DIFFERENTIAL COMPARATORS WITH STROBES

D1312, SEPTEMBER 1973—REVISED MARCH 1988

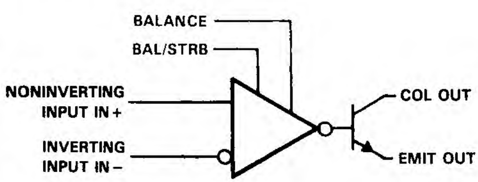
- **Fast Response Times**
- Strobe Capability
- **Designed to be Interchangeable with National Semiconductor LM111, LM211, and LM311**
- **Maximum Input Bias Current . . . 300 nA**
- **Maximum Input Offset Current . . . 70 nA**
- **Can Operate from Single 5-V Supply**

description

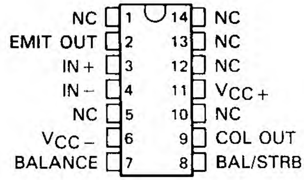
The LM111, LM211, and LM311 are single high-speed voltage comparators. These devices are designed to operate from a wide range of power supply voltage, including ±15-V supplies for operational amplifiers and 5-V supplies for logic systems. The output levels are compatible with most TTL and MOS circuits. These comparators are capable of driving lamps or relays and switching voltages up to 50 V at 50 mA. All inputs and outputs can be isolated from system ground. The outputs can drive loads referenced to ground, V_{CC+} or V_{CC-}. Offset balancing and strobe capability are available and the outputs can be wire-OR connected. If the strobe is low, the output will be in the off state regardless of the differential input.

The LM111 is characterized for operation over the full military range of −55 °C to 125 °C. The LM211 is characterized for operation from −25 °C to 85 °C, and the LM311 is characterized for operation from 0 °C to 70 °C.

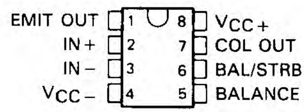
functional block diagram



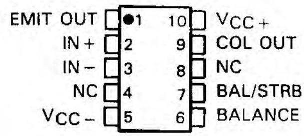
LM111 . . . J PACKAGE
(TOP VIEW)



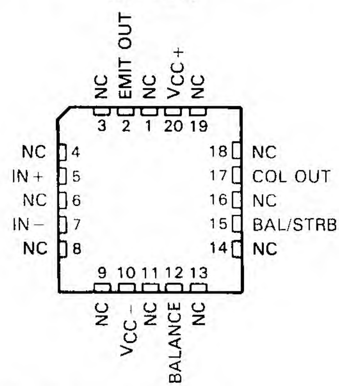
LM111 . . . JG PACKAGE
LM211, LM311 . . . D, JG, OR P PACKAGE
(TOP VIEW)



LM111 . . . U FLAT PACKAGE
(TOP VIEW)



LM111 . . . FK CHIP CARRIER PACKAGE
(TOP VIEW)



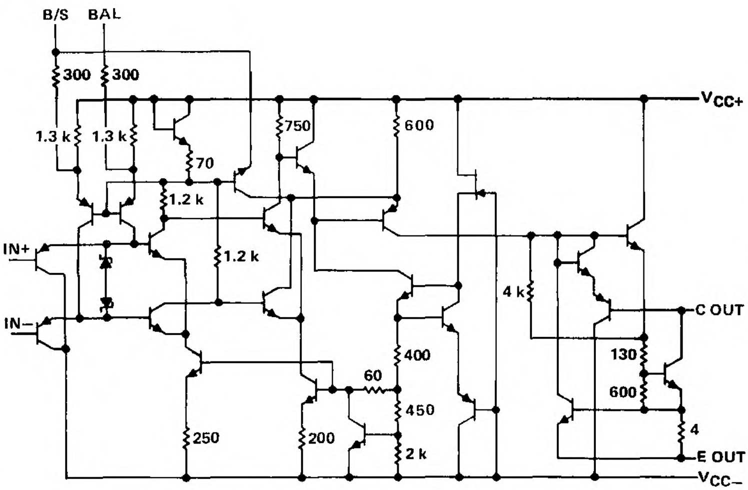
NC—No internal connection

AVAILABLE OPTIONS

OPERATING TEMPERATURE RANGE	V_{IO} MAX AT T_A = 25°C	PACKAGE					
		D SMALL OUTLINE	FK CERAMIC CHIP CARRIER	J CERAMIC DIP	JG CERAMIC DIP	P PLASTIC DIP	U FLATPACK
−55°C to 125°C	3 mV		LM111FK	LM111J			LM111U
−40°C to 85°C	3 mV	LM211D			LM211JG	LM211P	
0°C to 70°C	7.5 mV	LM311D			LM311JG	LM311P	

The D package is available in tape and reel. Add an R suffix when ordering, e.g., LM311DR.

schematic



BAL	Balance
B/S	Balance/Strobe
C OUT	Collector Output
E OUT	Emitter Output
IN+	Noninverting Input
IN−	Inverting Input
NC	No Internal Connection
V_{CC+}	Positive Supply Voltage
V_{CC-}	Negative Supply Voltage

Resistor values shown are nominal and in ohms.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

	LM111	LM211	LM311	UNIT
Supply voltage, V_{CC+} (see Note 1)	18	18	18	V
Supply voltage, V_{CC-} (see Note 1)	−18	−18	−18	V
Differential input voltage (see Note 2)	±30	±30	±30	V
Input voltage (either input, see Notes 1 and 3)	±15	±15	±15	V
Voltage from emitter output to V_{CC-}	30	30	30	V
Voltage from collector output to V_{CC-}	50	50	40	V
Duration of output short-circuit (see Note 4)	10	10	10	s
Continuous total dissipation	See Dissipation Rating Table			
Operating free-air temperature range	−55 to [illegible]	−25 to 85	0 to 70	°C
Storage temperature range	−65 to [illegible]	−65 to 150	−65 to 150	°C
Case temperature for 60 seconds: FK Package	260			°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: J, JG, or U package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: D or P package		260	260	°C

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	5.8 mW/°C	64°C	464 mW	[illegible] mW	–
FK	500 mW	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
J (LM111)	500 mW	11.0 mW/°C	105°C	500 mW	500 mW	275 mW
J	500 mW	8.2 mW/°C	89°C	500 mW	500 mW	–
JG (LM111)	500 mW	8.4 mW/°C	90°C	500 mW	500 mW	210 mW
JG	500 mW	6.6 mW/°C	74°C	500 mW	429 mW	–
P	500 mW	8.0 mW/°C	88°C	500 mW	500 mW	–
U	500 mW	5.4 mW/°C	57°C	432 mW	351 mW	135 mW

NOTES:
1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or ±15 volts, whichever is less.
4. The output may be shorted to ground or either power supply.

electrical characteristics at specified free-air temperature, $V_{CC\pm} = \pm 15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†			LM111 LM211			LM311			UNIT
					MIN	TYP‡	MAX	MIN	TYP‡	MAX	
V_{IO}	Input offset voltage	See Note 5		25°C		0.7	3		2	7.5	mV
				Full range			4			10	
I_{IO}	Input offset current	See Note 5		25°C		4	10		6	50	nA
				Full range			20			70	
I_{IB}	Input bias current	V_O = 1 V to 14 V		25°C		75	100		100	250	nA
				Full range			150			[illegible]	
$I_{IL(S)}$	Low-level strobe current (see Note 6)	$V_{(strobe)}$ = 0.3 V, $V_{ID} \le -10$ mV		25°C		−3			−3		mA
V_{ICR}	Common-mode input voltage range			Full range	13 to −14.5	13.8 to −14.7		13 to −14.5	13.8 to −14.7		V
A_{VD}	Large-signal differential voltage amplification	V_O = 5 V to 35 V, R_L = 1 kΩ		25°C	40	200		40	200		V/mV
I_{OH}	High-level (collector) output current	I_{strobe} = −3 mA, V_{ID} = 5 mV,	V_{OH} = 35 V	25°C		0.2	10				nA
				Full range			0.5				μA
		V_{ID} = 5 mV,	V_{OH} = 35 V	[illegible]					0.2	50	nA
V_{OL}	Low-level (collector-to-emitter) output voltage	I_{OL} = 50 mA	V_{ID} = −5 mV	25°C		0.75	1.5				V
			V_{ID} = −10 mV	25°C					0.75	1.5	
		V_{CC+} = 4.5 V, V_{CC-} = 0, I_{OL} = 8 mA	V_{ID} = −6 mV	Full range		0.23	0.4				
			V_{ID} = −10 mV	Full range					0.23	0.4	
I_{CC+}	Supply current from V_{CC+}, output low	V_{ID} = −10 mV,	No load	25°C		5.1	6		5.1	7.5	mA
I_{CC-}	Supply current from V_{CC-}, output high	V_{ID} = 10 mV,	No load	25°C		−4.1	−5		−4.1	−5	mA

†Unless otherwise noted, all characteristics are measured with the balance and balance/strobe terminals open and the emitter output grounded. Full range for LM111 is −55°C to 125°C, for LM211 is −25°C to 85°C, and for LM311 is 0°C to 70°C.
‡All typical values are at T_A = 25°C.

NOTES: 5. The offset voltages and offset currents given are the maximum values required to drive the collector output up to 14 V or down to 1 V with a pull-up resistor of 7.5 kΩ to V_{CC+}. Thus these parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.
6. The strobe should not be shorted to ground; it should be current driven at −3 to −5 mA, e.g., see Figures 13 and 27.

switching characteristics, V_{CC+} = 15 V, V_{CC-} = −15 V, T_A = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time, low-to-high-level output	R_C = 500 Ω to 5 V, C_L = 5 pF, See Note 7		115		ns
Response time, high-to-low-level output			165		ns

NOTE 7: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

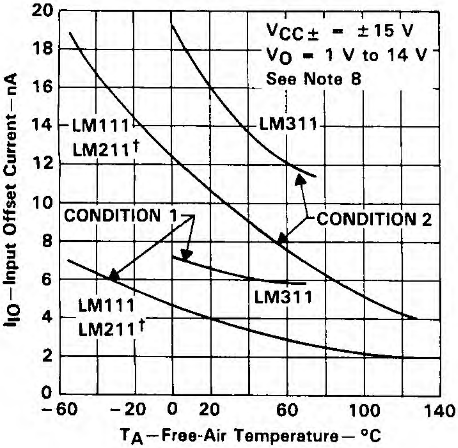


FIGURE 1

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

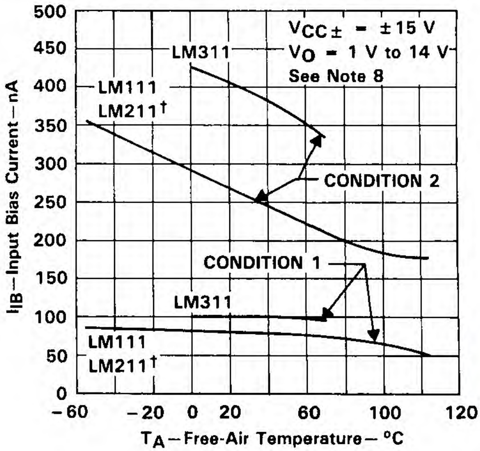


FIGURE 2

VOLTAGE TRANSFER CHARACTERISTICS

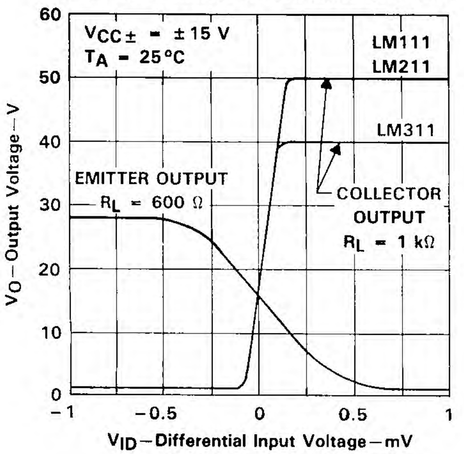
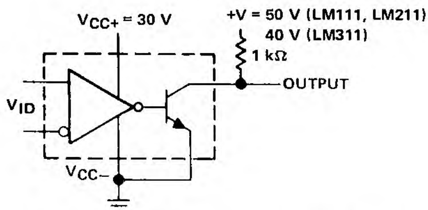
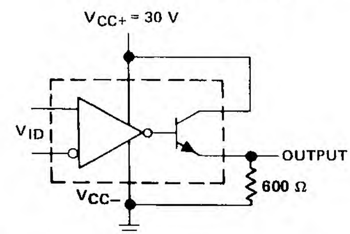


FIGURE 3



COLLECTOR OUTPUT TRANSFER CHARACTERISTIC
TEST CIRCUIT FOR FIGURE 3



EMITTER OUTPUT TRANSFER CHARACTERISTIC
TEST CIRCUIT FOR FIGURE 3

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

NOTE 8: Condition 1 is with the balance and balance/strobe terminals open. Condition 2 is with the balance and balance/strobe terminals connected to V_{CC+}.

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

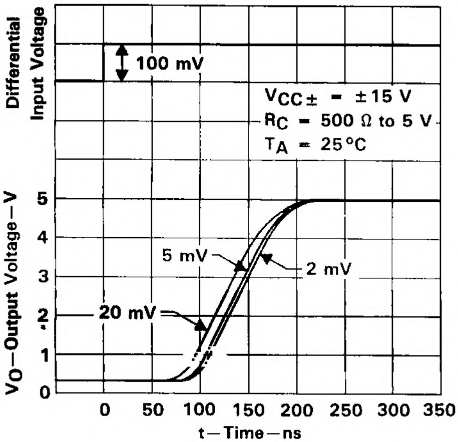


FIGURE 4

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

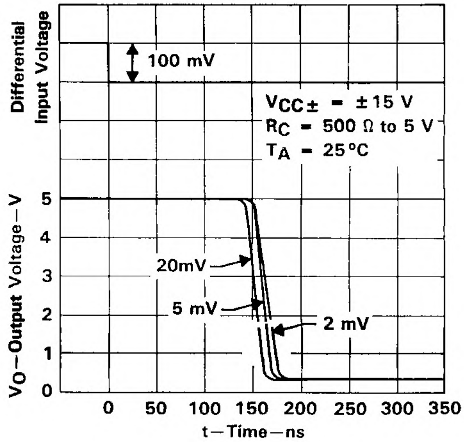
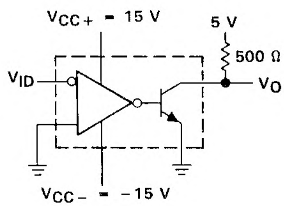


FIGURE 5



TEST CIRCUIT FOR FIGURES 4 AND 5

3

Voltage Comparators

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

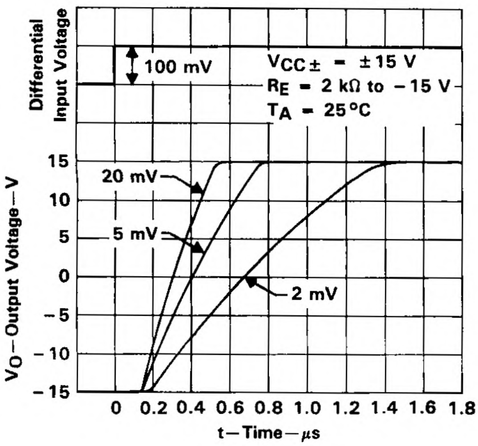


FIGURE 6

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

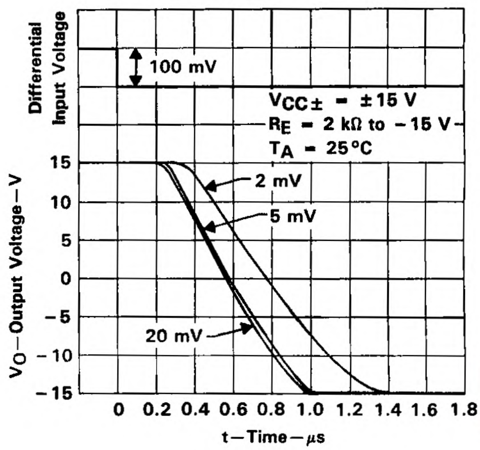
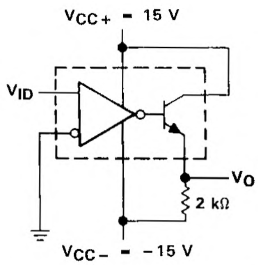


FIGURE 7



TEST CIRCUIT FOR FIGURES 6 AND 7

3

Voltage Comparators

TYPICAL CHARACTERISTICS

OUTPUT CURRENT and DISSIPATION
vs
OUPUT VOLTAGE

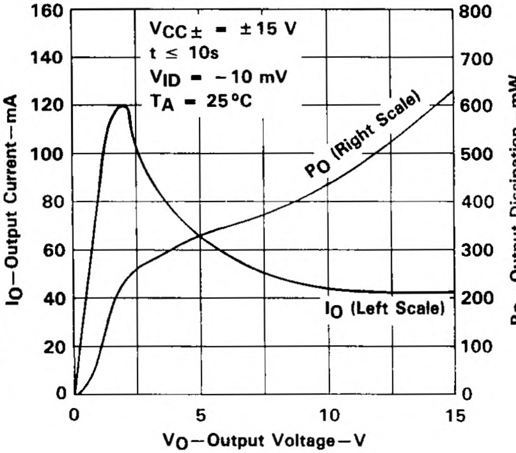


FIGURE 8

SUPPLY CURRENT FROM V_{CC+}
vs
SUPPLY VOLTAGE V_{CC+}

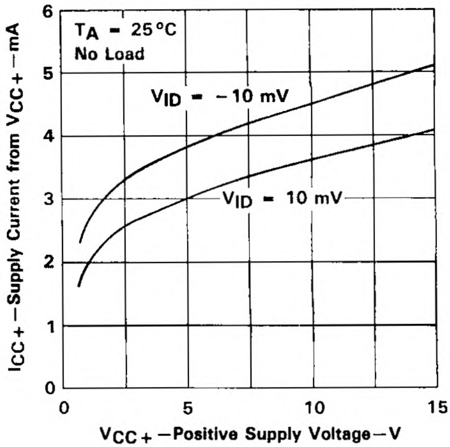


FIGURE 9

SUPPLY CURRENT FROM V_{CC-}
vs
SUPPLY VOLTAGE V_{CC-}

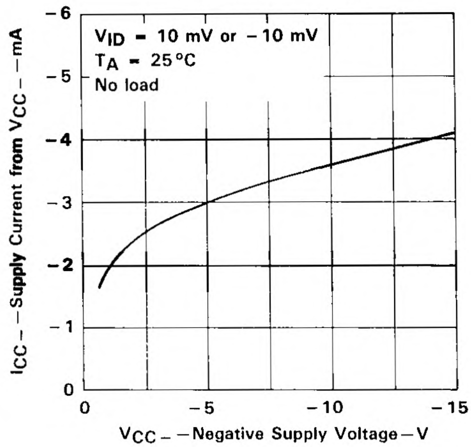


FIGURE 10

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA

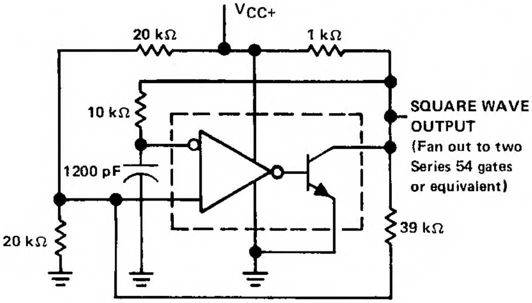


FIGURE 11. 100 kHz
FREE-RUNNING MULTIVIBRATOR

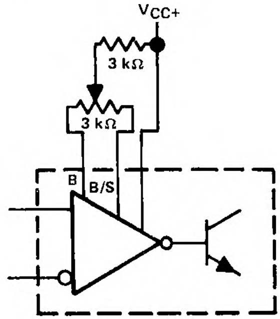


FIGURE 12. OFFSET BALANCING

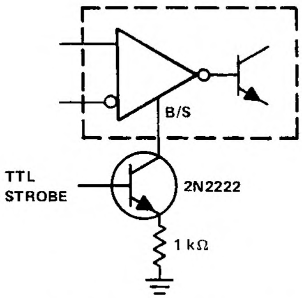


FIGURE 13. STROBING

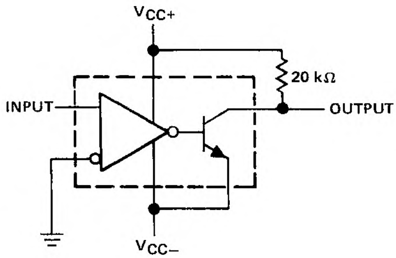
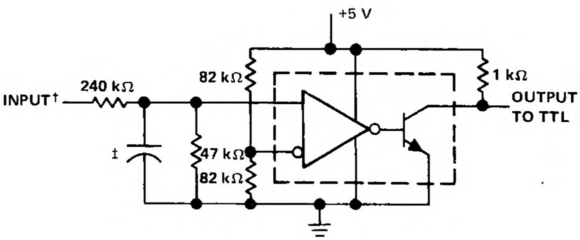


FIGURE 14. ZERO-CROSSING DETECTOR



†Resistor values shown are for a 0-to-30-V logic swing and a 15-V threshold.

‡May be added to control speed and reduce susceptibility to noise spikes.

FIGURE 15. TTL INTERFACE WITH HIGH-LEVEL LOGIC

3 Voltage Comparators

TYPICAL APPLICATION DATA

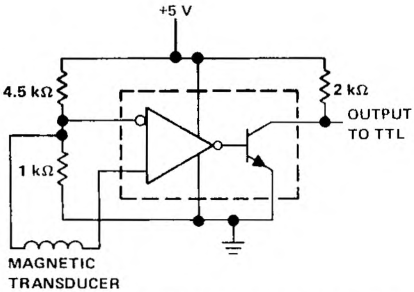


FIGURE 16. DETECTOR FOR MAGNETIC TRANSDUCER

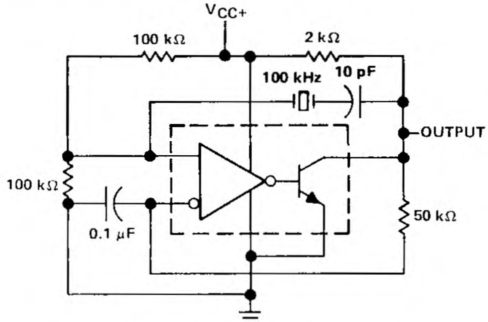


FIGURE 17. 100 kHz CRYSTAL OSCILLATOR

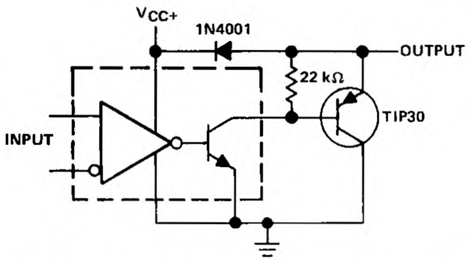
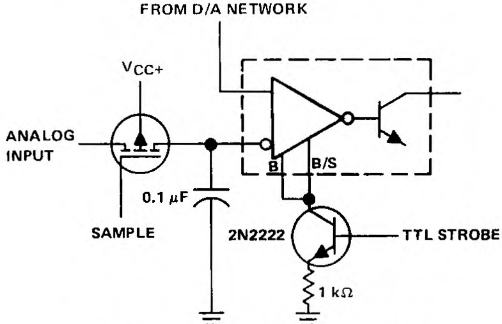


FIGURE 18. COMPARATOR AND SOLENOID DRIVER



Typical input current is 50 pA with inputs strobed off.

FIGURE 19. STROBING BOTH INPUT AND OUTPUT STAGES SIMULTANEOUSLY

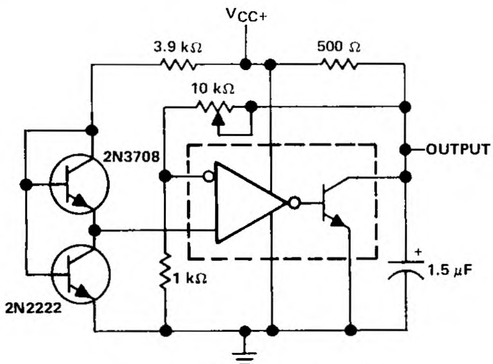


FIGURE 20. LOW-VOLTAGE ADJUSTABLE REFERENCE SUPPLY

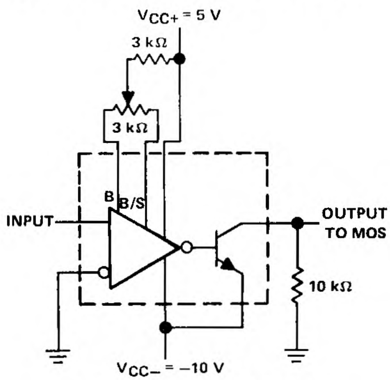
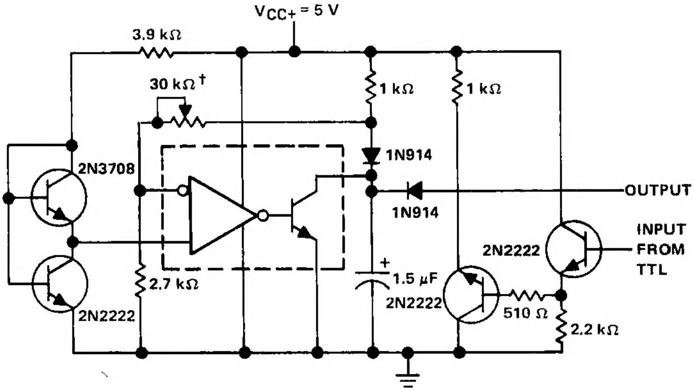


FIGURE 21. ZERO-CROSSING DETECTOR DRIVING MOS LOGIC

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA



†Adjust to set clamp level.

FIGURE 22. PRECISION SQUARER

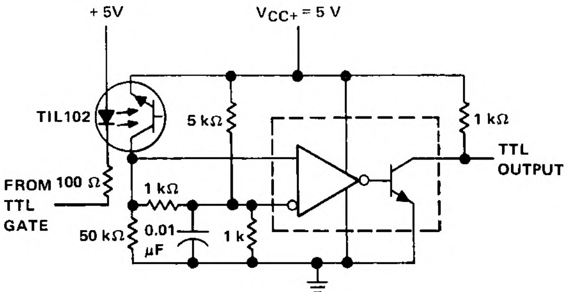


FIGURE 23. DIGITAL TRANSMISSION ISOLATOR

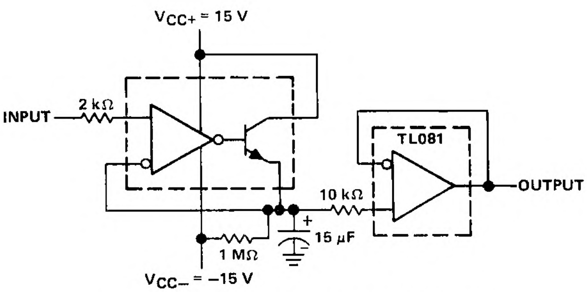


FIGURE 24. POSITIVE-PEAK DETECTOR

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA

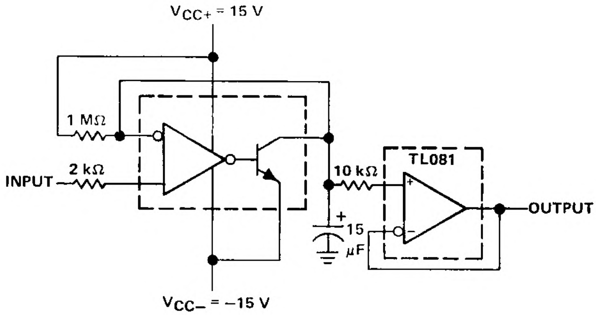
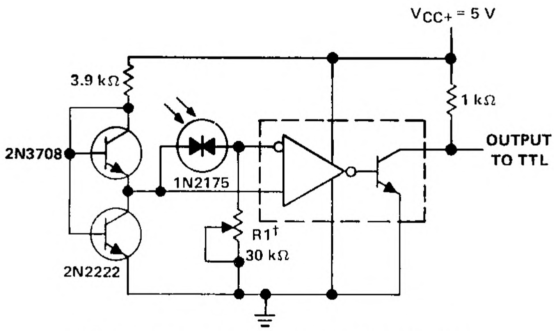
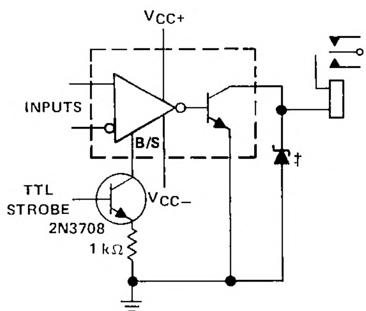


FIGURE 25. NEGATIVE-PEAK DETECTOR



†R1 sets the comparison level. At comparison, the photodiode has less than 5 mV across it decreasing dark current by an order of magnitude.

FIGURE 26. PRECISION PHOTODIODE COMPARATOR



‡Transient voltage and inductive kickback protection

FIGURE 27. RELAY DRIVER WITH STROBE

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA

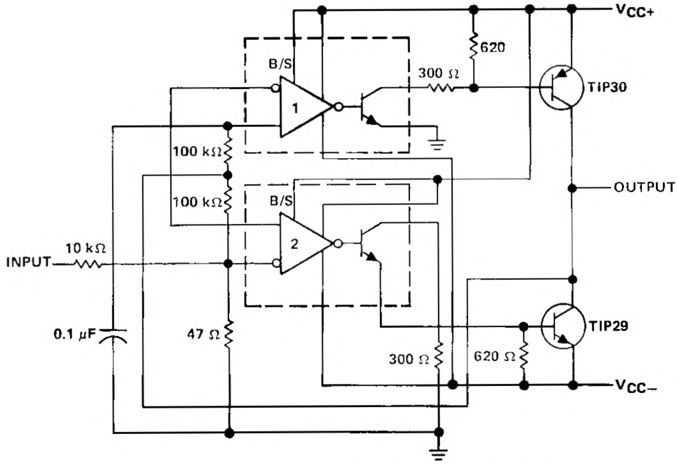


FIGURE 28. SWITCHING POWER AMPLIFIER

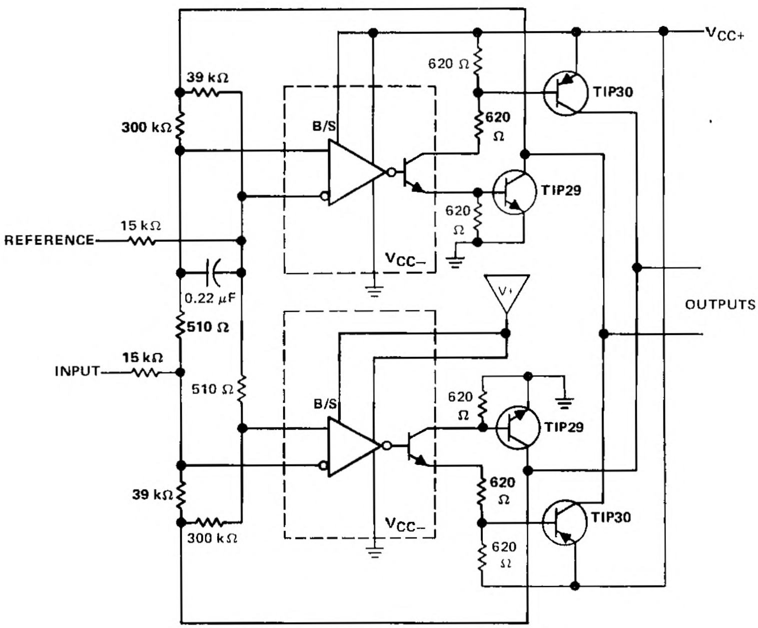
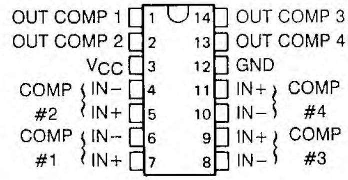


FIGURE 29. SWITCHING POWER AMPLIFIERS

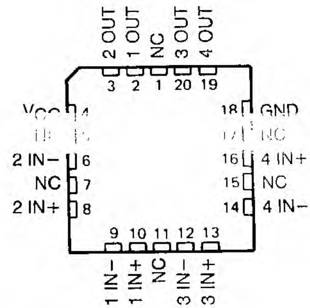
D1979, OCTOBER 1979–REVISED APRIL 1988

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 V
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (LM139)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±36 V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

LM139, LM139A . . . J PACKAGE
ALL OTHERS . . . D, J, OR N PACKAGE
(TOP VIEW)



LM139, LM139A
FK CHIP CARRIER PACKAGE
(TOP VIEW)

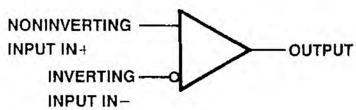


NC–No internal connection

description

These devices consist of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible as long as the difference between the two supplies is 2 V to 36 V and pin 3 is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

symbol (each comparator)

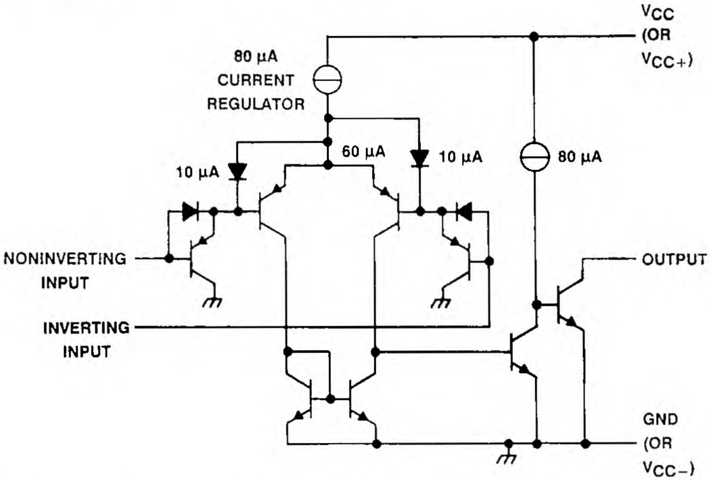


AVAILABLE OPTIONS

T_A	V_{IO} MAX at 25°C	PACKAGE SMALL OUTLINE (D)	CERAMIC (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)
0°C to 70°C	5 mV	LM339D	–	LM339J	LM339N
	2 mV	LM339AD	–	LM339AJ	LM339AN
−25°C to 85°C	5 mV	LM239D	–	LM239J	LM239N
	2 mV	LM239AD	–	LM239AJ	LM239AN
−40°C to 125°C	7 mV	LM2901ID	–	LM2901IJ	LM2091IN
−55°C to 125°C	5 mV	–	LM139FK	LM139J	–
	2 mV	–	LM139AFK	LM139AJ	–

The D package is available taped and reeled. Add the suffix R to the device type when ordering. (e.g., LM339DR)

schematic (each comparator)



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

Supply voltage, V_{CC} (see Note 2)		36 V
Differential input voltage (see Note 3)		±36 V
Input voltage range (either input)		−0.3 V to 36 V
Output voltage		36 V
Output current		20 mA
Duration of output short-circuit to ground (see Note 4)		unlimited
Continuous total dissipation		See Dissipation Rating Table
Operating free-air temperature range:	LM139	−55°C to 125°C
	LM239, LM239A	−25°C to 85°C
	LM339, LM339A	0°C to 70°C
	LM2901	−40°C to 125°C
Storage temperature range		−65°C to 150°C
Case temperature for 60 seconds: FK package		260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package		300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package		260°C

NOTES: 2. All voltage values, except differential voltages, are with respect to the network ground terminal.
3. Differential voltages are at the noninverting input terminal with respect to the inverting input.
4. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	900 mW	7.6 mW/°C	31°C	608 mW	494 mW	–
FK	900 mW	11.0 mW/°C	68°C	880 mW	715 mW	275 mW
J (LM139, LM139A)	900 mW	11.0 mW/°C	68°C	880 mW	715 mW	275 mW
J (All others)	900 mW	8.2 mW/°C	40°C	656 mW	533 mW	–
N	900 mW	9.2 mW/°C	52°C	736 mW	598 mW	–

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

PARAMETER		TEST CONDITIONS†		LM139 MIN	LM139 TYP	LM139 MAX	LM139A MIN	LM139A TYP	LM139A MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, V_{IC} = V_{ICR} min, V_O = 1.4 V	25°C		2	5		1	2	mV
			−55°C to 125°C			9			4	
I_{IO}	Input offset current	V_O = 1.4 V	25°C		3	25		3	25	nA
			−55°C to 125°C			100			100	
I_{IB}	Input bias current	V_O = 1.4 V	25°C		−25	−100		−25	−100	nA
			−55°C to 125°C			−300			−300	
V_{ICR}	Common-mode input voltage range		25°C	0 to V_{CC}−1.5			0 to V_{CC}−1.5			V
			−55°C to 125°C	0 to V_{CC}−2			0 to V_{CC}−2			
A_{VD}	Large-signal differential voltage amplification	$V_{CC\pm}$ = ±7.5 V, V_O = −5 V to 5 V	25°C		200		50	200		V/mV
I_{OH}	High-level output current	V_{ID} = 1 V, V_{OH} = 5 V	25°C		0.1			0.1		nA
		V_{ID} = 1 V, V_{OH} = 30 V	−55°C to 125°C			1			1	µA
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		150	400		150	400	mV
			−55°C to 125°C			700			700	
I_{OL}	Low-level output current	V_{ID} = −1 V, V_{OL} = 1.5 V	25°C	6	16		6	16		mA
I_{CC}	Supply current (four comparators)	V_O = 2.5 V, No load	25°C		0.8	2		0.8	2	mA

† All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF,‡ See Note 4	100-mV input step with 5-mV overdrive		1.3		µs
		TTL-level input step		0.3		

‡ C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

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

PARAMETER		TEST CONDITIONS†		LM239, LM339			LM239A, LM339A			LM2901			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, $V_{IC} = V_{ICR}$ min, V_O = 1.4 V	25°C		2	5		1	2		2	7	mV
			Full range			9			4			15	
I_{IO}	Input offset current	V_O = 1.4 V	25°C		5	50		5	50		5	50	nA
			Full range			150			150			200	
I_{IB}	Input bias current	V_O = 1.4 V	25°C		−25	−250		−25	−250		−25	−250	nA
			Full range			−400			−400			−500	
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			V
			Full range	0 to $V_{CC}-2$			0 to $V_{CC}-2$			0 to $V_{CC}-2$			
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1.4 V to 11.4 V, $R_L \geq 15\ k\Omega$ to V_{CC}	25°C	50	200		50	200		25	100		V/mV
I_{OH}	High-level output current	V_{ID} = 1 V, V_{OH} = 5 V	25°C		0.1	50		0.1	50		0.1	50	nA
		V_{ID} = 1 V, V_{OH} = 30 V	Full range			1			1			1	μA
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		150	400		150	400		150	500	mV
			Full range			700			700			700	
I_{OL}	Low-level output current	V_{ID} = −1 V, V_{OL} = 1.5 V	25°C	6	16		6	16		6	16		mA
I_{CC}	Supply current (four comparators)	V_O = 2.5 V, No load	25°C		0.8	2		0.8	2		0.8	2	mA
		V_{CC} = 30 V, V_O = 15 V, No load	25°C								1	2.5	

† Full range (MIN to MAX) for LM239 and LM239A is −25°C to 85°C, for LM339 and LM339A is 0°C to 70°C, and for LM2901 is −40°C to 125°C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF,‡ See Note 5	100-mV input step with 5-mV overdrive		1.3		μs
		TTL-level input step		0.3		

‡ C_L includes probe and jig capacitance.

