# CS209A

# Proximity Detector

The CS209A is a bipolar monolithic integrated circuit for use in metal detection/proximity sensing applications. The IC (see Figure 1) contains two on−chip current regulators, oscillator and low−level feedback circuitry, peak detection/demodulation circuit, a comparator and two complementary output stages.

The oscillator, along with an external LC network, provides controlled oscillations where amplitude is highly dependent on the Q of the LC tank. During low Q conditions, a variable low−level feedback circuit provides drive to maintain oscillation. The peak demodulator senses the negative portion of the oscillator envelope and provides a demodulated waveform as input to the comparator. The comparator sets the states of the complementary outputs by comparing the input from the demodulator to an internal reference. External loads are required for the output pins.

A transient suppression circuit is included to absorb negative transients at the tank circuit terminal.

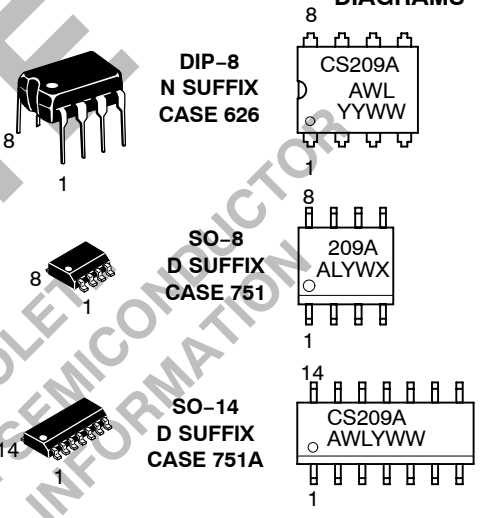
### Features

- Separate Current Regulator for Oscillator
- Negative Transient Suppression
- Variable Low−Level Feedback
- Improved Performance Over Temperature
- 6.0 mA Supply Current Consumption at $V_{CC}$ = 12 V
- Output Current Sink Capability
  - 20 mA at 4.0 $V_{CC}$
  - 100 mA at 24 $V_{CC}$

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**MARKING DIAGRAMS**




A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week

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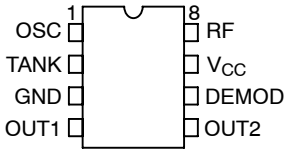
| Device | Package | Shipping |
|---|---|---|
| CS209AYN8 | DIP−8 | 50 Units/Rail |
| CS209AYD8 | SO−8 | 95 Units/Rail |
| CS209AYDR8 | SO−8 | 2500 Tape & Reel |
| CS209AYD14 | SO−14 | 55 Units/Rail |
| CS209AYDR14 | SO−14 | 2500 Tape & Reel |

