

# Application Notes

## Precision Potentiometers

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**PRECISION POTENTIOMETERS/  
POSITION SENSORS**

**1 TERMS AND DEFINITIONS**

The terms and definitions used in this section have been edited from the Variable Resistive Components Institute (VRCI) data for precision potentiometers. VRCI publishes generally accepted terms, definitions and test standards for precision potentiometers and for other variable resistive devices. If you would like additional information or definition on industry standards, please contact one of our application engineers.

1.1 LIST OF SYMBOLS

C	Conformity
CT	Center Tap
CW	Clockwise
CCW	Counterclockwise
E	Total Applied Voltage
e	Output Voltage
$e_i$	Inphase Output Voltage
$e_q$	Quadrature Voltage
$e/E$	Output Ratio (Output Voltage Ratio)
$V_e$	End Voltage
$R_T$	Total Resistance
$R_L$	Load Resistance
$R_e$	End Resistance
TC	Temperature Coefficient of Resistance
RTC	Resistance-Temperature Characteristic
A	Output Slope
G	Gradient
$\theta$	Shaft Position
$\phi$	Phase Shift
$\theta_T$	Theoretical Electrical Travel
$\theta_A$	Actual Electrical Travel

1.2 GENERAL TERMS

1.2.1 PRECISION POTENTIOMETER:

A mechanical-electrical transducer dependent upon the relative position of a moving contact (wiper) and a resistance element for its operation. It delivers to a high degree of accuracy a voltage output that is some specified function of applied voltage and shaft position.

1.2.1.1 WIREWOUND PRECISION  
POTENTIOMETER:

A precision potentiometer characterized by a resistance element made up of turns of wire on which the wiper contacts only a small portion of each turn.

1.2.1.2 NONWIREWOUND PRECISION  
POTENTIOMETER:

A precision potentiometer characterized by the continuous nature of the resistance element in the direction of wiper travel.

1.2.3 CUP:

A single mechanical section of a potentiometer which may contain one or more electrical resistance elements.

1.2.4 GANG:

An assembly of two or more cups on a common operating shaft.

1.2.5 SHAFT:

The mechanical input element of the potentiometer.

1.2.6 SHAFT POSITION:

An indication of the position of the wiper relative to a reference point.

1.2.7 TERMINAL:

An external member that provides electrical access to the potentiometer resistance element and wiper.

1.2.8 INTEGRAL RESISTOR:

An internal or external resistor preconnected to the electrical element and forming an integral part of the cup assembly to provide a desired electrical characteristic. The resistor may be a separate entity, a part of the wirewound or nonwirewound resistance element or a layer type resistor formed on the same insulating substrate as the resistance element.

1.2.9 TEST POINT:

An additional terminal used only to facilitate measurements.

1.2.10 TAP

1.2.10.1 CURRENT TAP:

An electrical connection fixed to the resistance element which is capable of carrying rated element current and may distort the output characteristic.

**Note: Current taps on non-wirewound units commonly have significant width, but low resistance. See paragraph 3.13.**

1.2.10.2 VOLTAGE TAP:

An electrical connection fixed to the resistance element which introduces no significant distortion in the output characteristic. A voltage tap usually has significant tap resistance and may not be capable of carrying rated element current.

**Note: The distinction between current and voltage taps basically applies to taps on non-wirewound units. Most taps on wirewound potentiometers are attached to one turn of wire and can carry rated element current. They do not usually have an effect on resolution or output characteristics.**

2 INPUT AND OUTPUT TERMS

2.1 INPUT TERMS

2.1.1 TOTAL APPLIED VOLTAGE: (E)

The total voltage applied between the designated input terminals.

**Note: When plus (+) and minus (-) voltages are applied to the potentiometer, the Total Applied Voltage (commonly called peak-to-peak applied voltage) is equal to the sum of the two voltages. Each individual voltage is referred to as zero-to-peak applied voltage.**

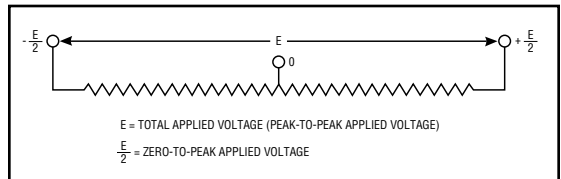
2.2 OUTPUT TERMS

2.2.1 OUTPUT VOLTAGE:

The voltage between the wiper and the designated reference point. Unless otherwise specified, the designated reference point is the CCW terminal.

2.2.2 OUTPUT RATIO:

The ratio of the Output Voltage to the designated input reference voltage. Unless otherwise specified, the reference voltage is the Total Applied Voltage (see Figure 2.1.1).



**FIGURE 2.1.1** Total Applied Voltage

2.2.3 TOTAL VARIABLE OUTPUT:

The difference between the maximum and minimum Output Ratios. These ratios correspond to the Minimum Voltages at each input terminal.

2.2.4 END VOLTAGE:

2.2.4.1 END VOLTAGE–WIREWOUND:

The voltage between the wiper terminal and an end terminal when the shaft is positioned at the corresponding End Point. End Voltage is expressed as a percent of the Total Applied Voltage.

2.2.4.2 END VOLTAGE–NONWIREWOUND:

The voltage between the wiper terminal and an end terminal when the shaft is positioned at the corresponding Theoretical End Point. End Voltage is expressed as a percent of the Total Applied Voltage.

**2.2.5 MINIMUM VOLTAGE:**

The smallest or lowest voltage between the wiper terminal and an end terminal when the shaft is positioned near the corresponding end of Electrical Continuity Travel. Minimum Voltage is expressed as a percent of the Total Applied Voltage.

**2.2.6 JUMP-OFF VOLTAGE (WIREWOUND POTENTIOMETERS ONLY):**

The magnitude of the first measurable voltage change as the wiper moves from the overtravel region onto the Actual Electrical Travel. It is expressed as a percent of the Total Applied Voltage.

**2.2.7 SHORTED SEGMENT:**

A portion of the resistance element over which the Output Ratio remains constant within specified limits as the wiper traverses the segment with a specified Load Resistance.

**2.2.8 OUTPUT SLOPE:**

The ratio between the rate of change of Output Ratio and the rate of change of shaft travel.  $\theta_A$  may be substituted for  $\theta_T$  where applicable.

MATHEMATICALLY: 
$$A = \frac{\Delta \frac{e}{E}}{\Delta \frac{\theta}{\theta_T}}$$

**Note: The theoretical output slope is the first derivative of the normalized Theoretical Function Characteristic.**

MATHEMATICALLY: 
$$A = \frac{df(\theta / \theta_T)}{d(\theta / \theta_T)} = \frac{d(e / E)}{d(\theta / \theta_T)}$$

**2.2.9 SLOPE RATIO:**

The ratio of the largest to the smallest Output Slopes of a monotonic Theoretical Function Characteristic.

**2.2.10 GRADIENT:**

The rate of change of Output Ratio relative to shaft travel.

MATHEMATICALLY: 
$$G = \frac{d(e / E)}{d\theta}$$

**2.3 LOAD TERMS**

**2.3.1 LOAD RESISTANCE: ( $R_L$ )**

The external resistance as seen by the Output Voltage (connected between the wiper and the designated reference point).

**Note: No load means an infinite Load Resistance.**

**2.3.2 LOADING ERROR:**

The difference between the Output Ratio with an infinite Load Resistance and the Output Ratio with a specified finite Load Resistance, at the same shaft position.

**Note: Elimination of Loading Error, by compensating the resistance element to give the desired output with a specified Load Resistance, is referred to as "Load Compensation."**

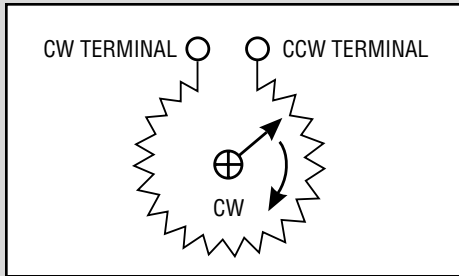
**3 ROTATION AND TRANSLATION**

**3.1 DIRECTION OF TRAVEL:**

For rotary potentiometers, clockwise (CW) or counterclockwise (CCW) when viewing the specified mounting end of the potentiometer. The designation of terminals in the figure corresponds to the direction of shaft travel.

For translatory potentiometers, "extending" or "retracting" when viewing the specified end of the potentiometer.

The Output Ratio and shaft position increases with clockwise (or extending) direction of travel unless otherwise specified.



**FIGURE 3.1** View of shaft and element from specified mounting end.

**3.2 TOTAL MECHANICAL TRAVEL:**

The total travel of the shaft between integral stops, under specified stop load. In potentiometers without stops, the mechanical travel is continuous.