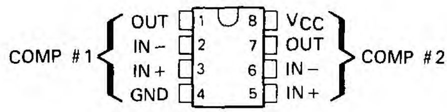
NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

LM193, LM293, LM393, LM293A, LM393A, LM2903
DUAL DIFFERENTIAL COMPARATORS

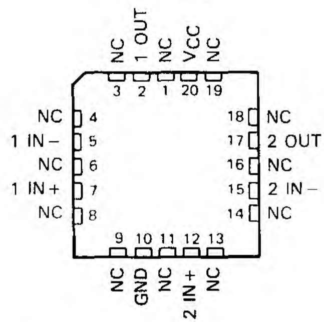
D2232, JUNE 1976—REVISED NOV[illegible] 1988

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 36 V
- Low Supply Current Drain Independent of Supply Voltage . . . 0.5 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ (LM139)
- Low Input Offset Voltage . . . 2 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±36 V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

LM193 . . . JG PACKAGE
ALL OTHERS . . . D, JG, OR P PACKAGE
(TOP VIEW)

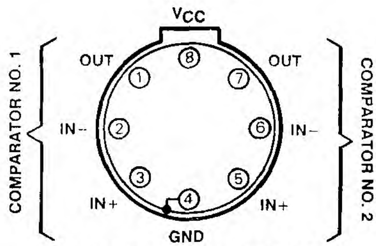


LM193 . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

LM193 . . . L
PLUG-IN PACKAGE
(TOP VIEW)



PIN 4 IS IN ELECTRICAL CONTACT WITH THE CASE.

description

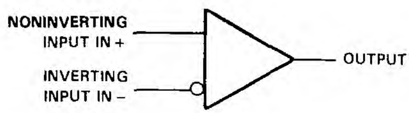
These devices consist of two independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible as long as the difference between the two supplies is 2 V to 36 V and pin 8 is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.

AVAILABLE OPTIONS

SYMBOLIZATION		OPERATING TEMPERATURE RANGE	V_{IO} MAX AT T_A = 25°C
DEVICE	PACKAGE SUFFIX		
LM193	L, FK, JG	−55°C to 125°C	5 mV
LM293	D, JG, P	−25°C to 85°C	5 mV
LM293A	D, JG, P	−25°C to 85°C	2 mV
LM393	D, JG, P	0°C to 70°C	5 mV
LM393A	D, JG, P	0°C to 70°C	2 mV
LM2903	D, JG, P	−40°C to 125°C	7 mV

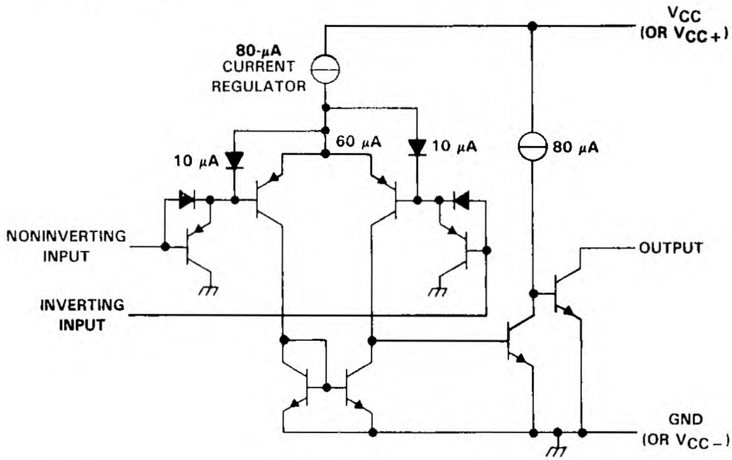
The D package is available in tape and reel. Add an R suffix when ordering. (e.g., LM393DR)

symbol (each comparator)



TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

schematic (each comparator)



Current values shown are nominal.

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

Supply voltage, V_{CC} (see Note 1)	36 V
Differential input voltage (see Note 2)	±36 V
Input voltage range (either input)	−0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: LM193	−55°C to 125°C
LM293, LM293A	−25°C to 85°C
LM393, LM393A	0°C to 70°C
LM2903	−40°C to 125°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: L package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input.
3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	25°C	464 mW	377 mW	–
FK	900 mW	11.0 mW/°C	68°C	880 mW	715 mW	275 mW
JG (LM193)	900 mW	8.4 mW/°C	43°C	672 mW	546 mW	210 mW
JG (All others)	825 mW	6.6 mW/°C	25°C	528 mW	429 mW	–
L	825 mW	6.6 mW/°C	25°C	528 mW	429 mW	165 mW
P	900 mW	8.0 mW/°C	37°C	640 mW	520 mW	–

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

PARAMETER		TEST CONDITIONS†		LM193 MIN	LM193 TYP	LM193 MAX	LM293, LM393 MIN	LM293, LM393 TYP	LM293, LM393 MAX	LM293A, LM393A MIN	LM293A, LM393A TYP	LM293A, LM393A MAX	LM2903 MIN	LM2903 TYP	LM2903 MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, $V_{IC} = V_{ICR}$, V_O = 1.4 V	25°C		2	5		2	5		1	2		2	7	mV
			Full range			9			9			4			15	
I_{IO}	Input offset current	V_O = 1.4 V	25°C		3	25		5	50		5	50		5	50	nA
			Full range			100			150			150			200	
I_{IB}	Input bias current	V_O = 1.4 V	25°C		25	100		25	250		25	250		25	250	nA
			Full range			300			400			400			500	
V_{ICR}	Common-mode input voltage range‡		25°C	0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			V
			Full range	0 to $V_{CC}-2$			0 to $V_{CC}-2$			0 to $V_{CC}-2$			0 to $V_{CC}-2$			
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1.4 V to 11.4 V, $R_L \geq$ 15 kΩ to VCC	25°C	50	200		50	200		50	200		25	100		V/mV
I_{OH}	High-level output current	V_{OH} = 5 V, V_{ID} = 1 V	25°C		0.1			0.1	50		0.1	50		0.1	50	nA
		V_{OH} = 30 V, V_{ID} = 1 V	Full range			1			1			1			1	μA
V_{OL}	Low-level output voltage	I_{OL} = 4 mA, V_{ID} = −1 V,	25°C		150	400		150	400		150	400		150	400	mV
			Full range			700			700			700			700	
I_{OL}	Low-level output current	V_{OL} = 1.5 V, V_{ID} = −1 V	25°C	6			6			6			6			mA
I_{CC}	Supply current	$R_L = \infty$, V_{CC} = 5 V	25°C		0.8	1		0.8	1		0.8	1		0.8	1	mA
		$R_L = \infty$, V_{CC} = 30 V	Full range			2.5			2.5			2.5			2.5	

† Full range (MIN to MAX) for LM193 is −55°C to 125°C, for LM293 and LM293A is 25°C to 85°C, for the LM393 and LM393A is 0°C to 70°C, and for LM2903 is −40°C to 125°C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.

‡ The voltage at either input or common-mode should not be allowed to go negative by more than 0.3 V. The upper end of the common-mode voltage range is $V_{CC+} - 1.5$ V, but either or both inputs can go to 30 V without damage.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF,§ See Note 4	100-mV input step with 5-mV overdrive		1.3		μs
		TTL-level input step		0.3		

§ C_L includes probe and jig capacitance.

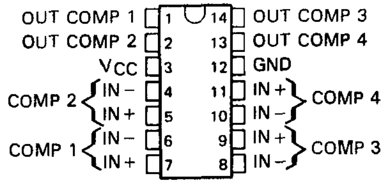
NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

LM3302
QUADRUPLE DIFFERENTIAL COMPARATOR

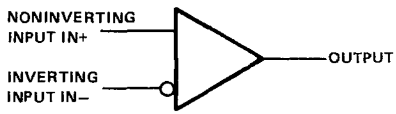
D2402, OCTOBER 1977—REVISED APRIL 1988

- Single Supply or Dual Supplies
- Wide Range of Supply Voltage . . . 2 to 28 Volts
- Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ
- Low Input Bias Current . . . 25 nA Typ
- Low Input Offset Current . . . 3 nA Typ
- Low Input Offset Voltage . . . 3 mV Typ
- Common-Mode Input Voltage Range Includes Ground
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±28 V
- Low Output Saturation Voltage
- Output Compatible with TTL, MOS, and CMOS

D, J, OR N PACKAGE
(TOP VIEW)



symbol (each comparator)



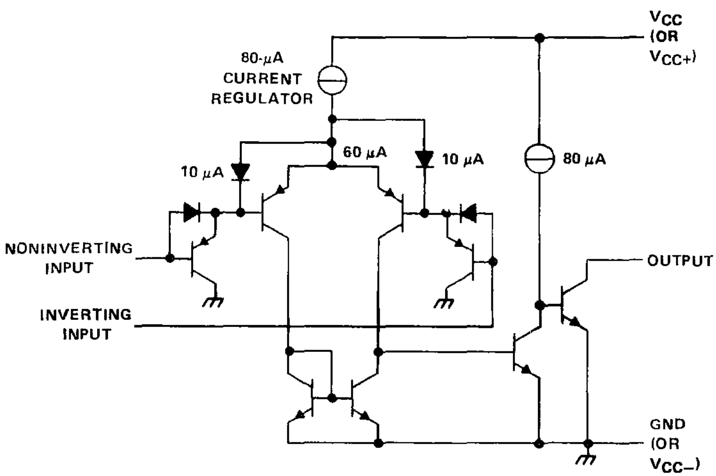
AVAILABLE OPTIONS

SYMBOLIZATION		OPERATING TEMPERATURE RANGE	V_{IO} MAX at 25°C
DEVICE	PACKAGE SUFFIX		
LM3302	D, J, N	−40°C to 85°C	20 mV

The D packages are available taped and reeled. Add the suffix R to the device type, when ordering. (i.e., LM3302DR)

description

This device consists of four independent voltage comparators that are designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 V to 28 V and pin 3 is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage. The outputs can be connected to other open-collector outputs to achieve wired-AND relationships.



Current values shown are nominal.

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

Supply voltage, V_{CC} (see Note 1)	28 V
Differential input voltage (see Note 2)	±28 V
Input voltage range (either input)	−0.3 V to 28 V
Output voltage	28 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range	−40°C to 85°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW
J	1025 mW	8.2 mW/°C	656 mW	533 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to 28 V, V_{IC} = V_{ICR} min, V_O = 1.4 V	25°C		3	20	mV
			−40°C to 85°C			40	
I_{IO}	Input offset current	V_O = 1.4 V	25°C		3	100	nA
			−40°C to 85°C			300	
I_{IB}	Input bias current		25°C		−25	−500	nA
			−40°C to 85°C			−1000	
V_{ICR}	Common-mode input voltage range		25°C	0 to V_{CC}−1.5			V
			−40°C to 85°C	0 to V_{CC}−2			
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1.4 V to 11.4 V, R_L = 15 kΩ to V_{CC}	25°C	2	30		V/mV
I_{OH}	High-level output current	V_{ID} = 1 V, V_{OH} = 5 V	25°C		0.1		nA
			−40°C to 85°C			1	μA
V_{OL}	Low-level output voltage	V_{ID} = 1 V, I_{OL} = 4 mA	25°C		150	500	mV
			40°C to 85°C			700	
I_{OL}	Low-level output current	V_{ID} = 1 V, V_{OL} = 1.5 V	25°C	6	16		mA
I_{CC}	Supply current (four comparators)	V_O = 2.5 V, No load	25°C		0.8	2	mA

† All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L = 5.1 kΩ to 5 V, C_L = 15 pF‡, See Note 4	100-mV input step with 5-mV overdrive		1.3		µs
		TTL-level input step		0.3		

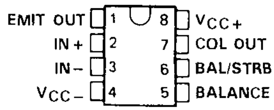
‡ C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

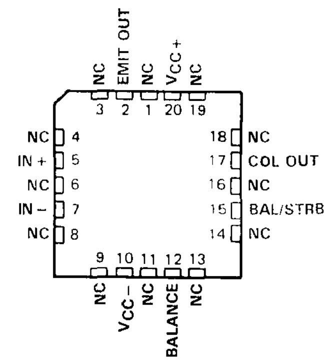
D3019, JUNE 1987–REVISED MAY 1988

- Low Power Drain — 900 μW Typical with 5-V Supply
- Operates from ±15 V or from a Single Supply as Low as 3 V
- Output Drive Capability of 25 mA
- Emitter Output Can Swing Below Negative Supply
- Response Time — 1.2 μs Typ
- Low Input Currents:
  Offset Current . . . 2 nA Typ
  Bias Current . . . 15 nA Typ
- Wide Common-Mode Input Range:
  −14.5 V to 13.5 V with ±15-V Supply
- Same Pinout as LM111, LM211, LM311
- Designed to be Interchangeable with National Semiconductor LP311

LP111 . . . JG DUAL-IN-LINE PACKAGE
LP211, LP311 . . . D, JG, OR P PACKAGE
(TOP VIEW)



LP111 . . . FK CHIP CARRIER PACKAGE
(TOP VIEW)

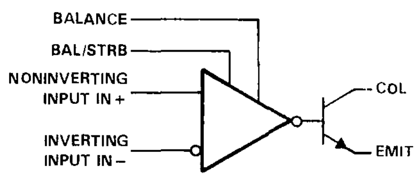


NC—No internal connection

description

The LP111, LP211, and LP311 are a low-power versions of the industry-standard LM111, LM211, and LM311. They take advantage of stable, high-value, ion-implanted resistors to perform the same function as the LM311 series, with a 30:1 reduction in power consumption but only a 6:1 slowdown in response time. Thus, they are well-suited for battery-powered applications and all other applications where fast response times are not needed. They operate over a wide range of supply voltages, from ±18 V down to a single 3-V supply with less than 300 μA current drain, but are still capable

functional block diagram



AVAILABLE OPTIONS

T_A	V_{IO} MAX AT 25°C	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	7.5 mV	LP311D	—	LP311JG	LP311P
−25°C to 85°C	7.5 mV	LP211D	—	LP211JG	LP211P
−55°C to 125°C	7.5 mV	—	LP111FK	LP111JG	—

The D package is available taped and reeled. Add the suffix R to the device type when ordering, (e.g., LP311DR)

3 Voltage Comparators

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

description (continued)

of driving a 25-mA load. The LP111, LP211, and LP311 are quite easy to apply free of oscillation if ordinary precautions are taken to minimize stray coupling from the output to either input or to the trim pins.

The LP111 is characterized for operation over the full military temperature range of −55°C to 125°C. The LP211 is characterized for operation from −25°C to 85°C, and the LP311 is characterized for operation from 0°C to 70°C.

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

Supply voltage, V_{CC+} (see Note 1)	18 V
Supply voltage, V_{CC-} (see Note 1)	−18 V
Differential input voltage (see Note 2)	±30 V
Input voltage (either input, see Notes 1 and 3)	±15 V
Voltage from emitter output to V_{CC-}	30 V
Voltage from collector output to V_{CC-}	40 V
Voltage from collector output to emitter output	40 V
Duration of output short-circuit (see Note 4)	40 V
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: LP111	−55°C to 125°C
LP211	−25°C to 85°C
LP311	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: D or P package	260°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

NOTES: 1. All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential input voltages are at the noninverting input terminal with respect to the inverting terminal.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage of ±15 V, whichever is less.
4. The output may be shorted to ground or to either power supply.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	5.8 mW/°C	64°C	464 mW	377 mW	–
FK	1375 mW	11.0 mW/°C	25°C	880 mW	715 mW	275 mW
JG (LP111)	1050 mW	8.4 mW/°C	25°C	672 mW	546 mW	210 mW
JG (LP_11)	825 mW	6.6 mW/°C	25°C	528 mW	429 mW	–
P	500 mW	8.0 mW/°C	88°C	500 mW	500 mW	–

recommended operating conditions

	MIN	NOM	MAX	UNITS
Input voltage ($\lvert V_{CC\pm} \rvert \le 15$ V)	V_{CC-} +0.5		V_{CC+} −1.5	V
Supply voltage, $V_{CC+} - V_{CC-}$	3.5		30	V

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

electrical characteristics at specified free-air temperature, $V_{CC\pm}$ = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	TYP†	MAX	UNIT
V_{ID}	Input offset voltage	RS < 100 kΩ, See Note 5	25°C			2	7.5	mV
			Full Range				10	
I_{IO}	Input offset current	See Note 5	25°C			2	25	nA
			Full Range				35	
I_{IB}	Input bias current		25°C			15		nA
			Full Range				150	
V_{OL}	Low-level output voltage	V_{ID} > 10 mV, I_{OL} = 25 mA, See Note 6	25°C			0.4	1.5	V
		V_{CC} = 4.5 V, V_{CC-} = 0, V_{ID} < −10 mV, I_{OL} = 1.6 mA, See Note 6	Full Range	LP111		0.1	0.7	
				LP211, LP311		0.1	0.4	
	Low-level strobe current	$V_{(strobe)}$ = 0.3 V, V_{ID} < −10 mV, See Note 7	25°C			100	300	μA
$I_{O(off)}$	Output off-state current	V_{ID} > 10 mV, V_{CE} = 35 V	25°C			0.2	100	nA
A_{VD}	Large signal differential voltage amplification	R_L = 5 kΩ	25°C		40	100		V/mV
I_{CC+}	Supply current from V_{CC+}	V_{ID} = −50 mV, R_L = ∞	Full Range			150	300	μA
I_{CC-}	Supply current from V_{CC-}	V_{ID} = 50 mV, R_L = ∞	Full Range			−80	−180	μA

†All typical values are at $V_{CC\pm}$ = ±15 V, T_A = 25°C.

NOTES: 5. The offset voltages and offset currents given are the maximum values required to drive the output within 1 V of either supply with a 1-mA load. Thus, these parameters define an error band and take into account the worst-case effects of voltage gain and input impedance.

6. Voltages are with respect to EMIT OUT and V_{CC-} tied together.

7. The strobe should not be shorted to ground; it should be current driven at 100 μA to 300 μA.

switching characteristics at $V_{CC\pm}$ = ±15 V, T_A = 25°C (unless otherwise noted)

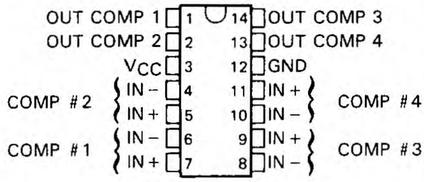
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	See Note 8		1.2		μs

NOTE 8: The response time is specified for a 100-mV input step with 5-mV overdrive.

D3044, OCTOBER 1987—REVISED MAY 1988

- **Ultralow Power Supply Current Drain . . . Typically 60 μA**
- **Low Input Biasing Current . . . 3 nA**
- **Low Input Offset Current . . . ±0.5 nA**
- **Low Input Offset Voltage . . . ±2 mV**
- **Common-Mode Input Voltage Includes Ground**
- **Output Voltage Compatible with MOS and CMOS Logic**
- **High Output Sink-Current Capability (30 mA at V_O = 2 V)**
- **Power Supply Input Reverse-Voltage Protected**
- **Single-Power-Supply Operation**
- **Pin-for-Pin Compatible with LM239, LM339, LM2901**

D, J, OR N PACKAGE (TOP VIEW)



description

The LP239, LP339, and LP2901 are low-power quadruple differential comparators. Each device consists of four independent voltage comparators designed specifically to operate from a single power supply and typically to draw 60-μA drain current over a wide range of voltages. Operation from split power supplies is also possible and the ultralow power supply drain current is independent of the power supply voltage.

Applications include limit comparators, simple analog-to-digital converters, pulse generators, squarewave generators, time delay generators, voltage controlled oscillators, multivibrators, and high-voltage logic gates. The LP239, LP339, and LP2901 were specifically designed to interface with the CMOS logic family. The ultralow power supply current makes these products desirable in battery-powered applications.

The LP239 is characterized for operation from −25 °C to 85 °C. The LP339 is characterized for operation from 0 °C to 70 °C. The LP2901 is characterized for operation from −40 °C to 85 °C.

AVAILABLE OPTIONS

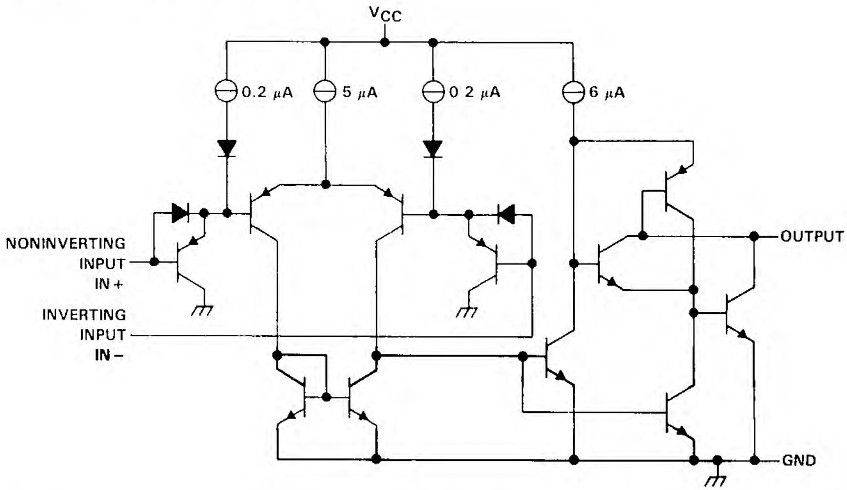
T_A	V_{IO} MAX AT 25 °C	PACKAGE		
		SMALL-OUTLINE (D)	PLASTIC DIP (N)	CERAMIC DIP (J)
0 °C to 70 °C	±5 mV	LP339D	LP339N	LP339J
−25 °C to 85 °C	±5 mV	LP239D	LP239N	LP239J
−40 °C to 85 °C	±5 mV	LP2901D	LP2901N	LP2901J

D packages are available taped-and-reeled. Add "R" suffix to device type when ordering (e.g., LP339DR).

3

Voltage Comparators

schematic diagram (each comparator)



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

Supply voltage, V_{CC} (see Note 1)	36 V
Differential input voltage, V_{ID} (see Note 2)	±36 V
Input voltage range (either input)	−0.3 V to 36 V
Input current, $V_I \leq -0.3$ V (see Note 3)	−50 mA
Duration of output short-circuit to ground (see Note 4)	unlimited
Continuous total dissipation (see Note 5)	See Dissipation Rating Table
Operating free-air temperature range: LP239	−25°C to 85°C
LP339	0°C to 70°C
LP2901	−40°C to 85°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. This input current only exists when the voltage at any of the inputs is driven negative. The current flows through the collector-base junction of the input clamping device. In addition to the clamping device action, there is lateral n-p-n parasitic transistor action. This action is not destructive and normal output states are re-established when the input voltage returns to a value more positive than −0.3 V at T_A = 25°C.
4. Short circuits between outputs to V_{CC} can cause excessive heating and eventual destruction.
5. If the output transistors are allowed to saturate, the low bias dissipation and the on-off characteristics of the outputs keep the dissipation very small (usually less than 100 mW).

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW
J	1025 mW	8 2 mW/°C	656 mW	533 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW

recommended operating conditions

		LP2901			LP239			LP339			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC}		5		30	[illegible]		30	5		30	V
Common-mode input voltage, V_{IC}	V_{CC} = 5 V	0		3	0		3	0		3	V
	V_{CC} = 30 V	0		28	0		28	0		28	V
Input voltage, V_I	V_{CC} = 5 V	0		3	0		3	0		3	V
	V_{CC} = 30 V	0		28	0		28	0		28	V
Operating free-air temperature, T_A		−40		85	−25		85	0		70	°C

electrical characteristics, V_{CC} = 5 V, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, V_O = 2 V, RS = 0, See Note 6		25°C		±2	±5	mV
				Full range			±9	
I_{IO}	Input offset current			25°C		±0.5	±5	nA
				Full range		±1	±15	
I_{IB}	Input bias current	See Note 7		25°C		−2.5	−25	nA
				Full range		−4	−40	
V_{ICR}	Common-mode input voltage range	Single supply		25°C	0 to V_{CC}−1.5			V
				Full range	0 to V_{CC}−2			
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, R_L = 15 kΩ				500		V/mV
	Output sink current	V_{I-} = 1 V, V_{I+} = 0	V_O = 2 V (see Note 8)	25°C	20	30		mA
				Full range	15			
			V_O = 0.4 V	25°C	0.2	0.7		
	Output leakage current	V_{I+} = 1 V, V_{I-} = 0	V_O = 5 V	25°C		0.1		nA
			V_O = 30 V	Full range			1	μA
V_{ID}	Differential input voltage	V_I ≤ 0 (or V_{CC-} on split supplies)					36	V
I_{CC}	Supply current	R_L = ∞ all comparators				60	100	μA

NOTES: 6. V_{IO} is measured over the full common-mode input voltage range.
7. Because of the p-n-p input stage, the direction of the current is out of the device. This current is essentially constant (i.e., independent of the output state). Therefore, no loading change exists on the reference or input lines as long as the common-mode input voltage range is not exceeded.
8. The output sink current is a function of the output voltage. These devices have a bimodal output section that allows them to sink (via a Darlington connection) large currents at output voltages greater than 1.5 V, and smaller currents at output voltages less than 1.5 V.

switching characteristics, V_{CC} = 5 V, T_A = 25°C, R_L connected to 5 V through 5.1 kΩ

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Large-signal response time	TTL logic swing, V_{ref} = 1.4 V		1.3		μs
Response time			8		μs

TYPICAL APPLICATION DATA

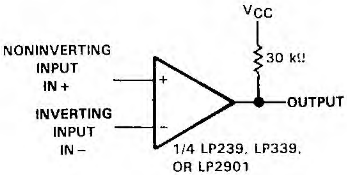


FIGURE 1. BASIC COMPARATOR

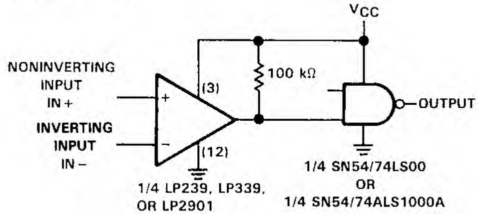


FIGURE 2. CMOS DRIVER

All pins of any unused comparators should be grounded. The bias network of the LP239, LP339, and LP2901 establishes a drain current that is independent of the magnitude of the power supply voltage over the range of 2 V to 30 V. It is usually necessary to use a bypass capacitor across the power supply line.

The differential input voltage may be larger than V_{CC} without damaging the device. Protection should be provided to prevent the input voltages from going negative by more than −0.3 V. The output section has two distinct modes of operation: a Darlington mode and a grounded-emitter mode. This unique drive circuit permits the device to sink 30 mA at V_O = 2 V in the Darlington mode and 700 μA at V_O = 0.4 V in the ground-emitter mode. Figure 3 is a simplified schematic diagram of the output section. The output section is configured in a Darlington connection (ignoring Q3). Therefore, if the output voltage is held high enough (above 1 V), Q1 is not saturated and the output current is limited only by the product of the h_{FE} of Q1, the h_{FE} of Q2, and I1 and by the 60-Ω saturation resistance of Q2. The devices are capable of driving LEDs, relays, etc., in this mode while maintaining an ultralow power supply current of 60 μA typically.

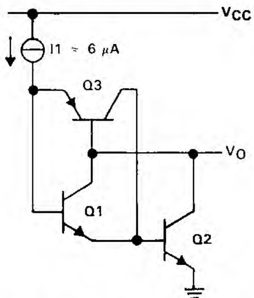


FIGURE 3. OUTPUT SECTION SCHEMATIC DIAGRAM

Without transistor Q3, if the output voltage were allowed to drop below 0.8 V, transistor Q1 would saturate and the output current would drop to zero. The circuit would be unable to pull low current loads down to ground or the negative supply, if used. Transistor Q3 has been included to bypass transistor Q1 under these conditions and apply the current I1 directly to the base of Q2. The output sink current is now approximately I1 times the h_{FE} of Q2 (700 μA at V_O = 0.4 V). The output of the devices exhibit a bimodal characteristic with a smooth transition between modes.

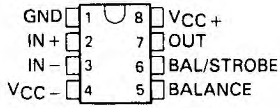
In both cases, the output is an uncommitted collector. Therefore several outputs can be tied together to provide a dot logic function. An output pull-up resistor can be connected to any available power supply voltage within the permitted power supply voltage range, and there is no restriction on this voltage based on the magnitude of the voltage that is applied to the V_{CC} terminal of the package.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

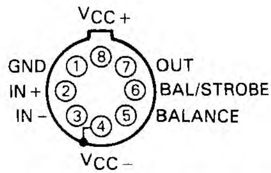
D3179, JANUARY 1989

- Low Input Offset Voltage . . . 1.5 or 0.5 mV Max
- Maximum Input Bias Current . . . 50 or 25 nA
- Low Input Offset Current . . . 4 or 3 nA Max
- Output Response Time . . . 250 ns Max
- Voltage Gain . . . 200 V/mV Min
- Output Current . . . 50 mA Source or Sink
- Differential Input Voltage . . . ±30 V
- Can Operate from Single 5-V Supply
- Pin-Compatible with LM111 Series
- Designed to be Interchangeable with Linear Technology LT1011 and LT1011A

JG OR P PACKAGE
(TOP VIEW)



L PACKAGE
(TOP VIEW)

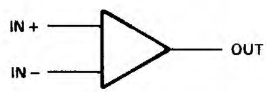


Pin 4 (L package) is in electrical contact with the case.

description

The LT1011 and LT1011A are general-purpose comparators that are pin-compatible with the LM111. The LT1011A offers significantly better input characteristics than the LM111: four times lower bias current, six times lower offset voltage, and five times higher voltage gain. Additionally, the supply current is considerably lower than that of the LM111 with no loss in speed. The offset voltage temperature coefficient of the LT1011A is 15 µV/°C. The LT1011 and LT1011A are fully specified for dc parameters and output response time when operating from a single 5-V supply.

symbol



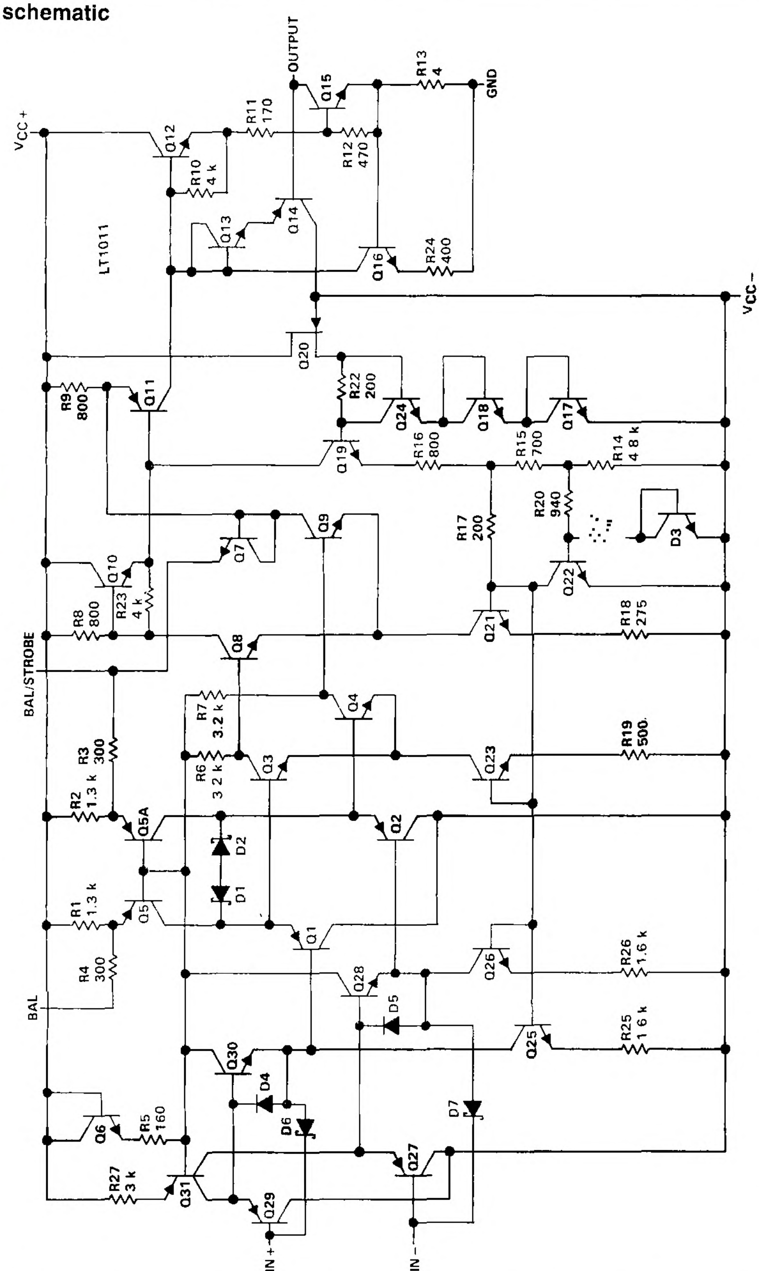
The LT1011 and LT1011A can be used in high-accuracy (≥ 12-bit) systems without trimming. The devices retain all the versatile features of the LM111 including single-supply operation (3 V to 36 V) or dual-supply operation (±1.5 V to ±18 V) and a floating transistor output with 50-mA source or sink capability. The devices can drive loads that are referenced to ground, the negative supply, or the positive supply, and are specified up to 50 V between V_{CC-} and the collector output. A differential input voltage up to the full supply voltage is allowed, even with ±18-V supplies, enabling the inputs to be clamped to the supplies with simple diode clamps.

M-suffix devices are characterized for operation over the full military temperature range of −55°C to 125°C. C-suffix devices are characterized for operation from 0°C to 70°C.

AVAILABLE OPTIONS

T_A	V_{IO} MAX at 25°C	PACKAGE		
		CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (P)
0°C to 70°C	1.5 mV 0.5 mV	LT1011CJG LT1011ACJG	LT1011CL LT1011ACL	LT1011CP LT1011ACP
−55°C to 125°C	1.5 mV 0.5 mV	LT1011MJG LT1011AMJG	LT1011ML LT1011AML	

schematic



Resistor values shown are nominal and in ohms.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

Supply voltage, V_{CC+}	18 V
Supply voltage, V_{CC-}	−18 V
Voltage from output to V_{CC-}: M-suffix	50 V
C-suffix	40 V
Voltage from GND to V_{CC-}	30 V
Voltage from strobe to V_{CC+}	5 V
Differential input voltage (see Note 1)	±36 V
Input voltage (either input, see Note 2)	$V_{CC\pm}$
Duration of output short circuit (see Note 3)	10 s
Continuous power dissipation	See Dissipation Rating Table
Operating free-air temperature range: M-suffix	−55°C to 125°C
C-suffix	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG or L package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: P package	260°C

NOTES: 1. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
2. Inputs may be clamped to supplies with diodes so that the maximum input voltage actually exceeds the supply voltage by one diode drop (refer to "input protection" in the applications section).
3. The output may be shorted to ground or to either power supply.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 125°C$ POWER RATING
JG (M-suffix)	1050 mW	8.4 mW/°C	672 mW	210 mW
JG (C-suffix)	825 mW	6.6 mW/°C	528 mW	N/A
L (M-suffix)	825 mW	6.6 mW/°C	528 mW	165 mW
L (C-suffix)	650 mW	5.2 mW/°C	416 mW	N/A
P	1000 mW	8.0 mW/°C	640 mW	N/A

recommended operating conditions

		M-SUFFIX			C-SUFFIX			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC+}				15			15	V
Supply voltage, V_{CC-}				−15			−15	V
Input voltage, V_I, (see Note 4)	$V_{CC\pm} = \pm 15$ V	−14.5		13	−14.5		13	V
	V_{CC} = single 5-V	0.5		3	0.5		3	
Operating free-air temperature, T_A		−55		125	0		70	°C

NOTE 4: See "Input Signal Range" under "Typical Application Data."

electrical characteristics, $V_{CC\pm}$ = ±15 V, V_{IC} = 0, R_S = 0, pin 1 at V_{CC-}, output at pin 7 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	LT1011 MIN	LT1011 TYP	LT1011 MAX	LT1011A MIN	LT1011A TYP	LT1011A MAX	UNIT
V_{IO}	Input offset voltage	I_O = 1.5 mA, V_O = 0	25°C		0.6	1.5		0.3	0.5	mV
			Full range			3			1	
		R_S ≤ 50 kΩ, See Note 5	25°C			2			0.75	
			Full range			3			1.5	
α_{VIO}	Average temperature coefficient of input offset voltage	See Note 6	Full range		4	25		4	15	µV/°C
I_{IO}	Input offset current	See Note 5	25°C		0.2	4		0.2	3	nA
			Full range			6			5	
I_{IB}	Input bias current	I_O = 1.5 mA, V_O = 0	25°C		−20	±50		−15	±25	nA
		See Note 5	25°C		−25	±65		−20	±35	
			Full range			±80			±50	
$I_{IL(S)}$	Low-level strobe current (See Note 7)		25°C			−500			−500	µA
V_{ICR}	Common-mode input voltage range		Full range	−14.5 to 13			−14.5 to 13			V
A_{VD}	Large-signal differential voltage amplification	R_L = 1 kΩ to V_{CC+}, V_O = −10 V to 14.5 V	25°C	200	500		200	500		V/mV
V_{OL}	Low-level output voltage	V_{ID} = −5 mV, I_{OL} = 8 mA, Pin 1 at 0 V	Full range			0.4			0.4	V
		V_{ID} = −5 mV, I_{OL} = 50 mA, Pin 1 at 0 V	Full range			1.5			1.5	
$I_{O(lkg)}$	Output leakage current	V_{ID} = 5 mV, Pin 1 at −15 V,	25°C		0.2	10		0.2	10	nA
		V_O = 35 V (25 V for LT1011C)	Full range			500			500	
CMRR	Common-mode rejection ratio	V_{IC} = $V_{ICR\,min}$, R_S ≤ 50 kΩ	25°C	90	115		94	115		dB
I_{CC+}	Supply current from V_{CC+}		25°C		3.2	4		3.2	4	mA
I_{CC-}	Supply current from V_{CC-}		25°C		−1.7	−2.5		−1.7	−2.5	mA
C_i	Input capacitance		25°C		6			6		pF

† Full range is −55°C to 125°C for the LT1011M and LT1011AM. Full range is 0°C to 70°C for the LT1011C and LT1011AC.

