Document Number: MC33941
Rev. 4

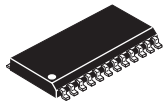
RoHS

Electric Field Imaging Device

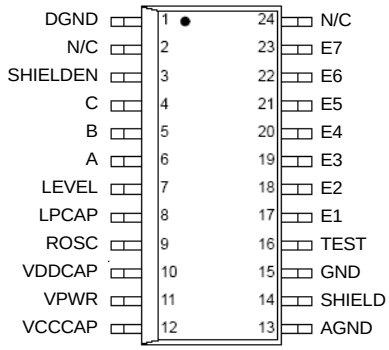
The MC33941 is intended for cost-sensitive applications where non-contact sensing of objects is desired. When connected to external electrodes, an electric field is created. The MC33941 detects objects in this electric field. The IC generates a low-frequency sine wave, which is adjustable by using an external resistor and is optimized for 120 kHz. The sine wave has very low harmonic content to reduce harmonic interference. The MC33941 also contains support circuits for a microcontroller unit (MCU) to allow the construction of a two-chip E-field system.

MC33941

ELECTRONIC FIELD IMAGING DEVICE



EG SUFFIX (Pb-FREE)
24-TERMINAL SOICW
CASE 751E-05



Pin Connections

Features

- Supports up to 7 Electrodes
- Shield Driver for Driving Remote Electrodes Through Coaxial
- High-Purity Sine Wave Generator Tunable with External Resistor
- Response Time Tunable with External Capacitor
- +5V Regulator to Power External Circuit
- Can support up to 28 touch pad sensors (2 way multiplexing)
- Extended Temperature Range -40° to 110°C
- Pb-Free and RoHS compliant

Typical Applications

- Appliance Control Panels and Touch Sensors
- Linear and Rotational Sliders
- Spill Over Flow Sensing Measurement
- Refrigeration Frost Sensing
- Industrial Control and Safety Systems Security
- Proximity Detection for Wake-Up Features
- Touch Screens
- Garage Door Safety Sensing
- PC Peripherals
- Patient Monitoring
- Point of Sale Terminals
- Size Detection
- Liquid Level Sensing

ORDERING INFORMATION			
Device Name	**Temperature Range**	**Drawing**	**Package**
MC33941EG/R2	-40° to 110°C	98ASB42564B	SOICW-24

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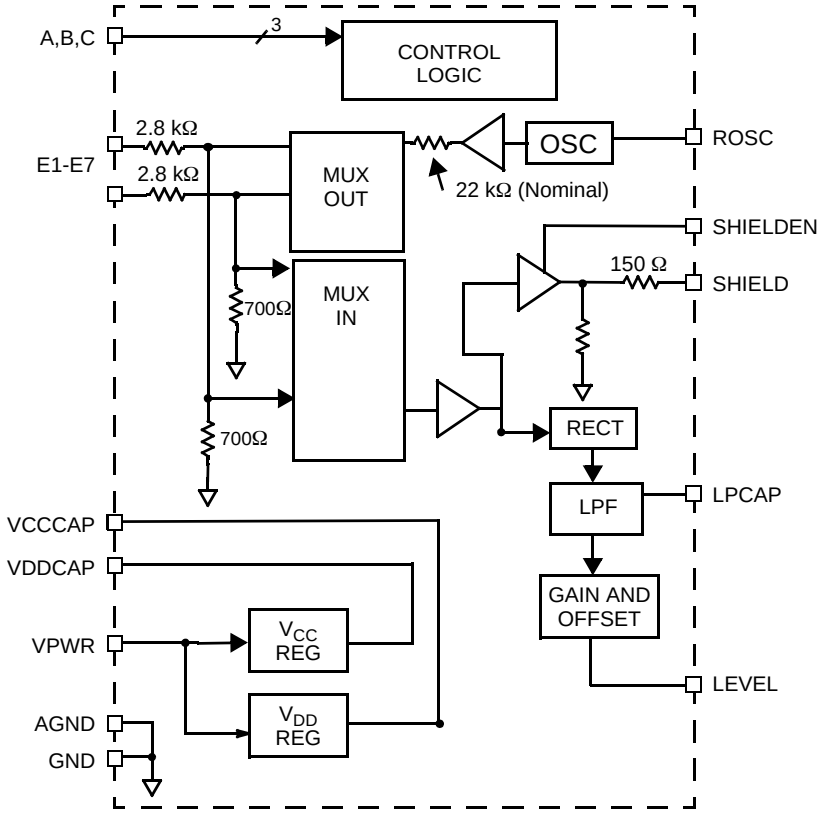


Figure 1 Simplified Functional Block Diagram

Table 1. Maximum Ratings

All voltages are with respect to ground unless otherwise noted. Exceeding these ratings may cause a malfunction or permanent damage to the device.

