LM311-MIL Differential Comparators

1 Features

- Fast Response Time: 165 ns
- Strobe Capability
- Maximum Input Bias Current: 300 nA
- Maximum Input Offset Current: 70 nA
- Can Operate From Single 5-V Supply
- Available in Q-Temp Automotive
  - High-Reliability Automotive Applications
  - Configuration Control and Print Support
  - Qualification to Automotive Standards
- On Products Compliant to MIL-PRF-38535, All Parameters Are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

2 Applications

- Desktop PCs
- Body Control Modules
- White Goods
- Building Automation
- Oscillators
- Peak Detectors

3 Description

The LM311-MIL device is a single high-speed voltage comparators. The device is designed to operate from a wide range of power-supply voltages, including ±15-V supplies for operational amplifiers and 5-V supplies for logic systems. The output level is compatible with most TTL and MOS circuits. The comparator is 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 capabilities are available, and the outputs can be wire-OR connected. If the strobe is low, the output is in the off state, regardless of the differential input.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE
LM311-MILPS	SO (8)	6.20 mm × 5.30 mm
LM311-MILD	SOIC (8)	4.90 mm × 3.91 mm
LM311-MILP	PDIP (8)	9.81 mm × 6.35 mm
LM311-MILPW	TSSOP (8)	3.00 mm × 4.40 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Simplified Schematic

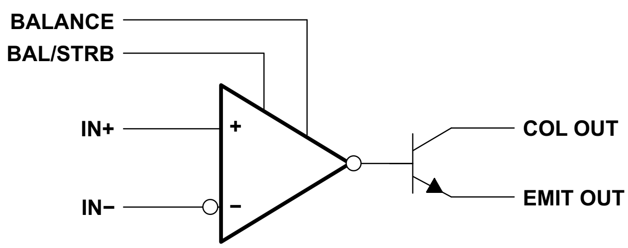

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Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
June 2017	*	Initial release.

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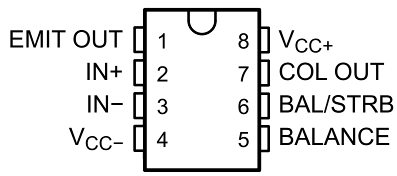
5 Pin Configuration and Functions

LM311-MIL D, JG, P, PS, or PW Package
8-Pin SOIC, CDIP, PDIP, SO or TSSOP
Top View



Pin Functions

PIN			I/O[1]	DESCRIPTION
NAME	LM311-MIL			
	SOIC, PDIP, TSSOP	SO		
IN+	2	2	I	Noninverting comparator
IN–	3	3	I	Inverting input comparator
BALANCE	5	5	I	Balance
BAL/STRB	6	6	I	Strobe
COL OUT	7	7	O	Output collector comparator
EMIT OUT	1	1	O	Output emitter comparator
V_{CC}–	4	4	—	Negative supply
V_{CC}+	8	8	—	Positive supply
NC	—	—	—	No connect (No internal connection)

(1) I = Input, O = Output

6 Specifications

6.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
	Supply voltage	V_{CC+}[2]		18	V
		V_{CC-}[2]		–18	
		$V_{CC+} - V_{CC-}$		36	
V_{ID}	Differential input voltage[3]			±30	V
V_I	Input voltage (either input)[2][4]			±15	V
	Voltage from emitter output to V_{CC-}			30	V
	Voltage from collector output to V_{CC-}			40	V
	Duration of output short circuit to ground			10	s
T_J	Operating virtual-junction temperature			150	°C
	Lead temperature 1,6 mm (1/16 inch) from case, 10 s	JG package		300	°C
	Lead temperature 1,6 mm (1/16 inch) from case, 60 s	D, P, PS, or PW package		260	°C
T_{stg}	Storage temperature		−65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values, unless otherwise noted, are with respect to the midpoint between V_{CC+} and V_{CC-}.
(3) Differential voltages are at IN+ with respect to IN–.
(4) The magnitude of the input voltage must never exceed the magnitude of the supply voltage or ±15 V, whichever is less.

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6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±750	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

		MIN	MAX	UNIT
$V_{CC+} – V_{CC–}$	Supply voltage	3.5	30	V
V_I	Input voltage ($\|V_{CC+}\| \leq 15$ V)	$V_{CC–}$ + 0.5	V_{CC+} – 1.5	V
T_A	Operating free-air temperature range	0	70	°C

6.4 Thermal Information

THERMAL METRIC[1]		LM311-MIL				UNIT
		D (SOIC)	P (PDIP)	PW (TSSOP)	PS (SO)	
		8 PINS	8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	114.3	57.5	162	121.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	60.7	47.3	44.6	81.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	54.5	34.6	93	66.5	°C/W
ψ_{JT}	Junction-to-top characterization parameter	17.4	24.9	2.6	31.4	°C/W
ψ_{JB}	Junction-to-board characterization parameter	54	34.5	90.8	65.8	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

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6.5 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS		T_A[1]	MIN	TYP[2]	MAX	UNIT
V_{IO}	Input offset voltage	See[3]		25°C		2	7.5	mV
				Full range			10	mV
I_{IO}	Input offset current	See[3]		25°C		6	50	nA
				Full range			70	nA
I_{IB}	Input bias current	1 V ≤ V_O ≤ 14 V		25°C		100	250	nA
				Full range			300	nA
$I_{IL(S)}$	Low-level strobe current[4]	$V_{(strobe)}$ = 0.3 V, V_{ID} ≤ –10 mV		25°C		–3		mA
V_{ICR}	Common-mode input-voltage range[3]	Lower range		Full range		–14.7	–14.5	V
		Upper range		Full range	13	13.8		V
A_{VD}	Large-signal differential-voltage amplification	5 V ≤ V_O ≤ 35 V, R_L = 1 kΩ		25°C	40	200		V/mV
I_{OH}	High-level (collector) output leakage current	$I_{(strobe)}$ = –3 mA, V_{ID} = 5 mV	V_{OH} = 35 V	25°C				nA
				Full range				μA
		V_{ID} = 5 mV, V_{OH} = 35 V		25°C		0.2	50	nA
V_{OL}	Low-level (collector-to-emitter) output voltage	I_{OL} = 50 mA	V_{ID} = –5 mV	25°C				V
			V_{ID} = –10 mV	25°C		0.75	1.5	V
		V_{CC+} = 4.5 V, V_{CC-} = 0 V, I_{OL} = 8 mA	V_{ID} = –6 mV	Full range				V
			V_{ID} = –10 mV	Full range		0.23	0.4	V
I_{CC+}	Supply current from V_{CC+} output low	V_{ID} = –10 mV,	No load	25°C		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	mA

(1) Unless otherwise noted, all characteristics are measured with BALANCE and BAL/STRB open and EMIT OUT grounded. Full range for LM111 is –55°C to 125°C, for LM211 is –40°C to 85°C, for LM211Q is –40°C to 125°C, and for LM311-MIL is 0°C to 70°C.
(2) All typical values are at T_A = 25°C.
(3) 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 pullup resistor of 7.5 kΩ to V_{CC+}. These parameters actually define an error band and take into account the worst-case effects of voltage gain and input impedance.
(4) The strobe must not be shorted to ground; it must be current driven at –3 mA to –5 mA (see Figure 18 and Figure 31).

