

# Photoelectric Smoke Detector IC with I/O

## For Line-Powered Applications

The CMOS MC145011 is an advanced smoke detector component containing sophisticated very-low-power analog and digital circuitry. The IC is used with an infrared photoelectric chamber. Detection is accomplished by sensing scattered light from minute smoke particles or other aerosols. When detection occurs, a pulsating alarm is sounded via on-chip push-pull drivers and an external piezoelectric transducer.

The variable-gain photo amplifier allows direct interface to IR detectors (photo-diodes). Two external capacitors C1 and C2, C1 being the larger, determine the gain settings. Low gain is selected by the IC during most of the standby state. Medium gain is selected during a local-smoke condition. High gain is used during pushbutton test. During standby, the special monitor circuit which periodically checks for degraded chamber sensitivity uses high gain, also.

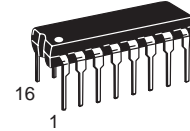
The I/O pin, in combination with  $V_{SS}$ , can be used to interconnect up to 40 units for common signaling. An on-chip current sink provides noise immunity when the I/O is an input. A local-smoke condition activates the short-circuit-protected I/O driver, thereby signaling remote smoke to the interconnected units. Additionally, the I/O pin can be used to activate escape lights, enable auxiliary or remote alarms, and/or initiate auto-dialers.

While in standby, the low-supply detection circuitry conducts periodic checks using a load current from the LED pin. The trip point is set using two external resistors. The supply for the MC145011 must be a dc power source capable of supplying 35 mA continuously and 45 mA peak. When the MC145011 is in standby, an external LED is continuously illuminated to indicate that the device is receiving power.

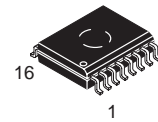
An extinguished LED accompanied by a pulsating audible alarm indicates a local-smoke condition. A pulsating audible alarm with the LED illuminated indicates a remote-smoke condition. A beep or chirp indicates a low-supply condition or degraded chamber sensitivity. A low-supply condition does not affect the smoke detection capability if  $V_{DD} \geq 6$  V. Therefore, the low-supply condition and degraded chamber sensitivity can be distinguished by performing a pushbutton (chamber) test. This circuit is designed to operate in smoke detector systems that comply with UL217 and UL268 specifications.

- Operating Voltage Range: 6 to 12 V
- Operating Temperature Range: -10 to 60°C
- Average Standby Supply Current (Visible LED Illuminated): 20 mA
- Power-On Reset Places IC in Standby Mode (Non-Alarm State)
- Electrostatic Discharge (ESD) and Latch Up Protection Circuitry on All Pins
- Chip Complexity: 2000 FETs, 12 NPNs, 16 Resistors, and 10 Capacitors

# MC145011



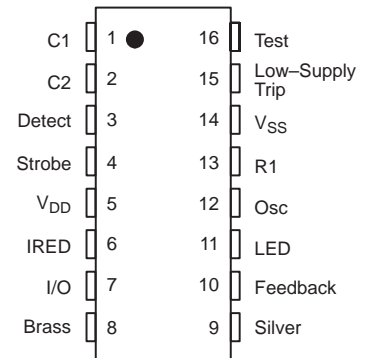
**P SUFFIX  
 PLASTIC DIP  
 CASE 648-08**



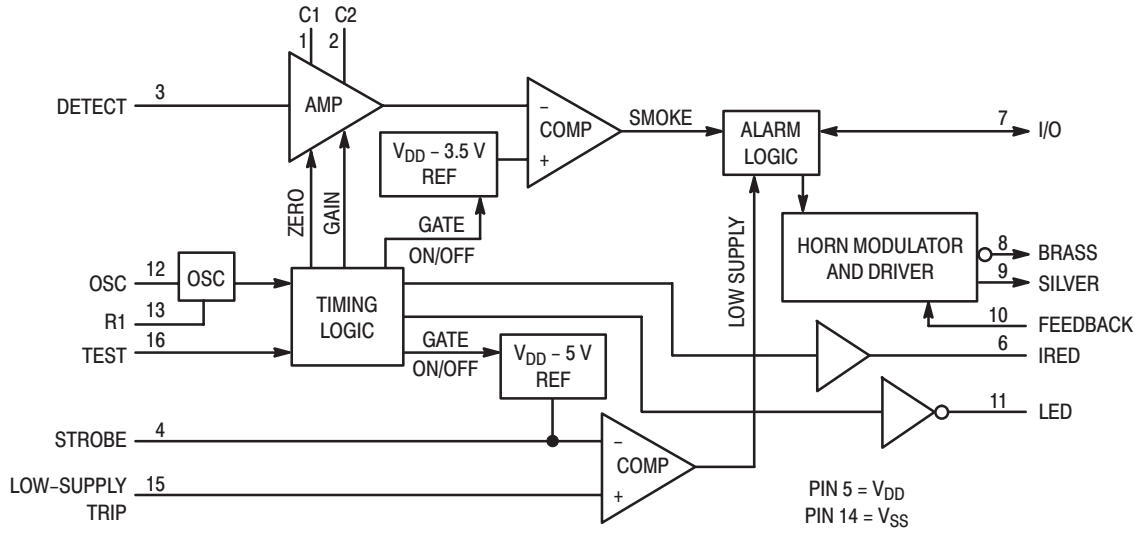
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### PIN ASSIGNMENT



Block Diagram



MAXIMUM RATINGS\* (Voltages referenced to V<sub>SS</sub>)

Symbol	Parameter	Value	Unit
V <sub>DD</sub>	DC Supply Voltage	- 0.5 to +12	V
V <sub>in</sub>	DC Input Voltage C1, C2, Detect Osc, Low-Supply Trip I/O Feedback Test	- 0.25 to V <sub>DD</sub> +0.25 - 0.25 to V <sub>DD</sub> +0.25 - 0.25 to V <sub>DD</sub> +10 - 15 to +25 - 1.0 to V <sub>DD</sub> +0.25	V
I <sub>in</sub>	DC Input Current, per Pin	± 10	mA
I <sub>out</sub>	DC Output Current, per Pin	± 25	mA
I <sub>DD</sub>	DC Supply Current, V <sub>DD</sub> and V <sub>SS</sub> Pins	+25 / - 150	mA
P <sub>D</sub>	Power Dissipation in Still Air, 5 Seconds Continuous	1200** 350***	mW
T <sub>stg</sub>	Storage Temperature	- 55 to +125	°C
T <sub>L</sub>	Lead Temperature, 1 mm from Case for 10 Seconds	260	°C

\* Maximum Ratings are those values beyond which damage to the device may occur. Functional operation should be restricted to the limits in the Electrical Characteristics tables.

