Converter Design for Serial Pseudo and Natural Code

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ABSTRACT: *Pseudorandom / natural code conversion time is the most important factor for the absolute position measurement cycle when using the pseudorandom positions encoder. Serial code converters are simple to implement and have advantages over other converters. In this paper, we provide examples of serial pseudo / natural code converters and a proposal for a new, faster converter.*

Keywords: Position Measurement, Pseudorandom Position Encoder, Serial Pseudorandom/Natural Code Converter

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1. Introduction

The pseudorandom position encoders, their main advantage, have only one code track regardless to the resolution. This solution for the absolute position measurement is based on property of n-bit pseudorandom binary sequence (PRBS) that each sliding window of length n, which passed along a sequence, will extract unique code word in every moment [1]. Also, the last (n-1) bits of the current code word are equivalent to the first (n-1) bits of the subsequent code word. The PRBS is useful type of periodic signal and also has the following properties: the signal is periodic and bipolar, signal exhibits a uniform power spectral density over a wide frequency band, signal is deterministic repeatable, etc. Pseudorandom binary sequences are also used in cryptography, bit-error-rate measurements, wireless communication systems, audio applications, etc. The PRBS generator can be implemented using discrete electronics (shift register with D flip-flop cells), using a microprocessor (flexible implementation), using a FPGA-based implementation (flexible and very fast), using virtual instrumentation concept [2], etc.

The main functional parts of pseudorandom position encoder are the code reading system [3, 4], where different solutions are developed (with one, two or more heads), code scanning methods in the sense of reliable code reading moment defining [4, 5], and error detection methods [3], which increase reliability of encoder. One more functional part of encoder, but no less important than previous ones, is pseudorandom/natural code conversion. Pseudorandom binary code is not suitable for direct application in digital electronics. There are different methods for pseudorandom/natural code conversion, and they can be separated on three distinct groups: parallel [6], serial [4] and serial–parallel code conversion [4]. Parallel solution for code conversion is fast, but expensive and impractical for long PRBS. Serial code conversion is developed as one simple and cheap way for conversion of long PRBS. However, conversion time is critical for one absolute position measurement cycle. Through development of different solutions of serial code converters the main goal is reducing of conversion time. Serial–parallel code conversion is one compromise solution, which combines serial and parallel conversion techniques. During mounting on the shaft pseudorandom encoder provides possibility of direct zero position adjustment without a significant change of hardware and software, but only when serial code conversion is used [7].

In the first part of the paper existing serial pseudorandom/natural code converters are explained, and then on new faster serial converter is proposed. This new solution employed different feedback configuration of logic gates. The presented solutions are detailed explained using appropriate concrete example.

2. The Serial Pseudorandom/Natural Code Converters

The simple solution for pseudorandom/natural code conversion is the serial or sequential pseudorandom/natural code conversion method [4], but in the case of high resolution, the conversion time becomes a limiting factor. This method finds the actual value of the position ‘p’ simply by counting the steps that the shift register with inverse feedback needs until it reaches the initial state by successive shifting from the read pseudorandom n-bit word. Serial pseudorandom/natural code conversion process for $n = 7$ is shown in Fig. 1. Pseudorandom code on the code track is read using of only one code reading head $x(7)$ [4]. In the code conversion process one Fibonacci generator with inverse feedback configuration is applied (Fig. 1). The Fibonacci implementation consists of a shift register in which a exclusive-OR (XOR) gates for modulo-2 sum of the binaryweighted taps are used for feedback configuration. The states of the shift register are actually sequential code words of pseudorandom binary sequence until it came to the state that corresponds to the initial code word. The forbidden state is usually referred to be 0000000, because when all the flip-flop

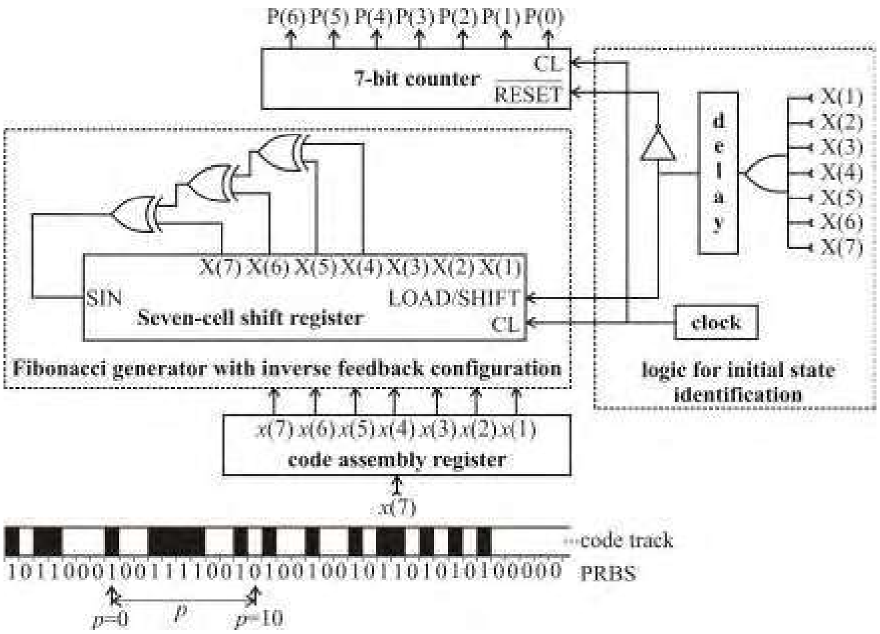

Figure 1. Serial pseudorandom/natural code converter based on Fibonacci implementation

values are 0, the XOR will reveal a 0 regardless of the location of the taps. Therefore, the fed back value is always 0, and the shift register stays in the 0000000 state. If one of the feedback values are inverted, or XNOR instead XORs are used, the forbidden state may be altered.