NOTES: 5. These specifications apply for single supply voltages from 5 V to 30 V and dual supply voltages from ±2.5 V to ±15 V for the entire input voltage range, and for both high and low output states. The high state is I_{OH} ≥ 100 µA and V_O ≥ (V_{CC+} − 1 V). The low state is I_{OL} ≤ 8 mA and V_O ≤ 0.8 V. Therefore, this specification defines a worst-case error band that includes effects due to common-mode signals, voltage gain, and output load.

6. Average temperature coefficient is calculated by dividing the offset voltage difference measured at minimum and maximum temperatures by the temperature difference.

7. This is the minimum current that must be drawn from the strobe to ensure that the output is off regardless of differential input voltage.

3

Voltage Comparators

TEXAS INSTRUMENTS

POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

electrical characteristics, V_{CC+} = 5 V, V_{CC-} = 0, V_{IC} = 0, R_S = 0, pin 1 at 0 V, output at pin 7 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	LT1011			LT1011A			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	R_S ≤ 50 kΩ, See Note 5	25°C			2			0.75	mV
			Full range			3			1.5	
I_{IO}	Input offset current	See Note 8	25°C		0.2	4		0.2	3	nA
			Full range			6			5	
I_{IB}	Input bias current	See Note 8	25°C		25	65		20	35	nA
			Full range			80			50	
$I_{IL(S)}$	Low-level strobe current (See Note 7)		25°C			−500			−500	µA
V_{ICR}	Common-mode input voltage range		Full range	0.5 to 3			0.5 to 3			V
A_{VD}	Large-signal differential voltage amplification	R_L = 0.5 kΩ to V_{CC+}, V_O = 0.5 V to 4.5 V	25°C	50	300		50	300		V/mV
V_{OL}	Low-level output voltage	V_{ID} = −5 mV, I_{OL} = 8 mA	Full range			0.4			0.4	V
		V_{ID} = −5 mV, I_{OL} = 50 mA	Full range			1.5			1.5	
I_O	Output leakage current	V_{ID} = 5 mV, V_O = 50 V (40 V for LT1011C)	25°C		0.2	10		0.2	10	nA
			Full range			500			500	
I_{CC+}	Supply current from V_{CC+}		25°C		3.2	4		3.2	4	mA
I_{CC-}	Supply current from V_{CC-}		25°C		−1.7	−2.5		−1.7	−2.5	mA

† Full range is −55°C to 125°C for the LT1011M and LT1011AM. Full range is 0°C to 70°C for the LT1011C and LT1011AC.

NOTES: 6. Average temperature coefficient is calculated by dividing the offset voltage difference measured at minimum and maximum temperatures by the temperature difference.
7. This is the minimum current that must be drawn from the strobe to ensure that the output is off regardless of differential input voltage.
8. These specifications apply for all single-supply voltages from 5 V to 30 V for the entire input voltage range, and for both high and low output states. The high state is I_{OH} ≥ 100 µA and V_O ≥ (V_{CC+} − 1 V). The low state is I_{OL} ≤ 8 mA and V_O ≤ 0.8 V. Therefore, this specification defines a worst-case error band that includes effects due to common-mode signals, voltage gain, and output load.

switching characteristics, V_{CC+} = 5 V, V_{CC-} = 0, pin 1 at 0 V, T_A = 25°C

PARAMETER	TEST CONDITIONS	LT1011			LT1011A			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Output response time	R_C = [illegible] to 5 V, C_L = 5 pF, [illegible] Note 9		150	250		150	250	ns

NOTE 9: The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.

TYPICAL CHARACTERISTICS†

INPUT OFFSET VOLTAGE
vs
COMMON-MODE INPUT VOLTAGE

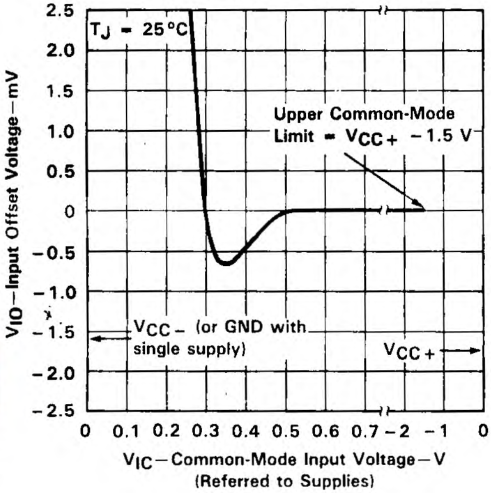


FIGURE 1

OFFSET ADJUSTMENT CHARACTERISTICS

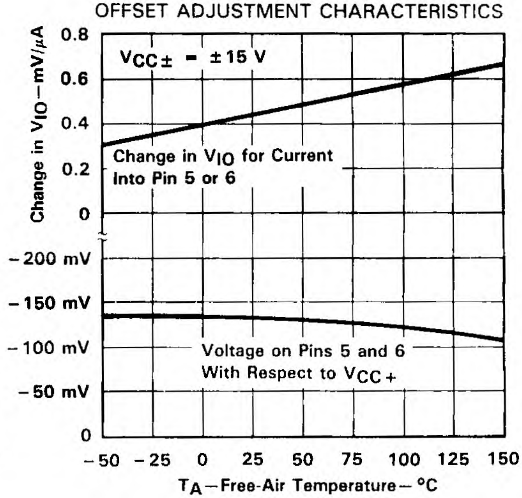


FIGURE 2

INPUT OFFSET CURRENT
vs
FREE-AIR TEMPERATURE

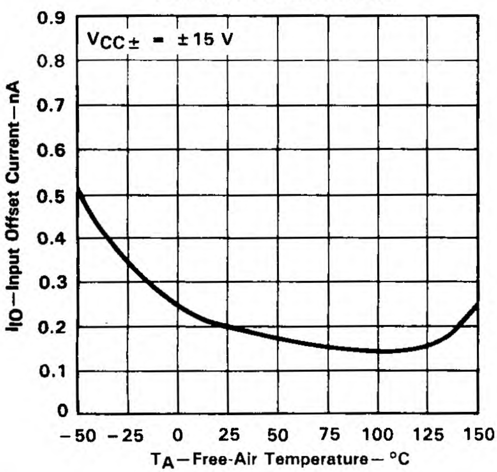


FIGURE 3

LT1011
INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

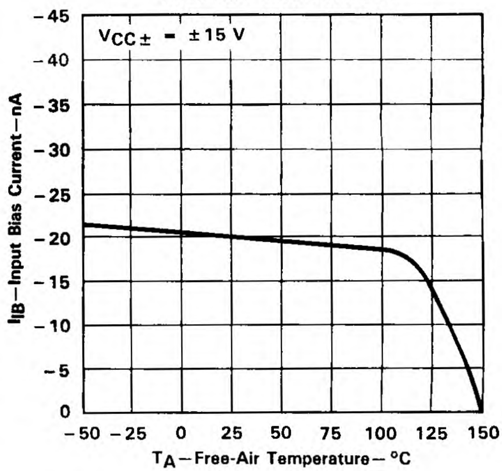


FIGURE 4

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS†

INPUT VOLTAGE LIMITS
vs
FREE-AIR TEMPERATURE

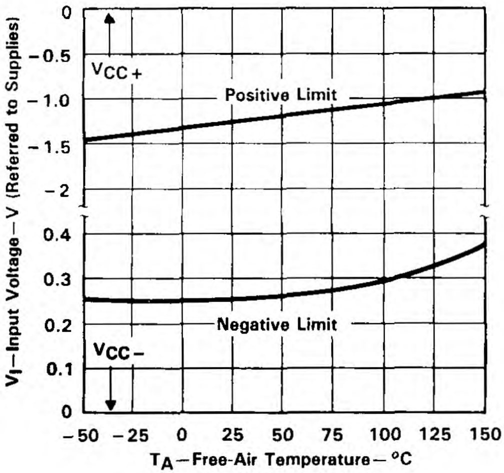


FIGURE 5

LT1011
INPUT CHARACTERISTICS
(EITHER INPUT WITH OTHER
INPUT GROUNDED)

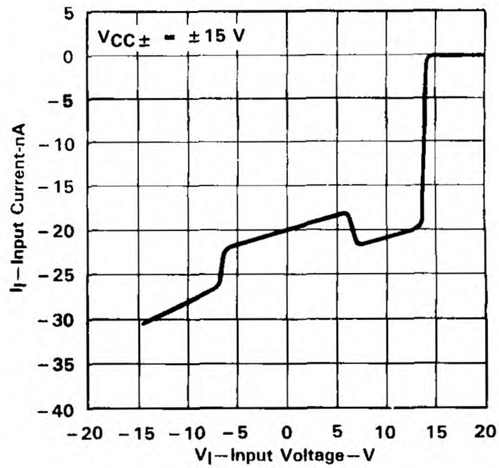


FIGURE 6

EQUIVALENT OFFSET VOLTAGE
vs
SOURCE RESISTANCE

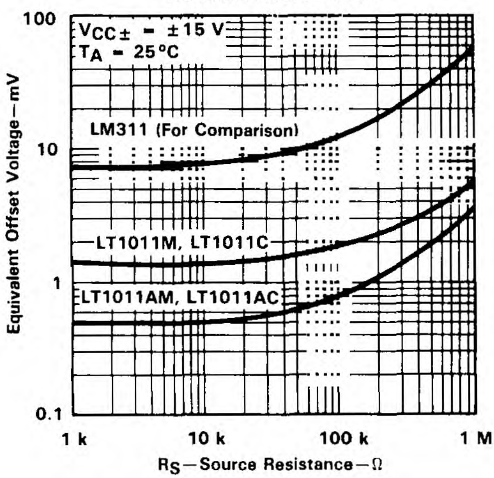


FIGURE 7

VOLTAGE TRANSFER CHARACTERISTICS

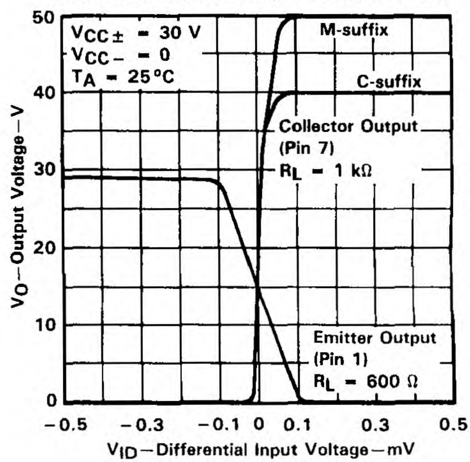


FIGURE 8

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

LOW-LEVEL OUTPUT VOLTAGE
vs
INPUT OVERDRIVE

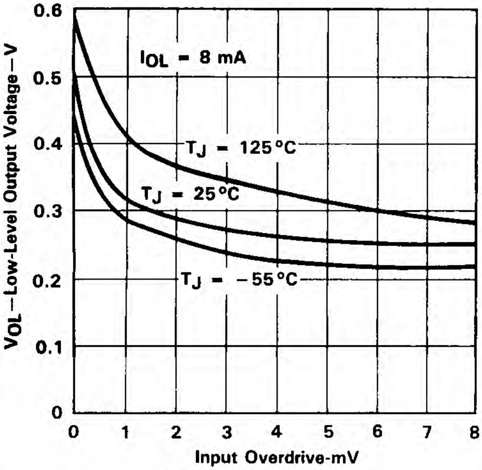


FIGURE 9

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

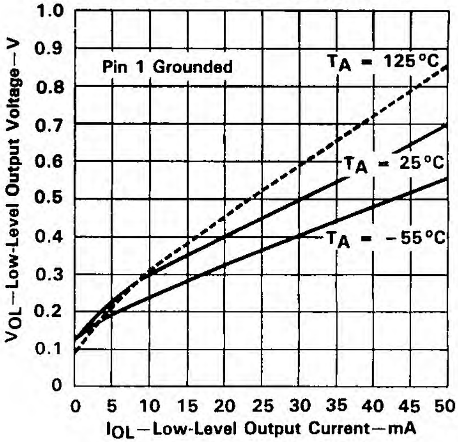


FIGURE 10

OUTPUT LEAKAGE CURRENT
vs
FREE-AIR TEMPERATURE

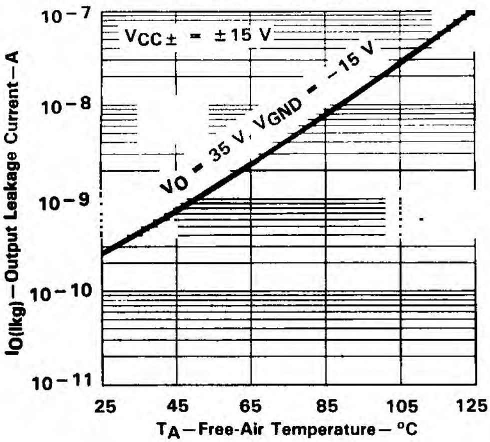


FIGURE 11

SHORT-CIRCUIT OUTPUT CURRENT
AND DISSIPATION
(3 MINUTES AFTER SHORT)
vs
OUTPUT VOLTAGE

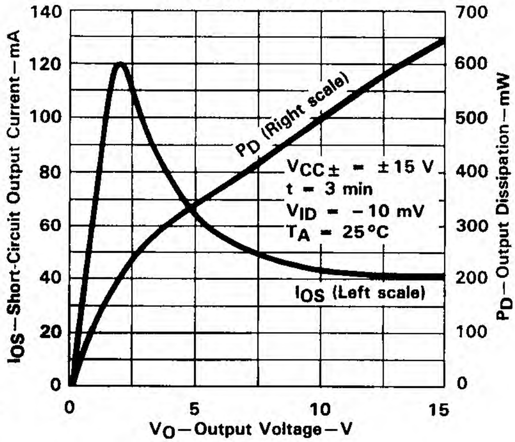


FIGURE 12

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

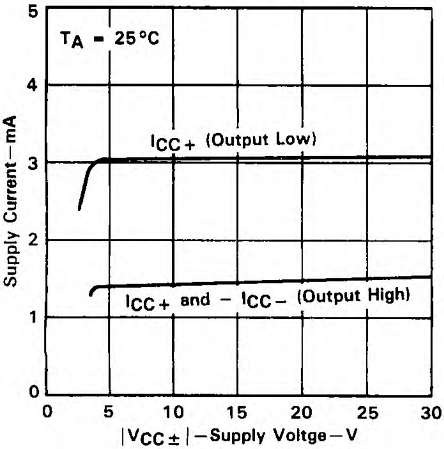


FIGURE 13

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

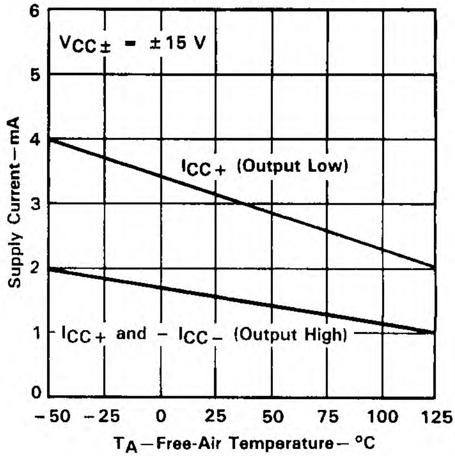


FIGURE 14

OUTPUT SATURATION VOLTAGE
(GROUND INPUT)
vs
OUTPUT CURRENT

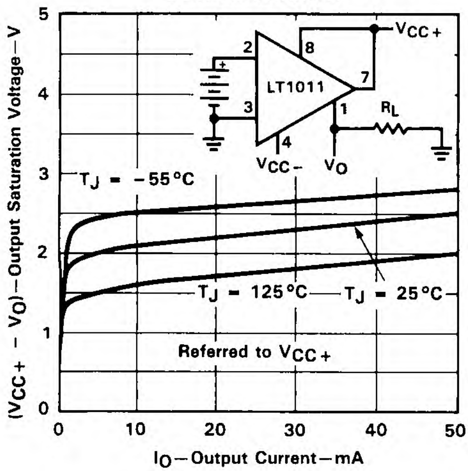


FIGURE 15

OUTPUT RESPONSE TIME
vs
INPUT STEP SIZE

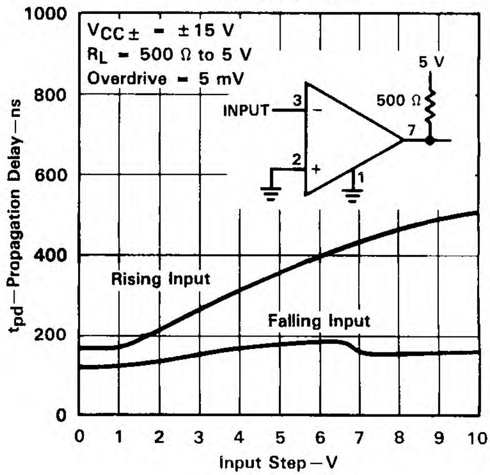


FIGURE 16

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

3

Voltage Comparators

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE
FOR VARIOUS INPUT OVERDRIVES

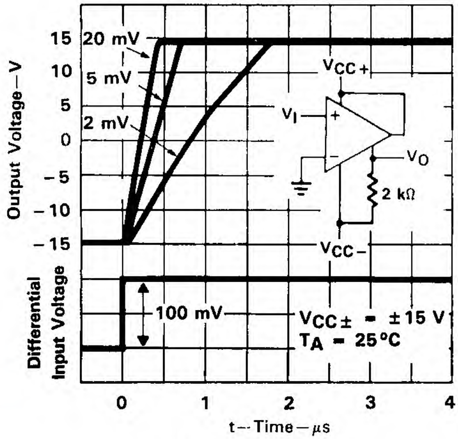


FIGURE 17

OUTPUT RESPONSE
FOR VARIOUS INPUT OVERDRIVES

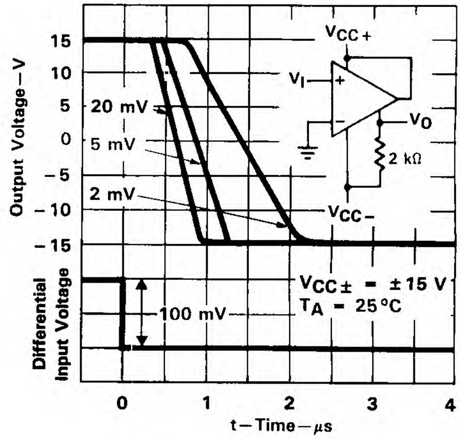


FIGURE 18

HIGH- TO LOW-LEVEL
OUTPUT RESPONSE
FOR VARIOUS INPUT OVERDRIVES

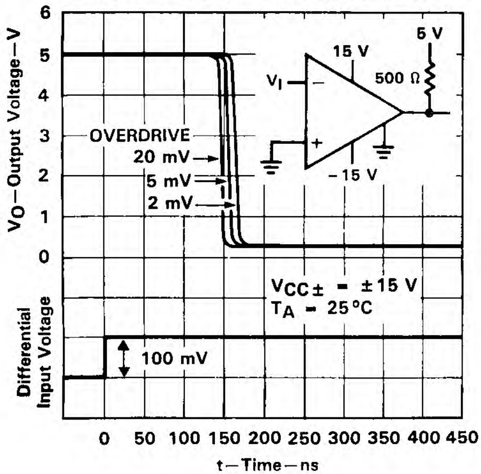


FIGURE 19

LOW- TO HIGH-LEVEL
OUTPUT RESPONSE
FOR VARIOUS INPUT OVERDRIVES

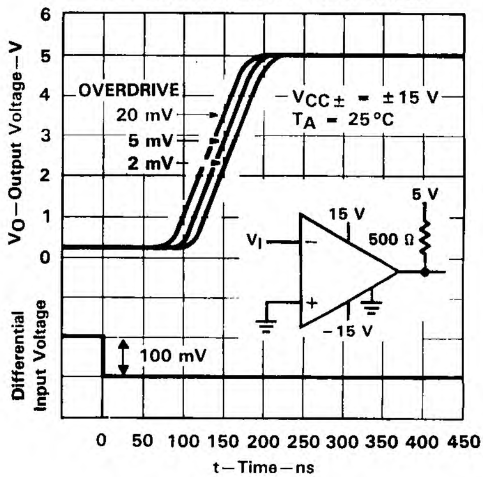


FIGURE 20

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA

preventing oscillation problems

Oscillation problems in comparators are often caused by stray capacitance between the output and inputs or between the output and other sensitive pins on the comparator. This is especially true for comparators with high gain and wide bandwidth, like the LT1011 (GBW ≥ 10 GHz), that are designed for fast switching with millivolt input signal levels. Because oscillation problems tend to occur at frequencies around 5 MHz, where the LT1011 has a gain of approximately 2 V/mV, attenuation of output signals must be at least 2000:1 at 5 MHz as measured at the inputs. If the source impedance is 1 kΩ, the effective stray capacitance between output and input must have a reactance of more than (2000)(1 kΩ) = 2 MΩ, or less than 2 pF. The actual inter-lead capacitance between input and output pins on the LT1011 is less than 0.002 pF when cut to mounting length for printed circuit boards. Additional stray capacitance due to printed circuit traces must be minimized by routing the output trace directly away from input lines and, if possible, running ground traces next to input traces to provide shielding.

Additional steps to prevent oscillation problems are:

1. Bypass the strobe/balance pins with a 0.01-µF capacitor connected from pin 5 to pin 6 to eliminate stray capacitive feedback from the output to the balance pins. The balance pins are nearly as sensitive to stray capacitive feedback as the inputs.
2. Bypass the negative supply (pin 4) with a 0.1-µF ceramic capacitor close to the comparator. A 0.1-µF capacitor can also be used for the positive supply (pin 8) if the pull-up load is tied to a separate supply. When the pull-up load is tied directly to pin 8, use a 2-µF solid tantalum bypass capacitor.
3. Bypass any slow-moving or dc input with a capacitor (≥ 0.01 µF) close to the comparator to reduce high-frequency source impedance.
4. Keep resistive source impedance as low as possible. If a resistor is added in series with one input, bypass it with a capacitor to balance source impedances for dc accuracy. The low input bias current of the LT1011 usually eliminates any need for source resistance balancing. A 5-kΩ imbalance, for example, creates only 0.25-mV offset.
5. Use hysteresis, which consists of shifting the input offset voltage of the comparator when the output changes state. Hysteresis forces the comparator to move quickly through its linear region, eliminating oscillations by "overdriving" the comparator under all input conditions. Hysteresis may be either ac or dc. An ac hysteresis technique does not shift the apparent offset voltage of the comparator but requires a minimum input signal slew rate to be effective. A dc hysteresis technique works for all input slew rates but creates a shift in offset voltage dependent on the previous condition of the input signal.

   The circuit shown in Figure 21 is an excellent compromise between ac and dc hysteresis. The 0.003-µF capacitor from pin 6 to pin 8 generates ac hysteresis by slightly shifting the voltage on the balance pins; both pins move about 4 mV depending on the state of the output. If pin 6 is bypassed, a level of ac hysteresis is created that is sufficient to switch the output at a speed near the comparator's maximum speed.

A small amount of dc hysteresis is also used to prevent problems due to low values of input slew rate. The sensitivity of the balance pins to current is about 0.5-mV input referred offset for each microampere of balance pin current. The 15-MΩ resistor tied from output to pin 5 generates 0.5-mV dc hysteresis.

The circuit is especially useful for general-purpose comparator applications because it does not force any signals directly back onto the input signal source. Instead, it takes advantage of the unique properties of the balance pins to provide extremely fast, clean output switching even with low-frequency input signals in the millivolt range. The combination of ac and dc hysteresis creates clean oscillation-free switching with very small input errors. The curve in Figure 22 plots input referred error versus switching frequency for the circuit shown in Figure 21. Note that at low frequencies, the error is simply the dc hysteresis, while at high frequencies, an additional error is created by the ac hysteresis. The high-frequency error can be reduced by reducing C_H, but lower values may not provide clean switching with very low slew-rate input signals.

TYPICAL APPLICATION DATA

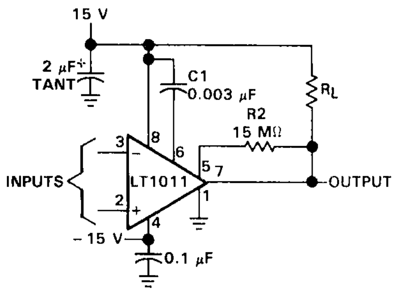


FIGURE 21. COMPARATOR WITH HYSTERESIS

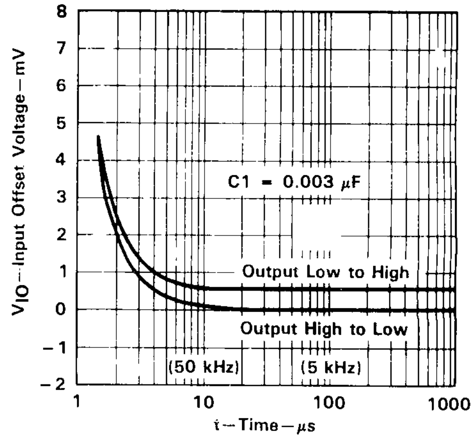
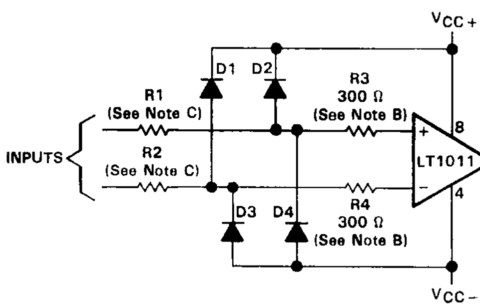


FIGURE 22

input protection

The inputs to the LT1011 are particularly suited to general-purpose comparator applications because large differential and/or common-mode voltages can be tolerated without damage to the comparator. Either or both inputs can be raised 40 V above the negative supply, independent of the positive supply voltage. Internal forward biased diodes conduct when the inputs are taken below the negative supply. In this condition, input current must be limited to 1 mA. If very large (fault) input voltages must be accommodated, series resistors and clamp diodes should be used, as shown in Figure 23.



NOTES: A. D1-D4 1N4148.
B. May be eliminated for fault current ≤ 1 mA.
C. Select according to allowable fault current and power dissipation.

FIGURE 23. LIMITING FAULT INPUT CURRENTS

TYPICAL APPLICATION DATA

The input resistors should limit fault current to a value between 0.1 mA and 20 mA. Power dissipation in the resistors must be considered for continuous faults, especially when the LT1011 supplies are off. Lightly loaded supplies may be forced to higher voltages by large fault currents flowing through D1-D4.

R3 and R4 limit input current to the LT1011 to less than 1 mA when the input signals are held below V_{CC-}. They may be eliminated if R1 and R2 are large enough to limit fault current to less than 1 mA.

input slew rate limitations

In the LT1011, step size is important because the slew rate of internal nodes increases response time for input step sizes larger than 1 V. For example, at 5-V step size, response time increases from 150 ns to 360 ns (see Figure 16). If response time is critical and large input signals are expected, clamp diodes across the inputs are recommended. The slew rate limitation can also affect performance when differential input voltage is low, but both inputs must slew quickly. The maximum suggested common-mode slew rate is 10 V/µs.

strobing

The LT1011 can be strobed by pulling current out of the strobe pin. The output transistor is forced to an off state, giving a high output at the collector (pin 7). Currents as low as −250 µA may cause strobing, but when the strobe current is low, strobe delay increases to between 200 ns and 300 ns. If strobe current is increased to −3 mA, strobe delay drops to about 60 ns. When the strobe current is 0, the voltage at the strobe pin is approximately 150 mV below V_{CC+}; when the strobe current is increased to −3 mA, the strobe pin voltage is approximately 2 V below V_{CC+}. Do not ground the strobe pin; it must be current driven.

Figure 24 shows a typical strobe circuit. Note that there is no bypass capacitor between pins 5 and 6, which maximizes strobe speed but leaves the comparator more sensitive to oscillation problems for slow, low-level inputs. A 1-pF capacitor between the output and pin 5 greatly reduces oscillation problems without reducing strobe speed.

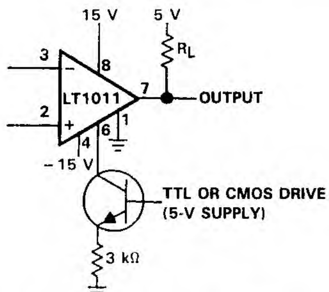


FIGURE 24. TYPICAL STROBE CIRCUIT

Placing a resistor from the output to pin 5 adds dc hysteresis. See step number 5 under "preventing oscillation problems."

The pin that is used for strobing (pin 6) is also one of the offset adjustment pins. Current into or out of pin 6 must be kept very low (< 0.2 µA) when not strobing to prevent input offset voltage shifts.

output transistor

When the LT1011 output transistor is in the off state, negligible current flows into or out of the collector or emitter. The equivalent circuit is shown in Figure 25.

TYPICAL APPLICATION DATA

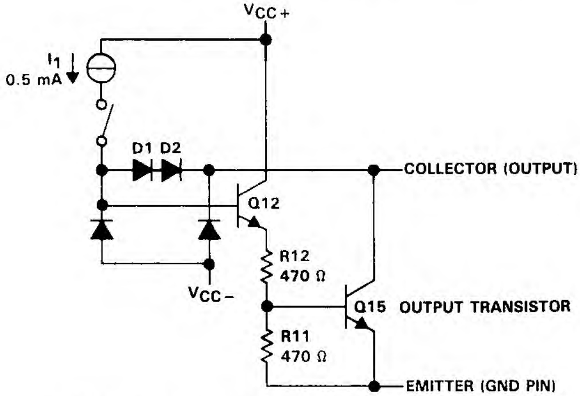


FIGURE 25. OUTPUT TRANSISTOR CIRCUITRY

output transistor (continued)

In the off state, I_1 is switched off and both Q12 and Q15 turn off. The collector of Q15 can then be held above V_{CC-} without conducting current. The maximum voltage above V_{CC-} is 50 V for the LT1011 and 40 V for the LT1011C (these maximum voltages may exceed V_{CC+}). The emitter can be held at any voltage between V_{CC-} and V_{CC+} as long as the voltage is negative with respect to the collector.

In the on state, I_1 is connected, which turns on both Q12 and Q15. Diodes D1 and D2 prevent deep saturation of Q15 to improve speed and also limit the drive current of Q12. The R11/R12 divider sets the saturation voltage of Q15 and provides turn-off drive. Either the collector or emitter pin can be held at a voltage between V_{CC-} and V_{CC+}, which allows the remaining pin to drive the load. In typical applications, the emitter is connected to V_{CC-} or ground, and the collector drives a load tied to V_{CC+} or a separate positive supply.

When the emitter is used as the output, the collector is typically tied to V_{CC+}, and the load is connected to ground or V_{CC-}. Note that the emitter output is phase reversed with respect to the collector output so that the "+" and "−" input designations must be reversed. When the collector is tied to V_{CC+}, the voltage at the emitter in the one state is about 2 V below V_{CC+}.

input signal range

The input voltage range of the LT1011 is typically 300 mV above the negative supply and 1.5 V below the positive supply, independent of the actual supply voltages. This is the input voltage range over which the output will respond correctly when a voltage within the range is applied to one input and a higher or lower signal is applied to the other input. If one input is inside the range and one is outside, the output will be correct. If both inputs are outside the range, in opposite directions, the output will still be correct. If, however, both inputs are outside the range in the same direction, the output will not respond to the differential input; it will remain unconditionally off.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATIONS

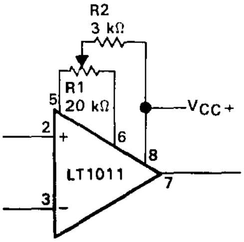
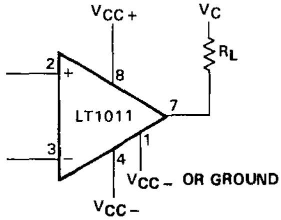
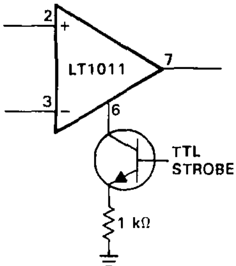


FIGURE 26. OFFSET BALANCING



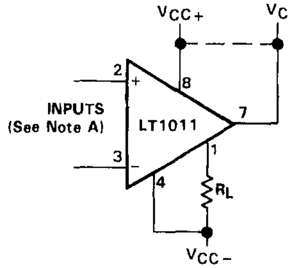
NOTE: V_C can be greater or less than V_{CC+}.

FIGURE 28. DRIVING LOAD REFERENCED TO POSITIVE SUPPLY



NOTE: Do not ground strobe pin

FIGURE 27. STROBING



NOTE A: Input polarity is reversed when using Pin 1 for output.

FIGURE 29. DRIVING LOAD REFERENCED TO NEGATIVE SUPPLY

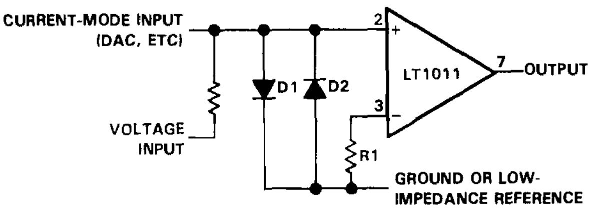
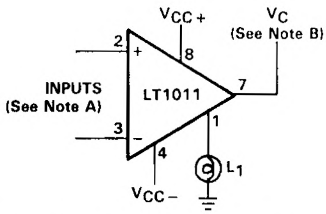


FIGURE 30. USING CLAMP DIODES TO IMPROVE FREQUENCY RESPONSE (See Figure 16)

3

Voltage Comparators

TYPICAL APPLICATIONS



NOTES: A. Input polarity is reversed when using Pin 1 for output.
B. V_C may be any voltage above V_{CC-}. Pin 1 swings to within approximately 2 V of V_{CC+}.

FIGURE 31. DRIVING LOAD REFERENCED TO GROUND

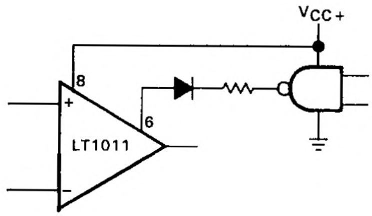
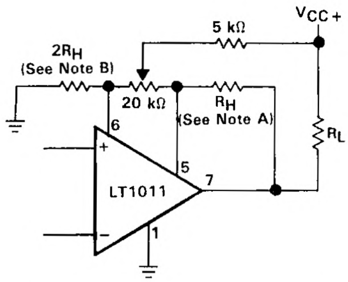


FIGURE 33. DIRECT STROBE DRIVE WHEN CMOS LOGIC USES SAME V_{CC+} SUPPLY AS LT1011 (Not applicable for TTL logic)



NOTES: A. Hysteresis is approximately 0.45 mV/μA change in current in R_H.
B. This resistor causes hysteresis to be centered around V_{IO}.

FIGURE 32. COMBINING OFFSET ADJUSTMENT AND HYSTERESIS

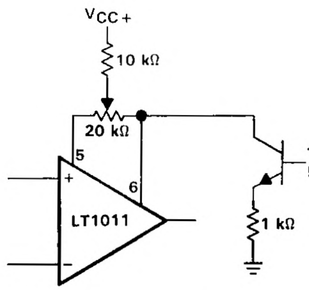
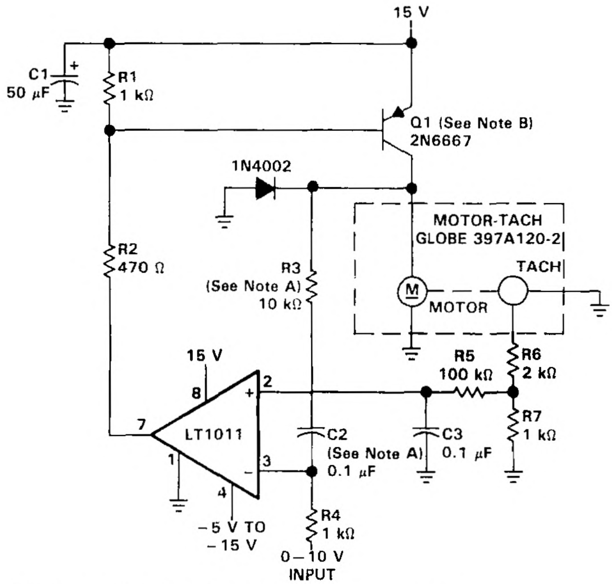


FIGURE 34. COMBINING OFFSET ADJUSTMENT AND STROBE

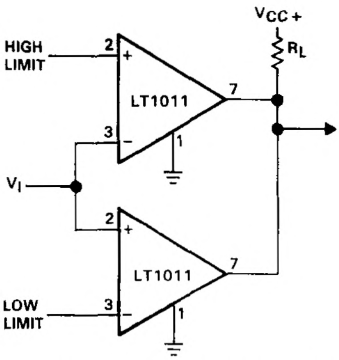
TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATIONS



NOTES: A. R3/C2 determines oscillation frequency of controller.
B. Q1 operates in switch mode.

FIGURE 35. HIGH-EFFICIENCY MOTOR SPEED CONTROLLER



NOTE: Output is high inside "window" and low above high limit or below low limit.