\*\* Derating: - 12 mW/°C from 25° to 60°C.

\*\*\* Derating: - 3.5 mW/°C from 25° to 60°C.

This device contains protection circuitry to guard against damage due to high static voltages or electric fields. However, precautions must be taken to avoid applications of any voltage higher than maximum rated voltages to this high-impedance circuit. For proper operation, V<sub>in</sub> and V<sub>out</sub> should be constrained to the range V<sub>SS</sub> ≤ (V<sub>in</sub> or V<sub>out</sub>) ≤ V<sub>DD</sub> except for the I/O, which can exceed V<sub>DD</sub>, and the Test input, which can go below V<sub>SS</sub>.

Unused inputs must always be tied to an appropriate logic voltage level (e.g., either V<sub>SS</sub> or V<sub>DD</sub>). Unused outputs and/or an unused I/O must be left open.

**ELECTRICAL CHARACTERISTICS** ( $T_A = -10$  to  $60^\circ\text{C}$  Unless Otherwise Indicated, Voltages Referenced to  $V_{SS}$ )

Symbol	Parameter	Test Condition	$V_{DD}$ V	Min	Max	Unit	
$V_{DD}$	Power Supply Voltage Range		—	6.0	12	V	
$V_{TH}$	Supply Threshold Voltage, Low-Supply Alarm	Low-Supply Trip: $V_{in} = V_{DD}/3$	—	6.5	7.8	V	
$I_{DD}$	Average Operating Supply Current, Excluding the Visible LED Current (per Package)	Standby Configured per Figure 5	12.0	—	12	$\mu\text{A}$	
$i_{DD}$	Peak Supply Current, Excluding the Visible LED Current (per Package)	During Strobe On, IRED Off Configured per Figure 5	12.0	—	2.0	mA	
		During Strobe On, IRED On Configured per Figure 5	12.0	—	3.0		
$V_{IL}$	Low-Level Input Voltage	I/O	9.0	—	1.5	V	
		Feedback	9.0	—	2.7		
		Test	9.0	—	7.0		
$V_{IH}$	High-Level Input Voltage	I/O	9.0	3.2	—	V	
		Feedback	9.0	6.3	—		
		Test	9.0	8.5	—		
$I_{in}$	Input Current	Osc, Detect	$V_{in} = V_{SS}$ or $V_{DD}$	12.0	—	$\pm 100$	nA
		Low-Supply Trip	$V_{in} = V_{SS}$ or $V_{DD}$	12.0	—	$\pm 100$	
		Feedback	$V_{in} = V_{SS}$ or $V_{DD}$	12.0	—	$\pm 100$	
$I_{IL}$	Low-Level Input Current	Test	$V_{in} = V_{SS}$	12.0	—	-1	$\mu\text{A}$
$I_{IH}$	Pull-Down Current	Test	$V_{in} = V_{DD}$	9.0	0.5	10	$\mu\text{A}$
		I/O	No Local Smoke, $V_{in} = V_{DD}$	9.0	25	100	
			No Local Smoke, $V_{in} = 17\text{ V}$	12.0	—	140	
$V_{OL}$	Low-Level Output Voltage	LED Silver, Brass	$I_{out} = 10\text{ mA}$	6.5	—	0.6	V
			$I_{out} = 16\text{ mA}$	6.5	—	1.0	
$V_{OH}$	High-Level Output Voltage	Silver, Brass	$I_{out} = -16\text{ mA}$	6.5	5.5	—	V
$V_{out}$	Output Voltage (For Line Regulation, see Pin Descriptions)	Strobe	Inactive, $I_{out} = -1\text{ }\mu\text{A}$	—	$V_{DD} - 0.1$	—	V
			Active, $I_{out} = 100\text{ }\mu\text{A}$ to $500\text{ }\mu\text{A}$ (Load Regulation)	9.0	$V_{DD} - 4.4$	$V_{DD} - 5.6$	
		IRED	Inactive, $I_{out} = 1\text{ }\mu\text{A}$	—	—	0.1	
			Active, $I_{out} = 6\text{ mA}$ (Load Regulation)	9.0	2.25*	3.75*	
$I_{OH}$	High-Level Output Current	I/O	Local Smoke, $V_{out} = 4.5\text{ V}$	6.5	-4	—	mA
			Local Smoke, $V_{out} = V_{SS}$ (Short Circuit Current)	12.0	—	-16	
$I_{OZ}$	Off-State Output Leakage Current	LED	$V_{out} = V_{SS}$ or $V_{DD}$	12.0	—	$\pm 1$	$\mu\text{A}$
$V_{IC}$	Common Mode Voltage Range	C1, C2, Detect	Local Smoke, Pushbutton Test, or Chamber Sensitivity Test	—	$V_{DD} - 4$	$V_{DD} - 2$	V
$V_{ref}$	Smoke Comparator Reference Voltage	Internal	Local Smoke, Pushbutton Test, or Chamber Sensitivity Test	—	$V_{DD} - 3.08$	$V_{DD} - 3.92$	V

\*  $T_A = 25^\circ\text{C}$  only.