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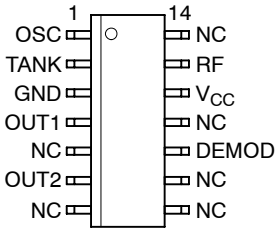
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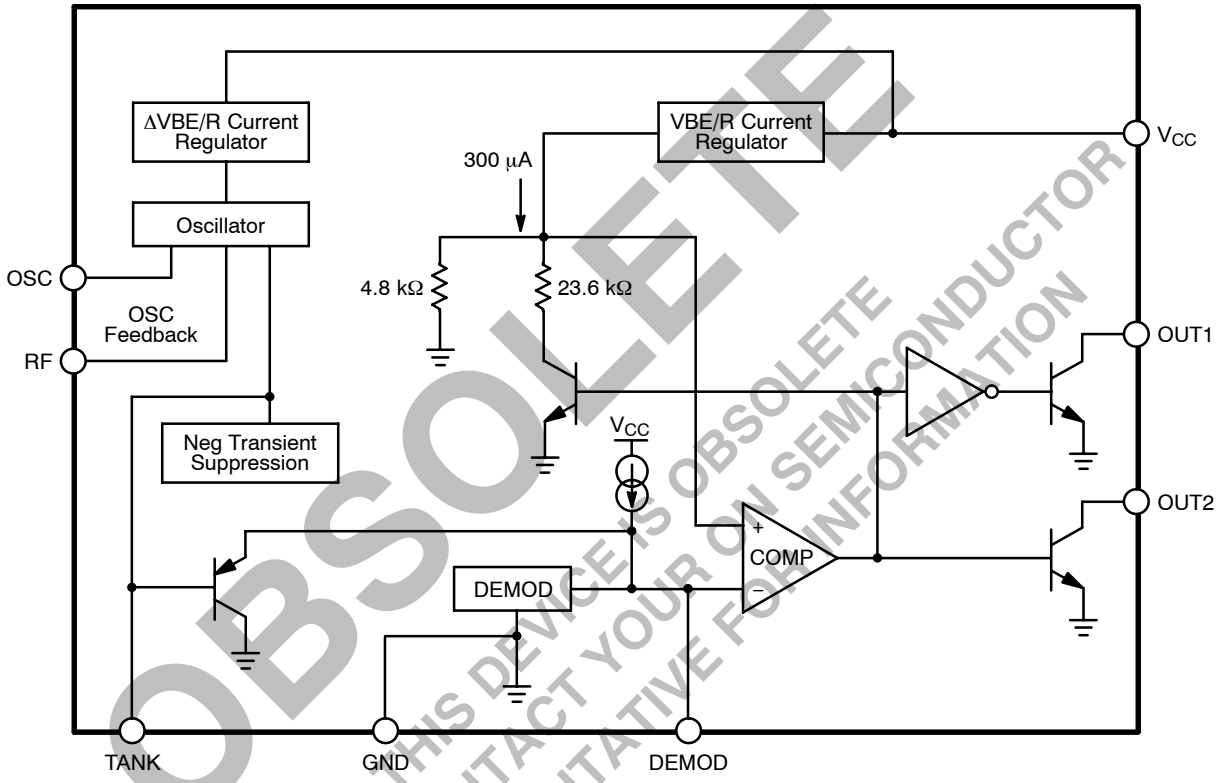
## PIN CONNECTIONS

**DIP−8 and SO−8**




**SO−14**




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**Figure 1. Block Diagram**

## ABSOLUTE MAXIMUM RATINGS*

| Rating | | Value | Unit |
|---|---|---|---|
| Supply Voltage | | 24 | V |
| Power Dissipation ($T_A$ = 125°C) | | 200 | mW |
| Storage Temperature Range | | −55 to +165 | °C |
| Junction Temperature Range | | −40 to +150 | °C |
| Electrostatic Discharge (except TANK pin) | | 2.0 | kV |
| Lead Temperature Soldering: | Wave Solder (through hole styles only) (Note 1)<br>Reflow (SMD style only) (Note 2) | 260 peak<br>230 peak | °C<br>°C |

1. 10 second maximum.
2. 60 second maximum above 183°C.

*The maximum package power dissipation must be observed.

**ELECTRICAL CHARACTERISTICS:** ($-40°C \le T_A \le +125°C$, unless otherwise specified.)

| Characteristic | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Supply Current $I_{CC}$ | $V_{CC}$ = 4.0 V<br>$V_{CC}$ = 12 V<br>$V_{CC}$ = 24 V | –<br>–<br>– | 3.5<br>6.0<br>11.0 | 6.0<br>11.6<br>20 | mA<br>mA<br>mA |
| TANK Current | $V_{CC}$ = 20 V | −550 | −300 | −100 | μA |
| Demodulator Charge Current | $V_{CC}$ = 20 V | −60 | −30 | −10 | μA |
| Output Leakage Current | $V_{CC}$ = 24 V | – | 0.01 | 10 | μA |
| Output $V_{SAT}$ | $V_{CC}$ = 4.0 V, IS = 20 mA<br>$V_{CC}$ = 24 V, IS = 100 mA | –<br>– | 60<br>200 | 200<br>500 | mV<br>mV |
| Oscillator Bias | $V_{CC}$ = 20 V | 1.1 | 1.9 | 2.5 | V |
| Feedback Bias | $V_{CC}$ = 20 V | 1.1 | 1.9 | 2.5 | V |
| OSC − RF Bias | $V_{CC}$ = 20 V | −250 | 100 | 550 | mV |
| Protect Voltage | $I_{TANK}$ = −10 mA | −10 | −8.9 | −7.0 | V |
| Detect Threshold | – | 720 | 1440 | 1950 | mV |
| Release Threshold | – | 550 | 1200 | 1700 | mV |