FIGURE 36. WINDOW DETECTOR

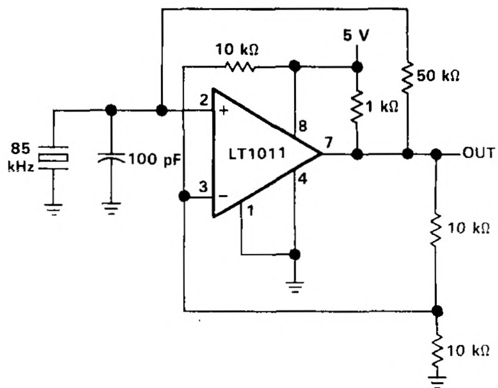
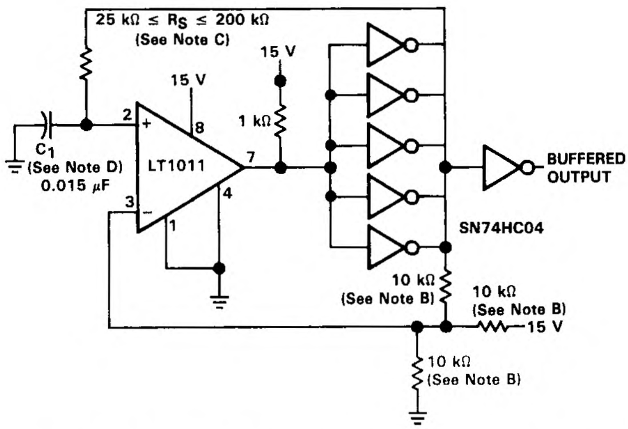


FIGURE 37. CRYSTAL OSCILLATOR

3

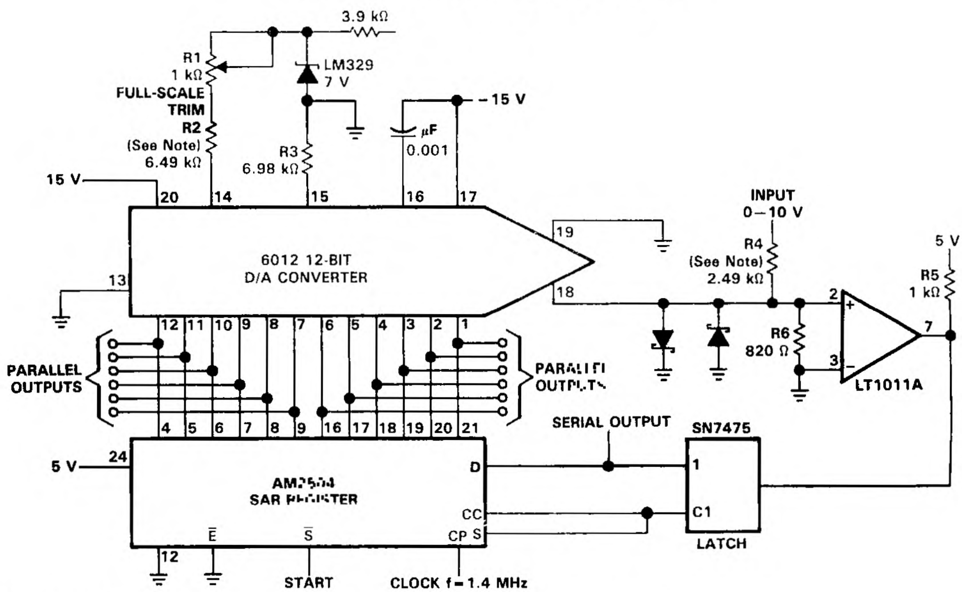
Voltage Comparators

TYPICAL APPLICATIONS



NOTES: A. Low drift and accurate frequency are obtained because this configuration rejects effects due to input offset voltage and input bias current of the comparator.
B. 1% metal film.
C. R_S = TRW type MTR-5/ + 120 ppm/°C.
D. C_1 = 0.015 µF = polystyrene : 120 ppm/°C ±30 ppm WESCO type 32-P.
E. Comparator contributes ≤ 10 ppm/°C drift for frequencies below 10 kHz.

FIGURE 38. LOW-DRIFT R/C OSCILLATOR

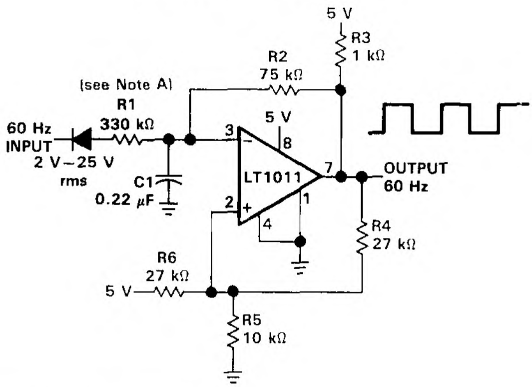


NOTE: R2 and R4 should TC track.

FIGURE 39. 10-µs 12-BIT A-D CONVERTER

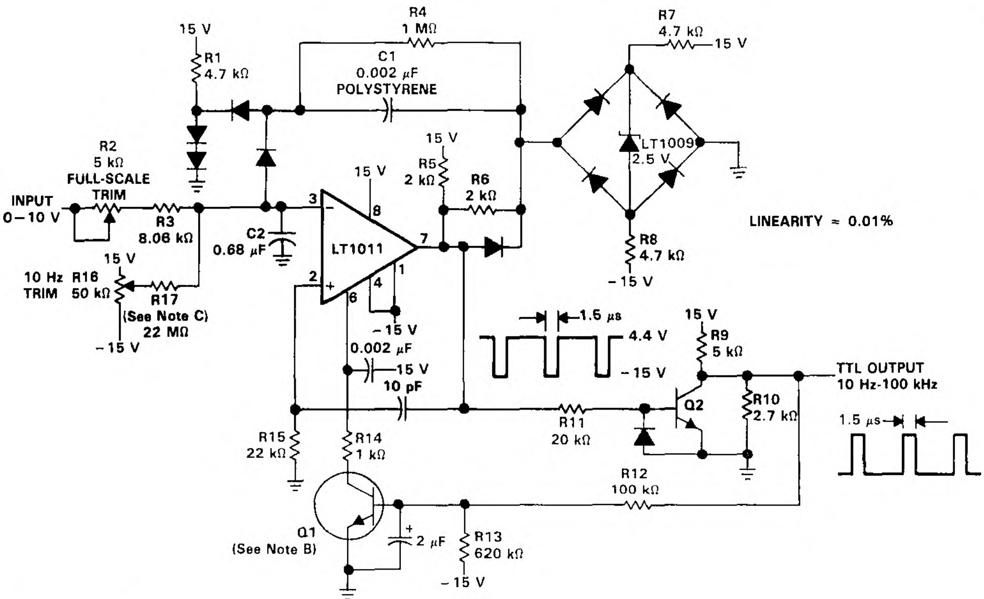
TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATIONS



NOTES: A. Increase R1 for larger input voltages.
B. LT1011 self-oscillates at approximately 60 Hz, thereby "locking" onto incoming line signal.

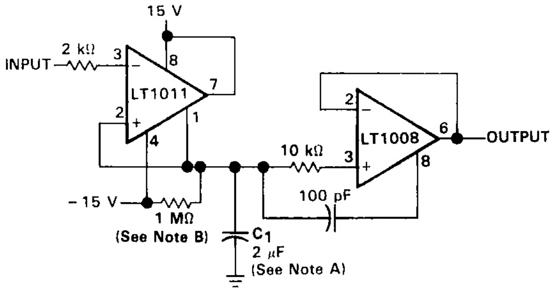
FIGURE 40. NOISE-IMMUNE 60-Hz LINE SYNCHRONIZATION



NOTES: A. All diodes 1N4148, transistors 2N3904.
B. Used only to guarantee start-up.
C. R17 may be increased for better 10-Hz trim resolution.

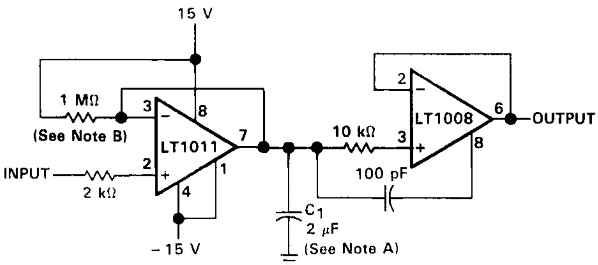
FIGURE 41. 10-Hz TO 100-kHz VOLTAGE-TO-FREQUENCY CONVERTER

TYPICAL APPLICATIONS



NOTES: A. Mylar
B. Set for required reset time constant.

FIGURE 42. POSITIVE PEAK DETECTOR

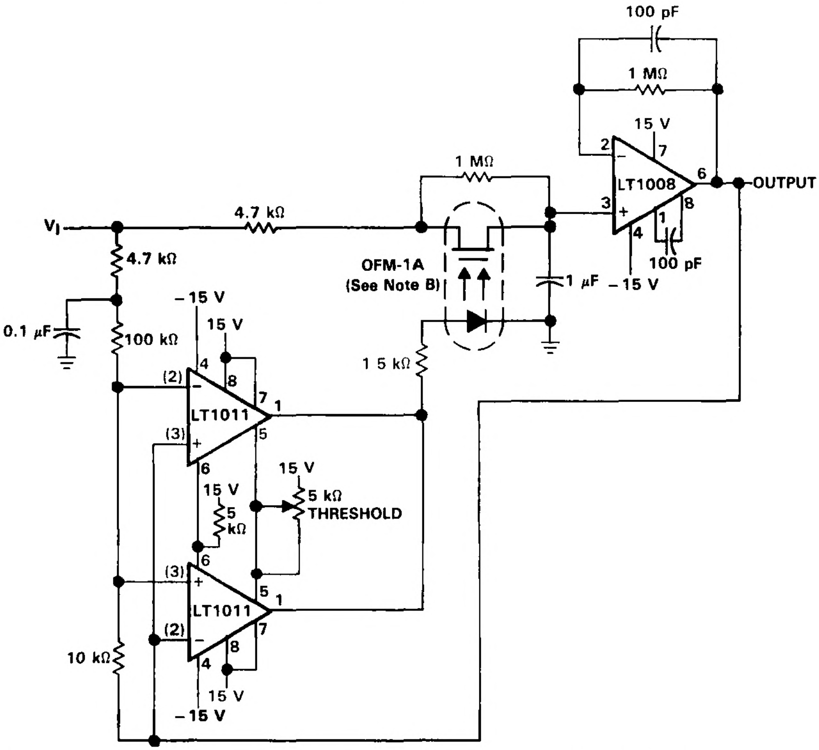


NOTES: A. Mylar
B. Select for required reset time constant.

FIGURE 43. NEGATIVE PEAK DETECTOR

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATIONS



NOTES: A. The comparators drive the opto-coupled FET "on" when the difference between the output and the input exceeds threshold. When the output approaches the input, the FET turns "off" and low-pass filtering occurs.

B. From Theta-J Corporation, Woburn, Massachusetts.

FIGURE 44. FAST-SETTLING FILTER

TYPICAL APPLICATIONS

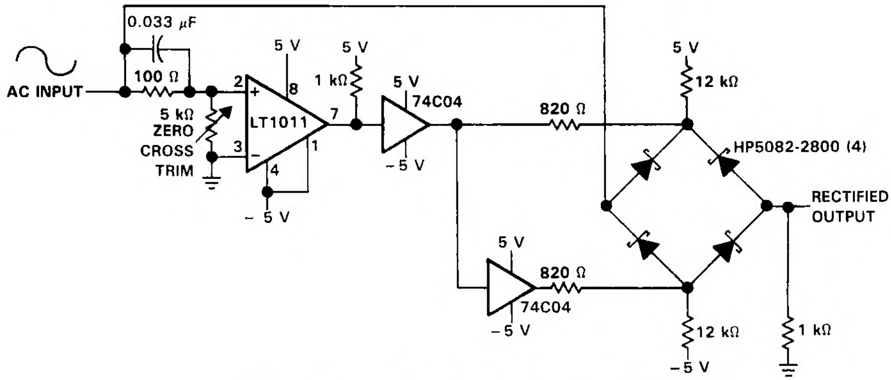
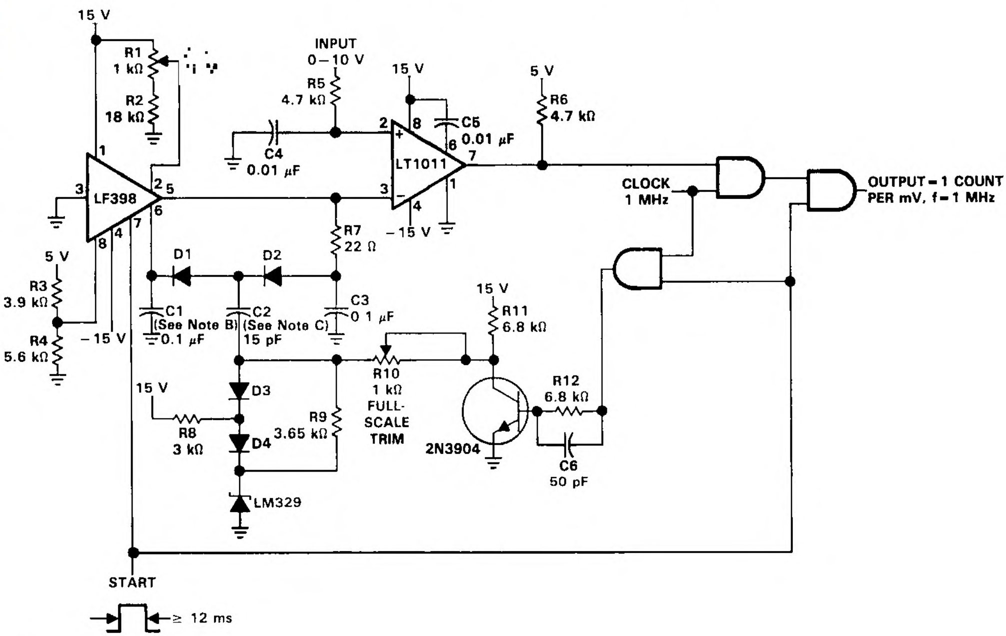


FIGURE 45. 100-kHz PRECISION RECTIFIER

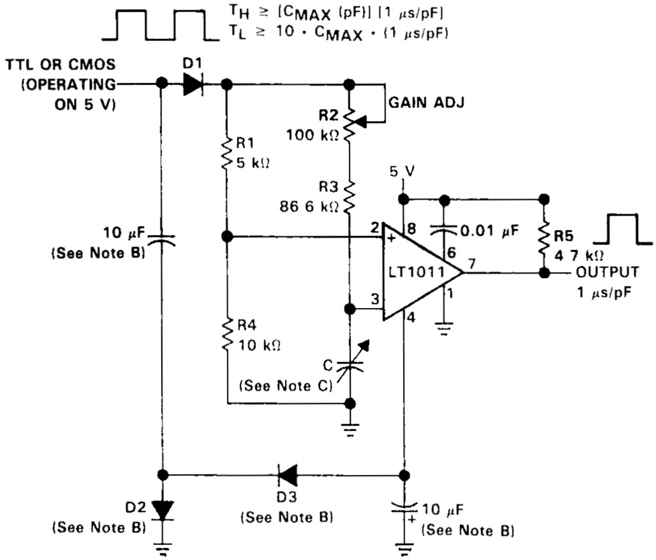


NOTES: A. All diodes 1N4148
B. Polystyrene
C. NPO

FIGURE 46. 4-DIGIT (10,000-COUNT) A-D CONVERTER

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATIONS



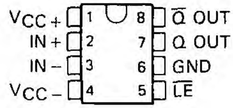
NOTES: A. PW = (R2 + R3) • (C) • [(R1 + R4)/R1]. The input capacitance of the LT1011 is approximately 6 pF. This is an offset term.
B. These components may be eliminated if negative supply is available (−1 V to −15 V).
C. Typical two sections of 365-pF variable capacitor when used as shaft-angle indication.

FIGURE 47. CAPACITANCE-TO-PULSE-WIDTH CONVERTER

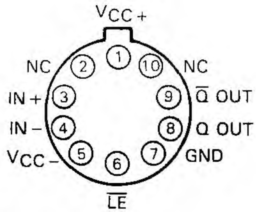
D3242, MAY 1988—REVISED MARCH 1989

- Ultra-Fast . . . 10 ns Typ t_{pd}
- Operates from Single 5-V or Dual ±5-V Supply
- Complementary TTL Outputs
- Low Input Offset Voltage . . . 0.8 mV or 1 mV Typ
- No Minimum Input Slew Rate Requirement
- No Supply Current Spiking
- Output Latch

D, JG, OR P PACKAGE
(TOP VIEW)



L PACKAGE
(TOP VIEW)



NC—No internal connection

All leads of the L package are electrically insulated from the case.

description

The LT1016 is an ultra-fast comparator specifically designed to interface directly to TTL logic while operating from either a dual ±5-V supply or a single 5-V supply. The LT1016 offers tight offset voltage specifications and high gain for precision applications. Matched complementary outputs further extend the versatility of the LT1016.

The LT1016 features a unique output stage that provides active drive in both directions for maximum speed into TTL-logic or passive loads yet does not exhibit the large current spikes normally found in totem-pole output stages. This eliminates the need for a minimum input slew rate typical of other fast comparators. The LT1016's ability to remain stable with the outputs in the active region greatly reduces the problem of output "glitching" when the input signal is slow moving or is at a low level.

The LT1016 has a true latch for retaining input data at the outputs. The outputs remain latched as long as the latch enable input L̄Ē is high. Quiescent negative supply current is only 3 mA, about ten times lower than competitive units. This feature reduces die temperature and allows the negative supply pin to be driven from virtually any supply voltage with a simple resistive divider. Device performance is not affected by variations in negative supply voltage.

The LT1016M is characterized for operation over the full military temperature range of −55°C to 125°C. The LT1016C is characterized for operation from 0°C to 70°C.

AVAILABLE OPTIONS

T_A	PACKAGE			
	SMALL OUTLINE (D)	CERAMIC DIP (JG)	METAL CAN (L)	PLASTIC DIP (P)
0°C to 70°C	LT1016CD	LT1016CJG	LT1016CL	LT1016CP
−55°C to 125°C		LT1016MJG	LT1016ML	

The D package is available taped and reeled. Add the suffix R to the device type (e.g., LT1016CDR).

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

Supply voltage, V_{CC+} (see Note 1) .... 7 V
Supply voltage, V_{CC-} .... −7 V
Differential input voltage (see Note 2) .... ±5 V
Input voltage (either input) .... $V_{CC\pm}$
Latch enable input voltage .... $V_{CC\pm}$
Output current, I_O .... ±20 mA
Operating free-air temperature range: LT1016M .... −55°C to 125°C
LT1016C .... 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: D or P package .... 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: JG package .... 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: L package .... 300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. The output may be shorted to ground or to either power supply.

recommended operating conditions

		LT1016M			LT1016C			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{CC+}				5			5	V
Supply voltage, V_{CC-}				−5			−5	V
Input voltage, V_I	$V_{CC\pm}$ = ±15 V	−3.75		3.5	−3.75		3.5	V
	V_{CC+} = 5 V, V_{CC-} = 0	1.25		3.5	1.25		1.25	
Operating free-air temperature, T_A		−55		125	0		70	°C

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

electrical characteristics, V_{CC+} = 5 V, V_{CC-} = −5 V, $V_{O(Q)}$ = 1.4 V, $\overline{LE}$ at 0 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	LT1016M MIN	LT1016M TYP	LT1016M MAX	LT1016C MIN	LT1016C TYP	LT1016C MAX	UNIT
V_{IO}	Input offset voltage (see Note 4)	$R_S \le 100\ \Omega$	25°C		0.8	2		1	3	mV
			Full range			3			3.5	
αV_{IO}	Average temperature coefficient of input offset voltage		Full range		4			4		μV/°C
I_{IO}	Input offset current (see Note 4)		25°C		0.3	1		0.3	1	μA
			Full range			1.3			1.3	
I_{IB}	Input bias current (see Note 5)	V_O = 1.4 V	25°C		5	10		5	10	μA
			Full range			13			13	
V_{ICR}	Common-mode input voltage range	Dual supply	Full range	−3.75 to 3.5			−3.75 to 3.5			V
		Single supply	Full range	1.25 to 3.5			1.25 to 3.5			
V_I	Input voltage	$\overline{LE}$ high	Full range	2			2			V
		$\overline{LE}$ low	Full range			0.8			0.8	
V_{OH}	High-level output voltage	$V_{CC+} \le 4.6$ V, I_O = 1 mA	Full range	2.7			2.7			V
		$V_{CC+} \le 4.6$ V, I_O = 10 mA		2.4			2.4			
V_{OL}	Low-level output voltage	I_O = 4 mA	Full range			0.5			0.5	V
		I_O = 10 mA	25°C		0.4			0.4		
A_{VD}	Small-signal differential voltage amplification	V_O = 1 V to 2 V	25°C	1400	3000		1400	3000		V/V
CMRR	Common-mode rejection ratio	V_{IC} = −3.75 V to 3.5 V	Full range	80			80			dB
k_{SVR}	Supply voltage rejection ratio	Positive supply, V_{CC+} = 4.6 V to 5.4 V	Full range	60			60			dB
		Negative supply, V_{CC-} = 2 V to 7 V		80			80			
I_{CC+}	Supply current from V_{CC+}		Full range			35			35	mA
I_{CC-}	Supply current from V_{CC-}		Full range			5			5	mA
I_I	Latch pin input current		Full range			500			500	μA

†Full range is −55°C to 125°C for the LT1016M. Full range is 0°C to 70°C for the LT1016C.

NOTES: 4. Input offset voltage is defined as the average of the two voltages measured by forcing first one output and then the other to 1.4 V. Input offset current is defined in an analogous way.

5. Input bias current is defined as the average of the two input currents.

3 Voltage Comparators

switching characteristics, V_{CC+} = 5 V, V_{CC-} = −5 V, $\overline{LE}$ at 0 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
t_{pd}	Propagation delay time	ΔV_I = 100 mV, 5-mV overdrive, See Note 6	25°C		10	14	ns
			Full range			16	
		ΔV_I = 100 mV, 20-mV overdrive, See Note 6	25°C		10	14	
			Full range			16	
Δt_{pd}	Differential propagation delay	ΔV_I = 100 mV, 5-mV overdrive, See Note 6	25°C			3	ns
	Latch minimum setup time		25°C		2		ns

†Full range is −55°C to 125°C for the LT1016M. Full range is 0°C to 70°C for the LT1016C.

NOTE 6: t_{pd} and Δt_{pd} cannot be measured in automatic-handling test equipment with low values of overdrive. The LT1016 is tested with a 1-V step and 500-mV overdrive. Correlation testing indicates that t_{pd} and Δt_{pd} limits shown can be met with this test. For low overdrive conditions, V_{IO} is added to the overdrive.

D2344, APRIL 1977—REVISED OCTOBER 1988

- **Single Supply or Dual Supplies**
- **Wide Range of Supply Voltage 2 to 36 V**
- **Low Supply Current Drain Independent of Supply Voltage . . . 0.8 mA Typ**
- **Low Input Bias Current . . . 25 nA Typ**
- **Low Input Offset Current 3 to 5 nA Typ**
- **Low Input Offset Voltage . . . 2 mV Typ**
- **Common-Mode Input Voltage Range Includes Ground**
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ±36 V**
- **Low Output Saturation Voltage**
- **Output Compatible with TTL, MOS, and CMOS**

D, JG, OR P PACKAGE
(TOP VIEW)

NC	1	8	NC
IN −	2	7	V_{CC}
IN +	3	6	OUT
GND	4	5	NC

NC—No internal connection

AVAILABLE OPTIONS

T_A	V_{IO} MAX at 25°C	PACKAGE SMALL OUTLINE (D)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	5 mV	TL331CD	TL331CJG	TL331CP
−25°C to 85°C	5 mV	TL331ID	TL331IJG	TL331IP

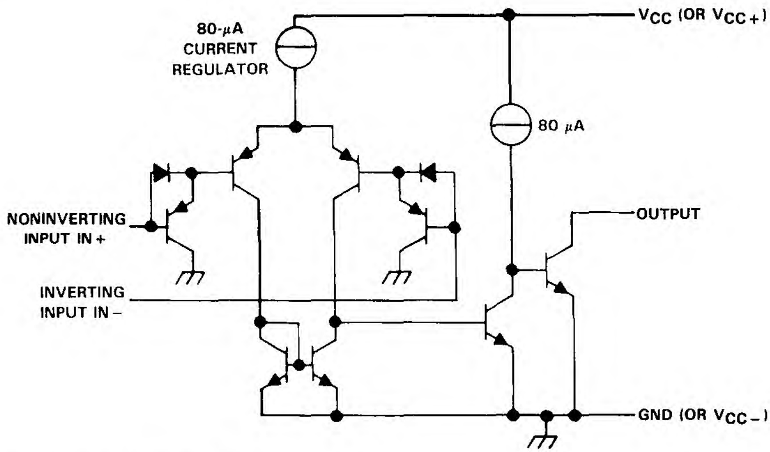
The D package is available taped and reeled. Add the suffix R to the device type (e.g., TL331CDR)

description

The TL331 is a voltage comparator that is designed to operate from a single power supply over a wide range of voltages. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 V to 36 V and pin 7 is at least 1.5 V more positive than the input common-mode voltage. Current drain is independent of the supply voltage.

The TL331I is characterized for operation from −25°C to 85°C. The TL331C is characterized for operation from 0°C to 70°C.

schematic



Current values shown are nominal.

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

Supply voltage, V_{CC} (see Note 1)	36 V
Differential input voltage (see Note 2)	±36 V
Input voltage range (either input)	−0.3 V to 36 V
Output voltage	36 V
Output current	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TL331I	−25°C to 85°C
TL331C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
D	[illegible] mW	5.8 mW/°C	464 mW	[illegible] mW
JG	680 mW	6.6 mW/°C	528 mW	429 mW
P	680 mW	8.0 mW/°C	640 mW	520 mW

recommended operating conditions

		TL331I MIN	TL331I MAX	TL331C MIN	TL331C MAX	UNIT
Supply voltage, V_{CC}		5	30	5	30	V
Common-mode input voltage, V_{IC}	V_{CC} = 5 V	0	3	0	3	V
	V_{CC} = 30 V	0	28	0	28	
Operating free-air temperature, T_A		−25	85	0	70	°C

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

PARAMETER		TEST CONDITIONS†			TL331I MIN	TL331I TYP	TL331I MAX	TL331C MIN	TL331C TYP	TL331C MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, V_{IC} = V_{ICR} min, V_O = 1.4 V		25°C		2	5		2	5	mV
				Full range			9			9	
I_{IO}	Input offset current	V_O = 1.4 V		2[illegible]		3	25		5	50	nA
				Full [illegible]			[illegible]			150	
I_{IB}	Input bias current			2[illegible]		−25	[illegible]		−25	[illegible]	nA
				Full range			−300			[illegible]	
V_{ICR}	Common-mode input voltage range	V_{CC} = 5 V to 30 V		25°C	0 to $V_{CC}-1.5$			0 to $V_{CC}-1.5$			V
				Full range	0 to $V_{CC}-2$			0 to $V_{CC}-2$			
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1.4 V to 11.4 V, R_L = 15 kΩ to V_{CC}		25°C		200			200		V/mV
I_{OH}	High-level output current	V_{ID} = 1 V	V_{OH} = 5 V	25°C		0.1			0.1		nA
			V_{OH} = 30 V	Full range			1			1	μA
V_{OL}	Low-level output voltage	V_{ID} = −1 V,	I_{OL} = 4 mA	25°C		150	[illegible]		150	400	mV
				Full range			[illegible]			700	
I_{OL}	Low-level output current	V_{ID} = −1 V,	V_{OL} = 1.5 V	25°C	6			6			mA
I_{CC}	Supply current	V_O = 2.5 V,	No load	25°C		0.5	0.8		0.5	0.8	mA

† Full range (MIN to MAX) for the TL331I is −25°C to 85°C and for the TL331C is 0°C to 70°C. All characteristics are measured with zero common-mode input voltage unless otherwise specified.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF,‡ See Note 4	[illegible]nV input step with 5-mV overdrive		1.3		μs
		TTL-level input step		0.3		

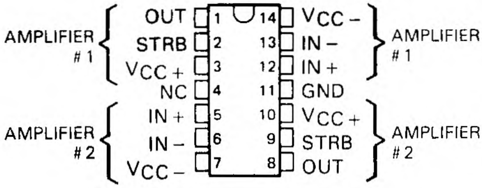
‡ C_L includes probe and jig capacitance.

NOTE 4: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

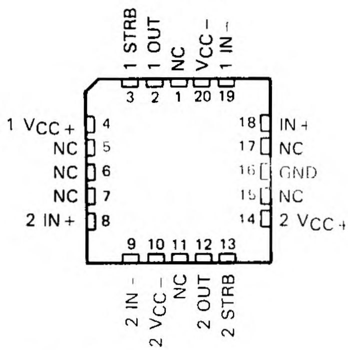
D999, OCT · :977–RE. M 1988

- Fast Response Times
- High Differential Voltage Amplification
- Low Offset Characteristics
- Outputs Compatible with Most TTL Circuits

J OR W PACKAGE
(TOP VIEW)



FK CHIP CARRIER
(TOP VIEW)



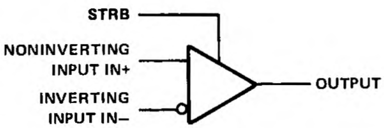
NC—No internal connection

description

The TL514 is an improved version of the TL720 dual high-speed voltage comparator. When compared with the TL720, these circuits feature higher amplification (typically 33,000) due to an extra amplification stage, increased accuracy because of lower offset characteristics, and greater flexibility with the addition of a strobe to each comparator. Since the output cannot be more positive than the strobe, a low-level input at the strobe will cause the output to go low regardless of the differential input.

These circuits are especially useful in applications requiring an amplitude discriminator, memory sense amplifier, or a high-speed limit detector. The TL514M is characterized for operation over the full military temperature range of −55°C to 125°C.

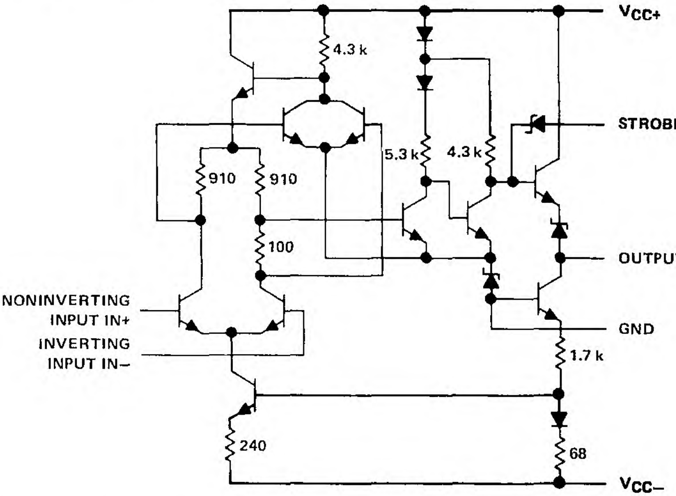
symbol (each comparator)



TEXAS INSTRUMENTS

POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

schematic (each comparator)



Resistor values shown are nominal in ohms

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

Supply voltage V_{CC+} (see Note 1)	14 V
Supply voltage V_{CC-} (see Note 1)	−7 V
Differential input voltage (see Note 2)	±5 V
Input voltage (any input, see Note 1)	±7 V
Strobe voltage (see Note 1)	6 V
Peak output current ($t_w \leq 1$ s)	10 mA
Continuous total dissipation (either comparator or both together)	See Dissipation Rating Table
Operating free-air temperature range	−55°C to 125°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or W package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 125°C$ POWER RATING
FK	[illegible] mW	11.0 [illegible]	[illegible]	[illegible] mW
J	600 mW	11.0 mW/°C	95°C	275 mW
W	600 mW	8.0 mW/°C	75°C	200 mW

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

electrical characteristics at specified free-air temperature, $V_{CC+} = 12$ V, $V_{CC-} = -6$ V

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$R_S \le 20\ \Omega$, See Note 4	25°C		0.6	2	mV
			−55°C to 125°C			3	
α_{VIO}	Average temperature coefficient of input offset voltage	$R_S = 50\ \Omega$, See Note 4	−55°C to 25°C		3	10	μV/°C
			25°C to 125°C		3	10	
I_{IO}	Input offset current	See Note 4	25°C		0.75	3	μA
			−55°C		1.8	7	
			125°C		0.25	3	
α_{IIO}	Average temperature coefficient of input offset current	See Note 4	−55°C to 25°C		15	75	nA/°C
			25°C to 125°C		5	25	
I_{IB}	Input bias current	See Note 4	25°C		7	15	μA
			−55°C		12	25	
$I_{IH(S)}$	High-level strobe current	$V_{(strobe)} = 5$ V, $V_{ID} = -5$ mV	25°C			±100	μA
$I_{IL(S)}$	Low-level strobe current	$V_{(strobe)} = -100$ mV, $V_{ID} = 5$ mV	25°C		−1	−2.5	mA
V_{ICR}	Common-mode input [illegible]ge range	$V_{CC} = -7$ V	−55°C to 125°C	±5			V
V_{ID}	[illegible]rential input voltage range		−55°C to 125°C	±5			V
A_{VD}	Large-signal differential voltage amplification	No load, $V_O = 0$ to 2.5 V	25°C	12.5	33		V/mV
			−55°C to 1[illegible]C	10			
V_{OH}	High-level output voltage	$V_{ID} = 5$ mV, $I_{OH} = 0$	−55°C to 125°C		4§	5	V
		$V_{ID} = 5$ mV, $I_{OH} = -5$ mA	−55°C to 125°C	2.5	3.6§		
V_{OL}	Low-level output voltage	$V_{ID} = -5$ mV, $I_{OL} = 0$	−55°C to 125°C	−1	−0.5§	0‡	V
		$V_{(strobe)} = 0.3$ V, $V_{ID} = 5$ mV, $I_{OL} = 0$	−55°C to 125°C	−1		0‡	V
I_{OL}	Low-level output current	$V_{ID} = -5$ mV, $V_O = 0$	25°C	2	2.4		mA
			−55°C	1	2.3		
			125°C	0.5	2.3		
r_o	Output resistance	$V_O = 1.4$ V	25°C		200		Ω
CMRR	Common-mode rejection ratio	$R_S \le 200\ \Omega$	−55°C to 125°C	80	100§		dB
I_{CC+}	Supply current from V_{CC+}¶	$V_{ID} = -5$ mV, No load	−55°C to 125°C		11§	18	mA
I_{CC-}	Supply current from V_{CC-}¶		−55°C to 125°C		−7§	−14	mA
P_D	Total power dissipation¶		−55°C to 125°C		180§	300	mW

† Unless otherwise noted, all characteristics are measured with the strobe open.

‡ The algebraic convention, where the most-positive (least-negative) limit is designated as maximum, is used in this data sheet for logic levels only, e.g., when 0 V is the maximum, the minimum limit is a more-negative voltage.

§ These typical values are at $T_A = 25$°C.

¶ Supply current and power dissipation limits apply for both comparators operating simultaneously.

