

## Universal Test Bench for Characterization of Distance-measuring and Strain Sensors

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### Abstract:

Following text describes a universal test bench that can be used for characterization of the sensors. It offers sufficient distance and force ability to characterize a wide sort of the sensors. It is suitable for precise distance setting. It is able to set the distance in the range of 10 cm with the resolution up to 10  $\mu\text{m}$ . The mechanical tolerance is negligible. It is less than five micrometers for unloaded viper. Possible relevant tolerance can be caused only by the structure frame bending when the high mechanical stress is applied. The test bench was developed as a research instrument for characterization of new sensor structures and it is also used as a teaching facilitation in the sensor systems tutorial. The test bench functionality is illustrated on five types of the sensors – the capacitive sensor, the optic sensor GP2D120, the Hall sensor A1301, the magneto resistive sensor HMC1501 and for the compression measurement was used the cantilever beam LC501-100.

### INTRODUCTION

The distance measurement is one of the most important tasks in automatization and industrial applications. There are many sensors that can be used for this purpose nevertheless their development is still in progress. The sensors exhibit several characteristics that determine their applicability for given purpose. The most important are linearity, resolution, hysteresis, maximal range, mechanical robustness, repeatability of the measurement, temperature stability, and long term stability. Presented test bench enables precise characterization of most of them; other features can be tested with the extra equipment. The test bench also exhibits quite high pressure force so it can be used also for application of the mechanical stress.

### MECHANICAL CONSTRUCTION

The test bench conception is based on brass rails sledging in the aluminum frame. The frame consists of aluminum panels and aluminum viper on the rails. Figure 2 presents an engineering drawing of the frame, where the aluminum panels and the viper are presented including the basic dimensions. In the vipers center there is a hole for gearing thread. The sledging viper is driven by the thread stem which is gripped in two bearings. The viper is guided on the brass rails and two other brass stems are conducting away the viper's movement. All this construction is mounted on the cuprexit board together with the driving and evaluating electronics. This concept guarantees the maximal steadiness and robustness of the mechanical movement.