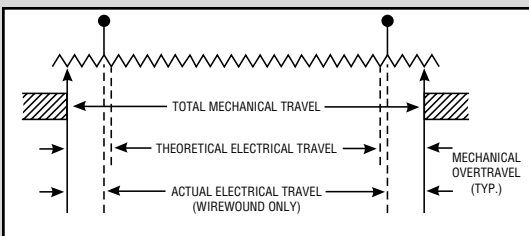
**3.3 MECHANICAL OVERTRAVEL**

**3.3.1 MECHANICAL OVERTRAVEL-WIREWOUND:**

The shaft travel between each End Point (or Theoretical End Point for Absolute Conformity or Linearity units) and its adjacent corresponding limit of Total Mechanical Travel.

**3.3.2 MECHANICAL OVERTRAVEL - NONWIREWOUND:**

The shaft travel between each Theoretical End Point and its adjacent corresponding limit of Total Mechanical Travel.



**FIGURE 3.3.2** Mechanical overtravel

**Note: The relationship of the electrical travels to each other and to the input terminals shown above is given for illustration only and may vary from one potentiometer to another.**

**3.4 BACKLASH:**

The maximum difference in shaft position that occurs when the shaft is moved to the same actual Output Ratio point from opposite directions.

**3.5 END POINT (WIREWOUND POTENTIOMETERS ONLY):**

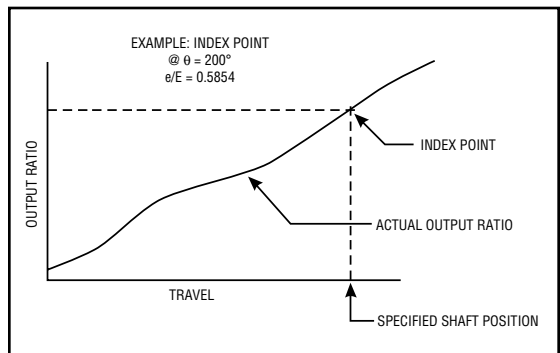
The shaft positions immediately before the first and after the last measurable change(s) in Output Ratio, after wiper continuity has been established, as the shaft moves in a specified direction.

**3.6 THEORETICAL END POINT:**

The shaft positions corresponding to the ends of the Theoretical Electrical Travel as determined from the Index Point.

**3.7 INDEX POINT:**

A point of reference fixing the relationship between a specified shaft position and the Output Ratio. It is used to establish a shaft position reference.



**FIGURE 3.7** Index point

**3.8 ACTUAL ELECTRICAL TRAVEL (WIREWOUND POTENTIOMETERS ONLY):**

The total travel of the shaft between End Points.

3.9 THEORETICAL ELECTRICAL TRAVEL:

The specified shaft travel over which the theoretical function characteristic extends between defined Output Ratio limits, as determined from the Index Point.

3.10 ELECTRICAL OVERTRAVEL

3.10.1 ELECTRICAL OVERTRAVEL -

WIREWOUND:

The shaft travel over which there is continuity between the wiper terminal and the resistance element beyond each end of the Actual Electrical Travel. (Theoretical Electrical Travel is substituted for Actual Electrical Travel in Absolute Conformity or Linearity units.)

3.10.2 ELECTRICAL OVERTRAVEL -

NONWIREWOUND:

The shaft travel over which there is continuity between the wiper terminal and the resistance element beyond each end of the Theoretical Electrical Travel.

3.11 ELECTRICAL CONTINUITY TRAVEL:

The total travel of the shaft over which electrical continuity is maintained between the wiper and the resistance element.

3.12 TAP LOCATION:

The position of a tap relative to some reference. This is commonly expressed in terms of an Output Ratio and/or a shaft position. When a shaft position is specified, the Tap Location is the center of the Effective Tap Width.

3.13 EFFECTIVE TAP WIDTH:

The travel of the shaft during which the voltage at the wiper terminal and the tap terminal are the same, as the wiper is moved past the tap in one direction.

**Note: In some instances, particularly nonwirewound pots, the tap width may be essentially zero (i.e., no flat zone), but the tap may have a significant effect on conformity. In these cases the term “Effective Tap Width” should not be applied. Instead, the effect of the tap on the output characteristics should be considered in terms of conformity.**

3.14 PHASING POINT - WHEN INDEX POINT (3.7) IS NOT EMPLOYED

3.14.1 PHASING POINT – WIREWOUND:

A reference point on a cup of a gang, usually an Output Ratio, an End Point or an intermediate tap.

3.14.2 PHASING POINT– NONWIREWOUND:

A reference point on a cup of a gang, usually an Output Ratio or an intermediate tap (not an end tap).

3.15 PHASING (SEE ALSO SIMULTANEOUS CONFORMITY PHASING PARA.5.10):

The relative alignment of the Phasing Points of each cup of a gang potentiometer.

**Note: Unless otherwise specified, phasing requirements apply to a single specified Phasing Point in each cup and all cups are aligned to the Phasing Point of the first cup.**

4 RESISTANCE

4.1 TOTAL RESISTANCE (DC INPUT IMPEDANCE):

The DC resistance between the input terminals with the shaft positioned so as to give a maximum resistance value.

4.2 DC OUTPUT IMPEDANCE:

The maximum DC resistance between the wiper and either end terminal with the input shorted.

4.3 MINIMUM RESISTANCE

4.3.1 MINIMUM RESISTANCE - WIREWOUND:

The resistance measured between the wiper terminal and any terminal with the shaft positioned to give a minimum value.

4.3.2 MINIMUM RESISTANCE - NONWIREWOUND:

Refer to Tap Resistance (4.5) or Minimum Voltage (2.2.5) for applicable definition.

4.4 END RESISTANCE

4.4.1 END RESISTANCE – WIREWOUND:

The resistance measured between the wiper terminal and an end terminal with the shaft positioned at the corresponding End Point.

4.4.2 END RESISTANCE –  
NONWIREWOUND:

Refer to End Voltage (2.2.4.2) for applicable definition.

4.5 TAP RESISTANCE (NONWIREWOUND  
POTENTIOMETERS ONLY):

The minimum resistance obtainable between a tap terminal and a wiper position on the resistance element, measured without drawer wiper current.

**Note: This definition applies only to intermediate taps. For End Terminations refer to End Voltage (2.2.4.2).**

4.6 APPARENT CONTACT RESISTANCE  
(NONWIREWOUND POTENTIOMETERS ONLY):

Refer to Output Smoothness (6.2).

4.7 EQUIVALENT NOISE RESISTANCE (ENR)

4.7.1 EQUIVALENT NOISE RESISTANCE–  
WIREWOUND:

Refer to Noise (6.1).

4.7.2 EQUIVALENT NOISE RESISTANCE–  
NONWIREWOUND:

Refer to Output Smoothness (6.2).

4.8 TEMPERATURE COEFFICIENT OF  
RESISTANCE (WIREWOUND  
POTENTIOMETERS ONLY):

The unit change in resistance per degree Celsius change from a reference temperature, expressed in parts per million per degree Celsius as follows:

$$T.C. = \frac{R_2 - R_1}{R_1 (T_2 - T_1)} \times 10^6$$

Where:

R<sub>1</sub> = Resistance at reference temperature in ohms.

R<sub>2</sub> = Resistance at test temperature in ohms.

T<sub>1</sub> = Reference temperature in degrees Celsius.

T<sub>2</sub> = Test temperature in degrees Celsius.

4.9 RESISTANCE - TEMPERATURE CHARACTERISTIC  
(NONWIREWOUND POTENTIOMETERS ONLY):

The change in Total Resistance over a specified temperature range expressed as a percent of the Total Resistance at a specified reference temperature.

$$RTC = \frac{R_2 - R_1}{R_1} \times 100$$

Where:

R<sub>1</sub> = Resistance at reference temperature in ohms.

R<sub>2</sub> = Maximum or minimum resistance at any of the test temperatures, in ohms.

**Note: Although Temperature Coefficient of Resistance can be applied to Nonwirewounds, the Tempo of many Nonwirewounds is not linear over the normal use temperature range and this can be misleading.**

**5 CONFORMITY AND LINEARITY**

**5.1 FUNCTION CHARACTERISTIC:**

The relationship between the Output Ratio and the shaft position.

MATHEMATICALLY:  $\frac{e}{E} = f(\theta)$

**5.2 CONFORMITY:**

The fidelity of the relationship between the actual function characteristic and the theoretical function characteristic.