Rating	Symbol	Value	Unit
ELECTRICAL RATINGS			
Peak V_{PWR} Voltage	V_{PWRPK}	40	V
Double Battery 1 Minute Maximum T_A = 30°C	V_{DBLBAT}	 26.5	V
ESD Voltage Human Body Model (C_{ZAP} = 100 pF, R_{ZAP} = 1500 W) Machine Model (C_{ZAP} = 200 pF, R_{ZAP} = 0 W) Charge Device Model (CDM), Robotic (C_{ZAP} = 4.0pF)	V_{ESD}	 ±2000 ±200 ±1200	V
THERMAL RATINGS			
Storage Temperature	T_{STG}	-55 to 150	°C
Operating Ambient Temperature	T_A	-40 to 110	°C
Operating Junction Temperature	T_J	-40 to 150	°C
Thermal Resistance Junction-to-Ambient (1) Junction-to-Case (2) Junction-to-Board (3)	 $R_{\theta JA}$ $R_{\theta JC}$ $R_{\theta JB}$	 41 0.2 3.0	°C/W
Soldering Temperature (4)			

Notes

1. Junction temperature is a function of on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance. In accordance with SEMI G38-87 and JEDEC JESD51-2 with the single layer board horizontal.
2. Indicates the average thermal resistance between the die and the case top surface as measured by the cold plate method (MILSPEC 883 Method 1012.1) with the cold plate temperature used for the case temperature.
3. Thermal resistance between the die and the printed circuit board per JEDEC JESD51-8. Board temperature is measured on the top surface of the board near the package.
4. Terminal soldering temperature limit is for 10 seconds maximum duration. The device is not designed for immersion soldering. Exceeding these limits may cause malfunction or permanent damage to the device.

Table 2. Static Electrical Characteristics

Characteristics noted under conditions 5.5 V ≤ V_{SUP} ≤ 18 V, -40°C ≤ T_A ≤ 110°C, GND = 0 V unless otherwise noted. Typical values noted reflect the approximate parameter means at T_A = 25°C under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
SUPPLY (V_{PWR})					
Supply Voltage	V_{PWR}	9.0	12	18	V
I_{DD} (V_{PWR} = 14V) (Quiescent supply current measured over temperature. Assumes that no external devices connected to internal voltage regulators)	I_{DD}	6.0	7.0	8.0	mA
VOLTAGE REGULATOR					
5V Regulator Voltage 7.0 V ≤ VPWR ≤ 18 V, 1.0 mA ≤ I_L ≤ 75 mA, CFILT = 47 μF	VCCCAP	4.75	5	5.25	V
ELECTRODE SIGNALS (E1–E7)					
Total Variance Between Electrode Measurements [5] All C_{LOAD} = 15 pF	ELV_{VAR}	–	–	3.0	%
Electrode Maximum Harmonic Level Below Fundamental [5] 5.0 pF ≤ C_{LOAD} ≤ 150 pF	EL_{HARM}	–	-20	–	dB
Electrode Transmit Output Range 5.0 pF ≤ C_{LOAD} ≤ 150 pF	EL_{TXV}	1.0	–	8.0	V
Receive Input Voltage Range	RX_V	0	–	9.0	V
Grounding Switch on Voltage[6] I_{SW} = 1.0 mA	SW_{VON}	–	–	5.0	V
LOGIC I/O (C, B, A)					
CMOS Logic Input Low Threshold	V_{THL}	0.3	–	–	V_{CC}
Logic Input High Threshold	V_{THH}	–	–	0.7	V_{CC}
Voltage Hysteresis	V_{HYS}	–	0.06	–	V_{CC}
Input Current V_{IN} = V_{CC} V_{IN} = 0 V	I_{IN}	10 -5.0	– –	50 5.0	μA
SIGNAL DETECTOR (LPCAP)					
Detector Output Resistance	DET_{RO}	–	50	–	kΩ
LPCAP to LEVEL Gain	A_{REC}	3.6	4.0	4.4	A_V
LPCAP to LEVEL Offset	V_{RECOFF}	-3.3	-3.0	-2.7	V

Notes

5. Verified by design and characterization. Not tested in production.
6. Current into grounded terminal under test = 1.0 mA.

