Reliable Electronic Solutions

Bourns® Linear Motion Potentiometers
Position Sensing Application Note

Abstract
Bourns® Linear Motion Potentiometers (LMPs) are an economical and reliable means of converting a mechanical displacement into an electrical signal that is proportional to that displacement. Bourns® LMP products are suitable for many sensor applications used in the industry today. They are unique design-in devices that deliver high quality and reliability at a low price.

Introduction
Technological advancements in the semiconductor industry have created a broad use of electronically controlled systems. This developing technology promotes the need for sensors that are inexpensive, yet able to withstand wide ranges of temperature in a robust package.

For many system manufacturers, there is a need to utilize components that are compact and affordable without compromising the quality criteria. There are various potentiometric sensor applications for linear motion being used in the industry today.
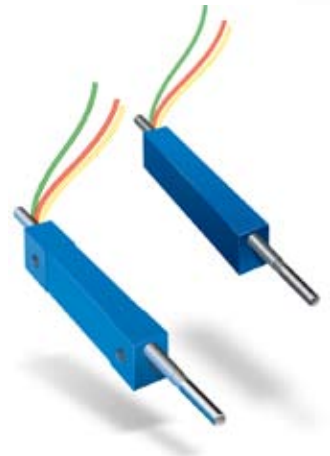
Typical Applications
• *Solenoid Positioning Sensor for Automated Controllers*
• *Joystick Controllers*
• *Satellite Dish Positioning*
• *Automotive Valve Positioning*
• *Robotics*

Bourns Solution
Bourns® Linear Motion Potentiometers are an economical solution for position sensing where size is a constraint. They are suited for systems designed to operate in environments that are not harsh. Bourns® LMP Models 3046 and 3048 are lightweight devices with infinite resolution, flexible wire leads and a long mechanical life.

The elements of the LMPs are manufactured with conductive plastic (CP) for extended wear capabilities. Unlike Trimmers, which are "set and forget," these devices are designed to monitor position and are thereby designed to have a very high cycle life capability. LMPs are ideal for converting a mechanical linear motion displacement into a proportional voltage output when used as a sensor.
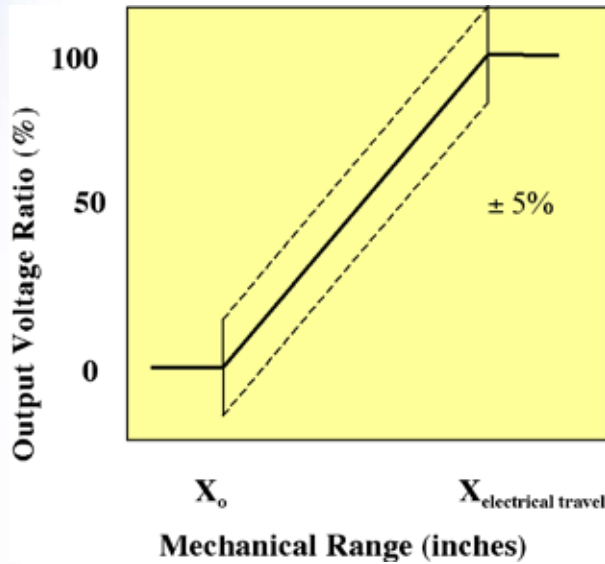

Joystick controller

Satellite dish

LMP Functionality

When choosing the best LMP that suits your specific design needs, one of the first aspects to consider is the available electrical travel supported by the system.

Graph 1. Output Voltage vs. Position (Ideal)

Since the LMP will be used to convert electrical travel to a proportional signal voltage, the LMP is connected as a voltage divider. In this type of application, the output voltage depends on the resistance of the load it drives.

