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FACULTY OF MECHANICAL ENGINEERING

DEPARTMENT OF AUTOMOTIVE, COMBUSTION ENGINE AND RAILWAY ENGINEERING

POSITIONING OF THE DYNAMOMETER OF THE OPEN-LOOP TEST STAND

MASTER THESIS

STUDY PROGRAM: MASTER OF AUTOMOTIVE ENGINEERING

BRANCH OF STUDY: ADVANCED POWERTRAINS

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The student should propose the system, which will allow the choice between automatic and manual positioning of the dynamometer placed in the laboratories of Automotive department in Juliska. The appropriate electric motor, and all necessary sensors and actuators should be chosen. The necessary changes of the actual test stand (e.g. mounting flanges) should be designed. The system, control and data acquisition should be programmed with help of Labview.

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Abstract

The Juliska Laboratories of Czech Technical University contain testing equipment for both in-house as well as commercial collaborative researches undertaken by the Automotive Department. One such apparatus is the Open-Loop test stand.

The open-loop test stand has a set of dynamometers installed on it for various testing purposes. The dynamometers are required to be moved linearly on their rails as per the test requirements. For this, the present work proposes a new system that accommodates the proper positioning of one of these two dynamometers within the rails. The proposal includes choosing of physical parts, including but not limited to sensors, valves, actuators and an electric motor. The physical parts make up the pneumatic and electric sub-systems also a part of the proposed work. All the necessary changes required to be made to the test stand are also incorporated into the proposal.

Lastly, the present work also proposes a virtual setup of the above-mentioned physical parts in the LabView environment, providing an alternative means of control. Hence, giving the user choices of both manual as well as automated ways of operation.

Keywords: *dynamometer, positioning, pneumatic, electric, sensors, valves, LabView*

Declaration

I hereby declare that I have completed this thesis with the topic “Positioning of the dynamometer of the open-loop test stand” independently, and that I have attached an exhaustive list of citations of the employed sources.

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In Prague, August 13th, 2021

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1 Introduction

“Besides black art, there is only automation and mechanization”

- **Federico Garcia Lorca**

These famous words of the renowned Spanish poet from 1931 still stand the test of time as we continue to evolve in the various fields of science, including automation. [LG40]

In the latter half of the 18th century, the beginning of the Industrial Revolution started a period of development that helped in transforming huge rural-agrarian societies in Europe and America into urban-industrialized ones.

Goods which were largely created laboriously by hands began being mass produced by machines in huge, enclosed spaces “factories”, all thanks to the introduction of new techniques and machinery.

Along with these magnanimous developments, few words gathered international importance for their effectiveness in increasing the spread of industrialization. One such word is Automation. Dr. Slava Gerovitch, quoted in his texts on Automation, “Automation does not simply transfer human functions to machines, but involves a deep reorganization of the work process, during which both the human and the machine functions are redefined.” [RRH03]

To ensure, ease of operation and increase speed of doing work, automation and mechanization are quintessential in today’s times. Any such works or projects, small or big that undertake this technique and try to apply it need to be promoted to increase the impact in everyday lives of people employed in all kinds of work.

Hence, a university - the place where education is imparted to inspire a young generation of leaders of tomorrow, can be a perfect place to apply such techniques of automation. To help prepare a better and much larger group of youngsters and to give them the opportunity to further develop this fast-paced industrial world.

1.1 Motivations

The Juliska Laboratory of the Automotive department has been carrying out research ever since its inception. With a greater emphasis on researches across the European Union through grants to member states under the Europe 2020 strategy, the member states have a renewed enthusiasm to improve their respective institutions at many levels. [EC20]

The Czech Technical University being the premier technical institution in the Eastern European region has a responsibility to lead in innovation as well as continuous improvement. This proposed work cements that underlying philosophy and tries to address the needs of a particular installation in the test facilities.

To describe the present scenario at Open-loop test stand, there are a lot of shortcomings and incomplete installations that inhibit quick and easy operation of the apparatus. The operation of the dynamometer can be broadly talked about in two contexts for problem definition: Pneumatics and Linear Movement control.

Pneumatics deals with the operation of the braking system of the dynamometer. For a better understanding,

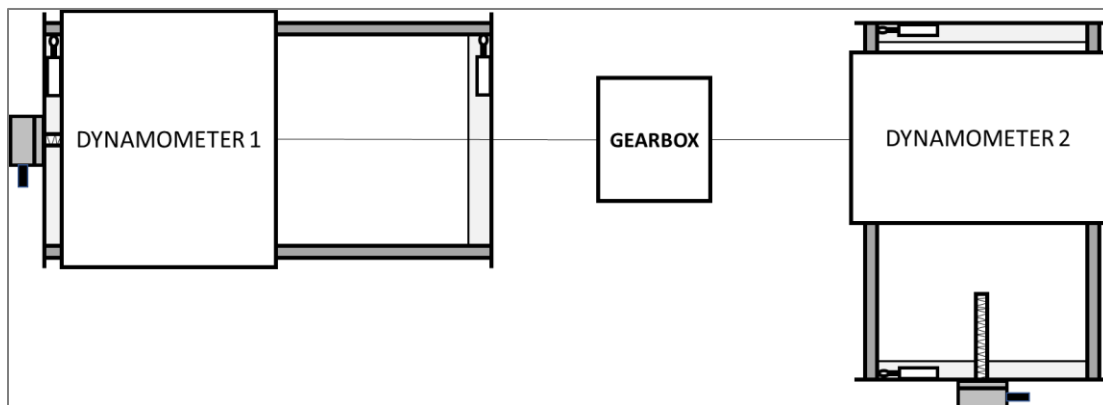


Figure 1: Open-loop test stand

the Pneumatics contains the following parts:

- Linear guideways: 04 NOS
- Pneumatic clamping elements: 02 NOS
- Compressor outlet
- Piping: From the compressor to the clamping elements

The dynamometer is mounted on a base plate which in-turn is placed on four linear guideways that permit the linear movement with the help of rolling elements. The function here of the linear guideways is to offer precise linear movement. The braking of the dynamometer for stopping its movement along the rails is attained with the help of a couple of pneumatic clamping elements, one on each rail. As the compressed air is passed through to the clamping elements the internal wedge-slide gear mechanism allows the contact

section to move away from the rails, hence allowing movement. In case the air supply is stopped, the contact section presses against the rails and inhibits any motion of the mounted dynamometer.

However, the current way of operating the brakes is quite inefficient. The main issue is the piping connection of the braking elements with the compressor. The pipes are manually attached/removed upon requirement from the compressor outlet causing the pipes to be spread haphazardly around the laboratory floors close to the machinery. This can also pose a safety hazard to other equipment as well personnel.

The Linear Movement control is another essential aspect of the functioning of the test stand. The Linear movement control contains the following parts:

- Leadscrew paired with a gearbox
- Linear guideways (mentioned in pneumatics as well)
- Manual rotation mechanism at output shaft of the gearbox

To define the sub-system, linear movement control is responsible for moving the dynamometer on the rails as required while setting up the test stand for experiments. This constitutes of a Leadscrew screwed at one end to the base plate that is placed on linear guideways, the component responsible for movement. The other end of the leadscrew is paired with a gearbox attached to the mounting base of the test stand, as depicted in the picture. The gearbox has an output shaft capable of providing turning motion to the leadscrew to enable linear movement. The present arrangement is a temporary and unsafe way of moving the dynamometer. It employs a ratchet wrench extension affixed to the output shaft of the gearbox. When, movement is required, the operator attaches a wrench to the extension and manually rotates the shaft to enable movement. This is an inefficient as well as unsafe way of movement which could also damage the output shaft if proper care is not taken in providing rotatory motion. Also, the gearbox hasn't been affixed rigidly to the test stand, giving an opportunity of a mis happening to occur to the operator or a damage to the gearbox.

Another, factor that makes a case for the proposed work, is the absence of a software-controlled operation of the stand. The only way at present of actuating the movement of the dynamometer is manual using the temporary method of wrench turned moving on the rails.

Therefore, the Automotive department of CVUT, intends to create a robust system that incorporates, a systematic approach to attain the objective of allowing fast and efficient setting up of the test stand as and when required before scheduled tests. It would also enable the conduction of various tests important not only for researches but also during planned practical demonstrations to students of the faculty.

1.2 Research question

The presented work has the goal of proposing a system that allows choice between automated and manual positioning of the dynamometer.

This provides the operator the freedom to choose appropriate method of operation based on his needs. For quick and most adjustments to the movement, the manual positioning suffices the requirements of operation. In tasks or experiments where miniscule precision in setting up the test stand is required; the automatic positioning comes into use.

Firstly, it is required to propose the electric motor and all the necessary sensors and actuators needed to create such a system. To reduce the complexity of the functioning of the main system, the proposed system can be divided into: Manual and Automated Systems. This helps us to simplify the system and provides us with a systematic approach to attaining the final proposal.

The two systems, based on the functioning can be divided into: -

1. Position measurement
2. Dynamometer motion and movement control
3. Pneumatic brakes actuation

This is essential as it helps cover all aspects of operation from choosing of parts to their electrical connections and so on.

It is also required to create a control and data acquisition through LabView for automated working of the positioning system.

The working of the system of course, relies on:

- Correct connection of the parts in the electric circuit.
 - Correct installation of the parts.
 - Calibration of the control in the software after physical connection with the parts.
-

1.3 Report overview

As per the requirements of the thesis, the proposed work has been divided into several chapters. The chapter 2 firstly talks about the existing arrangement of the dynamometer. It also explains in brief about the main functional parts of the test stand including the dynamometer, the screw jack, pneumatic clamping elements and the linear guideways.

Chapter 3 starts the detailed explanation of various parts of the thesis project. It deals with the aspect of position measurement. This is realized with the help of a draw-wire sensor. The need for such a part, reasons for the choice, way of operation, additional hardware and connection with data acquisition system are described in this chapter.

Chapter 4 begins with the task of realization of movement through a stepper motor. The need for a stepper, reasons for the selection, various comparable options, additional hardware requirements and the connection with the data acquisition system are explained.

Chapter 5 brings the braking mechanism of the test stand into focus. The requirements, selection criteria, detailed specifications and way of operation are explained in this section.

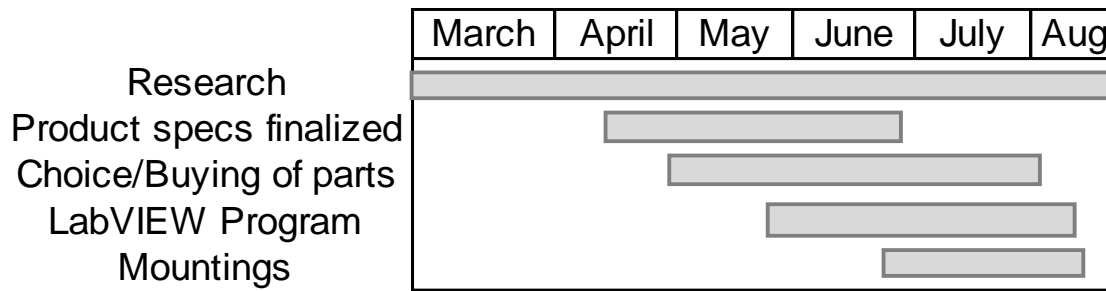
Chapter 6 presents the above chosen parts together in the form of a system. This can of course be divided into Manual Operation and an Automated way of operation. The schemes and flow of the communication of the systems are described and presented in a complete form.

Chapter 7 deals with the software aspect of the master thesis. The usage, implementation, and organization of a program in LabVIEW is explained. The virtual instrument for each part that is associated with data acquisition is described in detail and at the end the complete LabVIEW program is presented.

Chapter 9 sheds some light on the changes required to be made on the test stand for mounting of parts as well as to accommodate proper functioning of the positioning system. Several small accessories used throughout the system are also described briefly in this section.

Finally, the last chapter discusses the future scope and possible improvements in the project as well as the conclusion of the work accomplished.

1.4 Work organization



The master thesis was organized as depicted by the Gantt chart:

- Firstly, a substantial amount of time was spent in understanding the existing issues in the test stand. Upon extracting out all the issues and possible things to be controlled the research was initiated. The research consisted of catalogue search, understanding principles of operation, book consultations, technical paper study, journal referencing and laboratory visits.
 - The second phase was quite crucial as well as a time-consuming phase. Physical part selection and understanding its system implementation was a relatively new field in the personal experience. A large chunk of time was spent in arriving at decisions to choose parts after numerous consultations with part suppliers and the supervisor. Various changes were made in selections based on different feedbacks and findings.
 - Once, an overview of required parts and the main system was gathered then the work on their synchronization was initiated. This included comparison between various similar usage components, system flow diagrams, parts connection methods.
 - The development of manual and automated ways of operation was started in proximity as they were inter-related to one another in the main systems. It also acted as a stage wherein synchronization conflicts between the main two systems caused delays.
 - Finally, once a detailed study of the physical parts was completed, the work on the automated approach using LabView was initiated. This was also a time-demanding part of the thesis as many compatibility issues happened when the eventual connection was made between the physical parts and the software.
 - The eventual designing of the mounts was only initiated when it was confirmed that all parts are compatible with the software.
-

2 Open-loop test stand

The open-loop test stand is one of the many testing equipment present in the Juliska Laboratory of the Automotive department, CVUT. The main operating equipment mounted on this test stand is the dynamometer and hence the test stand functions to allow for proper testing of parts with this dynamometer.

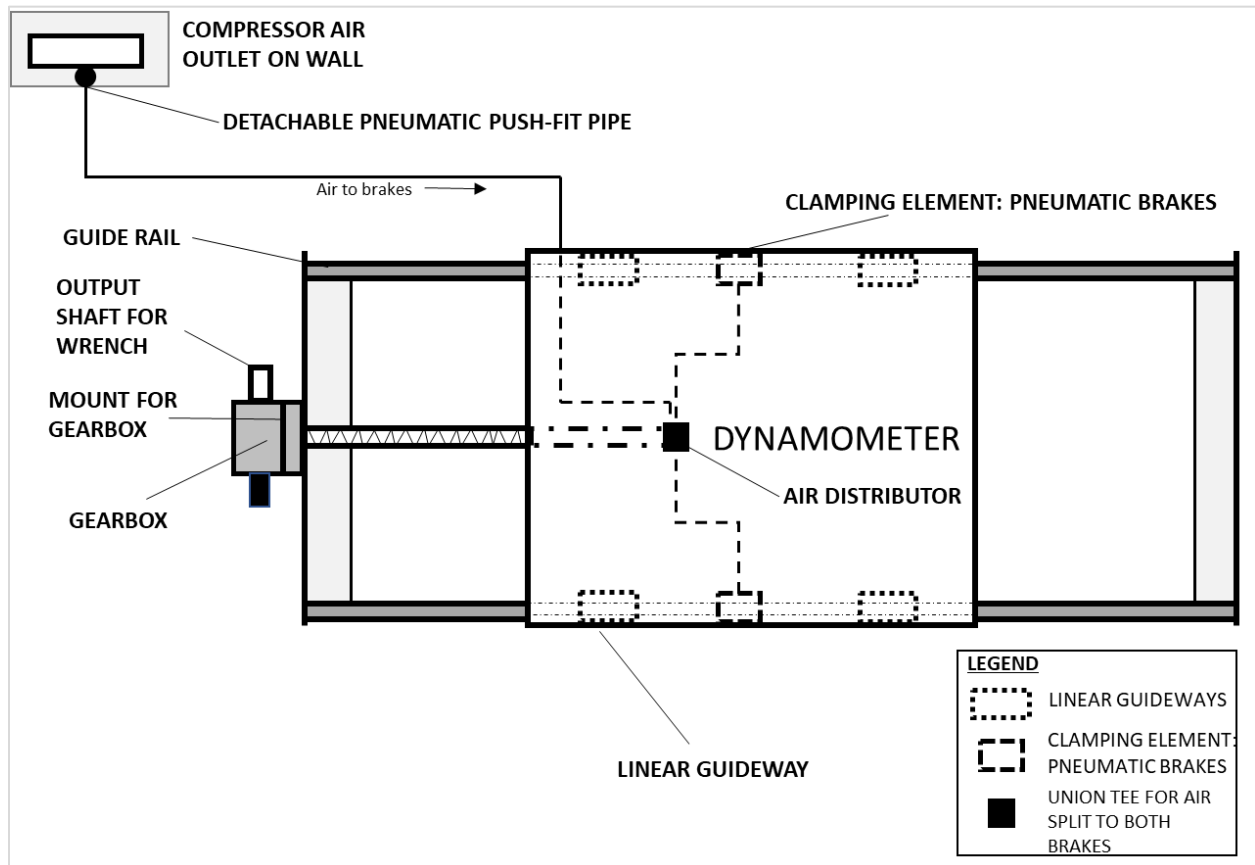


Figure 2: Pre-existing test stand setup: dynamometer-1

The above picture depicts the pre-existing arrangement on the test stand.