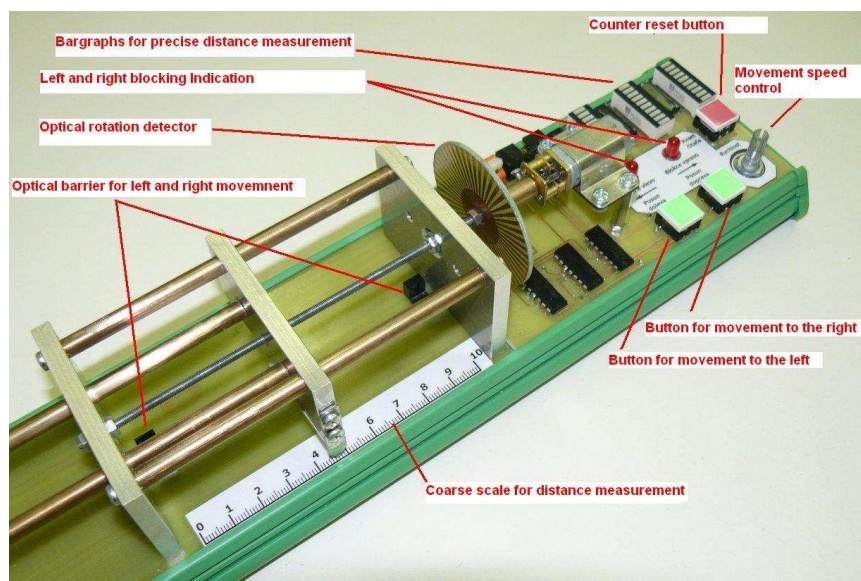


Fig. 1: Description of the bench

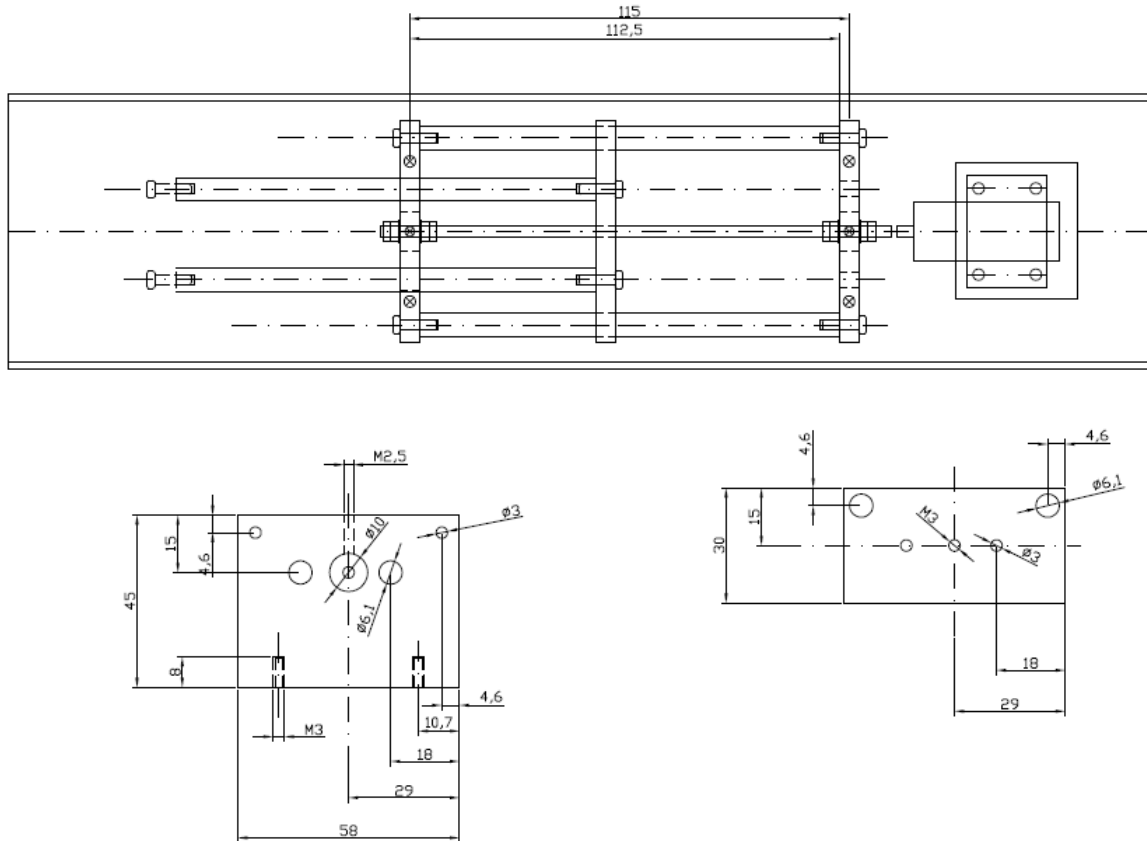


Fig. 2: Engineering drawing of the mechanical frame

The thread is driven by an electromotor which is equipped by the gear unite with the transfer ratio of 1:68. The screw thread is converting the rotation to the linear movement. This configuration exhibits a high pressure-force. This is why it can be also used as an actuator for strain gauges sensors or pressure sensors. The movement of the viper is relatively slow – maximum speed is around 1 mm per second, but the pressure can reach up to 200 N (with power consumption of the motor 5 V / 50 mA). This force can be dangerous for the mechanical parts of the viper - namely when the wiper reaches the end of the screw-thread. In order to avoid the damage there are implemented two optical barriers for movement to the left and to the right. Signal from the barriers is guided to the driving electronics and it inhibits any driving signals for the blocked direction.

The movement can be controlled manually using the pushbuttons on the right side or it can be driven by the electronic interface. The onboard electronics is protecting the motor against the operator's errors such as simultaneous button push to the left and right side, it can regulate the movement velocity and it is measuring the distance. The coarse distance is readable on the scale below the viper and fine displacement is readable on the bargraphs (see the figure 1). The distance on the bargraphs is counted optically using the barrier and ribbed rotating disc. There are 50 transparent ribs on the disc (cuprexitit

with out the copper layer is transparent for the infrared light). Taking into account the M3 screw rail dimensions and number of the ribs, it can be calculated that one impulse from the optical barrier equals to 10  $\mu\text{m}$  of the vipers translation.

