APPLICATION NOTES
A V A I L A B L E
AN99 • AN115 • AN120 • AN124 • AN133 • AN134

Low Noise, Low Power, Volatile

XICOR®

X9015

Single Digitally Controlled (XDCP™) Potentiometer

FEATURES

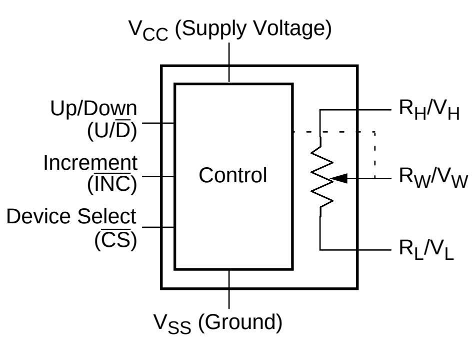
- **32 taps**
- **Three-wire up/down serial interface**
- **V_{CC} = 2.7V–5V**
- **Operating I_{CC} = 50µA max.**
- **Standby current = 1µA max.**
- **R_{TOTAL} = 10KΩ, 50KΩ, 100KΩ**
- **Packages SOIC-8, MSOP-8**

DESCRIPTION

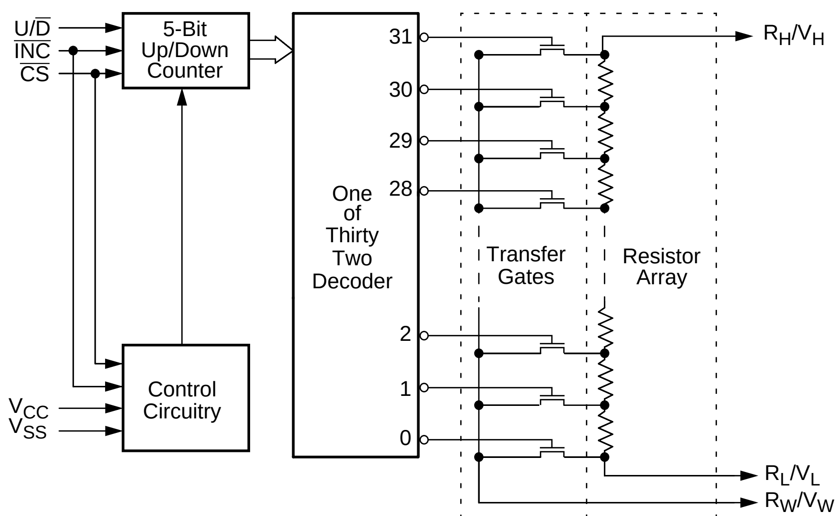
The Xicor X9015 is a 32 tap potentiometer that is volatile. The device consists of a string of 31 resistors that can be programmed to connect the R_W/V_W wiper output with any of the nodes between the connecting resistors. The connection point of the wiper is determined by information communicated to the device on the 3-wire port. The 3-wire port changes the tap position by a falling edge on the increment pin. The direction the wiper moves is determined by the state of the up/down pin. The wiper position at power up is Tap #15.

The X9015 can be used in a wide variety of applications that require a digitally controlled variable resistor to set analog values.

BLOCK DIAGRAM



General



Detailed

XDCP is a trademark of Xicor, Inc.

PIN DESCRIPTIONS

R_H/V_H and R_L/V_L

The high (R_H/V_H) and low (R_L/V_L) terminals of the X9015 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is V_{SS} and the maximum is V_{CC}. The terminology of R_L/V_L and R_H/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.

R_W/V_W

R_W/V_W is the wiper terminal and is 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 200Ω at V_{CC} = 5V. At power up the wiper position is at Tap #15. (V_L/R_L = Tap #0).