The circuit in Figure 1 shows the voltage divider without a load. From this circuit, we expect an open-circuit behavior whose output can be determined by the following relationship:

$$Vout = \frac{V_S R_2}{(R_1 + R_2)} \qquad [Eq.\ 1]$$

The circuit in Figure 2 shows the voltage divider circuit with a load, R_L. Thus, from the behavior under the load, the output voltage can be determined by the following relationship:

$$Vout = \frac{V_S (R_2 \parallel R_L)}{(R_1 + (R_2 \parallel R_L))} \qquad [Eq.\ 2]$$

Note: *It is important to keep in mind that the load must be a high enough impedence so that it does not affect the output voltage.*
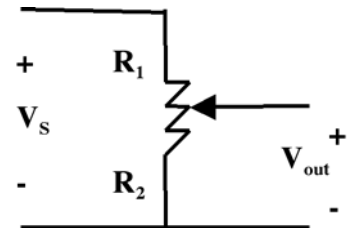

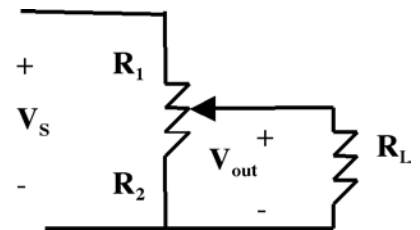*Figure 1. Voltage Divider Circuit without a Load*

Figure 2. Voltage Divider Circuit with a Load, R_L.

Understanding the LMP Linearity Function

As a linear position sensor, there is a direct proportional relationship between the mechanical range of the LMP and the voltage output ratio seen by the Electronic Controller Module (ECM). For simplification, let us observe the linearity function of a Bourns® LMP when it is functioning as a position sensor in greater detail.

Let *f(x)* = *output voltage ratio*
   x1 = *initial shaft position*
   x2 = *subsequent shaft position*
   x_O = *starting position of electrical travel*

The plots on the right are each ideal function output voltage ratio, f(x), with respect to shaft position, x. Based on the output ratio, the ECM can determine the position of an electronic component connected to the shaft of the LMP.

Example: Model 3046

P/N 3046L-3-102 has a standard electrical travel of 0.35 ". The function output voltage ratio, f(x) with respect to its mechanical range, x, is plotted in Figure 3a.

Using trigonometric properties, we find the following relationships:

$$\tan \theta = \frac{\Delta f(x)}{\Delta x},$$ *[Eq. 3]*

where,

$$\Delta x = x_2 - x_1$$ *[Eq. 4]*

Calculating f(x):

$$f(x) = \Delta x (\tan \theta) = (x_2 - x_1)(\tan \theta)$$ *[Eq. 5]*

Therefore,

$$x_2 = \frac{f(x)}{\tan \theta} + x_1$$ *[Eq. 6]*

For instance, if the output voltage ratio f(x) = 0.50, then the position of the shaft, x2, is calculated as follows:

$$x_2 = \frac{0.50}{\tan \theta} + x_1$$ *[Eq. 7]*

In reference to the position of X_1, the signed value of X_2 provides the direction and position of electrical travel:
– x2 �֎ n spaces to the left
+ x2 ✖ n spaces to the right

Mechanical Range & Electrical Travel

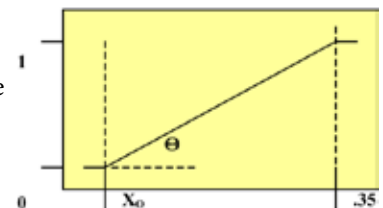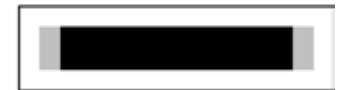Mechanical Range

Electrical Travel
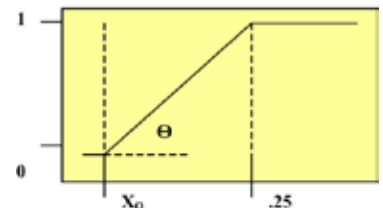
Figure 3a. Linearity Plot for P/n 3046L-3-502

Figure 3b. Linearity Plot for P/n 3046L-2-502

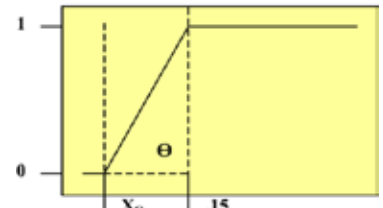*Figure 3c. Linearity Plot for P/n 3046L-1-502*

