APPLICATION NOTE
A V A I L A B L E
AN104

Low Noise, Low Power, 32 Taps

X9315

E²POT™ Nonvolatile Digital Potentiometer

FEATURES

- Low Power CMOS
  - —V_{CC} = 2.7V to 5.5V, Single Supply
  - —Active Current, 50µA (Increment) max
  - —Active Current, 400µA (Store) Max
  - —Standby Current, 1µA Max
- Low Noise
- 31 Resistive Elements
  - —Temperature Compensated
  - —± 20% End to End Resistance Range
  - —V_{SS} to V_{CC} Range
- 32 Wiper Tap Points
  - —Wiper Positioned via Three-Wire Interface
  - —Similar to TTL Up/Down Counter
  - —Wiper Position Stored in Nonvolatile Memory and Recalled on Power-Up
- 100 Year Wiper Position Data Retention
- X9315Z = 1KΩ
- X9315W = 10KΩ
- Packages
  - —8-Lead SOIC
  - —8-Lead MSOP
  - —8-Pin DIP

DESCRIPTION

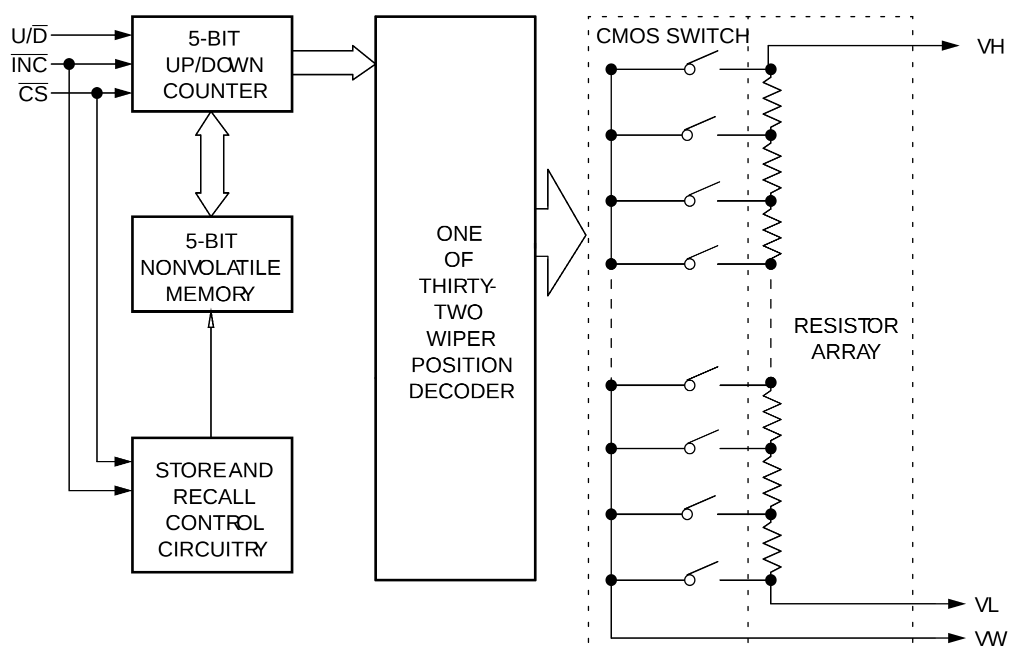
The Xicor X9315 is a solid state "micropower" nonvolatile potentiometer and is ideal for digitally controlled resistance trimming.

The X9315 is a resistor array composed of 31 resistive elements. Between each element and at either end are tap points accessible to the wiper element. The position of the wiper element is controlled by the $\overline{CS}$, U/$\overline{D}$, and $\overline{INC}$ inputs. The position of the wiper can be stored in nonvolatile memory and then be recalled upon a subsequent power-up operation.

The resolution of the X9315 is equal to the maximum resistance value divided by 31. As an example, for the X9315W (10KΩ) each tap point represents 323Ω.

All Xicor nonvolatile digital potentiometers are designed and tested for applications requiring extended endurance and data retention.

FUNCTIONAL DIAGRAM



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E²POT™ is a trademark of Xicor, Inc.

PIN DESCRIPTIONS

V_H and V_L

The high (V_H) and low (V_L) terminals of the X9315 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V_{SS} and the maximum is V_{CC}. It should be noted that the terminology of V_L and V_H references the relative position of the terminal in relation to wiper movement direction selected by the U/$\overline{D}$ input and not the voltage potential on the terminal.

V_W

V_W is the wiper terminal, equivalent to the movable terminal of a mechanical potentiometer. The position of the wiper within the array is determined by the control inputs. The wiper terminal series resistance is typically 400Ω.

Up/Down (U/$\overline{D}$)

The U/$\overline{D}$ input controls the direction of the wiper movement and whether the counter is incremented or decremented.

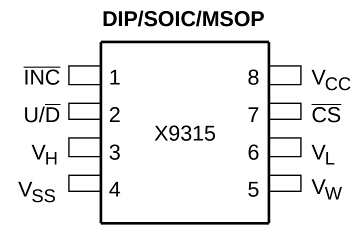
Increment ($\overline{INC}$)

The $\overline{INC}$ input is negative-edge triggered. Toggling $\overline{INC}$ will move the wiper and either increment or decrement the counter in the direction indicated by the logic level on the U/$\overline{D}$ input.

Chip Select ($\overline{CS}$)

The device is selected when the $\overline{CS}$ input is LOW. The current counter value is stored in nonvolatile memory when $\overline{CS}$ is returned HIGH while the $\overline{INC}$ input is also HIGH. After the store operation is complete the X9315 will be placed in the low power standby mode until the device is selected once again.