Also, in the serial pseudorandom/natural code converter one 7-bit counter is added that counts steps and also the logic for the initial state identification. The basic advantage of this code converter is simplicity, and the disadvantage is the serial connection of logical elements (XOR gates) in the feedback configuration, which increases the total propagation delay and thus conversion time is limited. On the other hand, the conversion time limits the maximum rotation speed of the encoder. The table which contains for maximal length pseudorandom sequences feedback sets for different shift register sizes is given in [2, 8].

One way of reducing the code conversion time of the previous method approximately two times is based on the idea that, thanks to PRBS cycling property, the initial state could be reached using feedback sets that are used for either “direct” or “inverse” PRBS generating [9]. Depending on the previous position of the movable system it is decided which PRBS generating low (“direct” or “inverse”) would be used for current code conversion.

Another solution for code conversion process is using the Galois implementation of PRBS generator, which consists of a shift register, the content of which is modified at every step by a binary-weighted value of the output stage, using XOR gates. The pseudorandom binary sequence generator with a parallel feedback logic configuration (Galois generator of pseudorandom binary sequence) is known as a faster pseudorandom binary sequence generator [10]. The Galois generator is generally faster than the Fibonacci in hardware due to the reduced number of logic gates in the feedback loop. Now, the total propagation delay in the feedback configuration is equal to the propagation delay of only one logical gate. The order of the Galois weights is opposite that of the Fibonacci weights, for given identical feedback set. The pseudorandom/natural code converter based on the Galois generator is shown in Fig. 2. It is added a logic that the read code word converts to the appropriate content of the shift register. When the code word is read, this logic provides the equivalent state of the shift register that is loaded in that shift register. This logic does not participate further in the code conversion process and thus negligibly influences to conversion time. Furthermore, the steps counted that are needed for the shift register with the determined and the written state come from the known initial state of the shift register. The obtained number is the result of the conversion, the same as in the case of the known serial code converter (Fig. 1). In the second part of the paper the proposed logic for translation of the read code word in the appropriate content of the shift register is explained in detail, without which it would not be possible to realise the new code converter.

3. Logicfor Initial Adjustment of Read Pseudorandom Code Word

The read n-bit pseudorandom code word (assigned as $x = x_n x_{n-1} x_{n-2} . . . . . x_2 x_1$) in real time is not identical to the n-bit current content of the shift register (assigned as $X = X_n X_{n-1} X_{n-2} . . . . . X_2 X_1$), which corresponds to the position of this code word in the generated pseudorandom binary sequence. For each n-bit code word of the pseudorandom binary sequence there corresponds exactly one state of the shift register with a parallel feedback logic configuration and it is possible to design a simple logic composed from XOR gates (Figure 2). For $n = 7$ will be shown process of logic design, and such a procedure is applicable to any other pseudorandom binary code word of arbitrary length. On the Fig. 3 is shown passing through the states of the 7-bit shift register with a parallel feedback logic, which is known as a ‘Galois’ shift register [8, 10]. On the start, suppose that the initial content of the shift register is $\{X_1, X_2, X_3, X_4, X_5, X_6, X_7\}$ and the pseudorandom code word $\{x_1, x_2, x_3, x_4, x_5, x_6, x_7\}$ corresponds to that content. The direct generation law of PRBS and the moving direction from $X1$ to $X7$ is applied. The pseudorandom bit output is always identical to the state X_7, and

$$X_7 = x_7 \qquad (1)$$

After the first clock pulse, the content of the shift register becomes $\{X_7', X_6', X_5', X_4', X_3', X_2', X_1'\}$, where, in accordance with the direct generation law of pseudorandom binary sequences for $n = 7$:

$$X_7' = X_6$$

$$X_6' = X_5$$

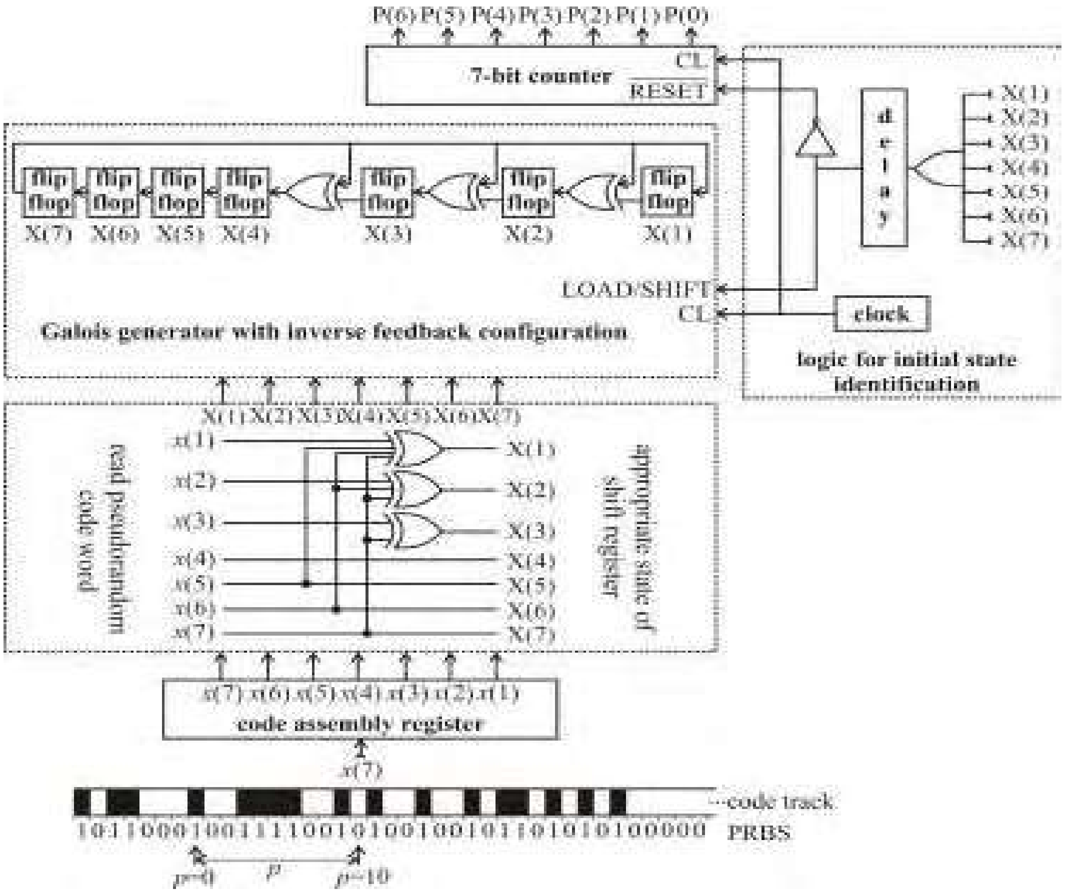

Figure 2. Faster serial pseudorandom/natural code converter based on Galois implementation

$X_5' = X_4$

$X_4' = X_7 \oplus X_3$

$X_3' = X_7 \oplus X_2$

$X_2' = X_7 \oplus X_1$

$X_1' = X_7$

The relations for the parallel feedback logic configuration are well known, based on the known serial feedback logic configuration of the *n*-bit shift register [8]. According to basic mathematical relationships $X_7' = X_5$, and $X_7' = X_6$, can be concluded

$$X_6 = x_6 \qquad (2)$$

Then, after the second clock pulse the content of the shift register becomes $\{X_7'', X_6'', X_5'', X_4'', X_3'', X_2'', X_1''\}$. According to previous principle the following relations are obtained:

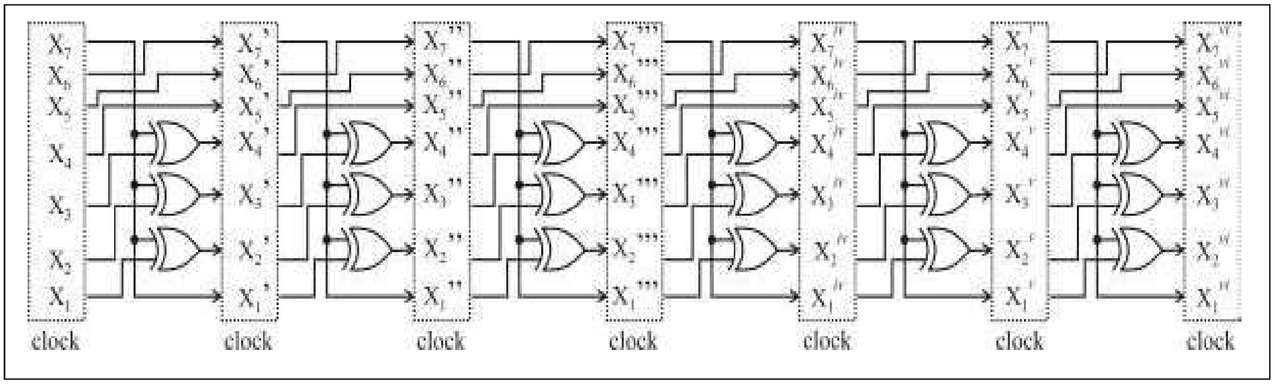

Figure 3. Contents of the ‘Galois’ shift register through 7 clock periods

$X_7'' = X_6'$

$X_6'' = X_5'$

$X_5'' = X_4'$

$X_4'' = X_7' \oplus X_3'$

$X_3'' = X_7' \oplus X_2'$

$X_2'' = X_7' \bullet \oplus X_1'$

$X_1'' = X_7'$

Since $X_7'' = x_5$ and $X_7'' = X_6'$, plus from the previous clock pulse the valid relation is $X_6' = X_7$, there is obtained

$$X_5 = x_5 \qquad (3)$$

With the identical procedure for the next clock pulse or by writing the relations on the same principle and using the relations from the previous clock pulse, and also properties of modulo-2 sum, the following dependences are obtained:

$$X_4 = x_4 \qquad (4)$$

$$X_3 = x_3 \oplus x7 \qquad (5)$$

$$X_2 = x_2 \oplus x_6 \bullet'' x_7 \qquad (5)$$

$$X_1 = x_1 \oplus x_5 \oplus x_6 \oplus x_7 \qquad (7)$$

These seven relations define relations between the content of the register and the appropriate pseudorandom binary code word, and also define the logic for initial adjustment of the read pseudorandom binary code word shown in Figure 2.