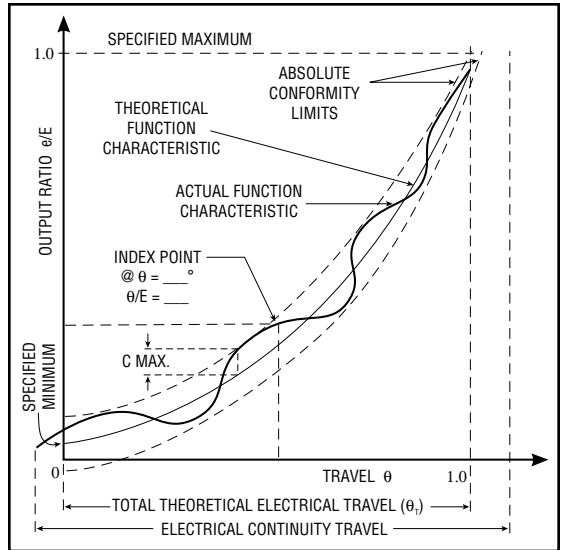
MATHEMATICALLY:  $\frac{e}{E} = f(\theta)$

**5.3 ABSOLUTE CONFORMITY:**

The maximum deviation of the actual function characteristic from a fully defined theoretical function characteristic. It is expressed as a percentage of the Total Applied Voltage and measured over the Theoretical Electrical Travel. An Index Point on the actual output is required.

MATHEMATICALLY:  $\frac{e}{E} = f(\theta / \theta_t) \pm C; 0 \leq \theta \leq \theta_t$

**Note: The theoretical function characteristic is assumed to be a smooth curve when it can be described by a mathematical expression. When empirical data are provided, the points are assumed to be joined by straight line segments.**



**FIGURE 5.3** Absolute Conformity

**5.4 LINEARITY:**

A specific type of conformity where the theoretical function characteristic is a straight line.

MATHEMATICALLY:  $\frac{e}{E} = A(\theta / \theta_t) + B \pm C$

Where:

A is given slope; B is given intercept at  $\theta = 0$ .

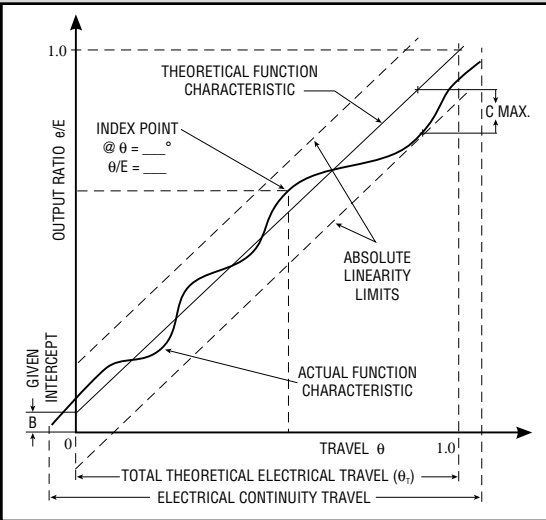
**5.5 ABSOLUTE LINEARITY:**

The maximum deviation of the actual function characteristic from a fully defined straight reference line. It is expressed as a percentage of the Total Applied Voltage and measured over the Theoretical Electrical Travel. An Index Point on the actual output is required.

The straight reference line may be fully defined by specifying the low and high theoretical end Output Ratios separated by the Theoretical Electrical Travel. Unless otherwise specified, these end Output Ratios are 0.0 and 1.0, respectively.

MATHEMATICALLY: 
$$\frac{e}{E} = A(\theta / \theta_1) + B \pm C$$

Where:  
 A is given slope; B is given intercept at  $\theta = 0$ .  
 Unless otherwise specified:  
 A = 1; B = 0.



**FIGURE 5.5** Absolute linearity

**5.6 TERMINAL BASED LINEARITY**  
 (WIREWOUND POTENTIOMETERS ONLY):  
 The maximum deviation, expressed as a percent of the Total Applied Voltage, of the actual function characteristic from a straight reference line drawn through the specified minimum and maximum Output Ratios which are separated by the Actual Electrical Travel. Unless otherwise specified, minimum and maximum Output Ratios are, respectively, zero and 100% of Total Applied Voltage.

MATHEMATICALLY: 
$$\frac{e}{E} = A(\theta / \theta_1) + B \pm C$$

Where:  
 A is given slope; B is given intercept at  $\theta = 0$ .  
 Unless otherwise specified:  
 A = 1; B = 0.

**5.7 ZERO BASED LINEARITY**  
 (WIREWOUND POTENTIOMETERS ONLY):

The maximum deviation, expressed as a percent of Total Applied Voltage, of the actual function characteristic from a straight reference line drawn through the specified minimum Output Ratio, extended over the Actual Electrical Travel, with its slope chosen to minimize the maximum deviations. Any specified End Voltage requirement may limit the slope of the reference line. Unless otherwise specified, the specified minimum Output Ratio will be zero.

MATHEMATICALLY: 
$$\frac{e}{E} = P(\theta / \theta_1) + B \pm C$$

Where:  
 P is unspecified slope limited by the End Voltage requirements, at the maximum output ratio end.  
 Unless otherwise specified:  
 B = 0.

**5.8 INDEPENDENT LINEARITY (BEST STRAIGHT LINE)**

**5.8.1 INDEPENDENT LINEARITY - WIREWOUND:**  
 The maximum deviation, expressed as a percent of the Total Applied Voltage, of the actual function characteristic from a straight reference line with its slope and position chosen to minimize deviations over the Actual Electrical Travel, or any specified portion thereof.

**Note: End Voltage requirements, when specified, will limit the slope and position of the reference line.**

$$\text{MATHEMATICALLY: } \frac{e}{E} = P(\theta / \theta_A) + Q \pm C$$

Where:

P is unspecified slope; Q is unspecified intercept at  $\theta = 0$ . And both are chosen to minimize C but are limited by the End Voltage requirements.

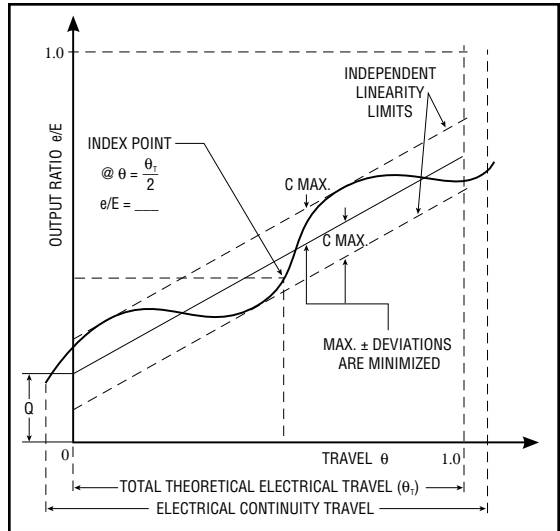
5.8.2 INDEPENDENT LINEARITY - NONWIREWOUND:

The maximum deviation of the actual function characteristics from a straight reference line with its slope and position chosen to minimize the maximum deviations. It is expressed as a percentage of the Total Applied Voltage and is measured over the specified Theoretical Electrical Travel. The slope of the reference line, if limited, must be separately specified. An Index Point on the actual output is required. Unless otherwise specified, the Index Point will be at  $\theta = \frac{\theta_T}{2}$ .

$$\text{MATHEMATICALLY: } \frac{e}{E} = P(\theta / \theta_T) + Q \pm C$$

Where:

P is unspecified slope; Q is unspecified intercept at



$\theta = 0$ . And both are chosen to minimize C but are limited by the End Voltage requirements.

**FIGURE 5.8.2** Independent linearity–nonwirewound

5.9 TOLERANCE LIMITS

5.9.1 CONSTANT LIMITS:

Permissible Conformity deviations specified as a percentage of the Total Applied Voltage.

**Note: Unless otherwise specified, all definitions in this document employ Constant Limits.**

5.9.1.1 ZERO-TO-PEAK CONSTANT LIMITS:

Permissible Conformity deviations specified as a percentage of Zero-To-Peak Applied Voltage.

**Note: The numerical value of zero-to-peak errors is double that of equal peak-to-peak errors, because the reference zero-to-peak applied voltage is one-half of the Total (peak-to-peak) Applied Voltage (see 2.1.1).**

5.9.2 PROPORTIONAL LIMITS:

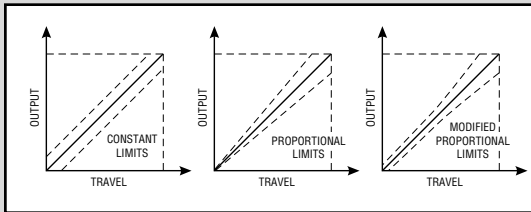
Permissible Conformity deviations specified as a percentage of the theoretical Output Ratio at the point of measurement.

**Note: Proportional limits may become impossibly restrictive in the vicinity of zero theoretical output and should be modified to provide a**

**practical tolerance in that region, if the theoretical Output Ratio approaches zero.**

**5.9.3 MODIFIED PROPORTIONAL LIMITS:**

Any combination of Constant and Proportional



Limits.