## AC ELECTRICAL CHARACTERISTICS (Reference Timing Diagram Figures 3 and 4)

(T<sub>A</sub> = 25°C, V<sub>DD</sub> = 9.0 V, Component Values from Figure 5: R1 = 100.0 KΩ, C3 = 1500.0 pF, R2 = 10.0 MΩ)

No.	Symbol	Parameter	Test Condition	Min	Max	Unit
1	1/f <sub>osc</sub>	Oscillator Period*	Free-Running Sawtooth Measured at Pin 12	9.5	11.5	ms
2	t <sub>LED</sub>	LED Status	No Local Smoke, and No Remote Smoke	Illuminated		
3			Remote Smoke, but No Local Smoke	Illuminated		
4			Local Smoke or Pushbutton Test	Extinguished		
5	t <sub>w(stb)</sub>	Strobe Pulse Width		9.5	11.5	ms
6	t <sub>IRED</sub>	IRED Pulse Period	Smoke Test	9.67	11.83	s
7			Chamber Sensitivity Test, without Local Smoke	38.9	47.1	
8			Pushbutton Test	0.302	0.370	
9	t <sub>w(IRED)</sub>	IRED Pulse Width		94	116	μs
10	t <sub>r</sub>	IRED Rise Time		—	30	μs
	t <sub>f</sub>	IRED Fall Time		—	200	
11	t <sub>mod</sub>	Silver and Brass Modulation Period	Local or Remote Smoke	297	363	ms
11, 12	t <sub>on</sub> /t <sub>mod</sub>	Silver and Brass Duty Cycle	Local or Remote Smoke	73	77	%
13	t <sub>CH</sub>	Silver and Brass Chirp Pulse Period	Low Supply or Degraded Chamber Sensitivity	38.9	47.1	s
14	t <sub>w(CH)</sub>	Silver and Brass Chirp Pulse Width	Low Supply or Degraded Chamber Sensitivity	9.5	11.5	ms
15	t <sub>RR</sub>	Rising Edge on I/O to Smoke Alarm Response Time	Remote Smoke, No Local Smoke	—	800	ms
16	t <sub>stb</sub>	Strobe Pulse Period	Smoke Test	9.67	11.83	s
17			Chamber Sensitivity Test, without Local Smoke	38.9	47.1	
18			Low Supply Test, without Local Smoke	38.9	47.1	
19			Pushbutton Test	0.302	0.370	

\* Oscillator period T (= T<sub>r</sub> + T<sub>f</sub>) is determined by the external components R1, R2, and C3 where T<sub>r</sub> = (0.6931) R2 C3 and T<sub>f</sub> = (0.6931) R1 C3. The other timing characteristics are some multiple of the oscillator timing as shown in the table.

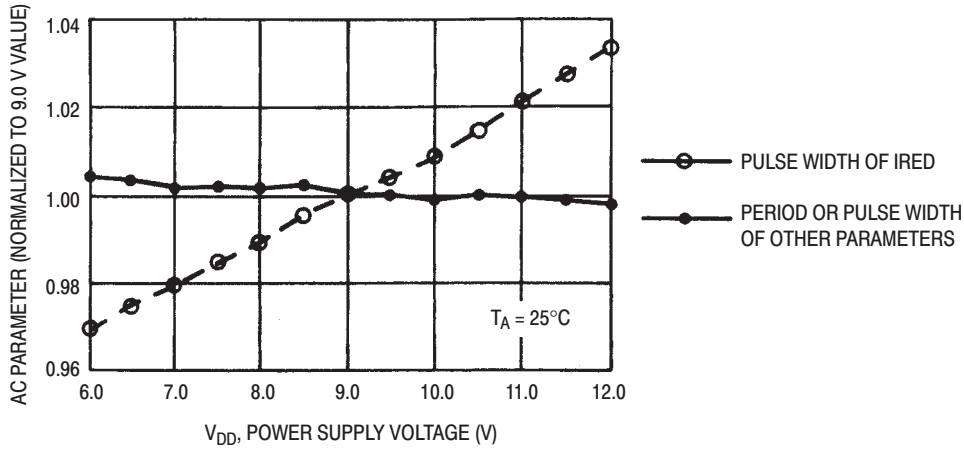
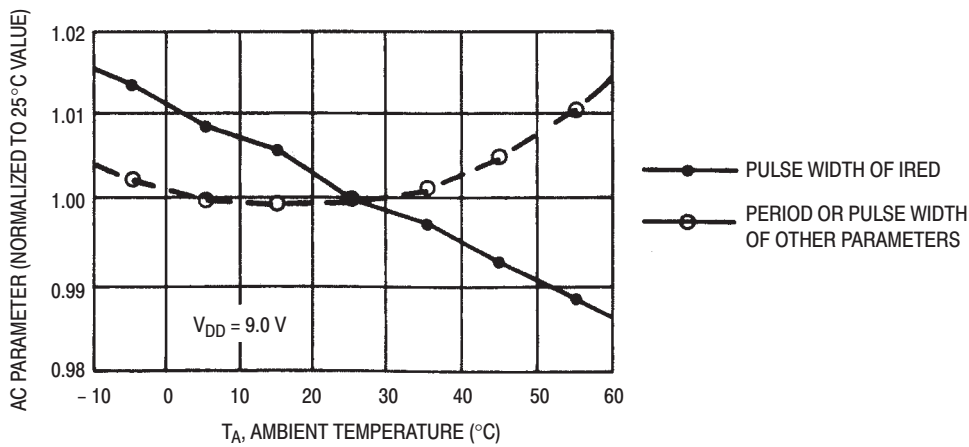
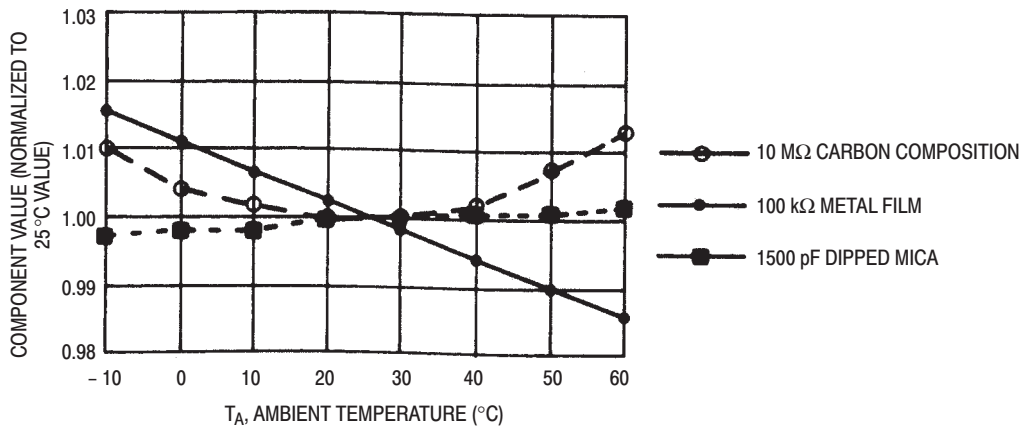