6.6 Switching Characteristics

$V_{CC\pm}$ = ±15 V, T_A = 25°C

PARAMETER	TEST CONDITIONS	LM311-MIL TYP	UNIT
Response time, low-to-high-level outputSee[1]	R_C = 500 Ω to 5 V, C_L = 5 pF, see [2]	115	ns
Response time, high-to-low-level outputSee[1]		165	ns

(1) 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.
(2) The package thermal impedance is calculated in accordance with MIL-STD-883.

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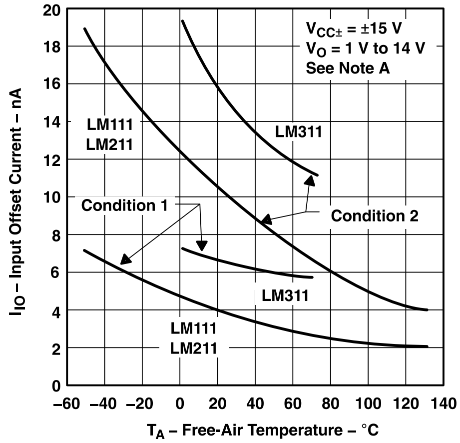
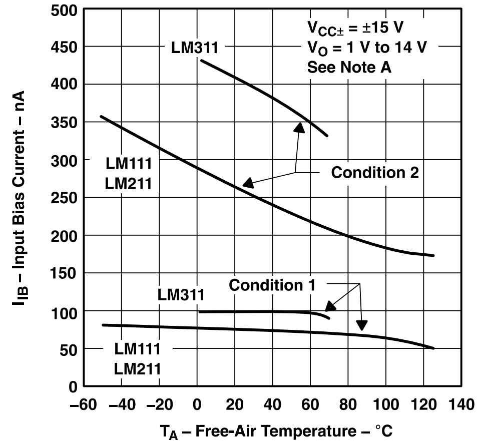
6.7 Typical Characteristics



Condition 1 is with BALANCE and BAL/STRB open.
Condition 2 is with BALANCE and BAL/STRB connected to V_{CC+}.

Figure 1. Input Offset Current vs Free-Air Temperature



Condition 1 is with BALANCE and BAL/STRB open.
Condition 2 is with BALANCE and BAL/STRB connected to V_{CC+}.

Figure 2. Input Bias Current vs Free-Air Temperature

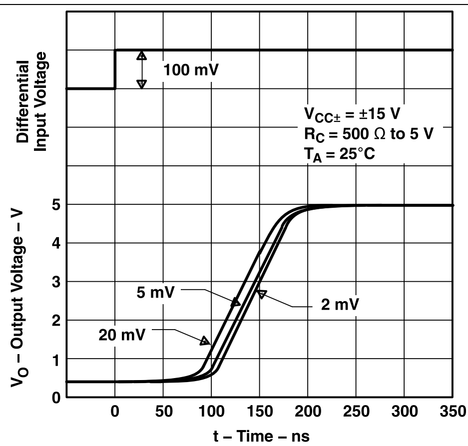


Figure 3. Output Response for Various Input Overdrives

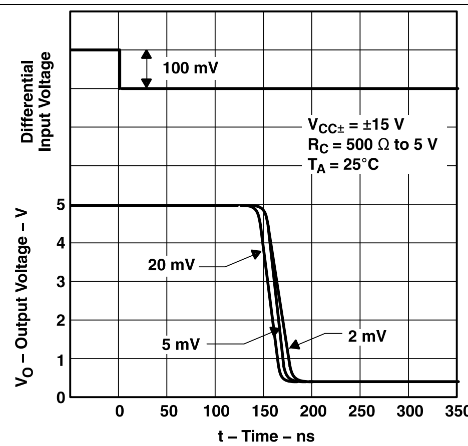


Figure 4. Output Response for Various Input Overdrives

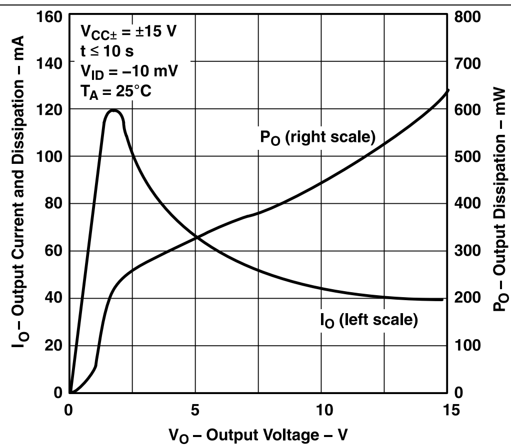


Figure 5. Output Current and Dissipation vs Output Voltage

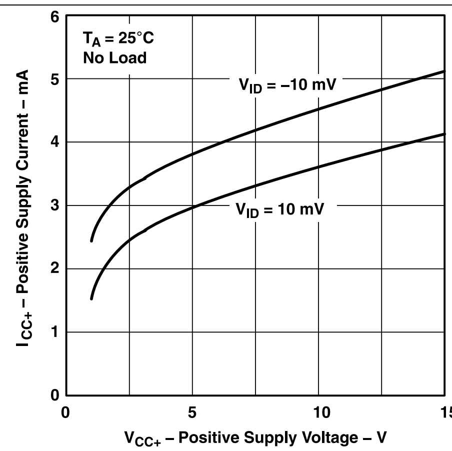


Figure 6. Positive Supply Current vs Positive Supply Voltage

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Typical Characteristics (continued)

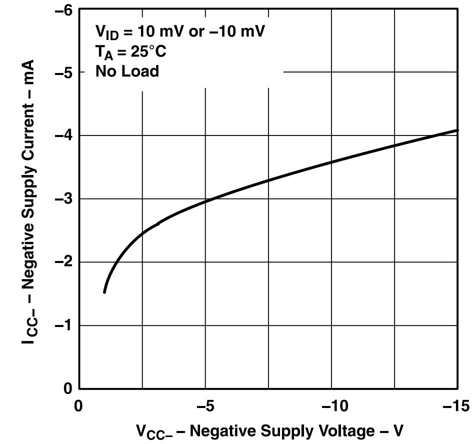

Figure 7. Negative Supply Current vs Negative Supply Voltage

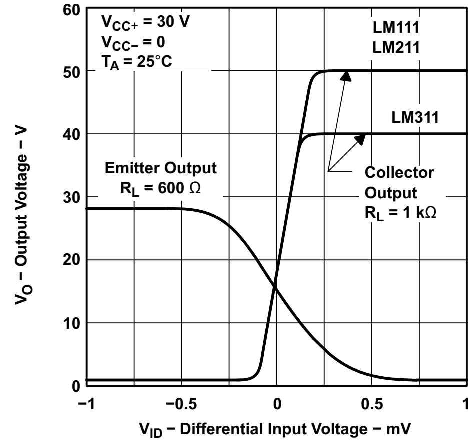

Figure 8. Voltage Transfer Characteristics and Test Circuits

7 Parameter Measurement Information

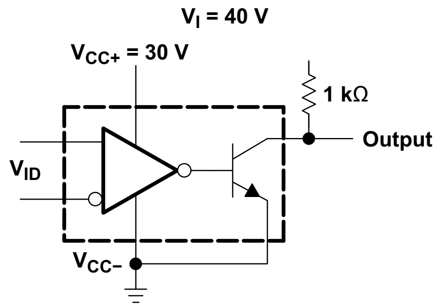

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Figure 9. Collector Output Transfer Characteristic Test Circuit

