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Small conveyor with proximity sensors and closing mechanism design

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***Abstract* — the paper describes a new design of a small conveyor line which can be used for presentations or educational purposes. The advantage of the designed conveyor line is that it can be used with any PLC currently available on the market. The designed conveyor line consist of eleven sensors, two stepper motors, plastic parts, aluminum parts, etc. The main purpose of the created device is packaging small boxes filled with metal parts. Several plastic parts such as a closing mechanism and motor holders were designed with the help of a 3D environment and a 3D printer. The paper also describes the functional principle of included schematics.**

***Keywords* — conveyor line, proximity sensor, stepper motor, tooth timing belt.**

I. Introduction

In present days the concept of conveyor line is well known. The conveyor lines are mostly used in an industry. The main purpose of the conveyors is doing repetitive work faster than humans. In some cases the conveyors can work in an unhealthy and dangerous environment for humans. Due to that the conveyors are very useful and most needed for present industry.

Common conveyors occupy a lot of space in the room. Therefore, for an education purposes with lack of space in the room, the common conveyors are very unpractical. This is the main reason why students in many schools cannot practice with the real sized conveyors but only in simulations. Therefore the goal of this paper presents a small sized conveyor model with different sensors which can be easily transported. The conveyor can move and closing small boxes. Manage that the several steps have to be done. Hence the paper briefly provides steps for achieving this goal.

The first chapter describes proposed concept of the conveyor model. The second chapter describes a way which can be used for a speed and a direction control of the proposed conveyor belt. The third chapter described a design for an object position determining. The very interesting part of the conveyor model is described in the fourth chapter. This chapter describes a way of close mechanism of small boxes. But first things first. The following chapter briefly provides proposed concept of the conveyor model.

II. Proposed Concept of the Conveyor Line

The concept of the conveyor was pointed to presentation and education purposes. First thing was determining dimensions. In this case the dimension of the whole conveyor is illustrated in the figure, Fig. 1. The Figure also shows the position of each sensor. The concept includes two types of position sensors, the one type of a light barrier and a one camera sensor.

The individual numbers are represented as follows: numbers 1 to 5 represents optical position sensors. The position sensor one represents a start state for added object. The second position sensor ensures right position for the camera sensor which is labeled with number seven. The camera sensor reads QR code of passing objects. The position sensor three detect the home position of a closing mechanism. The closing mechanism provides closing of the objects. More detailed description of the closing mechanism is presented in the chapter five. The position sensor with number four detects work position of the gripper. The position sensor five represents the end state of the process. The sensors with number 6 and

8 represents the induction position sensors. The position sensor six make sure that added object is not empty. If it so, the process will stop. The position sensor with number eight ensure right position for closing process. The sensors 9 to 11 ensures the presence of added object during the whole process and also provides control status during and after the closing process. These sensors are only receivers. The transmitters generate laser lights from the opposite side of these sensors which are labeled with the number 12.

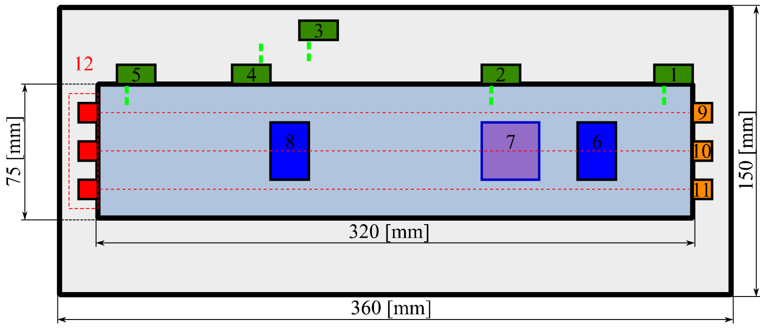

Fig. 1 Proposed concept of the conveyor

The dimension and layout of the conveyor are determined. The next step was designing the shape and drive of the conveyor belt itself. Hence the next chapter provides more information.

III. Speed and Direction Control of the Conveyor Belt

Based on proposed dimensions the main part of the conveyor was created as can be seen in the figure, Fig. 2. The black parts in the figure, Fig. 2 were created with the help of 3D environment called Blender. Then the created objects were exported to STL type of file. Subsequently, these parts were printed by the 3D printer.

