LM111, LM211, LM311 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

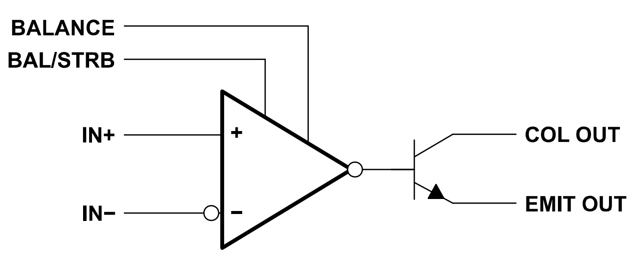
The LM111, LM211, and LM311 devices are single high-speed voltage comparators. These devices are designed to operate from a wide range of power-supply voltages, including ±15-V supplies for operational amplifiers and 5-V supplies for logic systems. The output levels are compatible with most TTL and MOS 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 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
LM111FK	LCCC (20)	8.89 mm × 8.89 mm
LM111JG	CDIP (8)	9.60 mm × 6.67 mm
LM311PS	SO (8)	6.20 mm × 5.30 mm
LM211D	SOIC (8)	4.90 mm × 3.91 mm
LM311D		
LM211P	PDIP (8)	9.81 mm × 6.35 mm
LM311P		
LM211PW	TSSOP (8)	3.00 mm × 4.40 mm
LM311PW		

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

Simplified Schematic



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4 Revision History

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

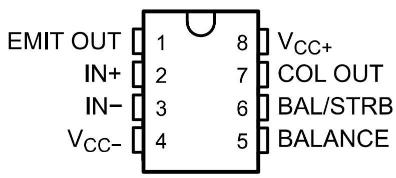
Changes from Revision J (January 2017) to Revision K	Page
• Changed Human body model (HBM) from: ±1000 to: ±500 in *ESD Ratings* table	4

Changes from Revision I (June 2015) to Revision J	Page
• Changed the data sheet title From: LMx11 Quad Differential Comparators To: LM111, LM211, LM311 Differential Comparators	1
• Updated the *Applications* list	1
• Updated the *Thermal Information (8-Pin Packages)* table	5
• Changed text From: "over a −25°C to +85°C temperature range..." To: ""over a −40°C to +85°C temperature range..." in the *Overview* section	10
• Added text "The LM311 has a temperature range of −40°C to +125°C." to the *Overview* section	10

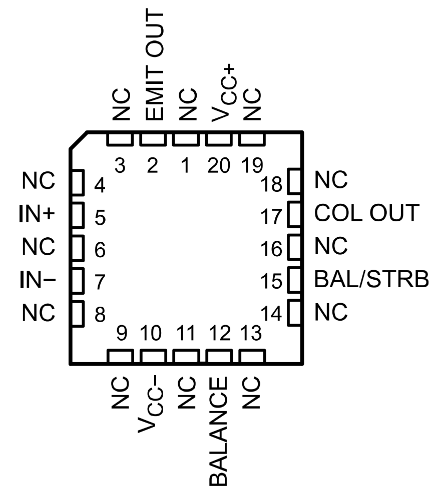
Changes from Revision H (August 2003) to Revision I	Page
• Updated *Features* with Military Disclaimer.	1
• Added *Applications*, *Device Information* table, *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section. No specification changes.	1

5 Pin Configuration and Functions

LMx11 D, JG, P, PS, or PW Package
8-Pin SOIC, CDIP, PDIP, SO or TSSOP
Top View



LM111 FK Package
20-Pin LCCC(1)
Top View



(1) NC = No internal connection

Pin Functions

PIN						
NAME	LM211, LM311 SOIC, PDIP, TSSOP	LM311 SO	LM111 CDIP	LM111 LCCC	I/O(1)	DESCRIPTION
IN+	2	2	2	5	I	Noninverting comparator
IN–	3	3	3	7	I	Inverting input comparator
BALANCE	5	5	5	12	I	Balance
BAL/STRB	6	6	6	15	I	Strobe
COL OUT	7	7	7	17	O	Output collector comparator
EMIT OUT	1	1	1	2	O	Output emitter comparator
V_{CC}–	4	4	4	10	—	Negative supply
V_{CC}+	8	8	8	20	—	Positive supply
NC	—	—	—	1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	—	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-}	LM111		50	V
		LM211		50	
		LM211Q		50	
		LM311		40	
	Duration of output short circuit to ground			10	s
T_J	Operating virtual-junction temperature			150	°C
	Case temperature for 60 s	FK package		260	°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.

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	LM111	–55	125	°C
		LM211	–40	85	
		LM211Q	–40	125	
		LM311	0	70	

6.4 Thermal Information (8-Pin Packages)

THERMAL METRIC(1)		LM211, LM311			LM311	LM111	UNIT
		D (SOIC)	P (PDIP)	PW (TSSOP)	PS (SO)	JG (CDIP)	
		8 PINS	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	14.5	°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.

6.5 Thermal Information (20-Pin Package)

THERMAL METRIC(1)		LM111	UNIT
		FK (LCCC)	
		20 PINS	
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	5.61	°C/W

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

6.6 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS		T_A (1)	LM111 LM211 LM211Q MIN	LM111 LM211 LM211Q TYP (2)	LM111 LM211 LM211Q MAX	LM311 MIN	LM311 TYP (2)	LM311 MAX	UNIT
V_{IO}	Input offset voltage	See (3)		25°C		0.7	3		2	7.5	mV
				Full range			4			10	
I_{IO}	Input offset current	See (3)		25°C		4	10		6	50	nA
				Full range			20			70	
I_{IB}	Input bias current	1 V ≤ V_O ≤ 14 V		25°C		75	100		100	250	nA
				Full range			150			300	
$I_{IL(S)}$	Low-level strobe current (4)	$V_{(strobe)}$ = 0.3 V, V_{ID} ≤ –10 mV		25°C		–3			–3		mA
V_{ICR}	Common-mode input-voltage range (3)	Lower range		Full range		–14.7	–14.5		–14.7	–14.5	V
		Upper range			13	13.8		13	13.8		
A_{VD}	Large-signal differential-voltage amplification	5 V ≤ V_O ≤ 35 V, R_L = 1 kΩ		25°C	40	200		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		0.2	10				nA
				Full range			0.5				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		0.75	1.5				V
			V_{ID} = –10 mV	25°C					0.75	1.5	
		V_{CC+} = 4.5 V, V_{CC-} = 0 V, 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

(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 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).

