CLICKS COUNTING METHODS FOR A SCOPE KNOB

Andrei DRUMEA[1], Robert DOBRE[1]

[1] Department of Electronics Technology, Politehnica University Bucharest, andrei.drumea@cetti.ro

Abstract: *A required feature of a high zoom scope from customer point of view is the clicks counting and display of windage and elevation corrections. The paper analyzes the methods for click counting usable with existing mechanical knobs. Implementation aspects like required changes in mechanical construction, influence of perturbations, complexity of electronics or power consumption are studied. For some methods considered by authors as easier to implement some experimental results are presented.*

Keywords*: clicks counting, knob, electronic module.*

1. Introduction

Knobs with large number of clicks per rotation are used in a wide range of mechanical, industrial or military applications requiring precise adjustment of displacement of a mechanical item. Typical examples are windage and elevation adjustment for a gun with a zoom scope or adjustments screws and knobs for precise mechanical positioning (Fig.1).

Fig. 1. Adjustment knobs.

Unfortunately, reading of the state of these knobs can be performed only by a person focused on knob scale and position, so no remote or automated readouts are possible. To solve this problem, present paper studies different methods for electronic readout of knob state and analyzes them from different points of view – mechanical construction, electronic implementation, power consumption and resistance to perturbations. The display unit of knob position is LCD based and can be placed away from the knob, so wire or wireless connection between sensing and display units is required; each solution has its own advantages and disadvantages.

2. Description of methods for clicks counting for a scope knob

Adjustment knob is rotating in equal steps, 100 per complete rotation in the particular case of zoom scope; each step is associated with a click. There are more methods for obtaining knob state information, like counting clicks relative to default (zero) position or by measuring an angle or observing its state. These methods can be implemented with different types of sensors like:

- incremental rotary encoders – clicks are not counted, knob rotation is measured. These encoders can be inductive, optical or mechanical.
- multiturn potentiometer in voltage divider connection - clicks are not counted, knob angle is measured. This method offers information regarding the absolute position of knob.
- video camera for image capture of the knob scale and gradations and image processing for position computing; the method mimics the human behaviour
- microphone for click detection and counting
- accelerometer for click detection and counting

These methods are described and compared; those that require complex efforts from implementation point of view are rejected and only for the remaining ones some experiments are performed and presented in this paper.

2.1 Knob position measurement with image processing

Rotation movement can be detected quite simple using digital processing of the video signal by identifying the position of a predetermined shape or by calculating the correlation between captured image and multiple images stored in memory (figure 2). This requires a camera with a resolution high enough to detect shape movement for one click angular rotation. A usable pattern for correlative method is shown in figure 3.

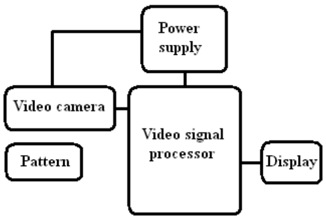

Fig. 2. Image processing method.

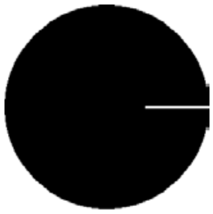

Fig. 3. Possible pattern for image processing method.

The method has some major drawbacks - high computing power requirements so high power consumption, it is difficult to mount in a specific installation and is sensible to vibrations, dust or smoke, factors that can affect image quality.

2.2 Knob position measurement with sound processing

This method is similar with image processing method but use a microphone instead of video camera (figure 4). It allows a sturdier, more compact construction, but is also susceptible to vibrations and knob mechanical properties (different knobs produce different click sounds) so complex sound processing is required to detect click sounds.

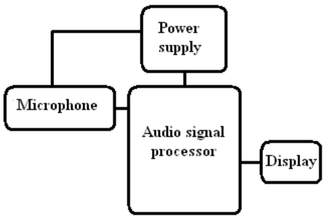

Fig. 4. Sound processing method.

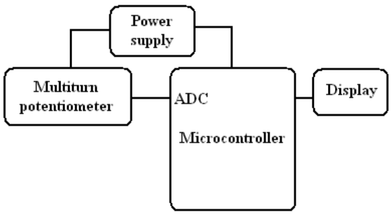

Fig. 5. Multiturn potentiometer method.

A major drawback of this method is its inability to offer sense information – it 'hears' clicks, but is unable to find rotation direction.