2.1 Operating sequence and key parts

To operate the existing setup, the following steps are followed:

- The compressor is switched on.
 - The pneumatic piping is connected to the push-fit socket in the wall.
 - This releases the clamps holding the dynamometer test stand.
-

- The movement is then provided by attaching the wrench to a temporary extension put on one of the output shafts of the gearbox.

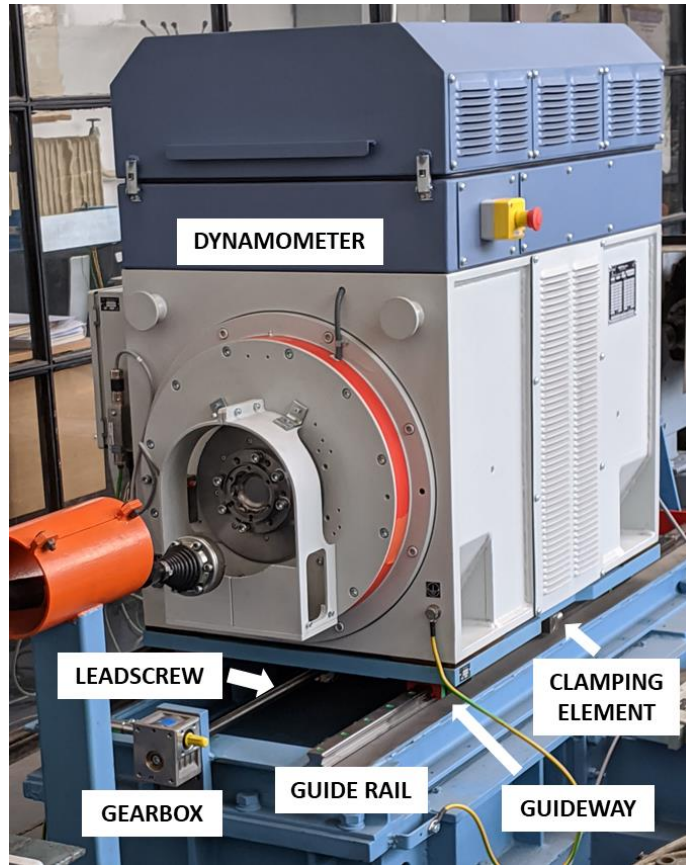


Figure 3: Dynamometer – 1 of open-loop test stand

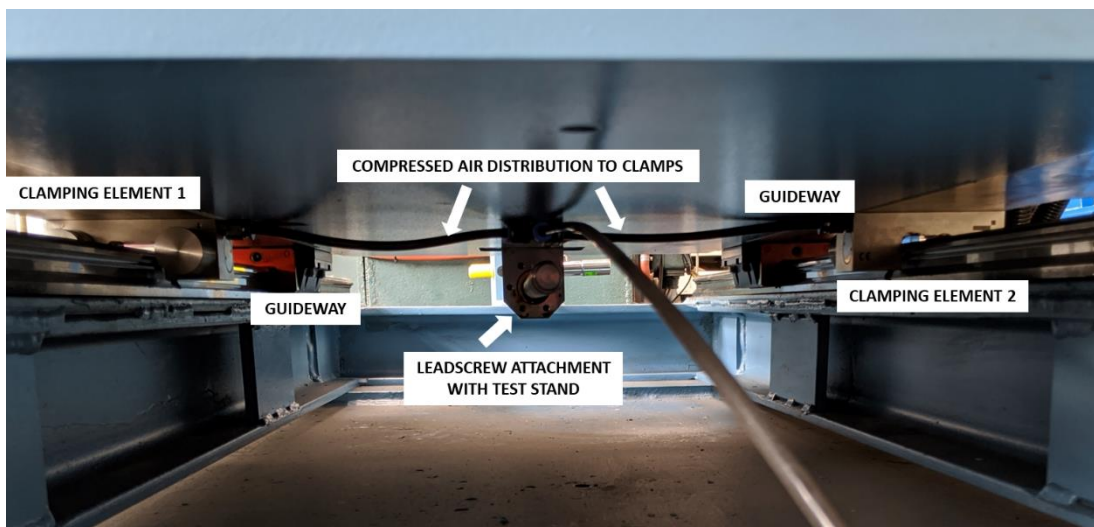


Figure 4: Setup below the dynamometer

The first dynamometer of the test stand can be distributed into the following key parts:

- The dynamometer
- Screw jack with gearbox
- Pneumatic clamping element
- Linear guideways

2.2 Dynamometer

To define a dynamometer in general, it is a device used for measuring the force, torque or power. For

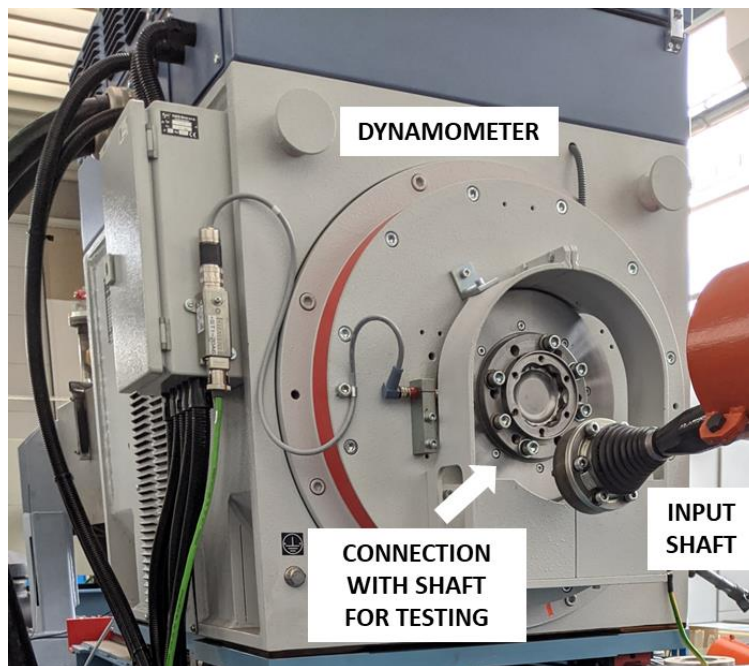


Figure 5: Asynchronous Dynamometer - 1

example, the power produced by an engine or motor can be calculated by measuring the torque and rotational speeds. However, the type of dynamometer mounted on this test stand is an asynchronous dynamometer. These types of dynamometers can be used both as a generator or a motor and can measure the mechanical power on the tested machine shaft. They can also generate controlled braking and driving torques. The devices that can be loaded and driven include gearboxes, engines and other electric machines.

2.3 Screw jack

Screw jack is a linear movement drive that helps in converting rotary motion into linear motion. It is commonly a combination of a gearbox assembly of worm gears transmitting power to a screw.

The screw jack used in the dynamometer test stand contains a gearbox with a gear ratio of 4:1 attached to a screw with a trapezoidal thread size of 20x4. This means that the nominal diameter is 20 mm and the pitch is 4 mm. [TT19]

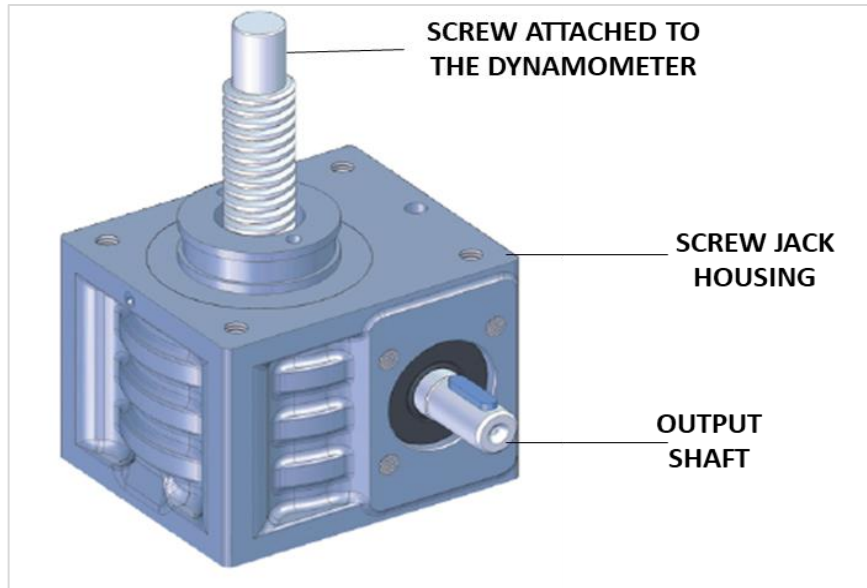


Figure 6: Screw jack TSE10-RN, TEA-TECHNIK [TT19]

KEY CHARACTERISTICS: TSE10-RN	
Max drive shaft speed	1800 RPM
Gear ratio	4:1
Max input drive torque	10,5 Nm
Screw	TR 20x4
Max load	10kN

Table 1: Key characteristics: screw jack [TT19]

2.4 Pneumatic clamping element

Pneumatic clamping element is a set of devices attached below dynamometer on both sides on top of the rails to provide the braking action. This is made possible by a system of spring, piston and wedge slide gear together altering the contact section's position.

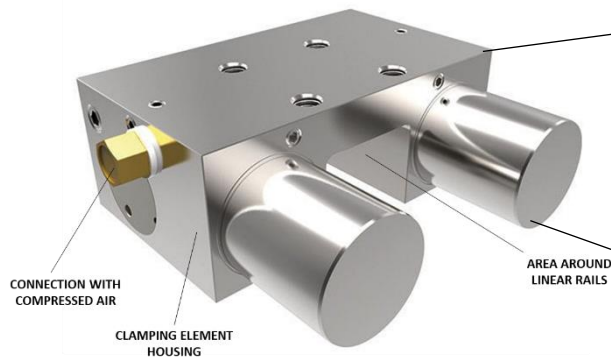


Figure 7: Pneumatic clamping element – ZIMMER MKRS [ZTW12]

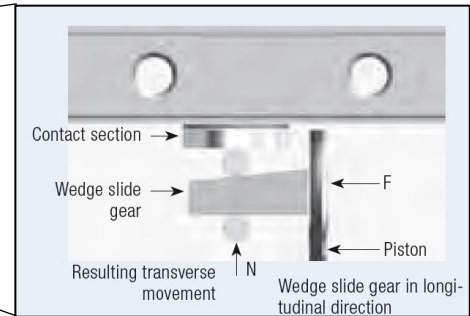


Figure 8: Inside mechanism - clamping system [ZTW12]

This figure shown above of the clamping element helps explain the phenomenon. The clamping element mainly contains a spring attached to a piston, a contact section that applies the braking effect, a wedge slide gear present inside the air pressure inlet of the element. The spring in the default position keeps the load on the piston that eventually keep the contact section pressed against the linear rail. Thus, providing the braking effect. This is the case when no air is provided to the element.

When compressed air is provided to the element, it helps move the piston away from the contact section thanks to a wedge slide gear that slides towards the piston. Hence, resulting in removal of the contact section from the rail, accommodating movement.

KEY CHARACTERISTICS – ZIMMER MKRS	
Min pressure	5,5 bar
Max pressure	8 bar
Holding force	350-1700 N

Table 2: Key characteristics clamping element [ZTW12]

2.5 Linear guideways

A linear guideway allows linear movement with the help of rolling elements. Usually, by using rollers or balls, a very precise linear movement can be obtained.

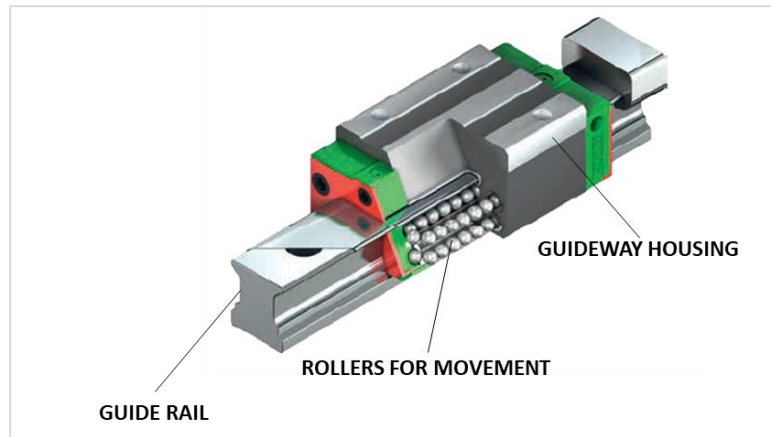


Figure 9: Linear guideway [HI]

3 Linear position measurement

This chapter deals with position measurement aspect of the master thesis. Position measurement mainly has to do with the measurement of the position of the dynamometer between the rails.

3.1 Need

The need for position measurement arises from the plan to automatize the open-loop test stand. As the open-loop test stand consists of two dynamometers that can be together used to run tests on mechanical parts like Gearbox or Engines, accurate positioning becomes very important for such experiments. Hence, by knowing the position of each dynamometer, we can align the axes of both dynos perfectly with respect to the tested part. This also aids in knowing how far the tested part should be placed from both dynos.