Table 3. Dynamic Electrical Characteristics [7]

Characteristics noted under conditions 5.5 V ≤ V_{SUP} ≤ 18 V, -40°C ≤ T_A ≤ 110°C, GND = 0 V unless otherwise noted. Typical values noted reflect the approximate parameter means at T_A = 25°C under nominal conditions unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
OSC (ROSC)					
OSC Frequency Stability	f_{STAB}	–	–	10	%
OSC Center Frequency ROSC = 39 kΩ ROSC = 20 kΩ ROSC = 82 kΩ	f_{OSC}	 – – –	 120 240 60	 – – –	kHz
Harmonic Content 2nd through 4th Harmonic Level 5th and Higher	$OSCH_{ARM}$	 – –	 – –	 -20 -60	dB
SHIELD DRIVER (SHIELD)					
Shield Driver Maximum Harmonic level below Fundamental 10 pF ≤ C_{LOAD} ≤ 500 pF	SD_{HARM}	 –	 -20	 –	dB
Shield Driver Gain Bandwidth Product Measured at 120 kHz	SD_{GBW}	 –	 4.5	 –	MHz

Notes

7. All parameters are guaranteed by design.

PRINCIPLE OF OPERATION

The 33941 generates a low radio frequency sine wave with nominal 5.0 V peak-to-peak amplitude. The frequency is set by an external resistor and is optimized for 120 kHz. An internal multiplexer routes the signal to one of the 7 terminals under control of the ABC input terminals. A receiver multiplexer simultaneously connected to the selected electrode and routes its signal to a detector, which converts the sine wave to a DC level. The DC level is filtered by an external capacitor, is multiplied and offset to increase sensitivity. All electrode outputs are grounded internally by the device when not selected.

The amplitude and phase of the sinusoidal wave at the electrode are affected by objects in proximity. A “capacitor” is formed between the driving electrode and the object, each forming a “plate” that holds the electric charge. The voltage measured is an inverse function of the capacitance between the electrode being measured, the surrounding electrodes, and other objects in the electric field surrounding the electrode. Increasing capacitance results in decreasing voltage. The value of the series resistor (22kohm) was chosen to provide a near linear relationship at 120 kHz over a range of 10pF to 70pF.

While exploring applications using the E-Field chip, it is always useful to approach the problem using the capacitor model.

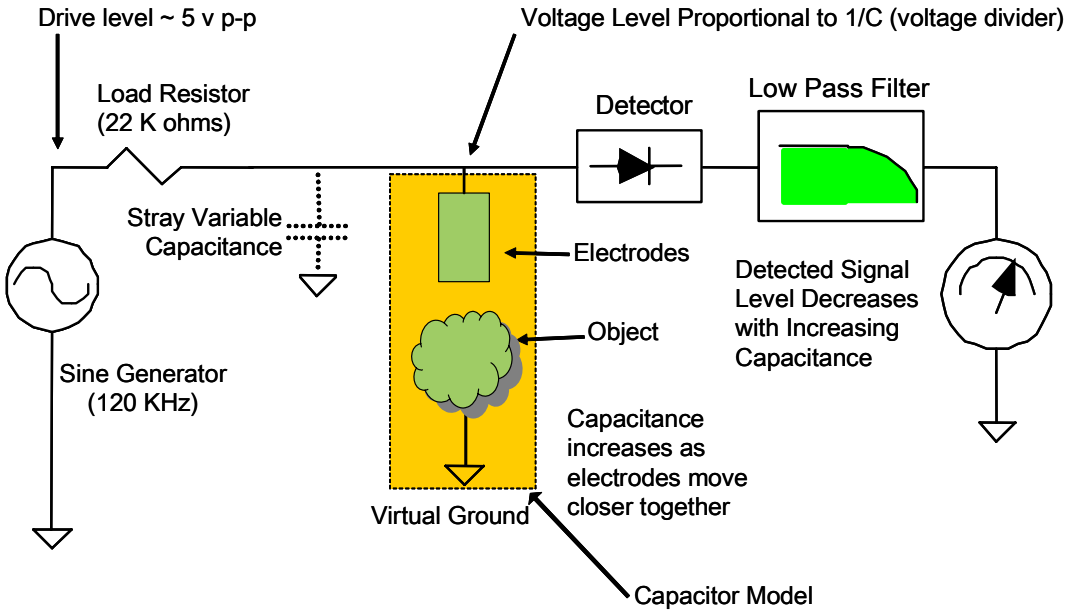


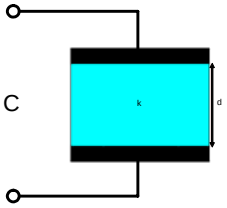
Figure 2 . Conceptual Block Diagram

CAPACITOR MODEL

The capacitance measured by the E-Field IC is:

- Proportional to the area of the electrode
- Proportional to the dielectric constant of the material between the electrodes
- Inversely proportional to the distance between the objects

$$C = \frac{k\varepsilon_0 A}{d}$$



C=The Capacitance in Farads (F)
A=The area of the plates in square meters (m2)
d=The distance between the plates in meters (m)
k=The dielectric constant of the material separating the plates
0=Is the permittivity of free space (8.85 x 10-12 F/m)

Figure 3. Capacitor Model

Table 4 Dielectric Constants of Various Materials

Dielectric Material	Thickness (mil)	*k*
Acrylic	84.5	2.4-4.5
Glass	74.5	7.5
Nylon Plastic	68	3.0-5.0
Polyester Film	10	3.2
Flexible Vinyl Film	9	2.8-4.5
Air	-	1
Water	-	80
Ice	-	3.2
Automotive Oil	-	2.1

FEATURES

SHIELD DRIVER

A shield driver is included to minimize the electrode signal along wires. This circuit provides a buffered version of the returned AC signal from the electrode. Since it has nearly the same amplitude and phase as the electrode signal, there is little or no potential difference between the two signals, thereby canceling out any electric field. In effect, the shield drive isolates the electrode signal from external virtual grounds. A common application is to connect the Shield Driver to the shield of a coax cable used to connect an electrode to the corresponding electrode terminal. Another typical use is to drive a ground plane that is used behind an array of touch sensor electrodes in order to cancel out any virtual grounds that could attenuate the AC signal.

TUNABLE FREQUENCY

The 33941 offers 3 operating frequencies. In addition to the default frequency of 120 kHz, the 33941 has also been characterized to work in two other frequencies (240 kHz and 60 kHz) for applications with specific needs. These frequencies are tunable by attaching a 20k and 82k resistor at ROSC respectively. If a wider capacitance range is needed, simply change the ROSC resistor value to 82k to have the signal generator operate at 60 kHz which will extend the capacitance range to 150pF as seen on Figure 4. The figure also shows that one can achieve higher sensitivity at lower capacitances by setting the ROSC resistor value to 20k. All resistor values listed above are for 5% tolerance resistors.

ADJUSTABLE RESPONSE TIME

The rectified sine wave is filtered by a Low Pass Filter formed by and internal resistor and an external capacitor attached to LP_CAP. The value of the external capacitor is selected to allow the designer to optimize the balance between noise and settling time. A typical value for the external capacitor is 10nF and in practice it will have a response time of 1.5ms. If faster response time is required a 1nF capacitor can be used and it will have response times < 200μS. Please note that reducing the LP_CAP capacitor value increases noise accordingly.