## ONBOARD ELECTRONICS

Most of the electronics is placed directly on the board with the mechanical frame and electromotor. The other is placed below the main board. Useful solution is to mount this auxiliary board on the distance posts down side from the posts of the electromotor mounting. In presented solution the power supply circuits, the pulse width modulation generator and transistor switch are mounted this way.

Other electronics such as circuits for sensor powering and evaluation can be soldered on the inner side of the cuprexitit board with the aluminum frame.

The electronics is designed universally and it is prepared for automatic external driving using the computer or microcontroller via the connector interfaces.

### Power supply and motor switch

The electronics is powered by 5V DC. The stabilization is provided by the standard circuits. There can be two stabilized voltages. The extra

voltage can be applied for the electromotor while it was not necessary for the presented solution.

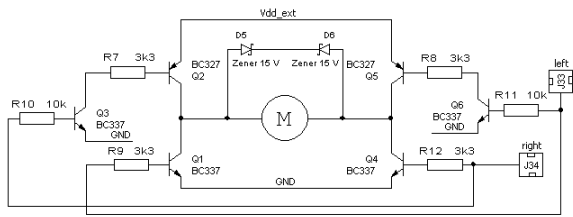


Fig. 3: Transistor bridge for motor driving

Figure 3 presents the transistor bridge driving the electromotor. Direction of the rotation is selected via the logic values on the pins *left* and *right*. The control logic circuits must guarantee protection against the simultaneous logic high on these inputs to protect the transistor bridge against the shortcut.

### PWM generator for viper's velocity control

The velocity of the viper's movement can be regulated using the pulse width modulation (PWM). There are two possibilities of generation the PWM signal. It can be done externally or it can be selected the signal from the internal generator. There are two jumpers on the main board for this purpose.

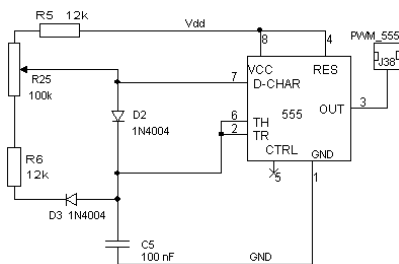


Fig. 4: PWM generator with the circuit 555 [1]

Figure 4 presents basic circuit for PWM signal generation with the 555 circuit. The potentiometer R25 is mounted directly on the main board while the electronics itself is hidden on the inner auxiliary board together with the power stabilization and switching bridge.

### Push buttons

The pushbuttons are used for controlling the movement direction and reset of the counter. They are mounted on the main board and have their own signalization. The signalization LED and resistor R31 serve also as a pull down resistance for ensure the logic zero on the inverter (figure 5). Both logic states (voltage on the signalizing LED and the inverted state) are important for the driving logic.

The logic state on the button can be sensed or forced also externally via the connector interface. This concept enables direct application of the external signal and thus combining the manual and automatic control.

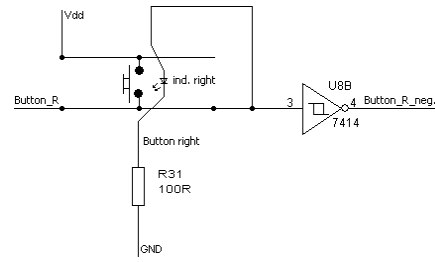


Fig. 5: Pushbutton electronics

### Optical barrier for blocking the movement and distance measurement

There are three optical barriers implemented on the main board. One is for sensing the screw thread rotation. The ribbed disc is interrupting the light beam and thus generates the signal. Then it is guided to the chain of the CMOS 4017 counters with the bargraph displays.

The other barriers serve for blocking the movement on the ends. Signal from the barriers is inverted and evaluated by the control logic. Figure 6 presents the scheme of the barriers for blocking the movement on the ends.