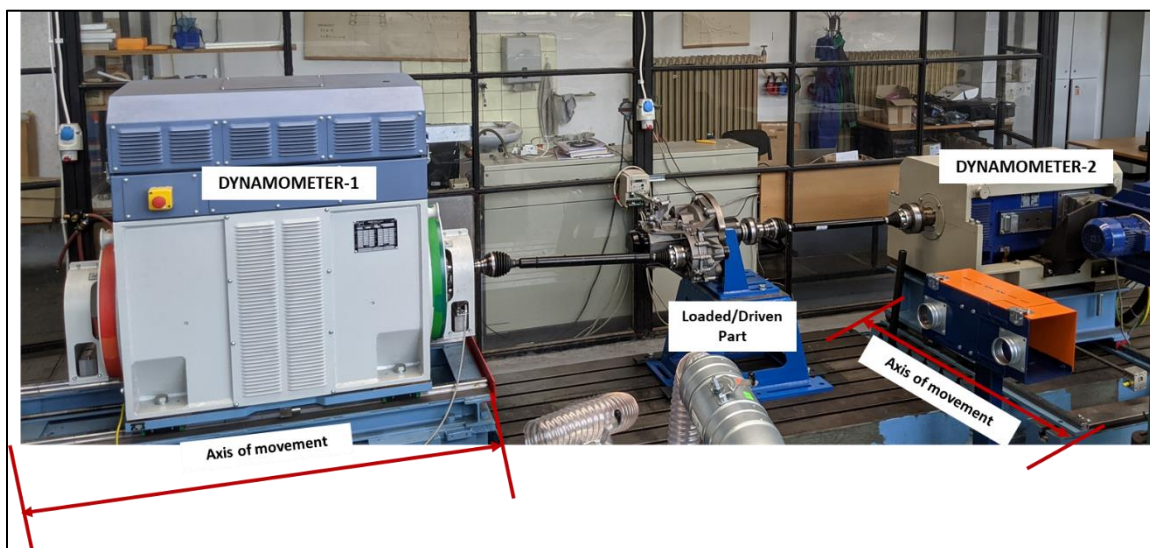


Figure 10: Open-Loop Test stand: present scenario

3.2 Objective

The main objectives for the linear position measurement can be summed up below: -

1. The position measurement should be very accurate with a resolution of at least 1 mm. This would allow movement of the dynamometers in increments of 1 mm for an exact positioning.
 2. The total distance in between which the positioning must be measured is 1005 mm. Hence, the positioning sensor should have a measurement range of at least 1100 mm.
-

3. The position measurement should be compatible with LabVIEW. Hence, the chosen solution should output the measurement in a form that can be used in LabVIEW.
4. The measured position should also be displayed near the test stand in real-time for easy referencing when the manual mode of operation is in use. (The position is always reference from one end of the test stand)

3.3 Present Scenario

At present, there is no existing way to measure the distance or the position of the dynamometer.

3.4 Approach and choosing of the sensor

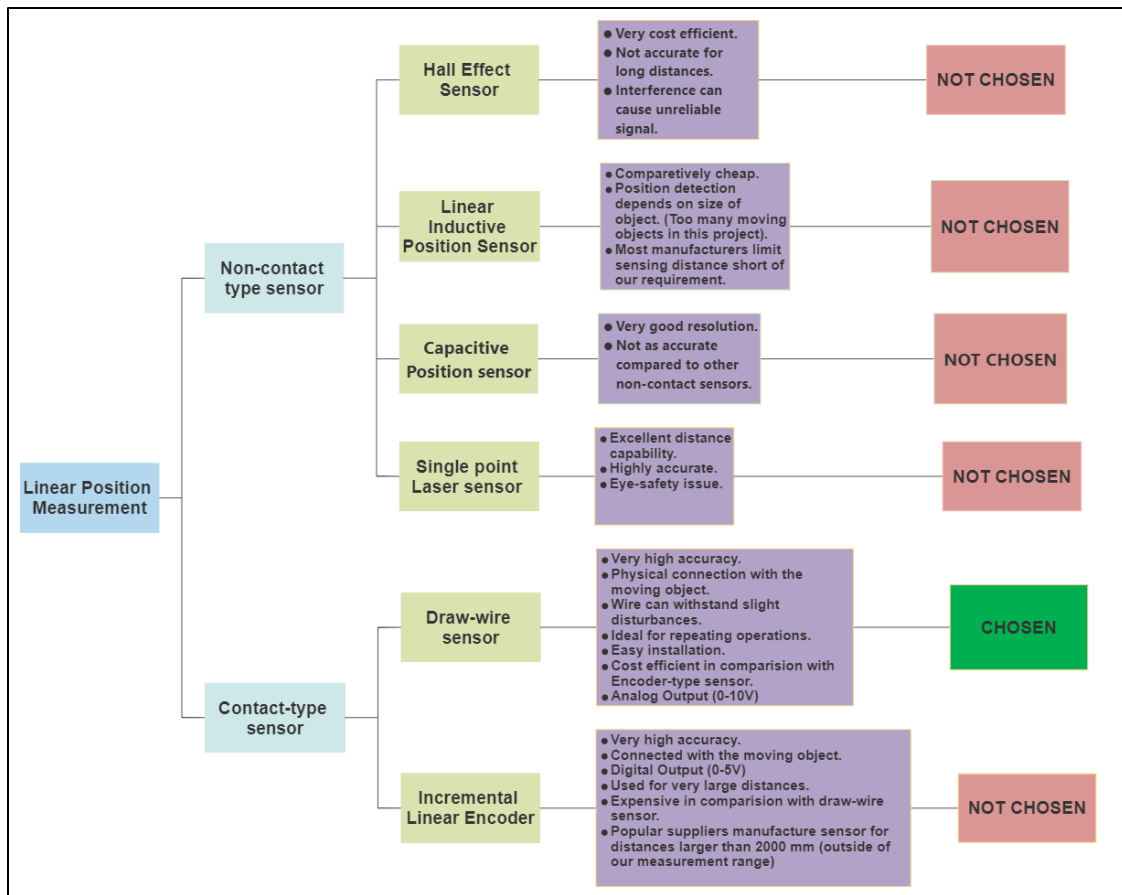


Figure 11: Decision-making ; position measurement

The decision-chart above explains very efficiently the process of arriving on a decision to choose a suitable position measurement sensor.

-
- The initial literature survey was focused on finding out common ways of position measurement in the industry.
 - This could be broadly divided into two main types: -
 - Non-contact type sensors
 - Contact type sensors
 - Non-contact type sensors as the name suggests, have no contact between the sensor and the object, whose position is being measured.
 - The most used Non-contact type sensors can be mainly classified as: -
 - *Hall-Effect Sensor*: This type of sensor works on the principle of Hall-Effect, where when a magnetic object comes in the range of the sensor, a flux is generated and that can in-turn be measured in the form of a voltage. Although, a very cost efficient and simple to use sensor, it has a lower accuracy when measuring longer distances and the presence of other parts can interfere with the output signal.
 - *Linear Inductive Sensor*: This type of sensor has a coil inside it that creates a magnetic field around the sensor. When the target metal object is in the range of the sensor, an eddy current is created due to electromagnetic induction and that changes the amplitude of the output signal. The closer the object the smaller the output signal. This sensor also suffers from low accuracy at large distances and is susceptible to interferences from other objects.
 - *Capacitive Position Sensor*: A capacitive sensor acts like a simple capacitor. A metal plate in the sensing face of the sensor is electrically connected to an internal oscillator circuit and the target to be sensed acts as the second plate of the capacitor. Unlike an inductive sensor that produces an electromagnetic field a capacitive sensor produces an electrostatic field. Although, having a good resolution, the sensing distance depends on how large the face of the object is, which in our case is quite small (base plate of the dyno stand: 30 mm).
 - *Single Point Laser Sensor*: This type of sensor employs a laser beam to accurately point towards the object being measured but is an impractical solution in an industrial environment, given the safety hazard of using a Laser.
 - In conclusion, with regards to the Non-Contact type sensors, for our application it can be said that they are unsuitable due to the constraints related to measuring range, sensitivity to other objects around or some safety issues in one the types.
 - The Contact type sensors seem to be the go-to choice due to reliability in accurate measurement that is provided by a physical contact between the sensor and the object whose position is being measured.
-

- The contact type sensors, for our application can be divided into two types: -
 - *Incremental Linear Encoder*: This type of position sensor converts the rotary or angular motion of a shaft into a digital output signal. This can be a 0-5V digital output. They have a very good resolution. Due to their high accuracy, they are used for very large distances. Although, this type of sensor fits our needs but most of the present-day sensor manufacturers make the encoders which measure ranges of more than 2000 mm. This goes beyond our range and hence makes it an unviable option.
 - *Draw-wire sensor*: As the name suggests, a draw wire sensor has a wire wound around a metal drum that wraps/unwraps around the drum based on how large the distance to the object is. This, outputs an analog voltage signal, usually in the range of 0-10V. Also, this sensor has a very good resolution and availability for short distance measurements. It is comparable to the linear encoder in terms of accuracy and resolution. The choice defining reason here is that there are many draw-wire sensors available in the distance measurement range of around 1100 mm that we have at the test stand and the encoder type sensors are not available for our measurement range. Hence, the draw-wire sensor is the go-to choice.

3.5 Draw-wire sensor

Draw-wire sensor is a low-cost position or change of position measurement device. As the name suggests, the sensor makes use of a wire and a sensor element arrangement. In our case, the sensor element is the potentiometer.

To describe its operating principle, a flexible stainless-steel wire used to measure the distance or change in position is wound around a metal drum using a long-life spring motor. This helps in retracting of the wire



Figure 12: Draw-wire sensor [ME19]

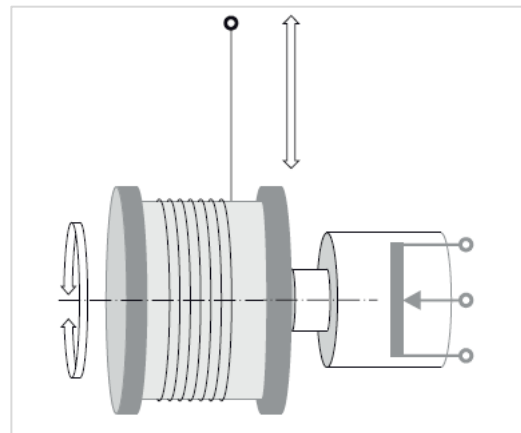


Figure 13: Functioning - draw wire [ME19]

if left free. This drum is then coupled axially to a multi-turn potentiometer. The potentiometer helps to output this change in the distance in the form of voltage.

As can be observed from the figure, the potentiometer is connected to the metal drum and it converts this movement into a voltage signal that can be read by a DAQ device.

Another thing worth mentioning about the measurement is the maximum distance that is required to be covered by the dynamometer when it is allowed to reach the very end of the linear rails. This was recommended to be kept at 1005 mm. This was a factor considered while choosing the specifications of the sensor.

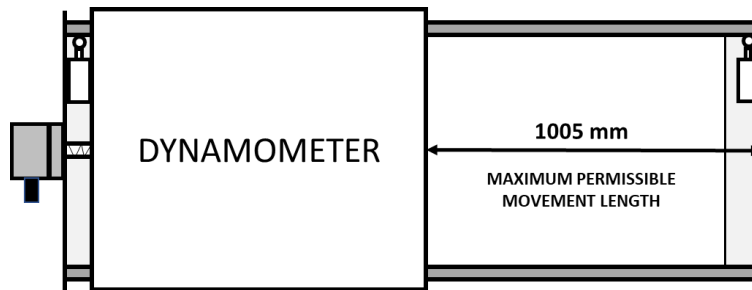


Figure 14: Maximum permissible movement

KEY CHARACTERISTICS	
Measuring range	1250 mm
Resolution	0,4 mm
Output type	Voltage
Supply voltage	max 32VDC
Resistance	1kOhm

Table 3: Key characteristics - draw-wire sensor [ME19]

This table highlights the main characteristics of the Draw-wire sensor from MICRO-EPSILON, model no. WPS-1250-MK46.

As of today, the Draw-wire sensor has been purchased and tested.

3.6 Additional hardware: LED display for distance

Another requirement along with the usage of a draw-wire sensor was to have a display near the test stand where the distance moved could be displayed in real-time.

The approach to the finding of a display began with basic LED panels that can display in numeric. But the issue that arrived with the basic displays was that the type of input these displays can take is either an NPN or current(I). In our case, the input had to be a voltage signal that the draw-wire sensor would generate. This then had to be extracted through the wires and then be used with the display to show the instantaneous movement distance.

Finally, after some researching and contacting the companies for exact specifications that would fit our requirements, I chose a display from the manufacturer Orbit Merret (also extensively used in CVUT laboratories) and hence recommend the OM502PM Display that can take 0-10 VDC input and then through a microprocessor, convert it into the distance moved.



Figure 15: OM502PM display [OM20]

KEY CHARACTERISTICS	
Rated Power	250 VAC
Input Type	0 -10 V
Display	5-digit

Table 4: Key Characteristics - OM502PM [OM20]

It was also found out upon enquiry in the Roztoky laboratory that there are a few existing displays that can take a voltage signal of 0 – 10 V as input. Hence, although the suggested display is a new type but it should be comparable with the existing options also from the same manufacturer, Orbit Merret.

3.7 Data Acquisition and Connection of the sensor

One of the objectives of distance measurement is to have a sensor that is compatible with LabVIEW. This is because the output from the sensor is an analog voltage signal of 0 – 10 V. But this signal in no way tells us how much distance the dynamometer has moved between the rails to know its exact position.

3.7.1 Data Acquisition

LabVIEW is a graphical system engineering software that allows successful conduction of tests, measurements by combining the hardware and software. This is where the role of data acquisition comes into play. To interact with the software and to process the signal from the draw-wire sensor to the software, we need specific hardware that can act a bridge for communication.

National Instruments, the company that developed LabVIEW also has various hardware solutions specific to various type of measurements or the type of output signals that the sensors produce. Based on that, in our case of an Analog Signal of 0 -10 V and the fact that many solutions from National Instruments are used in the laboratory at Juliska, a suitable hardware setting was found out.

The type of hardware chassis would be a Compact DAQ (data acquisition) system, a type of hardware solution from NI, that allows various types of measurements in one chassis.



Figure 16: NI-cDAQ 9174 Chassis [NI21]

The slots shown above in the picture can be used for various kinds of measurements. In our case, we can choose a compatible cDAQ CARD that can fit in one of these slots to allow data acquisition from our draw-wire sensor.

3.7.2 NI – cDAQ CARD 9205

NI 9205 is a 16-channel analog input data acquisition card that is compatible with the Compact DAQ chassis 9174. This type of the DAQ card can take analog input signals in the range of 0 -10 V, that is exactly what our draw-wire sensor outputs. The card can be easily put in one of the slots in the 9174 and can communicate with the PC through the connection of 9174 with a USB port.



Figure 17: NI-9205 DAQ Card [NI15]

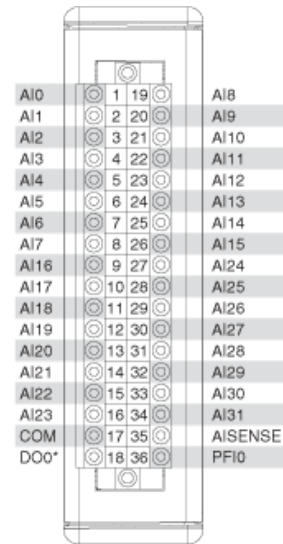


Figure 18: Port layout NI 9205 [NI15]

Analog Input: This is the signal that we receive from the draw-wire sensor. As this signal acts as an input for our DAQ device, we call it as an analog input.