Figure 1. AC Characteristics versus Supply



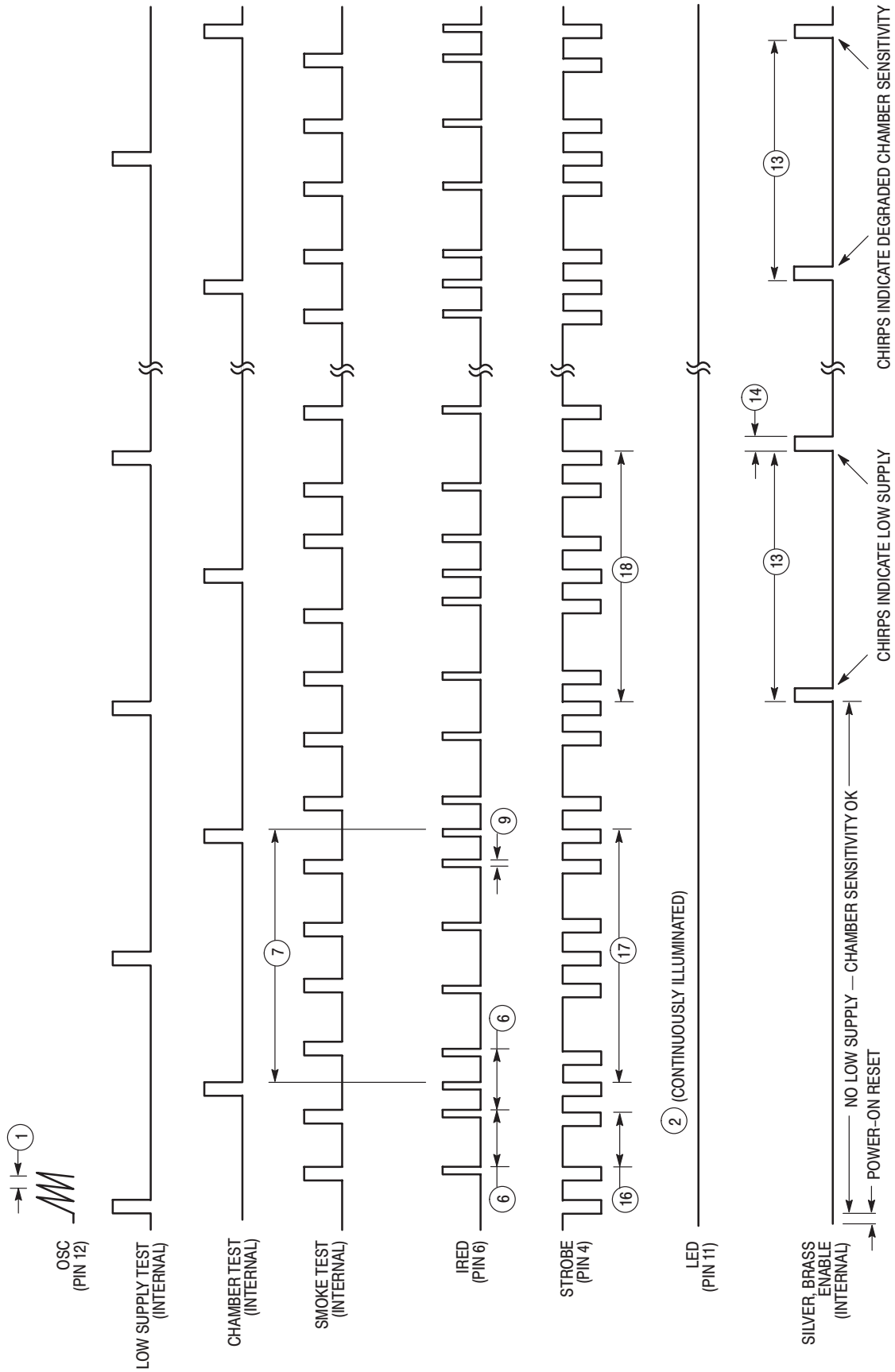
NOTE: Includes external component variations. See Figure 2B.

Figure 2A. AC Characteristics versus Temperature



NOTE: These components were used to generate Figure 2A.

Figure 2B. RC Component Variation Over Temperature



NOTES: Numbers refer to the AC Electrical Characteristics Table.  
Illustration is not to scale.