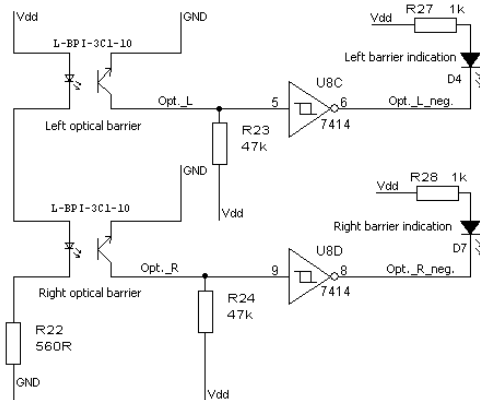


Fig. 6: Optical barrier electronics

Current for the transmitting LEDs is common. The transistors are opened so the logic state on the collector is zero. When the light beam is interrupted the transistor switches off and the logic state is one. There are important the inverted signals for the control logic. Outputs of the inverters also switch the indication LED on the main board when the wiper reaches the end.

### Control logic

The control logic is switching the transistor bridge for the electromotor and it is guarding correct signal generation. It consists of eight AND logic gates. Input signals for the logic are signals from the pushbuttons, optical barriers, external blocking signals and PWM signal. Figure 7 presents the control logic circuit and external connectors (there are two parallel connectors, one for communication with the computer and one for direct control).

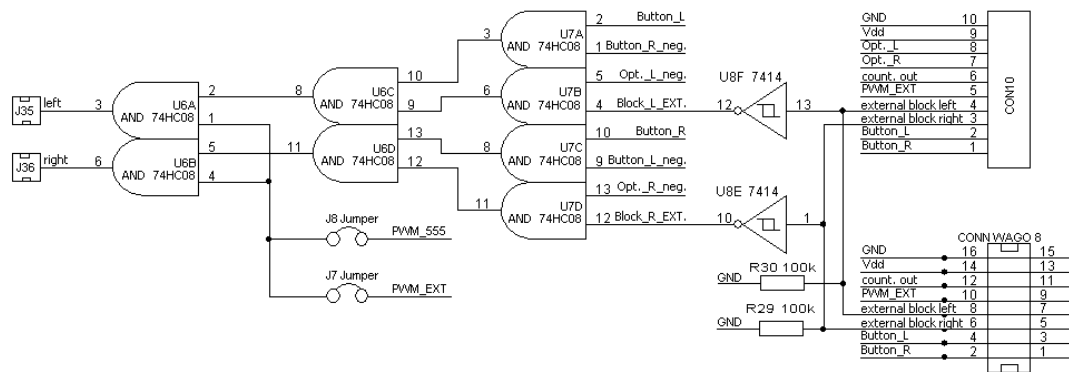


Fig. 7: Control logic and connectors

Other gates are forming the four-input logic gate. The output from the logic is enabled only when all the input signals are at logic one state. For example it can be described the output *left*. This output is high only when the left button is pressed, the right button is not pressed, the left optical barrier is not active and there is not external blocking signal. The PWM signal is applied in the last stage. The output *right* is analogues.

### EXAMPLES OF APPLICATION

Functionality of the bench was tested on several distance sensors. The Hall sensor was used for mechanical tolerance measurement. The tolerance was found to be negligible compared to the bargraph display resolution - there was instantaneous response of the sensor on the movement direction change).

Figure 3 presents application of the test bench with the optical sensor GP2D120.

Other measurement was performed with the linear Hall sensor A1301 and magneto-resistive bridge HMC1501 (figure 9). The test bench viper was equipped by the permanent magnet. The Hall sensor was measuring the axial magnetic field. The magneto-resistive bridge is sensitive only to the direction of the applied field. This is why it must be placed sideward to the permanent magnet [2].

Third measurement was realized using the oscillator (figure 10). The bench base and the viper were equipped by the planar electrodes to form the plate capacitor. Changing the distance between the electrodes the capacity is changing and consequently the output frequency of the internal oscillator changes too.