## PACKAGE PIN DESCRIPTION

| PACKAGE PIN # | | PIN SYMBOL | FUNCTION |
|---|---|---|---|
| DIP−8 & SO−8 | SO−14 | | |
| 1 | 1 | OSC | Adjustable feedback resistor connected between OSC and RF sets detection range. |
| 2 | 2 | TANK | Connects to parallel tank circuit. |
| 3 | 3 | GND | Ground connection. |
| 4 | 4 | OUT1 | Complementary open collector output; when OUT1 = LOW, metal is present. |
| 5 | 6 | OUT2 | Complementary open collector output; when OUT2 = HIGH, metal is present. |
| 6 | 10 | DEMOD | Input to comparator controlling OUT1 and OUT2. |
| 7 | 12 | $V_{CC}$ | Supply voltage. |
| 8 | 13 | RF | Adjustable feedback resistor connected between OSC and RF set detection range. |
| – | 5, 7, 8, 9, 11, 14 | NC | No connection. |

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## TYPICAL PERFORMANCE CHARACTERISTICS

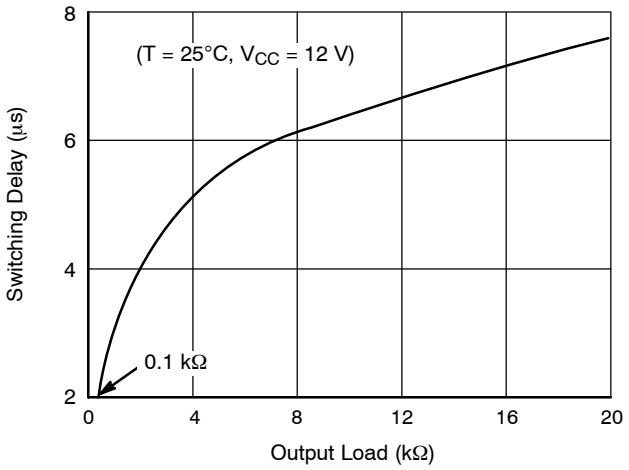



**Figure 2. Output Switching Delay vs. Output Load**

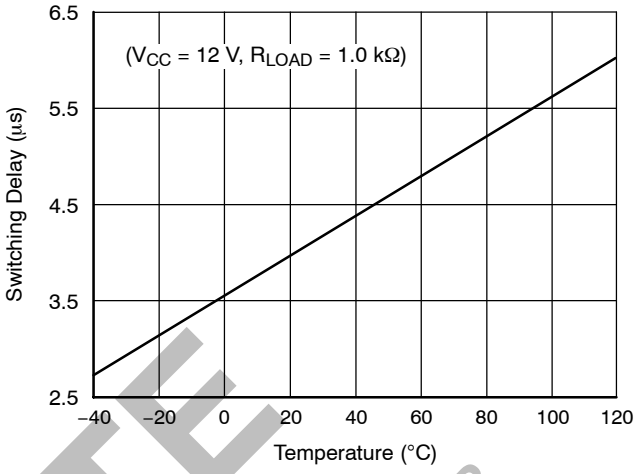



**Figure 3. Output Switching Delay vs. Temperature**

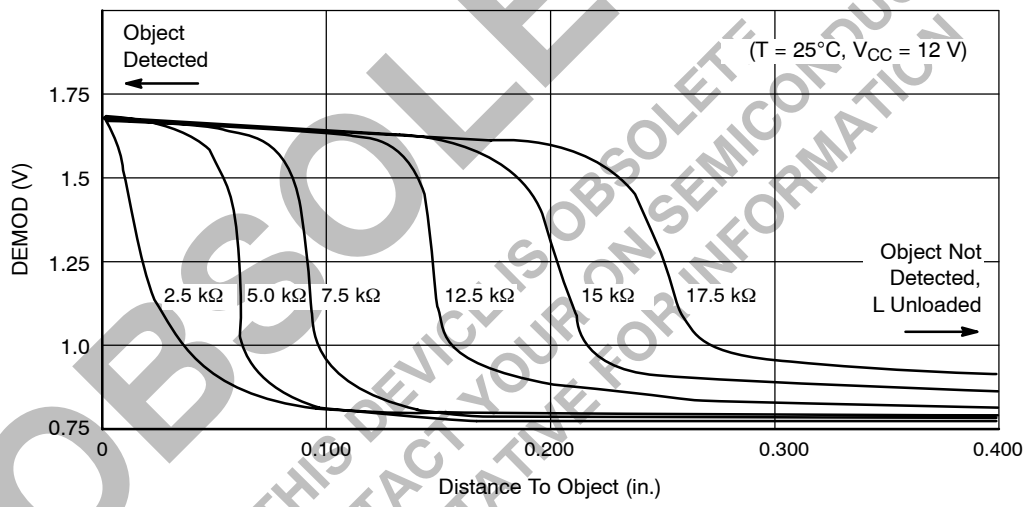



**Figure 4. Demodulator Voltage vs. Distance for Different RF**

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## PRINCIPLE OF OPERATION

The CS209A is a metal detector circuit which operates on the principle of detecting a reduction in Q of an inductor when it is brought into close proximity of metal. The CS209A contains an oscillator set up by an external parallel resonant tank and a feedback resistor connected between OSC and RF. (See Figure 5.) The impedance of a parallel resonant tank is highest when the frequency of the source driving it is equal to the tank's resonant frequency. In the CS209A the internal oscillator operates close to the resonant frequency of the tank circuit selected. As a metal object is brought close to the inductor, the amplitude of the voltage across the tank gradually begins to drop. When the envelope of the oscillation reaches a certain level, the IC causes the output stages to switch states.

The detection is performed as follows: A capacitor connected to DEMOD is charged via an internal 30 μA current source. This current, however, is diverted away from the capacitor in proportion to the negative bias generated by the tank at TANK. Charge is therefore removed from the capacitor tied to DEMOD on every negative half cycle of the resonant voltage. (See Figure 6) The voltage on the capacitor at DEMOD, a DC voltage with ripple, is then directly compared to an internal 1.44 V reference. When the internal comparator trips it turns on a transistor which places a 23.6 kΩ resistor in parallel to the 4.8 kΩ. The resulting reference then becomes approximately 1.2 V. This hysteresis is necessary for preventing false triggering.