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: $V_O = 1.8$ V at $T_A = -55$°C, $V_O = 1.4$ V at $T_A = 25$°C, and $V_O = 1$ V at $T_A = 125$°C. These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits this comparator is intended to drive.

switching characteristics, V_{CC+} = 12 V, V_{CC-} = −6 V, T_A = 25°C

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Response time	$R_L = \infty$ C_L = 5 pF, See Note 5		30	80	ns
Strobe release time	$R_L = \infty$ C_L = 5 pF, See Note 6		5	25	ns

NOTES: 5. The response time specified is for a 100-mV input step with 5-mV overdrive.
6. For testing purposes, the input bias conditions are selected to produce an output voltage of 1.4 V. A 5-mV overdrive is then added to the input bias voltage to produce an output voltage which rises above 1.4 V. The time interval is measured from the 50% point of the strobe voltage curve to the point where the overdriven output voltage crosses the 1.4-V level.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

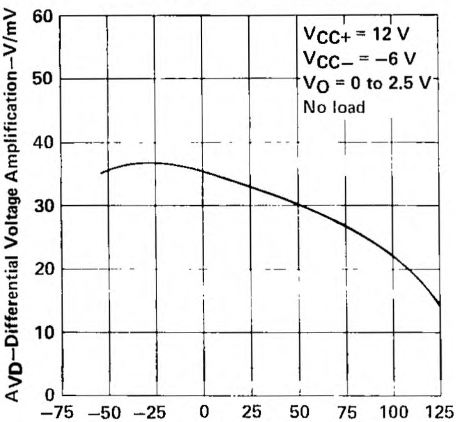


FIGURE 1

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs SUPPLY VOLTAGE

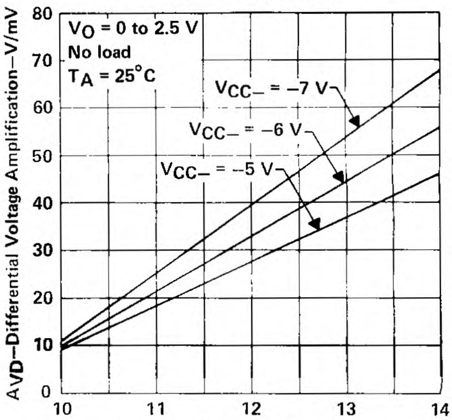


FIGURE 2

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE LEVELS
vs
FREE-AIR TEMPERATURE

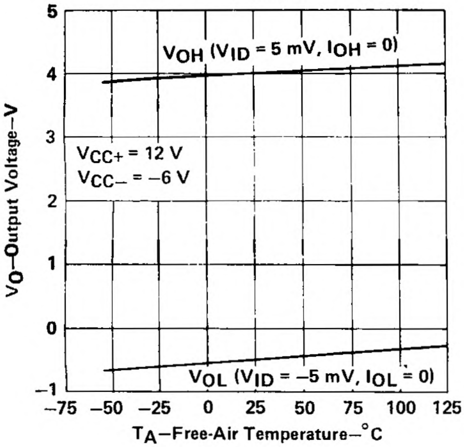


FIGURE 3

LOW-LEVEL OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

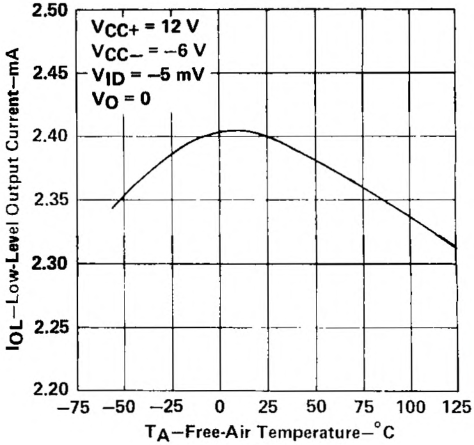


FIGURE 4

VOLTAGE TRANSFER CHARACTERISTICS

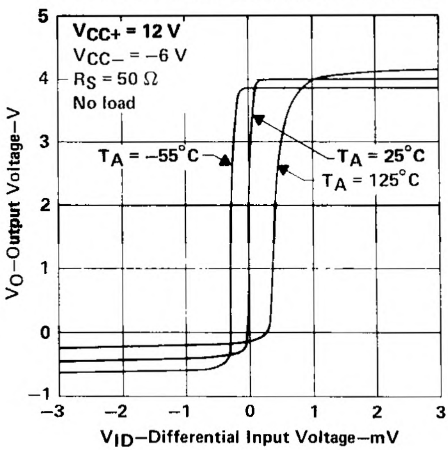


FIGURE 5

3

Voltage Comparators

TYPICAL CHARACTERISTICS

INPUT BIAS CURRENT
vs
FREE-AIR TEMPERATURE

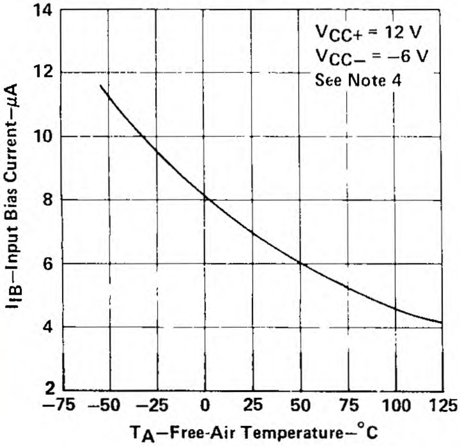


FIGURE 6

COMMON-MODE REJECTION RATIO
vs
FREE-AIR TEMPERATURE

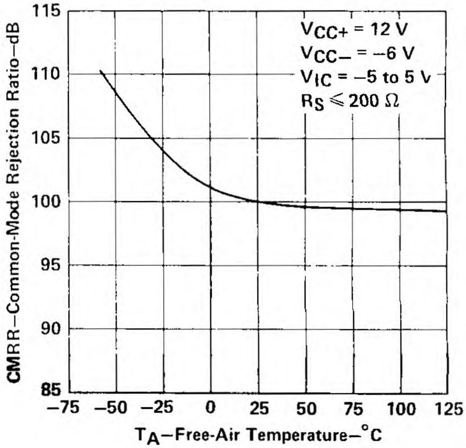


FIGURE 7

OUTPUT RESPONSE FOR
VARIOUS INPUT OVERDRIVES

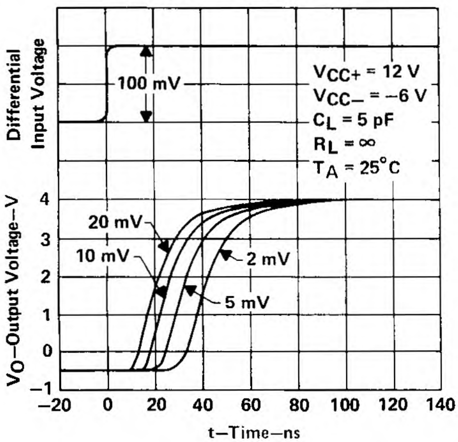


FIGURE 8

STROBE RELEASE TIME
FOR VARIOUS INPUT OVERDRIVES

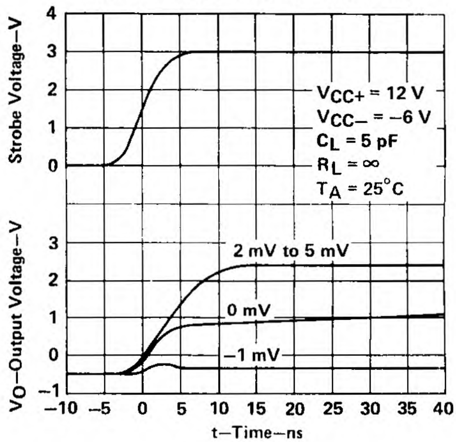


FIGURE 9

NOTE 4: These characteristics are verified by measurements at the following temperatures and output voltage levels: V_O = 1.8 V at T_A = −55°C, V_O = 1.4 V at T_A = 25°C, and V_O = 1 V at T_A = 125°C. These output voltage levels were selected to approximate the logic threshold voltages of the types of digital logic circuits this comparator is intended to drive.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

COMMON-MODE PULSE RESPONSE

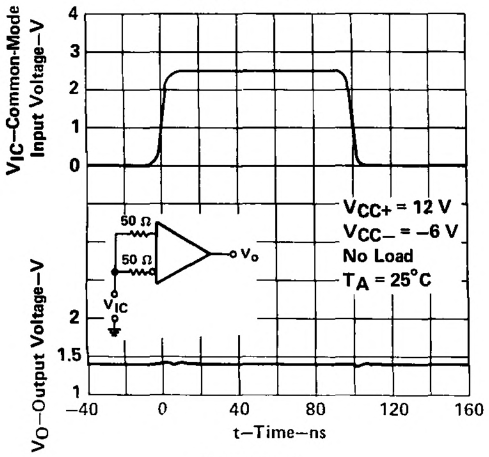


FIGURE 10

TOTAL POWER DISSIPATION
vs
FREE-AIR TEMPERATURE

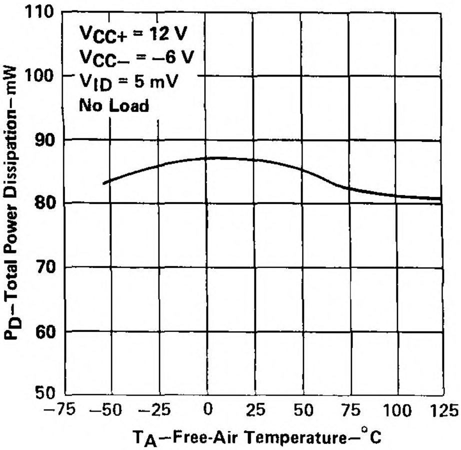
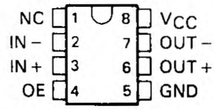


FIGURE 11

D2741, JUNE 1983—REVISED MARCH 1988

- Operates from a 5-V Supply
- 0 to 5 V Common-Mode Input Voltage Range
- Self-Biased Inputs
- Complementary 3-State Outputs
- Enable Capability
- Hysteresis . . . 5 mV Typ
- Response Times . . . 25 ns Typ

D, JG, OR P PACKAGE
(TOP VIEW)



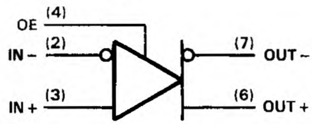
NC—No internal connection

description

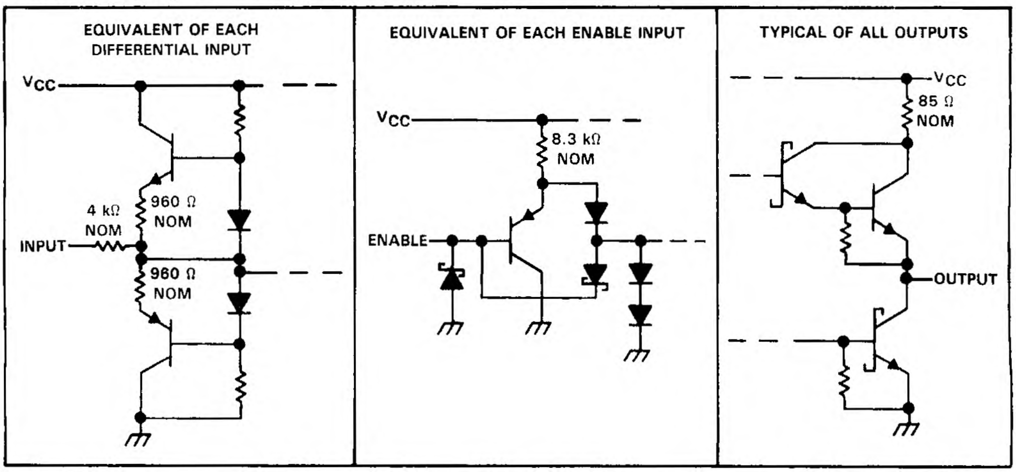
The TL712 is a high-speed comparator fabricated with bipolar Schottky† process technology. The circuit has differential analog inputs and complementary 3-state TTL-compatible logic outputs with symmetrical switching characteristics. When the output enable, OE, is low, both outputs are in the high-impedance state. This device operates from a single 5-V supply and is useful as a disk memory read-chain data comparator.

The TL712 is characterized for operation from 0°C to 70°C.

symbol (positive logic)



schematics of inputs and outputs



3

Voltage Comparators

TEXAS INSTRUMENTS

POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

Supply voltage, V_{CC} (see Note 1)	7 V
Input voltage, any differential input	±25 V
Differential input voltage (see Note 2)	±25 V
Enable input voltage	7 V
Low-level output current	50 mA
Operating free-air temperature range	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltage values are at the noninverting terminal with respect to the inverting terminal.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}	4.75	5	5.25	V
Common-mode input voltage, V_{IC}			±15	V
High-level output current, I_{OH}			−1	mA
Low-level output current, I_{OL}			16	mA
Operating free-air temperature, T_A	0		70	°C

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_T	Threshold voltage (V_{T+} and V_{T-})	V_{ICR} = 0 to 5 V	−[illegible]		[illegible]	mV
V_{hys}	Hysteresis ($V_{T+} - V_{T-}$)			5		mV
V_{OH}	High-level output voltage	V_{ID} = 100 mV, I_{OH} = −1 mA	2.7	3.5		V
V_{OL}	Low-level output voltage	V_{ID} = −100 mV, I_{OL} = 16 mA		0.4	0.5	V
I_{OZ}	Off-state output current	V_O = 2.4 V			−20	μA
I_I	Enable current	V_I = 5.5 V			100	μA
I_{IH}	High-level enable current	V_{IH} = 2.7 V			20	μA
I_{IL}	Low-level enable current	V_{IL} = 0.4 V			−360	μA
r_i	Differential input resistance		4			kΩ
r_o	Output resistance				100	Ω
I_{OS}	Short-circuit output current		−15		−85	mA
I_{CC}	Supply current	V_{ID} = 0, No load		17	20	mA

† The algebraic convention, where the more negative limit is designated as minimum, is used in this data sheet for input threshold voltage levels only.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	TTL load (see Figure 1), See Note 3		25		ns
t_{PHL}	Propagation delay time, high-to-low-level output			25		ns

NOTE 3: The response time specified is for a 100-mV input step with 5-mV overdrive (105 mV total), and is the interval between the input step function and the instant when the output crosses 2.5 V.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

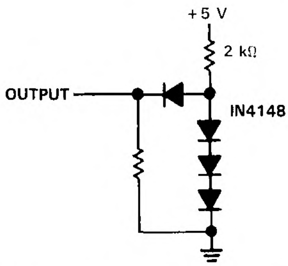


FIGURE 1. TTL OUTPUT LOAD CIRCUIT

TYPICAL CHARACTERISTICS

OUTPUT RESPONSE FOR VARIOUS
INPUT OVERDRIVES

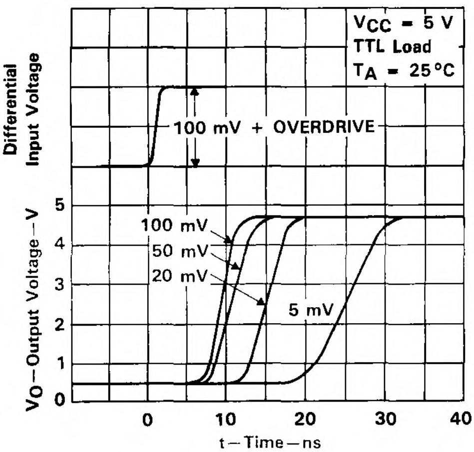


FIGURE 2

OUTPUT RESPONSE FOR VARIOUS
INPUT OVERDRIVES

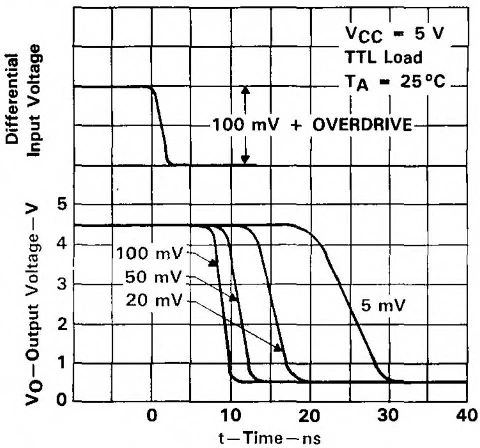


FIGURE 3

TYPICAL CHARACTERISTICS

COMMON-MODE
PULSE RESPONSE

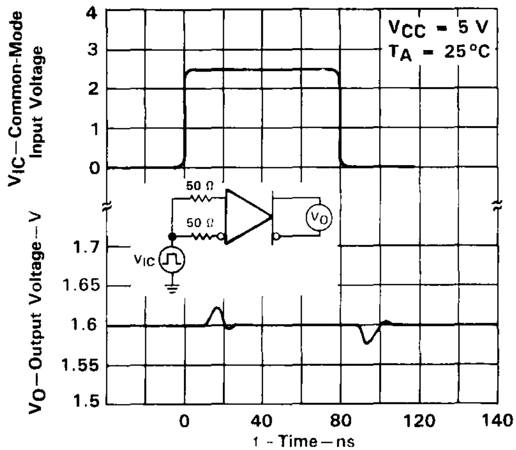


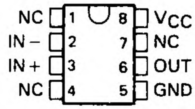
FIGURE 4

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

D3131, DECEMBER 1988

- **Operates from a 5-V Supply**
- **Self-Biasing Inputs**
- **Hysteresis . . . 10 mV Typical**
- **Response Time . . . 7 ns Typical**
- **Maximum Operating Frequency . . . 50 MHz Typical**

D OR P PACKAGE
(TOP VIEW)



NC—No internal connection

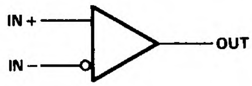
description

The TL714C is a high-speed differential comparator fabricated with bipolar Schottky process technology. The circuit has differential inputs and a TTL-compatible logic output with symmetrical switching characteristics.

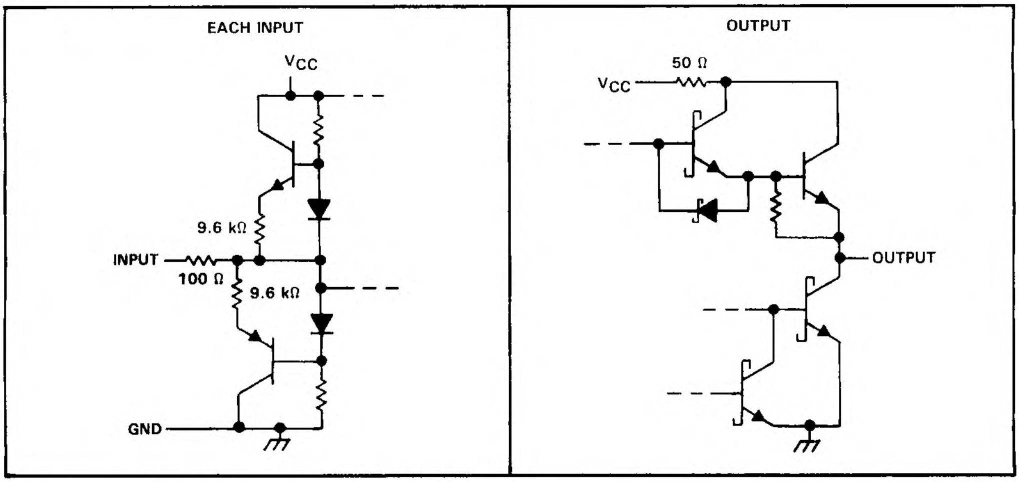
The device operates from a single 5-V supply and is useful as a disk-memory read-chain data comparator.

The TL714C is characterized for operation from 0°C to 70°C.

symbol



schematic of inputs and output



All resistor values shown are nominal.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

Supply voltage, V_{CC} (see Note 1) . . . . 7 V
Differential input voltage, V_{ID} (see Note 2) . . . . ±5 V
Input voltage range . . . . V_{CC} to GND
Low-level output current, I_{OL} . . . . 40 mA
Continuous total power dissipation . . . . See Dissipation Rating Table
Operating free-air temperature range . . . . 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

NOTES: 1. All voltage values, except for differential voltage, are with respect to the network ground.
2. Differential voltage values are at the noninverting terminal with respect to the inverting terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING
D	[illegible] mW	5.8 mW/°C	64°C	464 mW
P	500 mW	N/A	N/A	500 mW

recommended operating conditions

PARAMETER	MIN	MAX	UNIT
Supply voltage, V_{CC}	4.75	5.25	V
Common-mode input voltage, V_{IC}	1.4 to V_{CC} −1.4		V
High-level output current, I_{OH}		−1	mA
Low-level output current, I_{OL}		16	mA
Operating free-air temperature, T_A	0	70	°C

electrical characteristics over free-air operating temperature range, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
V_T	Threshold voltage	V_{IC} = 1.4 V to 3.6 V			±20	mV
V_{hys}	Hysteresis ($V_{T+} - V_{T-}$)		2	10	20	mV
V_{OH}	High-level output voltage	V_{ID} = 100 mV, I_{OH} = −1 mA	2.7	3.4		V
V_{OL}	Low-level output voltage	V_{ID} = −100 mV, I_{OL} = 16 mA		0.4	0.5	V
I_{OS}	Short-circuit output current		−15		−85	mA
r_i	Differential input resistance		2.9			kΩ
r_o	Output resistance				100	Ω
I_{CC}	Supply current	V_{ID} = 0, I_O = 0		7	20	mA

†All typical values are at T_A = 25°C.

switching characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{max}	Maximum operating frequency	V_{ID} = ±[illegible] mV, $t_r = t_f$ = 4 ns, C_L = 25 pF, Input duty cycle = 50%		50		MHz
t_{PLH}	Propagation delay time, low-to-high-level output	V_{ID} = ±100 mV, C_L = 25 pF, See Figures 1 and 2		7	25	ns
t_{PHL}	Propagation delay time, high-to-low-level output			7	25	ns
t_r	Rise time	V_{ID} = ±100 mV, C_L = 25 pF, See Figure 3		4	8	ns
t_f	Fall time			4	8	ns

PARAMETER MEASUREMENT INFORMATION

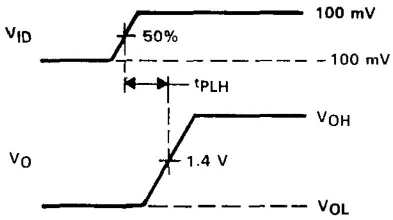


FIGURE 1. PROPAGATION DELAY TIME, LOW TO HIGH (t_{PLH})

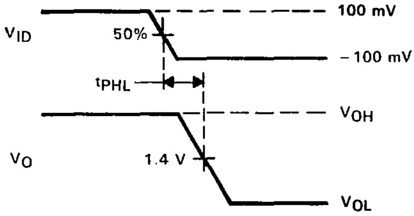


FIGURE 2. PROPAGATION DELAY TIME, HIGH TO LOW (t_{PHL})

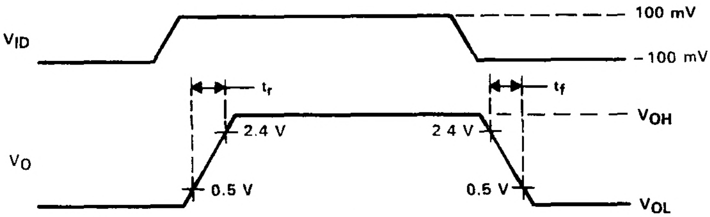


FIGURE 3. RISE AND FALL TIMES (t_r, t_f)

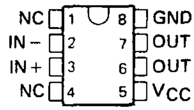
3

Voltage Comparators

D2781, FEBRUARY 1984—REVISED OCTOBER 1988

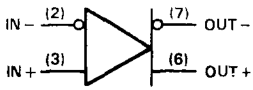
- Operates from a −5.2-V Power Supply
- Self-Biased Inputs
- Common-Mode Input Voltage Range 0 V to −5.2 V
- MECL III and MECL 10 000 Compatible
- Complementary ECL-Compatible Outputs
- Hysteresis . . . 5 mV Typ
- Response Times . . . 10 ns Typ

D, JG, OR P PACKAGE
(TOP VIEW)



NC—No internal connection

symbol



description

The TL721 is a high-speed voltage comparator fabricated with bipolar Schottky† process technology. The circuit has differential analog inputs and complementary ECL-compatible logic outputs with symmetrical switching characteristics. The device operates from a single −5.2-volt supply and is useful as a disk memory read-chain data comparator.

The TL721 is characterized for operation from 0°C to 70°C.

3

Voltage Comparators

†Integrated Schottky-Barrier diode-clamped transistor is patented by Texas Instruments. U.S. Patent Number 3,463,975.

TEXAS INSTRUMENTS

POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

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

Supply voltage, V_{CC} (see Note 1) . . . . −7 V
Input voltage, any differential input . . . . ±25 V
Differential input voltage (see Note 2) . . . . ±25 V
Low-level output current . . . . 50 mA
Operating free-air temperature range . . . . 0°C to 70°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package . . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package . . . . 260°C

NOTES: 1. All voltage values, except differential voltages, are with respect to the network ground terminal.
2. Differential voltage values are at the noninverting terminal with respect to the inverting terminal.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}		−5.2		V
Common-mode input voltage, V_{IC}			±7	V
High-level output current, I_{OH}			−1	mA
Low-level output current, I_{OL}			16	mA
Operating free-air temperature, T_A	0		70	°C

electrical characteristics at T_A = 25°C, V_{CC} = −5.2 V

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_T	Threshold voltage (V_{T+} and V_{T-})	$V_{IC} = V_{ICR}$ min		−1 [illegible]		[illegible]	mV
V_{hys}	Hysteresis ($V_{T+} - V_{T-}$)				5		mV
V_{OH}	High-level output voltage	V_{ID} = 100 mV,	R_L = 50 Ω to −2 V	−0.96†		−0.81	V
V_{OL}	Low-level output voltage	V_{ID} = −100 mV,	R_L = 50 Ω to −2 V	−1.85†		−1.65	V
V_{ICR}	Common-mode input voltage range			0 to −5.2			V
r_{in}	Input resistance			4			kΩ
I_{CC}	Supply current	V_{ID} = 0,	No load		−13	−17	mA

† The algebraic convention, in which the more negative limit is designated as minimum, is used in this data sheet for input threshold and output voltage levels only.

switching characteristics at T_A = 25°C, V_{CC} = −5.2 V

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	ΔV_{ID} = +200 mV to −200 mV or −200 mV to +200 mV, R_L = 50 Ω to −2 V		18		ns
t_{PHL}	Propagation delay time, high-to-low-level output			18		ns

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

OUTPUT RESPONSES FOR VARIOUS INPUT OVERDRIVES

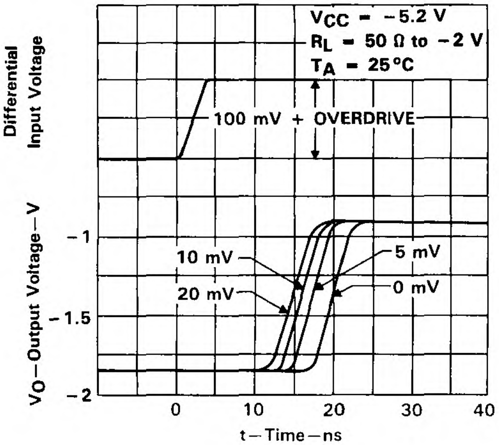


FIGURE 1

OUTPUT RESPONSES FOR VARIOUS INPUT OVERDRIVES

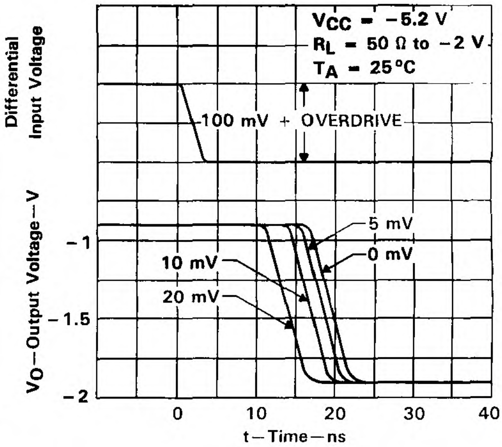


FIGURE 2

COMMON-MODE PULSE RESPONSE

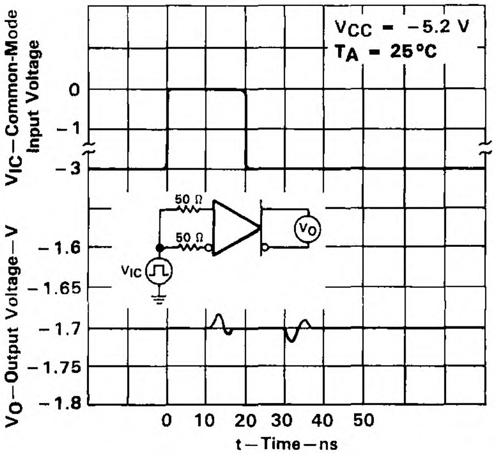


FIGURE 3

3

Voltage Comparators

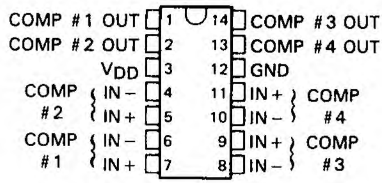
3

Voltage Comparators

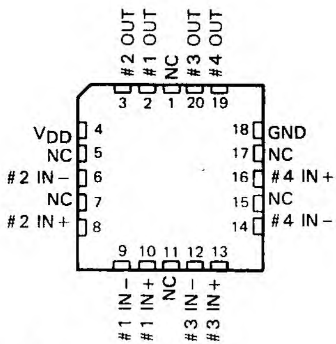
D3135, DECEMBER 1986 – REVISED FEBRUARY 1989

- Very Low Power . . . 200 μW Typ at 5 V
- Fast Response Time . . . 2.5 μs Typ with 5 mV Overdrive
- Single Supply Operation:
  TLC339M . . . 4 V to 16 V
  TLC339I . . . 3 V to 16 V
  TLC339C . . . 3 V to 16 V
- High Input Impedance . . . 10^{12} Ω Typ
- Input Offset Voltage Change at Worst Case Input Condition Typically 0.23 μV/Month Including the First 30 Days
- On-Chip ESD Protection

TLC339M . . . J PACKAGE
TLC339I, TLC339C . . . D, J, OR N PACKAGE
(TOP VIEW)



TLC339M . . . FK PACKAGE
(TOP VIEW)



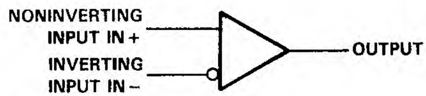
NC – No internal connection

description

The TLC339 consists of four independent differential-voltage comparators designed to operate from a single supply. It is functionally similar to the LM339 but uses 1/20th the power for similar response times. The open-drain MOS output stage will interface to a variety of loads and supplies, as well as "wired" logic functions. For a similar device with a push-pull output configuration, see the TLC3704 data sheet.

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias

symbol (each comparator)



AVAILABLE OPTIONS

T_A	V_{IO} max at 25°C	PACKAGE: SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)
0°C to 70°C	5 mV	TLC339CD	–	TLC339CJ	TLC339CN
−40°C to 85°C	5 mV	TLC339ID	–	TLC339IJ	TLC339IN
−55°C to 125°C	5 mV	–	TLC339MFK	TLC339MJ	–

The D package is available taped and reeled. Add the suffix R to the device type when ordering. (e.g., TLC339CDR)

[illegible] s a trademark of Texas Instruments Incorporated.

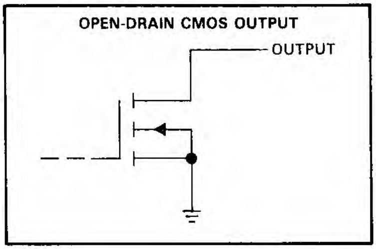
TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

description (continued)

currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

The TLC339M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC339I is characterized for operation over the extended industrial temperature range of −40°C to 85°C. The TLC339C is characterized for operation over the commercial temperature range of 0°C to 70°C.

schematic



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

Supply voltage, V_{DD} (see Note 1)	−0.3 V to 18 V
Differential input voltage (see Note 2)	±18 V
Input voltage, V_I	−0.3 V to V_{DD}
Output voltage, V_O	−0.3 V to V_{DD}
Input current, I_I	±5 mA
Output current, I_O (each output)	20 mA
Total supply current into V_{DD} terminal	40 mA
Total current out of ground terminal	60 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TLC339M	−55°C to 125°C
TLC339I	−40°C to 85°C
TLC339C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW	–
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J (TLC339M)	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J (TLC339I & C)	1025 mW	8.2 mW/°C	656 mW	533 mW	–
N	1150 mW	9.2 mW/°C	736 mW	598 mW	–

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	4	5	16	V
Common-mode input voltage, V_{IC}	0		$V_{DD}-1.5$	V
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−55		125	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.4	5	mV
			−55°C to 125°C			10	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			125°C			15	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			125°C			30	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			−55°C to 125°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			125°C		84		
			−55°C		84		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			125°C		84		
			−55°C		84		
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C		300	400	mV
			125°C			800	
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 V	25°C		0.8	40	nA
			125°C			1	µA
I_{DD}	Supply current (four comparators)	No load, Outputs low	25°C		44	80	µA
			−55°C to 125°C			175	

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD}.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
Low-level output current, I_{OL}		8	20	mA
Operating free-air temperature, T_A	−40		85	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 4	25°C		1.4	5	mV
			−40°C to 85°C			7	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			85°C			1	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			85°C			2	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			−40°C to 85°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			85°C		84		
			−40°C		84		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			85°C		85		
			−40°C		84		
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C		300	400	mV
			85°C			700	
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 V	25°C		0.8	40	nA
			85°C			1	µA
I_{DD}	Supply current (four comparators)	No load, Outputs low	25°C		44	80	µA
			−40°C to 85°C			125	

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
Low-level output current, I_{OL}		8	20	mA
Operating free-air temperature, T_A	0		70	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 4	25°C		1.4	5	mV
			0°C to 70°C			6.5	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			70°C			0.3	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			70°C			0.6	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			0°C to 70°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			70°C		84		
			0°C		84		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			70°C		85		
			0°C		85		
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C		300	400	mV
			70°C			650	
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 V	25°C		0.8	40	nA
			70°C			1	µA
I_{DD}	Supply current (four comparators)	No load, Outputs low	25°C		44	80	µA
			0°C to 70°C			100	

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

3

Voltage Comparators

switching characteristics, V_{DD} = 5 V, T_A = 25°C (see Figure 3)

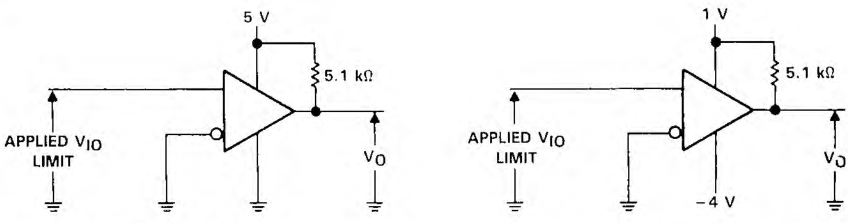
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high level output	f = 10 kHz, C_L = 15 pF	Overdrive = 2 mV		4.5		µs
			Overdrive = 5 mV		2.5		
			Overdrive = 10 mV		1.7		
			Overdrive = 20 mV		1.2		
			Overdrive = 40 mV		1.0		
		V_I = 1.4 V step at IN+ pin			1.1		
t_{PHL}	Propagation delay time, high-to-low level output	f = 10 kHz, C_L = 15 pF	Overdrive = 2 mV		3.6		µs
			Overdrive = 5 mV		2.1		
			Overdrive = 10 mV		1.3		
			Overdrive = 20 mV		0.85		
			Overdrive = 40 mV		0.55		
		V_I = 1.4 V step at IN+ pin			0.10		
t_{THL}	Transition time, high-to-low level output	f = 10 kHz, C_L = 15 pF	Overdrive = 50 mV		20		ns

PARAMETER MEASUREMENT INFORMATION

The TLC339 contains a digital output stage that, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternatives for testing parameters such as input offset voltage, common-mode rejection, etc., are suggested.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.



(a) V_{IO} with V_{IC} = 0 V   (b) V_{IO} with V_{IC} = 4 V

FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal but opposite in polarity to the input offset voltage, the output will change states.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching mode servo loop in which U1A generates a triangular waveform of approximately 20-mV amplitude. U1B acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1C through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

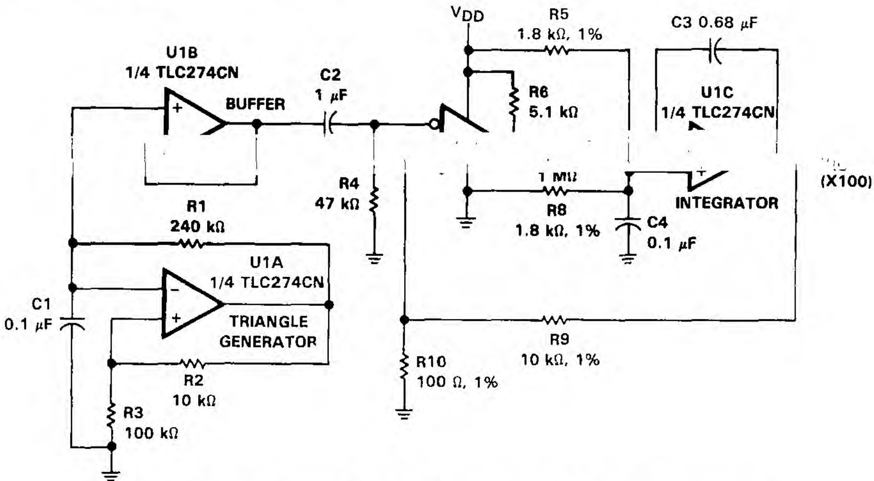
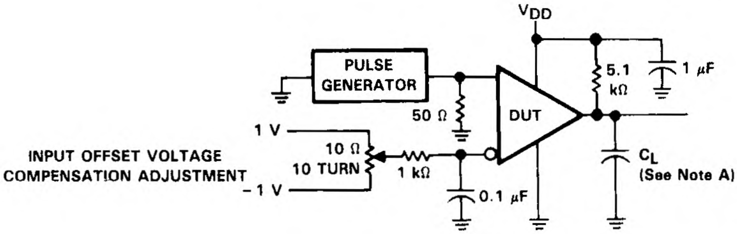


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

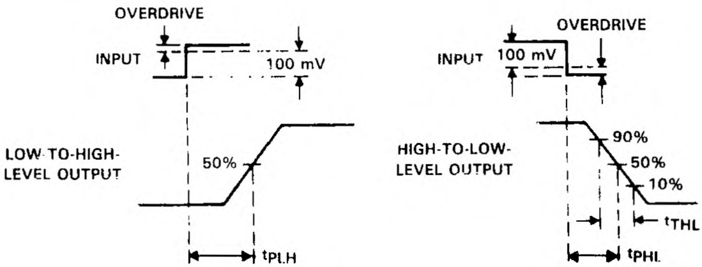
Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

PARAMETER MEASUREMENT INFORMATION

Propagation delay time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Propagation delay time, low-to-high-level output, is measured from the leading edge of the input pulse, while propagation delay time, high-to-low-level output, is measured from the trailing edge of the input pulse. Propagation delay time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

FIGURE 3. PROPAGATION DELAY, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS†

DISTRIBUTION OF INPUT OFFSET VOLTAGE

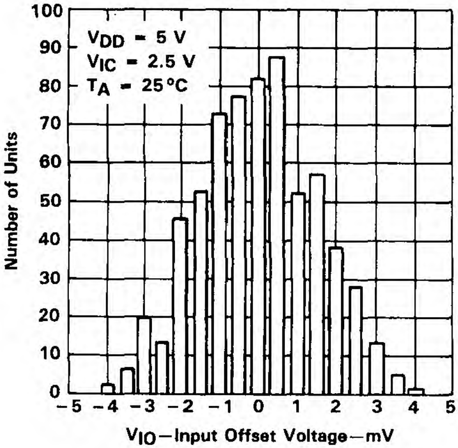


FIGURE 4

INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE

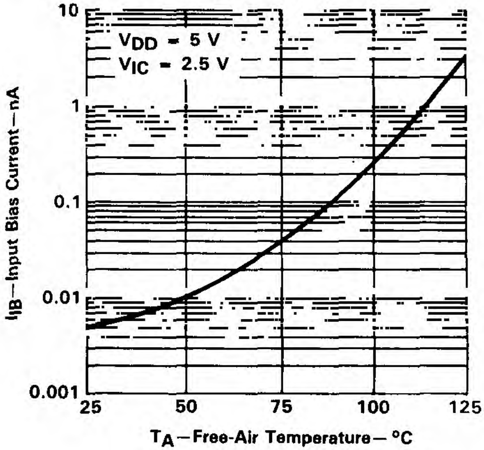


FIGURE 5

COMMON-MODE REJECTION RATIO vs FREE-AIR TEMPERATURE

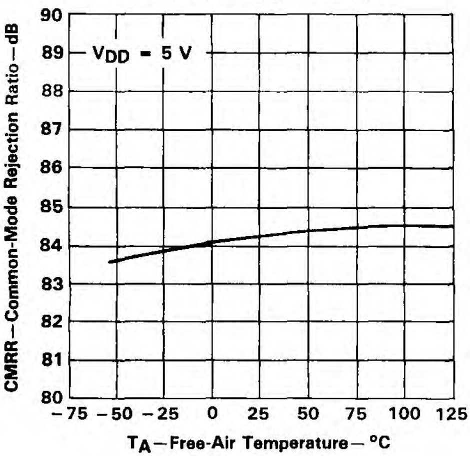


FIGURE 6

SUPPLY VOLTAGE REJECTION RATIO vs FREE-AIR TEMPERATURE

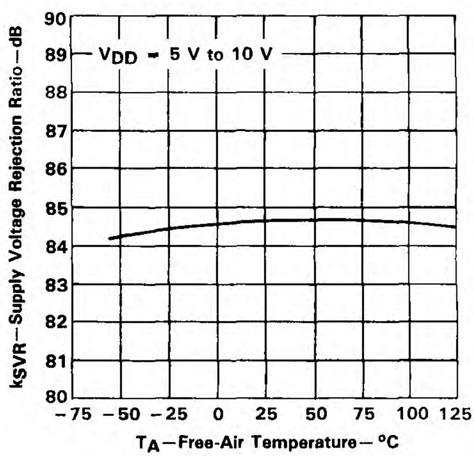


FIGURE 7

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT CURRENT
vs
HIGH-LEVEL OUTPUT VOLTAGE