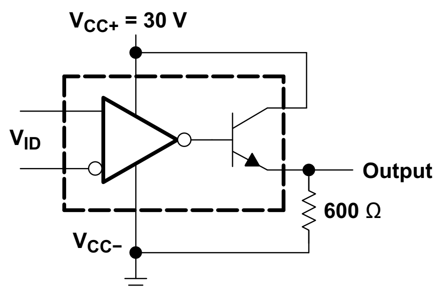

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Figure 10. Emitter Output Transfer Characteristic Test Circuit

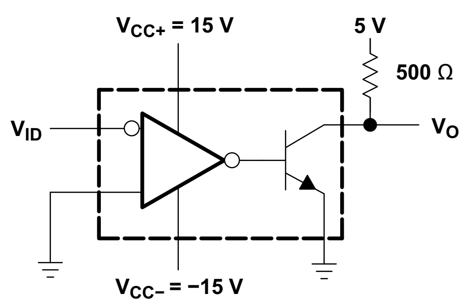

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Figure 11. Test Circuit for Figure 3 and Figure 4

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Parameter Measurement Information (continued)

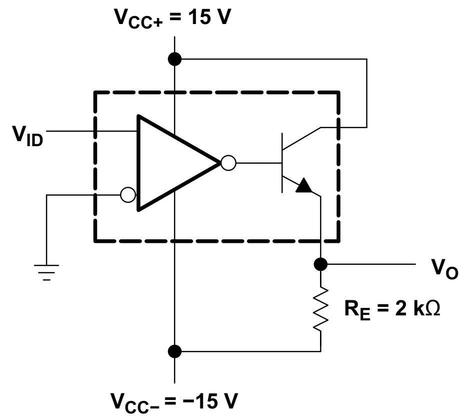

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Figure 12. Test Circuit for Figure 14 and Figure 15

8 Detailed Description

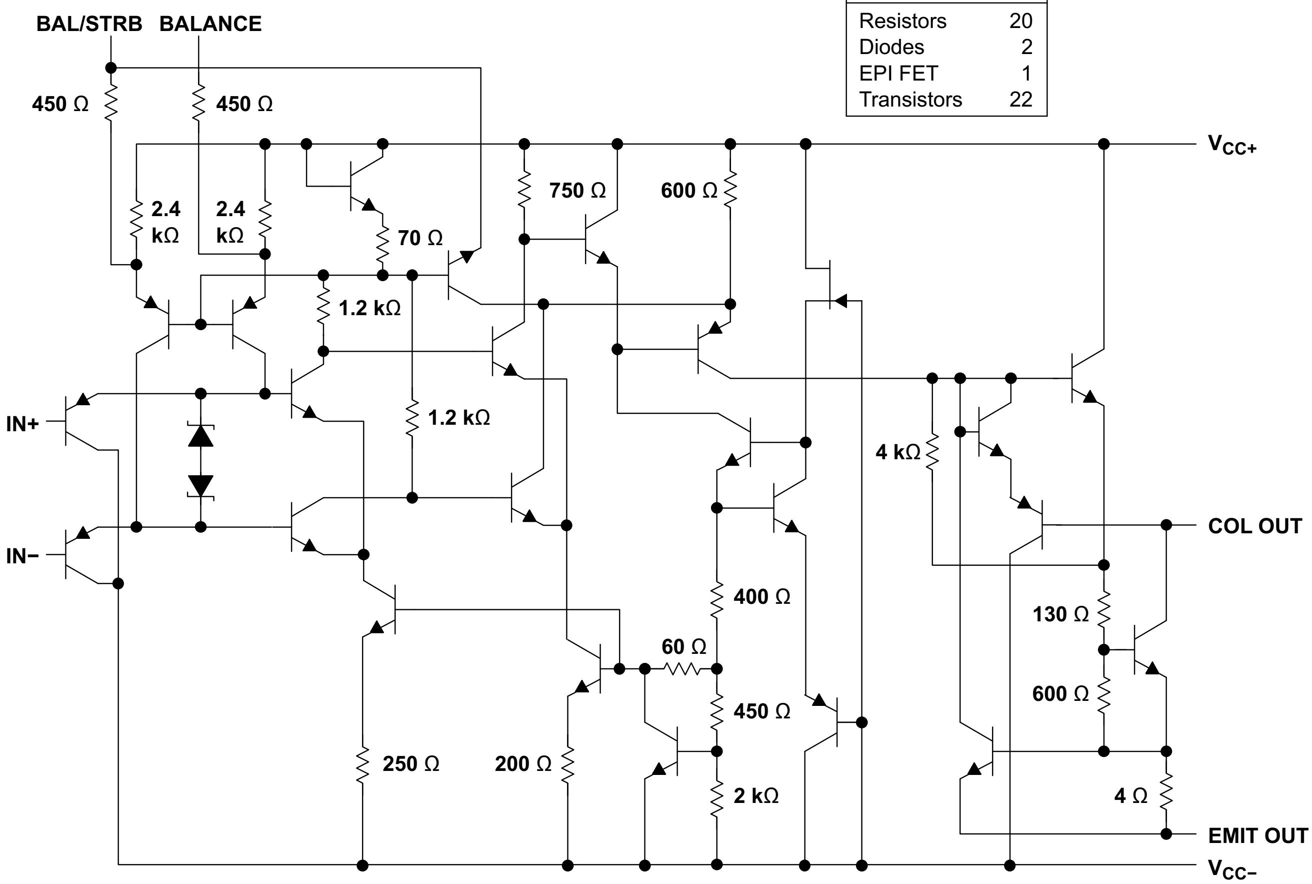
8.1 Overview

The LM311-MIL voltage comparator has input currents nearly a thousand times lower than legacy standard devices. The LM311-MIL is designed to operate over a wider range of supply voltages: from standard ±15-V op amp supplies down to the single 5-V supply used for device logic. Their output is compatible with RTL, DTL and TTL as well as MOS circuits. Further, they can drive lamps or relays, switching voltages up to 50 V at currents as high as 50 mA.

The LM311-MIL can be isolated from system ground, and the output can drive loads referred to ground, the positive supply or the negative supply. Offset balancing and strobe capability are provided and outputs can be wire ORed. The LM311-MIL has a temperature range of 0°C to +70°C.