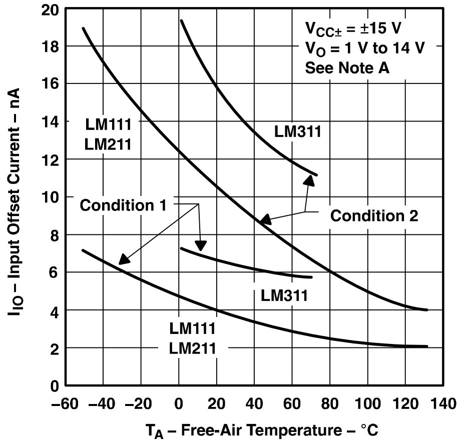
6.7 Switching Characteristics

$V_{CC\pm}$ = ±15 V, T_A = 25°C

PARAMETER	TEST CONDITIONS	LM111 LM211 LM211Q LM311 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

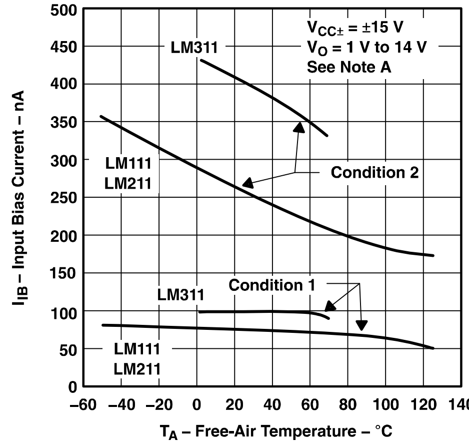
(1) The response time specified is for a 100-mV input step with 5-mV overdrive and is the interval between the input step function and the instant when the output crosses 1.4 V.
(2) The package thermal impedance is calculated in accordance with MIL-STD-883.

6.8 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

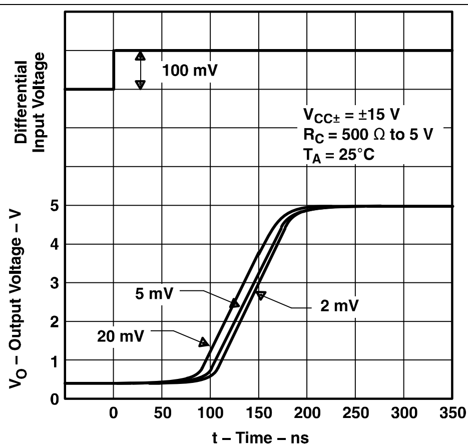


Figure 3. Output Response for Various Input Overdrives

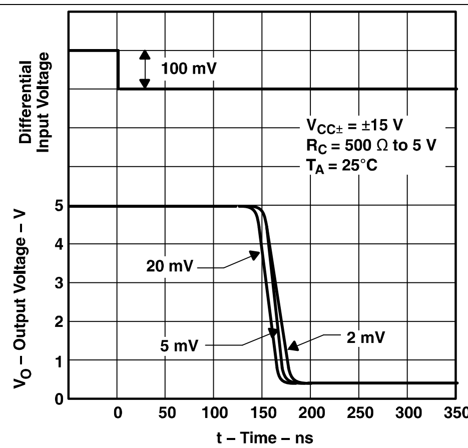


Figure 4. Output Response for Various Input Overdrives

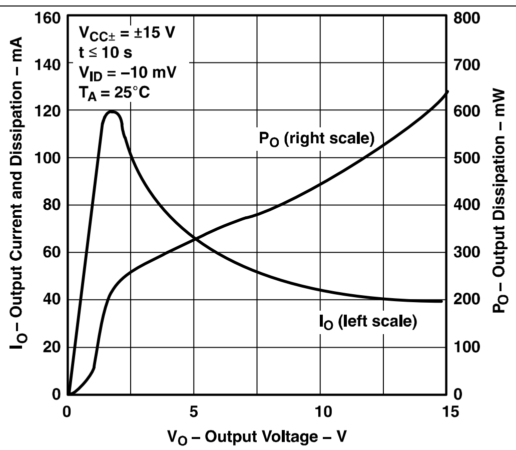


Figure 5. Output Current and Dissipation vs Output Voltage

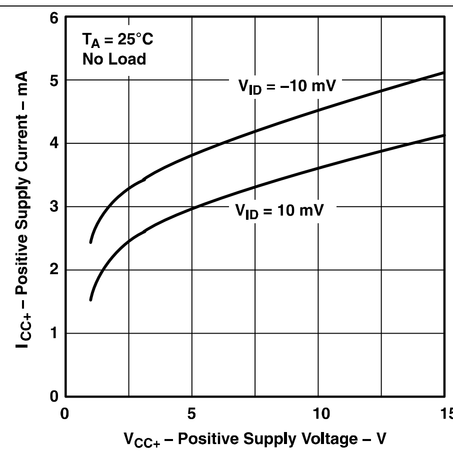


Figure 6. Positive Supply Current vs Positive Supply Voltage

Typical Characteristics (continued)