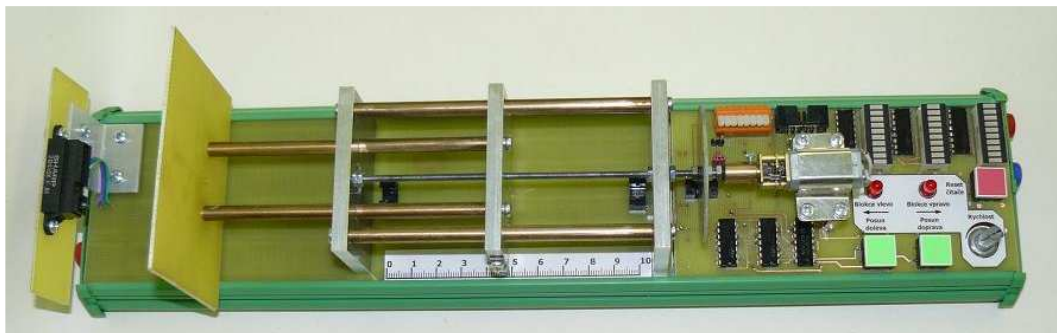


Fig. 8: Application of the test bench with the distance measuring optical sensor GP2D120

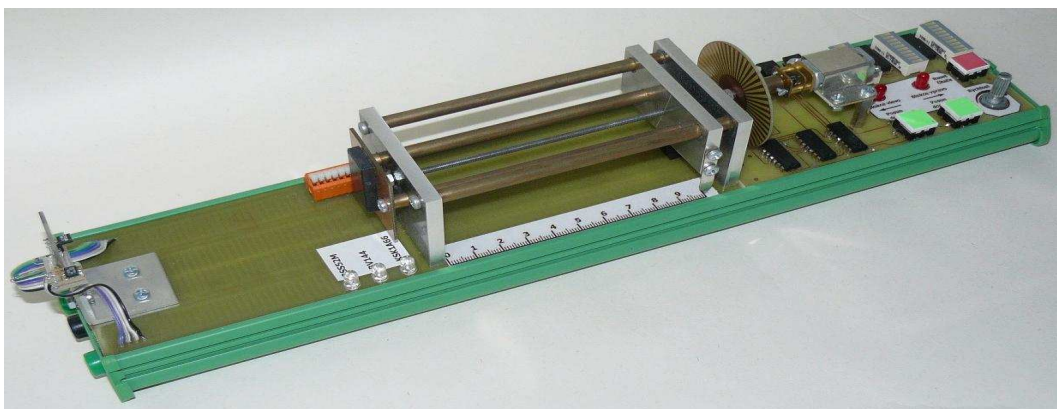


Fig. 9: Application of the test bench with the magnetic field sensors

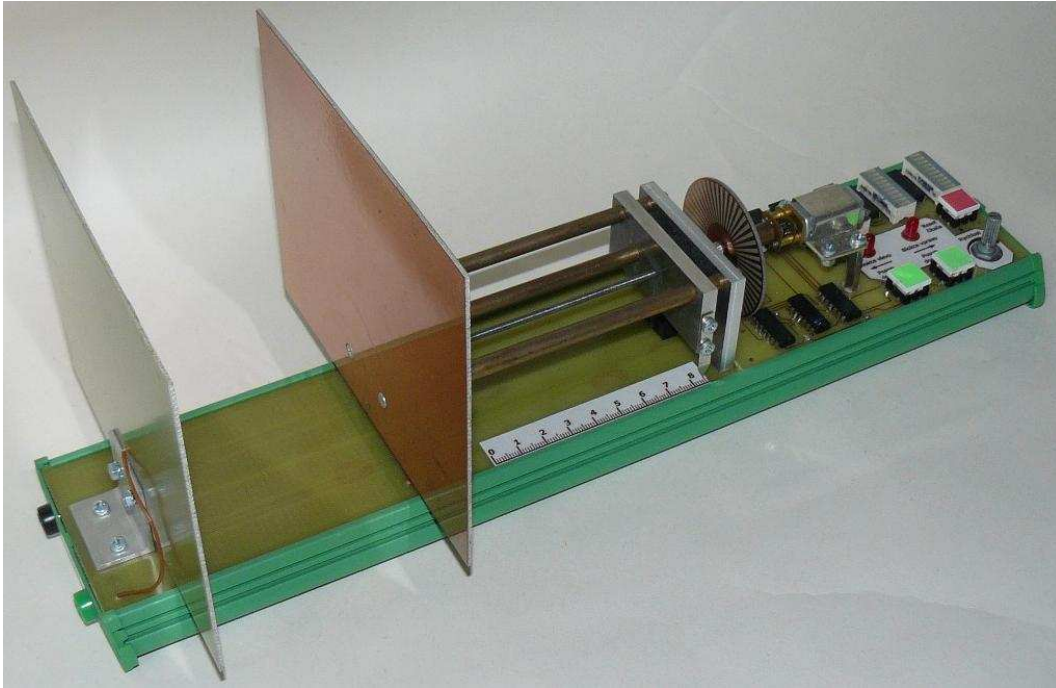


Fig. 10: Application of the test bench with the planar capacitor

### Measurement results

The distance measurement were performed for different sort of the sensors. The results confirm smooth and stable performance in all the possible range (for small distances as well as for the big distances). The measurement results are presented on the figures 11, 12 and 13.

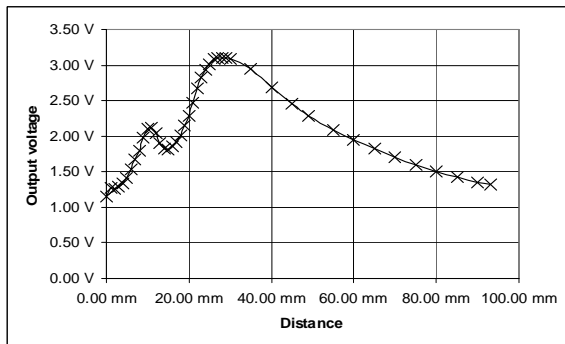


Fig. 11: Optic sensor GP2D120 measurement; compare with [3]

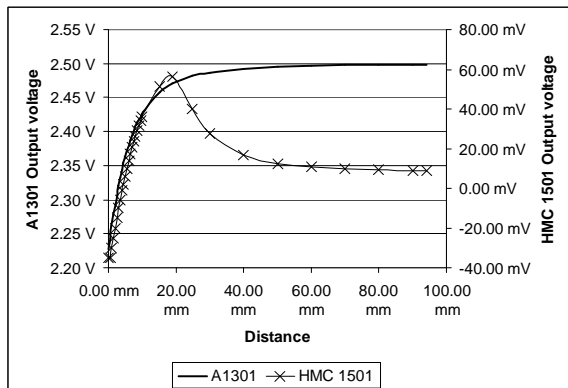


Fig. 12: : Hall and magnetoresistive sensor; compare with [2,4]

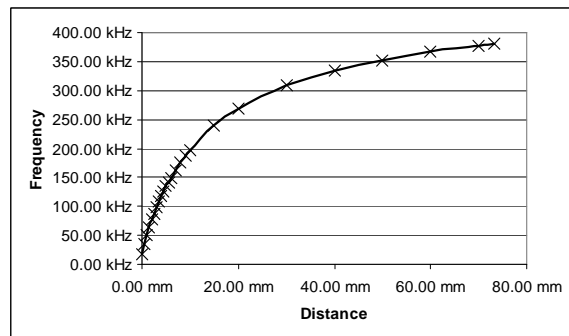


Fig. 13: Capacitive sensor measurement

The maximal compression force was measured using the cantilever beam LC501-100 and it is 200 N for power consumption of the electromotor 5 V / 50 mA.

Tab. 1: Basic characteristics of the test bench

Feature	Value
Full range of the guide shoe	10 cm
Viper velocity	0 – 1 mm·s <sup>-1</sup>
Mechanical tolerance	< 5 μm
Counter resolution	10 μm
Maximal pressure force (@ 5 V / 50 mA consumption)	200 N

### CONCLUSION

The paper describes a universal test bench that can be used for distance and pressure characterization of the sensors. It is suitable for precise distance setting – it is able to set the distance in the range of 10 cm with the resolution up to 10 μm. The mechanical tolerance is negligible – it is less than five micrometers.



Table 1 summarizes the basic characteristics of the bench.

The test bench was developed as a teaching facilitation for sensor systems tutorials and also as the tool for characterization of newly developed pressure sensors [5]. Its performance was presented on optical, magnetic and capacitive sensors and the pressure force was measured using the cantilever beam LC501-100.

### ACKNOWLEDGEMENT

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