PIN CONFIGURATION



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PIN NAMES

Symbol	Description
V_H	High Terminal
V_W	Wiper Terminal
V_L	Low Terminal
V_{SS}	Ground
V_{CC}	Supply Voltage
U/$\overline{D}$	Up/Down Input
$\overline{INC}$	Increment Input
$\overline{CS}$	Chip Select Input

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DEVICE OPERATION

There are three sections of the X9315: the input control, counter and decode section; the nonvolatile memory; and the resistor array. The input control section operates just like an up/down counter. The output of this counter is decoded to turn on a single electronic switch connecting a point on the resistor array to the wiper output. Under the proper conditions the contents of the counter can be stored in nonvolatile memory and retained for future use. The resistor array is comprised of 31 individual resistors connected in series. At either end of the array and between each resistor is an electronic switch that transfers the potential at that point to the wiper.

The $\overline{INC}$, U/$\overline{D}$ and $\overline{CS}$ inputs control the movement of the wiper along the resistor array. With $\overline{CS}$ set LOW the X9315 is selected and enabled to respond to the U/$\overline{D}$ and $\overline{INC}$ inputs. HIGH to LOW transitions on $\overline{INC}$ will increment or decrement (depending on the state of the U/$\overline{D}$ input) a seven bit counter. The output of this counter is decoded to select one of thirty two wiper positions along the resistive array.

The wiper, when at either fixed terminal, acts like its mechanical equivalent and does not move beyond the last position. That is, the counter does not wrap around when clocked to either extreme.

The value of the counter is stored in nonvolatile memory whenever $\overline{CS}$ transistions HIGH while the $\overline{INC}$ input is also HIGH.

When the X9315 is powered-down, the last counter position stored will be maintained in the nonvolatile memory. When power is restored, the contents of the memory are recalled and the counter is reset to the value last stored.

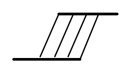
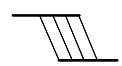
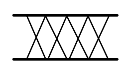
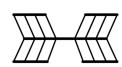
Operation Notes

The system may select the X9315, move the wiper and deselect the device without having to store the latest wiper position in nonvolatile memory. The wiper movement is performed as described above; once the new position is reached, the system would the keep $\overline{INC}$ LOW while taking $\overline{CS}$ HIGH. The new wiper position would be maintained until changed by the system or until a power-up/down cycle recalled the previously stored data.

This would allow the system to always power-up to a preset value stored in nonvolatile memory; then during system operation minor adjustments could be made. The adjustments might be based on user preference, system parameter changes due to temperature drift, etc...

The state of U/$\overline{D}$ may be changed while $\overline{CS}$ remains LOW. This allows the host system to enable the X9315 and then move the wiper up and down until the proper trim is attained.

SYMBOL TABLE

WAVEFORM	INPUTS	OUTPUTS
	Must be steady	Will be steady
	May change from Low to High	Will change from Low to High
	May change from High to Low	Will change from High to Low
	Don't Care: Changes Allowed	Changing: State Not Known
	N/A	Center Line is High Impedance

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ABSOLUTE MAXIMUM RATINGS*

Temperature under Bias .... –65°C to +135°C
Storage Temperature .... –65°C to +150°C
Voltage on $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ V_H, V_L and V_{CC}
with Respect to V_{SS} .... –1V to +7V
$\Delta V = |V_H – V_L|$ 5V
Lead Temperature (Soldering 10 seconds) .... 300°C
Wiper Current .... ±1mA

*COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and the functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied.

ANALOG CHARACTERISTICS

Electrical Characteristics

Temperature under Bias .... –65°C to +135°C
End-to-End Resistance Tolerance .... ±20%
Power Rating at 25°C 10mW
Wiper Current .... ±1mA Max.
Typical Wiper Resistance .... 400Ω at 1mA
Typical Noise .... < –140dB√Hz Ref: 1V

Resolution

Resistance 3%

Linearity

Absolute Linearity(1) .... ±1.0 Ml(2)
Relative Linearity(3) .... ±0.2 Ml(2)

Temperature Coefficient

(–40°C to +85°C) .... +300 ppm/°C Typical
Ratiometric Temperature Coefficient .... ±20 ppm

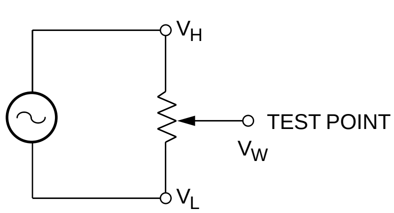
Wiper Adjustability

Unlimited Wiper Adjustment (Non-Store operation)
Wiper Position Store Operations 100,000

Physical Characteristics

Marking Includes
- Manufacturer's Trademark
- Resistance Value or Code
- Date Code

Test Circuit #1



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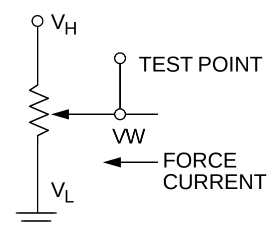
Test Circuit #2



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Notes: (1) Absolute Linearity is utilized to determine actual wiper voltage versus expected voltage $= (V_{w(n)}(\text{actual}) – V_{w(n)}(\text{expected})) = \pm 1$ Ml Maximum.
(2) 1 Ml = Minimum Increment = $R_{TOT}/31$.
(3) Relative Linearity is a measure of the error in step size between taps = $V_{W(n+1)} – [V_{w(n)} + \text{Ml}] = +0.2$ Ml.

RECOMMENDED OPERATING CONDITIONS

Temperature	Min.	Max.
Commercial	0°C	+70°C
Industrial	–40°C	+85°C

6732 PGM T02

Supply Voltage	Limits
X9315	5V ±10%
X9315-2.7	2.7V to 5.5V

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D.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified.)

