High Resolution Virtual Absolute Encoders

Dragan B. Denić[1] and Goran S. Miljković[2]

Abstract – **Absolute encoders are well known electromechanical components of all control systems for positioning. This paper considers virtual absolute encoders as a new type of absolute encoders that is very up to date. The possibility of applying developed methods for serial code reading of chain codes to high resolution virtual absolute encoders is considered. The solution that eliminates problems regarding the serial code reading with two detectors is proposed.**

Keywords – **Position measurement, pseudorandom code, optical encoders.**

I. Introduction

The absolute encoders are well - known electromechanical components. As a main part of all control systems for positioning, they provide measured information about sensor head position (detector) related to the measurement scale. Considering that each position is coded, the momentary one is defined apart from the previous position. This is the basic quality of the absolute encoders and hence proceeds their main feature that after the power is turned on, an information about the current position of the movable system is instantly obtained. There is no need for any initial moving. For the purpose of angle movement detection, the measurement scale is realized using a disc with concentric tracks, which provides n - bit code word for each discreet angle position. Reading of these circular code tracks is done using a sensor array, where each single sensor serves for reading of one code track and it provides an output signal that represents one bit. Thus, n - bit output code, which represents momentary position of the movable system, is obtained at the output of this sensor array. Code tracks often consist of segments which can be optically detected using transmission or reflection methods. Also, code tracks could consist of segments which can be detected using magnet capacitive or inductive methods. Thus, depending on the applied method of code tracks bit detection, the encoders are divided into optical, inductive, capacitive and magnet encoders. In any case, high resolutions of position measurement are achieved by increasing the number of code tracks, and that way providing a higher number of output code bits.

Virtual absolute encoders represent a new type of absolute encoders that are a result of tendency of avoiding a use of large number of code tracks which is typical in case of high-resolution absolute encoders. This is achieved by using cyclic or serial codes, which possess a feature that two n - bit code words, which correspond to two consecutive positions, comprehend an identical sequence of (n-1) bits. In other words, the last (n-1) bits of the current code word, (meaning, all bits besides the first one), are equivalent to the first (n-1) bits of the subsequent code word. A possibility of overlapping of the records of all 2^n code words on one code word is evident, [2]. To begin with, such encoder has an enormous advantage and it does not only solve a problem of increasing the number of code tracks with increasing of the resolution, yet it always has only one code track regardless of the resolution. Since nothing is ideal neither are the absolute encoders; we would still need n sensors for the instant reading of n - output code bits, one for each output code bit. Much bigger problem is that distance between sensor heads changes with the change of resolution. A technical problem of allocation of n sensor heads within that small physical area could also occur in case of high measurement resolutions.

Fortunately, cyclic code features provide a new way of reading of the code bits using only one detector, [3]. This method of serial code reading implies collecting of code bits into a shift register used for code forming. Only one bit is being read for each new position of the movable system and entered into the mentioned shift register. After the initial movement that corresponds to space width of n bits, forming of the code word which corresponds to the current position of the movable system will be executed. For each of the following positions a new bit is being read, and along with (n-1) bits of the previous code word, an output code word of a new position is obtained. This new type of absolute encoders possesses all the features of conventional ones, except one. That is the necessity of initial moving after the first plugging in/out. In those cases, it is necessary that the movable system (MS) crosses a distance equivalent to space width of n code bits, so that the first valid output n - bit code could be formed. This is the reason that these absolute encoders are called virtual absolute encoders. In the case of high resolution encoders, mentioned distance of initial movement is very small. However, this is still a virtual absolute encoders disadvantage. This disadvantage is rather attenuated and becomes almost negligible in relation to a new quality that is provided by virtual absolute encoder. It is evident that in case of high resolution virtual absolute encoders one of the most interesting moments is code reading. In this paper, methods for serial code reading are considered and a new approach in realization of virtual absolute encoders is suggested.