Now compare the conversion of the read pseudorandom code word {0, 1, 1, 0, 0, 0, 1} for the case of applying the first explained serial code converter and the proposed faster serial code converter. The initial code word is {1, 1, 1, 0, 0, 1, 0}. According to the algorithms described in [4], the pseudorandom/ natural code conversion is accomplished sequentially after loading it into a shift register having a reverse feedback equation $X(1) = X(4) \oplus X(5) \oplus X(6) \oplus X(7)$ (Figure 1). In the given example there are 10 shifts of register, and the counter state is p = 10 at the end, which is actualy the value of the current position of the movable system. Let us now look at the new code converter, which is shown in Figure 2. The code track is the same as shown in Figure 1. Now, the read code word is not written directly to the shift register, but feds the input of logic for the initial adjustment of the read code word (Figure 2). By the application of relations (1), (2), (3), (4), (5), (6), (7) the code word {0, 1, 1, 0, 0, 1, 1} is obtained as output. It is now directly saved in the shift registry. Now, the shift register sequentially passes through the following states: {1, 1, 0, 0, 1, 1, 0}, {1, 0, 0, 0, 0, 1, 1}, {0, 0, 0, 1, 0, 0, 1}, {0, 0, 1, 0, 0, 1, 0}, {0, 1, 0, 0, 1, 0, 0}, {1, 0, 0, 1, 0, 0, 0}, {0, 0, 1, 1, 1, 1, 1}, {0, 1, 1, 1, 1, 1, 0}, {1, 1, 1, 1, 1, 0, 0}, and {1, 1, 1, 0, 1, 1, 1} when the stop will be. The state {1, 1, 1, 0, 1, 1, 1} is the content of the register, which corresponds to the initial pseudorandom code word {1, 1, 1, 0, 0, 1, 0}. So, at the end of conversion the counter state is p = 10, which is exactly the same value as in the case of the first serial code converter.

4. Conclusion

During development of this faster serial pseudorandom/nature code converter the goal was to reduce the conversion time. It is achieved by the reduction in the number of serial connected gates in the feedback logic, which provides less propagation delay. For implementation of code converter, the parallel feedback logic configuration is applied and there has also been designed a simple logic of initial adjustment of the read code word into a appropriate state of the shift register, without which it would not be possible to realise the code converter proposed here.

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Destructive Testing Design for Surface Mounting

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ABSTRACT: *This paper reviews cutting methods to perform destructive testing for surface mounting. Demonstrates two ways of controlling processes during the production of technology equipment and process control. Demonstrates experimental results from a process for the production of laser-cut stencils.*

Keywords: Manufacturing, Production Process, Control Card, Control Point, Integrated System

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1. Introduction

Surface-mount technology is a major technology used in the manufacture of electronic equipment, from basic LED light sources [1] to complex computer systems and mobile devices [2]. Control over the technological process is crucial due to the widespread use of this technology. Destructive and non-destructive control methods exist. Optical methods for control are applied more frequently, including automated process control methods [3]. In spite of this automation, there are control points where the automated optical control systems are inappropriate to use. Those are processes that are applied relatively rarely and are designed to control individual elements. For example, control over application of solder paste in stencils. Solder paste-laying masks are manufactured based on different technologies [4], and the optical control is applied to assess the manufacturing technology. Both the dimensions and the shape of the resulting holes can be controlled though this method [5 by us]. The standard optical control in stencils sometimes is not able to evaluate the impact of all technological parameters and cannot address all questions. This paper will demonstrate a method for optical control on stencils that allows for a broader assessment of the process for laser cutting of stencils.

2. Laser Cut Stencils

Laser cut stencils feature many advantages compared to chemically pickled ones. Foremost, one can produce large, in terms of area, masks where the same precision in making the holes on the entire area is applied. At the same time, there are no limitations related to chemical methods' pickling to produce small holes.

An advantage of the method is also that a lower quantity of consumables is used during the manufacture of the stencils. Laser cutting treats the metal plate directly, as opposed to chemical etching, where the metal plate undergoes a procedure of preliminary treatment through photolithography, in addition to expenditures incurred to pickle and rinse the metal plate.

An advantage of the laser cut stencils is the ability to get relatively vertical walls of the holes – Figure 1.