Analog Output: This is the signal that the draw-wire sensor provides. As it's the signal that comes out of the sensor, hence we call it an analog output.

3.7.3 Wiring and electrical connections b/w DAQ and sensor

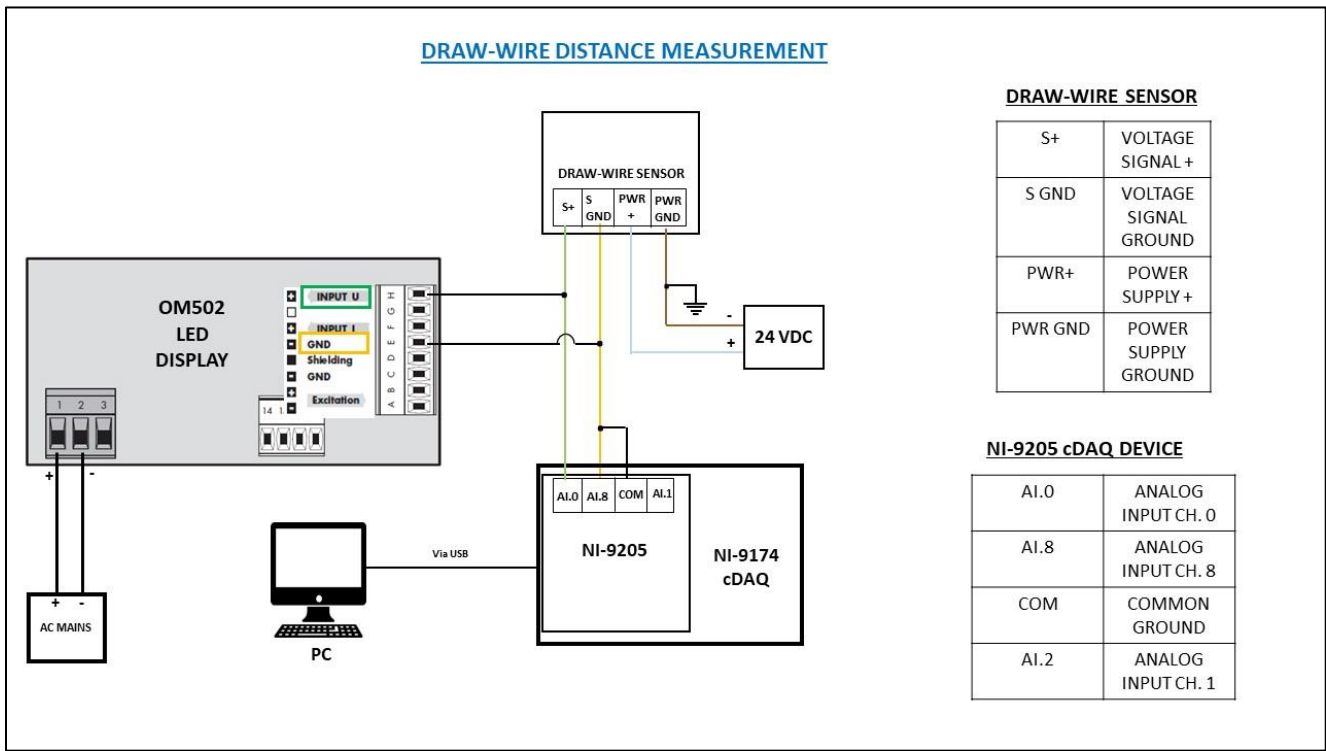


Figure 19: Draw-wire sensor: electric connections

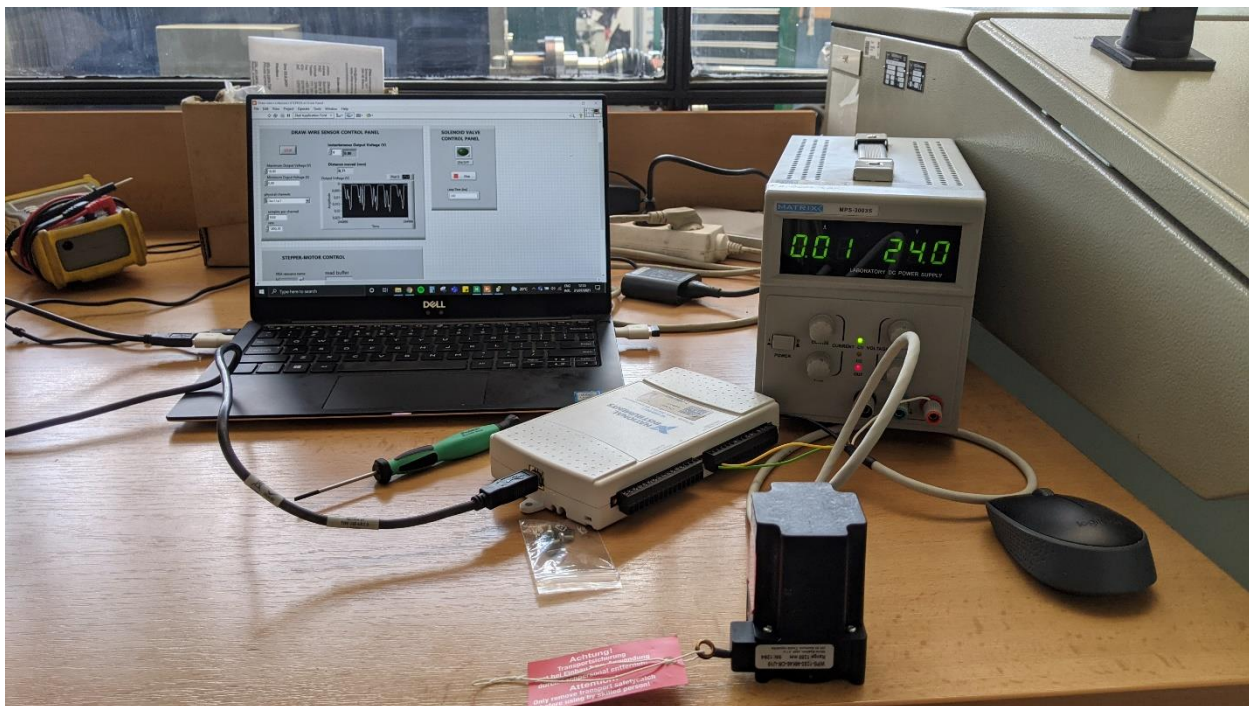


Figure 20: Testing of Draw-wire sensor at Juliska

4 Motion and movement control

This chapter deals with the motion and movement control aspects of the thesis project. Providing motion to the dynamometer is a fundamental part of the open-loop test stand. The testing of various engines/gearboxes involves aligning of the shaft connected to the dynamometer with the part being tested. This leads to adjustment of position of the dynamometer on the test stand and for that purpose motion and movement control play a key role.

4.1 Need

Allowing a perfect alignment of the test part and the dynamometer is an important task before a test can be started. This leads to a requirement for providing a fast and safer way to align and move the dynamometer between the rails.

- The proposed solution should eliminate any manual work required to be done by the user to move the dynamometer between the rails.
- The movement control aspect of the test stand should allow the maximum utilization of the available movement space on the rails with a control to prevent the dynamometer to reach the extreme ends of the rails, that could pose a danger to the user.
- In case of complex tests where accuracy is required to be as high as possible, a solution to allow such motion remotely should be proposed.

4.2 Objective

The main objectives related to the proposed motion and movement control can be summed up as: -

- The proposed solution should allow a permanent way of providing linear movement to the dynamometer between the rails with the minimum engagement by the user.
 - The proposed solution should be user-friendly and provide a very simplified way to control the linear movement of the dynamometer.
 - The proposed solution should prevent the dynamometer from reaching the extreme ends of the rails. Hence, safeguarding the user from danger.
 - The proposed solution should allow two ways of movement control to the user: -
 - Manual operation: Push-button based movement of the dynamometer on the rails for not very complex repeated experiments.
-

-
- Automated operation: A LabVIEW based mode of operation of the linear movement that allows highly precise movement, remotely while preventing the dynamometer from reaching the extreme endpoints of the rails.

4.3 Present Scenario

At present the open-loop test stand uses a non-standard way of linear movement of the dynamometer between the rails. This method utilizes a torque wrench head screwed to the gearbox that rotates the leadscrew, causing the eventual linear movement of the dynamometer.

A manual wrench can be attached to this head to manually rotate the gears in the gearbox, leading to the

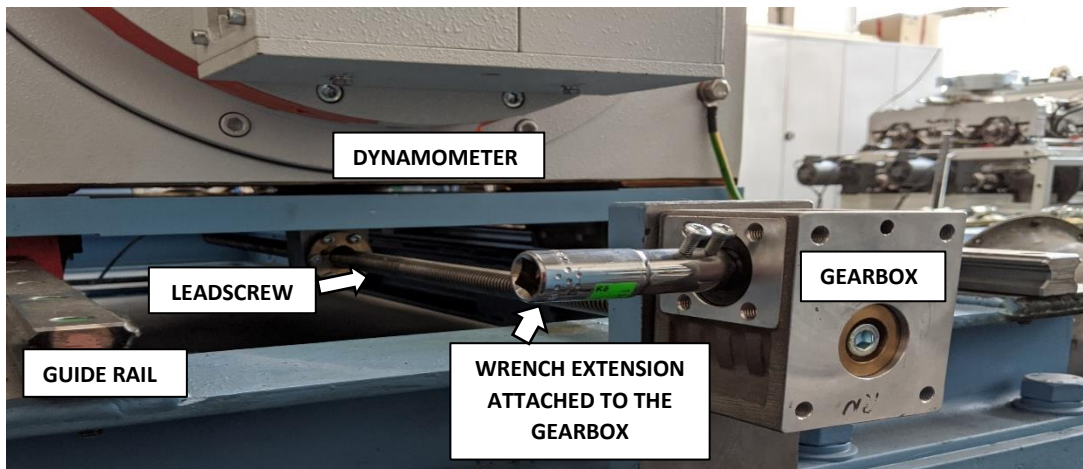


Figure 21: Test stand with existing movement control

movement of the dynamometer. This is a very tiresome and time-taking method to move the dynamometer while setting it up for tests.

4.4 Approach and the choice

The idea of the movement control should be to rotate the input shaft of the gearbox. This will lead to the rotation of the leadscrew attached with the gearbox and the rotary motion of the leadscrew will be transformed into the linear movement of the dynamometer between the rails.

The easiest and the most widely used method to propel or rotate a shaft is to use an electric motor. To simply define electric motor in a line, “It’s a device that converts electrical energy into mechanical energy”. That is exactly what we require but with some added constraints related to compatibility and function.

Hence for that purpose a comparison between the various available types of electric motor is done. This should make it easier in reducing the choice to a few types.

Although, there can be many ways to categorize the electric motors, for our application, I based my selection criteria on five main factors: -

- Torque: First and most importantly, is the motor able to provide enough torque to move the dynamometer between the rails?
- Accuracy: Can the electric motor provide enough resolution to allow movements as precise as 1 mm when required?
- Compatibility: Is the motor able to be easily controlled remotely via LabVIEW while allowing a simpler manual way of operation when needed?
- Size: Is the motor compact enough to be installed with the gearbox on the test stand?
- Cost: How does the motor fair, pricewise in comparison to what it offers?

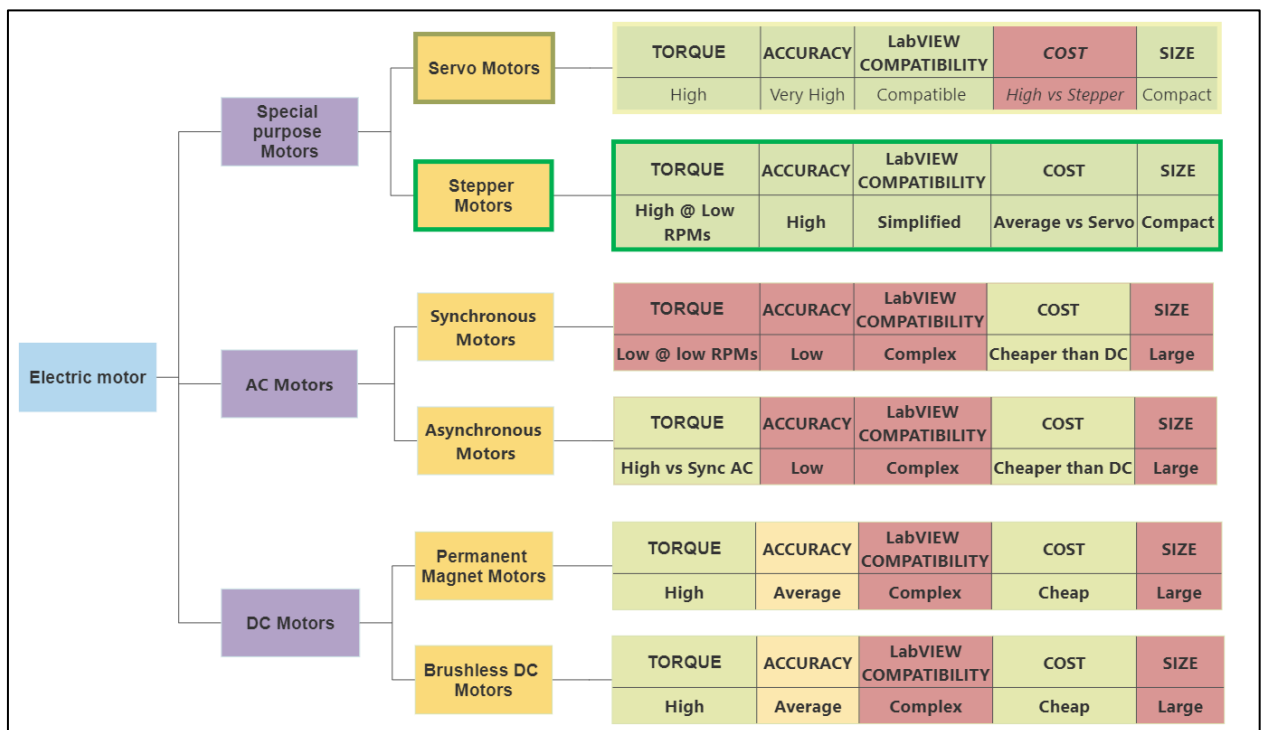


Figure 22: Choosing an electric motor

4.4.1 Torque calculation

An important aspect in deciding the specifications and type of motor is the torque requirement. It must be clearly specified how much torque is required to be provided to move the dynamometer between the rails.

4.4.1.1 Torque requirement measurement

To measure the torque required to move the dynamometer between the rails, accurately a torque wrench with a range between 1 Nm to 5 Nm was used.

The process of measurement can be described in steps as: -

-
- Firstly, the torque on the wrench was set as 1 Nm and it was tried, to rotate the input shaft of the gearbox. No rotation was observed in the leadscrew. Hence, this value was too short to move the dynamometer.
 - Then, the torque was increased by 0,5 Nm to 1,5 Nm and the process was repeated. Again, no rotation of the leadscrew was observed.