[1]Dragan B. Denić is with the Faculty of Electronic Engineering, University of Niš, Beogradska 14, 18000 Niš, Serbia and Montenegro, E-mail: ddenic@elfak.ni.ac.yu

[2]Goran S. Miljković is with the Faculty of Electronic Engineering, University of Niš, Beogradska 14, 18000 Niš, Serbia and Montenegro, E-mail: goranm@elfak.ni.ac.yu

II. Serial Code Reading in Case of Virtual Absolute Encoders

In order to explain the method of serial code reading, a concrete simple example of virtual absolute encoder will be considered. A rotary disc consists of two tracks, Fig. 1. Let us consider that these two tracks consist of transparent and non - transparent segments. Also, let us consider that appropriate optical methods for detection are applied. Interior track is identical to the one of incremental encoder, [4], and it is used in this example for generating of two bits in the output code with the smallest weight. Its main role is providing synchronized code reading and it is often called synchronization or "tact" or time track, [5]. In this simple example which considers 5 - bit binary encoder, it is adopted that the space - time width of one incremental cycle is equivalent to the space width of one code track bit. Otherwise, that ratio can change. External track, a code track, is coded in a way to provide residual important bits needed for forming of the complete absolute output code word. Applied cyclic code, named a shift register code [1], provides a unique code word for each new position of the encoder, which alludes reading of a new bit from the code track.

For the purpose of obtaining the output position code, three detectors are being used. Serial bit reading from the code track is done by detector x(0). Obtaining of the signal from the synchronized track is realized using two detectors, as in case of conventional incremental encoder, [4].

In this example, classic quadrature signals are required (two sine signals dislocated by 90°), because two additional bits are planned which would magnify the position measurement resolution four times. These two signals are also used for determining of the encoder disc rotation direction. These signals are then shaped into rectangular signals, and whenever a transition of signal A (with signal B on logical "0") is detected, reading of a new code bit is being performed. In order to entirely explain a principle of serial code reading, an example of realization of electronic block of this virtual absolute encoder is shown in Fig. 2.

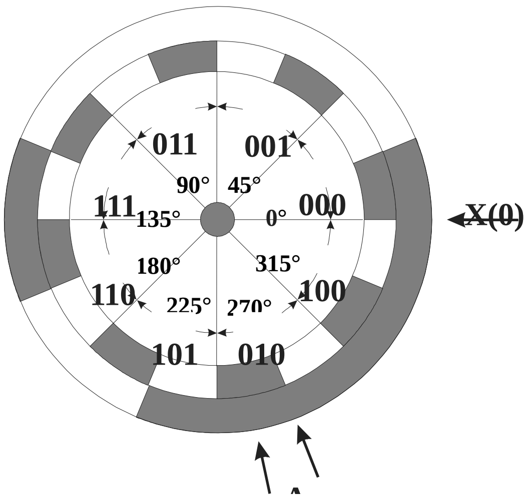

Fig. 1. Virtual absolute encoder disc

Light source, LED diode, for synchronization track is always actuated and it illuminates two detectors forming quadrature signals A and B at the comparator outputs C_1 and C_2. As said before, code reading is done whenever a transition of the signal A (with signal B on logical "0") takes place. Because of this, signal A goes to the input of a signal edge detection circuit, and then, the output signal of this circuit along with the signal B complement to the input of the AND circuit I_1. Whenever an impulse at the logical AND circuit output appears, a new bit reading is done. A simple realization of the signal edge detector is presented here. Rectangular signal A from the comparator output C_1 is brought to both inputs of the same EXOR circuit E_1, but with small delay at one of the inputs. In this case, the delay is generated using integrator in the form of RC circuit.