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

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

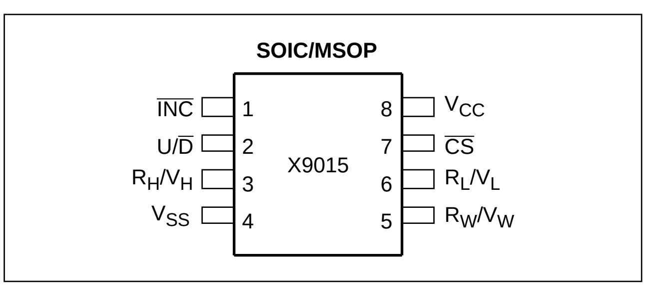
Increment ($\overline{INC}$)

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. When $\overline{CS}$ is returned HIGH while the $\overline{INC}$ input is also HIGH the X9015 will be placed in the low power standby mode until the device is selected once again.

PIN CONFIGURATION



PIN NAMES

Symbol	Description
R_H/V_H	High terminal
R_W/V_W	Wiper terminal
R_L/V_L	Low terminal
V_{SS}	Ground
V_{CC}	Supply voltage
$U/\overline{D}$	Up/Down control input
$\overline{INC}$	Increment control input
$\overline{CS}$	Chip select control input

PRINCIPLES OF OPERATION

There are two sections of the X9015: the input control, counter and decode section; 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. The resistor array is comprised of 31 individual resistors connected in series.

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 electronic switches on the device operate in a "make before break" mode when the wiper changes tap positions. If the wiper is moved several positions, multiple taps are connected to the wiper for t_{IW} (INC to V_W change). The R_{TOTAL} value for the device can temporarily be reduced by a significant amount if the wiper is moved several positions.

When the device is powered-down, the wiper position is lost. When power is restored, the wiper is set to Tap #15.

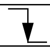
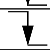
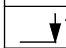
INSTRUCTIONS AND PROGRAMMING

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 device 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 five bit counter. The output of this counter is decoded to select one of thirty two wiper positions along the resistive array.

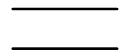
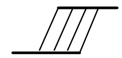
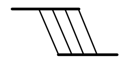
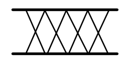
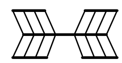
The system may select the X9015, move the wiper and deselect the device. The new wiper position will be maintained until changed by the system or until a power-up/down cycle.

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

MODE SELECTION

$\overline{CS}$	$\overline{INC}$	U/$\overline{D}$	Mode
L		H	Wiper up
L		L	Wiper down
*	H	X	Standby mode
L	L	X	Normal mode

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

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
I_W (10 seconds) .... ±7.5mA

COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only; functional operation of the device (at these or any other conditions above those listed in the operational sections of this specification) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING CONDITIONS

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

Supply Voltage (V_{CC})	Limits
X9015	5V ±10%
X9015-2.7	2.7V to 5.5V

POTENTIOMETER CHARACTERISTICS (Over recommended operating conditions unless otherwise stated.)

Symbol	Parameter	Limits				Test Conditions/Notes
		Min.	Typ.	Max.	Unit	
R_{TOTAL}	End to End Resistance Variation	–20		+20	%	
V_{VH}	V_H/R_H Terminal Voltage	0		V_{CC}	V	
V_{VL}	V_L/R_L Terminal Voltage	0		V_{CC}	V	
	Power Rating			10	mW	$R_{TOTAL} \le 1\ K\Omega$
R_W	Wiper Resistance		200	400	Ω	I_W = 1mA, V_{CC} = 5V
R_W	Wiper Resistance		400	1000	Ω	I_W = 1mA, V_{CC} = 2.7V
I_W	Wiper Current	-3.75		3.75	mA	
	Noise		-120		dBV	Ref: 1kHz
	Resolution		3		%	
	Absolute Linearity(1)	-1		+1	MI(3)	$V_{w(n)(actual)}–V_{w(n)(expected)}$
	Relative Linearity(2)	-0.2		+0.2	MI(3)	$V_{w(n+1)}–[V_{w(n)+MI}]$
	R_{TOTAL} Temperature Coefficient		±300		ppm/°C	
	Ratiometric Temperature Coefficient			±20	ppm/°C	
$C_H/C_L/C_W$	Potentiometer Capacitances		10/10/25		pF	See circuit #3

POWER UP AND DOWN REQUIREMENTS

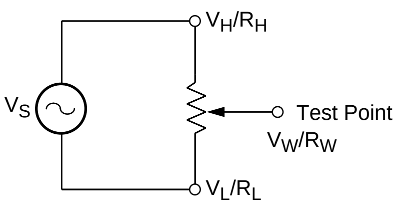
The are no restrictions on the power-up or power-down conditions of V_{CC} and the voltages applied to the potentiometer pins provided that V_{CC} is always more positive than or equal to V_H, V_L, and V_W, i.e., $V_{CC} \ge V_H, V_L, V_W$. The V_{CC} ramp rate spec is always in effect.