8.2 Functional Block Diagram

Component Count	
Resistors	20
Diodes	2
EPI FET	1
Transistors	22



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8.3 Feature Description

LM311-MIL consists of a PNP input stage to sense voltages near V_{CC-}. It also contains balance and strobe pins for external offset adjustment or trimming.

The input stage is followed by a very high gain stage for very fast response after a voltage difference on the input pins have been sensed.

This is then followed by the output stage that consists of an open collector NPN (pulldown or low-side) transistor. Unlike most open drain comparators, this NPN output stage has an isolated emitter from V_{CC-}, allowing this device to set the V_{OL} output value for collector output.

8.4 Device Functional Modes

8.4.1 Voltage Comparison

The LM311-MIL operates solely as a voltage comparator, comparing the differential voltage between the positive and negative pins and outputting a logic low or high impedance (logic high with pullup) based on the input differential polarity.

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Validate and test the design implementation to confirm system functionality.

9.1 Application Information

A typical LM311-MIL application compares a single signal to a reference or two signals against each other. Many users take advantage of the open-drain output to drive the comparison logic output to a logic voltage level to an MCU or logic device. The wide supply range and high voltage capability makes LM311-MIL optimal for level shifting to a higher or lower voltage.

9.2 Typical Application

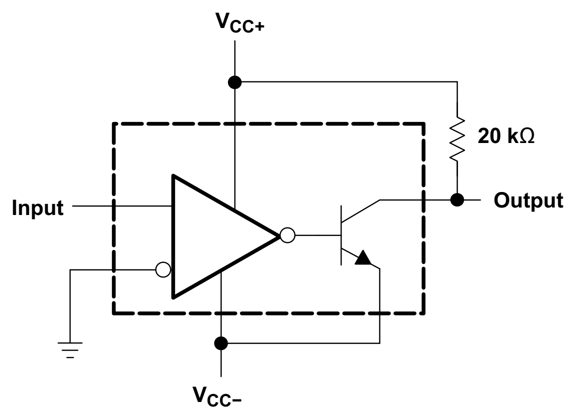

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Figure 13. Zero-Crossing Detector

9.2.1 Design Requirements

For this design example, use the parameters listed in Table 1 as the input parameters.

Table 1. Design Parameters

PARAMETER		MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range	–15		13	V
V_{CC+}	Positive supply voltage			15	V
V_{CC-}	Negative supply voltage	–15			
I_{OUT}	Output current			20	mA

9.2.2 Detailed Design Procedure

When using LM311-MIL in a general comparator application, determine the following:

- Input voltage range
- Minimum overdrive voltage
- Output and drive current
- Response time

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9.2.2.1 Input Voltage Range

When choosing the input voltage range, consider the input common mode voltage range (V_{ICR}). Operation outside of this range can yield incorrect comparisons.

The following list describes the outcomes of some input voltage situations.

- When both IN– and IN+ are both within the common-mode range:
  - If IN– is higher than IN+ and the offset voltage, the output is low and the output transistor is sinking current
  - If IN– is lower than IN+ and the offset voltage, the output is high impedance and the output transistor is not conducting
- When IN– is higher than common mode and IN+ is within common mode, the output is low and the output transistor is sinking current
- When IN+ is higher than common mode and IN– is within common mode, the output is high impedance and the output transistor is not conducting
- When IN– and IN+ are both higher than common mode, the output is undefined

9.2.2.2 Minimum Overdrive Voltage

Overdrive voltage is the differential voltage produced between the positive and negative inputs of the comparator over the offset voltage (V_{IO}). To make an accurate comparison the Overdrive voltage (V_{OD}) must be higher than the input offset voltage (V_{IO}). Overdrive voltage can also determine the response time of the comparator, with the response time decreasing with increasing overdrive. Figure 14 and Figure 15 show positive and negative response times with respect to overdrive voltage.

9.2.2.3 Output and Drive Current

Output current is determined by the pullup resistance and pullup voltage. The output current produces a output low voltage (V_{OL}) from the comparator, in which V_{OL} is proportional to the output current. Use Figure 5 to determine V_{OL} based on the output current.

The output current can also effect the transient response.

9.2.2.4 Response Time

The load capacitance (C_L), pullup resistance (R_{PULLUP}), and equivalent collector-emitter resistance (R_{CE}) levels determine the transient response. Equation 1 approximates the positive response time. Equation 2 approximates the negative response time. R_{CE} can be determine by taking the slope of Figure 5 in the linear region at the desired temperature, or by Equation 3.

$$\tau_P \cong R_{PULLUP} \times C_L \tag{1}$$

$$\tau_N \cong R_{CE} \times C_L \tag{2}$$

$$R_{CE} = \frac{V_{OL}}{I_{OUT}}$$

where

- V_{OL} is the low-level output voltage
- I_{OUT} is the output current (3)

9.2.3 Application Curves

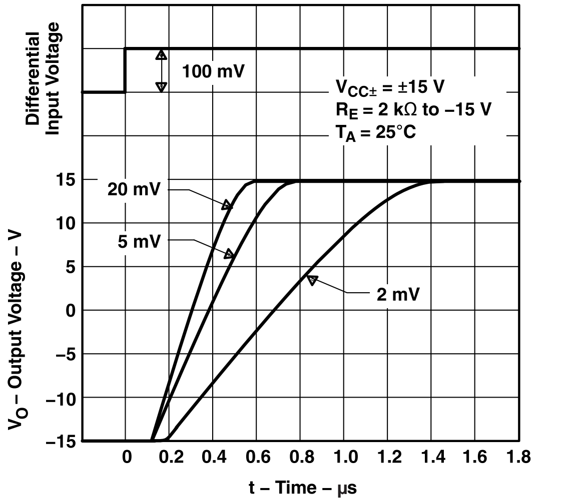

Figure 14. Output Response for Various Input Overdrives

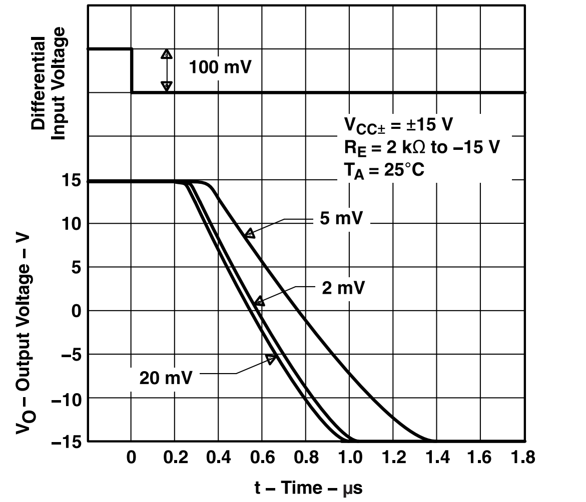

Figure 15. Output Response for Various Input Overdrives

9.3 System Examples

Figure 16 through Figure 33 show various applications for the LM111, LM211, and LM311-MIL comparators.