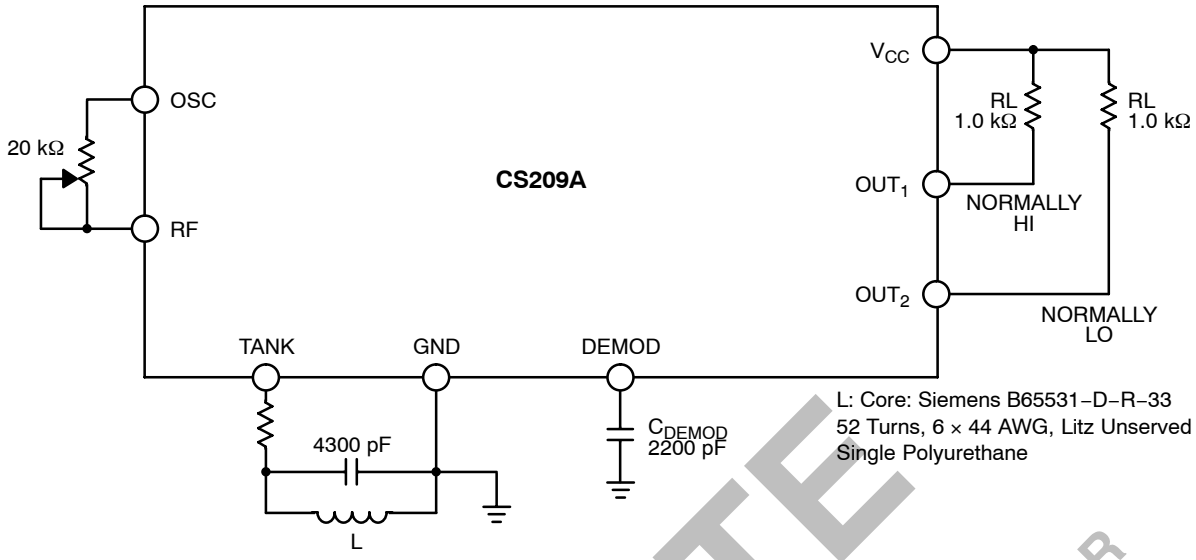



**Figure 5. Test and Application Diagram**

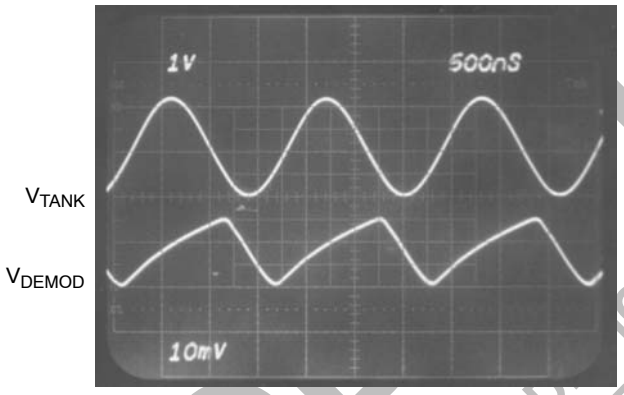



**Figure 6. Capacitor Ripple**

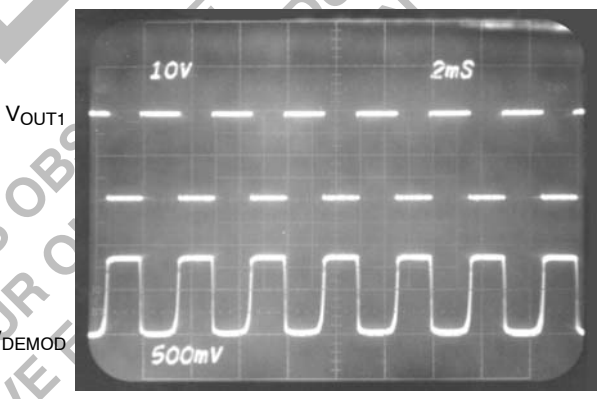



**Figure 7. Output Pulse for an 8 Tooth Gear**

The feedback potentiometer connected between OSC and RF is adjusted to achieve a certain detection distance range. The larger the resistance the greater the trip−point distance. (See Figure 4.) Note that this is a plot representative of one particular set−up since detection distance is dependent on the Q of the tank. Note also from the graph that the capacitor voltage corresponding to the greatest detection distance has a higher residual voltage when the metal object is well outside the trip point. Higher values of feedback resistance for the same inductor Q will therefore eventually result in a latched−ON condition because the residual voltage will be higher than the comparator's thresholds.

As an example of how to set the detection range, place the metal object at the maximum distance from the inductor the circuit is required to detect, assuming of course the Q of the tank is high enough to allow the object to be within the IC's detection range. Then adjust the potentiometer to obtain a lower resistance while observing one of the CS209A outputs return to its normal state. (See Figure 5.) Readjust the potentiometer slowly toward a higher resistance until the outputs have switched to their tripped condition. Remove the metal and confirm that the outputs switch back to their normal state. Typically the maximum distance range the circuit is capable of detecting is around 0.3 inch. The higher the Q, the higher the detection distance.

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For this application it is recommended to use a core which concentrates the magnetic field in only one direction. This is accomplished very well with a pot core half. The next step is to select a core material with low loss factor (inverse of Q). The loss factor can be represented by a resistance in series with the inductor which arises from core losses and is a function of frequency.

The final step in obtaining a high Q inductor is the selection of wire size. The higher the frequency the faster the decrease in current density towards the center of the wire. Thus most of the current flow is concentrated on the surface of the wire resulting in a high AC resistance. LITZ wire is recommended for this application. Considering the many factors involved, it is also recommended to operate at a resonant frequency between 200 and 700 kHz. The formula commonly used to determine the Q for parallel resonant circuits is:

$$Q_P \cong \frac{R}{2\pi f_R L}$$

where R is the effective resistance of the tank. The resistance component of the inductor consists primarily of core losses and “skin effect” or AC resistance.

The resonant capacitor should be selected to resonate with the inductor within the frequency range recommended in order to yield the highest Q. The capacitor type should be selected to have low ESR: multilayer ceramic for example.