Notes: (1) Absolute Linearity is utilized to determine actual wiper voltage versus expected voltage = ($V_{w(n)}$(actual)–$V_{w(n)}$(expected)) = ±1 MI Maximum.
(2) Relative Linearity is a measure of the error in step size between taps = $V_{W(n+1)}$ – [$V_{w(n)}$ + MI] = ±0.2 MI.
(3) 1 MI = Minimum Increment = R_{TOT}/31.
(4) Typical values are for T_A = 25°C and nominal supply voltage.
(5) This parameter is periodically sampled and not 100% tested.

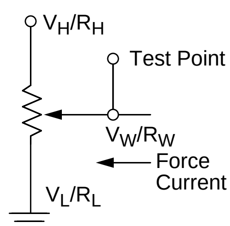
D.C. OPERATING CHARACTERISTICS (Over recommended operating conditions unless otherwise specified)

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 @ max. t_{CYC}
I_{CC2}	V_{CC} active current (Store) (EE-PROM Store)			400	µA	$\overline{CS}$ = V_{IH}, U/$\overline{D}$ = V_{IL} or V_{IH} and $\overline{INC}$ = V_{IH} @ max. t_{WR}
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	V_{CC} x 0.7		V_{CC} + 0.5	V	
V_{IL}	$\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ input LOW voltage	–0.5		V_{CC} x 0.1	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