**FIGURE 5.9.3** Tolerance limits

**5.10 SIMULTANEOUS CONFORMITY PHASING:**

The relative alignment of the cups of a gang potentiometer, from a common index point, such that the Output Ratios of all cups fall within their respective Conformity limits over the Theoretical Electrical Travel.

**5.11 VOLTAGE TRACKING ERROR:**

The difference, at any shaft position, between the Output Ratios of any two commonly actuated similar electrical elements, expressed as a percentage of the single total voltage applied to them.

**6 GENERAL ELECTRICAL CHARACTERISTICS**

**6.1 NOISE (WIREWOUND POTENTIOMETERS ONLY):**

Any spurious variation in the electrical output not present in the input, defined quantitatively in terms of an equivalent parasitic, transient resistance in ohms, appearing between the contact and the resistance element when the shaft is rotated or translated. The Equivalent Noise Resistance is defined independently of the resolution, the functional characteristics, and the total travel. The magnitude of the Equivalent Noise Resistance is the maximum departure from a specified reference line. The wiper of the potentiometer is required to be

excited by a specified current and moved at a specified speed.

**6.2 OUTPUT SMOOTHNESS (NONWIREWOUND POTENTIOMETERS ONLY):**

Output Smoothness is a measurement of any spurious variation in the electrical output not present in the input. It is expressed as a percentage of the Total Applied Voltage and measured for specified travel increments over the Theoretical Electrical Travel. Output Smoothness includes effects of contact resistance variations, resolution and other micrononlinearities in the output.

**6.3 RESOLUTION:**

A measure of the sensitivity to which the Output Ratio of the potentiometer may be set.

**6.4 THEORETICAL RESOLUTION (LINEAR WIREWOUND POTENTIOMETERS ONLY):**

The reciprocal of the number of turns of wire in resistance winding in the Actual Electrical Travel, expressed as a percentage.

$$N = \text{Total number of resistance wire turns.}$$

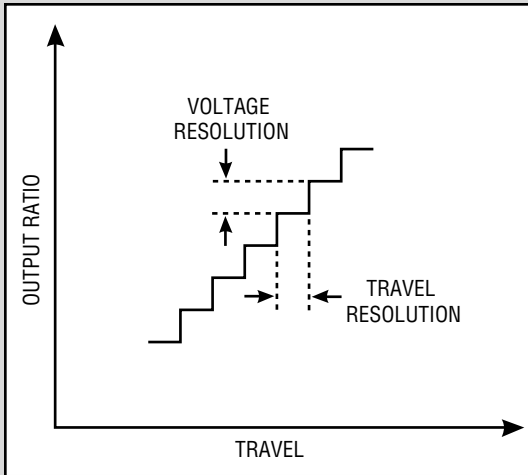
$$\frac{1}{N} \times 100 = \text{Theoretical Resolution percent.}$$

**6.5 TRAVEL RESOLUTION (WIREWOUND POTENTIOMETERS ONLY):**

The maximum value of shaft travel in one direction per incremental voltage step in any specified portion of the resistance element.

**6.6 VOLTAGE RESOLUTION:**

The maximum incremental change in Output Ratio with shaft travel in one direction in any specified portion of the resistance element.



**FIGURE 6.6** Wirewound resolution  
**Note:** The illustration above is valid only for wirewound potentiometers because of the “stepped” nature of the output function. For determination of the effect of resolution in a nonwirewound potentiometer, refer to Output Smoothness (6.2).

**6.7 DIELECTRIC WITHSTANDING VOLTAGE:**  
 Ability to withstand under prescribed conditions, a specified potential of a given characteristic between the terminals of each cup and the exposed conducting surfaces of the potentiometer, or between the terminals of each cup and the terminals of every other cup in the gang without exceeding a specified leakage current value.

**6.8 INSULATION RESISTANCE:**  
 The resistance to a specified impressed DC voltage between the terminals of each cup and the exposed conducting surfaces of the potentiometer, or between the terminals of each cup and the terminals of every other cup in the gang, under prescribed conditions.

**6.9 POWER RATING:**  
 The maximum power that a potentiometer can

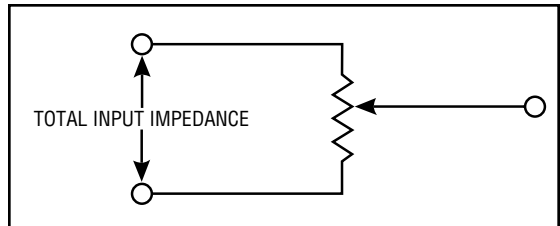
dissipate under specified conditions while meeting specified performance requirements.

**6.9.1 POWER DERATING:**  
 The modification of the nominal power rating for various considerations such as Load Resistance, Output Slopes, Ganging, nonstandard environmental conditions and other factors.

**6.10 LIFE:**  
 The number of shaft revolutions or translations obtainable under specific operating conditions and within specified allowable degradations of specific characteristics.

**7 AC CHARACTERISTICS**

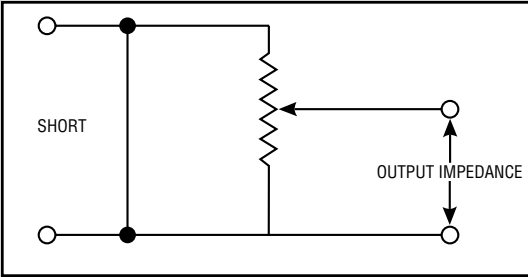
**7.1 TOTAL INPUT IMPEDANCE:**  
 The impedance between the two input terminals with open circuit between output terminals and measured at a specified voltage and frequency with



the shaft positioned to give a maximum value.

**FIGURE 7.1** Total input impedance

**7.2 OUTPUT IMPEDANCE:**  
 Maximum impedance between slider and either end terminal with the input shorted, and measured at a



specified voltage and frequency.

**FIGURE 7.2** Output impedance

**7.3 QUADRATURE VOLTAGE:**

The maximum value of that portion of the output voltage which is  $\pm 90^\circ$  out of time phase with the input voltage, expressed as volts per volt applied, measured at a specified input voltage and frequency.

**7.4 PHASE SHIFT:**

The phase difference, expressed in degrees, between the sinusoidal input and output voltages measured at

**MATHEMATICALLY:**  $\phi = \sin^{-1}(e_q/e) = \tan^{-1}(e_q/e_i)$

a specified input voltage and frequency with the shaft at a specified position.

Where:

$\theta$  = phase shift in degrees

$e_q$  = quadrature voltage

$e_i$  = inphase output voltage

$e$  = output voltage

**8 MECHANICAL CHARACTERISTICS**

**8.1 SHAFT RUNOUT:**

The eccentricity of the shaft diameter with respect to the rotational axis of the shaft, measured at a specified distance from the end of the shaft. The body of the potentiometer is held fixed and the shaft is rotated with a specified load applied radially to the shaft. The eccentricity is expressed in inches, TIR.

**8.2 LATERAL RUNOUT:**

The perpendicularity of the mounting surface with respect to the rotational axis of the shaft, measured on the mounting surface at a specified distance from the outside edge of the mounting surface. The shaft is held fixed and the body of the potentiometer is rotated with specified loads applied radially and axially to the body of the pot. The Lateral Runout is expressed in inches, TIR.

**8.3 PILOT DIAMETER RUNOUT:**

The eccentricity of the pilot diameter with respect to the rotational axis of the shaft, measured on the pilot diameter. The shaft is held fixed and the body of the potentiometer is rotated with a specified load applied radially to the body of the pot. The eccentricity is expressed in inches, TIR.

**8.4 SHAFT RADIAL PLAY:**

The total radial excursion of the shaft, measured at a specified distance from the front surface of the unit. A specified radial load is applied alternately in opposite directions at a specified point. Shaft Radial Play is expressed in inches.

**8.5 SHAFT END PLAY:**

The total axial excursion of the shaft, measured at the end of the shaft with a specified axial load supplied alternately in opposite directions. Shaft End Play is expressed in inches.

**8.6 STARTING TORQUE:**

The maximum moment in the clockwise and counterclockwise directions required to initiate shaft rotation anywhere in the Total Mechanical Travel.

**8.7 RUNNING TORQUE:**

The maximum moment in the clockwise and counterclockwise directions required to sustain uniform shaft rotation at a specified speed throughout the Total Mechanical Travel.

**8.8 MOMENT OF INERTIA:**

The mass moment of inertia of the rotating elements of the potentiometer about their rotational axis.

**8.9 STOP STRENGTH**

**8.9.1 STATIC STOP STRENGTH:**

The maximum static load that can be applied to the shaft at each mechanical stop for a specified period of time without permanent change of the stop positions greater than specified.

**8.9.2 DYNAMIC STOP STRENGTH:**

The inertia load, at a specified shaft velocity and a specified number of impacts, that can be applied to the shaft at each stop without a permanent change of

the stop position greater than specified.