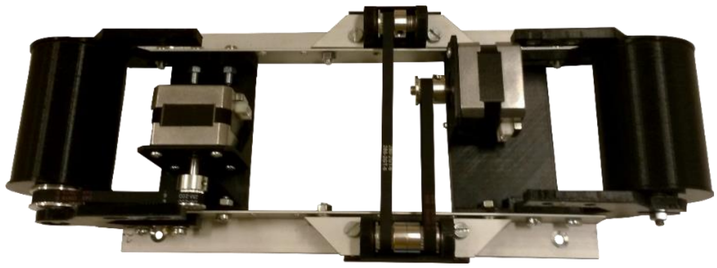

Fig. 2 Designed and created main part of the conveyor

As can be seen in the figure, Fig. 2 the conveyor consists of two stepper motors, tooth timing belts, timing pulleys, and plastic and aluminum parts. Concrete two bipolar stepper motors are used. Because the main subject is not describing the principle of stepper motors, the literatures [1] and [2] provides more information about them. The stepper motor on the left side ensure motion of the conveyor belt and the stepper motor on the right side ensure closing and opening of the claws which are described in the chapter five. The stepper motor is driven by the stepper motor driver with type of A4988. This stepper motor provides enough power for motors and it can be easily implemented. The power supply of the motor side for the motor driver can be 24 V. The power supply of the control electronics of the motor driver has to be lower than 6 V and higher than 4 V. The literatures [3] and [4] provide more information about motor drivers. Therefore the two voltage levels in this case are required. Also the control pulses must be at the same voltage levels as the voltage level of the control electronics of the motor driver. Hence the pulses from a PLC (Programmable Logic Controller) must be modified. In this case the pulses from the PLC are modified by the voltage divider which consist of two resistors as can be seen in the figure, Fig. 3.

As can be also seen in the figure 3 the pulses which determine the motor speed are generated with the help of an integrated circuit NE555 (analog timer). This analog timer in the scheme is working in astable mode. The frequency of pulses is determined by *RC* elements. In this case the element *R* can be changed by potentiometer. This type of connection provides pulses with a desirable frequency which in conclusion change the motor speed. The transistor Q2 in scheme turn on and off the pulse generator. Due of that when the motors are not used the pulse generator does not need to be powered up. From the proposed electrical scheme the printed circuit board was created (PCB) as can be seen in the figure, Fig. 4. A direction changing of the stepper motors is provided by the logic state of the pin number 8 of the stepper motor drivers. The stepper motors do not need to be powered up when they are not in use. Therefore the input state of the pin number 1 of the motor drivers can turn off and on the power for the stepper motors