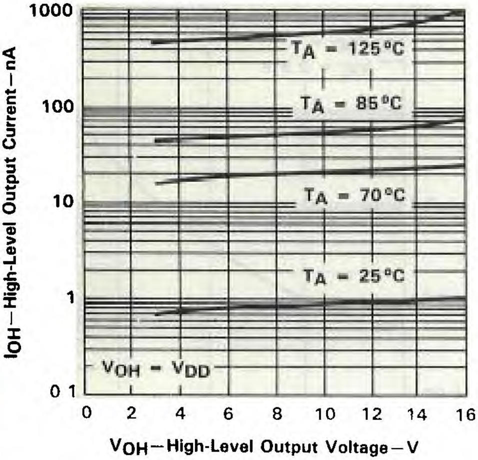


FIGURE 8

HIGH-LEVEL OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

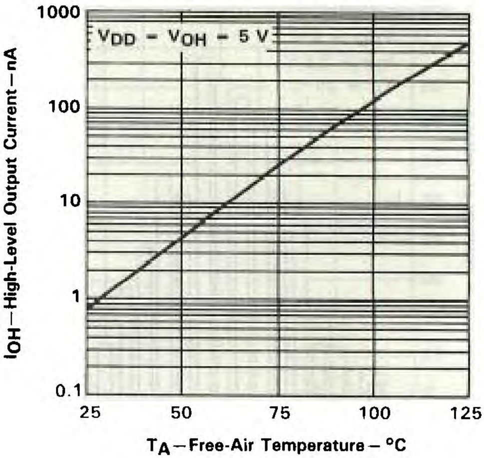


FIGURE 9

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

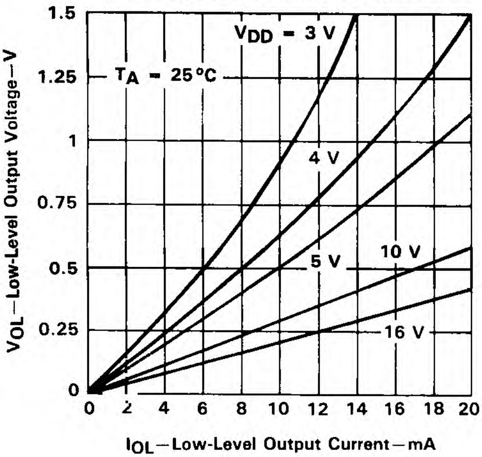


FIGURE 10

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

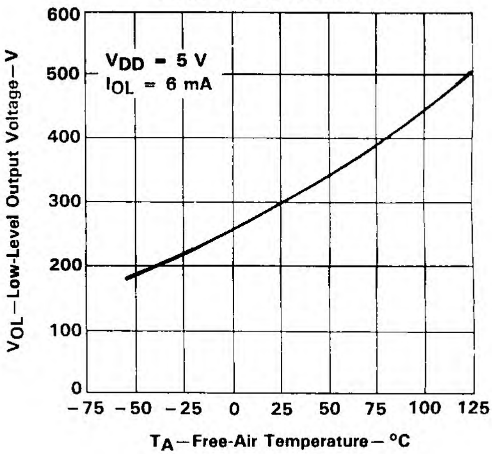


FIGURE 11

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

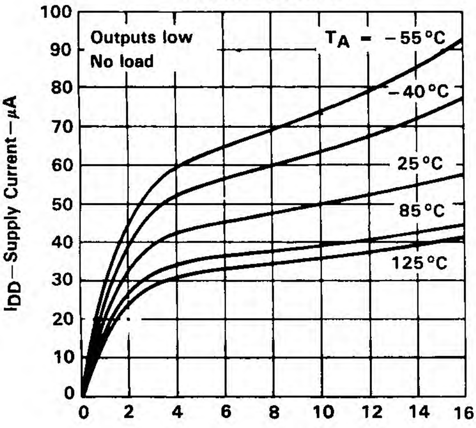


FIGURE 12

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

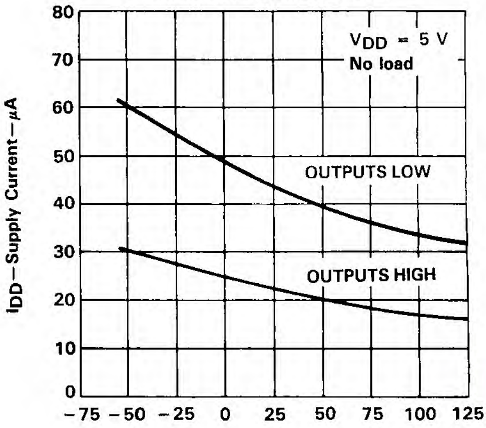


FIGURE 13

LOW-TO-HIGH-LEVEL
OUTPUT RESPONSE TIME
vs
SUPPLY VOLTAGE

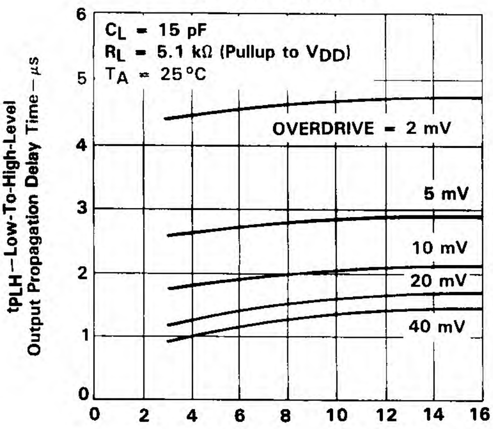


FIGURE 14

HIGH-TO-LOW-LEVEL
OUTPUT RESPONSE TIME
vs
SUPPLY VOLTAGE

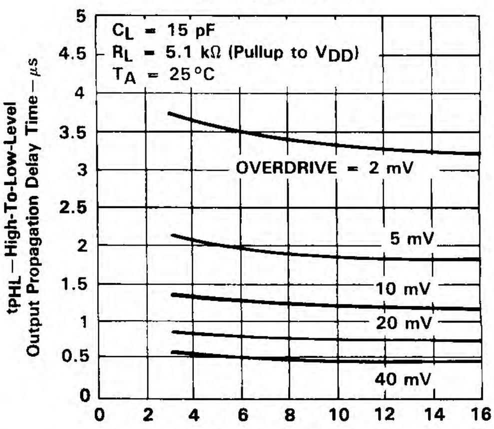


FIGURE 15

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

LOW-TO-HIGH-LEVEL OUTPUT PROPAGATION DELAY FOR VARIOUS OVERDRIVE VOLTAGES

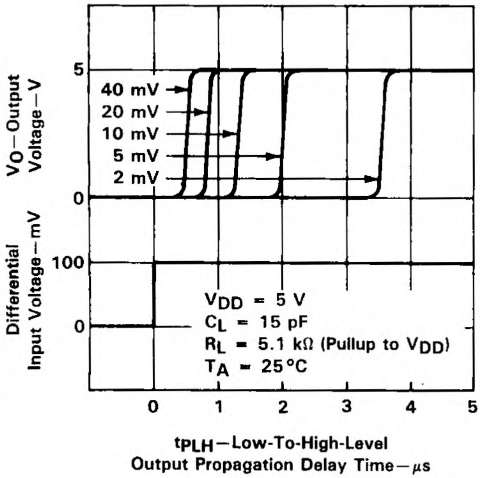


FIGURE 16

OUTPUT FALL TIME vs SUPPLY VOLTAGE

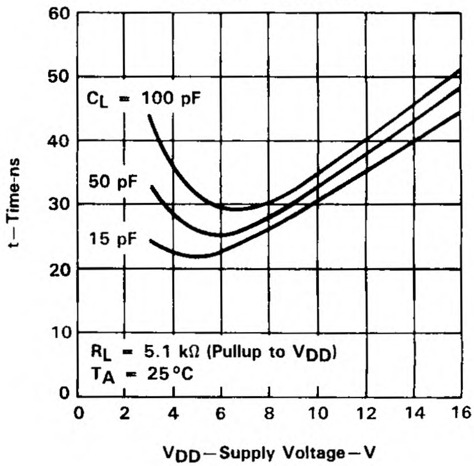


FIGURE 17

HIGH-TO-LOW-LEVEL OUTPUT PROPAGATION DELAY FOR VARIOUS OVERDRIVE VOLTAGES

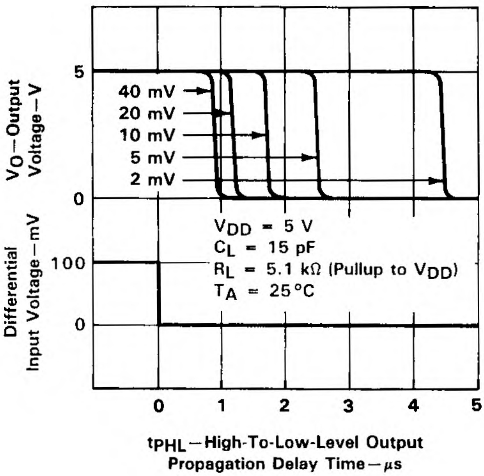


FIGURE 18

3

Voltage Comparators

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

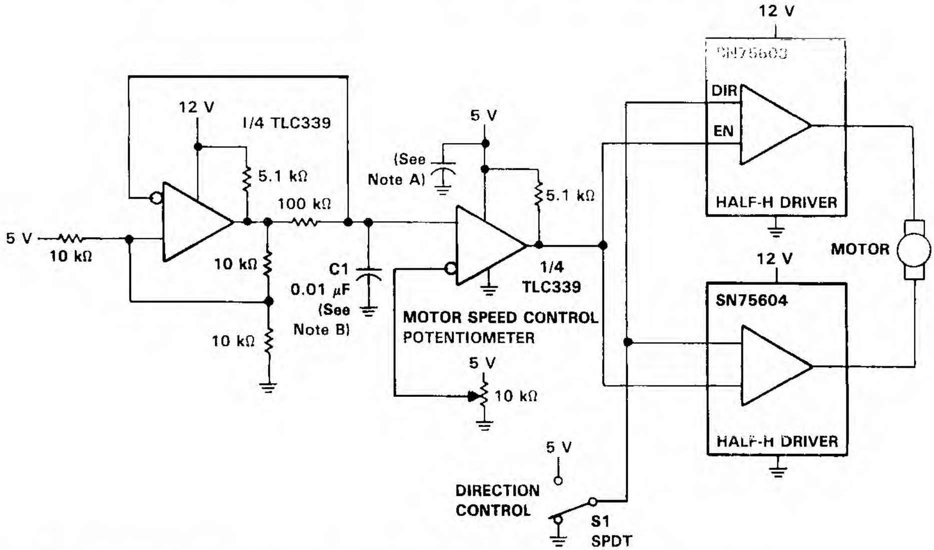
TYPICAL APPLICATION DATA

The inputs should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either input exceeds this range, the device will not be damaged as long as the input current is limited to less than 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with V_{DD} = 5 V, both inputs must remain between −0.2 V and 4 V to assure proper device operation.

To assure reliable operation, the supply should be decoupled with a capacitor (0.1 µF) positioned as close to the device as possible.

Be careful to note the output and supply current limitations since the TLC339 does not provide current protection. For example, each output can source or sink a maximum of 20 mA; however, the total current to ground can only be an absolute maximum of 60 mA. This prohibits sinking 20 mA from each of the four outputs simultaneously since the total current to ground would be 80 mA.

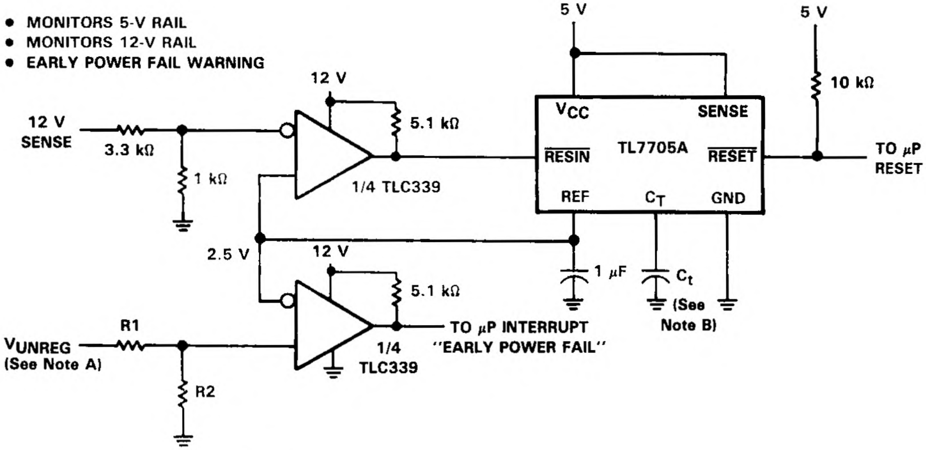
The TLC339 has internal ESD protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.



NOTES: A. The recommended minimum capacitance is 10 µF to eliminate common ground switching noise.
B. Select C1 for change in oscillator frequency.

FIGURE 19. PULSE-WIDTH-MODULATED MOTOR SPEED CONTROLLER

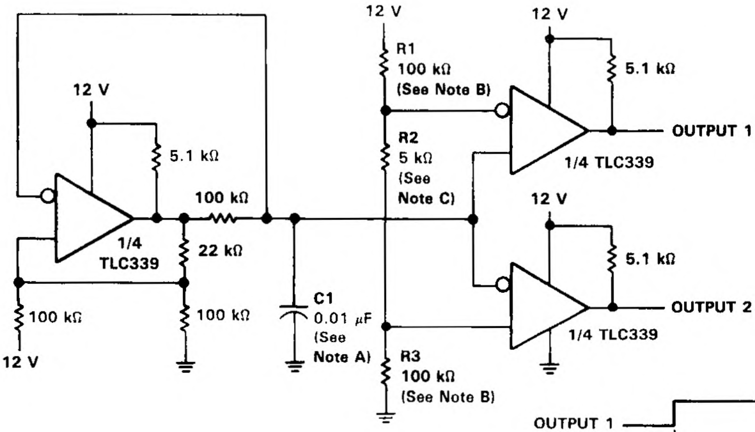
TYPICAL APPLICATION DATA

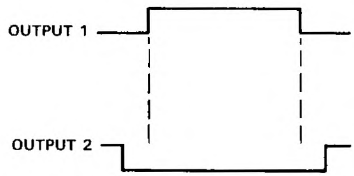


NOTES: A. $V_{UNREG} = 2.5\left(\frac{R1 + R2}{R2}\right)$

B. The value of C_t determines the time delay of reset.

FIGURE 20. ENHANCED SUPPLY SUPERVISOR





NOTES: A. Select C1 for a change in oscillator frequency where:
1/f = 1.85 (100 kΩ)C1

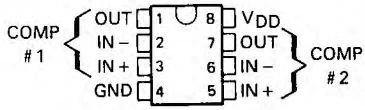
B. Select R1 and R3 to change duty cycle

C. Select R2 to change deadtime.

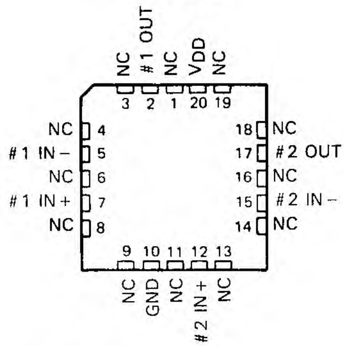
FIGURE 21. TWO-PHASE NONOVERLAPPING CLOCK GENERATOR

- **Single- or Dual-Supply Operation**
- **Wide Range of Supply Voltages . . . 1.4 V to 18 V**
- **Very Low Supply Current Drain**
  150 μA Typ at 5 V
  65 μA Typ at 1.4 V
- **Built-In ESD Protection**
- **High Input Impedance . . . 10^{12} Ω Typ**
- **Extremely Low Input Bias Current 5 pA Typ**
- **Ultrastable Low Input Offset Voltage**
- **Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 μV/Month, Including the First 30 Days**
- **Common-Mode Input Voltage Range Includes Ground**
- **Outputs Compatible with TTL, MOS, and CMOS**
- **Pin-Compatible with LM393**

TLC352M . . . JG PACKAGE
TLC352I, TLC352C . . . D, JG, OR P PACKAGE
(TOP VIEW)

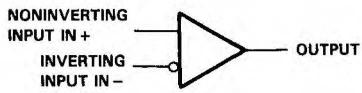


TLC352M . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

symbol (each comparator)



description

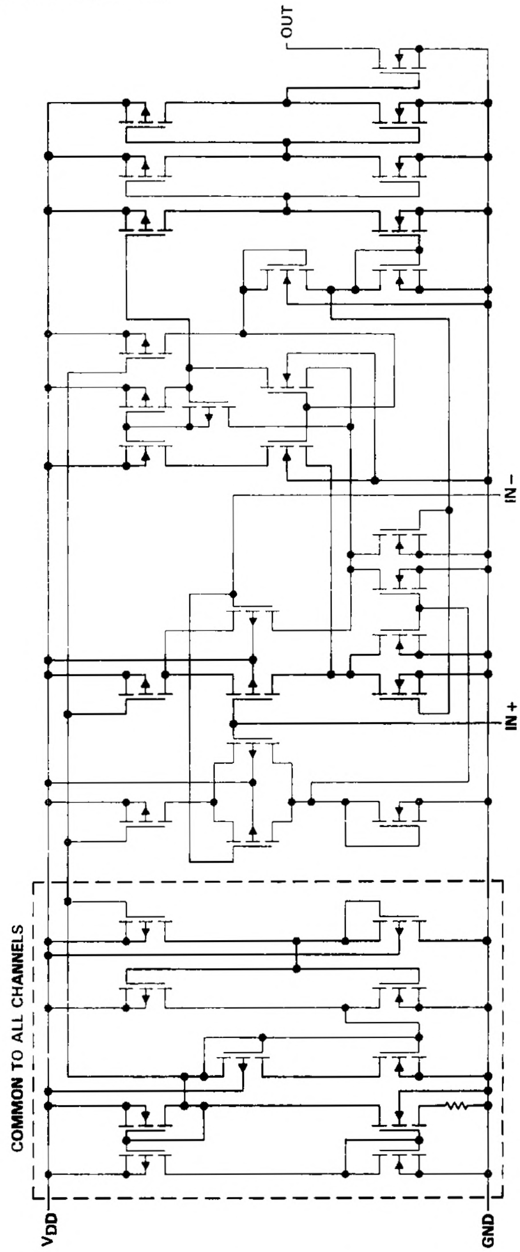
This device is fabricated using LinCMOS™ technology and consists of two independent voltage comparators, each designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 1.4 V to 18 V. Each device features extremely high input impedance (typically greater than 10^{12} Ω), which allows direct interface to high-impedance sources. The outputs are n-channel open-drain configurations and can be connected to achieve positive-logic wired-AND relationships. The capability of the TLC352 to operate from a 1.4-V supply makes this device ideal for low-voltage battery applications.

The TLC352 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015. However, care should be exercised in handling this device as exposure to ESD may result in degradation of the device parametric performance.

The TLC352M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC352I is characterized for operation over the industrial temperature range of −40°C to 85°C. The TLC352C is characterized for operation from 0°C to 70°C.

LinCMOS is a trademark of Texas Instruments Incorporated.

equivalent schematic (each comparator)



AVAILABLE OPTIONS

T_A	V_{IO} MAX AT 25°C	PACKAGE SMALL-OUTLINE (D)	CHIP-CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	5 mV	TLC352CD	—	TLC352CJG	TLC352CP
−40°C to 85°C	5 mV	TLC352ID	—	TLC352IJG	TLC352IP
−55°C to 125°C	5 mV	—	TLC352MFK	TLC352MJG	—

D packages are availabe taped and reeled. Add "R" suffix to device type when ordering (e.g., TLC352CDR).

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, V_I	V_{DD}
Input voltage range	−0.3 V to 18 V
Output voltage, V_O	18 V
Input current, I_I	±5 mA
Output current, I_O	20 mA
Duration of output short-circuit to ground (see Note 3)	unlimited
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TLC352M	−55°C to 125°C
TLC352I	−40°C to 85°C
TLC352C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C

NOTES: 1. All voltage values except differential voltages are with respect to network ground.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	[illegible] mW	5.8 mW/°C	64°C	464 mW	[illegible] mW	N/A
FK	500 mW	11.0 mW/°C	104°C	500 mW	500 mW	275 mW
JG (TLC352M)	500 mW	8.4 mW/°C	90°C	500 mW	500 mW	210 mW
JG (TLC352I, TLC352C)	500 mW	6.6 mW/°C	74°C	500 mW	429 mW	N/A
P	500 mW	N/A	N/A	500 mW	500 mW	N/A

recommended operating conditions

		M SUFFIX			I-SUFFIX			C-SUFFIX			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{DD}		4		16	3		16	3		16	V
Common-mode input voltage, V_{IC}	V_{DD} = 5 V	0		3.5	0		3.5	0		3.5	V
	V_{DD} = 10 V	0		8.5	0		8.5	0		8.5	
Operating free-air temperature, T_A		−55		125	−40		85	0		70	°C

electrical characteristics at specified free-air temperature, V_{DD} = 1.4 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†		TLC352M			TLC352I			T[illegible]			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	[illegible]	MAX	
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$ min, See Note 4	25°C		2	5		2	5		2	5	mV
			Full range			10			7			6.5	
I_{IO}	Input offset current		25°C		1			1			1		pA
			MAX T_A			10			1			0.3	nA
I_{IB}	Input bias current		25°C		5			5			5		pA
			MAX T_A			20			2			0.6	nA
V_{ICR}	Common-mode input voltage range		Full range	0 to 0 2			0 to 0.2			0 to 0.2			V
V_{OL}	Low-level output voltage	V_{ID} = −0.5 V, I_{OL} = 0.6 mA	25°C		100	200		100	200		100	200	mV
			Full range			200			200			200	
I_{OL}	Low-level output current	V_{ID} = −0.5 V, V_{OL} = 0.3 V	25°C	1	1.6		1	1.6		1	1.6		mA
I_{DD}	Supply current (two comparators)	V_{DD} = 0.5 V, No load	25°C		65	150		65	150		65	150	μA
			Full range			200			200			200	

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is −55°C to 125°C for TLC352M, 0°C to 70°C for TLC352C, and −40°C to 85°C for TLC352I. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 1.25 V or below 150 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

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

PARAMETER		TEST CONDITIONS†			TLC352M MIN	TLC352M TYP	TLC352M MAX	TLC352I MIN	TLC352I TYP	TLC352I MAX	TLC352C MIN	TLC352C TYP	TLC352C MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$ min,	See Note 5	25°C		1	5		1	5		1	5	mV
				Full range			10			7			6.5	mV
I_{IO}	Input offset current			25°C		1			1			1		pA
				MAX T_A			10			1			0.3	nA
I_{IB}	Input bias current			25°C		5			5			5		pA
				MAX T_A			20			2			0.6	nA
V_{ICR}	Common-mode input voltage range			25°C	0 to $V_{DD}-1$			0 to $V_{DD}-1$			0 to $V_{DD}-1$			V
				Full range	0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			V
I_{OH}	High-level output current	V_{ID} = 1 V	V_{OH} = 5 V	25°C		0.1			0.1			0.1		nA
			V_{OH} = 15 V	Full range			1			1			1	μA
V_{OL}	Low-level output voltage	V_{ID} = −1 V,	I_{OL} = 4 mA	25°C		150	400		150	400		150	400	mV
				Full range			700			700			700	mV
I_{OL}	Low-level output current	V_{ID} = −1 V,	V_{OL} = 1.5 V	25°C	6	16		6	16		6	16		mA
I_{DD}	Supply current (two comparators)	V_{DD} = 1 V,	No load	25°C		0.15	0.3		0.15	0.3		0.15	0.3	μA
				Full range			0.4			0.4			0.4	μA

†All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is −55°C to 125°C for TLC352M, 0°C to 70°C for TLC352C, and −40°C to 85°C for TLC352I. IMPORTANT. See Parameter Measurement Information.

NOTE 5 The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

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

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF‡, See Note 5	100-mV input step with 5-mV overdrive		650		ns
		TTL-level input step		200		ns

‡C_L includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

Voltage Comparators

3

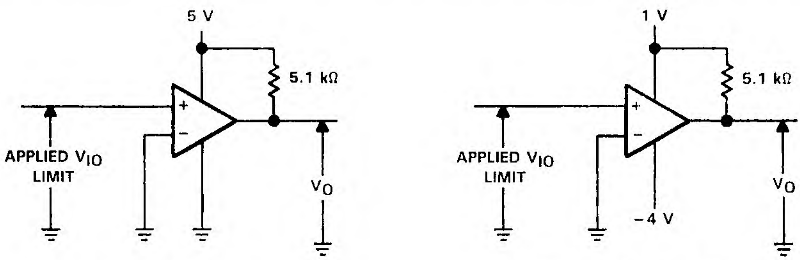
PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC352 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.



(a) V_{IO} with $V_{IC} = 0$ (b) V_{IO} with $V_{IC} = 4$ V

FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

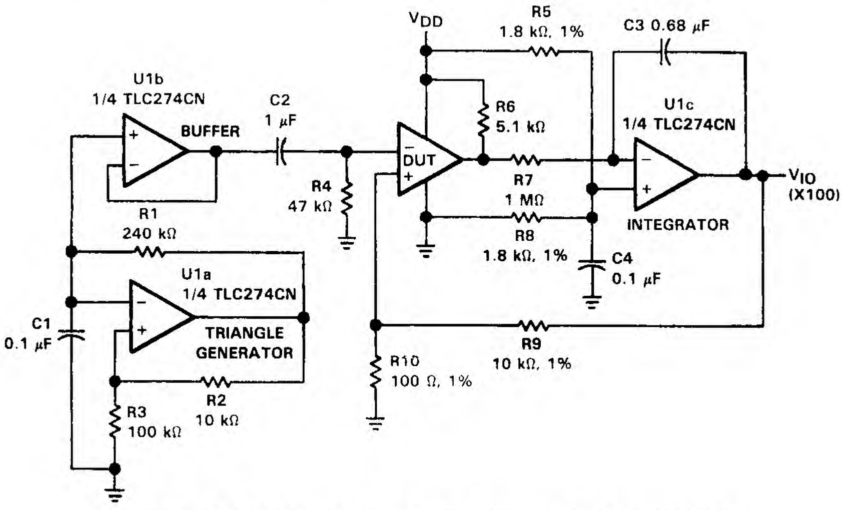
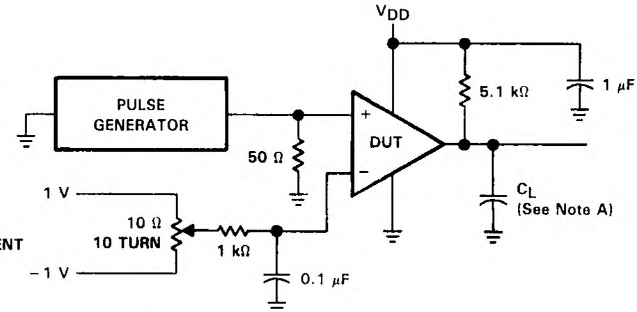


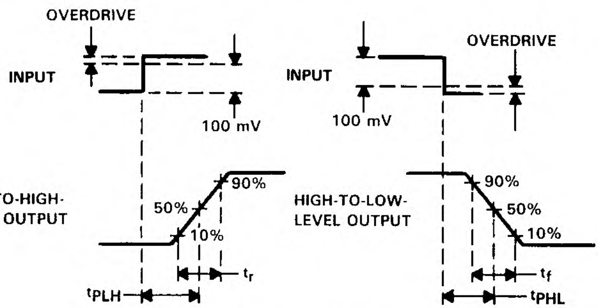
FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



TEST CIRCUIT



VOLTAGE WAVEFORMS

NOTE A: C_L includes probe and jig capacitance.

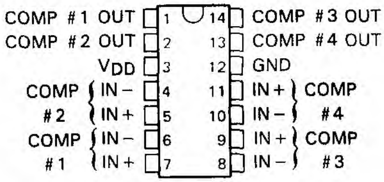
FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

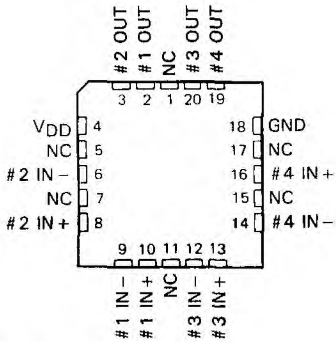
D2901, SEPTEMBER 1985—REVISED FEBRUARY 1989

- Single- or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 1.4 V to 18 V
- Very Low Supply Current Drain
  300 μA Typ at 5 V
  130 μA Typ at 1.4 V
- Built-In ESD Protection
- High Input Impedance . . . 10^{12} Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 μV/Month, Including the First 30 Days
- Common-Mode Input Voltage Range Includes Ground
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM339

TLC354M . . . J PACKAGE
TLC354I, TLC354C . . . D OR N PACKAGE
(TOP VIEW)



TLC354M . . . FK PACKAGE
(TOP VIEW)

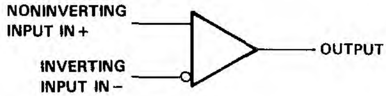


NC—No internal connection

description

This device is fabricated using LinCMOS™ technology and consists of four independent voltage comparators; each designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 1.4 V to 18 V. Each device features extremely high input impedance (typically greater than 10^{12} Ω), which allows direct interface to high-impedance sources. The outputs are n-channel open-drain configurations and can be connected to achieve positive-logic wired-AND relationships. The capability of the TLC354 to operate from a 1.4-V supply makes this device ideal for low-voltage battery applications.

symbol (each comparator)



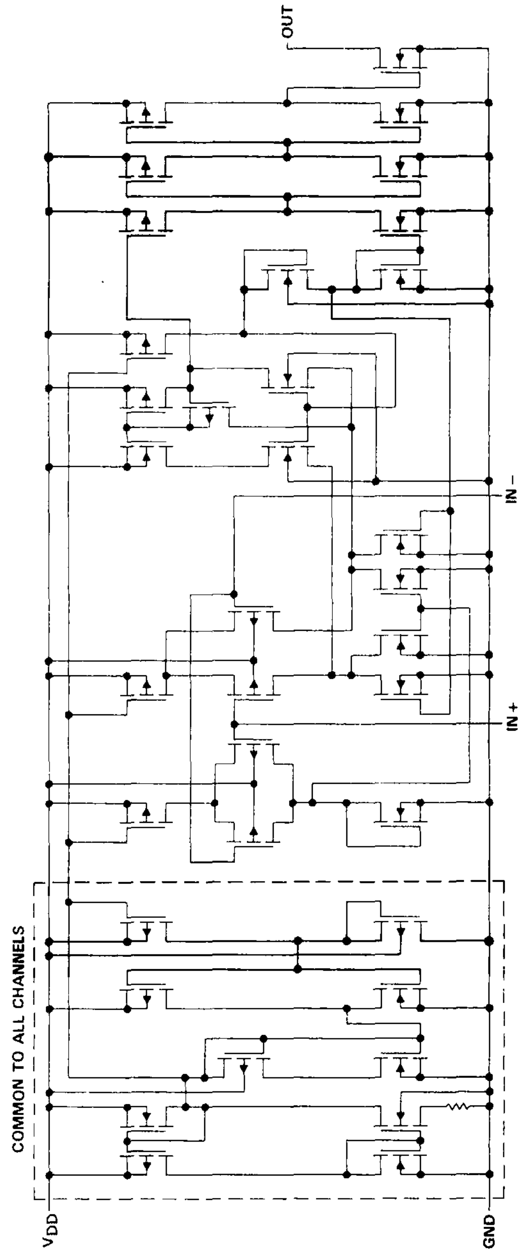
The TLC354 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015. However, care should be exercised in handling this device as exposure to ESD may result in degradation of the device parametric performance.

The TLC354M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC354I is characterized for operation over the industrial temperature range of −40°C to 85°C. The TLC354C is characterized for operation from 0°C to 70°C.

LinCMOS is a trademark of Texas Instruments Incorporated.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

equivalent schematic (each comparator)



AVAILABLE OPTIONS

T_A	V_{IO} MAX AT 25°C	PACKAGE			
		SMALL-OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)
0°C to 70°C	5 mV	TLC354CD	—	TLC354CJ	TLC354CN
−40°C to 85°C	5 mV	TLC354ID	—	TLC354IJ	TLC354IN
−55°C to 125°C	5 mV	—	TLC354MFK	TLC354MJ	—

D packages are availabe taped and reeled. Add "R" suffix to device type when ordering (e.g., TLC354CDR).

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, V_I . . . . . V_{DD}
Input voltage range . . . . . −0.3 V to 18 V
Output voltage, V_O . . . . . 18 V
Input current, I_I . . . . . ±5 mA
Output current, I_O . . . . . 20 mA
Duration of output short-circuit to ground (see Note 3) . . . . . unlimited
Continuous total dissipation . . . . . See Dissipation Rating Table
Operating free-air temperature range: TLC354M . . . . . −55°C to 125°C
TLC354I . . . . . −40°C to 85°C
TLC354C . . . . . 0°C to 70°C
Storage temperature range . . . . . −65°C to 150°C
Case temperature for 60 seconds: FK package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package . . . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package . . . . . 260°C

NOTES: 1. All voltage values except differential voltages are with respect to network ground.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	7.6 mW/°C	84°C	500 mW	494 mW	N/A
FK	500 mW	11.0 mW/°C	104°C	500 mW	500 mW	275 mW
J (TLC354M)	500 mW	11.0 mW/°C	104°C	500 mW	500 mW	275 mW
J (TLC354I, TLC354C)	500 mW	N/A	N/A	500 mW	500 mW	N/A
N	500 mW	N/A	N/A	500 mW	500 mW	N/A

recommended operating conditions

		M-SUFFIX			I-SUFFIX			C-SUFFIX			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{DD}		1.4		16	1.4		16	1.4		16	V
Common-mode input voltage, V_{IC}	V_{DD} = 5 V	0		3.5	0		3.5	0		3.5	V
	V_{DD} = 10 V	0		8.5	0		8.5	0		8.5	
Operating free-air temperature, T_A		−55		125	−40		85	0		70	°C

electrical characteristics at specified free-air temperature, V_{DD} = 1.4 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS†			TLC354M			TLC354I			TLC354C			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_{IC} = V_{ICR} min, See Note 4		25°C		2	5		2	5		2	5	mV
				Full range			10			7			6.5	
I_{IO}	Input offset current			25°C		1			1			1		pA
				MAX T_A			10			1			0.3	nA
I_{IB}	Input bias current			25°C		5			5			5		pA
				MAX T_A			20			2			0.6	nA
V_{ICR}	Common-mode input voltage range			25°C	0 to 0.2			0 to 0.2			0 to 0.2			V
I_{OH}	High-level output current	V_{ID} = 1 V	V_{OH} = 5 V	25°C		0.1			0.1			0.1		nA
			V_{OH} = 15 V	Full range			1			1			1	μA
V_{OL}	Low-level output voltage	V_{ID} = −0.5 V, I_{OL} = 0.6 mA		25°C		100	200		100	200		100	200	mV
				Full range			200			200			200	
I_{OL}	Low-level output current	V_{ID} = −0.5 V, V_{OL} = 300 mV		25°C	1	1.6		1	1.6		1	1.6		mA
I_{DD}	Supply current (four comparators)	V_{DD} = 0.5 V, No load		25°C		130	300		130	300		130	300	μA
				Full range			400			400			400	

†All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is −55°C to 125°C for TLC354M, −40°C to 85°C for TLC354I, and 0°C to 70°C for TLC354C. IMPORTANT See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 1.25 V or below 150 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

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

PARAMETER		TEST CONDITIONS†			T · M			TLC354I			TLC354C			UNIT
					MIN	:..	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$ min,	See Note 4	25°C		2	10		2	10		2	10	mV
				Full range			12			13			12	
I_{IO}	Input offset current			25°C		1			1			1		pA
				MAX T_A			10			1			0.3	nA
I_{IB}	Input bias current			25°C		5			5			5		pA
				MAX T_A			20			2			0.6	nA
V_{ICR}	Common-mode input voltage range			25°C	0 to $V_{DD}-1$			0 to $V_{DD}-1$			0 to $V_{DD}-1$			V
				Full range	0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			
I_{OH}	High-level output current	V_{ID} = 1 V	V_{OH} = 5 V	25°C		0.1			0.1			0.1		nA
			V_{OH} = 15 V	Full range			1			1			1	µA
V_{OL}	Low-level output voltage	V_{ID} = −1 V,	I_{OL} = 4 mA	25°C		150	400		150	400		150	400	mV
				Full range			700			700			700	
I_{OL}	Low-level output current	V_{ID} = −1 V,	V_{OL} = 1.5 V	25°C	6	16		6	16		6	16		mA
I_{DD}	Supply current (four comparators)	V_{DD} = 1 V,	No load	25°C		0.3	0.6		0.3	0.6		0.3	0.6	µA
				Full range			0.8			0.8			0.8	

† All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is − 55°C to 125°C for TLC354M, −40°C to 85°C for TLC354I, and 0°C to 70°C for TLC354C IMPORTANT. See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

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

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF‡, See Note 5	100-mV input step with 5-mV overdrive		650		ns
		TTL-level input step		200		

‡ C_L includes probe and jig capacitance

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC354 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

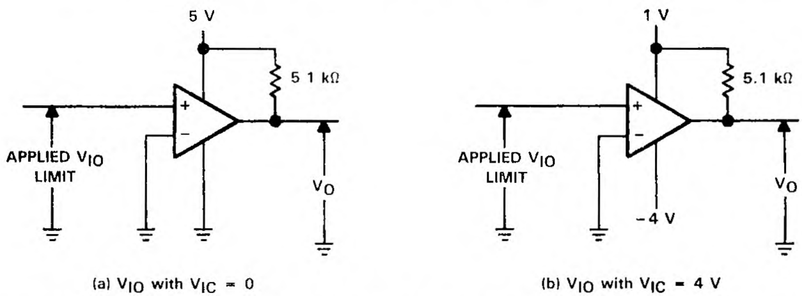


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is ''sliced'' symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

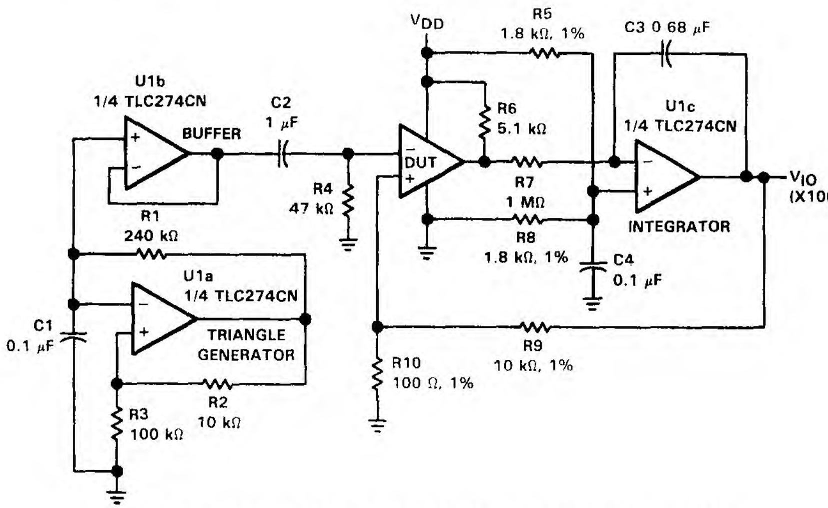
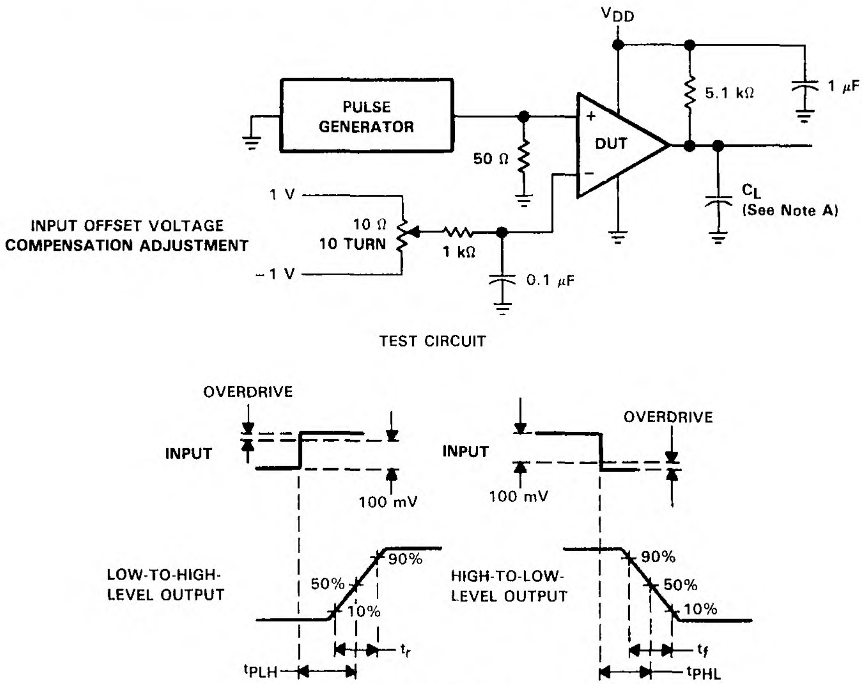


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



NOTE A: C_L includes probe and jig capacitance.