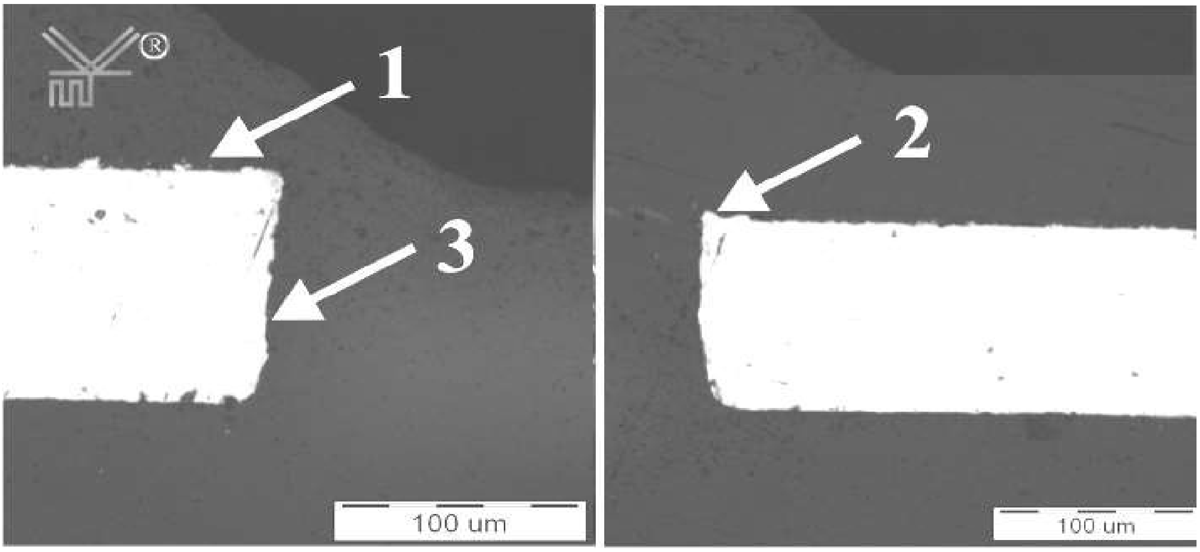

Figure 1. Cutting of a laser cut stencil. 1- plane of the mask, 2 – edge of the hole, 3 – wall of the hole

This verticality of the cutting, combined with the extreme movement precision of the laser beam and the small dimensions of the spot (cut), allow for complex holes featuring different orientations – figure 2.

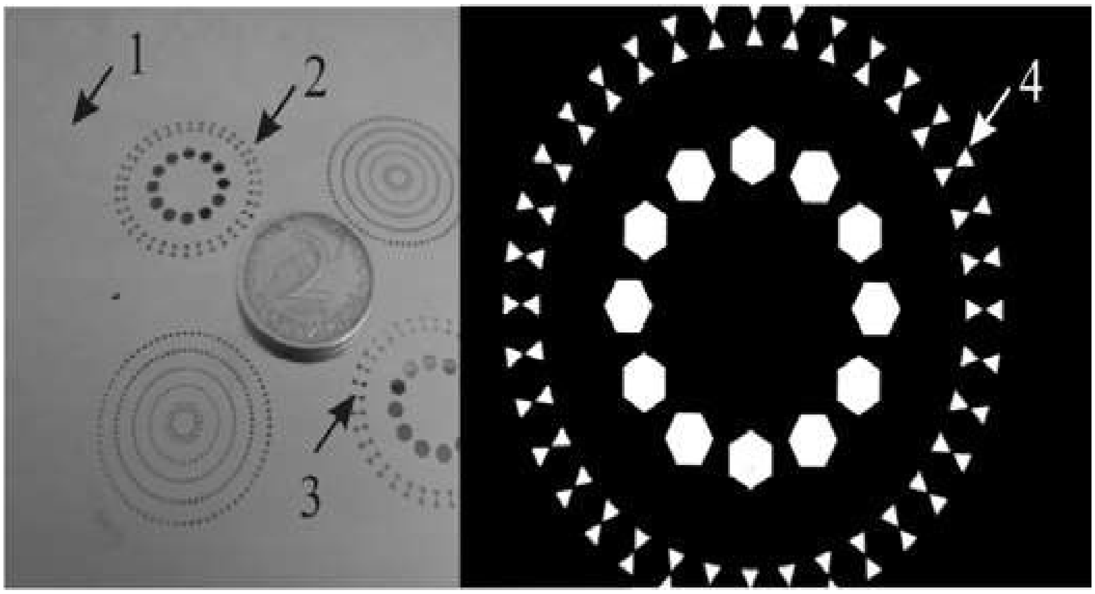

Figure 2. Shapes of holes in laser cut stencils

3. Optical Control

Both destructible and non-destructible optical control can be applied in the case of laser cut stencils. The shape and the dimensions of the holes can be viewed in horizontal plane in the case of non-destructible control. Variants of such an observation in two modes are showed on Fig. 2. In the case of observation in reflected light mode, one can see the surface of a stencil -1, the shape and location of different holes – 2, 3. For the purpose of precise control over the shape and dimensions of the holes, an observation method based on transmitted light is used and then figurations become contrasting – 4.

In the case of these stencils, the quality of the wall itself is crucial, not only the preciseness of the hole and the verticality of the walls. It might feature a different surface as well as defects – Figure 3.