**DESIGN AIDS**

**PRECISION NON-LINEAR POTENTIOMETERS**

**CERMET\*, WIREWOUND AND CONDUCTIVE PLASTIC MODELS**

Certain potentiometer applications require that the slider output voltage follow some predetermined non-linear function, as would be the case in employing a potentiometer to maintain a continuous balance between a non-linear mechanical drive and a linear bridge network. For such applications, BI Technologies manufactures non-linear potentiometers, identical to linear models in every way except for the resistance element. Non-linear models with outputs ranging from the simplest monotonic function to the most complex non-monotonic function can be supplied with either wirewound, cermet or conductive plastic resistance elements. Single-turn and multi-turn models are available in many different housing sizes and configurations.

**CRITICAL NON-LINEAR PARAMETER**

The critical parameter for any non-linear function is the maximum slope of the function. For rotating units:

$$\text{Slope} = \frac{de_o}{d\theta}$$

where:  $e_o$  = the output voltage

and:  $\theta$  = the angular rotation

By convention, this equation can be written as:

$$\text{Slope} = \frac{dy}{dx}$$

Where: y = normalized voltage ratio  $\left( \frac{\text{output voltage}}{\text{input voltage}} \right)$

And: x = normalized shaft rotation  $\left( \frac{\text{electrical travel}}{\text{shaft rotation}} \right)$

theoretical electrical travel

Once the maximum slope is known, other parameters can be approximated by using the following:

1. To determine the best conformity obtainable, select the potentiometer model that fits the application's mechanical requirements. Then multiply the maximum slope times the minimum practical linearity available in that potentiometer.
2. To determine the maximum total resistance which can be obtained, divide the maximum total resistance available in the linear potentiometer model by the maximum slope of the function.
3. To determine the maximum power dissipation obtainable in a non-linear function, divide the power rating of the linear potentiometer model by the square root of the maximum slope of the function.

\* Non-linear cermet potentiometers are available only in certain functions. Consult your local BI Technologies sales engineering representative for additional information.



**PRACTICAL DESIGN DATA**

Single-Turn Wirewounds	Nominal Diameter					
	$\frac{7}{8}$ " (22,225mm)	$1\frac{1}{16}$ " (26,975mm)	$1\frac{1}{8}$ " (33,325mm)	$1\frac{1}{4}$ " (36,500mm)	2" (50,800mm)	3" (76,200mm)
Min. Practical Linearity ( $\pm\%$ )	0.15	0.12	0.10	0.08	0.07	0.05
Max. Total Resistance (ohms)	60K	100K	45K	50K	215K	145K
Power Rating (watts at 40°C)	1.25	1.50	1.50	3.50	3.50	5.00

Multi-Turn Wirewounds	Nominal Diameter and Rotation					
	$\frac{7}{8}$ " 1,800° (22,225mm)	$\frac{7}{8}$ " 3,600° (22,225mm)	$1\frac{13}{16}$ " 1,080° (46,025mm)	$1\frac{13}{16}$ " 3,600° (46,025mm)	$3\frac{3}{16}$ " 5,400° (84,125mm)	$3\frac{3}{16}$ " 9,000° (84,125mm)
Min Practical Linearity ( $\pm\%$ )	0.075	0.05	0.04	0.025	0.025	0.025
Max. Total Resistance (ohms)	63K	125K	190K	650K	2 meg	3.3 meg
Power Rating (watts at 40°C)	1.4	2.0	3.0	5.0	10.0	15.0

Single Turn Cermet	Nominal Diameter			
	$\frac{7}{8}$ " (22,225mm)	$1\frac{1}{16}$ " (26,975mm)	$1\frac{1}{8}$ " (33,325mm)	2" (50,800mm)
Min Practical Linearity ( $\pm\%$ )	0.25	0.20	0.20	0.15
Max. Total Resistance (ohms)	1 meg	1 meg	1 meg	1 meg
Power Rating (watts at 85°C)	3.0	5.0	6.0	10.0

Single Turn Conductive Plastics	Nominal Diameter			
	$\frac{7}{8}$ " (22,225mm)	$1\frac{1}{16}$ " (26,975mm)	$1\frac{1}{8}$ " (33,325mm)	2" (50,800mm)
Min Practical Linearity ( $\pm\%$ )	0.25	0.10	0.075	0.05
Max. Total Resistance (ohms)	100K	100K	100K	150K
Power Rating (watts at 70°C)	1.0	1.5	2.0	2.5

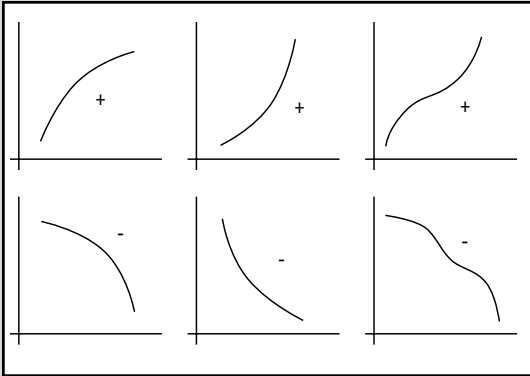
The tables list the minimum practical linearity, maximum total resistance and power rating for Helipot® linear potentiometers and are given for reference. These ratings can be used in the equations to approximate conformity, total resistance and power dissipation limits which can be provided in Helipot® non-linear potentiometers.

The methods given are for determining the best obtainable conformity and maximum resistance and do not include several other factors which influence the final values. These factors are:

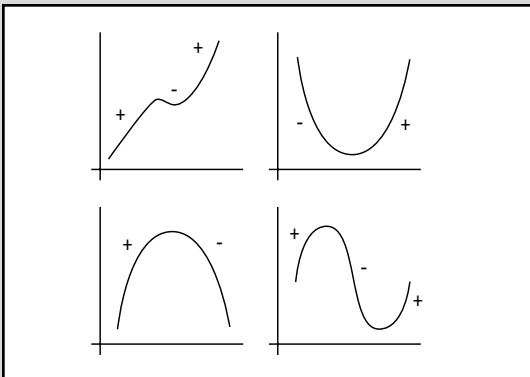
1. Whether the function is monotonic or reversing.
2. Type of conformity required - absolute, proportional, ohmic, etc.
3. Whether the application requires a resistance function, as in rheostat usage, or a voltage function, as in potentiometric or voltage divider usage.
4. The length of the resistance coil in wirewound units, or the potentiometer diameter in cermet and conductive plastic units.
5. Whether the application requires a slider load.
6. Whether the input is AC or DC.

**MONOTONIC AND REVERSING FUNCTIONS**

A monotonic function is one where the slope is either positive or negative throughout the entire function.



**FIGURE 1.** Monotonic Functions



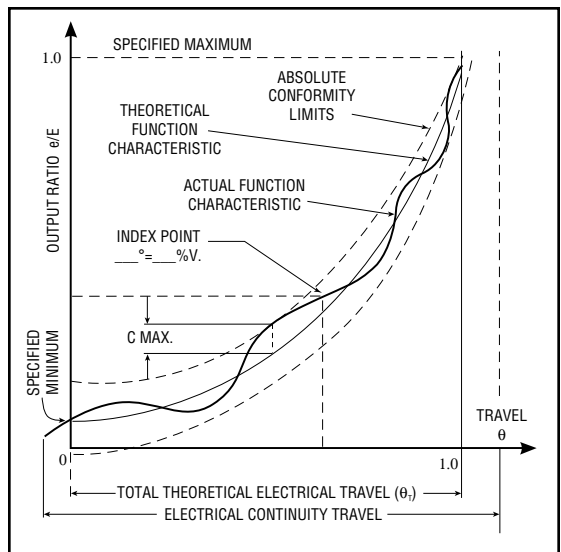
**FIGURE 2.** Reversing Function

BI Technologies' engineering personnel can provide specific electrical values, taking into consideration all factors, for any non-linear function and application.

**CONFORMITY**

Conformity is the fidelity of the relationship between the actual function characteristic and the theoretical function characteristic. In non-linear potentiometers, conformity can be specified as

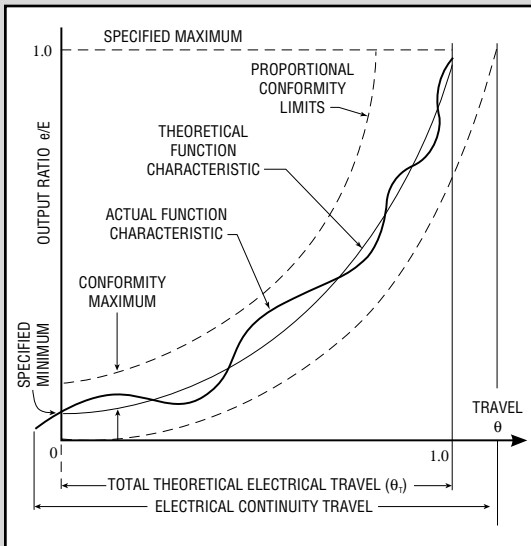
absolute conformity, proportional conformity or as stepped conformity. Absolute Conformity is the maximum deviation of the actual function characteristic from a fully defined theoretical function characteristic. It is expressed as a percentage of the total applied (input) voltage and measured over an absolute angle (theoretical electrical travel). This angle is defined by an index point usually located on the steepest slope area of the actual output. The index point may not coincide with the tap points. See Figure 3.