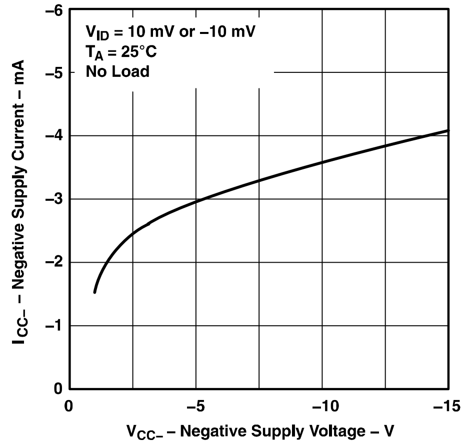


Figure 7. Negative Supply Current vs Negative Supply Voltage

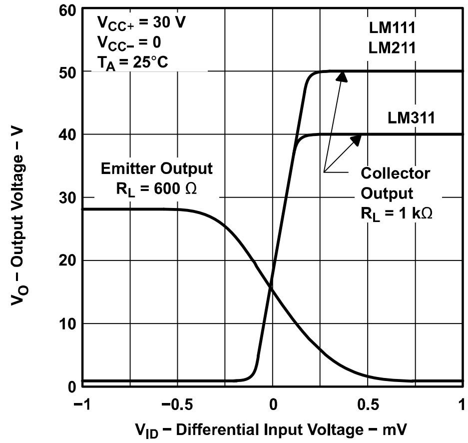


Figure 8. Voltage Transfer Characteristics and Test Circuits

7 Parameter Measurement Information

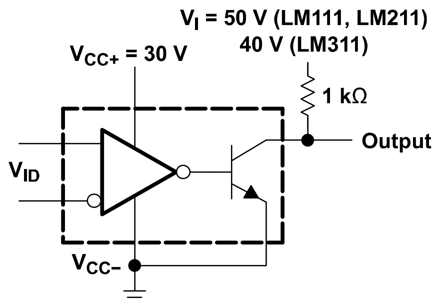


Figure 9. Collector Output Transfer Characteristic Test Circuit

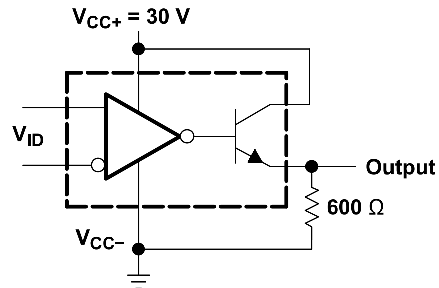


Figure 10. Emitter Output Transfer Characteristic Test Circuit

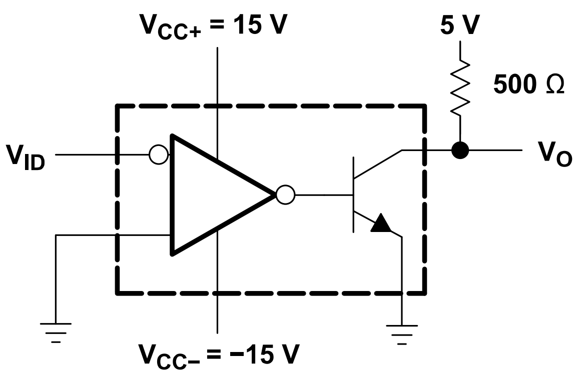


Figure 11. Test Circuit for Figure 3 and Figure 4

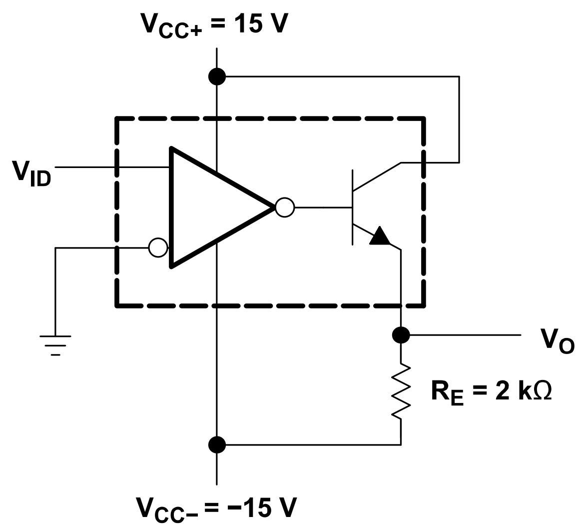


Figure 12. Test Circuit for Figure 14 and Figure 15

8 Detailed Description

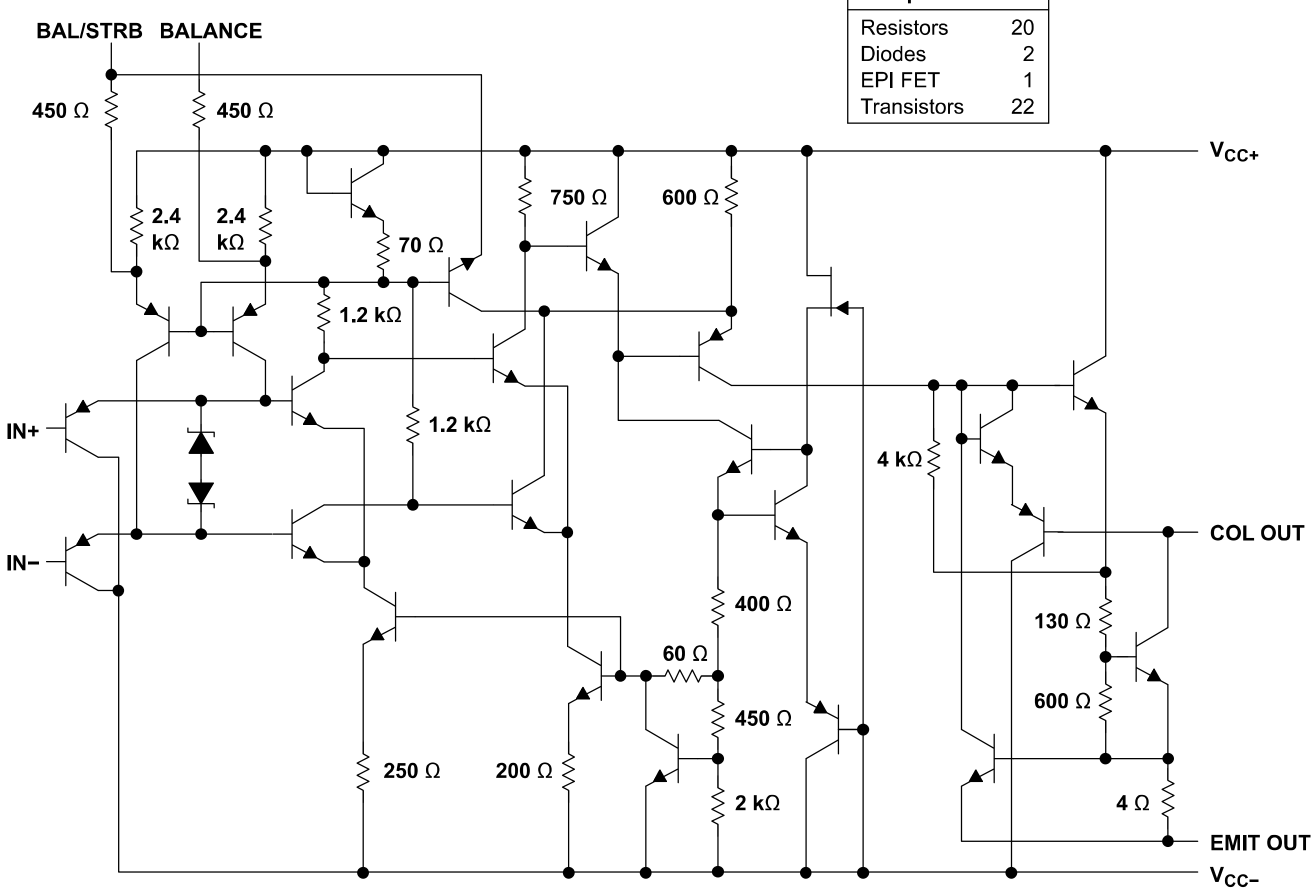
8.1 Overview

The LM111, LM211 and LM311 are voltage comparators that have input currents nearly a thousand times lower than legacy standard devices. They are also designed to operate over a wider range of supply voltages: from standard ±15V op amp supplies down to the single 5-V supply used for IC 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.