Figure 3. Standby Timing Diagram

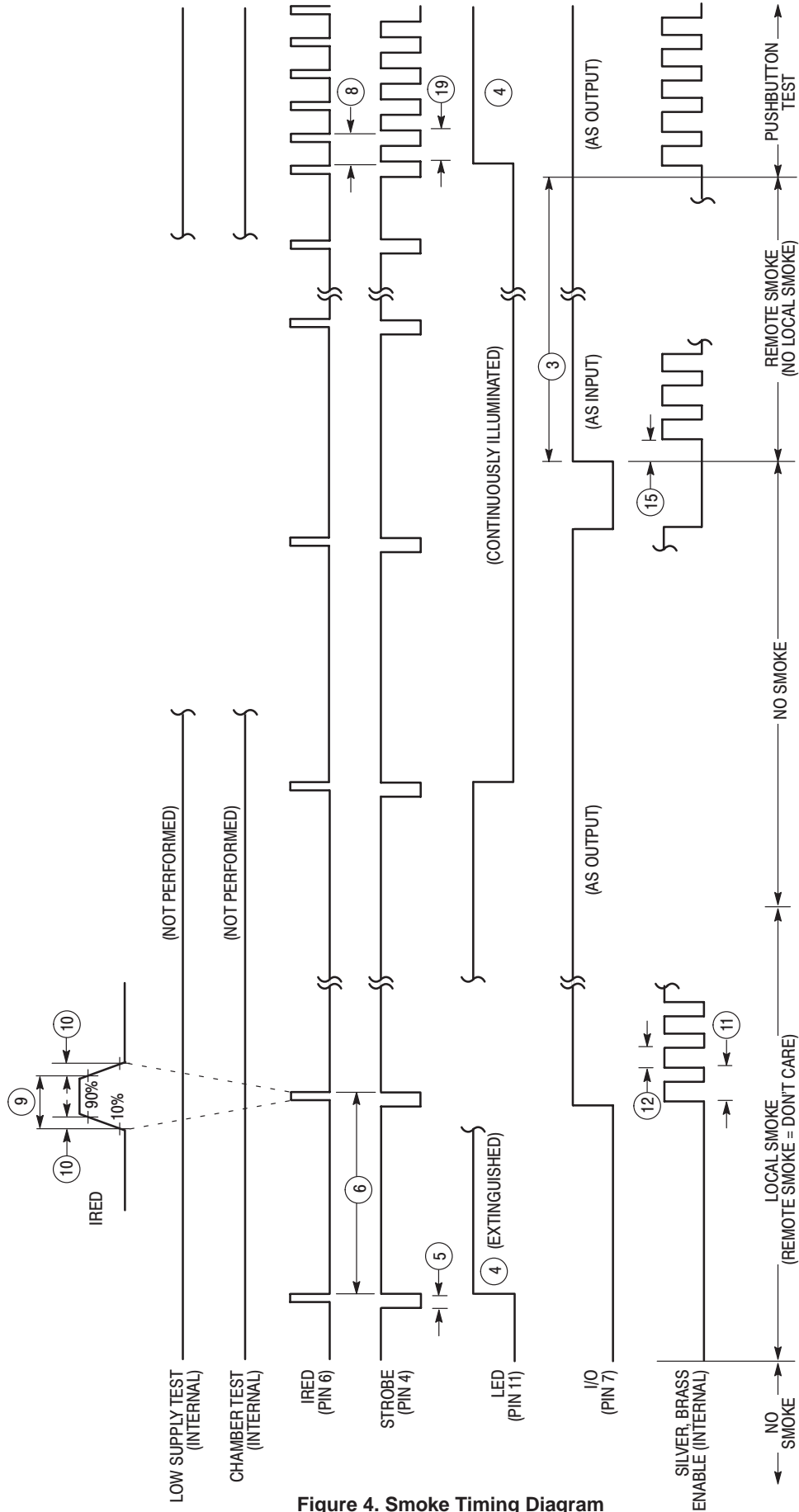
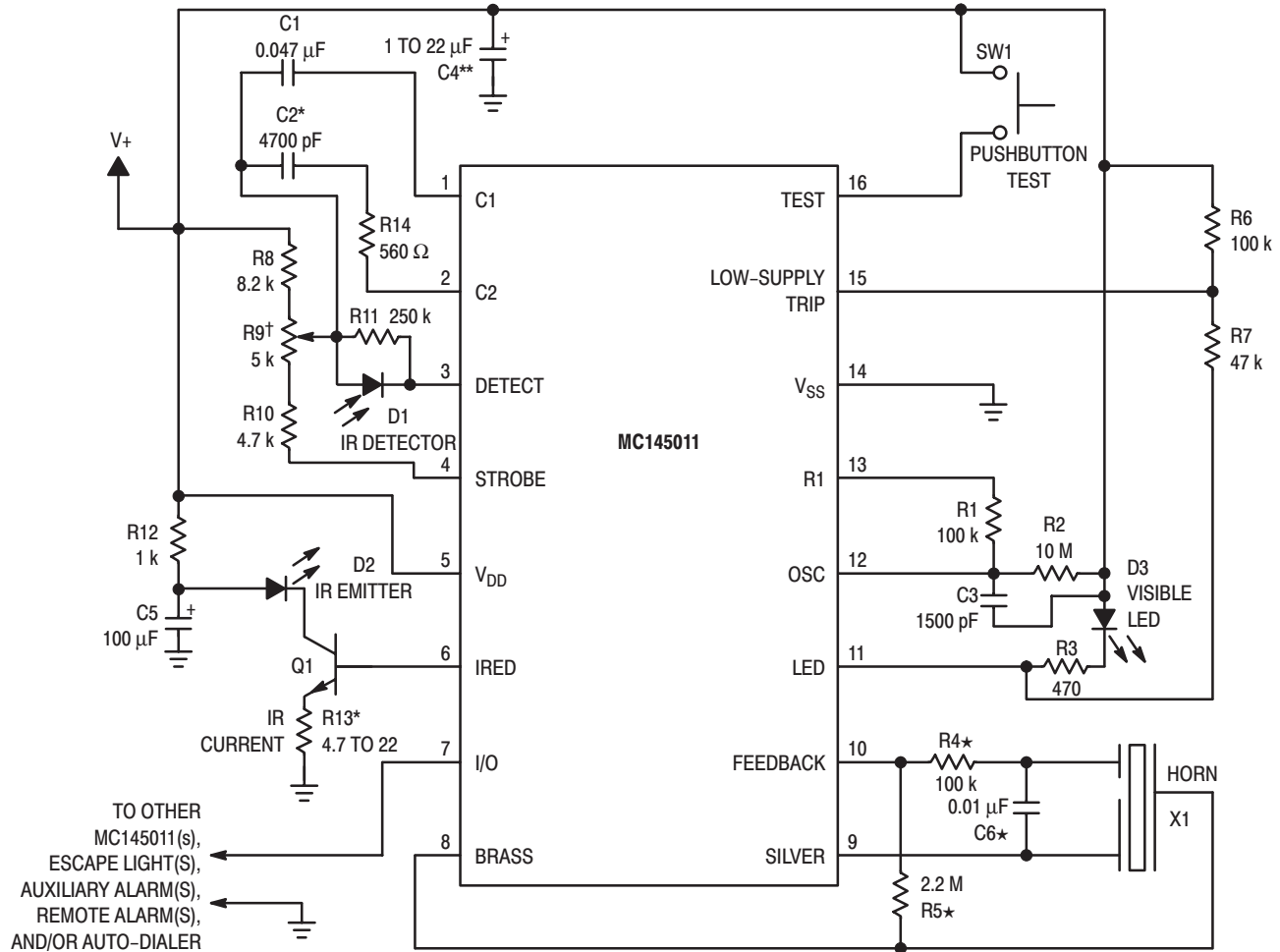


Figure 4. Smoke Timing Diagram

NOTES: Numbers refer to the AC Electrical Characteristics Table. Illustration is not to scale.