Symbol	Parameter	Limits			Units	Test Conditions
		Min.	Typ.(4)	Max.		
I_{CC1}	V_{CC} Active Current (Increment)			50	µA	$\overline{CS} = V_{IL}$, $U/\overline{D} = V_{IL}$ or V_{IH} and $\overline{INC}$ = 0.4V/2.4V @ max. t_{CYC}
I_{CC2}	V_{CC} Active Current (Store)			400	µA	$\overline{CS} = V_{IH}$, $U/\overline{D} = V_{IL}$ or V_{IH} and $\overline{INC} = V_{IH}$
I_{SB}	Standby Supply Current			1	µA	$\overline{CS} = V_{CC}$ – 0.3V, $U/\overline{D}$ and $\overline{INC} = V_{SS}$ or V_{CC} – 0.3V
I_{LI}	$\overline{CS}$, $\overline{INC}$, $U/\overline{D}$ Input Leakage Current			±10	µA	$V_{IN} = V_{SS}$ to V_{CC}
V_{IH}	$\overline{CS}$, $\overline{INC}$, $U/\overline{D}$ Input HIGH Voltage	2		V_{CC} + 1	V	
V_{IL}	$\overline{CS}$, $\overline{INC}$, $U/\overline{D}$ Input LOW Voltage	–0.5		0.8	V	
R_W	Wiper Resistence		400	1000	Ω	Max. Wiper Current ±1mA
V_{VH}	VH Terminal Voltage	V_{SS}		V_{CC}	V	
V_{VL}	VL Terminal Voltage	V_{SS}		V_{CC}	V	
C_{IN}(5)	$\overline{CS}$, $\overline{INC}$, $U/\overline{D}$ Input Capacitance			10	pF	V_{CC} = 5V, $V_{IN} = V_{SS}$, T_A = 25°C, f = 1MHz

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STANDARD PARTS

Part Number	Maximum Resistance	Wiper Increments	Minimum Resistance
X9315Z	1KΩ	32.3Ω	100Ω
X9315W	10KΩ	323Ω	100Ω

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Notes: (4) Typical values are for T_A = 25°C and nominal supply voltage.
(5) This parameter is periodically sampled and not 100% tested.

A.C. CONDITIONS OF TEST

Input Pulse Levels	0V to 3V
Input Rise and Fall Times	10ns
Input Reference Levels	1.5V

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MODE SELECTION

$\overline{CS}$	$\overline{INC}$	$U/\overline{D}$	Mode
L	↓	H	Wiper Up
L	↓	L	Wiper Down
↑	H	X	Store Wiper Position
H	X	X	Standby
↑	L	X	No Store, Return to Standby

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A.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

		Limits			
Symbol	**Parameter**	**Min.**	**Typ.(6)**	**Max.**	**Units**
t_{CI}	$\overline{CS}$ to $\overline{INC}$ Setup	100			ns
t_{ID}	$\overline{INC}$ HIGH to $U/\overline{D}$ Change	100			ns
t_{DI}	$U/\overline{D}$ to $\overline{INC}$ Setup	2.9			µs
t_{IL}	$\overline{INC}$ LOW Period	1			µs
t_{IH}	$\overline{INC}$ HIGH Period	1			µs
t_{IC}	$\overline{INC}$ Inactive to $\overline{CS}$ Inactive	1			µs
t_{CPH}	$\overline{CS}$ Deselect Time (NO STORE)	100			ns
t_{IW}	$\overline{INC}$ to Vw Change		1	5	µs
t_{CYC}	$\overline{INC}$ Cycle Time	4			µs
t_R, t_F(7)	$\overline{INC}$ Input Rise and Fall Time			500	µs
t_{PU}(7)	Power up to Wiper Stable			5	µs
t_R V_{CC}(7)	V_{CC} Power-up Rate	0.2		50	mV/µs
t_{WR}	Store Cycle		5	10	ms

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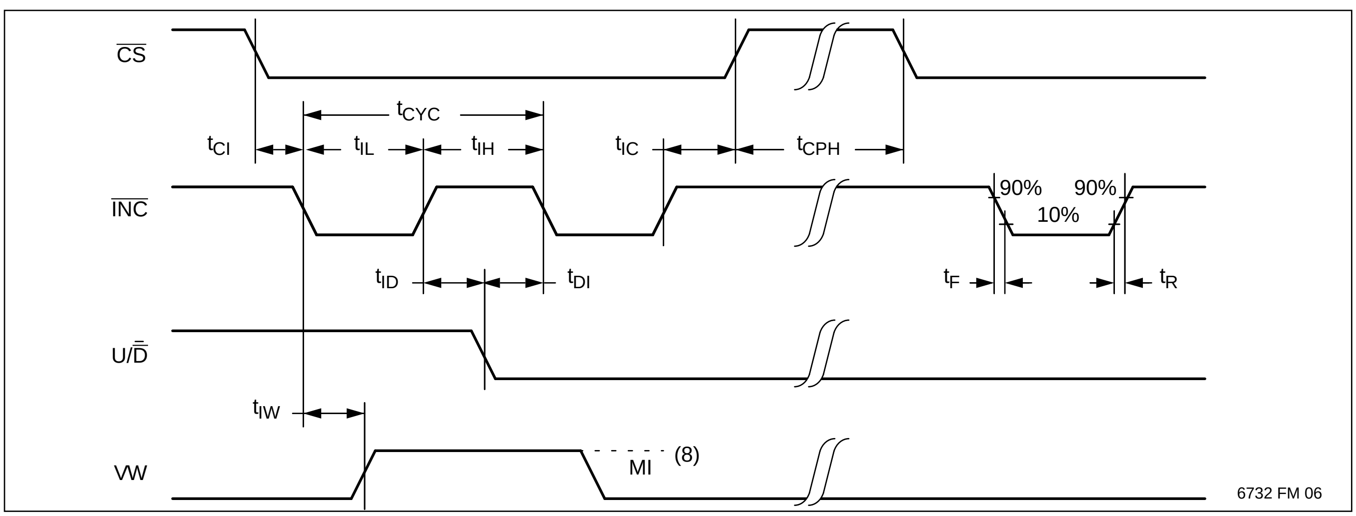
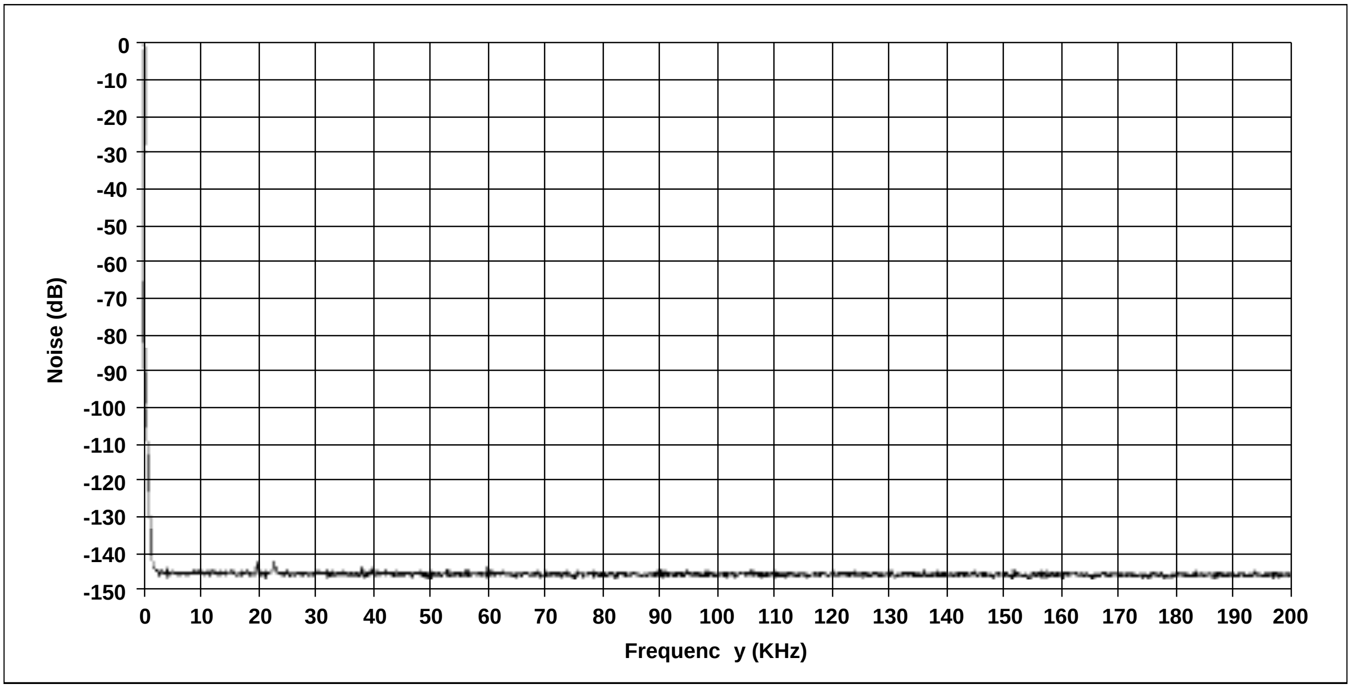
A.C. TIMING