2.3 Knob position measurement with multiturn potentiometer

Circular movement can be detected with a multiturn potentiometer (figure 5) in voltage divider connection. The method is very simple and straightforward, rotation direction information is always available because cursor position contains angle and turn number. The drawbacks of the method are: its reliability (cursor is a moving part susceptible to wearing) and limited precision (not suitable for knobs with more than 100 clicks per rotation).

2.4 Knob position measurement with inductive incremental encoder

Another option for click counting/knob position measurement is to use an incremental rotary encoder (figure 6). The encoder can be inductive, optical or mechanical, and it measures angular rotation in constant steps. The method finds only relative position, so a reference position must be known by the measurement system, usually the zero value for the knob.

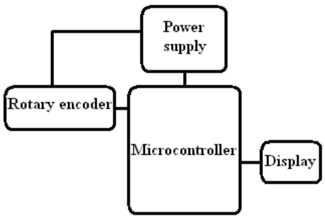

Fig. 6. Incremental encoder method.

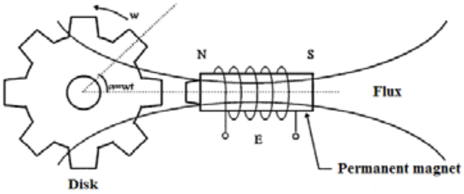

Fig. 7. Structure of an inductive incremental encoder.

The inductive incremental encoder is based on a coil with permanent magnet core placed near an iron/steel toothed disk. During rotation a rectangular voltage is induced into the coil with maximal value associated with tooth positioned near the core. The method can be very precise – more teeth on the disk, better precision – but, unfortunately, is not suited for fine mechanics devices with dimensions smaller than 5 centimetres, because a small disk with many teeth would require an extremely small coil.

2.5 Knob position measurement with mechanical and optical incremental encoders

An optical incremental encoder has a slotted disk (figure 8) and two pairs of sender-receiver optical sensors. There are 2 rows of slots, shifted with half slot (or 90 degrees phase shift for outputs), for direction detection (figure 9). To make the system immune to ambient light, infrared LEDs and detectors are used; LEDs are modulated with a 36 kHz frequency. The method is well suited for fine mechanics devices – small disk with many slots is usable because infrared light can be focused.

Fig. 8. Slotted disk for optical encoder.

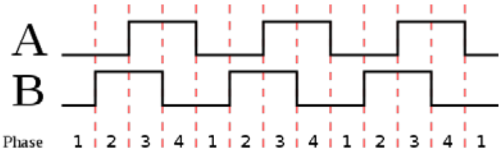

Fig. 9. Optical sensors' outputs for clockwise rotation.

This method can be implemented on an existing knob without important changes in mechanical construction. Only slotted disk is moving with the knob, optical and electronic devices are placed on the fixed side (figure 10). Because an incremental encoder offers only relative position, a zero setting button is needed to be pressed at zero knob position.

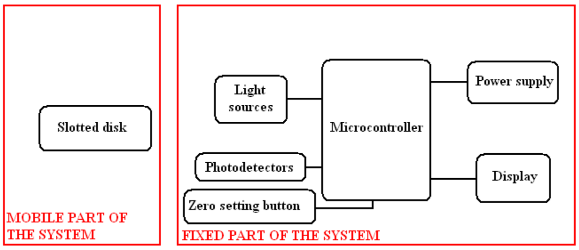

Fig. 10. Structure of an optical incremental encoder based method.

A mechanical incremental encoder has the same behaviour like optical one, but is simpler to use – no slotted disk to build, no optical devices to align, is available with reasonable price from different manufacturers. It switches the two outputs (figure 11) for each step/click as optical encoder, but has a drawback – as any mechanical switch, its outputs bounce during switching (figure 12).

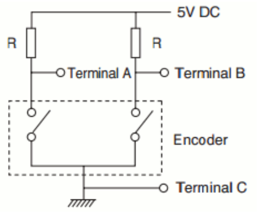

Fig. 11. Mechanical incremental encoder.

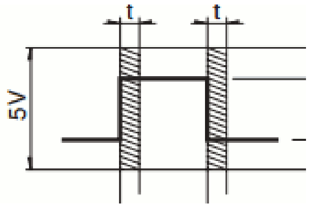

Fig. 12. Switching bouncing for mechanical encoder.

Mechanical incremental encoder solution is the simplest to implement and has also lowest power consumption - microcontroller can be kept in sleep state and only switching interrupts awake it.