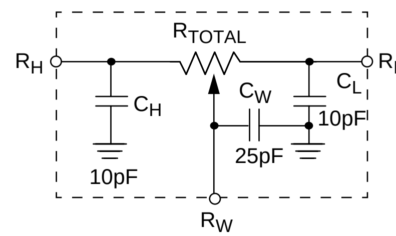
Test Circuit #1



Test Circuit #2



Circuit #3 SPICE Macro Model



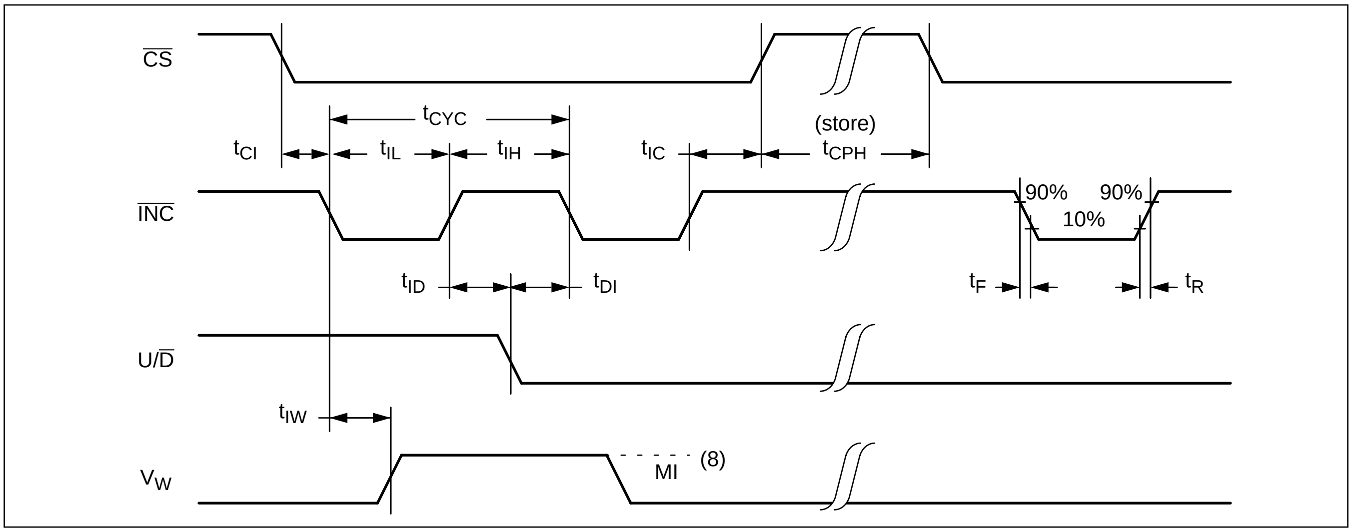
A.C. CONDITIONS OF TEST

Input pulse levels	0V to 3V
Input rise and fall times	10ns
Input reference levels	1.5V

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

Symbol	Parameter	Limits			Unit
		Min.	Typ.(6)	Max.	
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_{CPH}	$\overline{CS}$ deselect time (STORE)	10			ms
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	V/ms
t_{WR}	Store cycle		5	10	ms

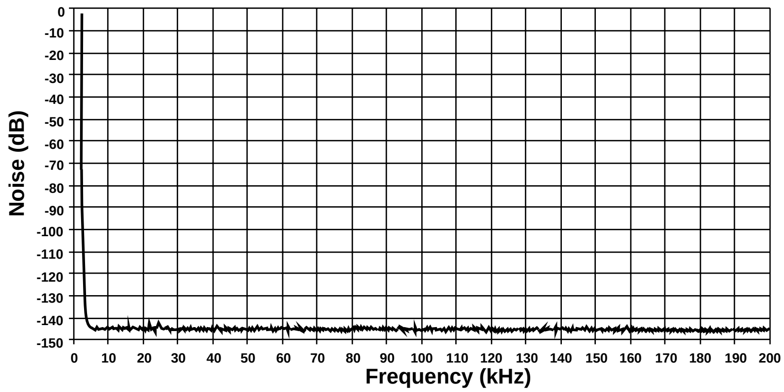
A.C. TIMING



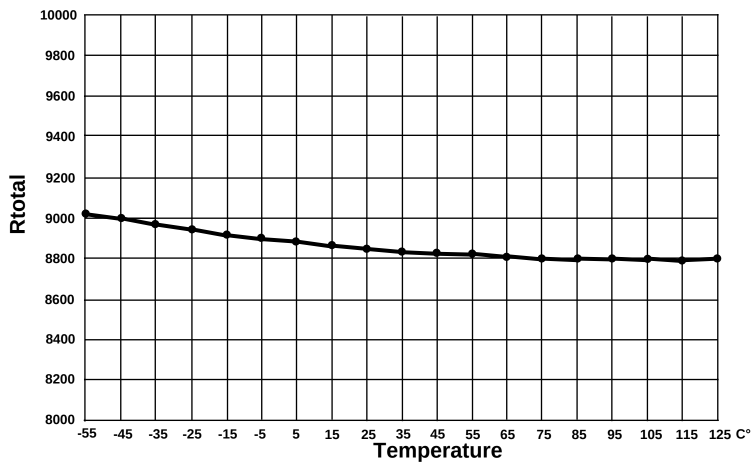
Notes: (6) Typical values are for T_A = 25°C and nominal supply voltage.
(7) This parameter is periodically sampled and not 100% tested.
(8) MI in the A.C. timing diagram refers to the minimum incremental change in the V_W output due to a change in the wiper position.

