AN-12 An IC Voltage Comparator for High Impedance Circuitry

ABSTRACT

The IC voltage comparators available in the past have been designed primarily for low voltage, high-speed operation. As a result, these devices have high input error currents, which limit their usefulness in high impedance circuitry. An IC is described here that drastically reduces these error currents, with only a moderate decrease in speed.

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1   Introduction

This new comparator is considerably more flexible than the older devices. Not only will it drive RTL, DTL and TTL logic; but also it can interface with MOS logic and FET analog switches. It operates from standard ±15 V op amp supplies and can switch 50 V, 50 mA loads, making it useful as a driver for relays, lamps or light-emitting diodes. A unique output stage enables it to drive loads referred to either supply or ground and provide ground isolation between the comparator inputs and the load.

Another useful feature of the circuit is that it can be powered from a single 5 V supply and drive DTL or TTL integrated circuits. This enables the designer to perform linear functions on a digital-circuit card without using extra supplies. It can, for example, be used as a low-level photodiode detector, a zero crossing detector for magnetic transducers, an interface for high-level logic or a precision multivibrator.
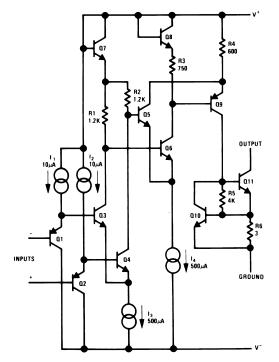

Figure 1. Simplified LM111 Schematic

Figure 1 shows a simplified schematic of this versatile comparator. PNP transistors buffer the differential input stage to get low input currents without sacrificing speed. Because the emitter base breakdown voltage of these PNPs is typically 70 V, they can also withstand a large differential input voltage. The PNPs drive a standard differential stage. The output of this stage is further amplified by the Q_5-Q_6 pair. This feeds a lateral PNP, Q_9, that provides additional gain and drives the output stage.

The output transistor is Q_{11}, which is driven by the level shifting PNP. Current limiting is provided by R_6 and Q_{10} to protect the circuit from intermittent shorts. Both the output and the ground lead are isolated from other points within the circuit, so either can be used as the output. The V⁻ terminal can also be tied to ground to run the circuit from a single supply. The comparator will work in any configuration as long as the ground terminal is at a potential somewhere between the supply voltages. The output terminal, however, can go above the positive supply as long as the breakdown voltage of Q_{11} is not exceeded.
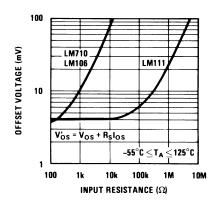
Figure 2. Illustrating the Influence of Source Resistance on Worst Case, Equivalent Input Offset Voltage

Figure 2 shows how the reduced error currents of the LM111 improve circuit performance. With the LM710 or LM106, the offset voltage is degraded for source resistances above 200 Ω. The LM111, however, works well with source resistances in excess of 30 kΩ. Figure 2 applies for equal source resistances on the two inputs. If they are unequal, the degradation will become pronounced at lower resistance levels.

Table 1 gives the important electrical characteristics of the LM111 and compares them with the specifications of older ICs.

A few, typical applications of the LM111 are illustrated in Figure 6. The first is a zero crossing detector driving a MOS analog switch. The ground terminal of the IC is connected to V⁻; hence, with ±15 V supplies, the signal swing delivered to the gate of Q_1 is also ±15 V. This type of circuit is useful where the gain or feedback configuration of an op amp circuit must be changed at some precisely-determined signal level. Incidentally, it is a simple matter to modify the circuit to work with junction FETs.

Table 1. Comparing the LM111 With Earlier IC Comparators [1]

Parameter	LM111	LM106	LM710	Units
Input Offset Voltage	4	3	3	mV
Input Offset Current	0.02	7	7	µA
Input Bias Current	0.15	45	45	µA
Common Mode Range	±14	±5	±5	V
Differential Input Voltage Range	±30	±5	±5	V
Voltage Gain [2]	200	40	1.7	V/mV
Response Time [2]	200	40	40	ns
Output Drive				
Voltage	50	24	2.5	V
Current	50	100	1.6	mA
Fan Out (DTL/TTL)	8	16	1	
Power Consumption	80	145	160	mW

[1] Values given are worst case over a −55°C to +125°C temperature range, except as noted.
[2] Typical at 25°C.

The second circuit is a zero crossing detector for a magnetic pickup such as a magnetometer or shaft-position pickoff. It delivers the output signal directly to DTL or TTL logic circuits and operates from the 5 V logic supply. The resistive divider, R_1 and R_2, biases the inputs 0.5 V above ground, within the common mode range of the device. An optional offset balancing circuit, R_3 and R_4, is included.

The next circuit shows a comparator for a low-level photodiode operating with MOS logic. The output changes state when the diode current reaches 1 µA. At the switching point, the voltage across the photodiode is nearly zero, so its leakage current does not cause an error. The output switches between ground and −10 V, driving the data inputs of MOS logic directly.

The last circuit shows how a ground-referred load is driven from the ground terminal of the LM111. The input polarity is reversed because the ground terminal is used as the output. An incandescent lamp, which is the load here, has a cold resistance eight times lower than it is during normal operation. This produces a large inrush current, when it is switched on, that can damage the switch. However, the current limiting of the LM111 holds this current to a safe value.

The applications described above show that the output-circuit flexibility and wide supply-voltage range of the LM111 opens up new fields for IC comparators. Further, its low error currents permit its use in circuits with impedance levels above 1 kΩ. Although slower than older devices, it is more than an order of magnitude faster than op amps used as comparators.

The LM111 has the same pin configuration as the LM710 and LM106. It is interchangeable with these devices in applications where speed is not of prime concern.
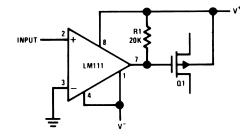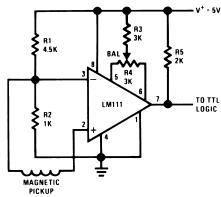
Figure 3. Zero Crossing Detector Driving Analog Switch

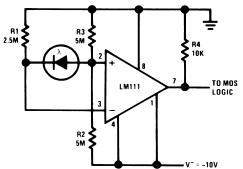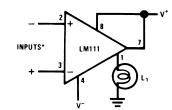**Figure 4. Comparator for Low-Level Photodiode**

Figure 5. Detector for Magnetic Transducer

d. driving ground—referred load

Figure 6. Driving Ground – Referred Load

Figure 7. Typical Applications of the LM111

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