2.6 Knob position measurement with accelerometer

An integrated accelerometer (figure 13) can be used for click counting if placed on the knob. The method uses some properties of the rotation movement of the knob – clicks are short and sharp steps with relevant tangential speed and acceleration (figure 14) – to count the clicks by observing acceleration pulses. Z-axis information is not used in this method, XY accelerations in board plane (or knob top side) are enough to find click number and direction. The accelerometer must have fast response time to be able to detect clicks during fast turnings of knob.

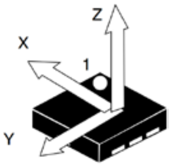

Fig. 13. 3-axis accelerometer.

Fig. 14. Accelerometer placement on knob.

This method can be implemented without any change in existing mechanical construction of the knob. One electronic module with battery, accelerometer and radio transmitter is attached to the knob and information is displayed on the display from the fixed part of the system (figure 15).

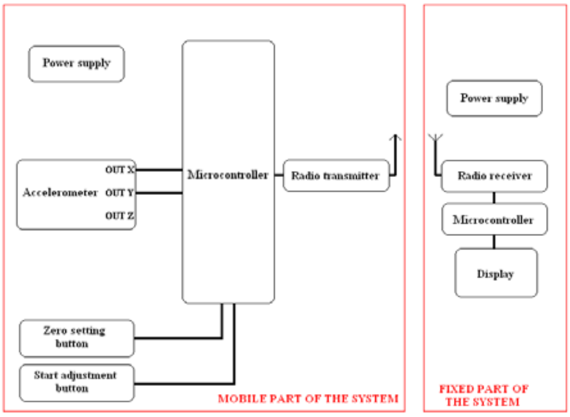

Fig. 15. Structure of an optical incremental encoder based method.

Comparing presented methods, only mechanical, optical encoder and accelerometer based methods are viable choices for real implementation. Some experiments and tests are performed on these sensors/solutions for further evaluation.

3. Experimental data regarding clicks counting for a scope knob

At the moment, test setup for optical encoder method is under construction but mechanical incremental encoder and accelerometer-based methods were investigated and first results are promising. For the mechanical incremental encoder method, an EC12E 24204A9 device with 24 steps per rotation was used. The signals for one step movement are shown in figures 16 and 17; they are very clean, no visible bouncing, and easy to process even with a simple microcontroller.

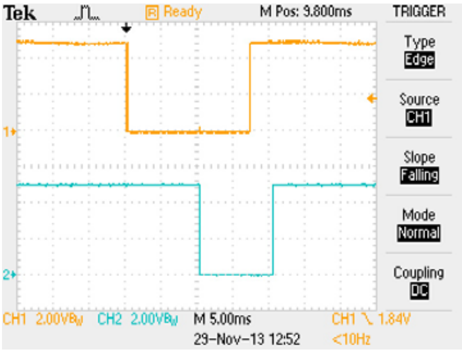

Fig. 16. Mechanical incremental encoder, one click counter-clockwise.

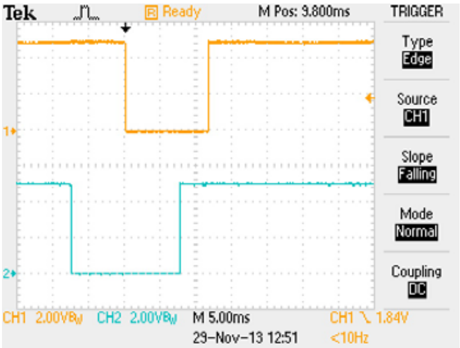

Fig. 17. Mechanical incremental encoder, one click clockwise.

For the accelerometer based method a test module with a ST Microelectronics 3-axis accelerometer with analogue output was designed and constructed. Module schematic is shown in figure 18 and its printed circuit board in figure 19. This module was attached to the knob and the whole construction was fixed on a vice. A digital oscilloscope was connected to sensor outputs.

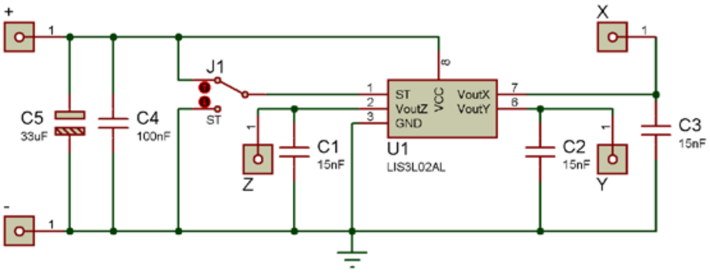

Fig. 18. Schematic of the accelerometer module.