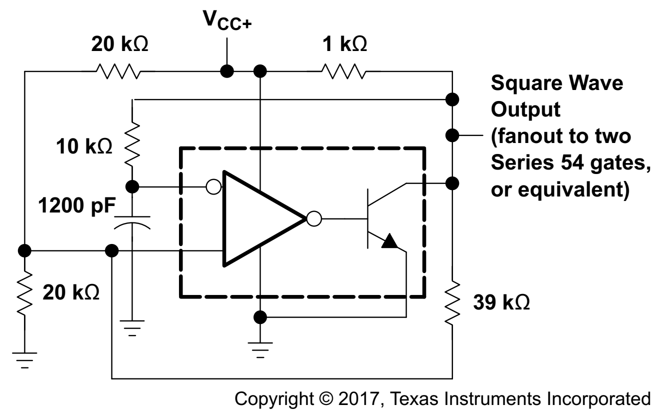

Figure 16. 100-kHz Free-Running Multivibrator

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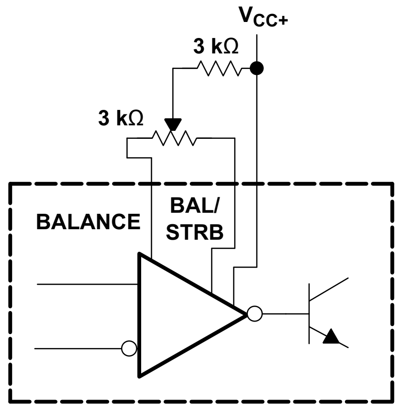
System Examples (continued)



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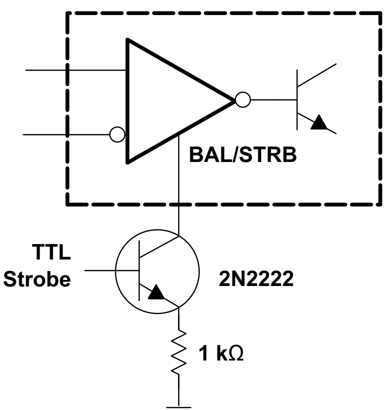
If offset balancing is not used, the BALANCE and BAL/STRB pins must be unconnected. It is also acceptable to short pins together.

Figure 17. Offset Balancing



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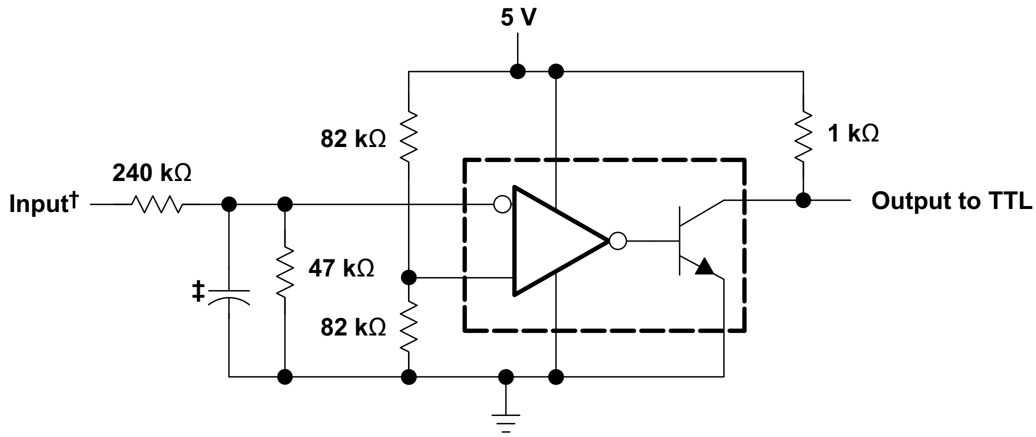
Do not connect strobe pin directly to ground, because the output is turned off whenever current is pulled from the strobe pin.

Figure 18. Strobing

System Examples (continued)



† 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

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Figure 19. TTL Interface With High-Level Logic

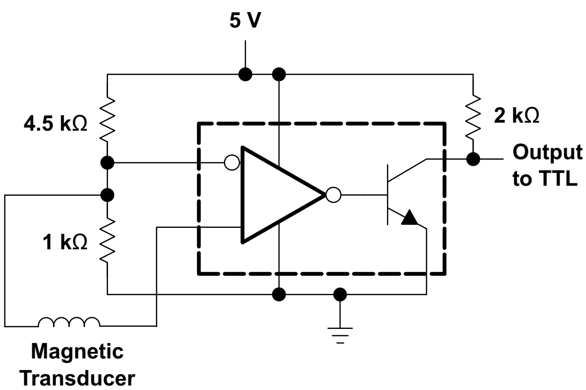

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Figure 20. Detector for Magnetic Transducer

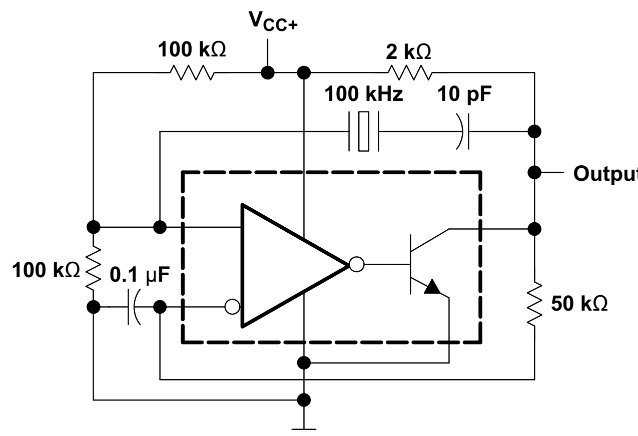

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Figure 21. 100-kHz Crystal Oscillator

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System Examples (continued)

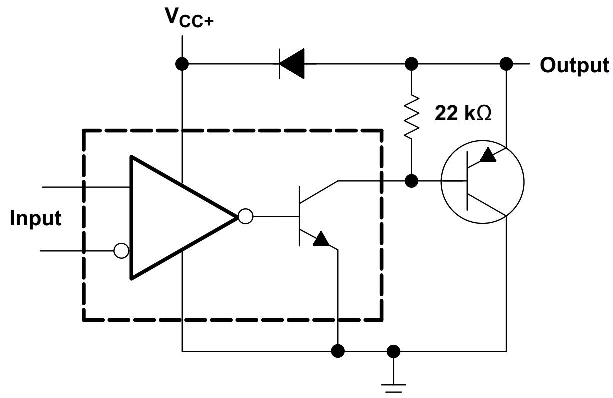

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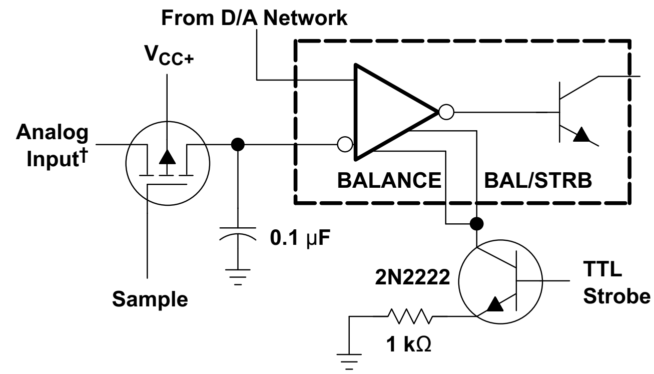
Figure 22. Comparator and Solenoid Driver



† Typical input current is 50 pA with inputs strobed off.