Both the inputs and the outputs of the LM111, LM211 or the LM311 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 LM211 is identical to the LM111, except that its performance is specified over a −40°C to +85°C temperature range instead of −55°C to +125°C. The LM311 has a temperature range of 0°C to +70°C. The LM211Q has a temperature range of −40°C to +125°C.

8.2 Functional Block Diagram

Component Count	
Resistors	20
Diodes	2
EPI FET	1
Transistors	22



8.3 Feature Description

LMx11 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 LMx11 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 LMx11 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 LMx11 optimal for level shifting to a higher or lower voltage.

9.2 Typical Application

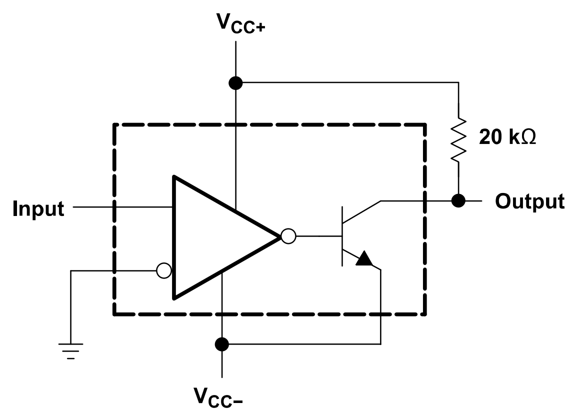


Figure 13. Zero-Crossing Detector

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 LMx11 in a general comparator application, determine the following:

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

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

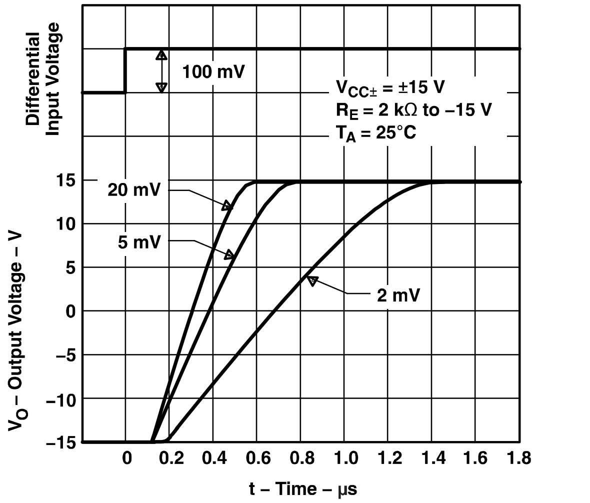


Figure 14. Output Response for Various Input Overdrives

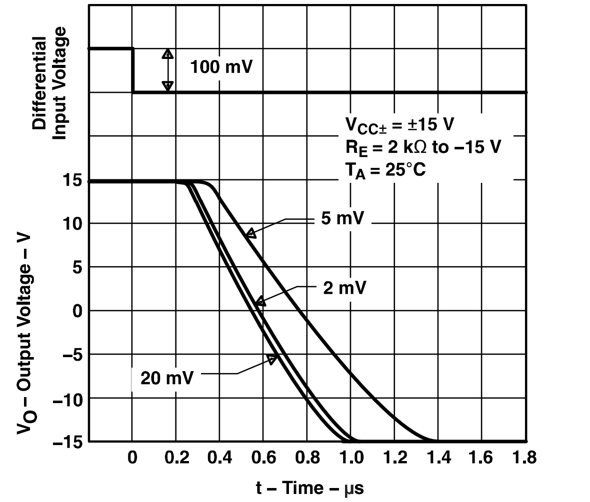


Figure 15. Output Response for Various Input Overdrives

9.3 System Examples

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

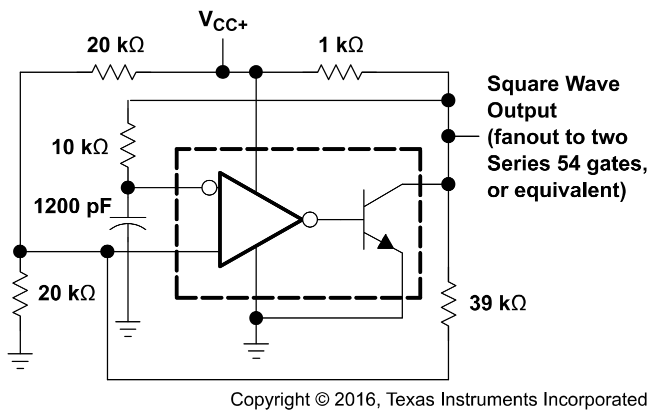
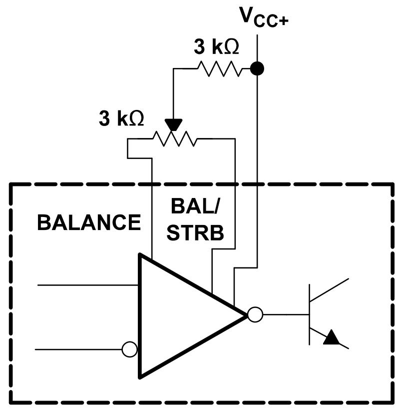


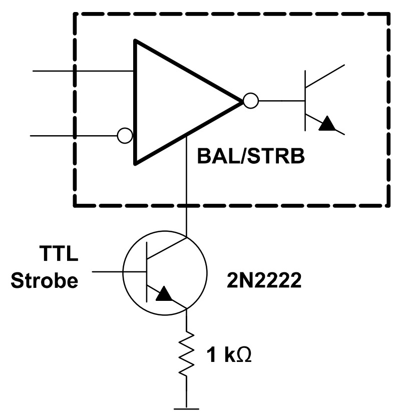
Figure 16. 100-kHz Free-Running Multivibrator