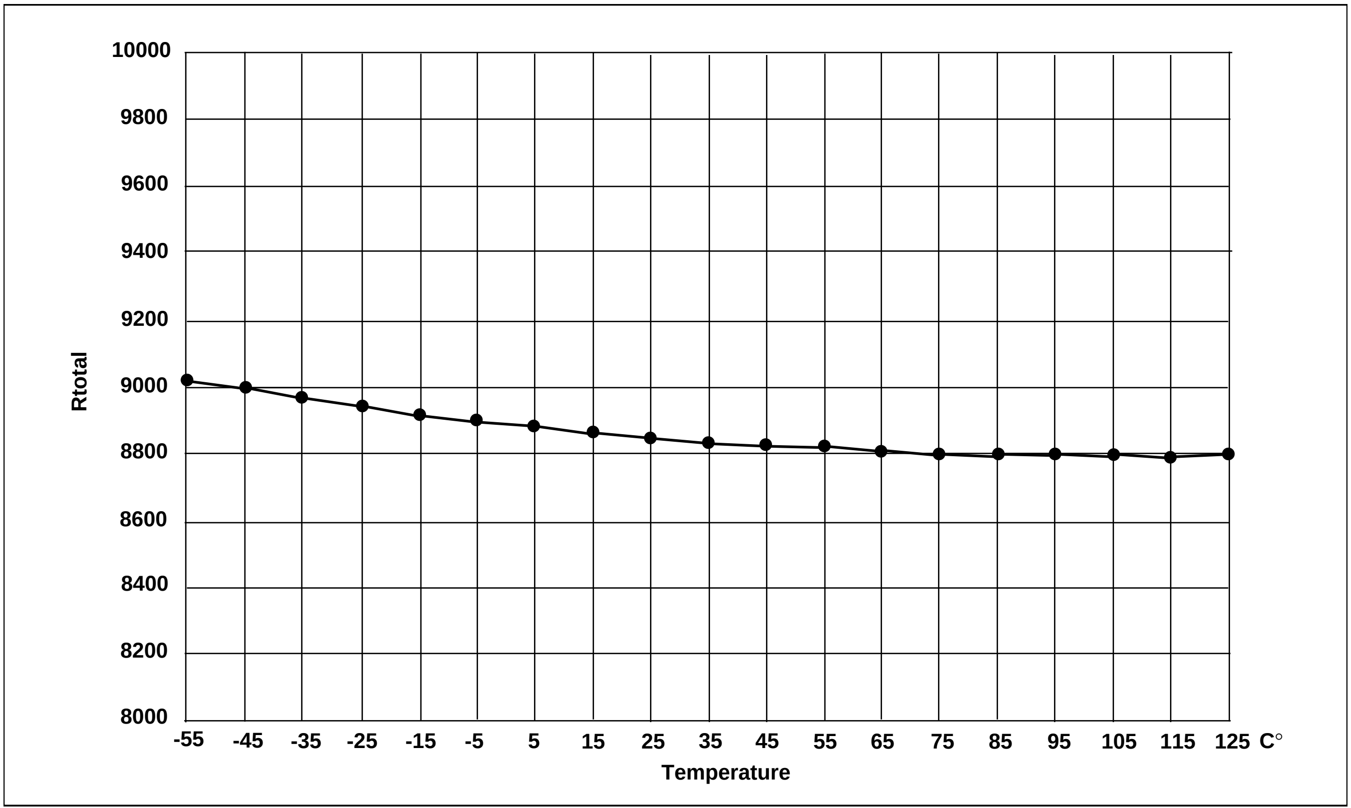


Notes: (6) Typical values are for T_A = 25°C and nominal supply voltage.
(7) This parameter is periodically sampled and not 100% tested.
(8) MI in the A.C. timing diagram refers to the minimum incremental change in the V_W output due to a change in the wiper position.

