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# New approach for all-in-one control of galvanometer scanners

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**Abstract**

A new approach to connect scanners directly with a standard PLC (Programmable Logic Controller) with the advantages of the openness, flexibility and real-time communication of industrial fieldbus system will be presented. The main advantage is a connection of all for the specific laser application necessary sensors and actors within one control solution. We present a communication module, which was developed to realize the communication between the industrial fieldbus system EtherCAT and the digital scanner protocol SL2-100. The possibilities of the device will be discussed on selected example.

Keywords: scanner control; remote technology; remote laser processing;

## 1. Introduction

Remote laser material processing covers a wide range of different laser applications in the fields of laser welding, cutting and ablation of metals or non-metals [1-3]. For this purpose, highly dynamic laser beam deflection systems are used in combination with high-brightness laser beam sources. The beam deflection units consist of galvanometer scanners or rotating polygon mirror dependent on the specific application. Polygon mirrors are used if high and constant scanning speeds are requested, as in case of laser micromachining [4]. On the other hand, scanners are used due to their flexibility, high dynamic and low inertia for e.g. macro laser processes, as shown in [1-3, 5].

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With the increasing demands in terms of quality, productivity and cost-efficiency networked components are essential to handle even more complex laser material processes. Additionally, scanner technology is used in new approaches like the high frequency beam oscillation for welding [3] or cutting [5] applications that requires a communication between the main machine control and the scanner control in order to transfer the process into a complex contour.

## 2. Scanner Control

Hitherto, galvanometer scanners are mostly controlled via control boards or system controller units, which offer a wide range of possibilities, like on-the-fly processing, laser control interface, digital interfaces etcetera. The synchronization of the scanner to peripheral equipment, like the main machine control or the laser beam source, can be realized by digital interfaces. The new approach for the scanner control offers the possibility to connect the scanner directly to a PLC (Programmable Logical Control) with the advantage of the openness, flexibility and real-time communication of existing fieldbus systems. The objective of the development was the control of the scanner position dependent on the specific event from e.g. the main machine or a specific process sensor. Therefore, a device, the so-called ESL2-100 module, was developed as gateway between the industrial fieldbus system EtherCAT and the SL2-100 scanner protocol from Scanlab, which will be described as follows.

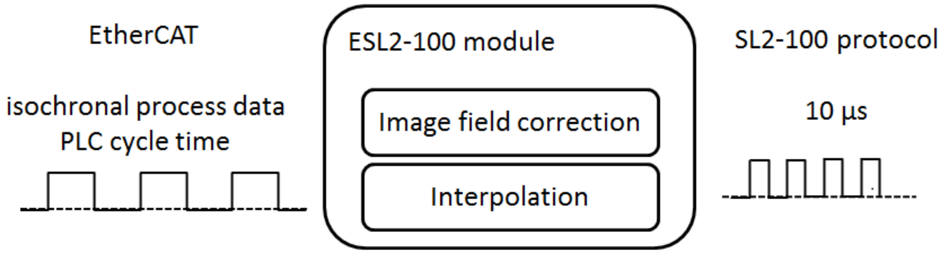



Fig. 1. Principle of the ESL2-100 module

Table 1. Process data interface of the ESL2-100 module

| notation | specification |
| --- | --- |
| Control Word | Activation, Interpolation Mode |
| Input | Feedback Position, Temperature |
| Status Word | Temperature OK, Position OK, Power OK |
| Output | Set Position |

The ESL2-100 module is designed as gateway between the industrial fieldbus system EtherCAT and the scanner protocol SL2-100. The device controls up to two axes as single axis or as x/y scanning system. The incoming isochronal process data are transferred into the SL2-100 specific protocol (see Fig. 1). Within each PLC cycle process data, including a control and status words as well as time-discrete input and output data (see Table 1), will be transmitted and, as in case of the position data, interpolated dependent in the selected interpolation method. For PLCs using slower output cycle-times, the module can be used in an oversampling-mode. That means, at every PLC-cycle the module get up to ten positions, which will be interpolated sequentially in this PLC-cycle. Additionally, the image field correction can be executed, if requested as in case of x/y scanning systems, at the ESL2-100 module. This image field correction should minimize the pincushion distortion, the optical distortion and additional nonlinearities of the scanning system

The amount and the position of the ESL2-100 modules within the fieldbus topologies are dependent on the application and the local industrial conditions. The devices are scalable if more than one scanning system is requested for the specific application and flexible if scanning system must be synchronized between different process steps, which are physically separated from each other.