System Examples (continued)



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



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)

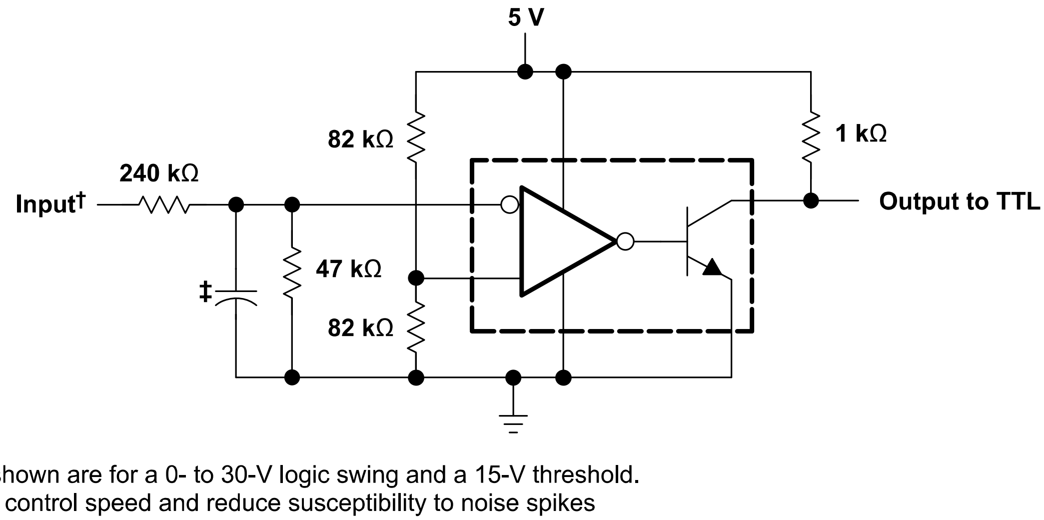


Figure 19. TTL Interface With High-Level Logic

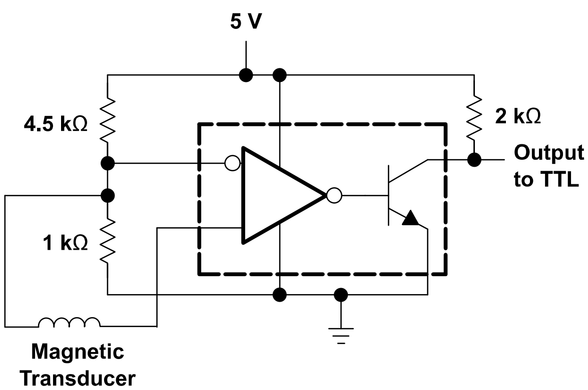


Figure 20. Detector for Magnetic Transducer

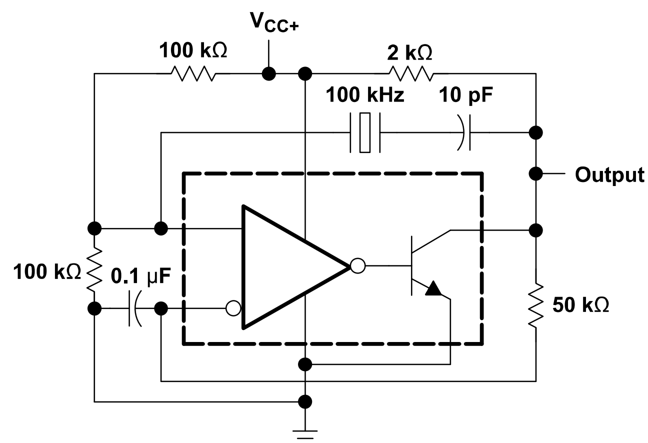


Figure 21. 100-kHz Crystal Oscillator

System Examples (continued)

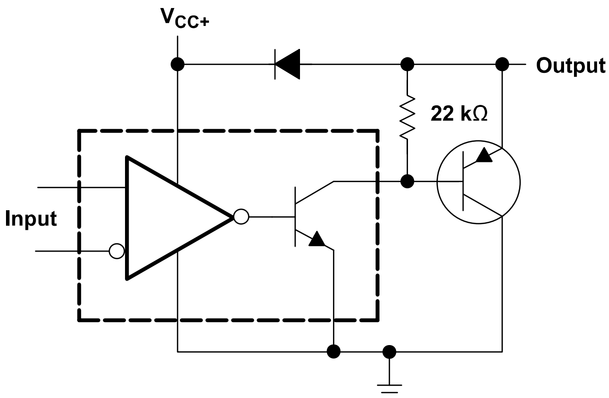
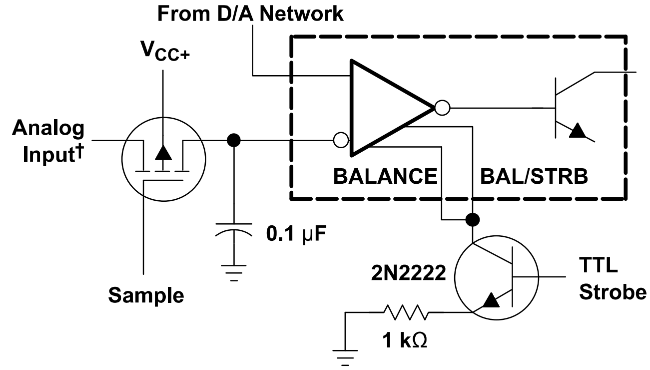