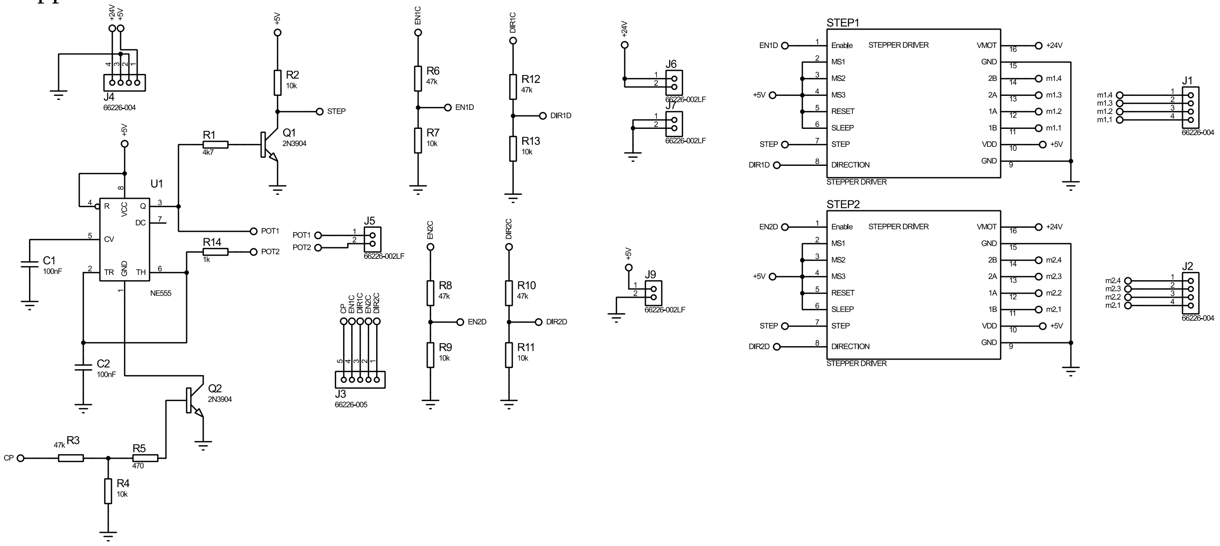

Fig. 3 Electrical schemes of motor speed and direction controlling

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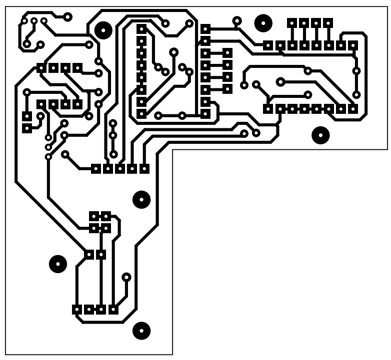

Fig. 4 Proposed PCB of motor speed and direction controlling

Subsequently the PCB was created and tested. The shape of PCB perfectly fits in behind of the right stepper motor shown in the figure, Fig. 2. The actuators of driving are functional. Now it is time to look at the position sensors and their way to use them for the conveyor purposes.

IV. Design for Object Position Determining

In present days exists too many sensors dedicated to object recognition. Disadvantage of most of them is that they do not work in such small distances properly and their case is too big for this purpose. Therefore the different way of the object recognition was implemented. The first requirement was that the sensor must detect object contactless. Hence the proximity IR sensor was considered. IR stands for infrared radiation where wavelengths are between 700 nanometers and 1 millimeter. The IR light is not visible to the human eye. It is used in many applications such as TV remote and Night-vision cameras. In a proximity sensor an IR diode and a phototransistor are used to find an obstacle. The IR diode transmits light in the forward direction when an obstacle is ahead the light reflect and the phototransistor is activated. Literatures [5] and [6] provide more information about IR proximity sensors. Basically the closer the object to the sensor is, the more light is reflected to the phototransistor which will be more closed. Therefore the output signal is analog. For this purpose the digital signal is required. Hence the analog comparator is used as can be seen in the figure, Fig. 5.

The LED diode *D1* indicates that the sensor is powered up. The LED diode *D2* indicates the presence of the object. In this case the diode is lit up when the object is not detected and light down when the object is detected. The distance when the analog comparator has to reverse its output value can be modified by the potentiometer *RV1*. This type of proximity sensor can operate in small distances, but with voltage level of 5V. But the digital input pins of the PLC operate with 24V logic. Therefore the output signals from the proximity sensors must be altered to 24V. This can be handled by using additional bipolar transistors as can be seen in the figure, Fig. 6.