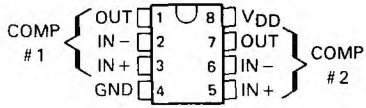
FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

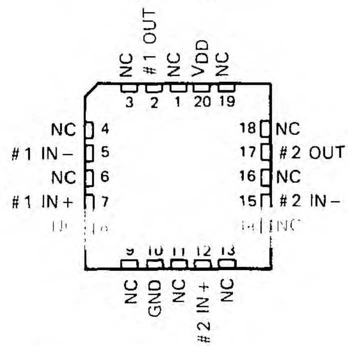
D2821, NOVEMBER 1983—REVISED SEPTEMBER 1988

- Single or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 2 V to 18 V
- Very Low Supply Current Drain 150 μA Typ at 5 V
- Fast Response Time . . . 200 ns Typ for TTL-Level Input Step
- Built-In ESD Protection
- High Input Impedance . . . 10^{12} Ω Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 μV/Month, Including the First 30 Days
- Common-Mode Input Voltage Range [illegible]
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM393

TLC372M . . . JG PACKAGE
TLC372I, TLC372C . . . D, JG, OR P PACKAGE
(TOP VIEW)



TLC372M . . . FK PACKAGE
(TOP VIEW)

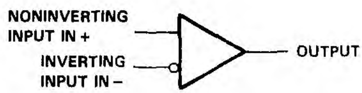


NC—No internal connection

description

This device is fabricated using LinCMOS™ technology and consists of two independent voltage comparators each designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 to 18 V. Each device features extremely high input impedance (typically greater than 10^{12} Ω) allowing direct interfacing with high-impedance sources. The outputs are n-channel open-drain configurations, and can be connected to achieve positive-logic wired-AND relationships.

symbol (each comparator)



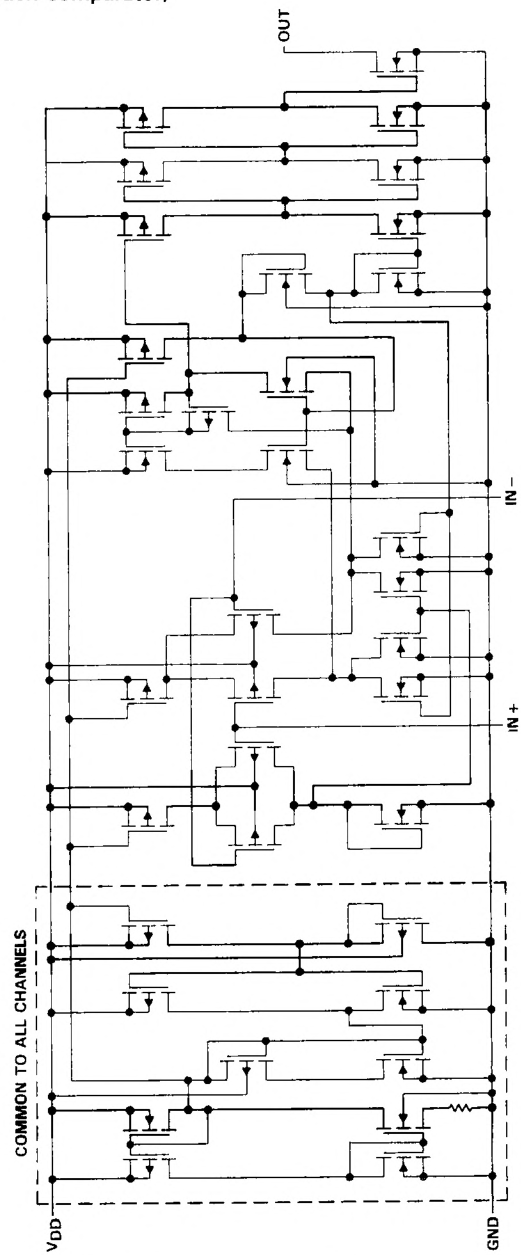
The TLC372 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling this device as exposure to ESD may result in a degradation of the device parametric performance.

The TLC372M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC372I is characterized for operation from −40°C to 85°C. The TLC372C is characterized for operation from 0°C to 70°C.

LinCMOS is a trademark of Texas Instruments Incorporated.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

equivalent schematic (each comparator)



TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

AVAILABLE OPTIONS

T_A	V_{IO} MAX AT 25°C	PACKAGE			
		SMALL-OUTLINE (D)	CHIP-CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	5 mV	TLC372CD	—	TLC372CJG	TLC372CP
−40°C to 85°C	5 mV	TLC372ID	—	TLC372IJG	TLC372IP
−55°C to 125°C	5 mV	—	TLC372MFK	TLC372MJG	—

D packages are availabe taped and reeled. Add "R" suffix to device type (e.g., TLC372CDR).

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, V_I .... −0.3 V to 18 V
Output voltage, V_O .... 18 V
Input current, I_I .... ±5 mA
Output current, I_O .... 20 mA
Duration of output short-circuit to ground (see Note 3) .... unlimited
Continuous total dissipation .... See Dissipation Rating Table
Operating free-air temperature range: TLC372M .... −55°C to 125°C
TLC372I .... −40°C to 85°C
TLC372C .... 0°C to 70°C
Storage temperature range .... −65°C to 150°C
Case temperature for 60 seconds: FK package .... 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package .... 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds, D or P package .... 260°C

NOTES: 1. All voltage values except differential voltages are with respect to network ground.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	5.8 mW/°C	64°C	464 mW	377 mW	N/A
FK	500 mW	11.0 mW/°C	104°C	500 mW	500 mW	275 mW
JG (TLC372M)	500 mW	8.4 mW/°C	90°C	500 mW	500 mW	210 mW
JG (TLC372I, TLC372C)	500 mW	6.6 mW/°C	74°C	500 mW	429 mW	N/A
P	500 mW	N/A	N/A	500 mW	500 mW	N/A

recommended operating conditions

		M-SUFFIX			I-SUFFIX			C-SUFFIX			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{DD}		4		16	3		16	3		16	V
Common-mode input voltage, V_{IC}	V_{DD} = 5 V	0		3.5	0		3.5	0		3.5	V
	V_{DD} = 10 V	0		8.5	0		8.5	0		8.5	
Operating free-air temperature, T_A		−55		125	−40		85	0		70	°C

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

PARAMETER		TEST CONDITIONS†			TLC372M			TLC372I			TLC372C			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$ min, See Note 4		25°C		1	5		1	5		1	5	mV
				Full range			10			7			6.5	
I_{IO}	Input offset current			25°C		1			1			1		pA
				MAX T_A			10			1			0.3	nA
I_{IB}	Input bias current			25°C		5			5			5		pA
				MAX T_A			20			2			0.6	nA
V_{ICR}	Common-mode input voltage range			25°C	0 to $V_{DD}-1$			0 to $V_{DD}-1$			0 to $V_{DD}-1$			V
				Full range	0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			
I_{OH}	High-level output current	V_{ID} = 1 V	V_{OH} = 5 V	25°C		0.1			0.1			0.1		nA
			V_{OH} = 15 V	Full range			3			1			1	μA
V_{OL}	Low-level output voltage	V_{ID} = −1 V,	I_{OL} = 4 mA	25°C		150	400		150	400		150	400	mV
				Full range			700			700			700	
I_{OL}	Low-level output current	V_{ID} = −1 V,	V_{OL} = 1.5 V	25°C	6	16		6	16		6	16		mA
I_{DD}	Supply current (two comparators)	V_{ID} = 1 V,	No load	25°C		150	300		150	300		150	300	μA
				Full range			400			400			400	

†All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is −55°C to 125°C for TLC372M, 0°C to 70°C for TLC372C, and −40°C to 85°C for TLC372I. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

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

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF‡, See Note 5	100-mV input step with 5-mV overdrive		650		ns
		TTL-level input step		200		

‡ C_L includes probe and jig capacitance.

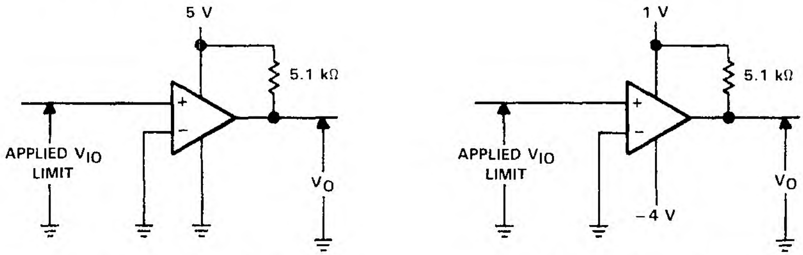
NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC372 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.



(a) V_{IO} with $V_{IC} = 0$ (b) V_{IO} with $V_{IC} = 4$ V

FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

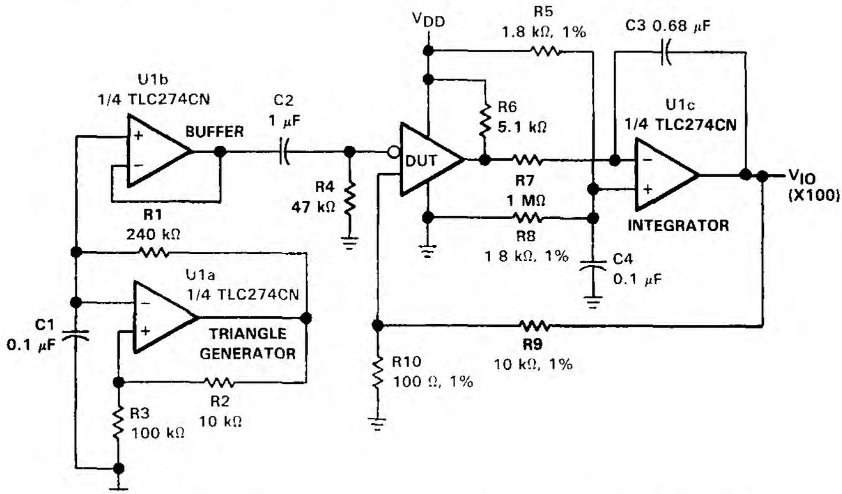
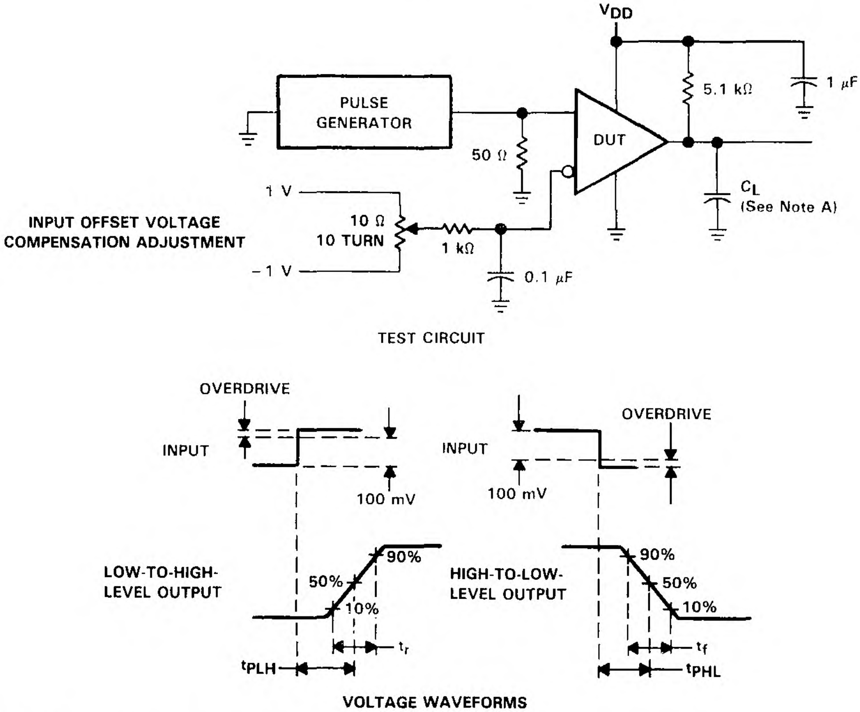


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



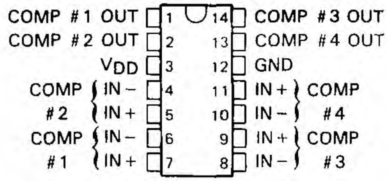
NOTE A: C_L includes probe and jig capacitance.

FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

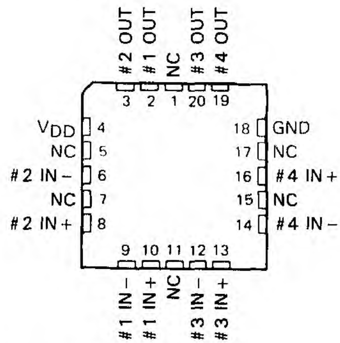
D2783, NOVEMBER 1983—REVISED SEPTEMBER 1988

- Single or Dual-Supply Operation
- Wide Range of Supply Voltages . . . 2 V to 18 V
- Very Low Supply Current Drain 0.3 mA Typ at 5 V
- Fast Response Time . . . 200 ns Typ for TTL-Level Input Step
- Built-In ESD Protection
- High Input Impedance . . . 10^{12} Typ
- Extremely Low Input Bias Current 5 pA Typ
- Ultrastable Low Input Offset Voltage
- Input Offset Voltage Change at Worst-Case Input Conditions Typically 0.23 µV/Month, Including the First 30 Days
- Common-Mode Input Voltage Range Includes Ground
- Outputs Compatible with TTL, MOS, and CMOS
- Pin-Compatible with LM339

TLC374M . . . J PACKAGE
TLC374I, TLC374C . . . D, J, OR N PACKAGE
(TOP VIEW)



TLC374M . . . FK PACKAGE
(TOP VIEW)

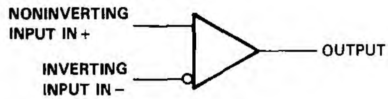


NC—No internal connection

description

This device is fabricated using LinCMOS™ technology and consists of four independent voltage comparators designed to operate from a single power supply. Operation from dual supplies is also possible so long as the difference between the two supplies is 2 to 18 V. Each device features extremely high input impedance (typically greater than $10^{12}\ \Omega$) allowing direct interfacing with high-impedance sources. The outputs are n-channel open-drain configurations, and can be connected to achieve positive-logic wired-AND relationships.

symbol (each comparator)

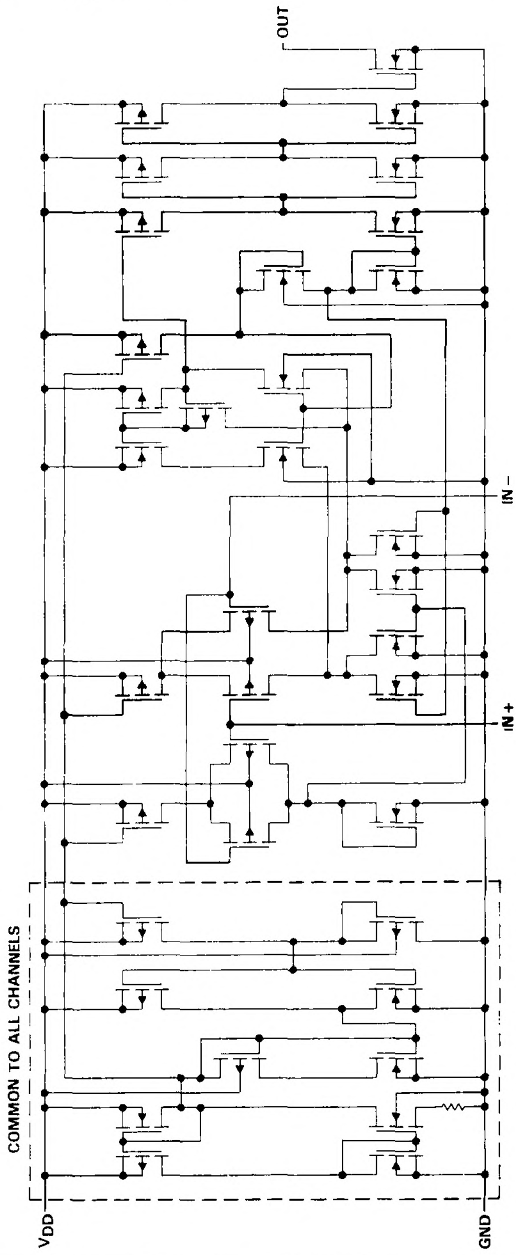


The TLC374 has internal electrostatic discharge (ESD) protection circuits and has been classified with a 2000-V ESD rating tested under MIL-STD-883C, Method 3015.1. However, care should be exercised in handling this device as exposure to ESD may result in a degradation of the device parametric performance.

The TLC374M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC374I is characterized for operation from −40°C to 85°C. The TLC374C is characterized for operation from 0°C to 70°C.

LinCMOS is a trademark of Texas Instruments Incorporated.

equivalent schematic (each comparator)



AVAILABLE OPTIONS

T_A	V_{IO} MAX AT 25°C	PACKAGE			
		SMALL-OUTLINE (D)	CHIP-CARRIER (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)
0°C to 70°C	5 mV	TLC374CD	—	TLC374CJ	TLC374CN
−40°C to 85°C	5 mV	TLC374ID	—	TLC374IJ	TLC374IN
−55°C to 125°C	5 mV	—	TLC374MFK	TLC374MJ	—

D packages are available taped and reeled. Add "R" suffix to device type (e.g., TLC374CDR).

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, V_I . . . V_{DD}
Input voltage range . . . −0.3 V to 18 V
Output voltage, V_O . . . 18 V
Input current, I_I . . . ±5 mA
Output current, I_O . . . 20 mA
Duration of output short-circuit to ground (see Note 3) . . . unlimited
Continuous total dissipation . . . See Dissipation Rating Table
Operating free-air temperature range: TLC374M . . . −55°C to 125°C
TLC374I . . . −40°C to 85°C
TLC374C . . . 0°C to 70°C
Storage temperature range . . . −65°C to 150°C
Case temperature for 60 seconds: FK package . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds, D or N package . . . 260°C

NOTES: 1. All voltage values except differential voltages are with respect to network ground.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Short circuits from outputs to V_{DD} can cause excessive heating and eventual device destruction.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	500 mW	7.6 mW/°C	84°C	494 mW	377 mW	N/A
FK	500 mW	11.0 mW/°C	104°C	500 mW	500 mW	275 mW
J (TLC374M)	500 mW	11.0 mW/°C	104°C	500 mW	500 mW	275 mW
J (TLC374I, TLC374C)	500 mW	N/A	N/A	500 mW	500 mW	N/A
N	500 mW	N/A	N/A	500 mW	500 mW	N/A

recommended operating conditions

		M-SUFFIX			I-SUFFIX			C-SUFFIX			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	MIN	NOM	MAX	
Supply voltage, V_{DD}		4		16	3		16	3		16	V
Common-mode input voltage, V_{IC}	V_{DD} = 5 V	0		3.5	0		3.5	0		3.5	V
	V_{DD} = 10 V	0		8.5	0		8.5	0		8.5	
Operating free-air temperature, T_A		−55		125	−40		85	0		70	°C

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

PARAMETER		TEST CONDITIONS†			TLC374M			TLC374I			TLC374C			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$ min,	See Note 4	25°C		1	5		1	5		1	5	mV
				Full range			10			7			6.5	mV
I_{IO}	Input offset current			25°C		1			1			1		pA
				MAX T_A			10			1			0.3	nA
I_{IB}	Input bias current			25°C		5			5			5		pA
				MAX T_A			20			2			0.6	nA
V_{ICR}	Common-mode input voltage range			25°C	0 to $V_{DD}-1$			0 to $V_{DD}-1$			0 to $V_{DD}-1$			V
				Full range	0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			0 to $V_{DD}-1.5$			V
I_{OH}	High-level output current	V_{ID} = 1 V	V_{OH} = 5 V	25°C		0.1			0.1			0.1		nA
			V_{OH} = 15 V	Full range			1			1			1	μA
V_{OL}	Low-level output voltage	V_{ID} = −1 V,	I_{OL} = 4 mA	25°C		150	400		150	400		150	400	mV
				Full range			700			700			700	mV
I_{OL}	Low-level output current	V_{ID} = −1 V,	V_{OL} = 1.5 V	25°C	6	16		6	16		6	16		mA
I_{DD}	Supply current (four comparators)	V_{ID} = 1 V,	No load	25°C		300	600		300	600		300	600	μA
				Full range			800			800			800	μA

†All characteristics are measured with zero common-mode input voltage unless otherwise noted. Full range is −55°C to 125°C for TLC374M, 0°C to 70°C for TLC374C, and −40°C to 85°C for TLC374I. IMPORTANT: See Parameter Measurement Information.

NOTE 4: The offset voltage limits given are the maximum values required to drive the output above 4 V or below 400 mV with a 10-kΩ resistor between the output and V_{DD}. They can be verified by applying the limit value to the input and checking for the appropriate output state.

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

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Response time	R_L connected to 5 V through 5.1 kΩ, C_L = 15 pF‡, See Note 5	mV input step with 5-mV overdrive		650		ns
		TTL-level input step		200		ns

‡C_L includes probe and jig capacitance.

NOTE 5: The response time specified is the interval between the input step function and the instant when the output crosses 1.4 V.

PARAMETER MEASUREMENT INFORMATION

The digital output stage of the TLC374 can be damaged if it is held in the linear region of the transfer curve. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternative for measuring parameters such as input offset voltage, common-mode rejection, etc., are offered.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

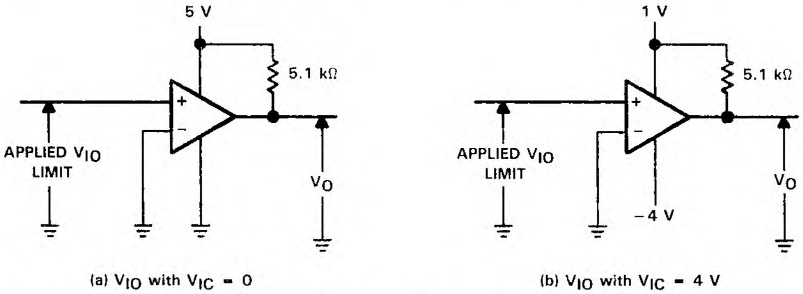


FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo loop in which U1a generates a triangular waveform of approximately 20-mV amplitude. U1b acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1c through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open-socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

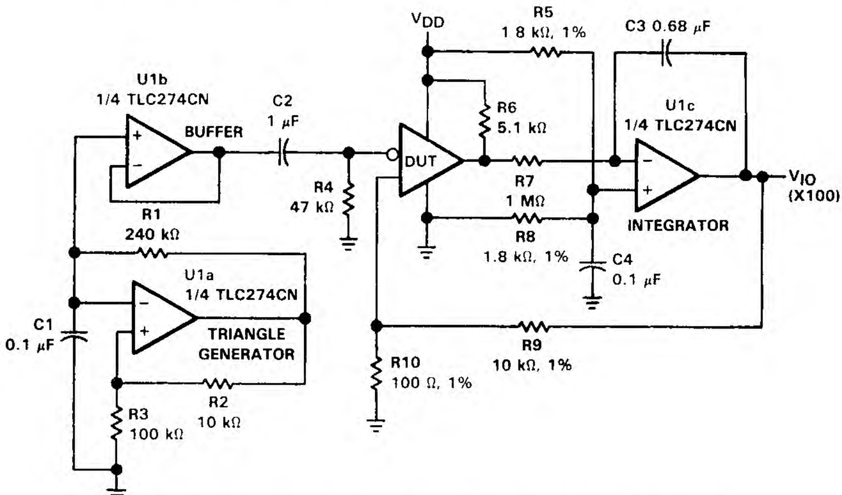
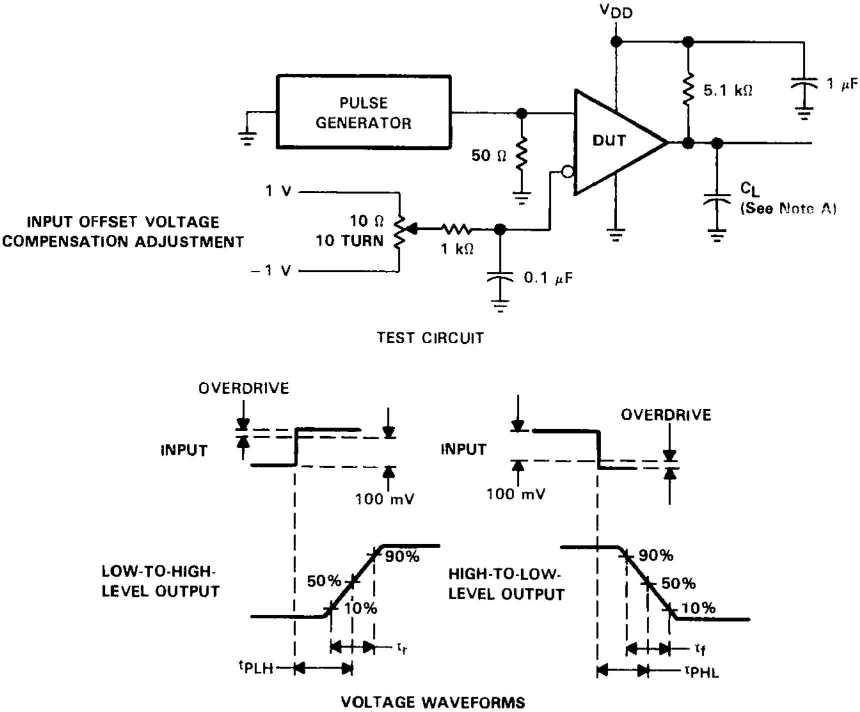


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

PARAMETER MEASUREMENT INFORMATION

Response time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Response time, low-to-high-level output, is measured from the leading edge of the input pulse, while response time, high-to-low-level output, is measured from the trailing edge of the input pulse. Response-time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105-mV or 5-mV overdrive, will cause the output to change state.



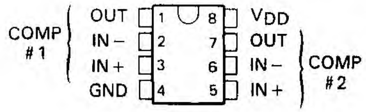
NOTE A: C_L includes probe and jig capacitance.

FIGURE 3. RESPONSE, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

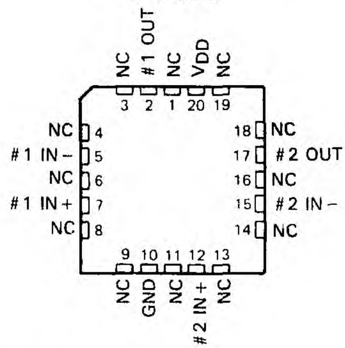
D3241, ...R 1986—REV... FE... 1989

- Very Low Power . . . 100 μW Typ at 5 V
- Fast Response Time . . . 2.5 μs Typ with 5 mV Overdrive
- Single Supply Operation:
  - TLC393M . . . 4 V to 16 V
  - TLC393I . . . 3 V to 16 V
  - TLC393C . . . 3 V to 16 V
- High Input Impedance . . . 10^{12} Ω Typ
- Input Offset Voltage Change at Worst Case Input Condition Typically 0.23 μV/Month Including the First 30 Days
- On-Chip ESD Protection

TLC393M . . . JG PACKAGE
TLC393I, TLC393C . . . D, JG, OR P PACKAGE
(TOP VIEW)



TLC393M . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

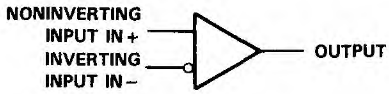
description

The TLC393 consists of two independent differential-voltage comparators designed to operate from a single supply. It is functionally similar to the LM393 but uses 1/20th the power for similar response times. The open-drain MOS output stage will interface to a variety of loads and supplies, as well as "wired" logic functions. For a similar device with a push-pull output configuration, see the TLC3702 data sheet.

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

The TLC393M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC393I is characterized for operation over the extended industrial temperature range of −40°C to 85°C. The TLC393C is characterized for operation over the commercial temperature range of 0°C to 70°C.

symbol (each comparator)



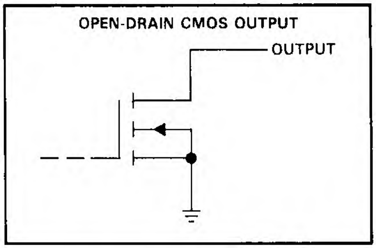
AVAILABLE OPTIONS

T_A	V_{IO}max at 25°C	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	5 mV	TLC393CD	—	TLC393CJG	TLC393CP
−40°C to 85°C	5 mV	TLC393ID	—	TLC393IJG	TLC393IP
−55°C to 125°C	5 mV	—	TLC393MFK	TLC393MJG	—

The D package is available taped and reeled. Add the suffix R to the device type. (e.g., TLC393CDR)

LinCMOS is a trademark of Texas Instruments Incorporated.

schematic



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

Supply voltage, V_{DD} (see Note 1)	−0.3 to 18 V
Differential input voltage (see Note 2)	±18 V
Input voltage, V_I	−0.3 V to V_{DD}
Output voltage, V_O	−0.3 V to V_{DD}
Input current, I_I	±5 mA
Output current, I_O (each output)	20 mA
Total supply current into V_{DD} terminal	40 mA
Total current out of ground terminal	40 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TLC393M	−55°C to 125°C
TLC393I	−40°C to 85°C
TLC393C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	—
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG (TLC393M)	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
JG (All others)	825 mW	6.6 mW/°C	528 mW	429 mW	—
P	1000 mW	8.0 mW/°C	640 mW	520 mW	—

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	4	5	16	V
Common-mode input voltage, V_{IC}	0		$V_{DD} - 1.5$	V
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−55		125	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.4	5	mV
			−55°C to 125°C			10	mV
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			125°C			15	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			125°C			30	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD} - 1$			V
			−55°C to 125°C	0 to $V_{DD} - 1.5$			V
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			125°C		84		dB
			−55°C		84		dB
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			125°C		84		dB
			−55°C		84		dB
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C		300	400	mV
			125°C			800	mV
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 V	25°C		0.8	40	nA
			125°C			1	μA
I_{DD}	Supply current (both comparators)	No load, Outputs low	25°C		22	40	μA
			−55°C to 125°C			90	μA

†All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V with a 2.5-kΩ load to V_{DD}.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−40		85	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 4	25°C		1.4	5	mV
			−40°C to 85°C			7	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			85°C			1	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			85°C			2	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			−40°C to 85°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			85°C		84		
			−40°C		84		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			85°C		85		
			−40°C		84		
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C			400	mV
			85°C			700	
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 V	25°C		0.8	40	nA
			85°C			1	μA
I_{DD}	Supply current (both comparators)	No load, Outputs low	25°C		22	40	μA
			−40°C to 85°C			65	

†All characteristics are measured with zero common-mode voltage unless otherwise noted.
NOTE 4: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	0		70	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 4	25°C		1.4	5	mV
			0°C to 70°C			6.5	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			70°C			0.3	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			70°C			0.6	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			0°C to 70°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			70°C		84		
			0°C		84		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			70°C		85		
			0°C		85		
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 6 mA	25°C		300	400	mV
			70°C			650	
I_{OH}	High-level output current	V_{ID} = 1 V, V_O = 5 V	25°C		0.8	40	nA
			70°C			1	μA
I_{DD}	Supply current (both comparators)	No load, Outputs low	25°C		22	40	μA
			0°C to 70°C			50	

†All characteristics are measured with zero common-mode voltage unless otherwise noted.
NOTE 4: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

switching characteristics, V_{DD} = 5 V, T_A = 25°C (see Figure 3)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH} Propagation delay time, low-to-high level output	f = 10 kHz, C_L = 15 pF	Overdrive = 2 mV		4.5		µs
		Overdrive = 5 mV		2.5		
		Overdrive = 10 mV		1.7		
		Overdrive = 20 mV		1.2		
		Overdrive = 40 mV		1.1		
	V_I = 1.4 V step at IN+ pin			1.1		
t_{PHL} Propagation delay time, high-to-low level output	f = 10 kHz, C_L = 15 pF	Overdrive = 2 mV		3.6		µs
		Overdrive = 5 mV		2.1		
		Overdrive = 10 mV		1.3		
		Overdrive = 20 mV		0.85		
		Overdrive = 40 mV		0.55		
	V_I = 1.4 V step at IN+ pin			0.10		
t_{THL} Transition time, high-to-low level output	f = 10 kHz, C_L = 15 pF	Overdrive = 50 mV		20		ns

3

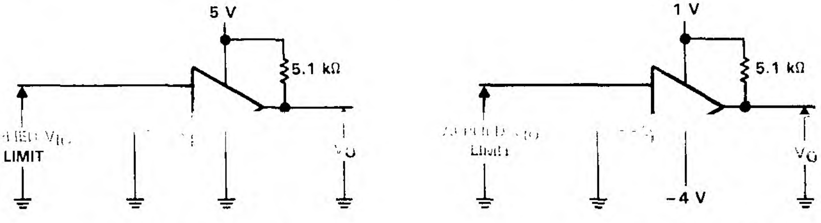
Voltage Comparators

PARAMETER MEASUREMENT INFORMATION

The TLC393 contains a digital output stage which, if held in the linear region of the transfer curve, can cause damage to the device. Conventional operational amplifier/comparator testing incorporates the use of a servo-loop that is designed to force the device output to a level within this linear region. Since the servo-loop method of testing cannot be used, the following alternatives for testing parameters such as input offset voltage, common-mode rejection, etc., are suggested.

To verify that the input offset voltage falls within the limits specified, the limit value is applied to the input as shown in Figure 1(a). With the noninverting input positive with respect to the inverting input, the output should be high. With the input polarity reversed, the output should be low.

A similar test can be made to verify the input offset voltage at the common-mode extremes. The supply voltages can be slewed as shown in Figure 1(b) for the V_{ICR} test, rather than changing the input voltages, to provide greater accuracy.



(a) V_{IO} with $V_{IC} = 0$ (b) V_{IO} with $V_{IC} = 4$ V

FIGURE 1. METHOD FOR VERIFYING THAT INPUT OFFSET VOLTAGE IS WITHIN SPECIFIED LIMITS

A close approximation of the input offset voltage can be obtained by using a binary search method to vary the differential input voltage while monitoring the output state. When the applied input voltage differential is equal, but opposite in polarity, to the input offset voltage, the output will change states.

PARAMETER MEASUREMENT INFORMATION

Figure 2 illustrates a practical circuit for direct dc measurement of input offset voltage that does not bias the comparator into the linear region. The circuit consists of a switching-mode servo-loop in which U1A generates a triangular waveform of approximately 20-mV amplitude. U1B acts as a buffer, with C2 and R4 removing any residual dc offset. The signal is then applied to the inverting input of the comparator under test, while the noninverting input is driven by the output of the integrator formed by U1C through the voltage divider formed by R9 and R10. The loop reaches a stable operating point when the output of the comparator under test has a duty cycle of exactly 50%, which can only occur when the incoming triangle wave is "sliced" symmetrically or when the voltage at the noninverting input exactly equals the input offset voltage.

Voltage divider R9 and R10 provides a step-up of the input offset voltage by a factor of 100 to make measurement easier. The values of R5, R8, R9, and R10 can significantly influence the accuracy of the reading; therefore, it is suggested that their tolerance level be 1% or lower.

Measuring the extremely low values of input current requires isolation from all other sources of leakage current and compensation for the leakage of the test socket and board. With a good picoammeter, the socket and board leakage can be measured with no device in the socket. Subsequently, this open socket leakage value can be subtracted from the measurement obtained with a device in the socket to obtain the actual input current of the device.