### 3. Application

The ESL2-100 module can be used to control a x/y scanning system. One possible application, which demonstrates the possibilities of the device, is the high frequency beam oscillation. This technique is characterized by a x/y scanning system that deflects the laser beam relative to the feed direction of the main machine. In comparison to conventional processes, beam oscillation offers the possibility to influence the energy deposition under consideration of additional process parameters like the oscillation frequency, the amplitude and the phase shift. In the most cases harmonic oscillations are used to obtain Lissajous figures, as discussed e.g. in [5, 6]. The main objective of the tests is adjustment of the oscillation pattern with respect to the contour path in order to transfer the process into a complex contour and the adjustment of the oscillation parameters dependent on a specific trigger event.

The functional principle used for the tests is shown in Fig. 2. The oscillation of the each scanning axis is calculated on the PLC. The isochronal position values x(t),y(t) are adjusted based on the feedback position of the main axes system in order to rotate the oscillation pattern dependent on the contour path. The rotated position values x’(t),y’(t) are transferred over EtherCAT to the ESL2-100 module and subsequently over the SL2-100 protocol to the x/y scanning system.

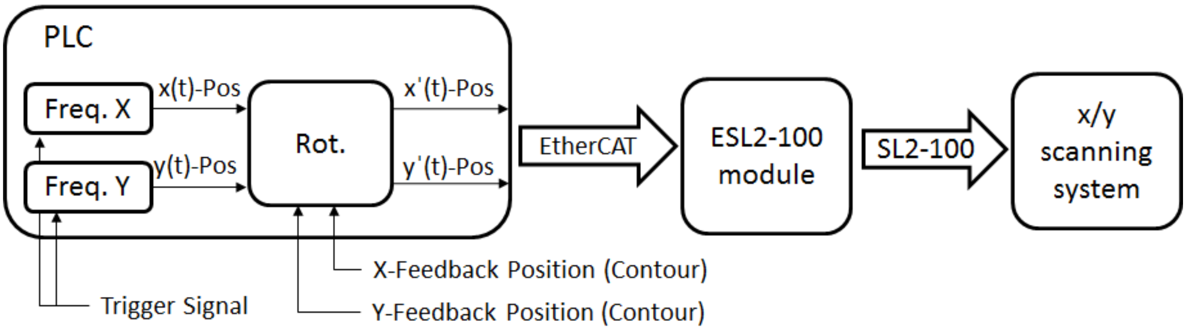
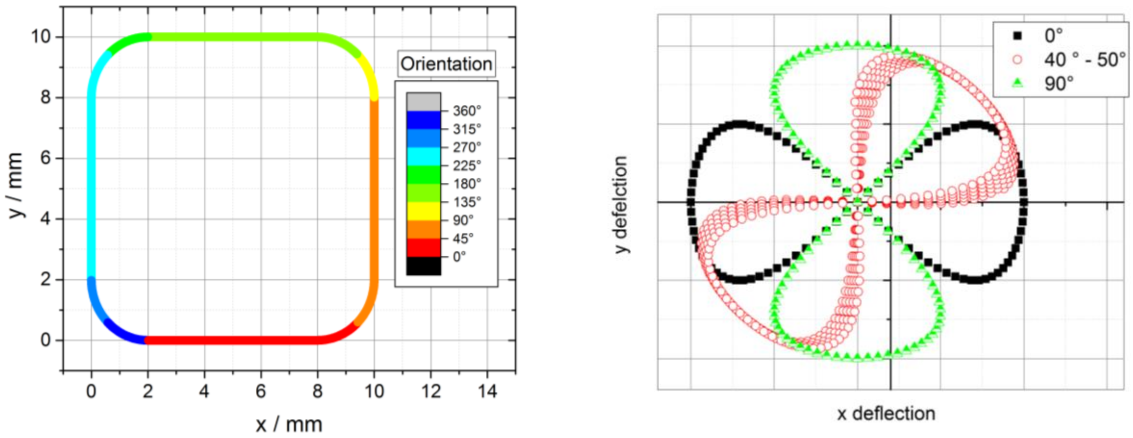