Whenever an impulse appears at the transistor T base, it leads, whereby the LED diode which illuminates code track is excited. Considering that at that moment the code track detector is located at the middle of the sector that defines current code track bit, reliable reading of that bit can be done. A logical value of the read bit is located at the comparator output C_3. That bit is brought to the appropriate shift register input depending on the disc rotation direction. Considering that impulses at the signal edge detector output always appear at the moment immediately after the detected transition on the synchronization track, then, based on the logical value of the quadrature signal A, encoder rotation direction is being determined, Fig. 1. If A equals 1 when the impulse appears, then the rotation direction is clockwise (CW). Then, an impulse appears at the output of the logical AND circuit I_4, shift register shifts to the left and newly read bit is accepted at the appropriate shift register input. In case of reverse encoder disc rotation, an impulse occurs at the output of the logical AND circuit I_5. After the initial movement of (n-2) bits at same direction, a correct code word is formed and there is a valid information about position at the output. It is obvious, that it is necessary to preconvert a cyclic code at the shift register output into a desired output code, usually into the natural binary code. There are few known methods for code conversion, [6, 7], of which the one named parallel conversion method that uses table memory located in PROM, is applied here. At the end, two bits of the smallest weight are obtained at the quadrature detector output, which consists of one EXOR circuit and one logical NOT circuit.

Basic reason for using of the impulse stimulus of the LED diode, is that there is one gap for bit reading, in contrast to conventional incremental optical encoders where a number of gaps is used for fine tracks observing (multiple-line slits). Impulse stimulus allows greater pick values for current, whereby greater momentary illumination is achieved and thus, a probability of amplitude loss due to usage of only one gap (single line slit), is reduced. Only in case of low resolution measurements when gap is width enough to provide enough signal amplitude from photodetector, DC activating of LED diode is possible.

Illustrated example in a simple way presents the manner in which the virtual absolute encoder functions, using only one detector x(0) for serial code reading. However, this method

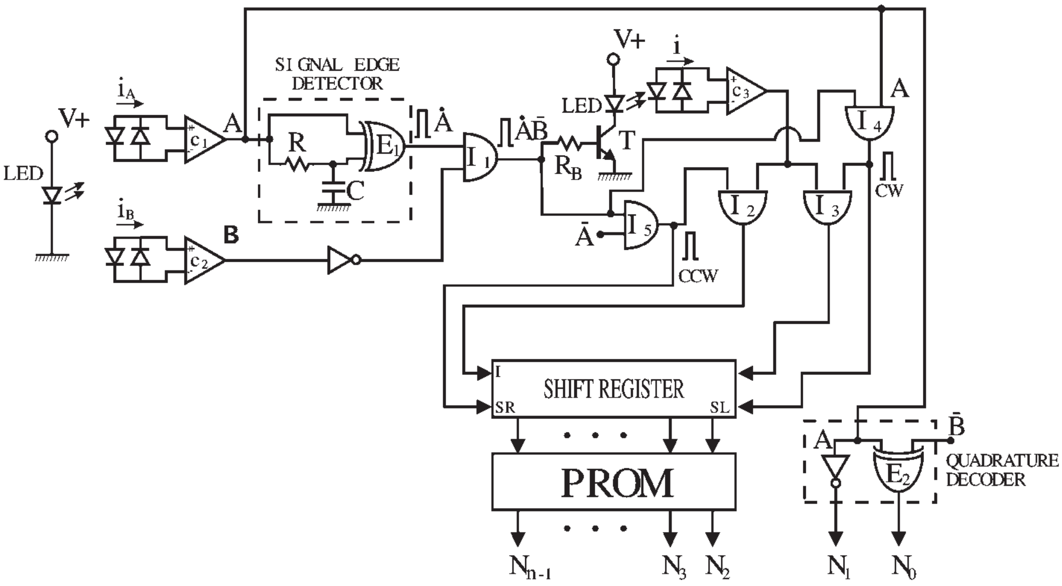

Fig. 2. An example of electronic block realization of virtual absolute encoder

for code reading meets a problem of loosing position information after each change of encoder disc rotation direction. After each direction change, initial movement is needed for obtaining valid information at the output of the encoder electronic block. This disadvantage could be resolved by various methods of additional operations after each change of direction, such as additional movement of shift register content, etc. If they do not cause significant performance violation of the encoder system, such solutions would certainly make it much more complex. A new method for code reading, adopted to high resolution encoders, is suggested here [8].