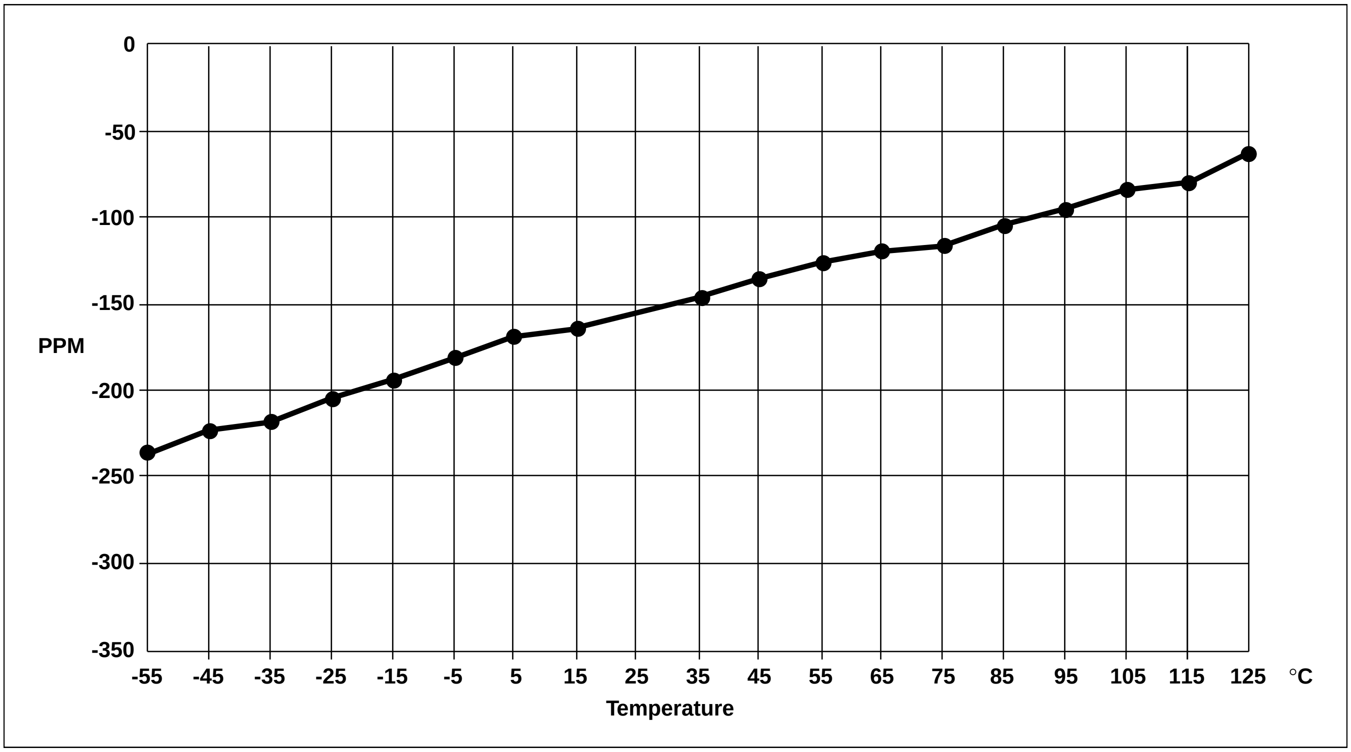
TYPICAL NOISE



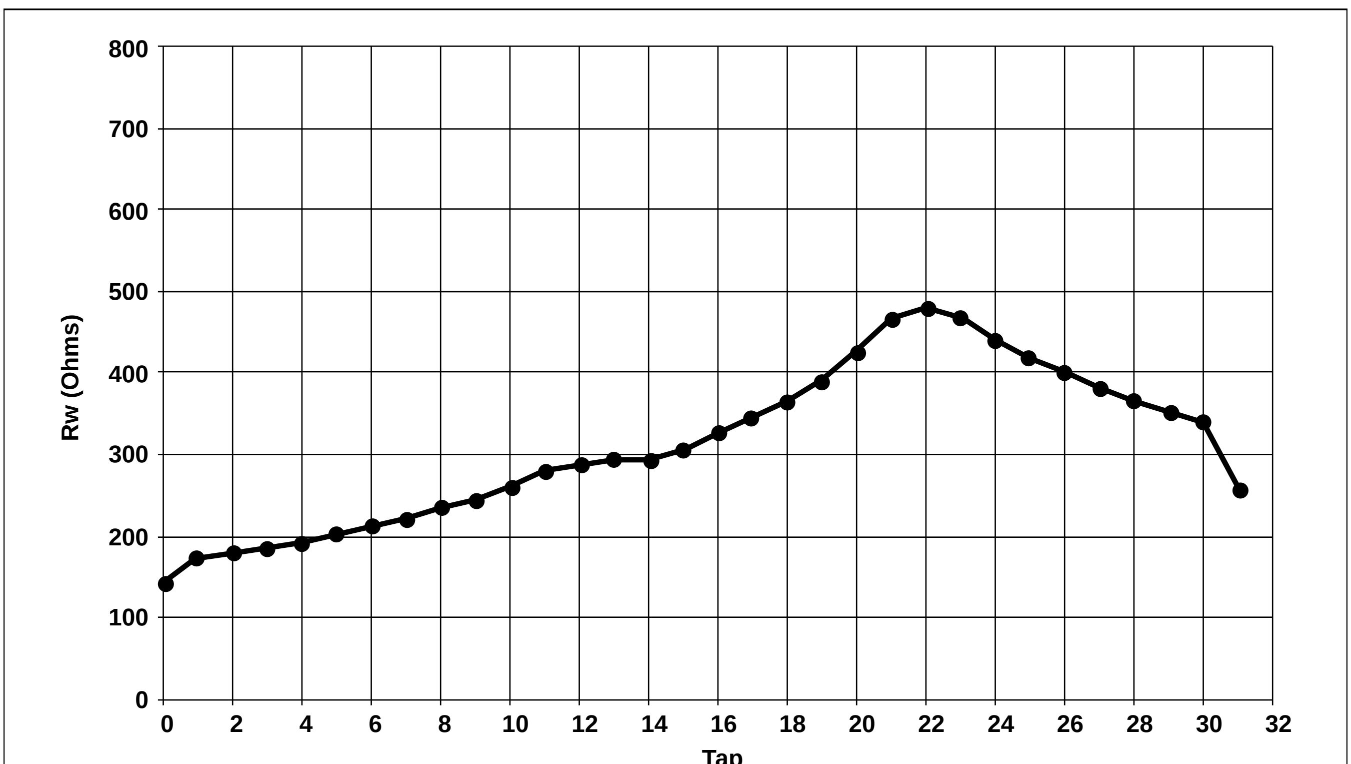
TYPICAL RTOTAL vs. TEMPERATURE



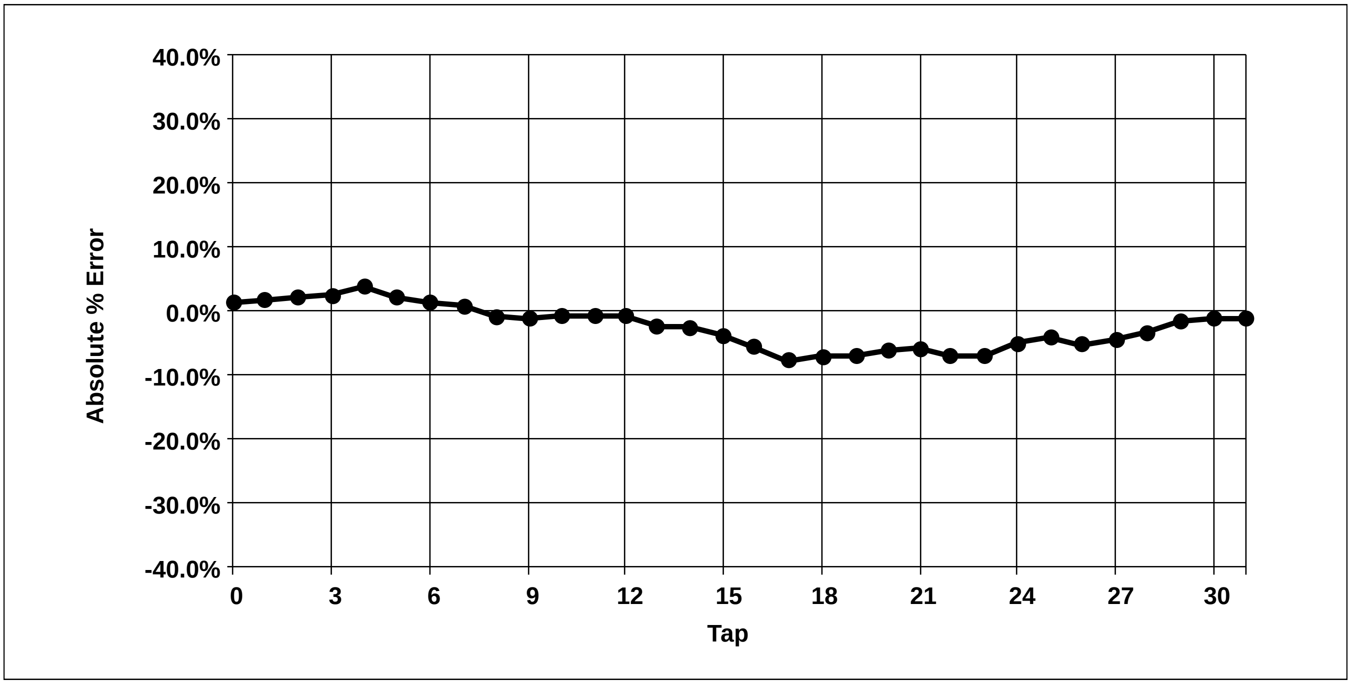
TYPICAL TOTAL RESISTANCE TEMPERATURE COEFFICIENT