Fig. 2. Functional principle of the control structure for beam oscillation

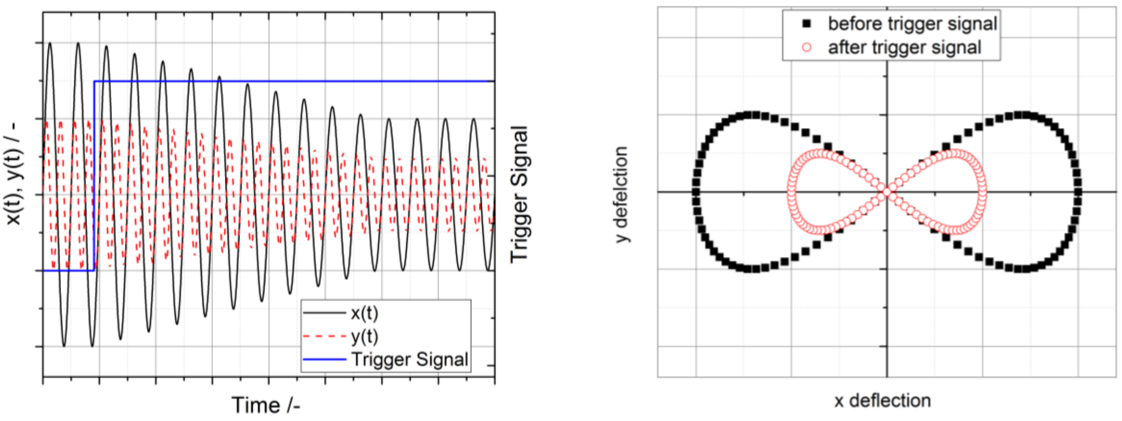
The path tracking and correction is theoretically demonstrated on a simple contour path for an eight-shaped Lissajous figure aligned longitudinal to the movement direction of the contour path. The orientation of Lissajous figure is adapted dependent on the feedback position of the main axes, as exemplary shown for the rounded corner on the bottom right side of the contour (seen Fig. 3). In Fig. 3(b) the start orientation of the eight-shaped Lissajous figure at 0°, an intermediate position (40° to 50°) and the end orientation of 90° at the exit of the corner are illustrated.

Another advantage of the ESL2-100 module is the modification of the scanning path dependent on a specific event. The event can be generated by an additional process sensor or on user request etcetera. However, the signal must be triggered and transferred to the scanning system. Here we use the trigger signal to reduce the size of the Lissajous figure (2:1) by changing the amplitude, as can be seen in Fig. 4. A linear fitting function was implemented for a smooth reshaping of the oscillation pattern (see Fig. 4(a)). The parameter of the fitting function can be modified in order to adjust the transition behavior. Beside of the oscillation amplitude, the frequency and the phase shift can also be modified which offer the possibility to select e.g. other Lissajous figure. The combination of both, the contour path adjustment by calculating of the orientation and the modification of the oscillation parameters are also possible.




(a) (b)

Fig. 3. (a) contour path of the main axes system (Feed rate F = 0.6 m/min, movement counter-clockwise) and calculated orientation and (b) oscillation figure, eight (longitudinal) for different orientations




(a) (b)

Fig. 4. (a) Signal diagram x(t), y(t) and trigger signal and (b) reshaping of oscillation amplitude (2:1), eight (longitudinal) before and after the trigger signal

## 4. Conclusion

ESL2-100 module can be used to control galvanometer scanner as single axis or x/y scanning system. The device can be integrated into the existing industrial fieldbus system and offers the possibility to adapt the scanning path. We have demonstrated possibilities of the ESL2-100 module exemplary shown for beam oscillation. On the one hand we have shown the possibility to track the position of the main axes system in order to adapt the orientation of the oscillation pattern dependent on the contour path. On the other hand we demonstrate the real-time capability by adjusting the oscillation parameters dependent on a trigger event, which could be generated for process sensors or on user request etcetera.

The beam oscillation is one possible application where the ESL2-100 module can effectively be used. Additionally, we see the possibility to use consider the dynamic of the galvanometer scanner comparable to conventional NC axis and to use G-Code as program language.

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