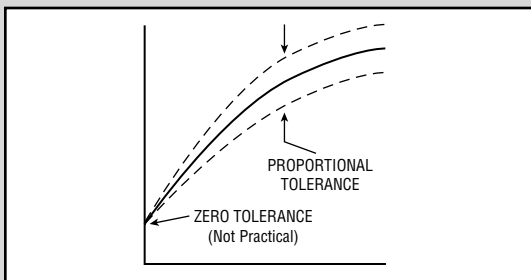
**FIGURE 3.** Absolute Conformity

Proportional Conformity is the maximum deviation of the actual function characteristic from a fully defined theoretical function characteristic. However, unlike absolute conformity, it is expressed as a percentage of the output voltage (see Figure 4). A true proportional conformity would be zero at the zero end of the function, as shown in Figure 5A. However, this is not practical and cannot be produced in a non-linear potentiometer. Figure 5B shows a modified proportional conformity where the conformity is a constant value over a small segment

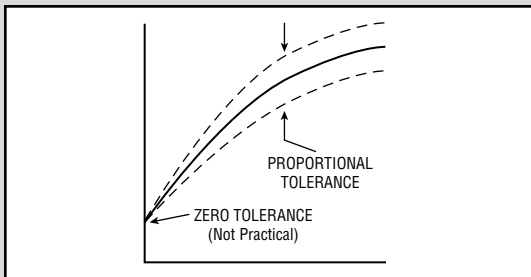
of the theoretical function characteristic and is proportional to the output voltage over the balance of the function.



**FIGURE 4.** Proportional Conformity



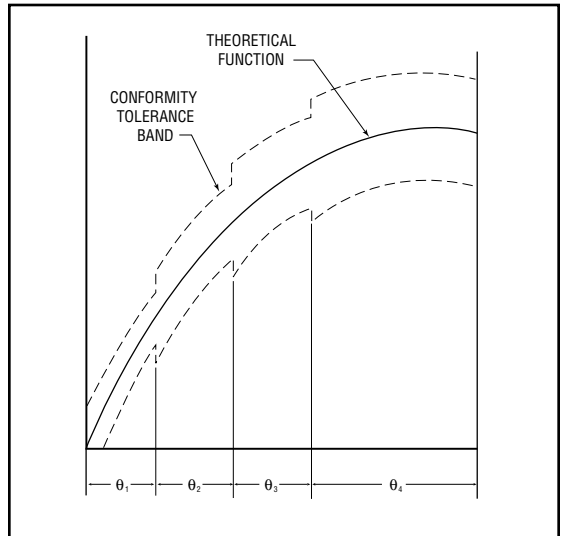
**FIGURE 5A**



**FIGURE 5B**

**STEPPED CONFORMITY**

Another type of conformity sometimes used is stepped conformity, which is similar to proportional conformity in that closer tolerances are used only when needed. Tolerances are relaxed in other parts of the function. A typical example of a stepped conformity is shown in Figure 6.



**FIGURE 6**

In applications where the function passes through a zero voltage point in the middle of the function, the tolerances for either absolute or proportional conformity can be specified in two ways (see Figure 7).

- (1) Peak-to-peak tolerances - expressed as a percentage of the total input voltage;
- (2) Zero-to-peak tolerances - expressed as a percentage of one-half of the total input. For example, if the specified zero-to-peak conformity tolerance is  $\pm 0.10\%$ , the peak-to-peak conformity tolerance would be  $\pm 0.05\%$ .

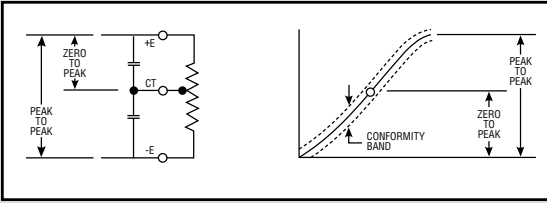


FIGURE 7

**LOAD COMPENSATION**

When a slider load is a part of the circuit, the effects of loading produces errors which must be compensated for so that when the load is applied, the output voltage will follow the desired function. The magnitude of the loading error is a function of the ratio of the slider load to the total resistance of the potentiometer. This error varies inversely with the load ratio. That is, a small load ratio will produce a large error. The following table gives the conformity error for various load ratios.

Load Ratio	Conformity Error
1:1	12.30%
2:1	6.74%
5:1	2.90%
10:1	1.45%
20:1	0.75%
50:1	0.30%
100:1	0.15%

A slider load may be applied to either end of a function, or to the center tap as shown in Figure 8.

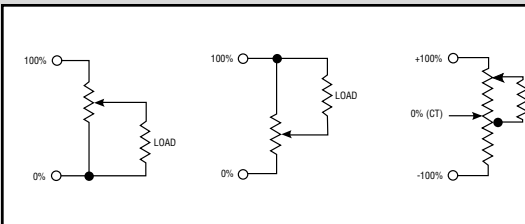


FIGURE 8

**VOLTAGE DIVIDER AND RHEOSTAT APPLICATIONS**

When a non-linear potentiometer is used as a three terminal device, as shown in Figure 9, the output voltage ( $e_{out}$ ) is a function of the ratio of the resistance between the slider terminal and one end terminal, and the total resistance. Since it is a ratio, the total resistance does not affect the output voltage in potentiometric or voltage divider applications. An exception is when considerable slider current is drawn, for example, when there is very low load ratio.

When a non-linear potentiometer is used in a two terminal or rheostat application, the output of interest is the resistance between the slider and one end terminal, with the other end terminal unconnected. In these applications, conformity tolerance is generally expressed in ohms since the total resistance tolerance is a part of the conformity tolerance.

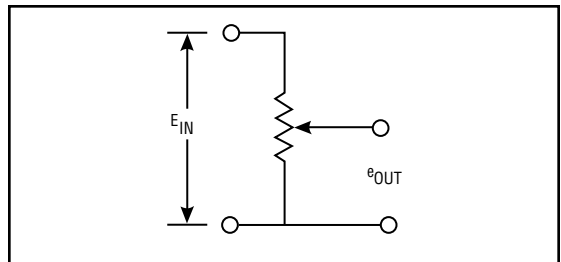


FIGURE 9. Voltage Divider

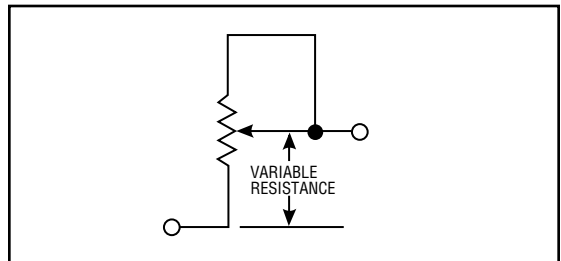
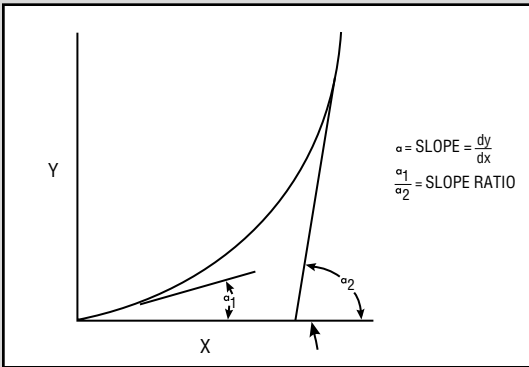


FIGURE 10. Rheostat

**SLOPE RATIO**

In addition to the maximum slope, the slope ratio of a non-linear function is also an important parameter. It is defined as the ratio of the maximum slope divided by the minimum slope (see Figure 11). Any function, where the minimum slope is zero, has an infinite slope ratio. BI Technologies can supply non-linear potentiometers with a minimum slope of zero. Although the total resistance of the unit is determined by the maximum slope and the rate of slope change over the part of the curve nearest the maximum slope, the slope ratio affects the accuracy.