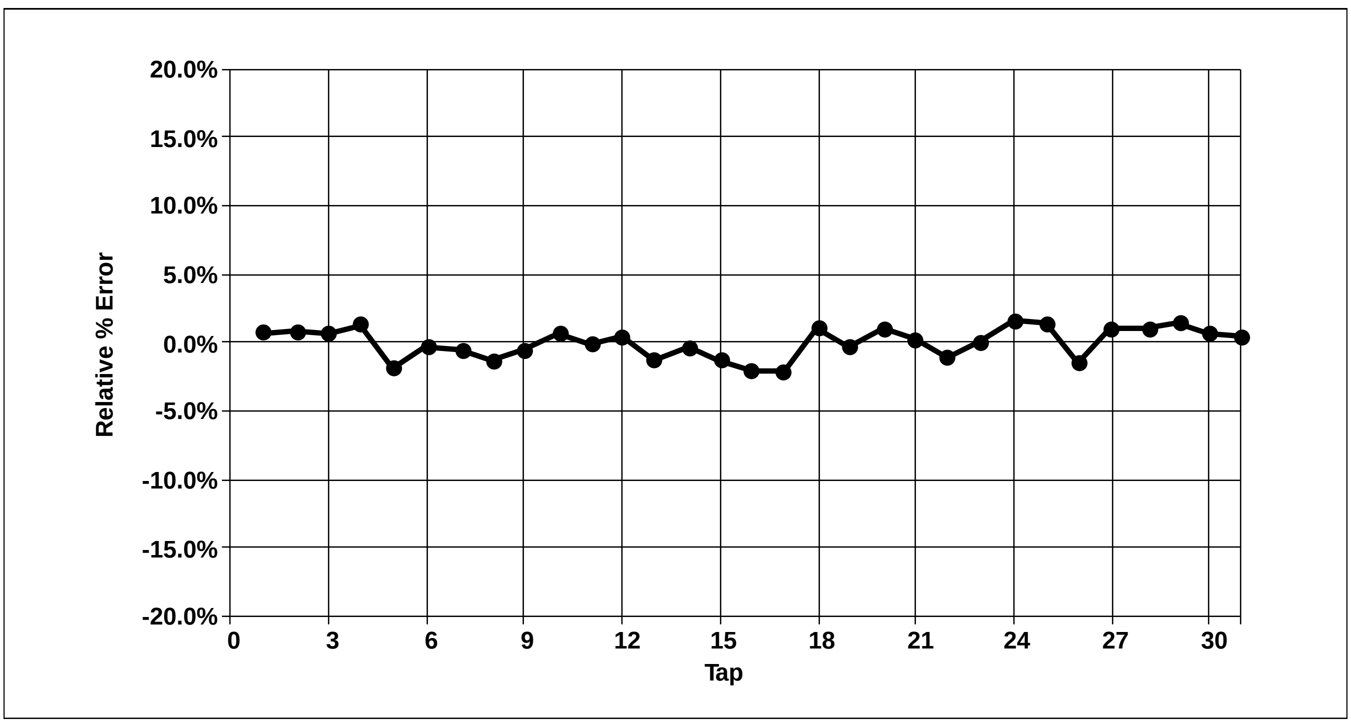
TYPICAL WIPER RESISTANCE



TYPICAL ABSOLUTE % ERROR PER TAP POSITION

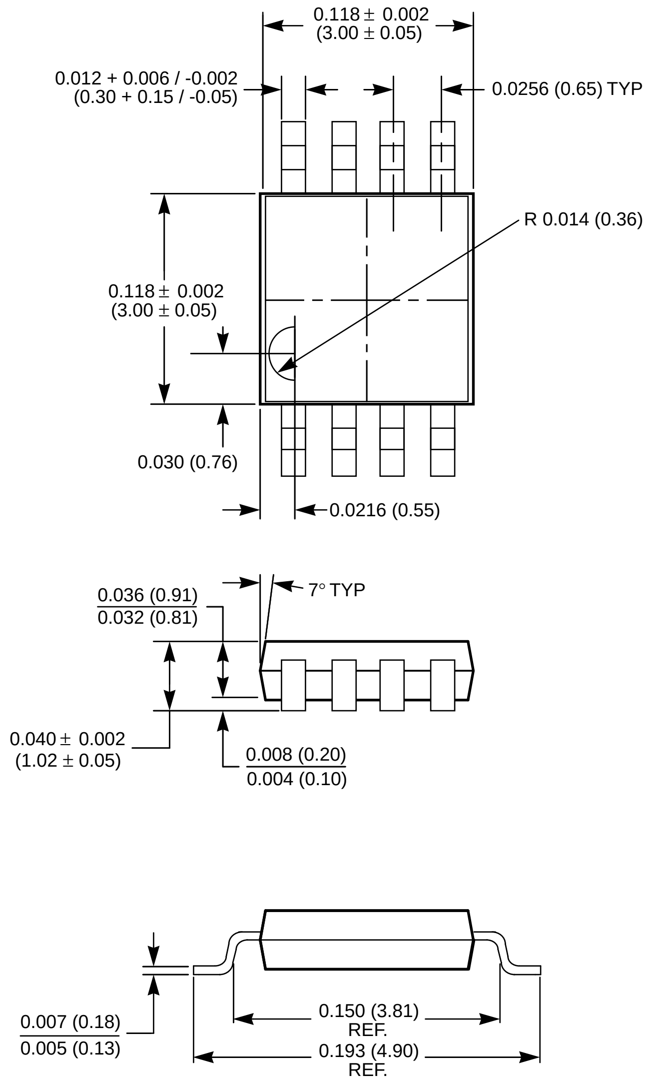


TYPICAL RELATIVE % ERROR PER TAP POSITION



PACKAGING INFORMATION