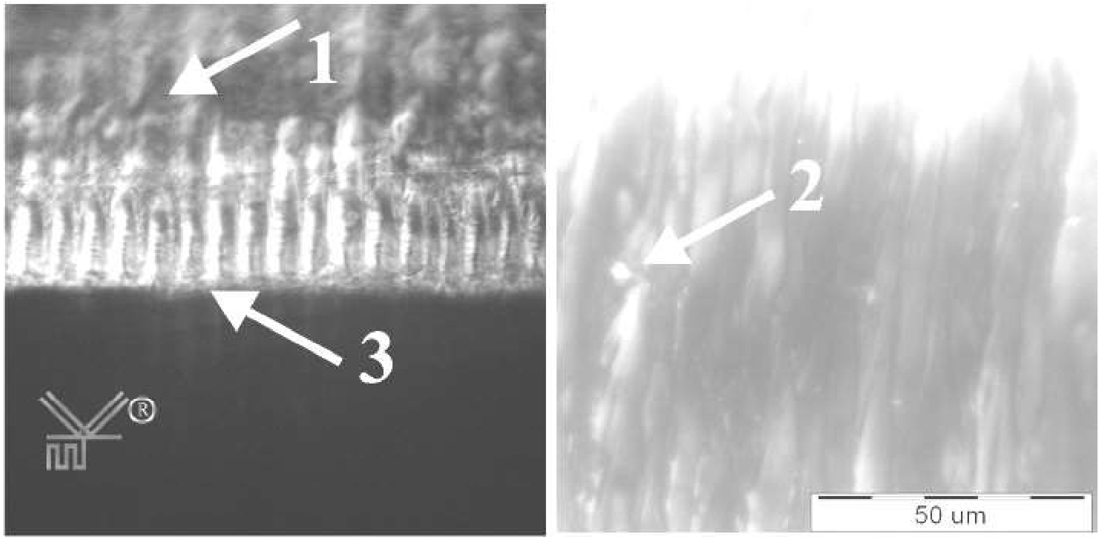

Figure 3. A wall of cut stencil. 1 – wall, 2 – defect, metal droplet, 3 – edge

Samples that have been cut along the holes have been used, allowing for better observation, while enabling observation of edges and walls – Figure 4.

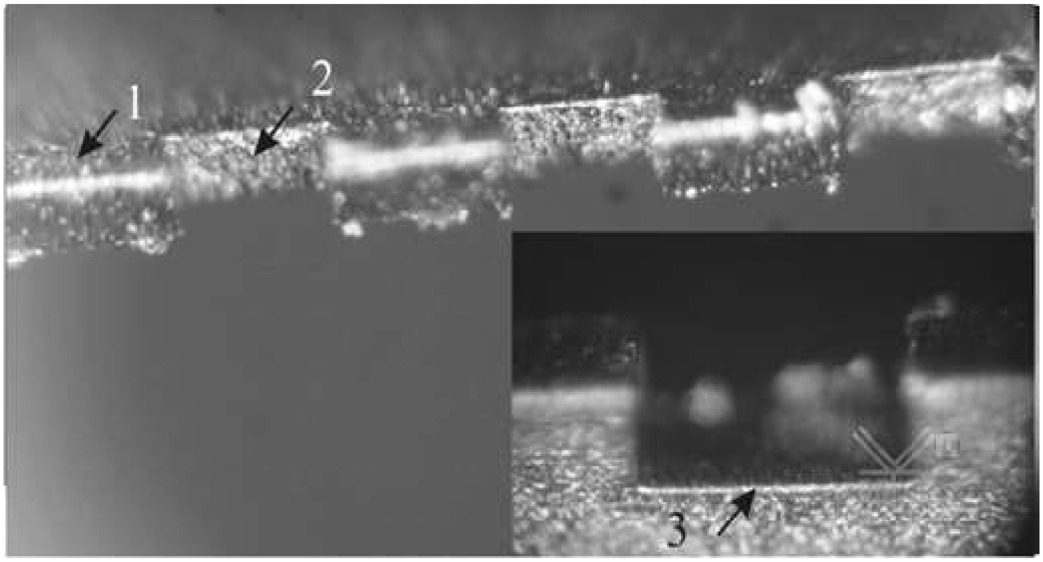

Figure 4. Samples for observation of cuts

At the above figure, one can see the surface of the stencil - 1, its wall – 2, and the edge of the hole – 3, where angled lighting is used.

In optimizing the modes of operation of the laser (power, impulse frequency, duration, movement speed), the possibility to compare the outcome of cutting against the consequential surface of the wall is essential. It can take the shape of channels, grooves, lusterless, and others – Fig. 5.

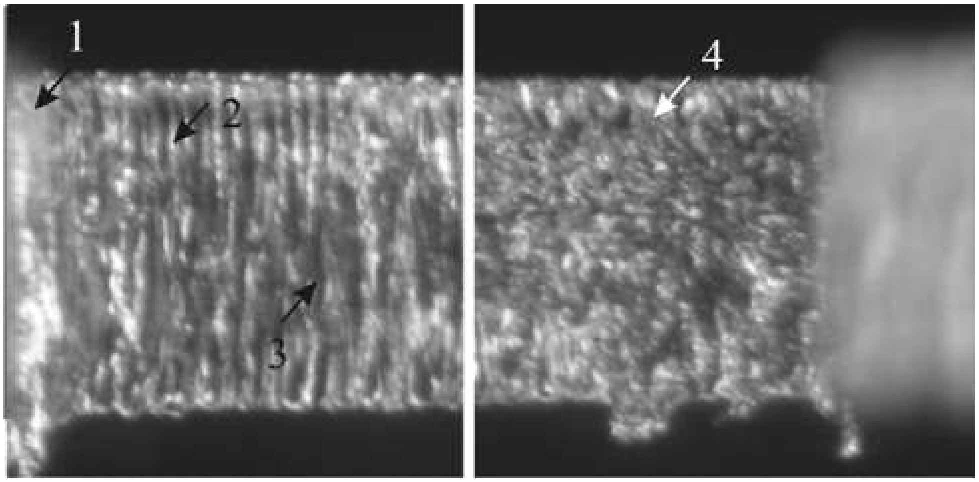

Figure 5. Different surface in laser cutting

Figure 5 shows the shapes of the wall at edge (angle of the hole) – 1, top of a groove – 2, pore – 3, lusterless surface – 4. The direct optical observation does not allow to assess the surface of the cut in detail despite that special samples have been made.

The height of the grooves, the presence of sub-surface cavities, etc., should be assessed. The assessment of the surface as a profile of the plane in different levels is of special interest.