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Figure 23. Strobing Both Input and Output Stages Simultaneously

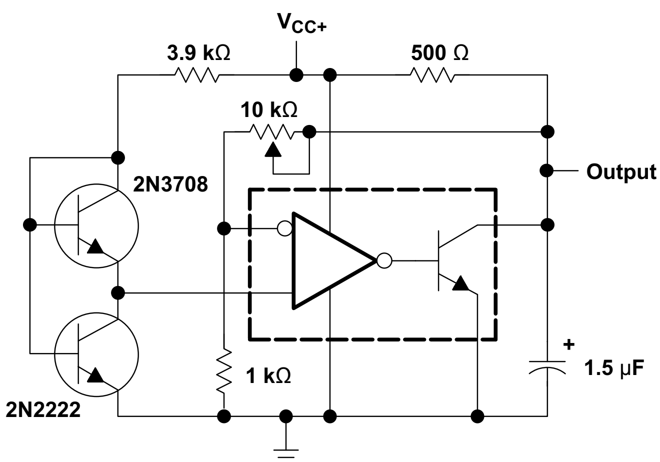

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Figure 24. Low-Voltage Adjustable Reference Supply

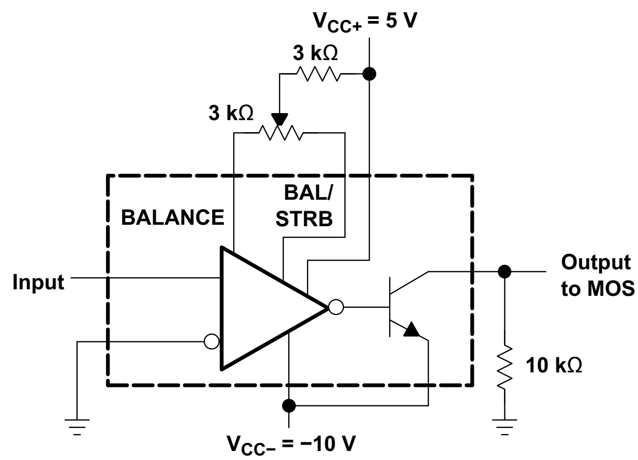

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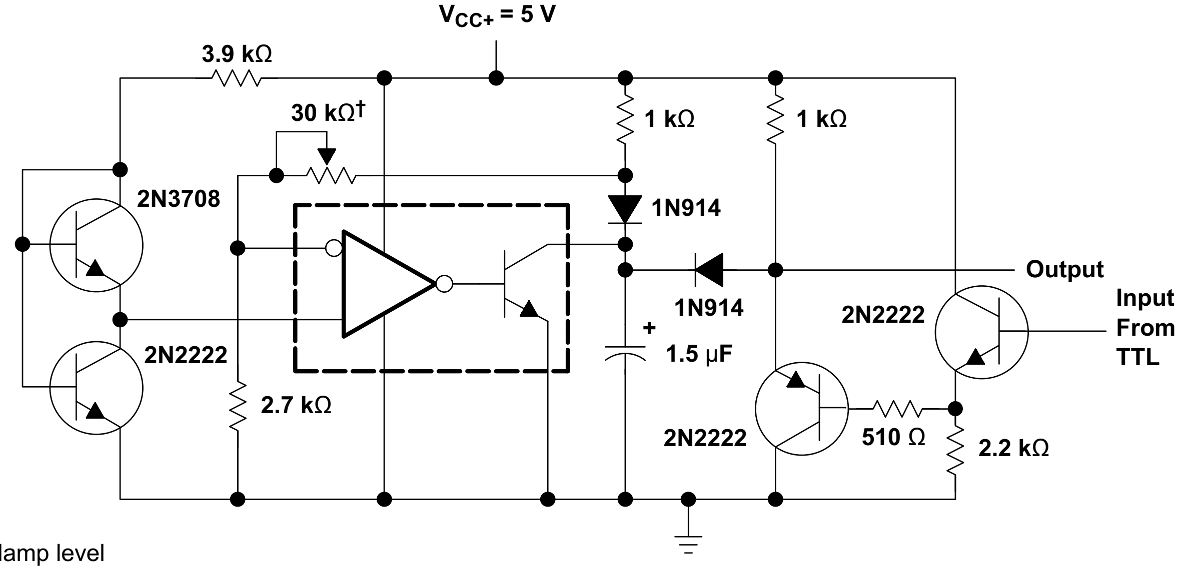
Figure 25. Zero-Crossing Detector Driving MOS Logic

System Examples (continued)



† Adjust to set clamp level

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Figure 26. Precision Squarer

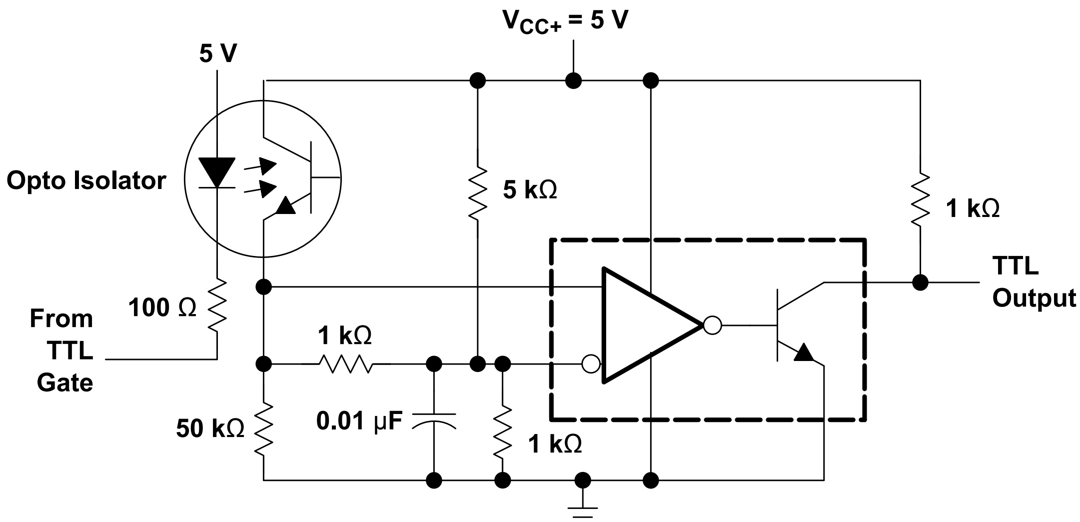

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Figure 27. Digital Transmission Isolator

System Examples (continued)