Figure 23: Torque measurement using wrench

- Next, another increment of 0,5 Nm was made bringing the input torque to 2 Nm. Now, for the first time, the rotation of the leadscrew was observed.
- Observing movement at 5 Nm, the wrench of a higher torque range of 5 – 60 Nm was employed, and the measurement was continued. This was continued in increments of 0,5 Nm until 6 Nm when no movement was observed in the leadscrew.
- Now, the increments were reduced to 0,1 Nm and from 5 Nm the input shaft of the gearbox was rotated for torque with increments of 0,1 Nm.
- At 5,7 Nm, no rotation of the leadscrew was observed.
- Hence the torque range for moving the leadscrew came out to be in the range: 2 Nm to 5,6 Nm.

Hence, the motor to be chosen must have an input torque in the range of **2 Nm to 5,6 Nm**.

4.4.2 Factors that define the choice

In the above chart comparing all the different type of motors, there were a few factors that played a greater role in deciding the preferred choice: -

- LabVIEW compatibility and Size were the deciding factors, going in favor of the Stepper and Servo Motors.
- With regards to conventional AC and DC Motors the synchronization with LabVIEW is complicated with requirements of Frequency Converters to be able to communicate with the software.
- Size constraint all but very clearly tilts the choice making it in the favor of Stepper and the Servo motors. The space available next to the input shaft of the gearbox is concise and the mounting should not be connected to the ground.

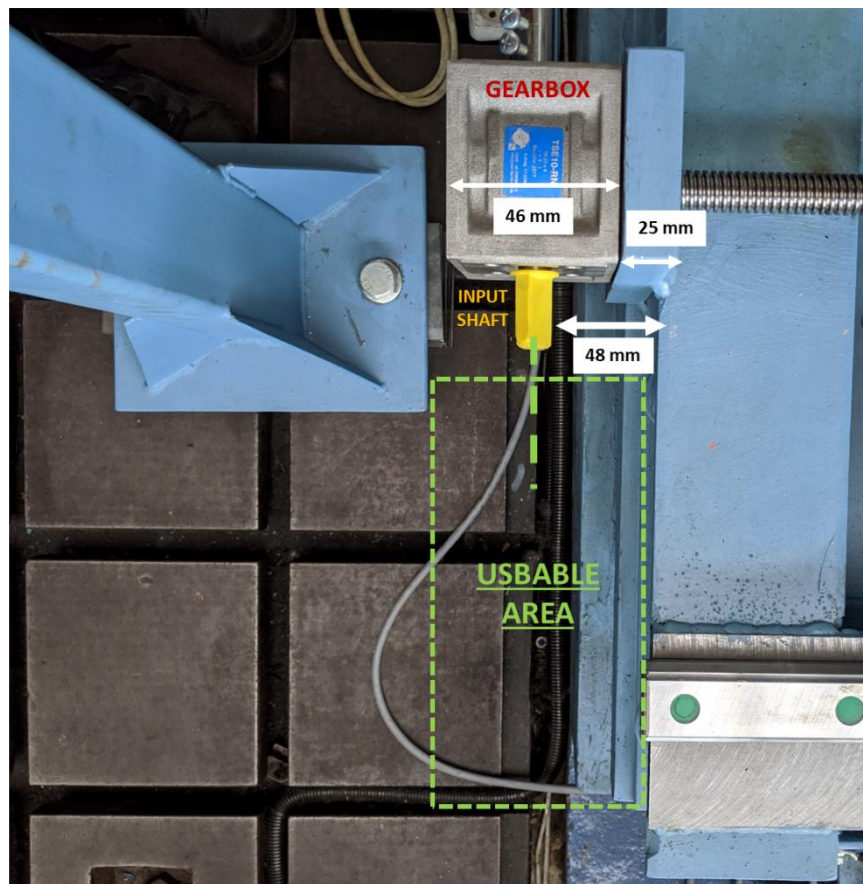


Figure 24: Space availability for motor mounting

- Once, it was clear that the choice must be made between Stepper and Servo motors, the deciding factor had to be the cost. Due to the feedback-type working of the Servo motors, they are more expensive than simple Stepper motors. Although, Servo motors can offer even more precision, but as speed of rotation
-

shouldn't be very high, hence the precision should remain comparable between Stepper and Servo for low rotation speeds of up to 800 – 1000 RPMs.

- Hence, the type of electric motor suggested should be a Stepper Motor.

4.5 Stepper motor

Stepper Motor is an electric motor that rotates by performing steps, that is by moving by a fixed number of degrees. A standard stepper motor has a step angle of 1,8 deg. That translates to roughly 200 steps per revolution.

The way a stepper motor communicates for control with a software like LabVIEW is through a drive.

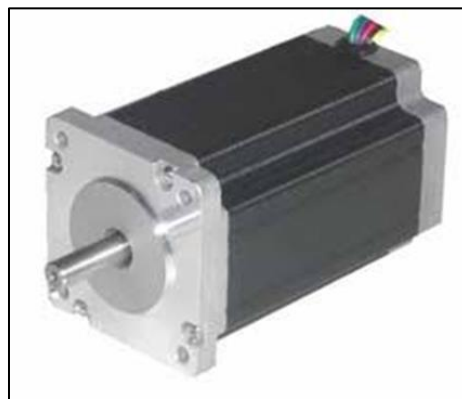


Figure 25: Stepper Motor

4.5.1 Stepper driver

Stepper driver can be defined as a device that allows a stepper to do the function it's built to do: make precise steps but smoother and possibly with even higher resolution. It takes care of the communication between the software and ensures smooth jerk-free movements. Now a days, the technique of microstepping is also widely applied using stepper drivers. Microstepping can be defined as breaking down the movement of a stepper into even finer steps. That can go up to 64000 steps in modern stepper drivers. That gives an unmatched resolution and can be used in very high accuracy demanding applications.

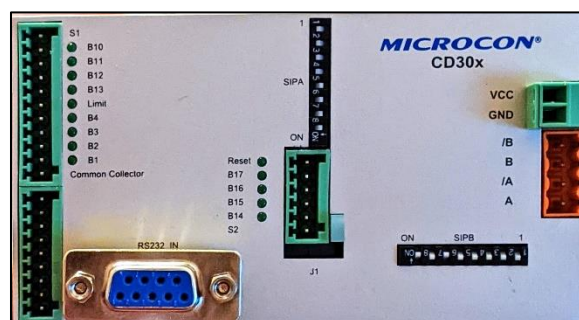


Figure 26: Stepper driver

4.5.2 Choosing between two sets of Stepper and driver combinations
 After choosing to work with stepper motors, initially based on the torque requirement and availability, a suitable combination of Stepper and driver was made.

• **Type 1 (PURCHASE)**

SANMOTION 2861-5055 Stepper + RTA NDC 96 Drive

Current	2 A
Type	Bipolar AC
Holding Torque	3,6 Nm
Size	NEMA 34
Voltage Supply	115/230 V AC
Weight	1,7 Kg




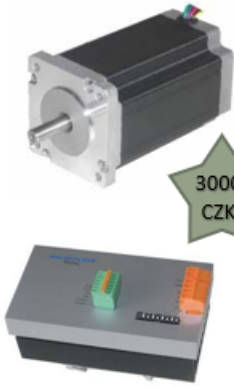
Figure 27: Suggested Combination 1 - Stepper and driver

- This combination of Stepper and driver uses a Stepper motor from SANMOTION and a compatible driver from RTA.
- The torque and other characteristics fall in an acceptable range.
- This combination costs around 7500 CZK and would be required to be purchased.

• **Type 2 (AVAILABLE IN-HOUSE)**

MICROCON SX34-2740 Stepper + Controller CD30X

Current	3,3 A
Type	Bipolar DC
Holding Torque	2,8 Nm
Size	NEMA 34
Voltage Supply	48 V DC
Weight	2,3 Kg



CHOICE

3000 CZK

Figure 28: Suggested combination 2 - Stepper and driver

- This option of a Stepper motor and driver/microcontroller from the Czech manufacturer MICROCON was found upon enquiry in the laboratories at Juliska and Roztoky, if there was a presence of any spare hardware for providing linear motion.
- Yet again, the torque and other characteristics fall in the acceptable range.
- The biggest plus point with this suggestion is the readily available parts that are free-of-cost to test and use, in-house in the university.
- Hence, this suggested combination was chosen as the final choice for providing linear motion to the dynamometer.
- This also helps the department save around 5000 CZK!

4.5.3 MICROCON 2740 Stepper and CD30x Driver

SX34-2740 STEPPER	
Current	3,3 A
Type	Bipolar DC
Holding Torque	2,8 Nm
Size	NEMA 34
Voltage Supply	48 V DC
Weight	2,3 Kg

Table 5: Stepper motor characteristics

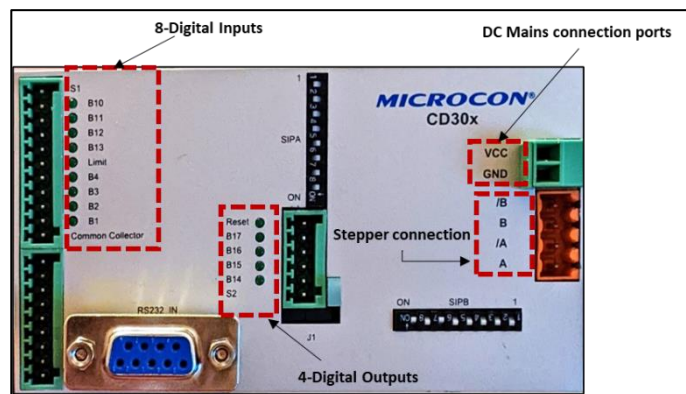


Figure 29: Stepper Driver connection ports

4.6 Additional Hardware

The motion and movement control part of the thesis project requires the use of some additional hardware to be able to perform all needed functions.

These additional parts could be divided as: -

- Limit switches
- Push button switches
- Emergency stop switch

4.6.1 Limit Switches

Limit switches as the name suggests limit an object from moving beyond a point. In case our application the task remains the same with a slight modification. In our case, the limit switch can be moved and fixed anywhere along the linear length of the dynamometer.

The idea is to place two limit switches very close to one another at one end of the dynamometer. This is ideal when a very precise positioning is required. Hence, while adjusting the position, in case the dynamometer goes too wide, the limit switches can prevent damage to testing parts or other attachment.

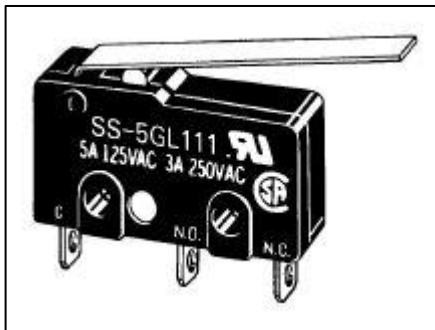


Figure 30: OMRON SS-01 GL111-3 Limit Switch [OM07]

KEY CHARACTERISTICS	
Rated Power	0-30 VDC
Type	SPST- NO
Lever Type	Long hinge lever
Terminals	Solder

Table 6: Limit Switch characteristics [OM07]

4.6.2 Push button switches

Push button switches are normal ON/OFF switches that allow performing certain functions with the help of the stepper driver. For our case, this function would be the operation of the stepper motor in clockwise (CW) and counterclockwise (CCW) directions.

To explain a little more, when push button-1 would remain pressed, it would move the stepper motor in the CW direction and the motor would stop rotations only when the switch is once again depressed or if the dynamometer triggers one of the limit switches.

Likewise, when push button-2 remains pressed, it should move the stepper motor in the CCW direction.

The logic/functioning of the software is explained later in the software chapter.

4.6.3 Emergency stop switch

This type of switch is a manual way of overriding the movement of the dynamometer. This type of switch if once pressed, should immediately cut-off the power supply to the microcontroller and hence in-turn to the stepper motor, causing a shut-down of the system.

This is a switch that is used in the rarest of cases when the stepper seems to be malfunctioning and doesn't seem to respond well to commands.

4.7 Data acquisition and wiring diagram

As explained earlier when introducing LabVIEW, data acquisition mainly deals with all connected hardware parts synced with the software for a seamless communication.

Most of the communication with LabVIEW requires some form of NI-hardware. However, in our case as the in-house Stepper motor has an accompanying stepper driver from the same manufacturer MICROCON, this eliminates the need of additional hardware from NI.

All the necessary additional hardware is connected to the Stepper driver. This driver is then finally connected to the computer via a Serial Port.

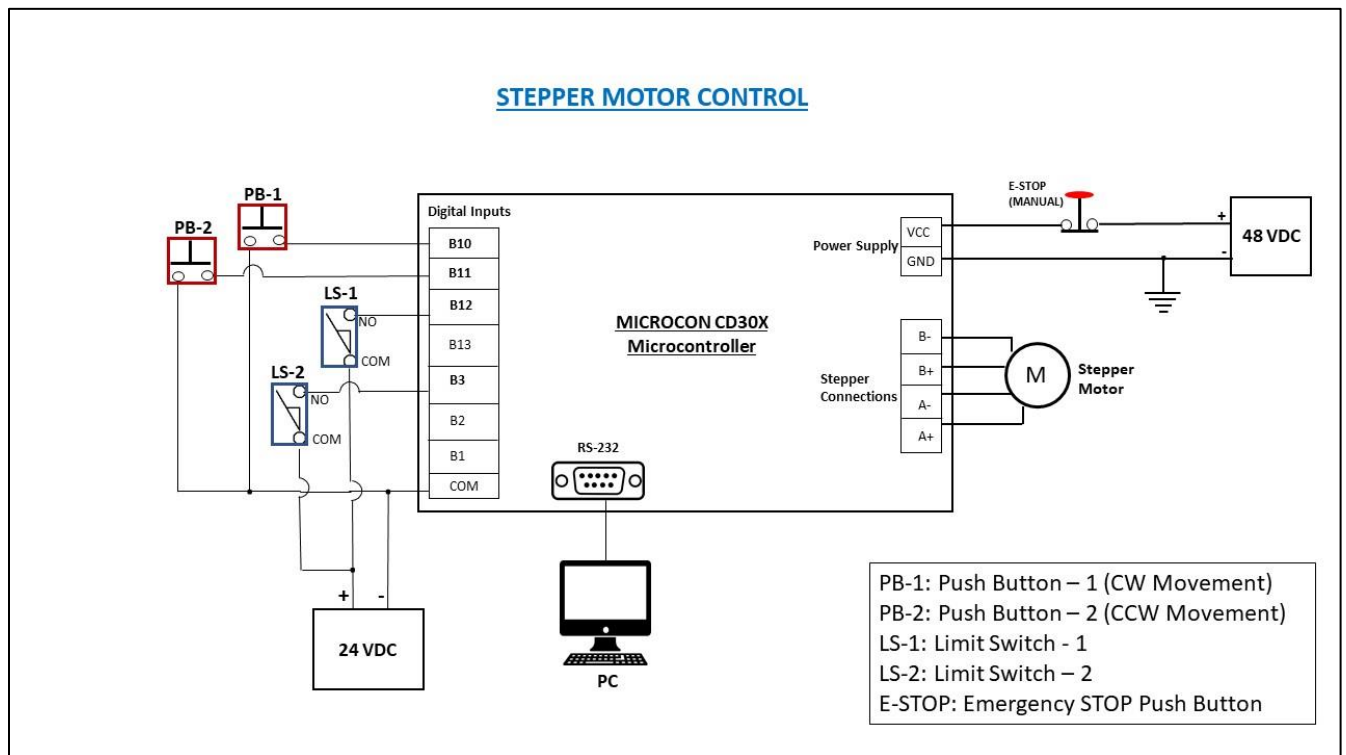


Figure 31: Stepper motor control - scheme

5 Pneumatics and dynamometer braking

This chapter deals with another major part of the proposed positioning system: the pneumatics. The test stand on which the dynamometer moves, has a braking system to lock the dynamometer in place when a test is done. This system utilizes compressed air that passes through pneumatic brakes to release or hold them in place. The proposed system aims to provide an efficient and a permanent way of using the pneumatics on the test stand.

