

Potentiometer tappers (contact points) are usually manufactured from pure metals to ensure a high consistency of contact resistance across the windings.

Potentiometer units are usually sealed to prevent the possibility of dirt gathering on windings. Dirt on the windings could cause an increase in contact resistance, producing 'noise' in the system.

'Noise' means any electrical signal other than the required measurand.

(iii) ***The loading effect*** (departure from linearity).

This is probably the most serious drawback to the voltage transmission system and warrants therefore a more detailed analysis. Consider the circuit shown in FIGURE 11.

We require an expression for how the non-linearity $N(x)$ varies with the potentiometer setting x , where x can vary between 0 and 1.

The loaded potentiometer can be replaced by its Thévenin equivalent circuit:

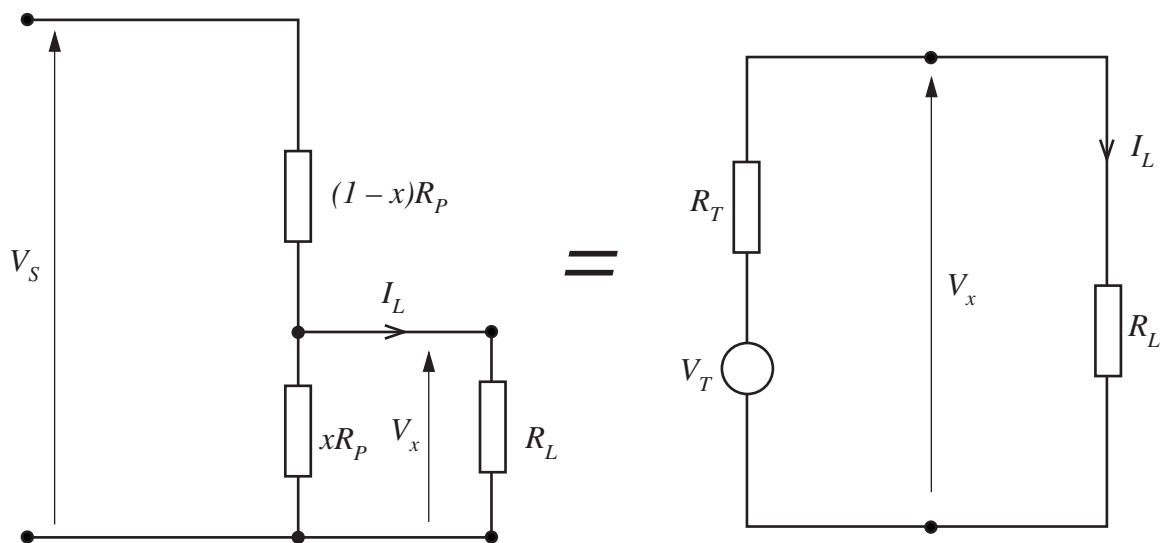


FIG. 11

From the equivalent circuit we can readily establish that:

- The voltage with the load removed (the 'ideal straight line' (ISL) voltage) is:

$$V_{x(\text{ISL})} = V_T$$

- The voltage with the load in circuit is:

$$V_{x(\text{actual})} = V_T \times \frac{R_L}{R_L + R_T}$$

The non-linearity is given by the difference between these two voltages, i.e.

$$\begin{aligned} N(x) &= V_{x(\text{actual})} - V_{x(\text{ISL})} \\ &= V_T \times \frac{R_L}{R_L + R_T} - V_T \\ &= V_T \left(\frac{R_L}{R_L + R_T} - 1 \right) \\ \therefore N(x) &= V_T \left(\frac{R_L - (R_L + R_T)}{R_L + R_T} \right) \\ &= V_T \left(\frac{R_L - R_L - R_T}{R_L + R_T} \right) \\ &= V_T \left(\frac{-R_T}{R_L + R_T} \right) \\ &= -V_T \left(\frac{R_T}{R_L + R_T} \right) \end{aligned}$$

The negative sign indicates that the actual value is less than the ISL value.

Now, by Thévenin's theorem, $V_T = xV_S$ and $R_T = x(1 - x)R_P$

$$\begin{aligned}\therefore N(x) &= -xV_S \left(\frac{x(1 - x)R_P}{R_L + x(1 - x)R_P} \right) \\ &= -xV_S \left(\frac{x(1 - x)}{\frac{R_L}{R_P} + x(1 - x)} \right) \\ &= -V_S \left(\frac{x^2(1 - x)}{\frac{R_L}{R_P} + x(1 - x)} \right)\end{aligned}$$

Generally, the load resistance is very much greater than the potentiometer resistance ($R_L \gg R_P$) so that $\frac{R_L}{R_P}$ is very much greater than 1.

The value of x is between 0 and 1, thus $x(1 - x)$ is always less than 1 (in fact $x(1 - x)$ has a maximum value of 0.5).