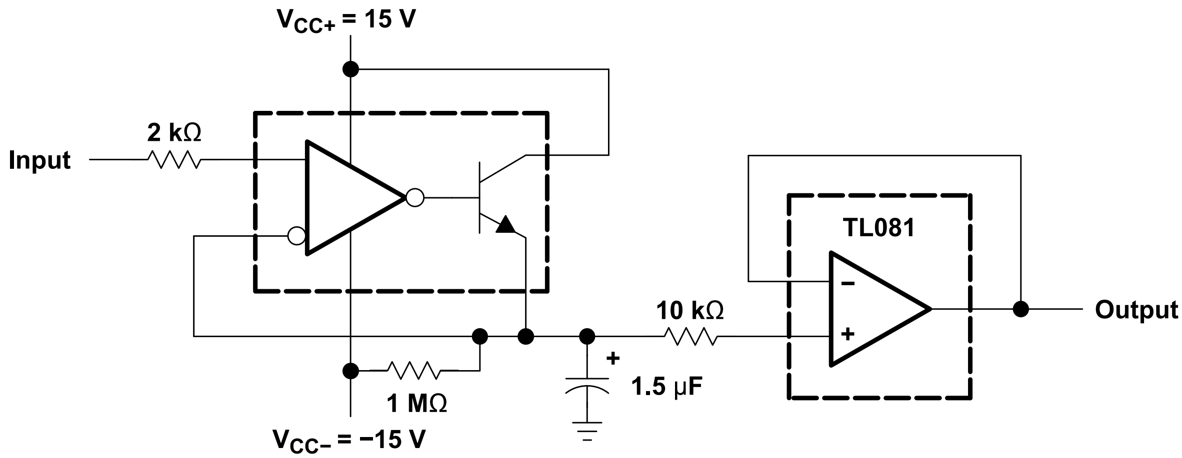

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Figure 28. Positive-Peak Detector

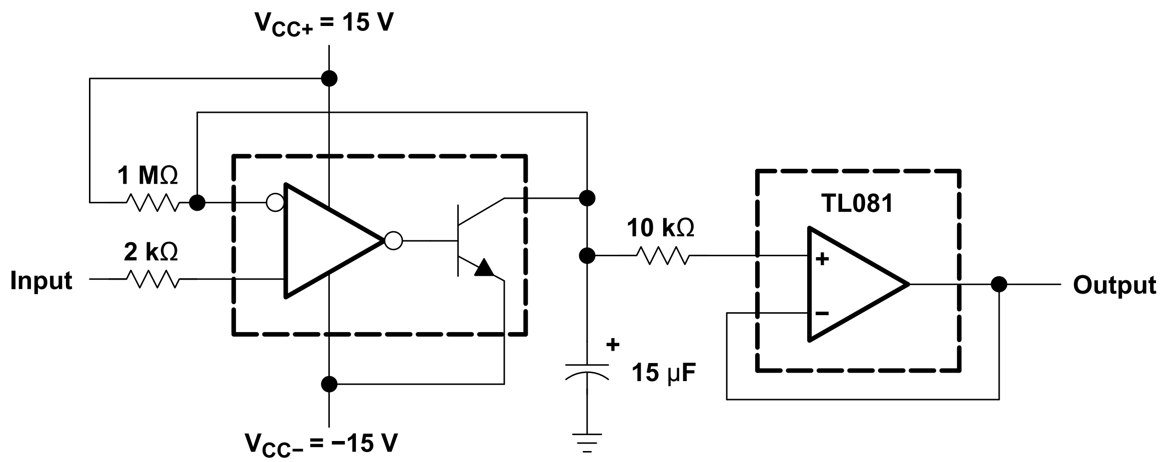

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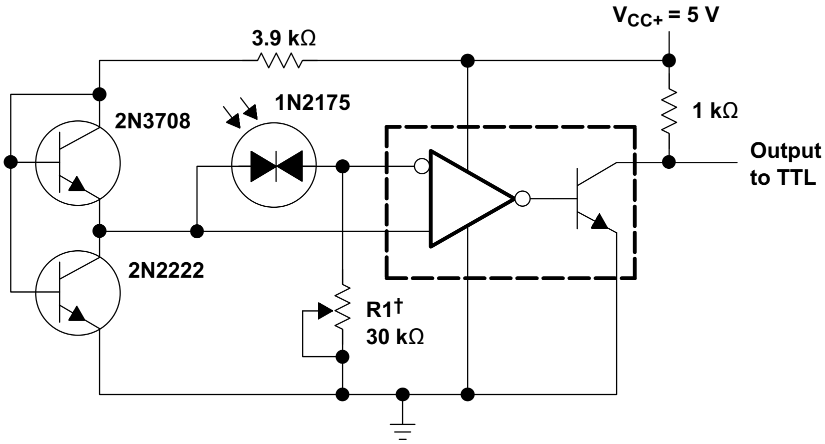
Figure 29. Negative-Peak Detector

System Examples (continued)



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

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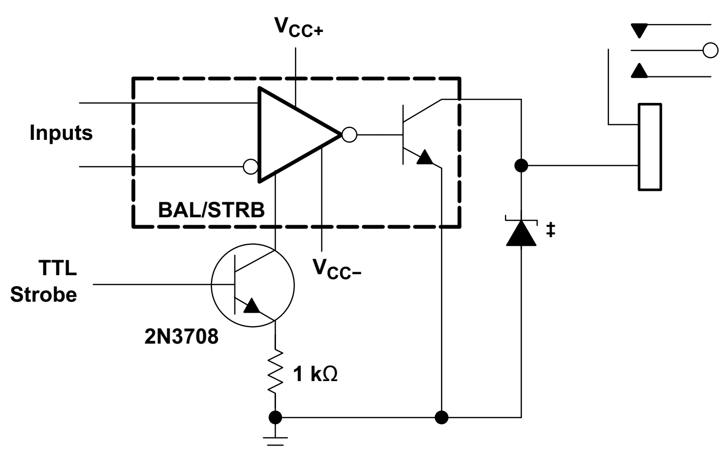
Figure 30. Precision Photodiode Comparator



‡ Transient voltage and inductive kickback protection

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Figure 31. Relay Driver With Strobe

System Examples (continued)