PERFORMANCE CHARACTERISTICS (TYPICAL)

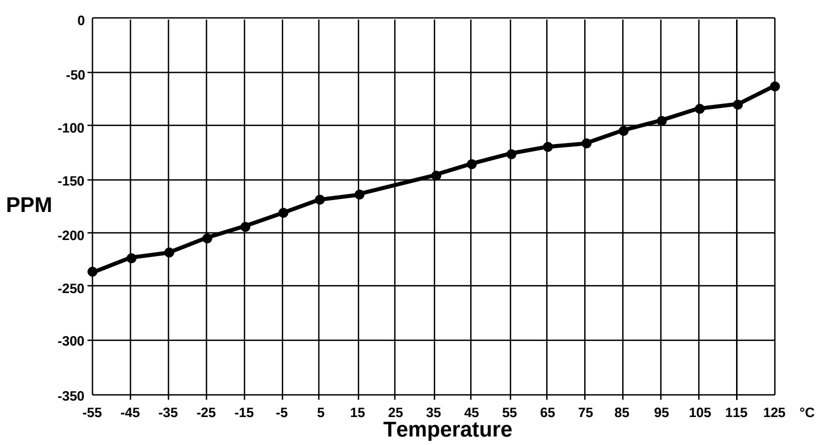
Typical Noise



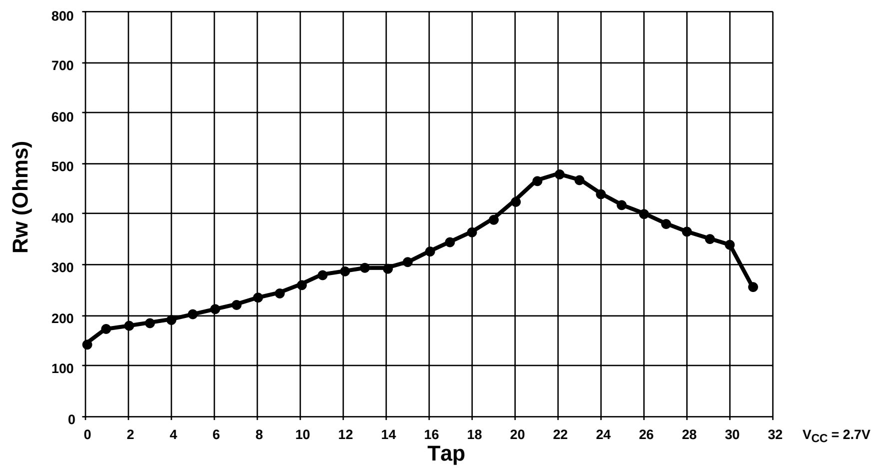
Typical Rtotal vs. Temperature



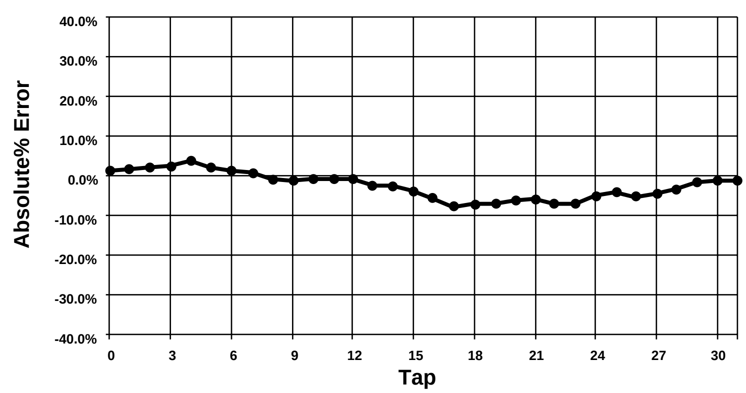
Typical Total Resistance Temperature Coefficient