Detection distances vary for different metals. Following are different detection distances for some selected metals and metal objects relative to one particular circuit set−up:

**Commonly Encountered Metals**

| | |
|---|---|
| Stainless Steel | 0.101″ |
| Carbon Steel | 0.125″ |
| Copper | 0.044″ |
| Aluminum | 0.053″ |
| Brass | 0.052″ |

**Coins**

| | |
|---|---|
| US Quarter | 0.055″ |
| Canadian Quarter | 0.113″ |
| 1 German Mark | 0.090″ |
| 1 Pound Sterling | 0.080″ |
| 100 Japanese Yen | 0.093″ |
| 100 Italian Lira | 0.133″ |

**Other**

| | |
|---|---|
| 12 oz. soda can | 0.087″ |

Note that the above is only a comparison among different metals and no attempt was made to achieve the greatest detection distance.

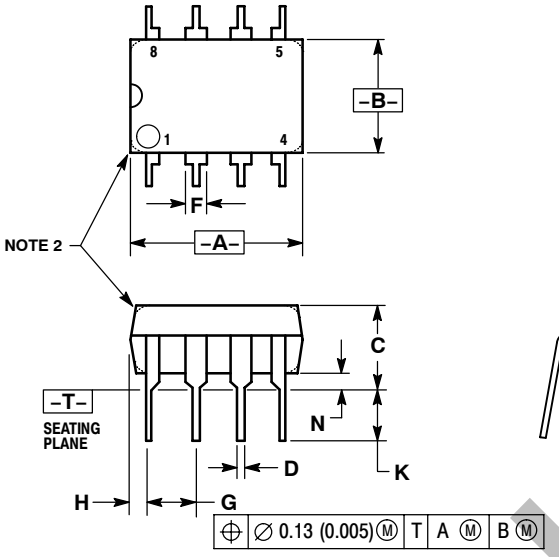
A different type of application involves, for example, detecting the teeth of a rotating gear. For these applications the capacitor on DEMOD should not be selected too small (not below 1000 pF) where the ripple becomes too large and not too large (not greater than 0.01 μF) that the response time is too slow. Figure 6 for example shows the capacitor ripple only and Figure 7 shows the entire capacitor voltage and the output pulses for an 8−tooth gear rotating at about 2400 rpm using a 2200 pF capacitor on the DEMOD pin.

Because the output stages go into hard saturation, a time interval is required to remove the stored base charge resulting in both outputs being low for approximately 3.0 μs. (See Figure 3.)

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## PACKAGE DIMENSIONS

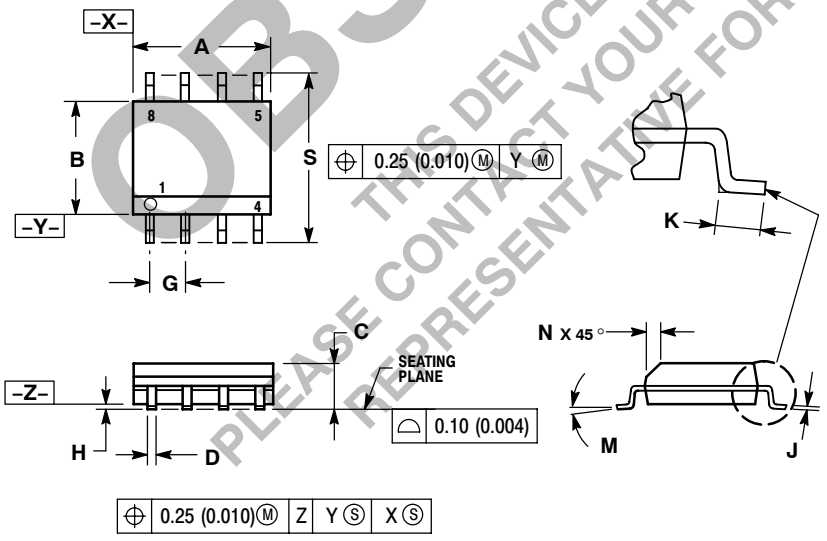
**DIP–8**
**N SUFFIX**
CASE 626–05
ISSUE L




NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

| | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 9.40 | 10.16 | 0.370 | 0.400 |
| B | 6.10 | 6.60 | 0.240 | 0.260 |
| C | 3.94 | 4.45 | 0.155 | 0.175 |
| D | 0.38 | 0.51 | 0.015 | 0.020 |
| F | 1.02 | 1.78 | 0.040 | 0.070 |
| G | 2.54 BSC | | 0.100 BSC | |
| H | 0.76 | 1.27 | 0.030 | 0.050 |
| J | 0.20 | 0.30 | 0.008 | 0.012 |
| K | 2.92 | 3.43 | 0.115 | 0.135 |
| L | 7.62 BSC | | 0.300 BSC | |
| M | --- | 10° | --- | 10° |
| N | 0.76 | 1.01 | 0.030 | 0.040 |

**SO–8**
**D SUFFIX**
CASE 751–07
ISSUE W

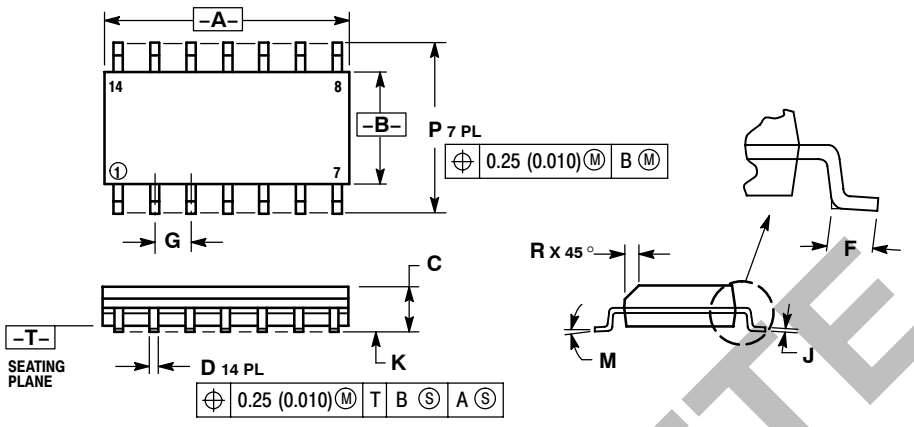



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

| | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 4.80 | 5.00 | 0.189 | 0.197 |
| B | 3.80 | 4.00 | 0.150 | 0.157 |
| C | 1.35 | 1.75 | 0.053 | 0.069 |
| D | 0.33 | 0.51 | 0.013 | 0.020 |
| G | 1.27 BSC | | 0.050 BSC | |
| H | 0.10 | 0.25 | 0.004 | 0.010 |
| J | 0.19 | 0.25 | 0.007 | 0.010 |
| K | 0.40 | 1.27 | 0.016 | 0.050 |
| M | 0° | 8° | 0° | 8° |
| N | 0.25 | 0.50 | 0.010 | 0.020 |
| S | 5.80 | 6.20 | 0.228 | 0.244 |

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**SO−14**
**D SUFFIX**
CASE 751A−03
ISSUE F




NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSIONS A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.

| | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 8.55 | 8.75 | 0.337 | 0.344 |
| B | 3.80 | 4.00 | 0.150 | 0.157 |
| C | 1.35 | 1.75 | 0.054 | 0.068 |
| D | 0.35 | 0.49 | 0.014 | 0.019 |
| F | 0.40 | 1.25 | 0.016 | 0.049 |
| G | 1.27 BSC | | 0.050 BSC | |
| J | 0.19 | 0.25 | 0.008 | 0.009 |
| K | 0.10 | 0.25 | 0.004 | 0.009 |
| M | 0 ° | 7 ° | 0 ° | 7 ° |
| P | 5.80 | 6.20 | 0.228 | 0.244 |
| R | 0.25 | 0.50 | 0.010 | 0.019 |

**PACKAGE THERMAL DATA**

| Parameter | | DIP−8 | SO−8 | SO−14 | Unit |
|---|---|---|---|---|---|
| $R_{\Theta JC}$ | Typical | 52 | 45 | 30 | °C/W |
| $R_{\Theta JA}$ | Typical | 100 | 165 | 125 | °C/W |

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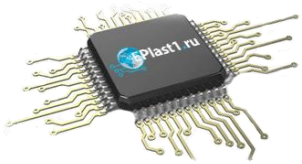
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