**FIGURE 11**



**TAPPED AND PADDED FUNCTIONS**

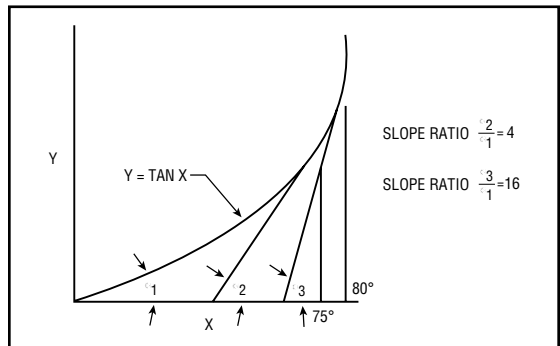
It is sometimes possible to obtain an acceptable non-linear function in a wirewound potentiometer by tapping and padding a linear resistance element. This can be done only where tolerances are not extremely close. The resulting function is a series of straight line segments which may closely approximate the desired function. The accuracy then becomes a function of the number of taps and pads. More accurate non-linear wirewound functions are obtained by winding a variable pitch coil. BI Technologies can supply non-linear potentiometers using either of the above methods.

**INFINITE SLOPE FUNCTIONS**

Certain mathematical functions, such as tangents, secants, cosecants, square roots and inverse functions have slopes which approach infinity. For

these applications, it is necessary to limit the function at some point on the curve since an infinite slope cannot be achieved using any resistance material. For example, the tangent function shown in Figure 12 is usually limited to 75 degrees. At this point, the slope ratio is 4:1. If the function is extended only 5 degrees more to 80 degrees, the slope ratio becomes 16:1. In general, the higher the maximum slope, the poorer the conformity and the lower the total resistance obtainable.

**FIGURE 12**



**PHASING**

When multi-gang units are required, attention must be given to the problem of phasing the functions with respect to one another. For units where all the sections are non-linear functions, the standard practice is to phase the sections to meet simultaneous conformity. One of the sections, usually the section nearest the shaft end, is used as a reference. The reference unit contains an index which relates the start of the angular rotation to the output voltage. For multi-gang units with both linear and non-linear functions, the standard method is to phase the linear sections to the zero function angle of the reference non-linear section. The index of the non-linear section defines the starting point. Any combination of wirewound, cermet or conductive plastic non-linear or linear units can be ganged on a common shaft.

**RESISTANCE ELEMENT SELECTION**

Wirewound, cermet and conductive plastic

resistance elements can be used for most mathematical or empirical non-linear functions. However, the requirements of the specific application can determine which type will provide the best performance and reliability. Wirewound elements offer maximum design flexibility and can be supplied in both multi-turn and single-turn models. In addition, they provide extremely low resistance change over a wide temperature range due to their low tempco. The maximum total resistance of wirewound models is limited primarily to values below 100K. Although the tempco may be 100

ppm/°C, cermet's exhibit excellent resistance stability over a wide range of environments and can dissipate high power with little or no change in performance. In addition, cermet can be made with total resistances of several megohms. Conductive plastic units generally have better electrical noise characteristics, whether measured as ENR, output smoothness or by dither test. Life of a conductive plastic is greater than that of other types. Also, better conformities can be provided in conductive plastic than in cermet's.

**GENERAL NOTES**

**INFLUENCE OF RESISTOR ELEMENT ON POTENTIOMETER CHARACTERISTICS**

ELEMENT TYPE	RATING:								
	RESISTANCE RANGE	TEMPERATURE COEFFICIENT	BEST LINEARITY	SETTLEABILITY	NOISE OR CONTACT RESOLUTION	ROTATIONAL LIFE	HIGH TEMPERATURE	RELATIVE COST	
WIREWOUND	2	1	1	4	1	3	2	3	
CONDUCTIVE PLASTIC	3	4	3	2	3	1	4	1	
HYBRID ( HIGH TEMP CP OVER WW COIL )	4	2	2	1	4	2	3	4	
CERMET	1	3	4	3	2	4	1	2	

NOTE: All element types are available in single turn units but only hybrid and wirewound are available in multiturn units.

1. Unless otherwise stated, all specifications are measured at room conditions (temperature 15°C to 35°C; air pressure 650 to 800 millimeters of mercury, relative humidity 45 to 75%).
2. Unless otherwise specified, all dimensions used in this catalog are in inches.
3. Standard tolerances for all drawings in this catalog are as follows:  
 Fractional tolerance -  $\pm 1/64"$  and  $\pm 0.38\text{mm}$   
 Decimal tolerancing -  $XXX = \pm .005"$   
                                    $XX = \pm .01"$   
 Angular tolerance-  $\pm 2^\circ$
4. Metric equivalents, based on 1 inch = 25.4mm, are rounded to the same number of decimal places as in the original English units and are provided for general information only.
5. Noise specifications for all wirewound potentiometers listed in this catalog are stated at speeds up to 100 RPM with 1 milliamp of slider current unless otherwise specified.
6. All specifications, drawings and military specification information used in this catalog are subject to change without notice. Please check specification and drawing accuracy with your local BI Technologies representative prior to ordering.
7. A characteristic of most non-wirewound resistance elements is that the end points are difficult to locate precisely by direct measurement. Verification is made by extrapolating from the 1% and 99% voltage points.
8. HYBRID, infinite resolution, versions are also available.
9. Helipot and Helitrim are registered trademarks of BI Technologies.
10. References to parts per million (ppm) equal  $p/10^6$ .

## RANGE OF APPLICATIONS

The versatility of the precision potentiometer is

absolutely astounding. For more than 50 years, BI Technologies has provided technical and product leadership in this market and has supplied high quality precision potentiometers to an ever expanding array of applications. We are continually amazed at the application growth. The vast majority of our customer application efforts have resulted in a customized or modified potentiometer that has been created to serve a specific customer requirement. We are committed to provide this kind of customer service in a cost effective manner.

From the invention of the HELIPOT (multi-turn helical potentiometer) to the pioneering developments in CERMET and CONDUCTIVE PLASTIC element technologies, BI has remained at the forefront in new technical innovation. We welcome an opportunity to demonstrate our capabilities by solving one of your tough problems.

Some of the broad application categories that utilize precision potentiometers include:

- Heavy industrial equipment
- Automotive equipment
- Airborne equipment
- Process controls
- Electric vehicles
- Military and commercial aircraft
- Scientific equipment
- Electronic equipment
- Medical equipment
- Heating and air conditioning equipment

In general, the specific function of a precision potentiometer falls into one of the two categories below:

1. Position Sensors
2. Precision Controls

As a way of illustrating both applications and functions, the following lists are provided. These lists will illustrate the practical range of solutions that we have implemented with BI Precision Potentiometer products and engineering expertise.

**AUTOMOTIVE/VEHICLES/HEAVY EQUIPMENT**

This is a rapidly growing field in which vehicle manufacturers are quickly moving to take advantage of electronic controls, sensors and feedback systems. BI precision potentiometers can be found in:

- Handwheel (steering) position sensors
- Golf cart and other electrically driven vehicle speed controls
- Automotive fuel level sensors
- Heavy equipment speed controls
- Rapid transit speed controls
- Linkage position sensors

**CONTROLLERS**

Since their introduction, BI precision potentiometers have been an integral part of control systems. Their use has broadened to an enormous list of applications, such as:

- Oil field and refinery equipment
- Building heating and air conditioning controls
- Scientific and laboratory instrument controls
- Limit setting controls for blood pressure monitors
- Color controls for printing presses
- Music system amplifier controls
- Controls for gates in water treatment plants
- Table position controls for X-ray machines
- Theater lighting and stage controls
- Army tank gunsight controls
- Nuclear submarine propulsion controls

The avionics and aerospace industry has required some of the most sophisticated precision potentiometers ever devised, and BI has been a leader in filling those needs. In virtually every case, a special product was required. Here are some examples:

- Air-to-air missile control surface feedback sensors
- Nose up/down attitude sensors for commercial and military aircraft
- Control surface position sensors
- Fluid level sensors
- Cabin environmental controls for commercial and military aircraft
- Ground equipment controls
- Service vehicle controls
- Helicopter flight controls
- Guided missile stage separation sensors
- Guidance control feedback sensors
- Communications system controls
- Aircraft lighting system controls

**INSTRUMENTATION**

In the field of instrumentation, proper control and analysis requires input from sensors, which are “near the action.” BI precision potentiometers have been, and are, excellent choices for many such applications. Among other things, they are robust in design, dependable and accurate. Here is a brief list of BI sensors now in use:

- Ships roll indicator systems
- Hydrofoil rudder position feedback sensors
- Ships’ tank level sensors
- Meteorological measuring equipment
- Gyro compass sensors
- Robotics position sensors
- X-Y plotter position sensors

**APPLICATION CONSIDERATIONS**

**AVIONICS/AEROSPACE**



When specifying a precision potentiometer, bear in mind that potentiometer design is the result of a series of trade-offs that have proven most generally useful and widely acceptable. The potentiometer manufacturer can optimize your design based on your application and requirements. Furthermore, the manufacturer knows many materials not normally used - i.e., precious metals, special lubricants, etc. - which can solve problems for you if cognizant of all the details of the application.