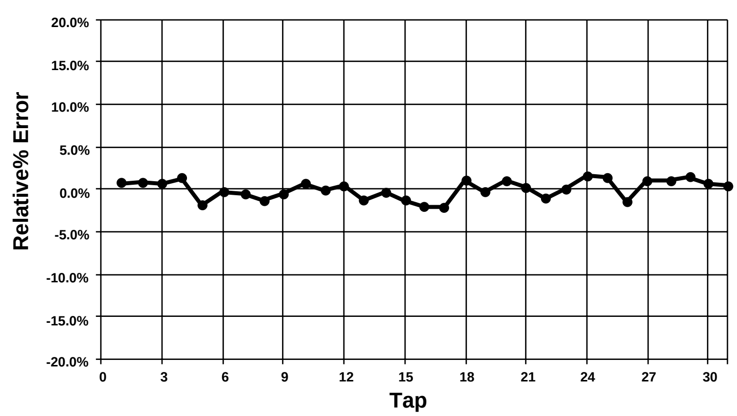
Typical Wiper Resistance



Typical Absolute% Error per Tap Position



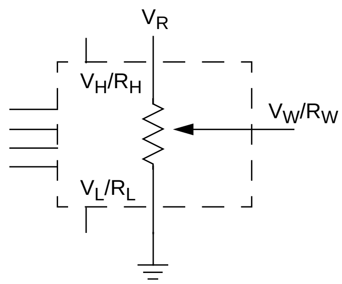
Typical Relative% Error per Tap Position



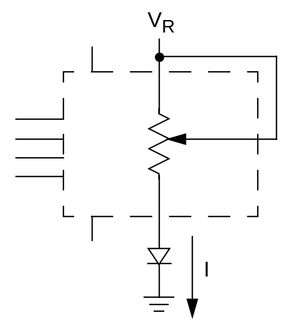
APPLICATIONS INFORMATION

Electronic digitally controlled potentiometers provide two powerful application advantages; (1) the variability and reliability of a solid-state potentiometer, and (2) the flexibility of computer-based digital controls.

Basic Configurations of Electronic Potentiometers



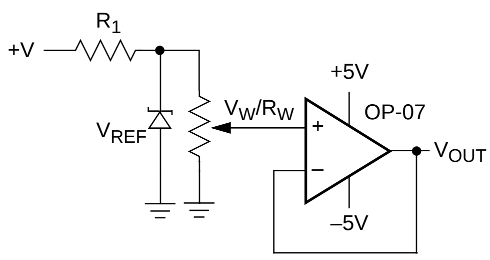
Three terminal potentiometer;
variable voltage divider