★ Values for R4, R5, and C6 may differ depending on type of piezoelectric horn used.

\* C2 and R13 are used for coarse sensitivity adjustment. Typical values are shown.

† R9 is for fine sensitivity adjustment (optional). If fixed resistors are used, R8 = 12 k, R10 is 5.6 k to 10 k, and R9 is eliminated. When R9 is used, noise pickup is increased due to antenna effects. Shielding may be required.

\*\* C4 should be 22 μF if supply line resistance is high (up to 50 Ω). C4 could be reduced to 1 μF when supply line resistance is < 30 Ω.

Figure 5. Typical Application

## PIN DESCRIPTIONS

### C1 (Pin 1)

A capacitor connected to this pin as shown in Figure 5 determines the gain of the on-chip photo amplifier during pushbutton test and chamber sensitivity test (high gain). The capacitor value is chosen such that the alarm is tripped from background reflections in the chamber during pushbutton test.

$A_v \approx 1 + (C1/10)$  where C1 is in pF. CAUTION: The value of the closed-loop gain should not exceed 10,000.

### C2 (Pin 2)

A capacitor connected to this pin as shown in Figure 5 determines the gain of the on-chip photo amplifier except during pushbutton or chamber sensitivity tests.

$A_v \approx 1 + (C2/10)$  where C2 is in pF. This gain increases about 10% during the IRED pulse, after two consecutive local smoke detections.

Resistor R14 must be installed in series with C2.  $R14 \approx [1/(12\sqrt{C2})] - 680$  where R14 is in ohms and C2 is in farads.

### DETECT (Pin 3)

This input to the high-gain pulse amplifier is tied to the cathode of an external photodiode. The photodiode should have low capacitance and low dark leakage current. The diode must be shunted by a load resistor and is operated at zero bias.

The Detect input must be ac/dc decoupled from all other signals, V<sub>DD</sub>, and V<sub>SS</sub>. Lead length and/or foil traces to this pin must be minimized, also. See Figure 6.

### STROBE (Pin 4)

This output provides a strobed, regulated voltage referenced to V<sub>DD</sub>. The temperature coefficient of this voltage is  $\pm 0.2\%/^{\circ}\text{C}$  maximum from  $-10^{\circ}$  to  $60^{\circ}\text{C}$ . The supply-voltage coefficient (line regulation) is  $\pm 0.2\%/V$  maximum from 6 to 12 V. Strobe is tied to external resistor string R8, R9, and R10.



**V<sub>DD</sub> (Pin 5)**

This pin is connected to the positive supply potential and may range from +6 to +12 V with respect to V<sub>SS</sub>.

**IRED (Pin 6)**

This output provides pulsed base current for external NPN transistor Q1 used as the infrared emitter driver. Q1 must have  $\beta \geq 100$ . At 10 mA, the temperature coefficient of the output voltage is typically +0.5%/°C from -10° to 60°C. The supply-voltage coefficient (line regulation) is  $\pm 0.2\%/V$  maximum from 6 to 12 V. The IRED pulse width (active-high) is determined by external components R1 and C3. With a 100 k $\Omega$ /1500 pF combination, the nominal width is 105  $\mu$ s.

To minimize noise impact, IRED is not active when the visible LED and horn outputs are active. IRED is active near the end of Strobe pulses for Smoke Tests, Chamber Sensitivity Test, and Pushbutton Test.

**I/O (Pin 7)**

This pin can be used to connect up to 40 units together in a wired-OR configuration for common signaling. V<sub>SS</sub> is used as the return. An on-chip current sink minimizes noise pick up during non-smoke conditions and eliminates the need for an external pull-down resistor to complete the wired-OR. Remote units at lower supply voltages do not draw excessive current from a sending unit at a higher supply voltage.

I/O can also be used to activate escape lights, auxiliary alarms, remote alarms, and/or auto-dialers.

As an input, this pin feeds a positive-edge-triggered flip-flop whose output is sampled nominally every 625 ms during standby (using the recommended component values). A local-smoke condition or the pushbutton-test mode forces this current-limited output to source current. All input signals are ignored when I/O is sourcing current.

I/O is disabled by the on-chip power-on reset to eliminate nuisance signaling during battery changes or system power-up.

If unused, I/O must be left unconnected.

**BRASS (Pin 8)**

This half of the push-pull driver output is connected to the metal support electrode of a piezoelectric audio transducer and to the horn-starting resistor. A continuous modulated tone from the transducer is a smoke alarm indicating either local or remote smoke. A short beep or chirp is a trouble alarm indicating a low supply or degraded chamber sensitivity.

**SILVER (Pin 9)**

This half of the push-pull driver output is connected to the ceramic electrode of a piezoelectric transducer and to the horn-starting capacitor.

**FEEDBACK (Pin 10)**

This input is connected to both the feedback electrode of a self-resonating piezoelectric transducer and the horn-starting resistor and capacitor through current-limiting resistor R4. If unused, this pin must be tied to V<sub>SS</sub> or V<sub>DD</sub>.

**LED (Pin 11)**

This active-low open-drain output directly drives an external visible LED.

The load for the low-supply test is applied by this output. This low-supply test is non-coincident with the smoke tests, chamber sensitivity test, pushbutton test, or any alarm signals.