Figure 22. Comparator and Solenoid Driver



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

Figure 23. Strobing Both Input and Output Stages Simultaneously

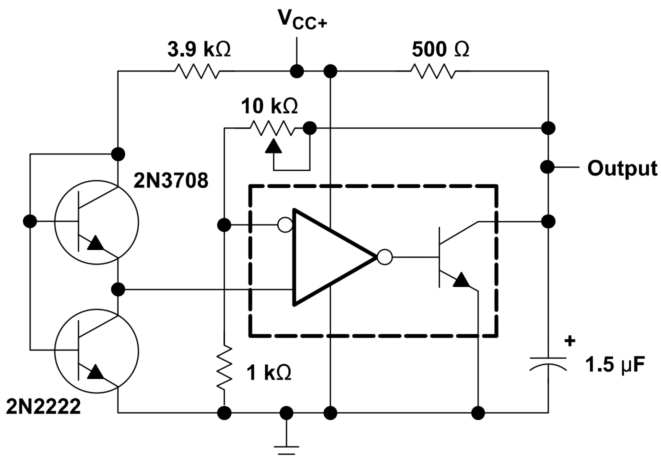


Figure 24. Low-Voltage Adjustable Reference Supply

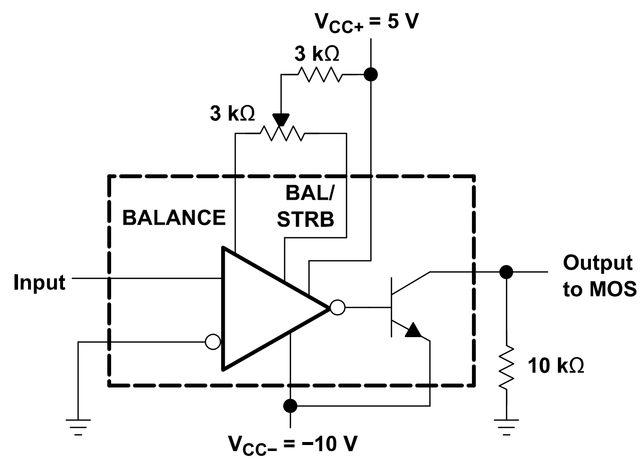
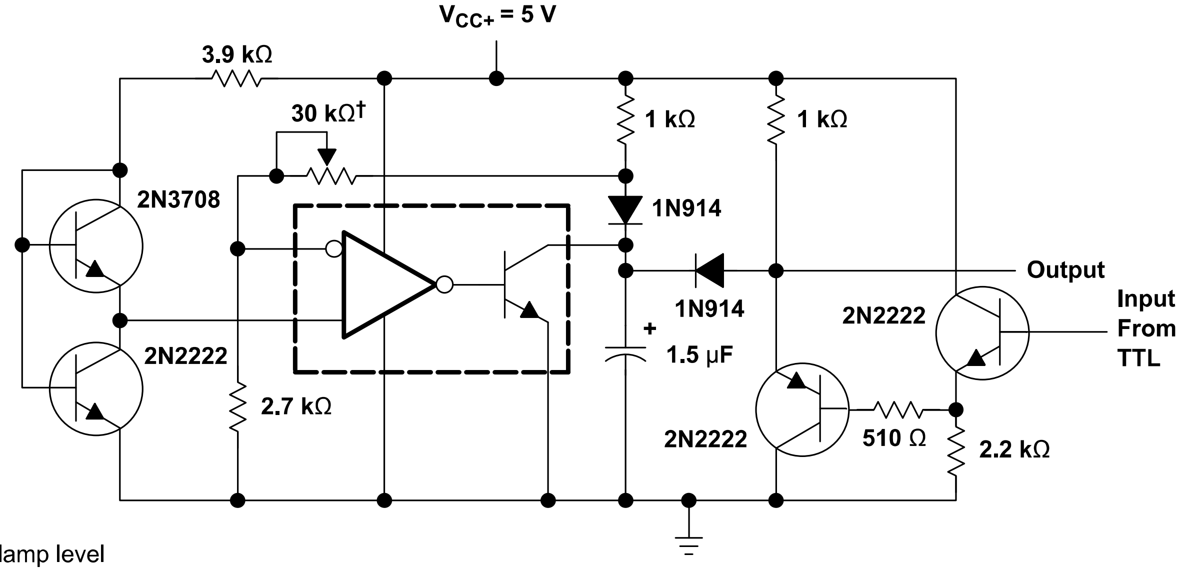


Figure 25. Zero-Crossing Detector Driving MOS Logic

System Examples (continued)



† Adjust to set clamp level

Figure 26. Precision Squarer

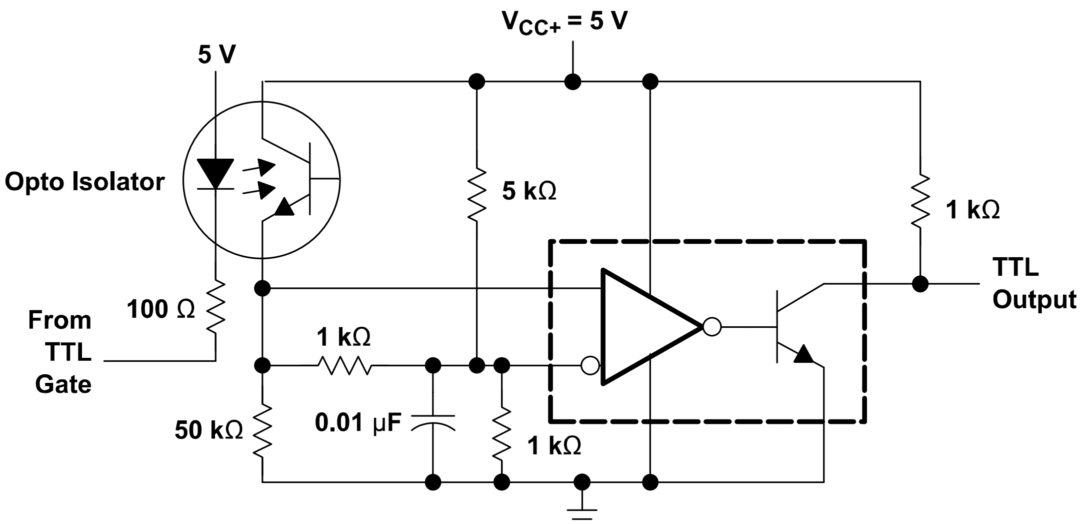


Figure 27. Digital Transmission Isolator

System Examples (continued)