Compressed air: Supplied?	Brakes
Yes	Released
No	Applied

Table 7: Pneumatic Brakes mechanism

5.1 Need

The use of pneumatics on the test stand is although simple but needs some modifications to provide maximum efficiency to the user.

The system should be always ready to be used, without requiring any additional work by the user before he/she can apply/release the brakes.

The system should be able to be used in dual modes, a stand-alone manual operation, where the pneumatic brakes could be released/applied by just a press of a button. On the other hand, there should be a way to remotely apply or release brakes. This could also be done using the software.

5.2 Objective

The objectives can be described as follows: -

- The first objective should be to allow a permanent connection of the compressor with the brakes on the test stand. This should ensure a continuous supply of compressed air, hence providing the option to release or apply the brakes, when needed.
 - There should be a choice of controlling the application of brakes via two modes: -
 - Manual Mode: A simple mode in which the pneumatic brakes could be applied or released by just a press of a switch, installed near the test stand.
 - Automated Mode: A remote way of operating the brakes, with the help of software, LabVIEW.
-

5.3 Present scenario

The present operation of the pneumatic brakes can be termed as, not user friendly. This can be attributed to the way the brakes are controlled presently.

- When a user wishes to use the pneumatic brakes, first the connection from the compressor to the pneumatic brake pipes should be made. This involves attaching a push-fit connector to the compressor outlet.
- This immediately allows air to reach the pneumatic brakes and hence, the brakes are activated immediately as the connector is connected with the compressor outlet.
- Once the user has moved the dynamometer to the desired position, the connection between the compressor outlet and the pipes of the pneumatic brakes must be broken, to release the pressure in the pipes and help in re-engaging the brakes.
- Hence, the push-fit connector is removed from the compressor outlet and placed aside near the test stand.

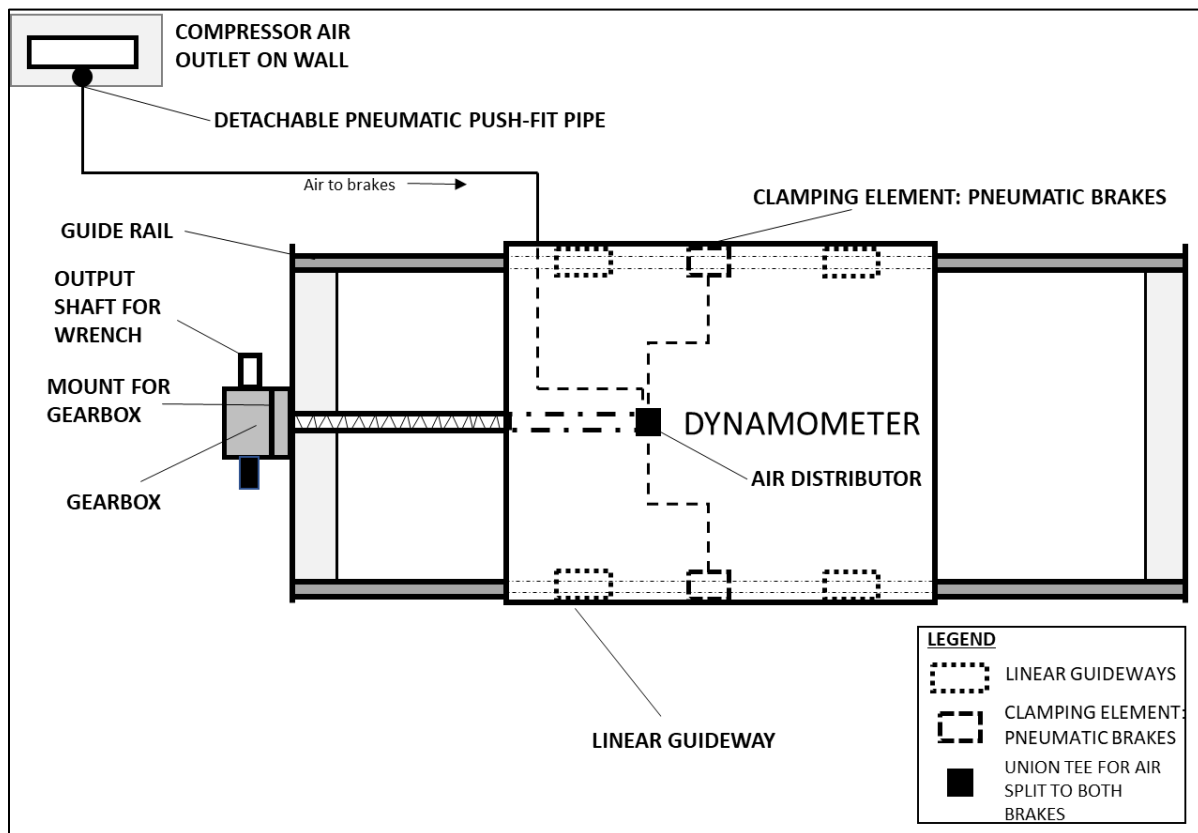


Figure 32: Current pneumatic brake actuation system

5.4 Approach towards providing a solution

The first thought that comes to mind when you need to control the flow of something is a device called as a valve.

Taking this as the starting point, I tried to base my research on the following factors: -

- Medium: Compressed air
- Pressure: Up to 10 bar
- Power choices
- Actuation: via a Switch/ remotely via LabVIEW
- Speed
- Lifecycle
- Cost

Based on the application, in the initial literature survey, the choice of valve was reduced to two types

- Solenoid Valve
- Ball Valve

Then, the two types of valves were judged on five factors to decide the preference.

SOLENOID VALVE Vs BALL VALVE					
Type of valve	Pressure: 0-10 bar	Actuation	Speed	Life-cycle	Power choice
Solenoid Valve	Ideal for this pressure range	Electrical signal	Faster response time	Higher	Mostly 120VAC or 24VDC
Ball Valve	Suitable for higher pressures	Pneumatic/Electric signal/Lever	Slower in comparison	Low	Variety of AC or DC options

Table 8: Solenoid valve and ball valve comparison

Solenoid Valve Vs Ball Valve:

- **Pressure range (0-10 bars):** Although, both types of valves are available in the commercial market for the pressure range, Ball valves are mostly employed for much higher-pressure range operation.
 - **Actuation:** Ball valve offers much diverse options of actuation, from the pneumatic actuation to electric signal to even manual levers on the device. On the other hand, solenoid valve is mostly actuated via an electric signal. This point, however, is an important consideration for choosing the
-

solenoid valve as ahead in the literature research it was found that a dual mode of pneumatic brake application could be realized by just using a single solenoid valve.

- **Speed:** In comparison, the solenoid valve responds faster to actuation requests in comparison to a ball valve. They might be less important for our application; however, this is also a differentiating factor.
- **Duty-cycle:** This consideration is also quite significant in deciding one valve over the other. Solenoid valves in comparison have a much greater duty cycle than the ball valves, meaning the valve could remain in operation on the test stand for a longer duration before it needs to be replaced.
- **Power choice:** This is one of the factors, that is similar for both the type of valves. Both valves offer standard AC or DC supply options, with the solenoid valve offering more variety of options.

5.5 Solenoid Valve: choosing the right type

The next step in providing a suitable pneumatic actuation solution for the brakes was in choosing a suitable solenoid valve.

After being sure, that the type of valve will be a solenoid valve, the literature research was focused on looking at various types of solenoid valves.

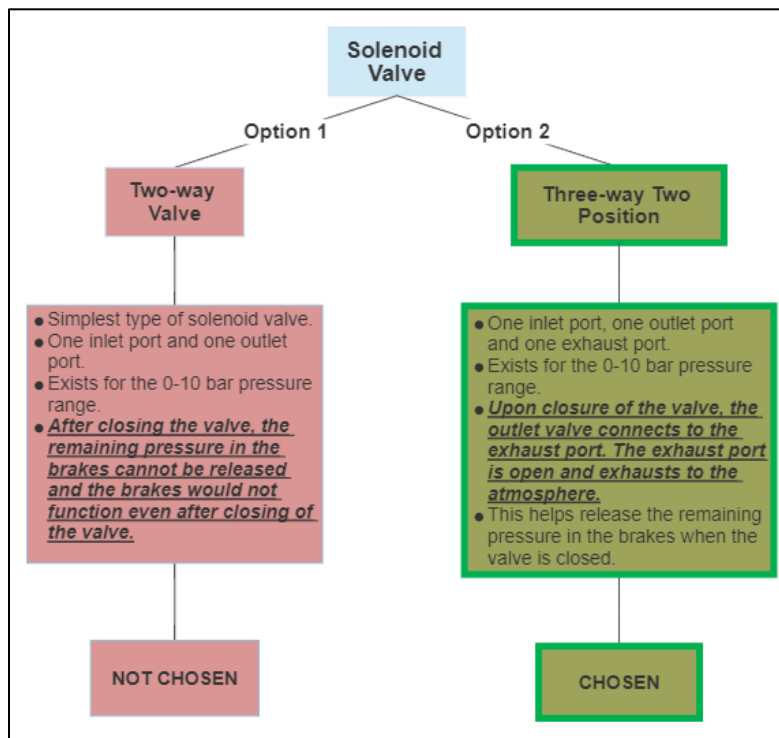


Figure 33: Choosing a solenoid valve

The two applicable types of solenoid valves were considered to make the final decision: -

1. Two-way Solenoid Valve
2. Three-position, two-way Solenoid Valve

Main factor for the decision: -

- The defining factor for choosing one type of valve over the other was if the valve could release the existing pressure behind the inlet valve (after closure) in the system.
- The Two-way valve is a standard solenoid valve, where the valve's function is only to block/ allow the supply of compressor air through the outlet port. This, however, is not sufficient for our application where the existing pressure inside the braking system pipes must be released. This cannot happen, if there is no port or a way to ventilate the braking system once the valve has been closed (no flow of air into the valve).
- Here, the Three-Position Two-Way Valve, comes into application. The differentiating feature of this valve is the presence of an exhaust port. This exhaust port exclusively operates to relieve the pressure in the area behind the inlet valve once it closes. This is exactly what we need as a function.

5.6 Burkert 6012 Three-Way Two-Position Solenoid Valve

After considering factors such as availability and suitability, the Burkert 6012 3/2 Solenoid Valve is recommended as a choice for controlling the pneumatic brakes application/release.



Figure 34: Burkert Solenoid Valve [BU21]

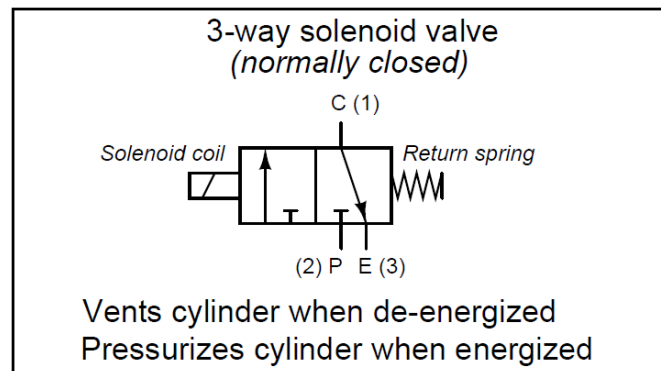


Figure 35: Functioning of the valve

The exact specifications for the valve were determined after consultation with the manufacturer. The key specifications are described below in the table.

BURKERT 6012 3-position 2-way Solenoid Valve		
Voltage	Pressure range	Power consumption
24 VDC	0 - 10 bar	4 Watts

Table 9: Solenoid valve characteristics [BU21]

Valve Functioning		
Status	Valve Position	Effect
Turned on	Inlet port connected with the outlet port ; Exhaust port remains closed	Pneumatic brakes released
Turned off	Outlet port connected with the exhaust port ; Inlet port remains closed	Pneumatic brakes applied

Table 10: Valve functioning

However, to create a pneumatic system that allows a choice between manual actuation and a remote actuation via LabVIEW, there is need to add more parts to the solenoid valve.

This is described in the following sections.

5.7 Additional hardware: Pneumatic system

To successfully actuate the solenoid valve, additional parts are required.

These parts then together form the pneumatic system.

- Toggle Switch
 - Push-button switch
 - Electromechanical Relay
-

5.7.1 Toggle Switch

The application of a toggle switch is to choose the way of operation of the solenoid valve: Manual or Automated.

To define it exactly, it's a Single-Pole Double-Throw switch. A Single-Pole switch only controls one electric circuit. Double-Throw refers to an actuator with two positions where the circuit is closed. That means by toggling the switch UP/DOWN, in both conditions a circuit is closed/allowed to function by completing the connection.

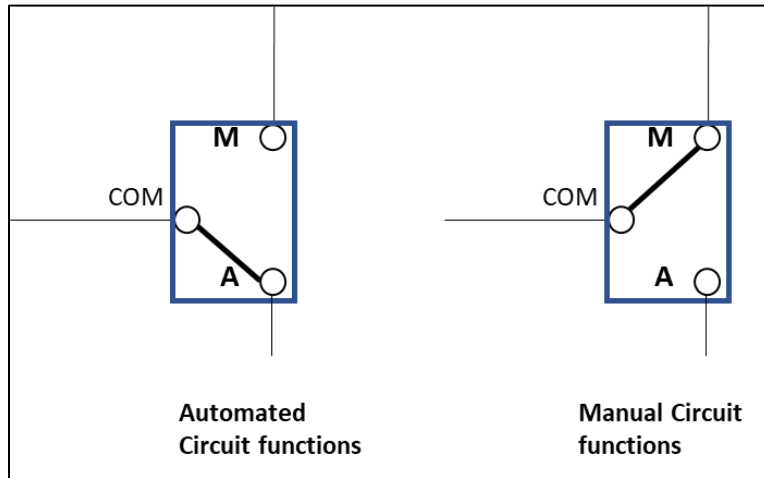


Figure 36: Toggle switch functioning

5.7.2 Push-button Switch (for Manual Actuation of Valve)

Push-button switch is a switch that is used in electric circuit to interrupt or complete the circuit when pressed. The Normally-Open switch keeps the circuit open until pressed (the circuit cannot function). The Normally-Closed switch allows the circuit to function until pressed.