III. A New Method for Code Reading

The simplest way of solving the problem of loosing position information after each change of rotation direction is by introducing one more detector at distance of (n-2)q, where q is code track quantization step [8]. Using simple logic, consisted of two AND and one OR circuit [8], selection of one, out of two available heads for code reading, is done.. When moving to the left, code track bits read by head x(n-2) are accepted, and when moving to the right the ones read by sensor head x(0). In that way, code words formed after direction change correspond to current positions of the movable system. A circuit for error protection which can occur when MS changes the direction of movement, described in reference [3], is no longer needed. Most importantly, a continuity of code word forming is now achieved even in cases of possible MS oscillating in the direction of movement. In case of systems where there are potential oscillations, use of suggested method for code reading is fairly reasonable. Suggested arrangement of sensor heads additionally annihilates need for a correction element in form of parallel adder, because of the elimination of systematical errors made during code reading.

Besides it simply solves problems of serial code reading, this method, at the same time, provides continuous review of accuracy of formed code words [8,9]. Such method certainly detects real possible errors in code reading, [9]. Thus, using this high - quality error detector, virtual absolute encoder provides an output position information which is incomparably more reliable then the one obtained by any conventional absolute encoder. Because of its importance, this new method is cited and commented in the VI chapter of the newest edition of ”Measurement, instrumentation and sensors handbook” [10]. It was noticed that this new method is not appropriate for use in case of high resolution rotary encoders, since this solution was developed for positioning of flexible movable systems with large range of moving. Application of this solution in the field of micropositioning is critical because two sensors are located at small distance on the same armature. Because of that, different influences (like temperature or vibrations) can cause variation of space distance between these two sensors, which could cause errors in code reading in case of very high resolutions. Thus, a modified method is suggested for use in high resolution measurements. That could be achieved by introducing one additional code track, that would include the same code as the previous one, but it would be dislocated, revolved, for n-2 bits. This way, each of two code tracks would have their own code bit detector and they would be locating in the same line as in case of conventional absolute encoders. A module for code reading from the disc would be same for different encoder discs with different resolutions. Namely, all problems tied to the method of serial code reading using two detectors (two sensor heads) are this way eliminated. At the same time, all good features of this method are retained. Of course, price is introducing one more code track, which is negligible comparing to what is obtained using this method. Continuity in code word forming in case of multiple direction changes, extremely simple realization of encoder electronic block, a possibility of realizing new encoder functions, magnifying of system redundancy because of the possibility of working even if one of detectors breaks down, and simple realization of high - quality error detector, are obtained. The last possibility would represent special, original quality of virtual absolute encoders and is itself more than enough of excuse for adding one more code track and using the suggested method for serial code reading.

IV. Conclusion

The virtual absolute encoders are momentary the greatest hit, as something new with entirely new quality. They are especially interesting because they own great number of possibilities for further upgrading of their performance. Their price is less than the one of conventional absolute encoders, in return of great new quality. That is magnifying of the system reliability and possibility of providing additional information to user about validity of output measured information. In contrast to pseudorandom encoders [2], virtual absolute encoders obligatory include one of methods for serial code reading using cyclic code. Modification of already developed new method for serial code reading [8] for its fully application in high resolution virtual absolute encoders, is proposed here.. The only price we need to pay for this new approach is introducing one additional code track.. Fortunately, that is not that big of a problem considering that the number of code tracks in virtual absolute encoder is fixed, apart from used measurement resolution. Two code tracks compared to 16 or more in case of conventional absolute encoders are entirely acceptable variant. This way, suggested method for code reading would significantly increase quality of virtual absolute encoders. It is quite enough to mention that high - quality error detector could be then directly applied [9] and that it would certainly detect each possible error during reading and forming of the code word.

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