Two terminal variable resistor;
variable current

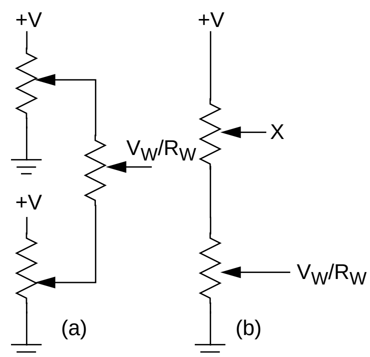
Basic Circuits

Buffered Reference Voltage

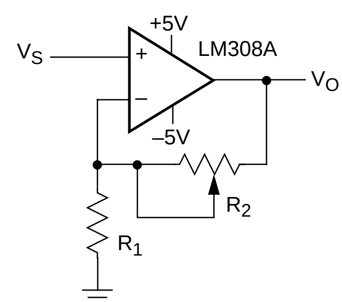


$V_{OUT} = V_W$

Cascading Techniques

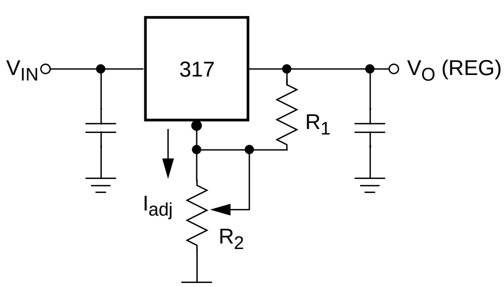


Noninverting Amplifier



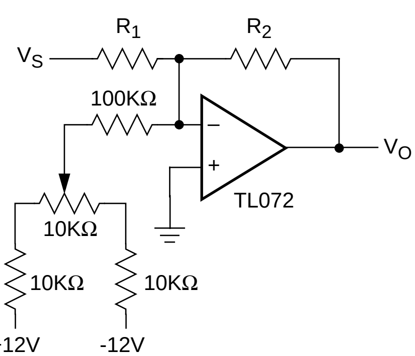
$V_O = (1+R_2/R_1)V_S$

Voltage Regulator

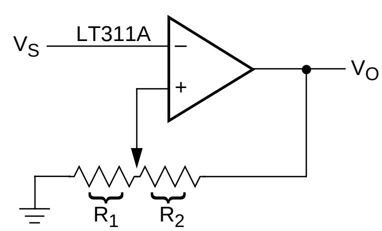


$V_O\ (REG) = 1.25V\ (1+R_2/R_1)+I_{adj}\ R_2$

Offset Voltage Adjustment



Comparator with Hysteresis

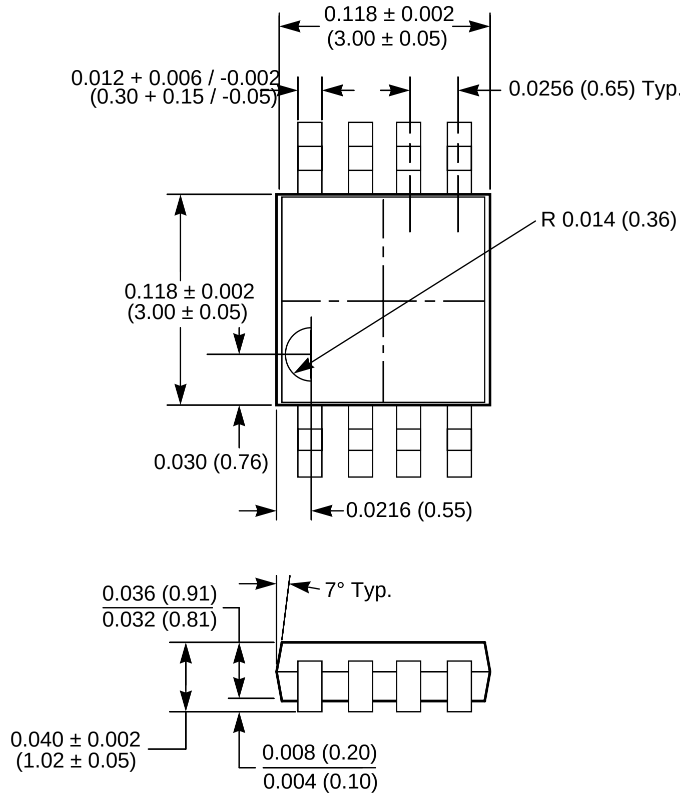


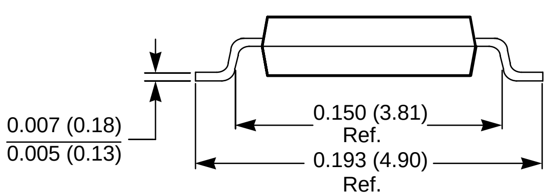
$V_{UL} = \{R_1/(R_1+R_2)\}\ V_O(max)$
$V_{LL} = \{R_1/(R_1+R_2)\}\ V_O(min)$

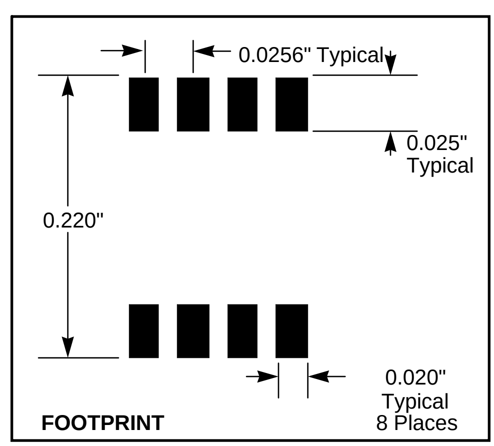
(for additional circuits see AN115)