4. Experimental Results

A standard approach to profile a surface involves the use of mechanical profile-measuring devices. Here, there are two restric-

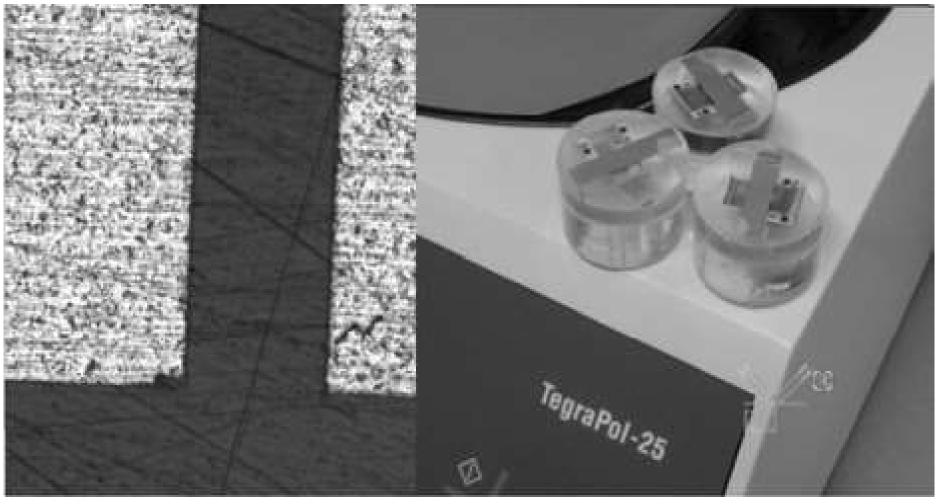

Figure 6. Samples of cutting in horizontal plane

tions. The wall of the hole is relatively small and narrow, requiring high level of precision during manipulation. On the other hand, the mechanical profile-measuring device is not applicable in the case of complex shapes – for example, curved groove. Bearing the abovementioned in mind, a decision has been made to make horizontal cross-sections, taking profiles of the hole. For this purpose, epoxy resin has been poured on samples of stencils, which have been placed vertically to the cutting plane – Figure 6.

The width of the sample has been under continuous control during the cutting process to determine the cutting plane. The cutting has been performed at 250 rpm, pressure of 30 Newtons per sample, and processing period of 30 seconds. Cut levels have been within 30 µm. In the beginning, cuts appeared at the levels of the metal droplets that occurred due to the cut – Figure 7, and then at the surface of the stencil.

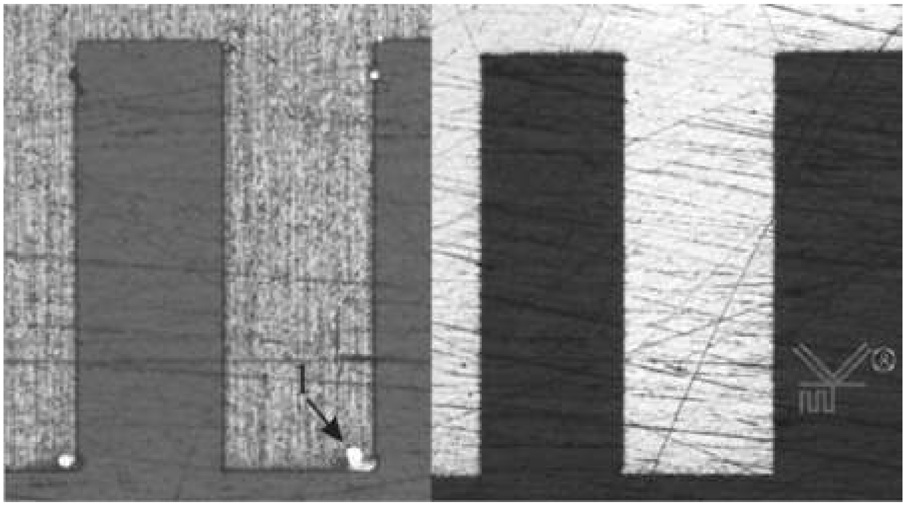

Figure 7. Horizontal cutting of a stencil. 1 – metal droplets

When performing cutting at particular distances, the shapes of the wall as resulting from different handling techniques emerged – Figure 8.

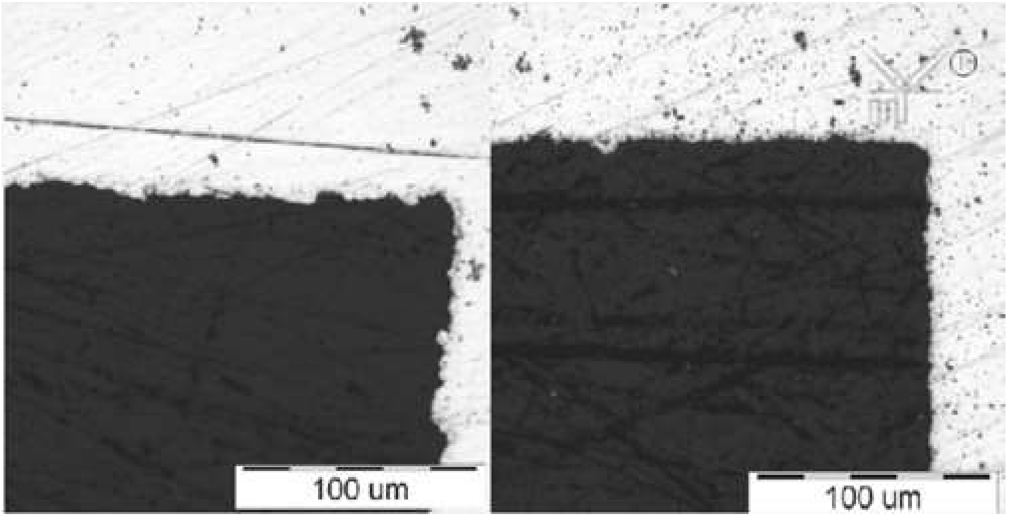

Figure 8. Different modes of cutting. Cuts after grinding

Software has been used to process the optical image to increase contrast and get sharp contour – Figure 9.