The LED also provides a visual indication of the detector status as follows, assuming the component values shown in Figure 5:

Standby (includes low-supply and chamber sensitivity tests) — constantly illuminated

Local Smoke — constantly extinguished

Remote Smoke — constantly illuminated

Pushbutton Test — constantly extinguished (system OK); constantly illuminated (system problem)

**OSC (Pin 12)**

This pin is used in conjunction with external resistor R2 (10 M $\Omega$ ) to V<sub>DD</sub> and external capacitor C3 (1500 pF) to V<sub>DD</sub> to form an oscillator with a nominal period of 10.5 ms.

**R1 (Pin 13)**

This pin is used in conjunction with resistor R1 (100 k $\Omega$ ) to pin 12 and C3 (1500 pF, see pin 12 description) to determine the IRED pulse width. With this RC combination, the nominal pulse width is 105  $\mu$ s.

**V<sub>SS</sub> (Pin 14)**

This pin is the negative supply potential and the return for the I/O pin. Pin 14 is usually tied to ground.

**LOW-SUPPLY TRIP (Pin 15)**

This pin is connected to an external voltage which determines the low-supply alarm threshold. The trip voltage is obtained through a resistor divider connected between the V<sub>DD</sub> and LED pins. The low-supply alarm threshold voltage (in volts)  $\approx (5R7/R6) + 5$  where R6 and R7 are in the same units.

**TEST (Pin 16)**

This input has an on-chip pull-down device and is used to manually invoke a test mode.

The *Pushbutton Test* mode is initiated by a high level at pin 16 (usually depression of a S.P.S.T. normally-open pushbutton switch to V<sub>DD</sub>). After one oscillator cycle, IRED pulses approximately every 336 ms, regardless of the presence of smoke. Additionally, the amplifier gain is increased by automatic selection of C1. Therefore, the background reflections in the smoke chamber may be interpreted as smoke, generating a simulated-smoke condition. After the second IRED pulse, a successful test activates the horn-driver and I/O circuits. The active I/O allows remote signaling for system testing. When the Pushbutton Test switch is released, the Test input returns to V<sub>SS</sub> due to the on-chip pull-down device. After one oscillator cycle, the amplifier gain returns to normal, thereby removing the simulated-smoke condition. After two additional IRED pulses, less than a second, the IC exits the alarm mode and returns to standby timing.

## CALIBRATION

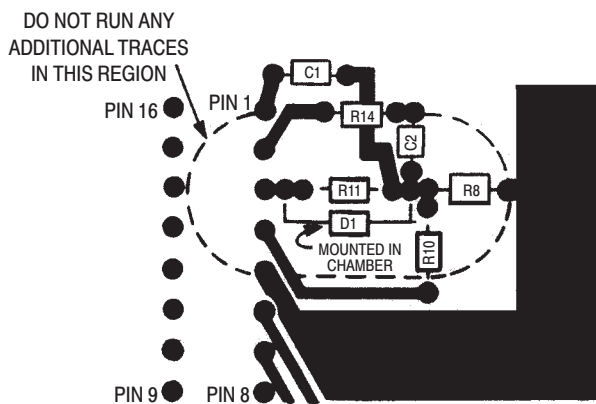
To facilitate checking the sensitivity and calibrating smoke detectors, the MC145011 can be placed in a calibration mode. In this mode, certain device pins are controlled/reconfigured as shown in Table 1. To place the part in the calibra-

tion mode, Pin 16 (Test) must be pulled below the  $V_{SS}$  pin with 100  $\mu A$  continuously drawn out of the pin for at least one cycle on the OSC pin. To exit this mode, the Test pin is floated for at least one OSC cycle.

In the calibration mode, the IRED pulse rate is increased to one for every OSC cycle. Also, Strobe is always active low.