So, if $R_L \gg R_P$ then $\frac{R_L}{R_P} + x(1 - x) \approx \frac{R_L}{R_P}$.

$$\begin{aligned}\therefore N(x) &\approx -V_S \left(\frac{x^2(1 - x)}{\frac{R_L}{R_P}} \right) \\ \therefore N(x) &\approx -V_S \frac{R_L}{R_P} (x^2(1 - x))\end{aligned}$$

Intuitively, we might assume that the maximum non-linearity is given when $x = 0.5$. To test this assumption we need to find the maximum value of $N(x)$. This can be done by differentiating the above expression with respect to x :

$$\begin{aligned}\therefore \frac{d}{dx}(N(x)) &= \frac{d}{dx} \left(-V_s \frac{R_P}{R_L} (x^2 (1 - x)) \right) \\ &= -V_s \frac{R_P}{R_L} \frac{d}{dx} ((x^2 (1 - x))) \\ &= -V_s \frac{R_P}{R_L} \frac{d}{dx} (x^2 - x^3)\end{aligned}$$

$$\therefore \frac{d}{dx}(N(x)) = -V_s \frac{R_P}{R_L} (2x - 3x^2)$$

$$\frac{d}{dx}(N(x)) = 0$$

$$\therefore -V_s \frac{R_P}{R_L} (2x - 3x^2) = 0$$

At a 'turning point' $\therefore 2x - 3x^2 = 0$

$$\therefore 2 - 3x = 0$$

$$\therefore x = \frac{2}{3}$$

Maximum non-linearity occurs when the slider is two-thirds of the way along the potentiometer.

This 'loading' effect, i.e. departure from linearity, can cause a serious error in our transmitted signal. To illustrate this point further consider FIGURE 12 which shows a series of graphs to illustrate the effect of changing the load resistance (R_L) on a voltage transmission system. We can see from this series of graphs that the greater the reduction of the internal resistance of the receiver, the greater the degree of error within the system.

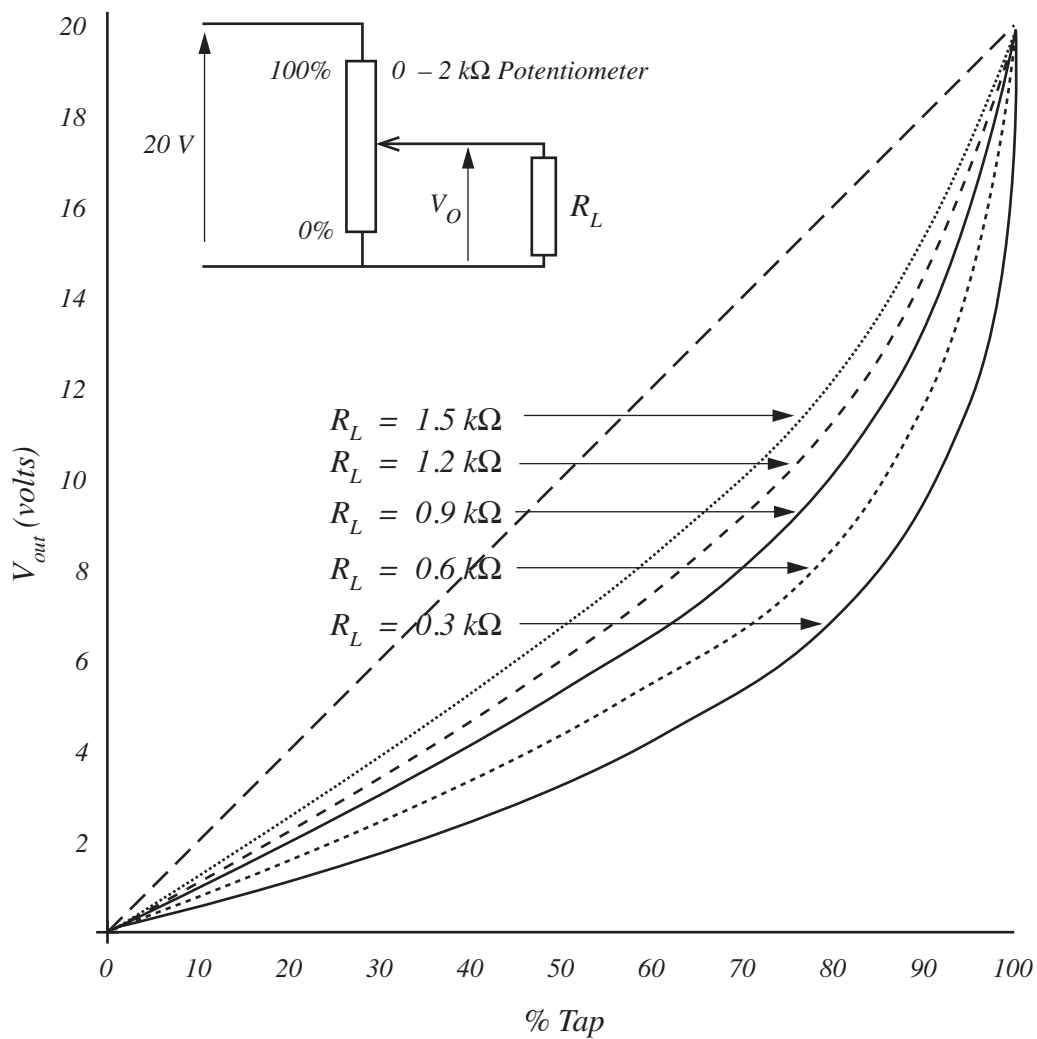


FIG. 12

Similarly, as the internal resistance of the receiver increases, the closer the output approaches linearity. It is for this reason that manufacturers produce high input impedance receivers for use with voltage transmission systems (i.e. the receivers have a large internal resistance). However, by producing receivers with a high input impedance, they introduce the system to another problem - interference. The system is now susceptible to interference (noise) from sources such as induced e.m.f.s from power cables, etc.

With such problems voltage transmission systems tend to be overlooked in favour of current transmission systems for use on plant. However there are still many applications for the voltage transmission system especially in control rooms.