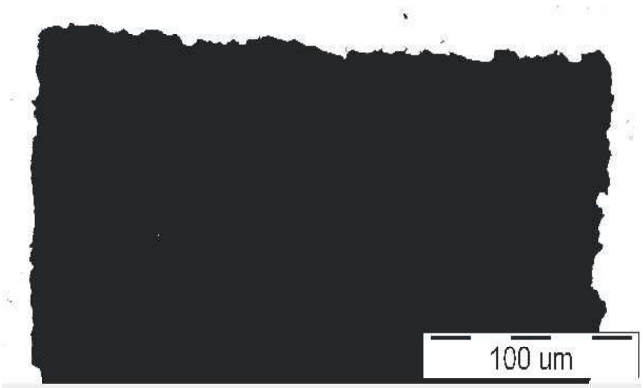

Figure 9. Contrast processing of a cutting

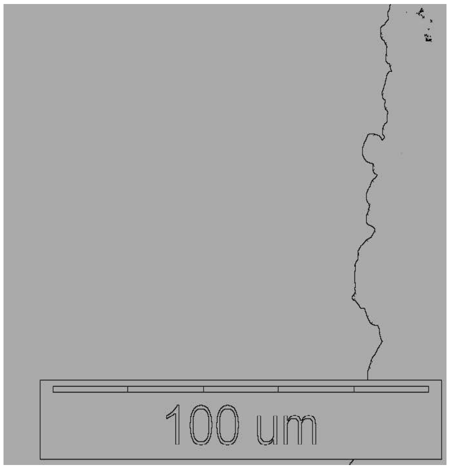

Figure 10. Contours of the cut surface after extracting

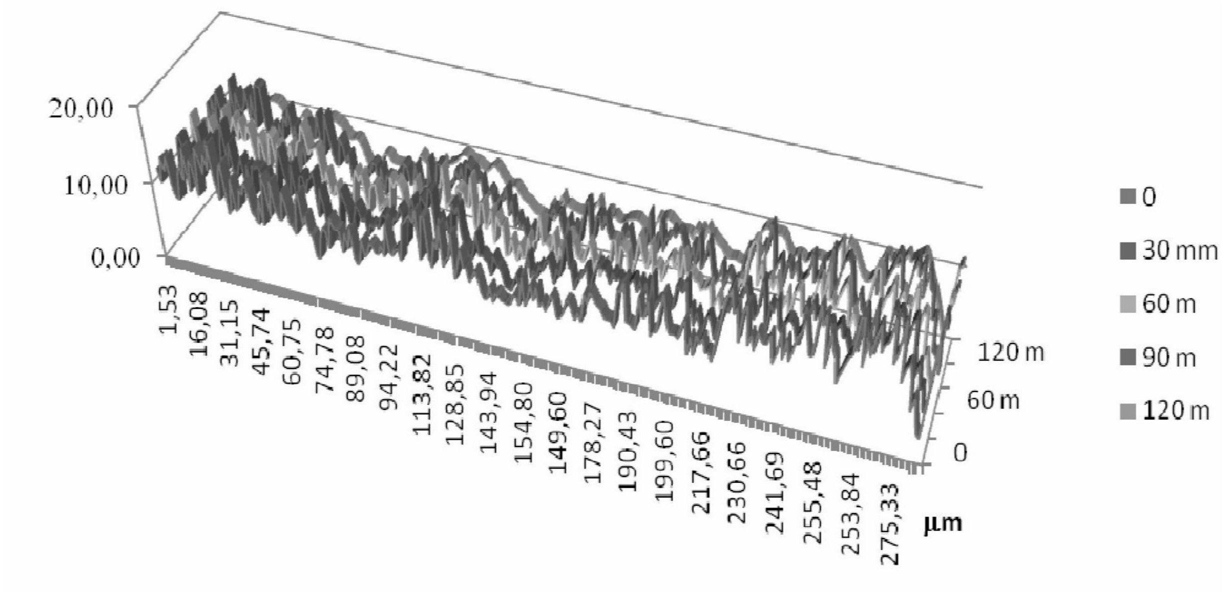

Figure 11. 3D diagram

A diagram of the contour itself is easy to extract, following the application of a respective processing method, where such a contour exists – Figure 10.

The transformation of the resultant contour into digital data is not hard to realize as well. All and every cut is processed using the demonstrated methodology and is transformed into digital data. Those may be presented graphically and may be used in different types of processing. The below figure 11 shows a sample how the results derived from the wall's contours can be displayed as a 3-D diagram.

5. Conclusion

This paper provides a method for destructive control over laser cut stencils designed for surface-mount assembly. This method allows for a wall profile of the hole, measured in absolute measurements, to be achieved and makes it possible to complement the assessment of cutting parameters. Combining profiles that have been accomplished at different cut levels with digital presentation of those profiles allows for creation of a 3-D digital image of the surface.

The efforts to obtain such a digital image using other methods, like mechanical scanning through profile-measuring device, face difficulties.

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