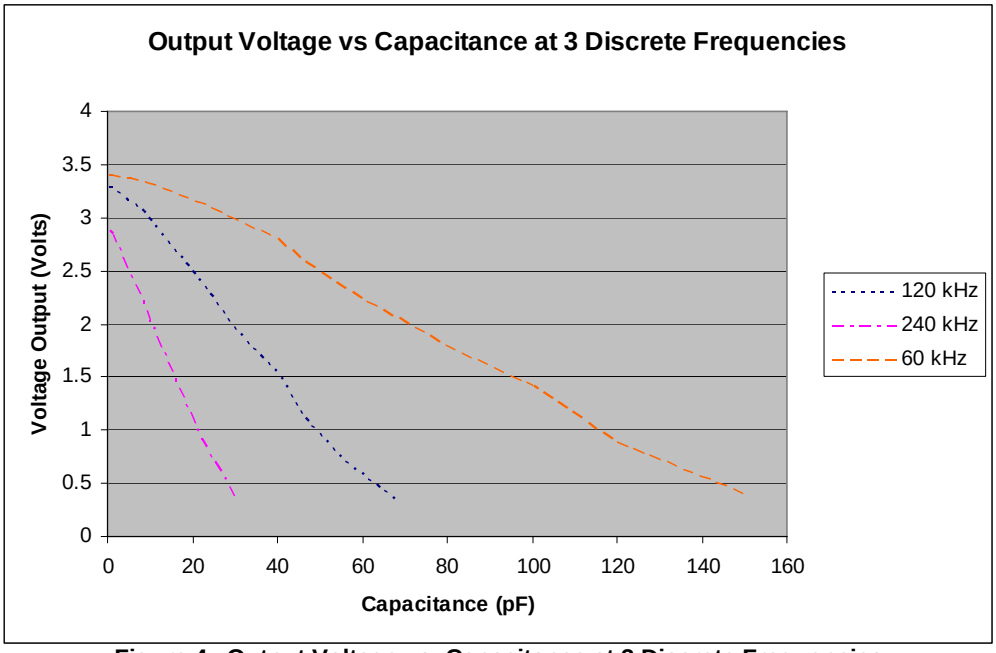


Figure 4 . Output Voltage vs. Capacitance at 3 Discrete Frequencies

PIN DESCRIPTIONS

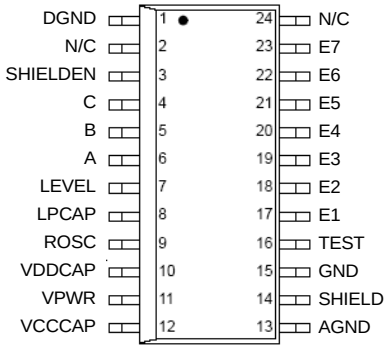


Figure 5. Pin Descriptions

Table 5. Electrode Selection

Terminal/SIGNAL	C	B	A
No electrodes selected	0	0	0
E1	0	0	1
E2	0	1	0
E3	0	1	1
E4	1	0	0
E5	1	0	1
E6	1	1	0
E7	1	1	1

Table 6. Pin Description

Pin Number	Pin Name	Definition
1	DGND	Connected to the ground return
2, 24	N/C	These pins should be left open.
3	SHIELDEN	Used to enable the shield signal
4,5,6	C, B, A	Controls electrode or reference activity
7	LEVEL	This is the detected, amplified, and offset representation of the signal voltage on the selected electrode
8	LPCAP	A capacitor on this pin forms a low pass filter with the internal series resistance from the detector to this pin
9	ROSC	A resistor from this pin to circuit ground determines the operating frequency of the oscillator
10	VDDCAP	A 47μF capacitor is connected to this pin to filter the internal analog regulated supply
11	VPWR	12 V power applied to this pin will be converted to the internal regulated voltages needed to operate the part
12	VCCCAP	A 47μF capacitor is connected to this pin and VCCCAP provides a regulated 5.0 V to power external circuits 75 mA Max
13	AGND	Connected to the ground return of the analog circuitry
14	SHIELD	Connects to cable shields to cancel cable capacitance.
15	GND	Main IC ground
16	TEST	Connect to circuit ground
17-23	E1–E7	Electrode pins