8-LEAD MINIATURE SMALL OUTLINE GULL WING PACKAGE TYPE M



NOTE:
1. ALL DIMENSIONS IN INCHES AND (MILLIMETERS)

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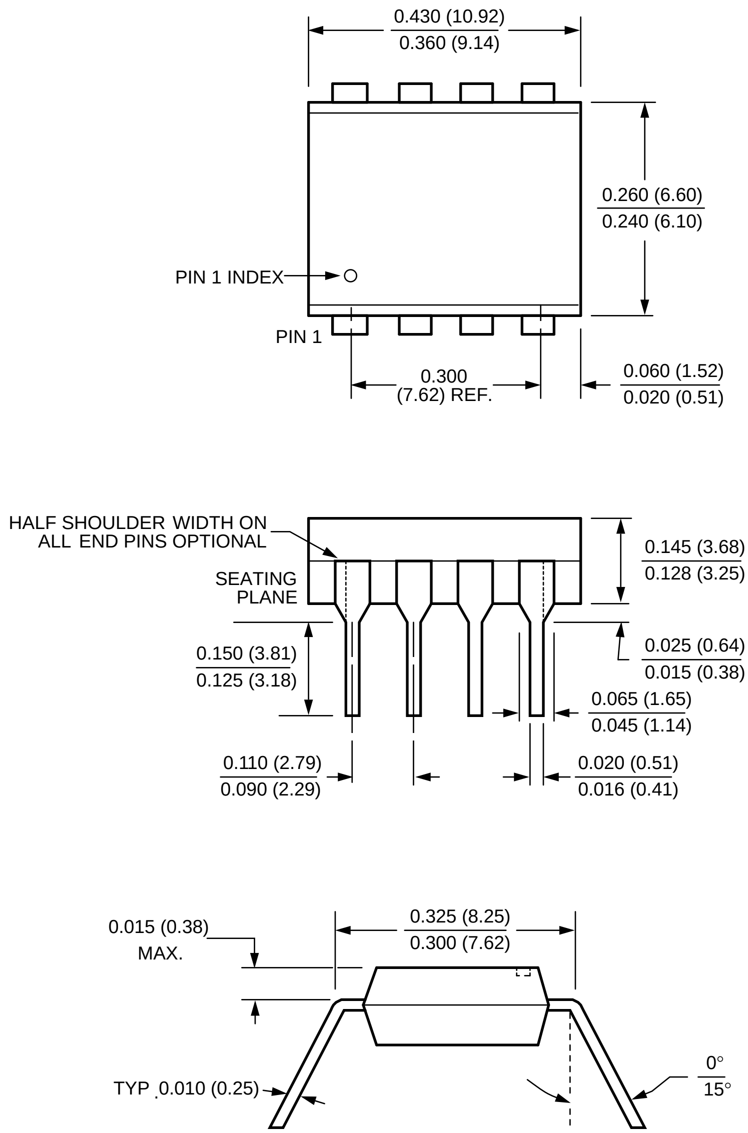
PACKAGING INFORMATION