Table 1. Configuration of Pins in the Calibration Mode

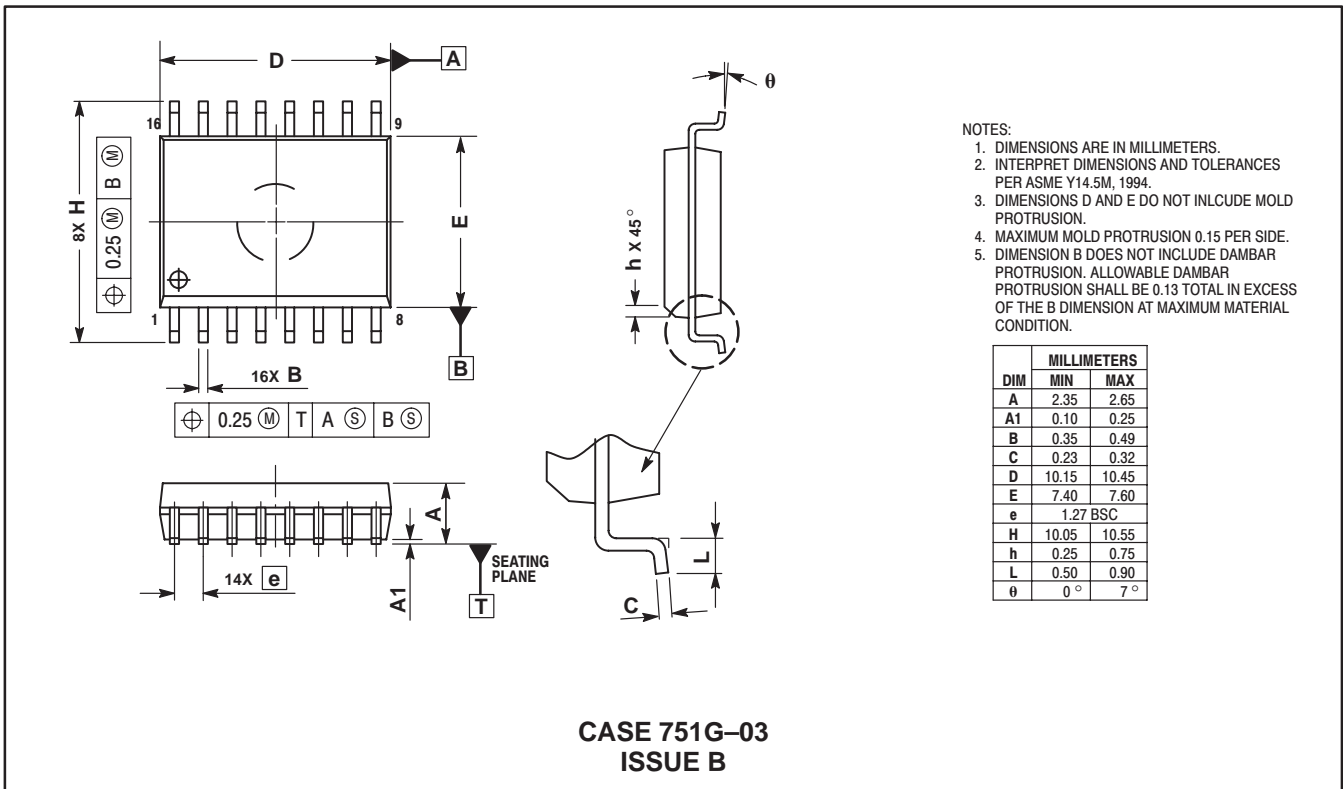
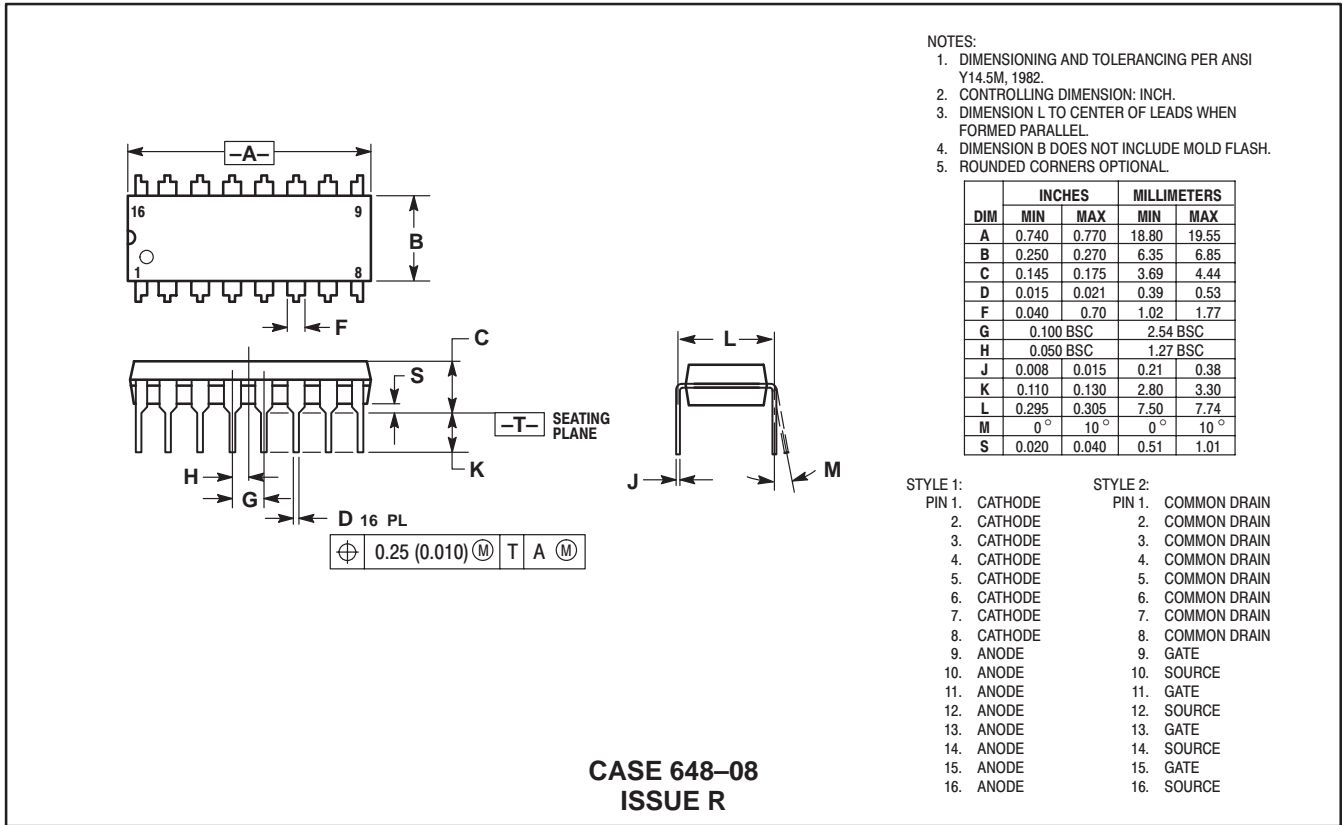
Description	Pin	Comment
I/O	7	Disabled as an output. Forcing this pin high places the photo amp output on pin 1 or 2, as determined by Low-Supply Trip. The amp's output appears as pulses and is referenced to $V_{DD}$ .
Low-Supply Trip	15	If the I/O pin is high, pin 15 controls which gain capacitor is used. Low: normal gain, amp output on pin 1. High: supervisory gain, amp output on pin 2.
Feedback	10	Driving this input high enables hysteresis (10% gain increase) in the photo amp; pin 15 must be low.
Osc	12	Driving this input high brings the internal clock high. Driving the input low brings the internal clock low. If desired, the RC network for the oscillator may be left intact; this allows the oscillator to run similar to the normal mode of operation.
Silver	9	This pin becomes the smoke comparator output. When the OSC pin is toggling, positive pulses indicate that smoke has been detected. A static low level indicates no smoke.
Brass	8	This pin becomes the smoke integrator output. That is, 2 consecutive smoke detections are required for "on" (static high level) and 2 consecutive no-detections for "off" (static low level).




- NOTES: Illustration is bottom view of layout using a DIP. Top view for SOIC layout is mirror image.  
 Optional potentiometer R9 is not included.  
 Drawing is not to scale.  
 Leads on D1, R11, R8, and R10 and their associated traces must be kept as short as possible.  
 This practice minimizes noise pick up.  
 Pin 3 must be decoupled from all other traces.

Figure 6. Recommended PCB Layout

PACKAGE DIMENSIONS



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