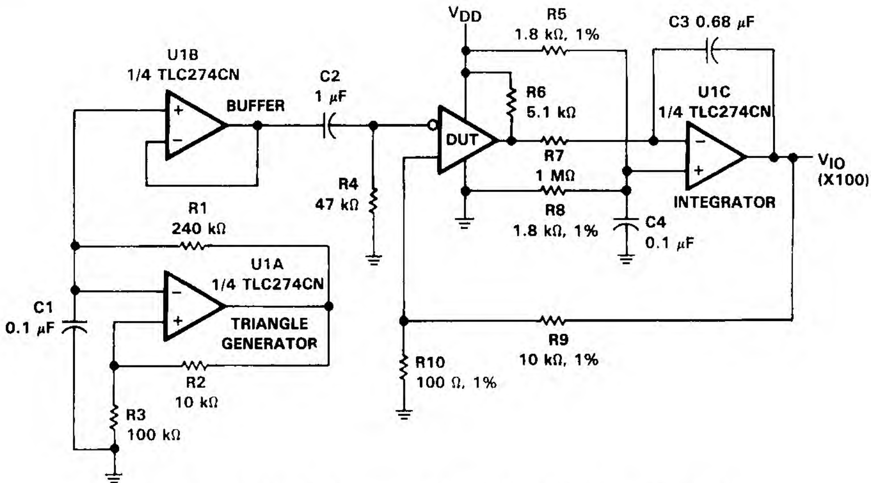
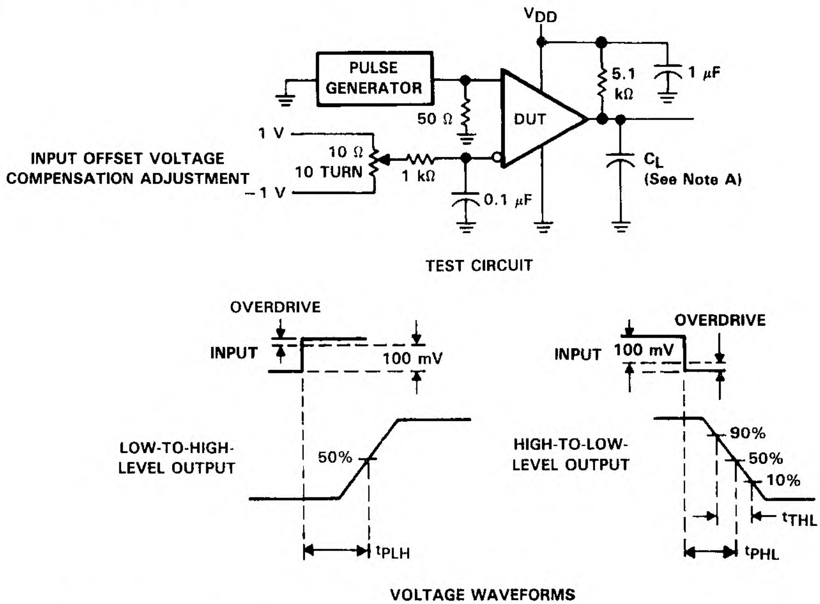


FIGURE 2. CIRCUIT FOR INPUT OFFSET VOLTAGE MEASUREMENT

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

PARAMETER MEASUREMENT INFORMATION

Propagation delay time is defined as the interval between the application of an input step function and the instant when the output reaches 50% of its maximum value. Propagation delay time, low-to-high-level output is measured from the leading edge of the input pulse, while propagation delay time, high-to-low-level output, is measured from the trailing edge of the input pulse. Propagation delay time measurement at low input signal levels can be greatly affected by the input offset voltage. The offset voltage should be balanced by the adjustment at the inverting input (as shown in Figure 3) so that the circuit is just at the transition point. Then a low signal, for example 105 mV or 5 mV overdrive, will cause the output to change state.



NOTE A: C_L includes probe and jig capacitance.

FIGURE 3. PROPAGATION DELAY, RISE, AND FALL TIMES CIRCUIT AND VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS†

DISTRIBUTION OF INPUT OFFSET VOLTAGE

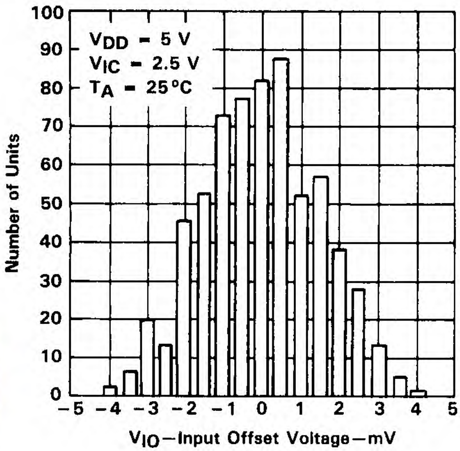


FIGURE 4

INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE

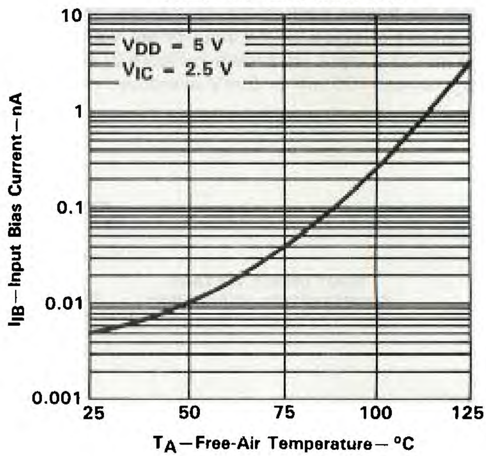


FIGURE 5

COMMON-MODE REJECTION RATIO vs FREE-AIR TEMPERATURE

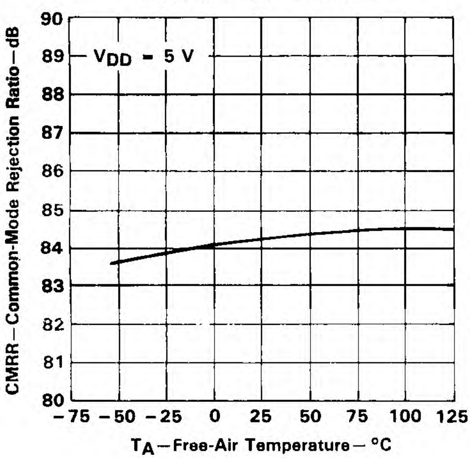


FIGURE 6

SUPPLY VOLTAGE REJECTION RATIO vs FREE-AIR TEMPERATURE

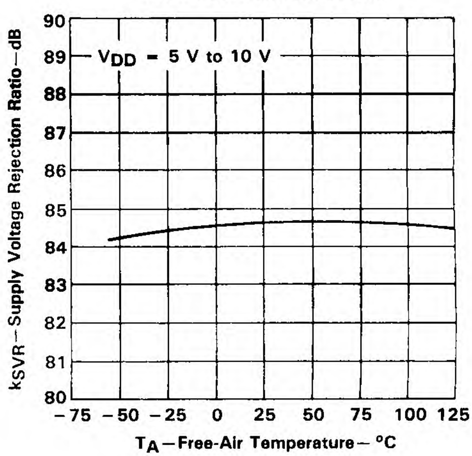


FIGURE 7

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices

3

Voltage Comparators

TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT CURRENT
vs
HIGH-LEVEL OUTPUT VOLTAGE

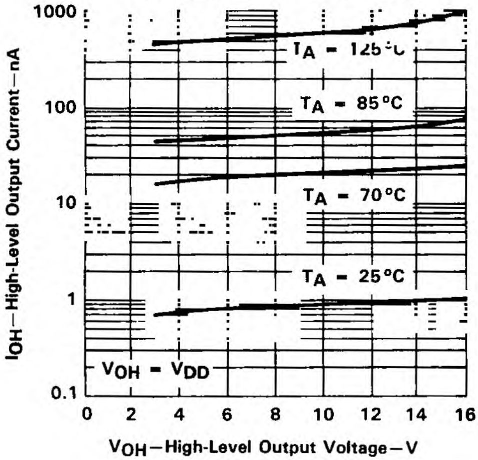


FIGURE 8

HIGH-LEVEL OUTPUT CURRENT
vs
FREE-AIR TEMPERATURE

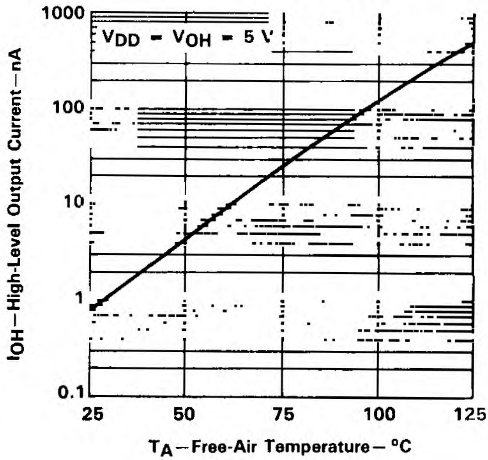


FIGURE 9

LOW-LEVEL OUTPUT VOLTAGE
vs
LOW-LEVEL OUTPUT CURRENT

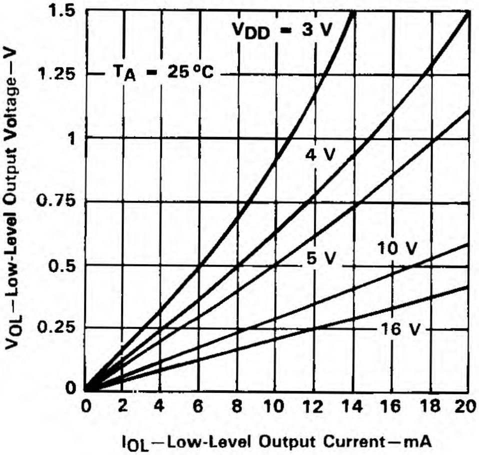


FIGURE 10

LOW-LEVEL OUTPUT VOLTAGE
vs
FREE-AIR TEMPERATURE

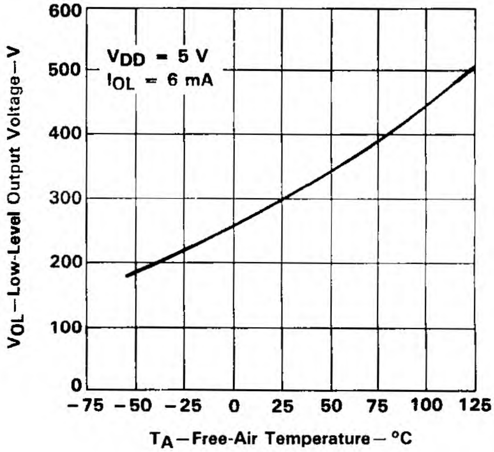


FIGURE 11

3

Voltage Comparators

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

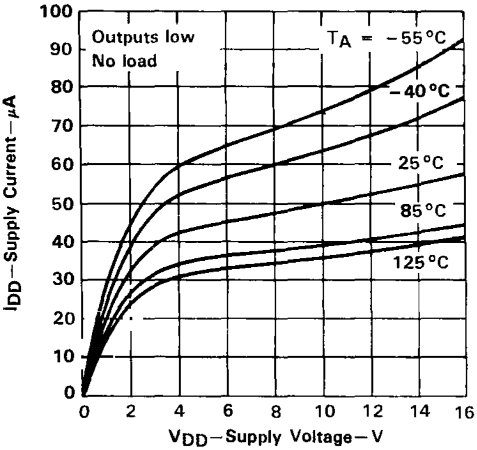


FIGURE 12

SUPPLY CURRENT
vs
FREE-AIR TEMPERATURE

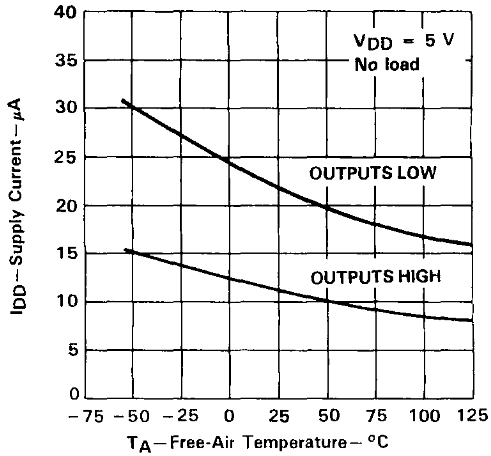


FIGURE 13

LOW-TO-HIGH-LEVEL
OUTPUT RESPONSE TIME
vs
SUPPLY VOLTAGE

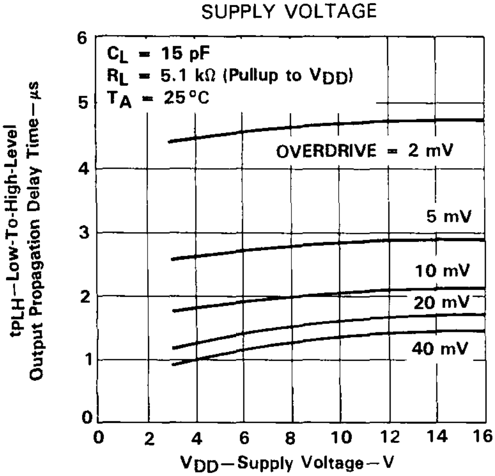


FIGURE 14

HIGH-TO-LOW-LEVEL
OUTPUT RESPONSE TIME
vs
SUPPLY VOLTAGE

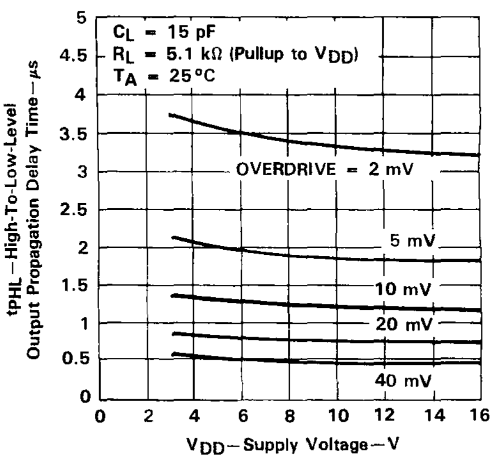


FIGURE 15

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

LOW-TO-HIGH-LEVEL OUTPUT PROPAGATION DELAY FOR VARIOUS OVERDRIVE VOLTAGES

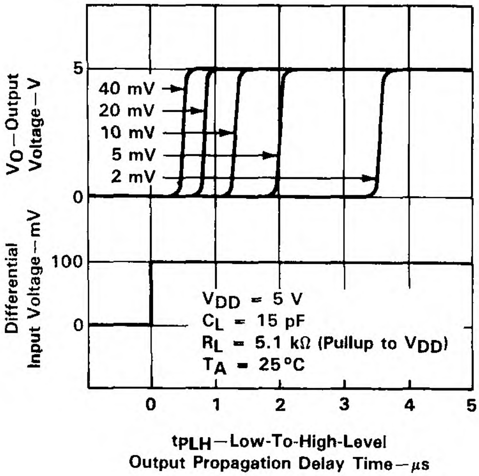


FIGURE 16

OUTPUT FALL TIME vs SUPPLY VOLTAGE

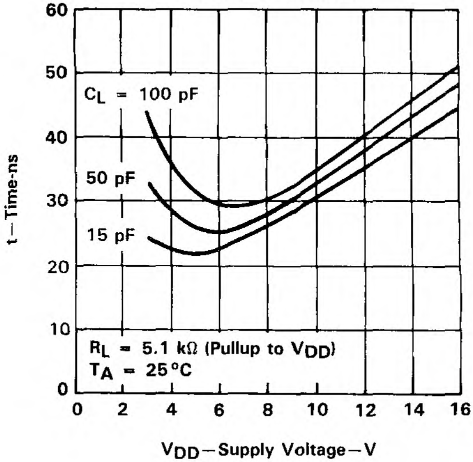


FIGURE 17

HIGH-TO-LOW-LEVEL OUTPUT PROPAGATION DELAY FOR VARIOUS OVERDRIVE VOLTAGES

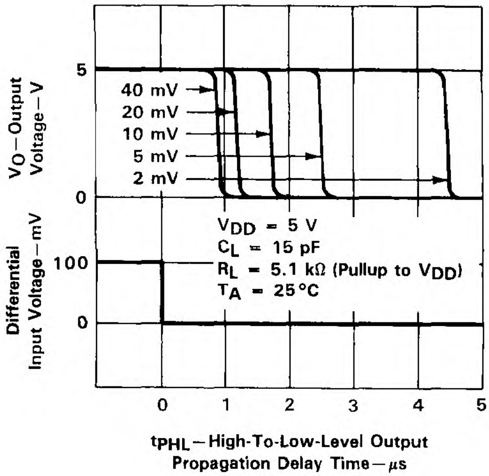


FIGURE 18

3

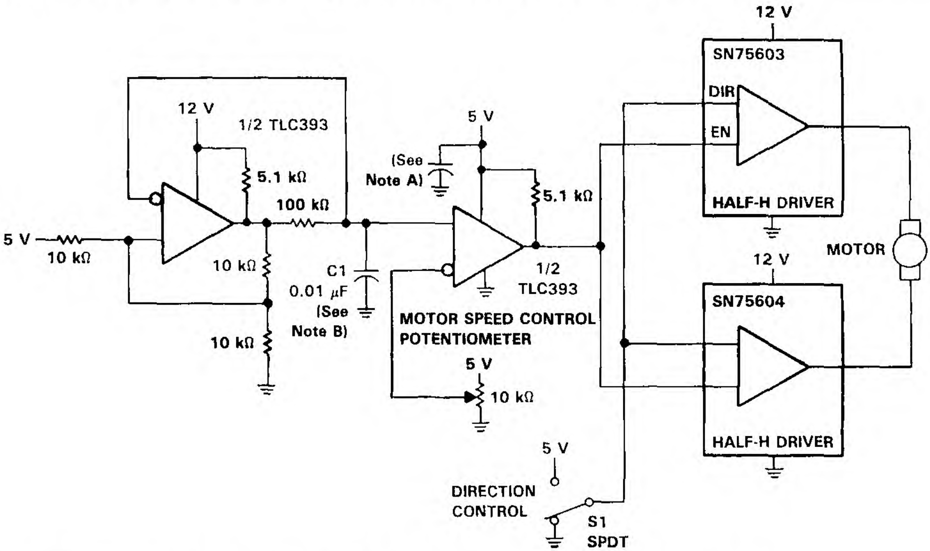
Voltage Comparators

TYPICAL APPLICATION DATA

The input should always remain within the supply rails in order to avoid forward biasing the diodes in the electrostatic discharge (ESD) protection structure. If either input exceeds this range, the device will not be damaged as long as the input current is limited to less then 5 mA. To maintain the expected output state, the inputs must remain within the common-mode range. For example, at 25°C with V_{DD} = 5 V, both inputs must remain between −0.2 V and 4 V to assure proper device operation.

To assure reliable operation, the supply should be decoupled with a capacitor (0.1 µF) positioned as close to the device as possible.

The TLC393 has internal ESD-protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised in handling these devices as exposure to ESD may result in the degradation of the device parametric performance.

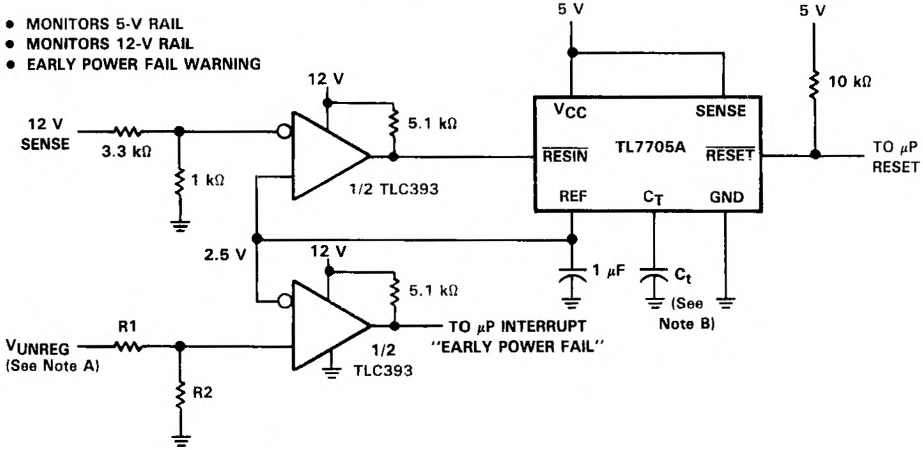


NOTES: A. The recommended minimum capacitance is 10 µF to eliminate common ground switching noise.
B. Select C1 for change in oscillator frequency.

FIGURE 19. PULSE-WIDTH-MODULATED MOTOR SPEED CONTROLLER

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

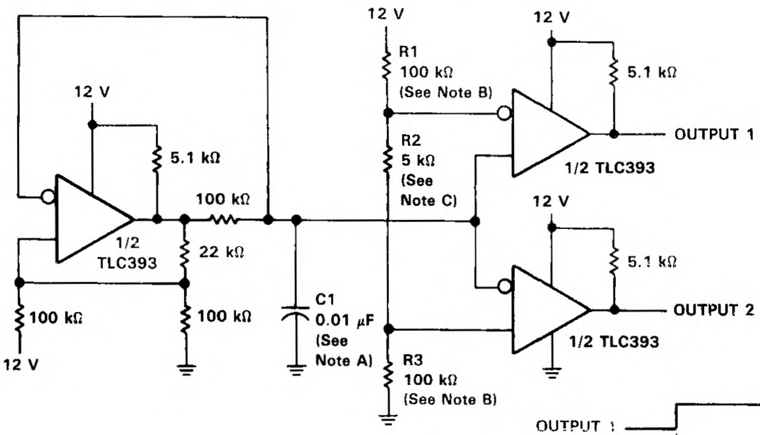
TYPICAL APPLICATION DATA

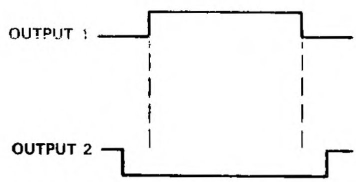


NOTES: A. $V_{UNREG} = 2.5\left(\frac{R1 + R2}{R2}\right)$

B. The value of C_t determines the time delay of reset.

FIGURE 20. ENHANCED SUPPLY SUPERVISOR





NOTES: A. Select C1 for a change in oscillator frequency where:
1/f = 1.85 (100 kΩ)C1

B. Select R1 and R3 to change duty cycle.

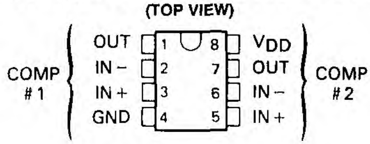
C. Select R2 to change deadtime.

FIGURE 21. TWO-PHASE NONOVERLAPPING CLOCK GENERATOR

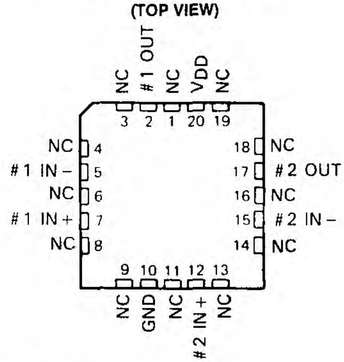
D3209, NOVEMBER 1986–REVISED JANUARY 1989

- Push-Pull CMOS Output Drives Capacitive Loads without Pull-Up Resistor, $I_O = \pm 8$ mA
- Very Low Power . . . 100 µW Typ at 5 V
- Fast Response Time . . . 2.5 µs Typ with 5 mV Overdrive
- Single Supply Operation:
  TLC3702M . . . 4 V to 16 V
  TLC3702I . . . 3 V to 16 V
  TLC3702C . . . 3 V to 16 V
- High Input Impedance . . . 10^{12} Ω Typ
- Input Offset Voltage Change at Worst Case Input Condition Typically 0.23 µV/Month Including the First 30 Days
- On-Chip ESD Protection

TLC3702M . . . JG PACKAGE
TLC3702I, TLC3702C . . . D, JG, OR P PACKAGE
(TOP VIEW)



TLC3702M . . . FK PACKAGE
(TOP VIEW)

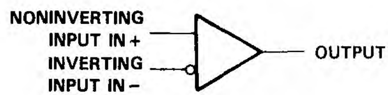


NC–No internal connection

description

The TLC3702 consists of two independent differential-voltage comparators designed to operate from a single supply and be compatible with modern HCMOS logic systems. It is functionally similar to the LM393 but uses 1/20th the power for similar response times. The push-pull CMOS output stage will drive capacitive loads directly without a power-consuming pull-up resistor to achieve the stated response time. Eliminating the pull-up resistor not only reduces power dissipation, but also saves board space and component cost. The output stage is also fully compatible with TTL requirements.

symbol (each comparator)



AVAILABLE OPTIONS

T_A	V_{IO} max at 25°C	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	5 mV	TLC3702CD	–	TLC3702CJG	TLC3702CP
–40°C to 85°C	5 mV	TLC3702ID	–	TLC3702IJG	TLC3702IP
–55°C to 125°C	5 mV	–	TLC3702MFK	TLC3702MJG	–

The D package is available taped and reeled. Add the suffix R to the device type when ordering. (e.g., TL3702CDR)

LinCMOS is a trademark of Texas Instruments Incorporated.

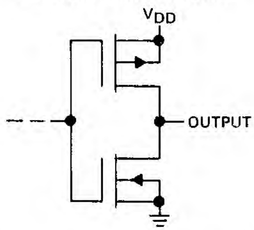
description (continued)

Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

The TLC3702M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC3702I is characterized for operation over the extended industrial temperature range of −40°C to 85°C. The TLC3702C is characterized for operation over the commercial temperature range of 0°C to 70°C.

schematic

PUSH-PULL CMOS OUTPUT



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

Supply voltage, V_{DD} (see Note 1)	−0.3 V to 18 V
Differential input voltage (see Note 2)	±18 V
Input voltage, V_I	−0.3 V to V_{DD}
Output voltage, V_O	−0.3 V to V_{DD}
Input current, I_I	±5 mA
Output current, I_O (each output)	±20 mA
Total supply current into V_{DD} terminal	40 mA
Total current out of ground terminal	40 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TLC3702M	−55°C to 125°C
TLC3702I	−40°C to 85°C
TLC3702C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	–
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG (TLC3702M)	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
JG (All others)	825 mW	6.6 mW/°C	528 mW	429 mW	–
P	1000 mW	8.0 mW/°C	640 mW	520 mW	–

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	4	5	16	V
Common-mode input voltage, V_{IC}	0		$V_{DD}-1.5$	V
High-level output current, I_{OH}			−20	mA
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−55		125	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.2	5	mV
			−55°C to 125°C			10	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			125°C			15	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			125°C			30	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			−55°C to 125°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			125°C		83		
			−55°C		82		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			125°C		85		
			−55°C		82		
V_{OH}	High-level output voltage	V_{ID} = 1 V, I_{OH} = −4 mA	25°C	4.5	4.7		V
			125°C	4.2			
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		210	300	mV
			125°C			500	
I_{DD}	Supply current (both comparators)	No load, Outputs low	25°C		18	40	µA
			−55°C to 125°C			90	

† All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Commor[illegible] nput [illegible], V_{IC}	−0.2		$V_{DD}-1.5$	V
High-leve[illegible] curr[illegible], I_{OH}			−20	mA
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−40		85	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.2	5	mV
			−40°C to 85°C			7	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			85°C			1	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			85°C			2	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			−40°C to 85°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			85°C		84		
			−40°C		83		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			85°C		85		
			−40°C		83		
V_{OH}	High-level output voltage	V_{ID} = 1 V, I_{OH} = −4 mA	25°C	4.5	4.7		V
			85°C	4.3			
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		210	300	mV
			85°C			400	
I_{DD}	Supply current (both comparators)	No load, Outputs low	25°C		18	40	µA
			−40°C to 85°C			65	

† All characteristics are measured with zero common-mode voltage unless otherwise noted.
NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
High-level output current, I_{OH}			−20	mA
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	0		70	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.2	5	mV
			0°C to 70°C			6.5	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			70°C			0.3	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			70°C			0.6	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			0°C to 70°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			70°C		84		
			0°C		84		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			70°C		85		
			0°C		85		
V_{OH}	High-level output voltage	V_{ID} = 1 V, I_{OH} = −4 mA	25°C	4.5	4.7		V
			70°C	4.3			
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		210	300	mV
			70°C			375	
I_{DD}	Supply current (both comparators)	No load, Outputs low	25°C		18	40	µA
			0°C to 70°C			50	

† All characteristics are measured with zero common-mode voltage unless otherwise noted.
NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

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

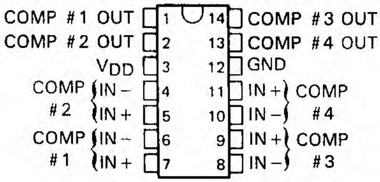
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	f = 10 kHz, C_L = 50 pF	Overdrive = 2 mV		4.5		µs
			Overdrive = 5 mV		2.7		
			Overdrive = 10 mV		1.9		
			Overdrive = 20 mV		1.4		
			Overdrive = 40 mV		1.1		
		V_I = 1.4 V step at IN+ pin			1.1		
t_{PHL}	Propagation delay time, high-to-low-level output	f = 10 kHz, C_L = 50 pF	Overdrive = 2 mV		4.0		µs
			Overdrive = 5 mV		2.3		
			Overdrive = 10 mV		1.5		
			Overdrive = 20 mV		0.95		
			Overdrive = 40 mV		0.65		
		V_I = 1.4 V step at IN+ pin			0.15		
t_f	Fall time	f = 10 kHz, C_L = 50 pF	Overdrive = 50 mV		50		ns
t_r	Rise time	f = 10 kHz, C_L = 50 pF	Overdrive = 50 mV		125		ns

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

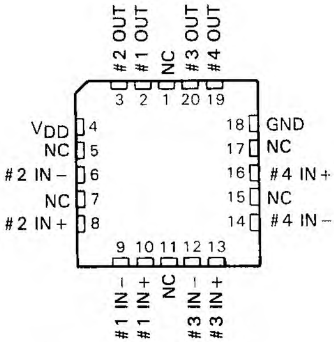
D3240, NOVEMBER 1986—REVISED MARCH 1989

- Push-Pull CMOS Output Drives Capacitive Loads without Pull-Up Resistor, $I_O = \pm 8$ mA
- Very Low Power . . . 200 μW Typ at 5 V
- Fast Response Time . . . 2.5 μs Typ with 5 mV Overdrive
- Single Supply Operation:
  TLC3704M . . . 4 V to 16 V
  TLC3704I . . . 3 V to 16 V
  TLC3704C . . . 3 V to 16 V
- High Input Impedance . . . 10^{12} Ω Typ
- Input Offset Voltage Change at Worst Case Input Condition Typically 0.23 μV/Month Including the First 30 Days
- On-Chip ESD Protection

TLC3704M . . . J PACKAGE
TLC3704I, TLC3704C . . . D, J, OR N PACKAGE
(TOP VIEW)



TLC3704M . . . FK PACKAGE
(TOP VIEW)



NC—No internal connection

description

The TLC3704 consists of four independent differential-voltage comparators designed to operate from a single supply and be compatible with modern HCMOS logic systems. It is functionally similar to the LM339 but uses 1/20th the power for similar response times. The push-pull CMOS output stage will drive capacitive loads directly without a power-consuming pull-up resistor to achieve the stated response time. Eliminating the pull-up resistor not only reduces power dissipation, but also saves board space and component cost. The output stage is also fully compatible with TTL requirements.

AVAILABLE OPTIONS

T_A	V_{IO}max at 25°C	PACKAGE			
		SMALL OUTLINE (D)	CERAMIC (FK)	CERAMIC DIP (J)	PLASTIC DIP (N)
0°C to 70°C	5 mV	TLC3704CD	—	TLC3704CJ	TLC3704CN
−40°C to 85°C	5 mV	TLC3704ID	—	TLC3704IJ	TLC3704IN
−55°C to 125°C	5 mV	—	TLC3704MFK	TLC3704MJ	—

The D package is available taped and reeled. Add the suffix R to the device type. (e.g., TLC3704CDR)

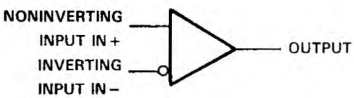
LinCMOS is a trademark of Texas Instruments Incorporated.

description (continued)

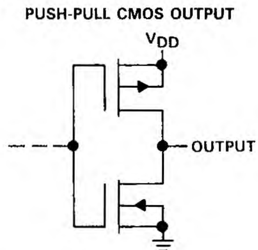
Texas Instruments LinCMOS™ process offers superior analog performance to standard CMOS processes. Along with the standard CMOS advantages of low power without sacrificing speed, high input impedance, and low bias currents, the LinCMOS™ process offers extremely stable input offset voltages, even with differential input stresses of several volts. This characteristic makes it possible to build reliable CMOS comparators.

The TLC3704M is characterized for operation over the full military temperature range of −55°C to 125°C. The TLC3704I is characterized for operation over the extended industrial temperature range of −40°C to 85°C. The TLC3704C is characterized for operation over the commercial temperature range of 0°C to 70°C.

symbol (each comparator)



schematic



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

Supply voltage, V_{DD} (see Note 1)	−0.3 to 18 V
Differential input voltage (see Note 2)	±18 V
Input voltage, V_I	−0.3 V to V_{DD}
Output voltage, V_O	−0.3 V to V_{DD}
Input current, I_I	±5 mA
Output current, I_O (each output)	±20 mA
Total supply current into V_{DD} terminal	40 mA
Total current out of ground terminal	60 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TLC3704M	−55°C to 125°C
TLC3704I	−40°C to 85°C
TLC3704C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Case temperature for 60 seconds: FK package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C

NOTES: 1. All voltage values, except differential voltages, are with respect to network ground.
2. Differential voltages are at the noninverting input with respect to the inverting input.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	950 mW	7.6 mW/°C	608 mW	494 mW	–
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J (TLC3704M)	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
J (All others)	1025 mW	8.2 mW/°C	656 mW	533 mW	–
N	1150 mW	9.2 mW/°C	736 mW	598 mW	–

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	4	5	16	V
Common-mode input voltage, V_{IC}	0		$V_{DD}-1.5$	V
High-level output current, I_{OH}			−20	mA
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−55		125	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.2	5	mV
			−55°C to 125°C			10	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			125°C			15	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			[illegible]			30	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			[illegible]
			−55°C to 125°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			125°C		83		
			−55°C		82		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			[illegible]		85		
			[illegible]		82		
V_{OH}	High-level output voltage	V_{ID} = 1 V, I_{OH} = −4 mA	25°C	4.5	4.7		V
			125°C	4.2			
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		210	300	mV
			125°C			500	
I_{DD}	Supply current (four comparators)	No load, Outputs low	25°C		35	80	μA
			−55°C to 125°C			175	

†All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
High-level output current, I_{OH}			−20	mA
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	−40		85	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, V_{DD} = 5 V to 10 V, See Note 3	25°C		1.2	5	mV
			−40°C to 85°C			7	
I_{IO}	Input offset current	V_{IC} = 2.5 V	25°C		1		pA
			85°C			1	nA
I_{IB}	Input bias current	V_{IC} = 2.5 V	25°C		5		pA
			85°C			2	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			−40°C to 85°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			85°C		84		
			−40°C		83		
k_{SVR}	Supply voltage rejection ratio	V_{DD} = 5 V to 10 V	25°C		85		dB
			85°C		85		
			−40°C		83		
V_{OH}	High-level output voltage	V_{ID} = 1 V, I_{OH} = −4 mA	25°C	4.5	4.7		V
			85°C	4.3			
V_{OL}	Low-level output voltage	V_{ID} = −1 V, I_{OL} = 4 mA	25°C		210		mV
			85°C			[illegible]	
I_{DD}	Supply current (four comparators)	No load, Outputs low	25°C		35	80	μA
			−40°C to 85°C			125	

†All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

recommended operating conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	3	5	16	V
Common-mode input voltage, V_{IC}	−0.2		$V_{DD}-1.5$	V
High-level output current, I_{OH}			−20	mA
Low-level output current, I_{OL}			20	mA
Operating free-air temperature, T_A	0		70	°C

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

PARAMETER		TEST CONDITIONS†		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = V_{ICR}$min, $V_{DD} = 5$ V to 10 V, See Note 3	25°C		1.2	5	mV
			0°C to 70°C			6.5	
I_{IO}	Input offset current	$V_{IC} = 2.5$ V	25°C		1		pA
			70°C			0.3	nA
I_{IB}	Input bias current	$V_{IC} = 2.5$ V	25°C		5		pA
			70°C			0.6	nA
V_{ICR}	Common-mode input voltage range		25°C	0 to $V_{DD}-1$			V
			0°C to 70°C	0 to $V_{DD}-1.5$			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C		84		dB
			70°C		84		
			0°C		84		
k_{SVR}	Supply voltage rejection ratio	$V_{DD} = 5$ V to 10 V	25°C		85		dB
			70°C		85		
			0°C		85		
V_{OH}	High-level output voltage	$V_{ID} = 1$ V, $I_{OH} = -4$ mA	25°C	4.5	4.7		V
			70°C	4.3			
V_{OL}	Low-level output voltage	$V_{ID} = -1$ V, $I_{OL} = 4$ mA	25°C		210	[illegible]	mV
			70°C			[illegible]	
I_{DD}	Supply current (four comparators)	No load, Outputs low	25°C		35	80	μA
			0°C to 70°C			100	

†All characteristics are measured with zero common-mode voltage unless otherwise noted.

NOTE 3: The offset voltage limits given are the maximum values required to drive the output up to 4.5 V or down to 0.3 V.

3

Voltage Comparators

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	f = 10 kHz, C_L = 50 pF	Overdrive = 2 mV		4.5		μs
			Overdrive = 5 mV		2.7		
			Overdrive = 10 mV		1.9		
			Overdrive = 20 mV		1.4		
			Overdrive = 40 mV		1.1		
		V_I = 1.4-V step at IN+ pin			1.1		
t_{PHL}	Propagation delay time, high-to-low-level output	f = 10 kHz, C_L = 50 pF	Overdrive = 2 mV		4.0		μs
			Overdrive = 5 mV		2.3		
			Overdrive = 10 mV		1.5		
			Overdrive = 20 mV		0.95		
			Overdrive = 40 mV		0.65		
		V_I = 1.4-V step at IN+ pin			0.15		
t_f	Fall time, high-to-low-level output	f = 10 kHz, C_L = 50 pF	Overdrive = 50 mV		50		ns
t_r	Rise time, low-to-high-level output	f = 10 kHz C_L = 50 pF	Overdrive = 50 mV		125		ns