

Displacement Joystick/Thumb Wheel Switch Control Profile for Precision and Jerk Free Speed Control Application in Open Loop System

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ABSTRACT

Displacement joystick controls are considered as most suitable for manual controls wherever proportional outputs are required for dynamic applications such as when variable speed sensitivity or position are required. These joysticks are being used widely in both open loop as well as in close loop controls. The operator applies force to either the joystick itself or to its proportional linear displacement thumb wheel switches. This movement is then detected by either resistive or Hall Effect sensors, placed right inside joystick, and converted into an electrical signal. These joysticks, along with proportional linear displacement thumb wheel switches, find a wide range of applications in off-road vehicles such construction and forestry vehicles, harvester machines, and etc. for applications like attachment speed controls, boom position control, rotation speed control, and etc. The higher the displacement of the joystick, or its linear displacement thumb wheel switches, the better will be the control over the control parameter.

When it comes to open loop attachment control systems, where joystick displacement is directly linked with speed, most times the displacement provided by joystick or linear displacement thumb wheel switches is just not enough to fine tune the control parameter. In such cases, a small variation in displacement results in a large change in output parameter. The operator needs to move the joystick very slowly and cautiously to ensure fine adjustments in the control parameters.

It takes a good amount of time to learn to achieve these fine adjustments using a joystick. In a shaky environment it becomes even more difficult to precisely control the parameters using a joystick. In these conditions, a small variation in joystick displacement, or linear displacement thumb wheel displacement, leads to either over or under adjustment of the control parameter. When working in tight places, where there is not much space available to move the vehicle or attachment, it is necessary to control the joystick displacement or linear displacement thumb wheel displacement precisely to ensure objects around vehicle or attachment are not damaged. Due to an operator's mistake, or due to jerks and vibrations to joystick or linear displacement thumb wheel switches, a large amount of change can occur in the control parameter, erroneously leading to accidents or damage to the environment around the machine.

For accident and worry free operation, with better efficiency, an operator controlling such attachments or vehicles requires a means to adjust the sensitivity of the joystick or linear displacement thumb wheel switches. There are many ways to achieve this. For example, a switch can be provided to set & lock the upper limit of the control parameter to a level lower than its usual maximum. Reducing the upper limit reduces the effective range. In this way, normal displacement of the joystick or linear displacement thumb wheel switch will be converted to a relatively lower range of the control parameter. This gives the effect of reduced sensitivity.

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INTRODUCTION

In open loop attachment control systems, displacement of joystick or thumb wheel switches is directly linked to the control parameter; like current, voltage, and pulse width; being set, which then controls the dynamic physical parameter like the speed of the attachment or vehicle.

Since the range of the displacement of the joystick or thumb wheel switches is usually very short compared to the range of control parameter, mapping of the short range displacement to the wide range control parameter results in the joystick losing its ability to precisely adjust the control parameter. This makes it difficult for the operator to precisely adjust the speed of the attachment or vehicle.



Fig. 1. Joystick along with thumb wheel switch. Courtesy: Elobau Sensor Technology [4]

In an attempt to control the speed precisely, an operator ends up setting the speed much higher than desired when raising the joystick or thumb wheel switch. In the same way, while lowering the speed with the joystick or thumb wheel switch, an operator ends up setting the speed to a much lower value than desired. Attempts to set the speed lower than its current value frequently results in setting the speed to the zero level, halting the vehicle or attachment completely. When it takes several cautious attempts to set the desired speed precisely, it becomes a difficult and cumbersome task.

To prevent erroneous halting of the attachment or vehicle, the operator may set the speed higher than desired. While closing an attachment, a high speed set results in a jerk that can eventually damage the attachment, hydraulics, and vehicle itself. It also makes the operation annoying to the operator. This problem can be solved by using a proper joystick control profile that sets the proper correlation between the joystick displacement sensor output and the physical controlling parameter.

CONTROL PROFILE

The joystick control profile sets the relationship of the displacement of the joystick, or its displacement switches, with the physical output parameter being controlled. That is, it relates the output of sensor and actuator to each other. This displacement of the joystick or the displacement switches is sensed by an analog or digital sensor. If the displacement sensor is analog, then the displacement is sensed in terms of resistance, analog voltage, and etc. If it is digital, then the displacement is sensed in terms of digital pulse counts. The relation set between displacement of the joystick or thumb wheel switches and the output parameter being controlled determines the aggressiveness and nature of the joystick control profile.

The joystick control profile can be either linear or non-linear, depending on the need. Usually non-linear profiles are not very popular and not used in open loop control systems.

Linear Control Profile

A linear control profile delivers a consistent level of precision throughout the travel path of joystick or control switches. I.e., the displacement of the joystick or switches brings an equal amount change in its control output throughout the travel path; $\Delta x = \Delta y$ where, x =displacement of the joystick and y =change in the output control parameter. Due to its ratio metric nature, a linear control profile is easy to configure. Some possible linear control profiles are shown below.

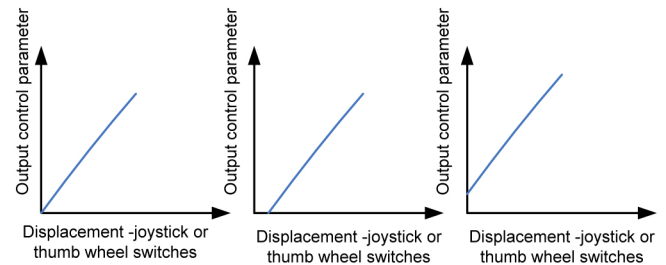


Fig.2. Linear Control profiles

The aggressiveness of the profile depends on the range of input and the output parameters to be controlled. If the range of input quantity, i.e. displacement, is small and the output quantity to be controlled is relatively large, then the joystick or displacement switch control profile will be aggressive. If the range of the input quantity is large and the range of output quantity to be controlled is small, then the joystick or switch control profile will be less aggressive.

This can make the control profile either too aggressive or too sluggish, and there would be no control of the control profile aggressiveness. Therefore, to set desired control profile, system designers may either have to choose input output components that can provide the desired range of parameters or, they may have to adjust the range of the parameters by defining the active region in the given range of these components; enabling their scaling to be adjusted to achieve the desired aggressiveness. In an open loop system, if the range of displacement of the joystick or switches is small, then the ratio-metric effect cannot be clearly felt.

Non-Linear Control Profile

Non-linear profiles are sometimes used in closed-loop control systems to make movement smooth and gradual during ramp-up and ramp-down phases. However, these control profiles, especially in an open loop environment, are not very popular; since it is difficult to comprehend the unexpected changes it brings in the output parameter.

Non-linear profiles can be of varying nature. These include exponential, parabolic, and etc. Sometimes, components like sensors and actuators exhibit non-linear nature; either partially, during some part of their active region, or fully, throughout their entire active region. In such cases, designing a control system becomes a tedious task as it brings unwanted variations in the output parameter being controlled. In this case, inherent non-linearity needs to be controlled to make the system deterministic in nature.