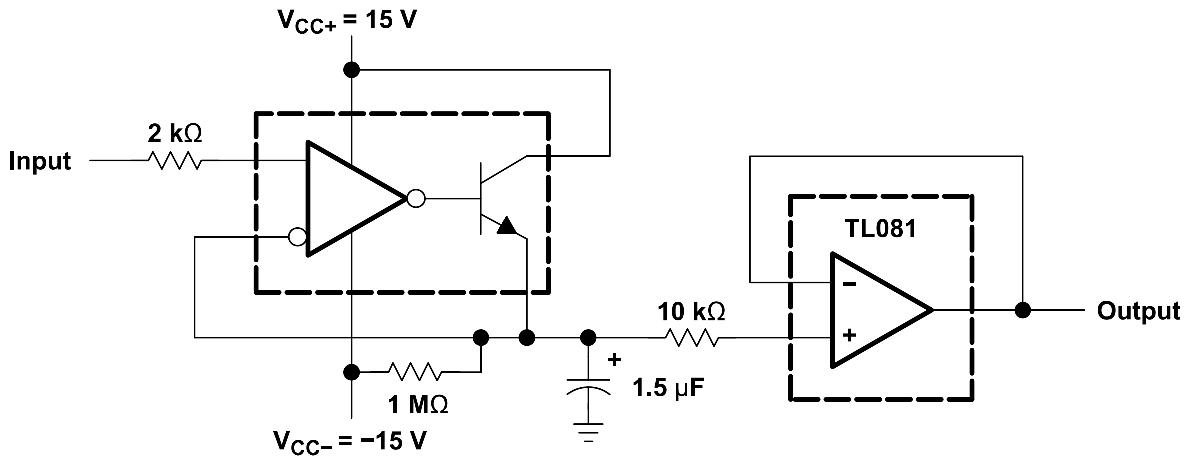


Figure 28. Positive-Peak Detector

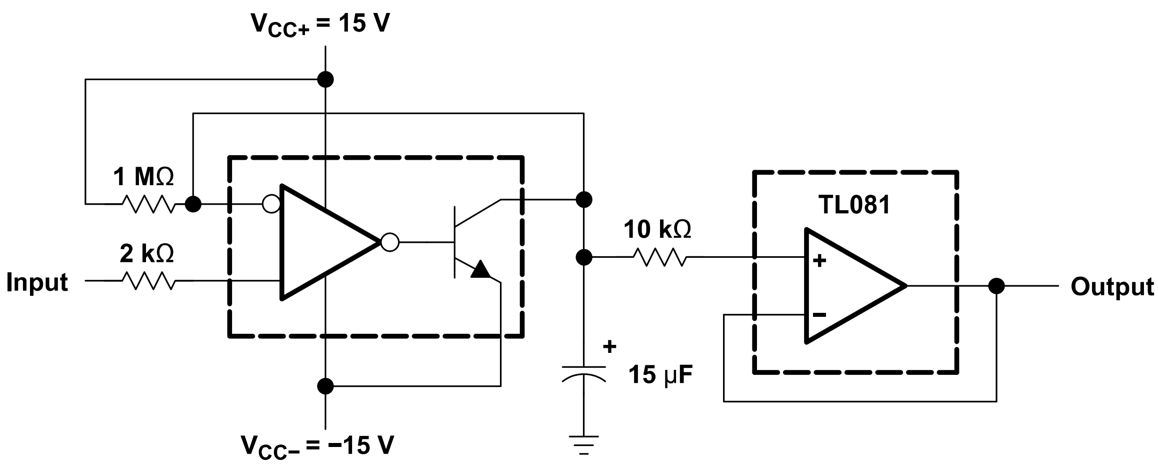
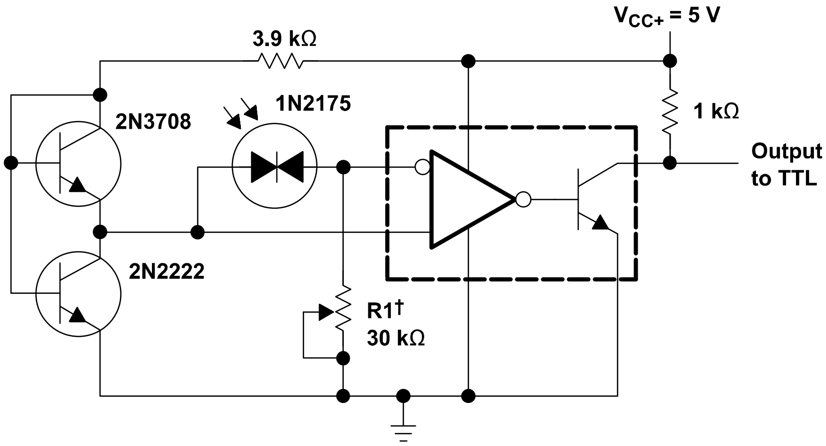


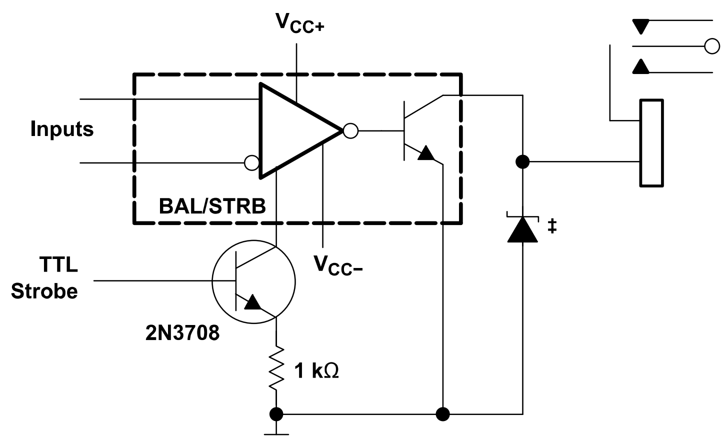
Figure 29. Negative-Peak Detector

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.

Figure 30. Precision Photodiode Comparator



‡ Transient voltage and inductive kickback protection

Figure 31. Relay Driver With Strobe

System Examples (continued)