MSOP PACKAGING INFORMATION

8-Lead Miniature Small Outline Gull Wing Package Type M





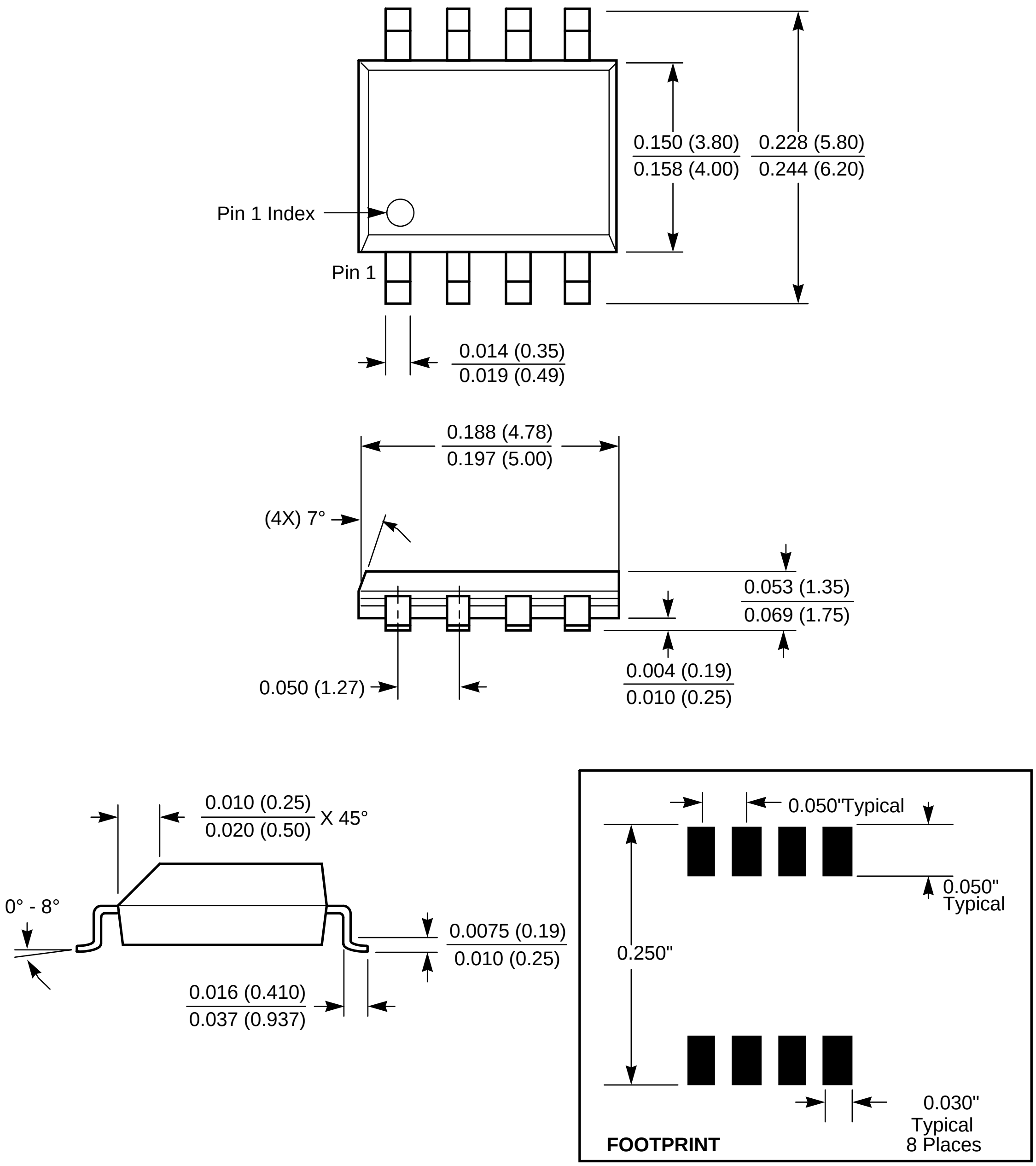


NOTE:

1. ALL DIMENSIONS IN INCHES AND (MILLIMETERS)

SOIC PACKAGING INFORMATION

8-Lead Plastic Small Outline Gull Wing Package Type S



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

ORDERING INFORMATION

X9015 X X X X

V_{CC} Limits
–2.7 = 2.7V to 5.5V

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

Package
S8 = 8-Lead SOIC
M8 = 8-Lead MSOP

End to End Resistance
U = 50KΩ

Physical Characteristics

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

Part Marking

MSOP Package	Top Mark
X9015UM8	ABB
X9015UM8-2.7	ABC
X9015UM8I	ABD
X9015UM8I-2.7	ABE