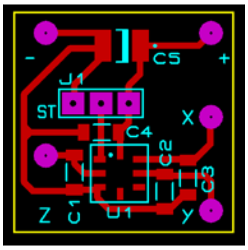

Fig. 19. PCB of test module.

The clicks are detected as pulses in X and Y components of acceleration. The Z axis component is neglected because is very small and offers no extra information – the direction of rotation is already found from XY components. In figures 20-23 accelerometer outputs (X blue, Y orange) are shown for one and three clicks in both directions – clockwise and counter-clockwise.

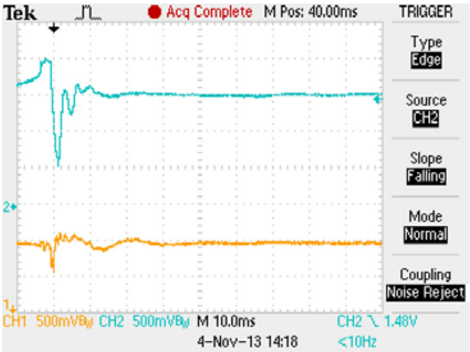

Fig. 20. Accelerometer outputs , one step clockwise.

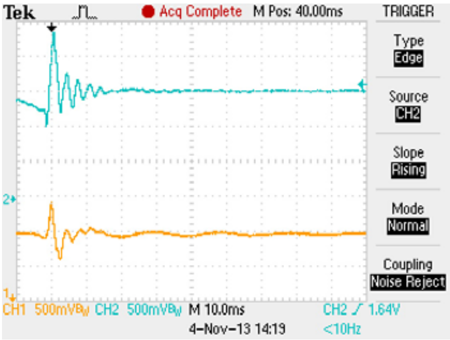

Fig. 21. Accelerometer outputs , one step counter-clockwise.

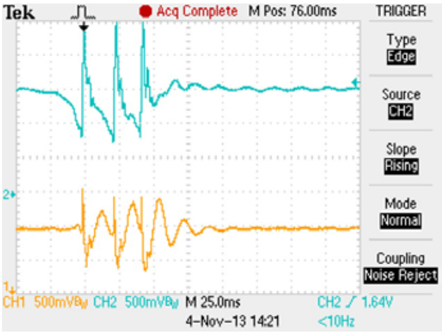

Fig. 22. Accelerometer outputs , three steps clockwise.

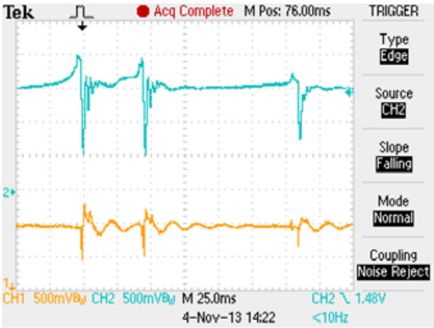

Fig. 23. Accelerometer outputs , three steps counter-clockwise.

The oscilloscope screen captures prove the ability of the method to count knob clicks, but robust measurement requires careful signal processing of accelerometer outputs as these signals have only about 1 Volt peak to peak amplitude and their shape depends on knob rotation speed and number of clicks. For better results, more sensible accelerometers can be used. Another possible improvement of method is to use 2 accelerometers, placed diametrically opposed and use for data processing the difference between their outputs. The authors are testing now different accelerometer configurations to find an optimal solution for clicks count for a real knob.

4. Conclusions

The analysis of the presented methods and their application reveals the most efficient ones in terms of implementation – accelerometer and optical or mechanical incremental encoder based methods. All three methods require small mechanical parts, can be implemented using low processing power microcontrollers and therefore have low power consumption. The incremental encoder based methods require constructive changes in the structure of the knob, yet easy mechanical changes. These methods offer robust operation, no lost clicks and require very simple electronics to work thus lowest power consumption. Accelerometer -based method does not require any modification of the mechanical design because the electronic module is placed directly over the knob. There may however be some problems in clicks counting while the equipment is subjected to movement (additional occurring accelerations must be rejected in terms of useful information) so more data processing is required compared to incremental encoder methods.

All three methods are viable and choosing the best one can be done only after following a set of rigorous tests and depending on application conditions and requirements.

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