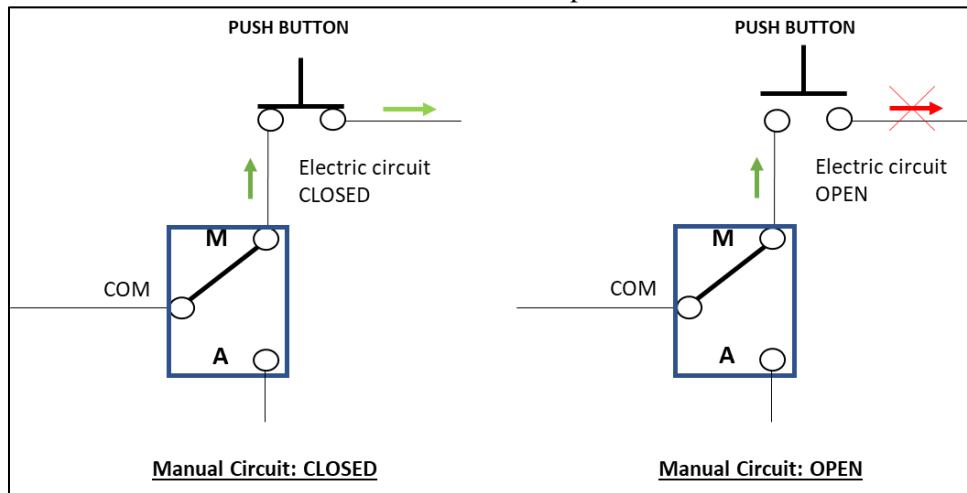


Figure 37: Manual actuation with push-button

For our case, the idea is to use a push-button in the manual mode to allow the opening or closing of the inlet valve of the solenoid. Hence, the push button has to be placed on the Manual side of the toggle switch and should be a Normally-Open type.

5.7.3 Electromechanical Relay

This is one of the most important parts of the pneumatic system after the solenoid valve itself. The idea behind using an electromechanical relay comes from the need of providing a manual and automated way of operation.

- The solenoid valve cannot handle two parallel connections for different ways of operation.
- Hence, a device needs to be added before the solenoid valve that can handle two ways of actuation and then in-turn energize/de-energize the solenoid.
- For such purposes, the most used devices in industrial applications are Relays. Relays can be defined as electrically operated switches that allow a contact circuit to be closed when a sufficient voltage is applied to the coil or the input section of the relay.

The main types of Relays could be: Electromechanical and Solid-State Relays.

The decision to choose the Electromechanical Relay is described by the factors affecting the choice in the table below.

ELECTROMECHANICAL Vs SOLID-STATE RELAYS				
Relay	Switching Type	Switching current	Initial Cost	Typical Applications
Electromechanical Relay	via Physical contacts	Low	Lower	General Purpose, Low Voltage
Solid-State Relay	via Semiconductors	High	Higher	High Voltage, Areas with vibrations/harsh environment

Table 11: Electromechanical Vs Solid-state relays

As it can be said about the Solid-State relays that they are mostly used in harsh and demanding work environments with High contact voltage requirements. Hence, we do not require such high spec relays.

For a simplified operation of actuating a 24 VDC Solenoid valve, I recommend using an Electromechanical Relay.

Electromechanical Relay can be simply defined as a device that can be controlled electrically to generate an electromechanical force in the relay coil when a voltage is applied. This causes the contact circuit to close and hence complete the electric circuit.

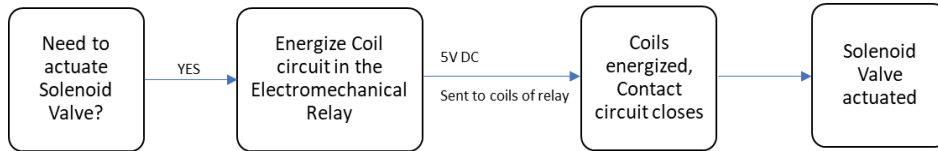


Figure 38: Solenoid valve actuation process using relay

OMRON G2R General Purpose Relay

The relay suggested for our application is the OMRON G2R Relay.



Figure 39: OMRON Relay [OM18]

OMRON G2R-1A ELECTROMECHANICAL RELAY					
Type	Poles	Coil		Contacts	
		Voltage	Rated Current	Rated Voltage	Rated Load
Normally Open	Single	5 VDC	106 mA	Up to 30 VDC	10 Amps

Table 12: Relay characteristics [OM18]

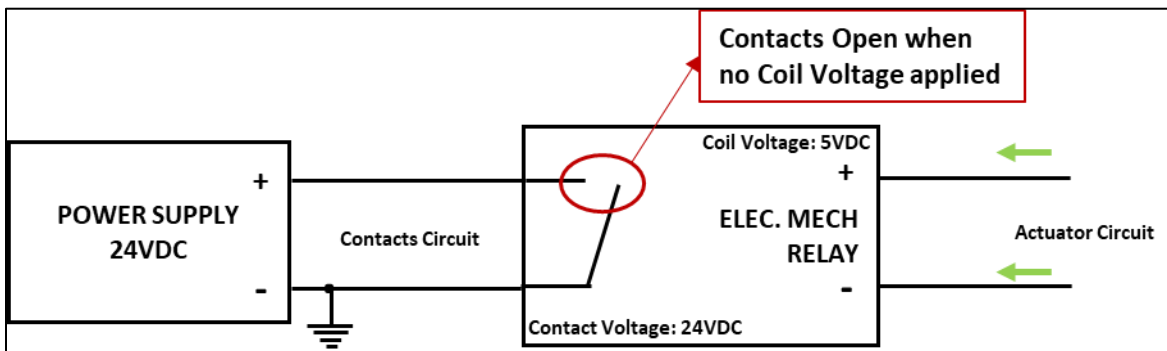


Figure 40: Relay, Normally Open contacts type

5.8 Data Acquisition, Wiring and Pneumatic Circuit

This section combines all the hardware introduced in the previous sections and introduces synchronization of the hardware with data acquisition. Finally, the completed schemes of Wiring the electrical parts and the Pneumatic circuitry is presented.

5.8.1 Data Acquisition: Solenoid Valve

In the pneumatic system, the solenoid valve is not actuated directly. In-turn it's the electromechanical relay that is controlled in two ways: a manual operation and an automated way of operation.

5.8.1.1 Manual Way of operation: As explained in the section with Push-button switch. The manual way of operation is realized through the Push-button switch. The push button switch closes a circuit with a 5 VDC Power supply. This is also the voltage required by the coil to be energized and hence, close the contacts circuit. This, then eventually actuates the solenoid. This means that the Valve is turned on and the brakes are released.

Automated Way of operation: The automated way of operation is realized through a program in LabVIEW. The details of the program are explained extensively in an exclusive chapter on LabVIEW later. For now, the acquisition and connection of parts are described.

To energize the coil circuit of the relay, the automated way uses a DAQ Card from National Instruments to send a 5 VDC voltage signal to the coils of the relay. This signal once received, energizes the coil, closes the contacts circuit and eventually turns on the solenoid valve once again.

Hence, for the hardware point of view, we require a suitable hardware to generate this 5VDC digital signal from the computer. Here, the NI-9472 Digital Output DAQ card comes in.

5.8.1.2 NI-9472

NI-9472 is a Digital Output data acquisition card from National Instruments that is compatible with the compact DAQ chassis – 9174, commonly used in the Juliska Laboratory at CTU-Prague.

This DAQ card has 8 digital output channels and can provide 6V to 30 V as a sourcing voltage.



Figure 41: NI-9472 DAQ Card [NI07]

The NI-9472 is connected to the Automated end of the toggle switch described earlier in this chapter. Once selected, upon requirement a 5 VDC voltage signal can be generated to be sent to the coil circuit of the electromechanical relay. This energizes the coil and closes the contacts circuit, in-turn turning on the solenoid valve.

5.8.2 Wiring Diagram: Pneumatic brakes circuit

This section presents the complete diagram of all electrical connections made between the various parts of this pneumatic system.

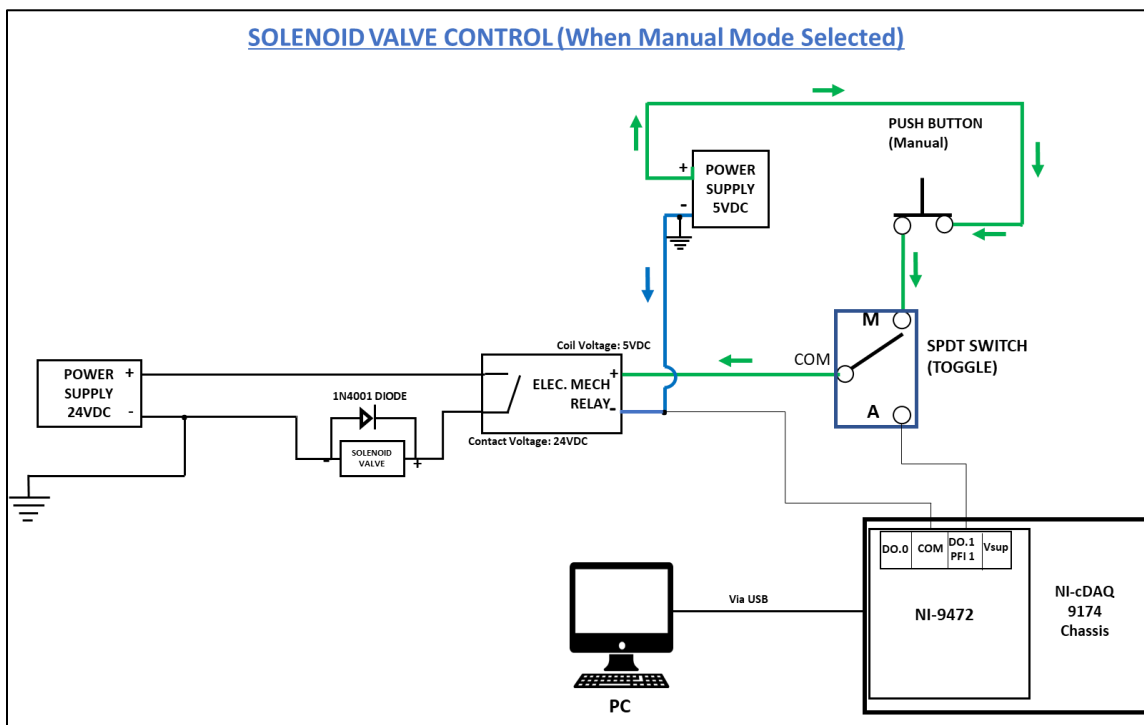


Figure 42: Solenoid valve manual mode

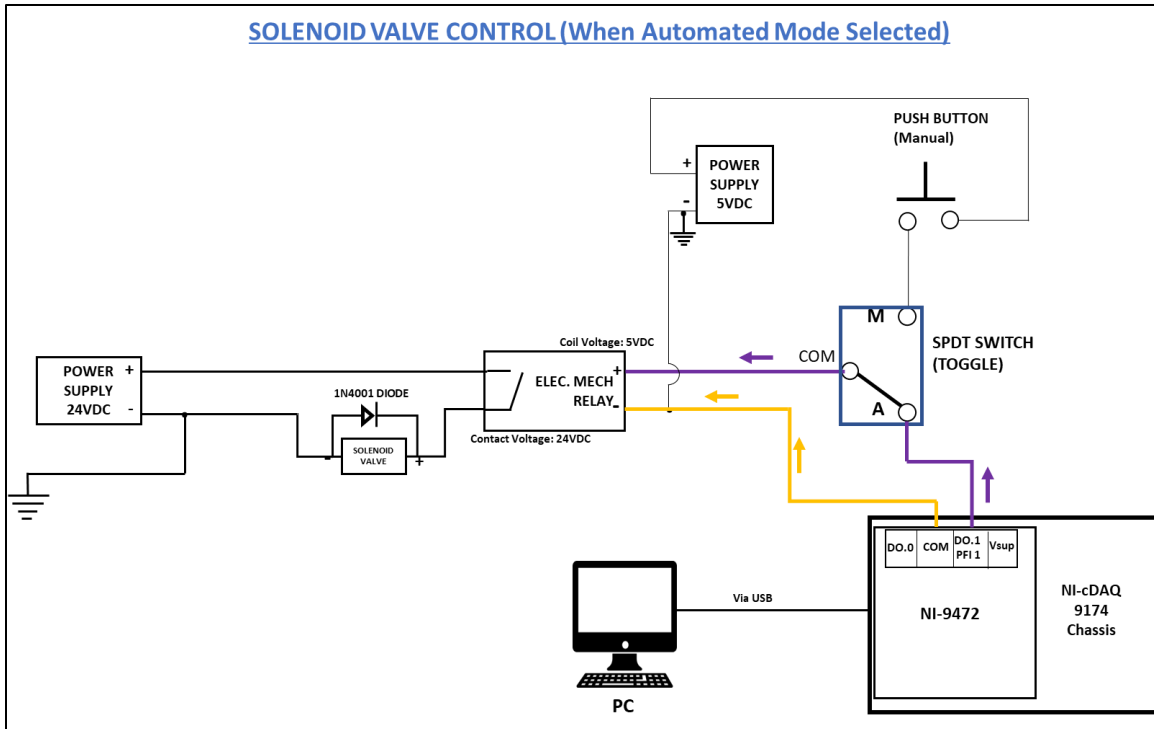


Figure 43: Solenoid Valve automated mode

5.8.3 Pneumatic Circuit

The pneumatic circuit of the positioning system mainly consists of three main physical parts: -

- Air distributor: A distributor mounted on the wall near the test stand from where the connection to compressed air can be obtained. This distributor is directly connected to the compressor present in the basement of the laboratory.

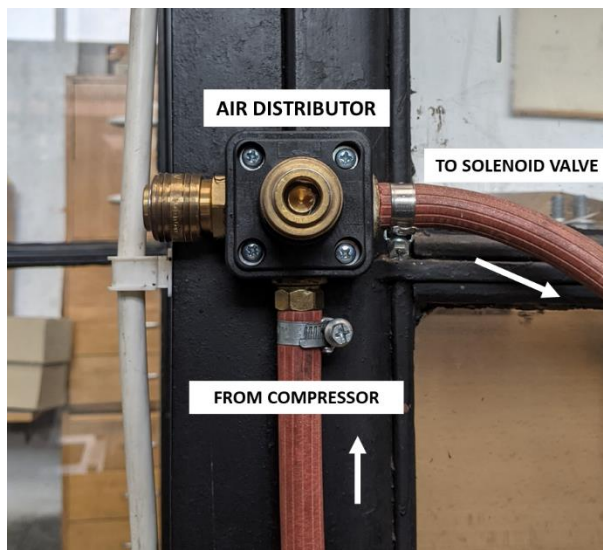


Figure 44: Air distributor at the test stand

-
- Solenoid Valve: As described in the section about the chosen type of valve, a three-position, two-way solenoid valve is connected to the air distributor and controls the flow of compressed air into the pneumatic brakes of the test stand.
 - Pneumatic brakes: Lastly, the brakes itself located underneath the base plate on which the dynamometer is mounted, complete the pneumatic circuit of the test stand. The pipes carry the compressed air from the outlet of the solenoid valve to the air distributor the brakes. This distributor splits the supply towards the two clamping elements.