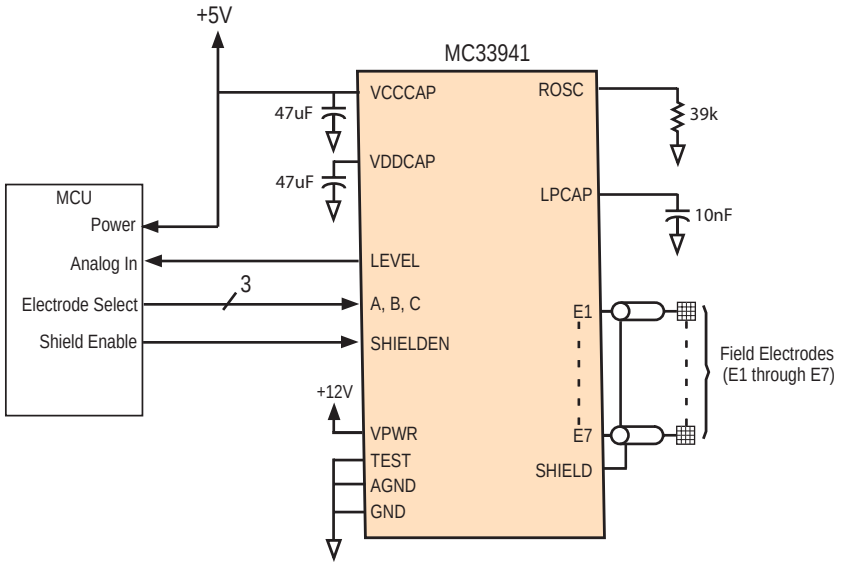
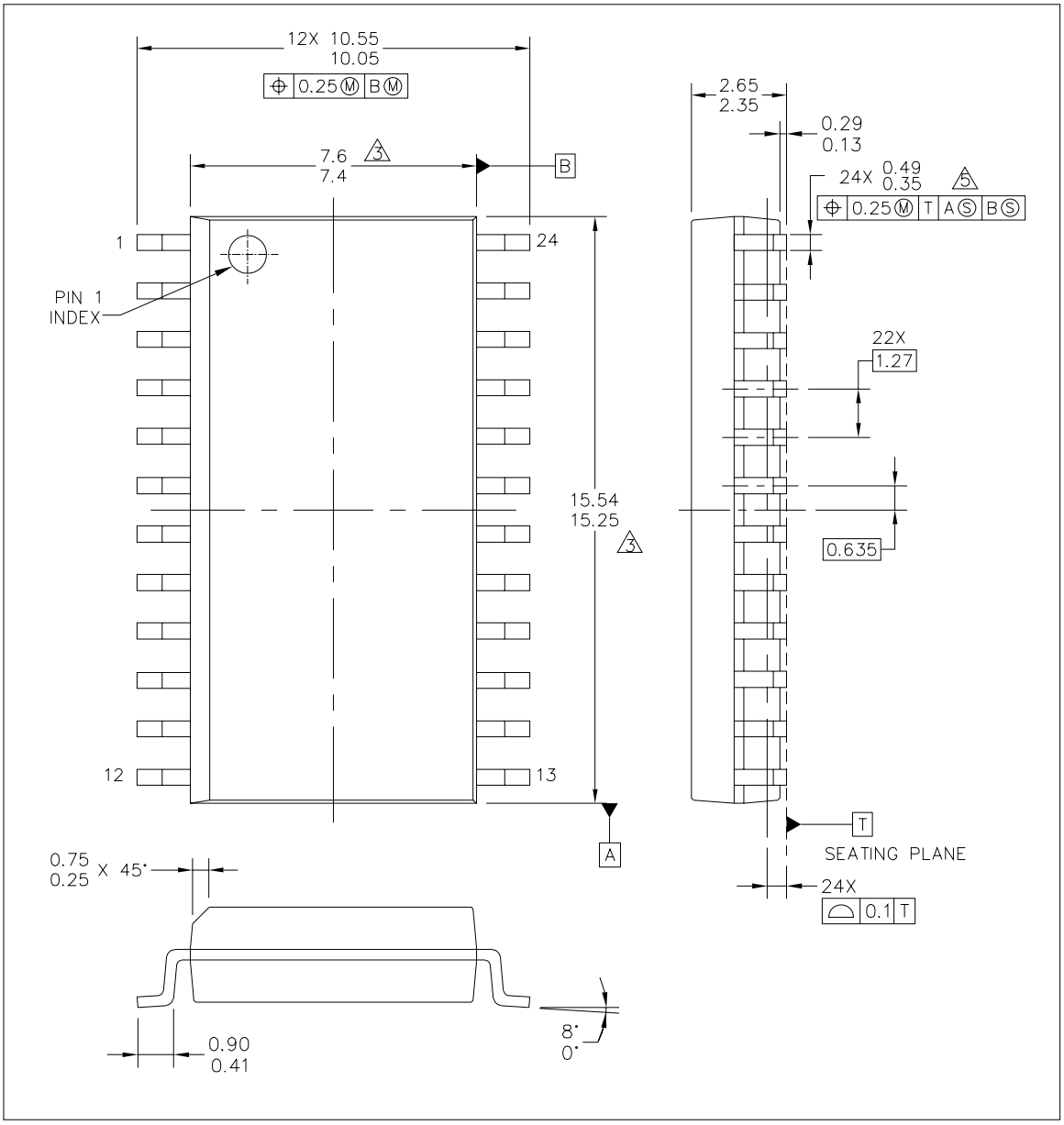


Figure 6 . Simplified Application Diagram

PACKAGE DIMENSIONS



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	CASE NUMBER: 751E–05	05 DEC 2007
	STANDARD: JEDEC MS–013 AD	

CASE 751E-05
ISSUE G
24-LEAD SOIC

PACKAGE DIMENSIONS

NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M–1994.
2. DIMENSIONS ARE IN MILLIMETERS.
3. THIS DIMENSION DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15(0.006) PER SIDE.
5. THIS DIMENSION DOES NOT INCLUDE DAM BAR PROTRUSION. ALLOWABLE DAM BAR PROTRUSION SHALL BE 0.13(0.005) TOTAL IN EXCESS OF THIS DIMENSION AT MAXIMUM MATERIAL CONDITION.

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