Position Sensor Application

For LMPs, there is a direct correlation between the shaft position and the voltage division ratio. As a position sensor, the wiper is mechanically connected to a moving part, free of load, to an operational amplifier, or any other component with high impedence. As the wiper arm moves the signal voltage output changes. At the point of contact, the available voltage is the signal voltage output from which the electronic controller can determine the position of a component. In other words, the closer that the wiper arm gets to the Vcc voltage, the greater the signal voltage output. Thus, the desired output function is directly proportional to the linear movement that is input.
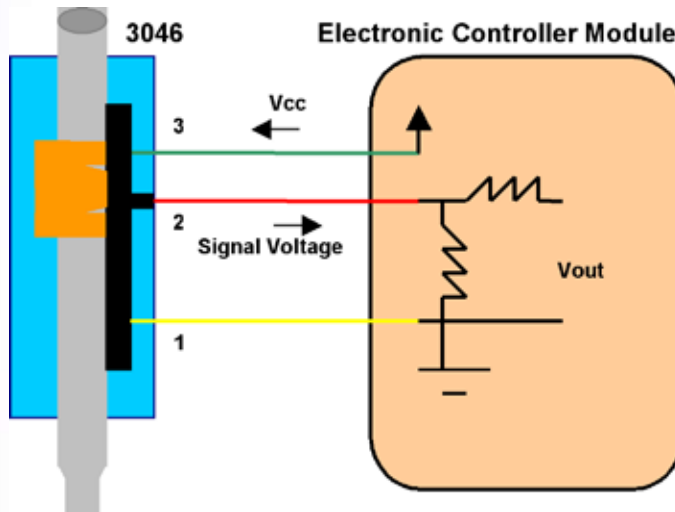

Figure 4. *Bourns® Model 3046 functioning as a position sensor for an automotive valve positioning application.*

Network Analysis

Let us continue our analysis of the valve positioning system discussed earlier. An equivalent circuit diagram is given in the figure below:
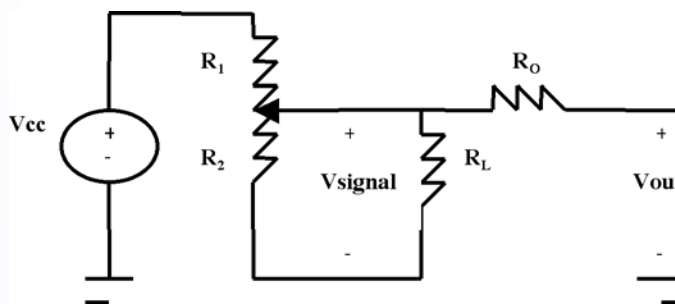

Figure 5. *Equivalent circuit diagram of the valve positioning system.*

Using voltage division properties, the input voltage signal, Vsignal, and the output voltage signal, Vout, are determined in the equations on the right.

$$V_{signal} = \frac{Vcc(R_2 \| R_L)}{R_1 + (R_2 \| R_L)} \qquad \text{[Eq. 8]}$$

and

$$V_{signal} = \frac{V_{output}(R_2 \| R_L)}{R_O + (R_2 \| R_L)} \qquad \text{[Eq. 9]}$$

Therefore

$$V_{output} = \frac{V_{signal}(R_O + (R_2 \| R_L))}{(R_2 \| R_L)} \qquad \text{[Eq. 10]}$$

and

$$V_{output} = \frac{Vcc(R_O + (R_2 \| R_L))}{R_1 + (R_2 \| R_L)} \qquad \text{[Eq. 11]}$$

The Bourns Advantage
Bourns® LMP products are unique design-in devices that deliver high quality and reliability at low prices. They are manufactured with robust packages. Modifications to fit particular requirements are available. Consult with the factory for more detail.

Backed by Bourns commitment to quality, reliability, and value, the LMP product line is a reliable solution for linear displacement applications.

Bourns® LMPs meet the design needs for systems whose criteria may be one of the following:

☉ *Size is a constraint*

☉ *Affordability without compromising performance and reliability*

☉ *Wide temperature range*

☉ *Non-critical application*

☉ *Extended wear capabilities*

In addition, Bourns® LMP products are built with the following features:

☉ *Infinite resolution*

☉ *Free shaft rotation*

☉ *Flexible wire leads*

☉ *Long mechanical life*

☉ *Compatible with AC or DC signals*

☉ *Electrical travels of 0.2 " to 0.5 " and 0.1 " to 0.3 "*

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