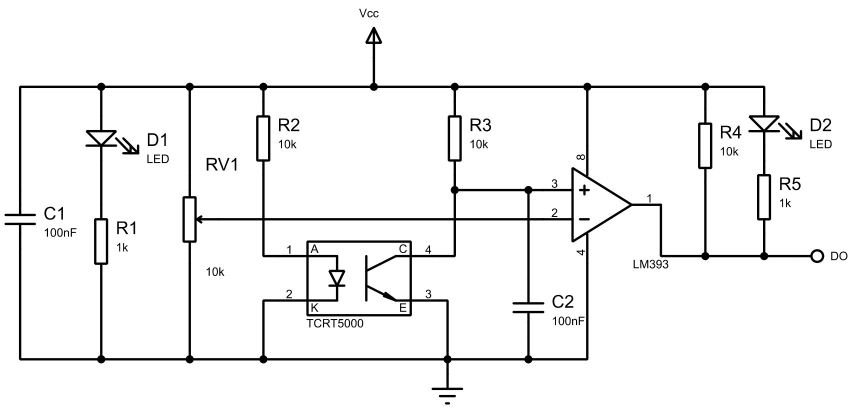

Fig. 5 Schematic of IR proximity sensor

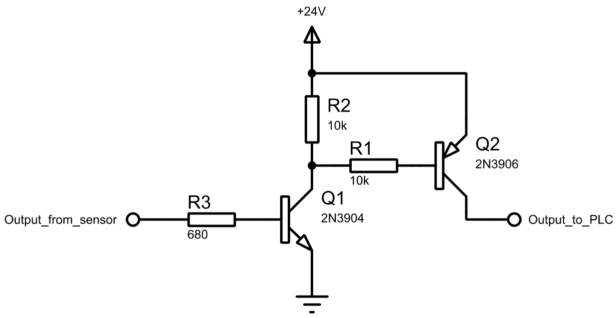

Fig. 6 The schematic of voltage level adjustment

As can be seen in the figure, Fig. 6 the voltage level adjustment consist of two bipolar transistor. The reason is that the PLC drain a small amount of current (20mA) to detect voltage level. Hence the additional PNP transistor must be implemented. The proposed PCBs of voltage level modifiers and terminal are illustrated in the figure, Fig. 7.

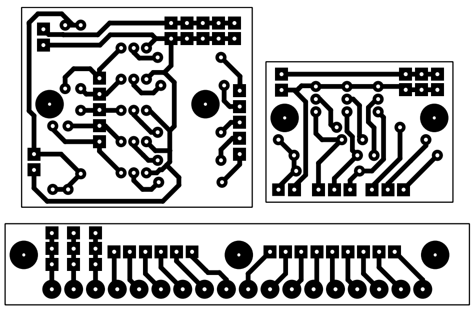

Fig. 7 The proposed PCBs of voltage level modifier and main terminal

The schematic in figure, Fig. 5 and the figure, Fig. 6 are used for each proximity sensor. Thus, for sensor from number 1 to 5 in the figure, Fig. 1. Therefore the two PCBs was created. The first PCB can handle five sensors. The second PCB can handle three sensors. The PCBs were divided because the sensors are on different sides of the conveyor line. The main terminal PCB provides simple connection between the PLC and the device itself. Detailed description is presented in the Table. I.

For sensors detecting the presence of the object (sensor 9 to 11 in figure, Fig. 1) are used the same schematic, but instead of the IR diode and the phototransistor the laser diodes and the photo-resistors are used. The principle of using this schematic is the same. The difference is that this design behave as a light barrier. The sensors displacement on real device are illustrated in figure, Fig. 7. The device in addition has two induction sensors (number 6 and number 8 in figure, Fig. 1). This sensors uses schematic which is illustrated in the figure, Fig. 6 to alter the voltage level to 24V. The inductive sensor 6 detects metal parts of added objects. For example screws or nuts. The inductive sensor 8 serves as a position sensor for closing box with metal parts. All aluminum parts were manually processed. As the conveyor belt a textile material was used.

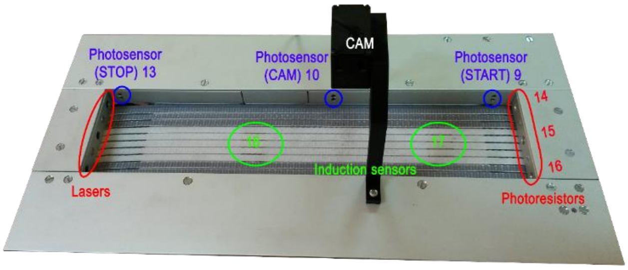

Fig. 8 Displacement of sensors on the proposed conveyor

The labels in the figure, Fig. 7 are different as labels in the figure, Fig. 1. It is because the labels in the figure, Fig. 7 represents the numbers of terminal pins which is illustrated in the figure, Fig. 8.

Fig. 9 Main terminal of the conveyor

The meaning of these numbers is explained in Table. I.