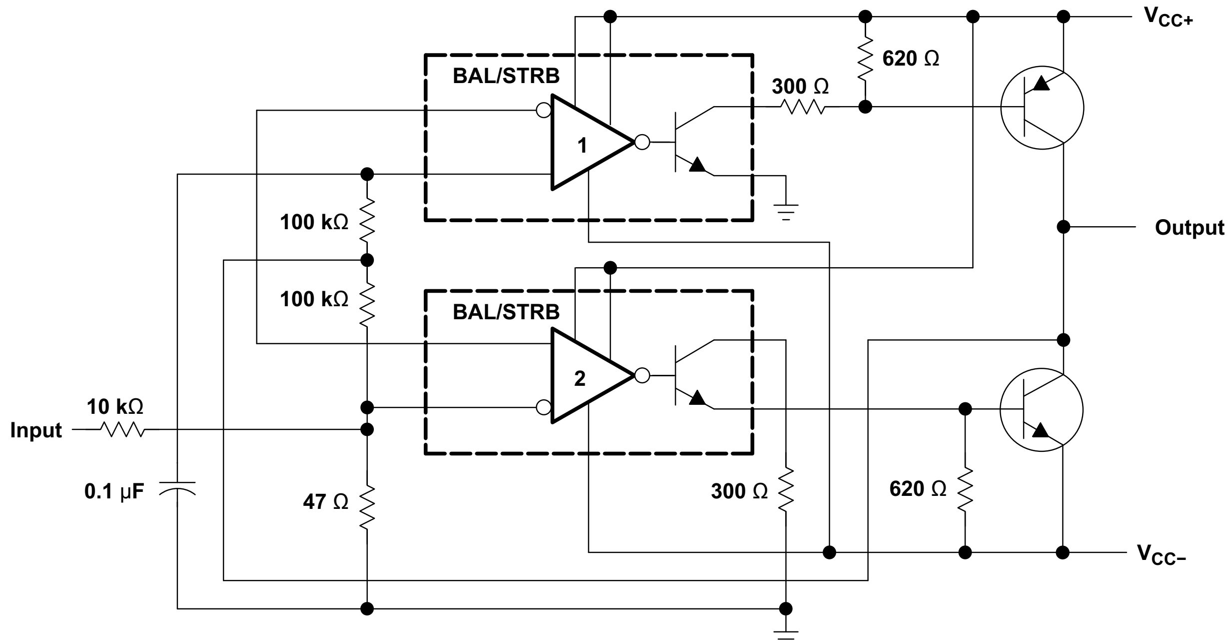

Figure 32. Switching Power Amplifier

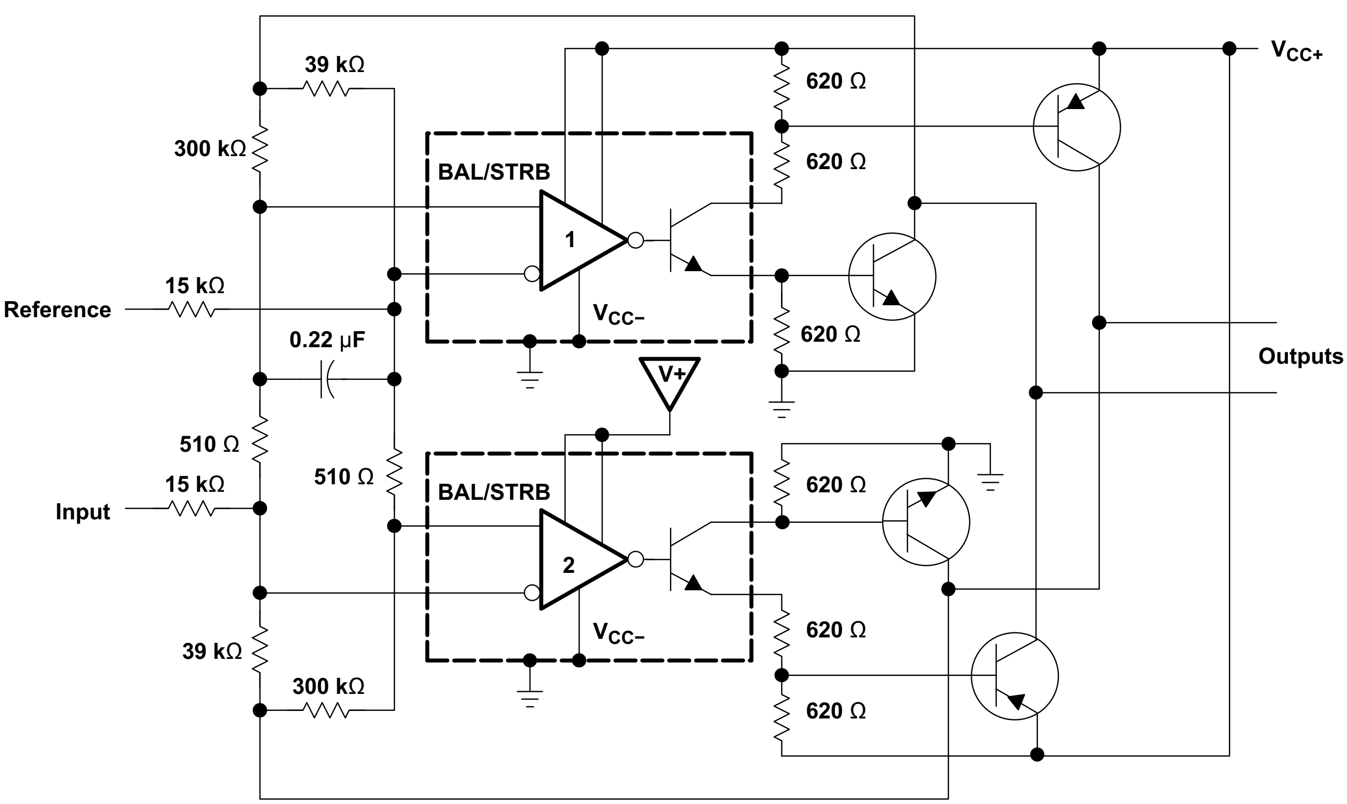

Figure 33. Switching Power Amplifiers

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10 Power Supply Recommendations

For fast response and comparison applications with noisy or AC inputs, use a bypass capacitor on the supply pin to reject any variation on the supply voltage. This variation can affect the common-mode range of the comparator input and create an inaccurate comparison.

11 Layout

11.1 Layout Guidelines

To create an accurate comparator application without hysteresis, maintain a stable power supply with minimized noise and glitches, which can affect the high level input common-mode voltage range. To achieve this accuracy, add a bypass capacitor between the supply voltage and ground. Place a bypass capacitor on the positive power supply and negative supply (if available).

11.2 Layout Example

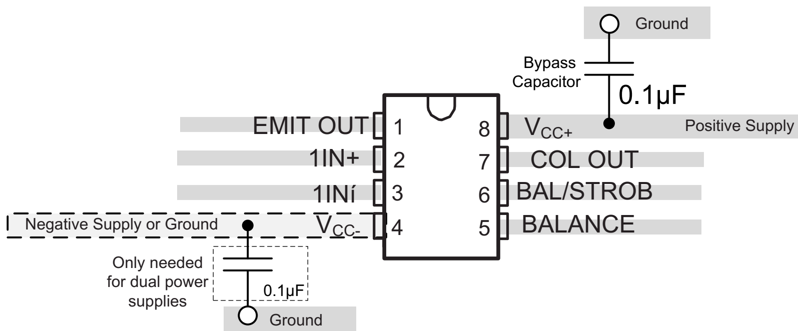

Figure 34. LM311-MIL Layout Example

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12 Device and Documentation Support

12.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 2. Related Links

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LM311-MIL	Click here	Click here	Click here	Click here	Click here

12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.3 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser based versions of this data sheet, refer to the left hand navigation.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM311-MWC	ACTIVE	WAFERSALE	YS	0	1	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-40 to 85		Samples

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

[2] **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

[4] There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

[5] Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

[6] Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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