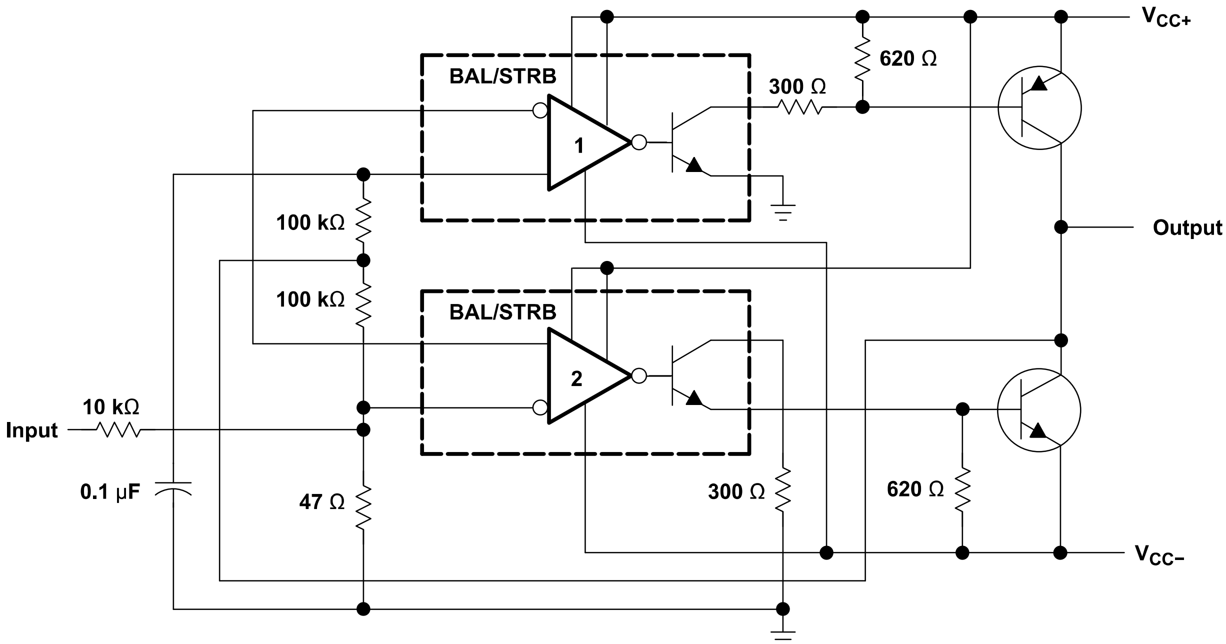


Figure 32. Switching Power Amplifier

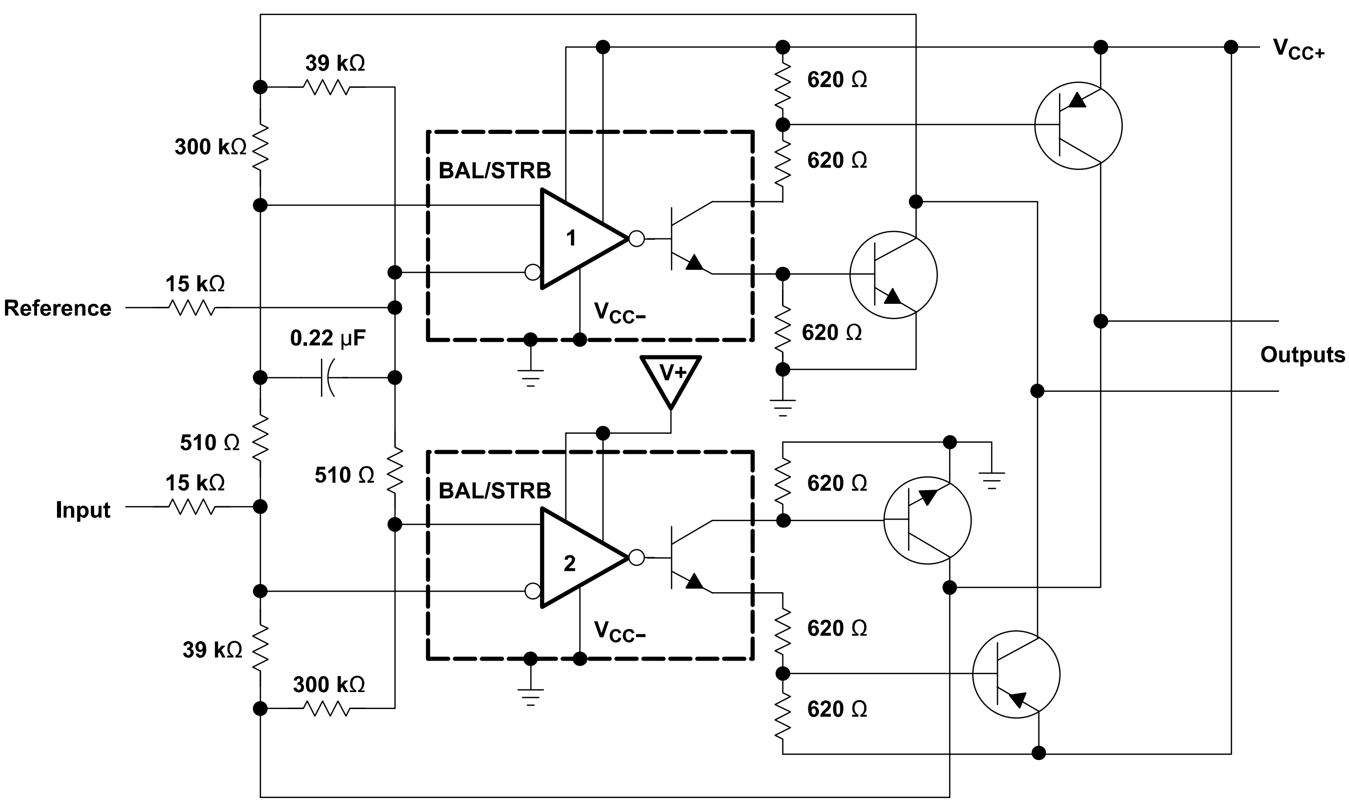


Figure 33. Switching Power Amplifiers

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

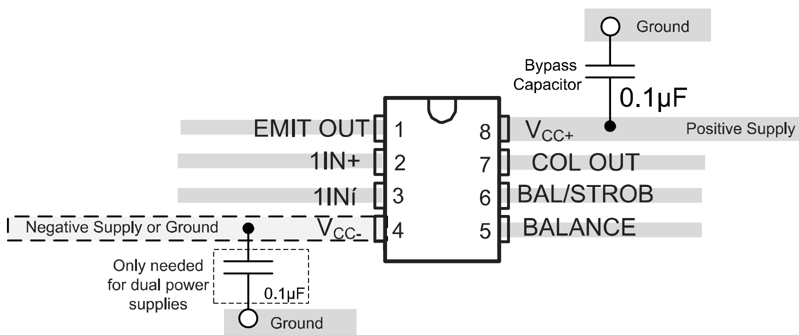


Figure 34. LMx11 Layout Example

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
LM111	Click here	Click here	Click here	Click here	Click here
LM211	Click here	Click here	Click here	Click here	Click here
LM311	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.