Table. I
Main terminal pin description

Pin number	Type	Shortcut	Description
1	-	GND	Ground
2	-	+24V	Mains supply voltage for the stepper motors and the voltage level adjustments
3	-	+5V	Mains supply voltage for the sensors
4	INPUT	EN_PULSES	Turn signal on and off for the stepper motors. +24V – the signal is on GND – the signal is off
5	INPUT	EN_CON	Turn on and off the power supply for the conveyor belt driver +24V – power supply on GND – power supply off
6	INPUT	DIR_CON	Change direction of conveyor belt +24V – the conveyor belt is moving toward to start position GND – the conveyor belt is moving toward to stop position
7	INPUT	EN_GRIP	Turn on and off the power supply for closing mechanism +24V – the closing mechanism is activated GND – the closing mechanism is deactivated
8	INPUT	DIR_GRIP	Change direction of closing mechanism +24V – the closing mechanism is moving toward to work position GND – the closing mechanism is moving toward to home position
9	OUTPUT	S_START	Sensor of start position (+24V-no object, GND – object detected)
10	OUTPUT	S_CAM	Sensor of right position for the camera (+24V-no object, GND – object detected)
11	OUTPUT	S_HOME	Sensor of home position of closing mechanism +24V – the closing mechanism is out of home position GND – the closing mechanism is in home position
12	OUTPUT	S_WORK	Sensor of work position of closing mechanism +24V – the closing mechanism is in work position GND – the closing mechanism is out of work position
13	OUTPUT	S_STOP	Sensor of stop position (+24V-no object, GND – object detected)
14	OUTPUT	S_LASER1	Sensor for object presence detection (first from the Start sensor) +24V – the object is detected GND – the object is not detected
15	OUTPUT	S_LASER2	Sensor for object presence detection (middle) +24V – the object is detected GND – the object is not detected
16	OUTPUT	S_LASER2	Sensor for object presence detection (far from the Start sensor) +24V – the object is detected GND – the object is not detected
17	OUTPUT	S_IND1	Sensor for metal parts presence +24V – the object is detected GND – the object is not detected
18	OUTPUT	S_IND2	Sensor for closing mechanism right position +24V – the object is detected GND – the object is not detected

Although the sensors are located the closing mechanism has to be described more detailed. Therefore the next chapter except of functional of principle of closing mechanism also shows the closing mechanism displacement.

V. Design of Closing Mechanism

The grip, also called closing claws in this case the closing mechanism is dedicated to close small boxes filled with metal parts. The drive of closing mechanism is also provided by the stepper motor. In this case the two tooth timing belts are used. The first tooth timing belt connected to the motor timing pulley drive common shaft of the second tooth timing belt as can be seen in the figure, Fig. 2. To the second tooth timing belt is connected a part of the closing mechanism which were also 3D printed. The plastic parts of the closing mechanism are connected to the linear bearings as can be seen in the figure, Fig. 9. From the figure the connection between the linear bearings and the linear rail can be seen. The right side of the figure shows the 3D printed part of the closing mechanism and an illustration of the used linear bearing rails.

Fig. 10 The closing mechanism

The sensors which detect home and work position are located near to the one claw as can be seen in the figure, Fig. 10. The measuring distance of these sensors is very small. With included potentiometers the home and the work position can be modified according to box size. If the work position is set incorrectly the two things can happen. If the work position is set to far, the added box will be deformed. If the work position is set to near, the added box won't close enough. Hence the work position sensor must be modified according to box size.

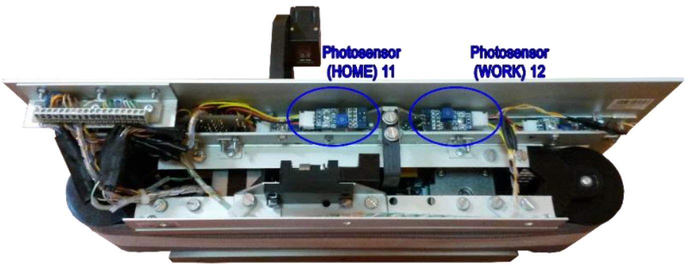

Fig. 11 The location of the home and work position sensors

VI. Conclusion

The paper presented one way to build the small conveyor line for presentation or educational purposes. The advantage of this device is that it can be used with any PLC currently available on the market. The goal was achieved. The one an additional function could be the current measuring of the motor drivers. With that function the PLC can take action if the conveyor belt will be stuck. The disadvantage of the designed conveyor line is that the speed of the conveyor belt can be modified only with screwdriver manually. In next the additional function could be in implementing an analog multiplexer which will connect different resistor responsible for capacitor charging/discharging speed based on a logic combination from the PLC.

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