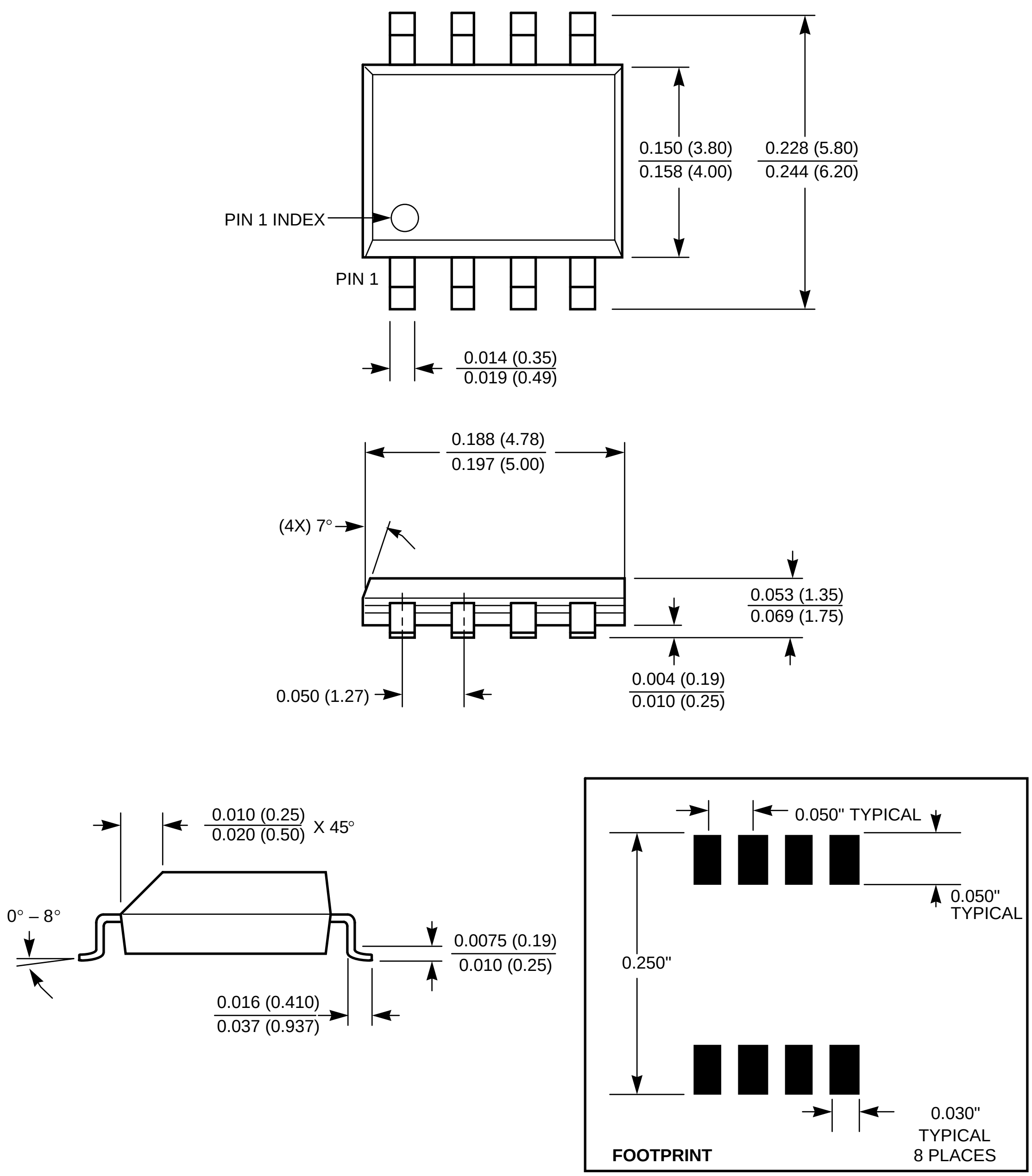
8-LEAD PLASTIC DUAL IN-LINE PACKAGE TYPE P



NOTE:
1. **ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)**
2. **PACKAGE DIMENSIONS EXCLUDE MOLDING FLASH**

PACKAGING INFORMATION

8-LEAD PLASTIC SMALL OUTLINE GULL WING PACKAGE TYPE S



NOTE: ALL DIMENSIONS IN INCHES (IN PARENTHESES IN MILLIMETERS)

ORDERING INFORMATION

X9315X X X X

V_{CC} Limits
Blank = 5V ±10%
–2.7 = 2.7V to 5.5V

Temperature Range
Blank = Commercial = 0°C to +70°C
I = Industrial = –40°C to +85°C

Package
M = 8-Lead MSOP
P = 8-Lead Plastic DIP
S = 8-Lead SOIC

End to End Resistance
Z = 1KΩ
W = 10KΩ