**ELECTRICAL CHARACTERISTICS**

- Linear or nonlinear? If a nonlinear, has the function been adequately specified?
- Type of linearity or conformity (absolute, zero-base or independent) and accuracy? Absolute conformity is usually required for direct readout potentiometers. Independent is sufficient when trimmers are used. Is it a closed loop function? If so, express conformity tolerance as zero-to-peak or peak-to-peak.
- Resistance and tolerance? Is it clear between what terminals resistance is measured? Or should you specify open loop resistance? Does it include or exclude end trimmers? Can the potentiometer be shunted to get low resistance while maintaining good resolution? Can it be shunted by a very high resistance to meet a close resistance tolerance? Has the effect of wiper shorting been considered?
- When specifying resistance of sine/cosine potentiometers, specify the required resistance/quadrant (that is the effective resistance per quadrant after the loop is closed).
- What type (angular or voltage) and value resolutions are necessary?
- What noise is tolerable in the system? Can certain frequencies be excluded in measuring noise or can sharp spikes of short duration be

permitted (or filtered out)? Is the standard noise test pertinent or do you need a different one? At what speed should it be run?

- Have you considered the effect wiper load is going to have on output accuracy? Manufacturers can compensate for most loads and achieve any desired accuracy more easily than you can.
- Are special taps needed? Are they to be used as voltage reference points (voltage tap) or as input points (current tap)? How are they to be located voltage-wise relative to the index point? Relative to mechanical stops? Relative to end taps (standard)?
- What is the electrical angle? How is it related to the required function? To the electrical angles or functions in other sections (phasing)? Is overtravel necessary? How is it related to the mechanical angle?
- Is end resistance critical? Should it be measured by resistance or voltage (a resistance measurement includes wiper circuit resistance, which a voltage measurement does not)? Should measurement be at the point of minimum resistance or voltage (standard) or at the stop (special)?
- What voltage is applied? How much current will flow through contact? Is this a rheostat application? What power is dissipated?
- What maximum dielectric strength is desirable? At sea level or what altitude?
- Is temperature coefficient of resistance important? Must it be matched to fixed resistors? Over what temperature range?
- Are AC characteristics important? Quadrature voltage? Capacitive reactance? Other? At what frequency? At what wiper setting? Measured between what points?
- How much backlash is tolerable?

**MECHANICAL CONSIDERATIONS**

- Weldable or solderable terminals? What size (diameter, length) and weights are permissible?
- What type of mounting-servo, bushing, locking bushing, three-hole? A no-turn lug is usually advisable on a bushing mount. Will the bushing length specified satisfy your maximum panel thickness with all hardware in place?
- What kind of shaft-splined, flatted, slotted? Must special diameter, length or shoulder be considered? What runout is permissible relative to mounting surface?

**Note: Potentiometer manufacturers do not recommend machining operations on the shaft after assembly.**

- What materials are required for housing, shaft, terminals, etc.?
- Is there a shaft load or a speed requirement that necessitates ball bearings or is a sleeve bearing satisfactory? Is there an axial load on the shaft?
- Lateral runout, pilot diameter runout, shaft end play, radial play?
- Are stops required? What strength must they have? Does the application require a static or dynamic load? (Avoid using potentiometer stops for anything but emergency use; provide system stops.) What mechanical angle and tolerance necessary?
- If there is more than one section, must they be phasable in the field?
- Any special terminals or terminal locations required?
- Is very high or very low operating torque required? At room temperature or over a range of temperatures?
- Is special marking required? Fungus treatment?

**OPERATING CONSIDERATIONS**

- How many shaft revolutions will be required? At what rpm? To what value may any of the original electrical or mechanical requirements be permitted to degrade? Is the rotation continuous (over the bridge)? In one direction? Will there be a problem with dither?
- What is the operating temperature range? How much can the original requirements change over this temperature range?
- Are there other special operating conditions such as humidity, vibration, shock acceleration or altitude?

**TESTING CONSIDERATIONS**

- What acceptance testing is necessary? What documentation? Source inspection? Certification? Traceability? Would it pay to “burn-in” units to eliminate infant mortality?
- What qualification test information is necessary?
- In each case have the criteria for failure been specified?
- Is failure mode parametric or catastrophic?

**GENERAL**

Much of this information never appears on procurement documents. This is unfortunate because the potentiometer manufacturer can choose more wisely and economically among the factors that influence potentiometer performance if thoroughly aware of the application. If you are unsure about your requirements, please don't hesitate to call and discuss your requirements with one of our B.I. Technologies application engineers.

BI Precision Potentiometers and Duodial® turns counting dials are available from BI sales engineering representatives in the United States, Canada and throughout the world. Many models are

stocked locally, ready for immediate off-the-shelf delivery.

To order a precision potentiometer:

- 1.** Select the BI wirewound, conductive plastic hybrid or cermet precision potentiometer model which best suits your specific application.
- 2.** Specify the basic model number (example: Model 7286). This would be a 7/8" diameter, 10-turn wirewound unit with bushing mount and sleeve bearing.
- 3.** Add to the basic model number "R," followed by the specific resistance value required (example: Model 7286 R10K). This specifies a 10,000 ohm total resistance. Model 7286 R100 would be for a 100 ohm total resistance.
- 4.** Unless otherwise specified, the standard resistance tolerance for the model ordered will be assumed. If another resistance tolerance is desired, place the desired value, in parentheses, following the total resistance value (example: Model 7286 R10K (1) ). This specified a  $\pm 1\%$  tolerance.
- 5.** To specify a linearity, add the letter "L" after the resistance value or non-standard resistance tolerance followed by the desired linearity (example: Model 7286 R10K L.25 would refer to a linearity of  $\pm 0.25\%$ ).
- 6.** Complete ordering information should include:  
Example:  
7286R – 10K – L.25  
(Model – Resistance Value – Linearity)
- 7.** Special coded features are available on most precision pots. Coded features include: center taps, flatted and slotted shafts, linearity tape, rear shaft and shaft locks. These coded features require no special engineering and

only a modest increase in potentiometer price. Check with your local BI Technologies sales engineering representative for additional information and cost for the model you wish to order.

**CUSTOM CAPABILITIES**

**ROTARY MOTION PRECISION POTENTIOMETERS**

BI Technologies single and multi-turn precision potentiometers offer compact size and high precision with a very wide range of special features:

- Industrial and MIL grade construction
- Linearity 0.25% is standard; reduced tolerances available to suit application requirements.
- Resistance tolerance to 1%.
- Wirewound or hybrid elements.
- Housing manufactured from metallic, phenolic or plastic materials.
- Special shaft configurations to suit application requirements.
- Multiple potentiometer outputs to suit application requirements.
- Several potentiometers can be ganged on a single shaft. Each section can have any value of linearity, resistance or other special feature that will suit the application requirements.

**OIL-FILLED PRECISION POTENTIOMETERS**

A special version of the rotary precision potentiometer that is designed for longer life in hostile environments. Most BI potentiometer specifications can be provided in an oil-filled configuration that will suit the specific application.

**RECTILINEAR PRECISION POTENTIOMETERS**

Rectilinear precision potentiometers are designed to provide a direct transfer of line motion to a proportional electrical output. BI rectilinear precision potentiometers offer:

- Stroke lengths from 1/2" to 6" (12mm to 150mm); other sizes on special order.
- Industrial or MIL grade construction.
- Linearity 0.5% is standard; reduced tolerances available to suit application requirements.
- Conductive plastic, wirewound or hybrid elements.
- Housings sealed against contaminants; metallic construction is standard; non-metallic housings are available on special order.
- Special shaft configurations to suit application requirements.

**MOTORIZED PRECISION POTENTIOMETERS**

Motorized potentiometers are ideally suited to a wide variety of industrial applications, such as automatic remote controls and readouts, servo-feedback and other analog functions. A precision potentiometer, motor, gearhead and clutch are precisely matched to provide optimum performance and reliability in a compact and economical unit. Motors can be supplied as AC, DC, DC torque, servo, stepper or synchronous to suit the specific application. Most BI potentiometer specifications (linearity, resistance, materials of construction, etc.) can be provided in a motor-driven configuration.

**CONTROL SYSTEMS AND ELECTRONIC ASSEMBLIES**

The Special Products Group is an experienced and versatile engineering team that designs special control systems and custom electronic assemblies. Our designs can be based on servo-devices or any other current technology.

The Special Products Group includes a sophisticated

job shop. Systems or assemblies designed by our engineering team can be simulated, prototyped, assembled or manufactured and tested in-house. This Special Products Group's design/build capability was specifically created to solve individual customer requirements . . . quickly and efficiently.



**Bi**