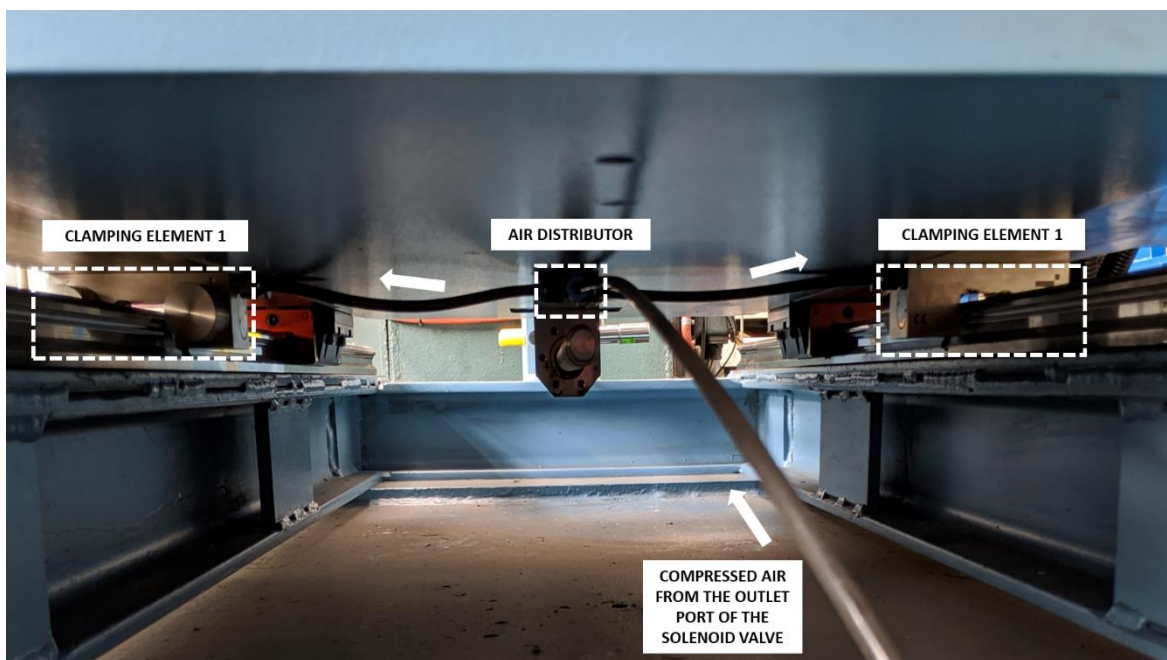


Figure 45: Distribution of air in the test stand brakes

5.8.3.1 Pneumatic Circuit: When Solenoid Valve is turned off

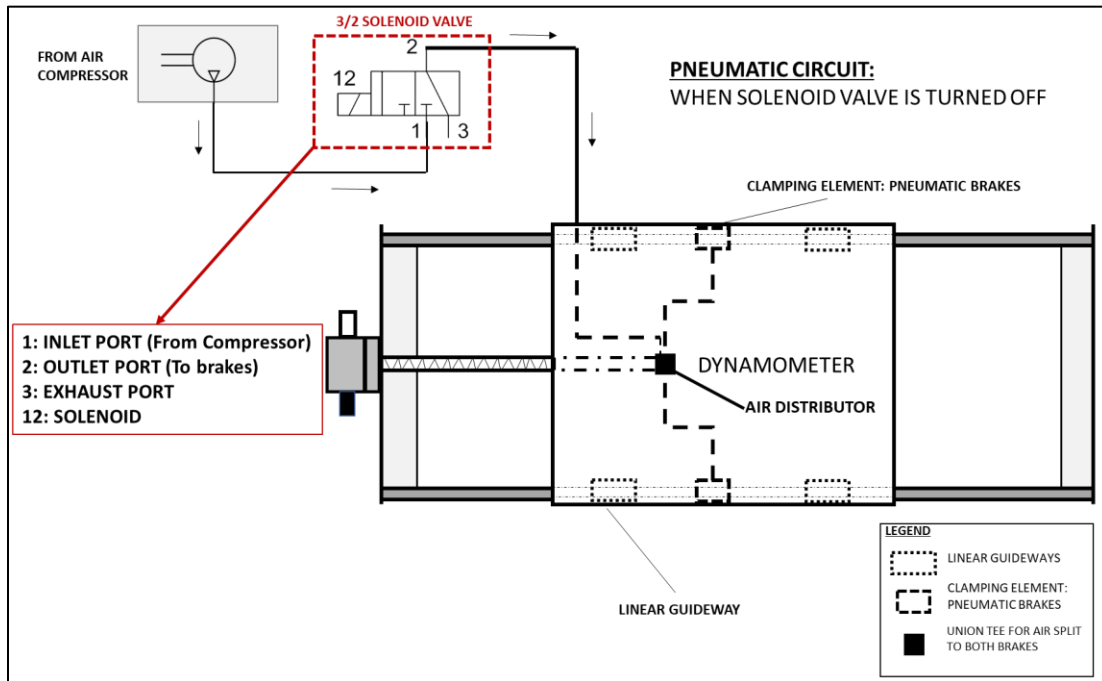


Figure 46: Pneumatic circuit: when solenoid is OFF

5.8.3.2 Pneumatic circuit: When solenoid valve is turned on

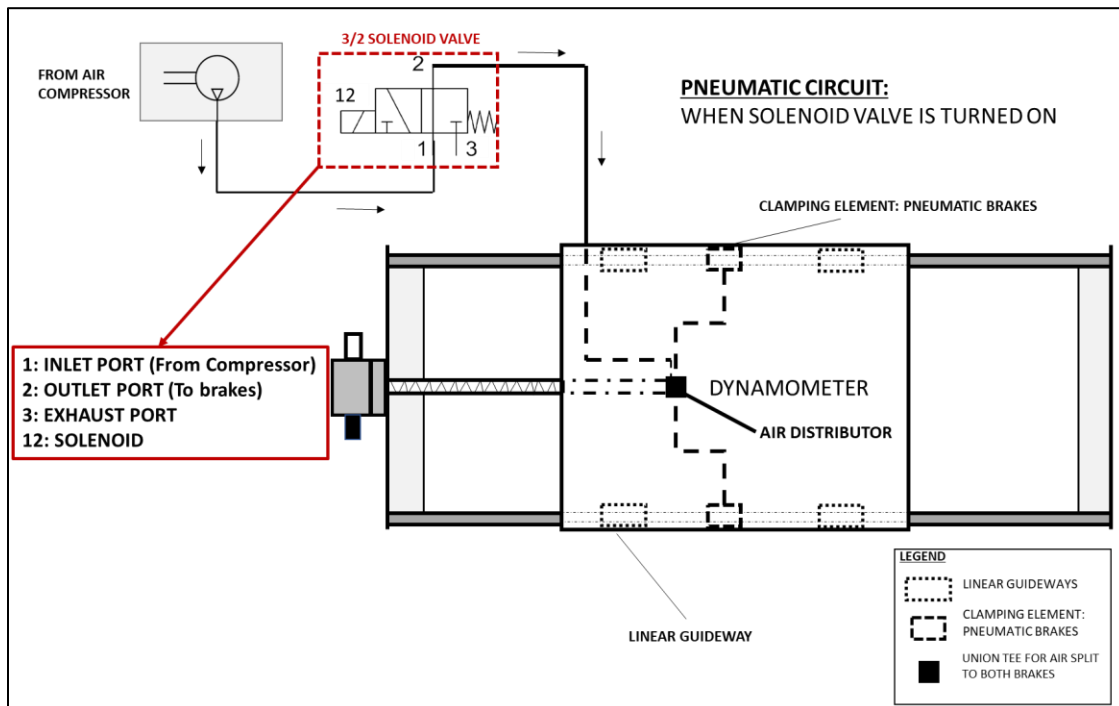


Figure 47: Pneumatic circuit: when solenoid is ON

6 The Positioning System: Complete Scheme

This chapter aims to combine all functional areas that together form the positioning system of the open-loop test stand. This includes the Position measurement, motion and movement control, pneumatics, and dynamometer braking.

The positioning system has been sub-divided into manual and automated systems with the active paths of connections highlighted by colored wires and arrows. This approach makes it easier to understand what parts of the scheme are being used in which mode to a person that hasn't seen the system scheme before.

6.1 Overall Positioning System: Scheme

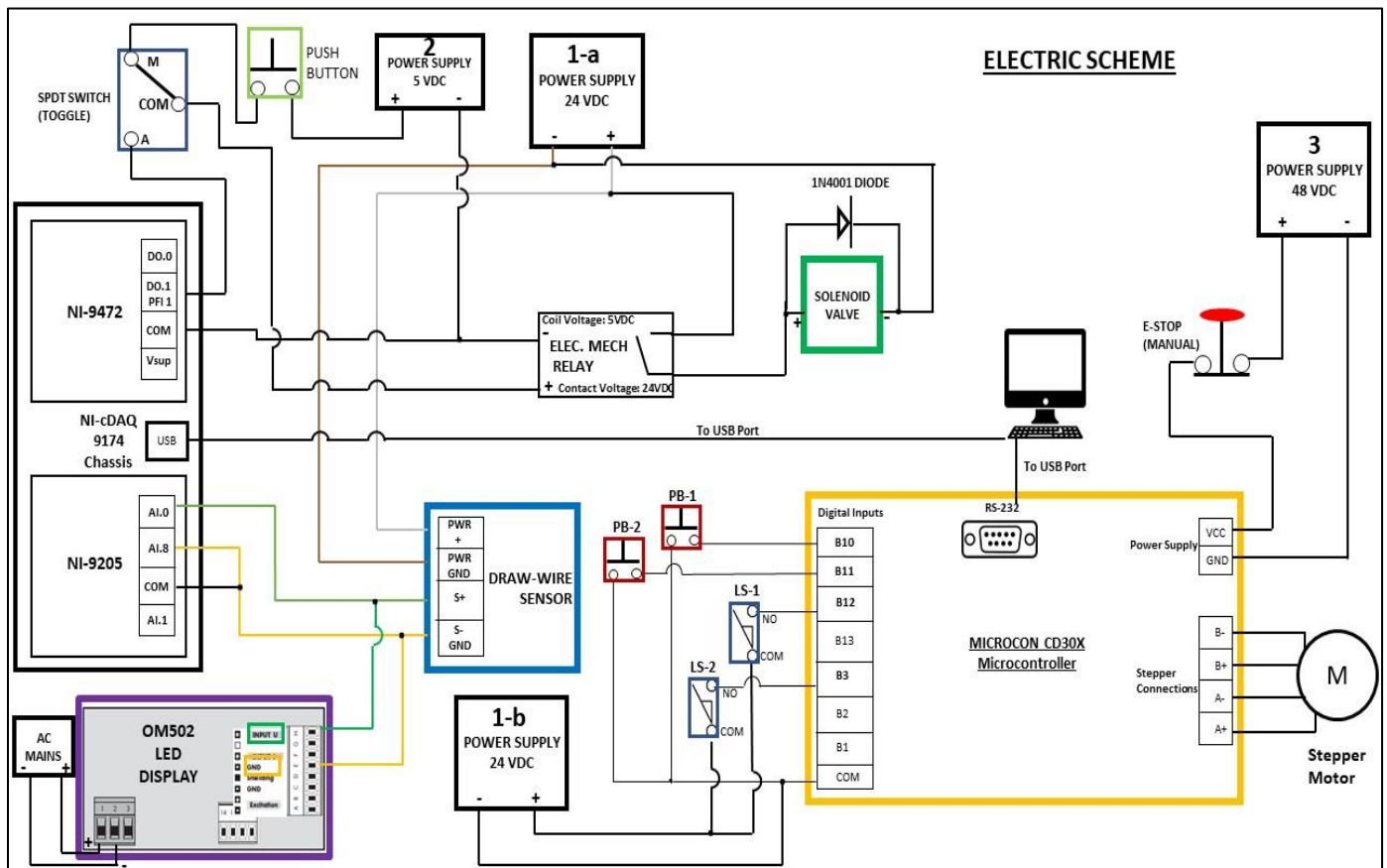


Figure 48: Complete Positioning system

6.2 Manual Positioning System: Scheme

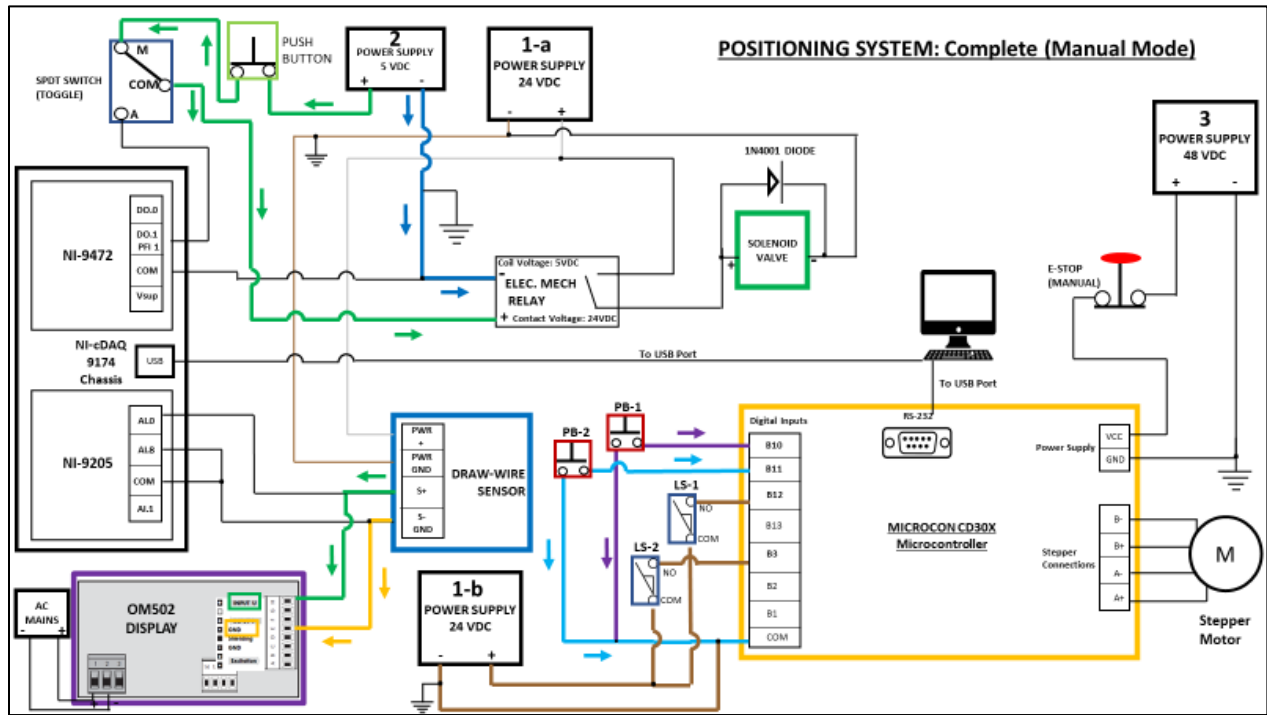


Figure 49: Manual Positioning System: scheme

6.3 Automated Positioning System: Scheme

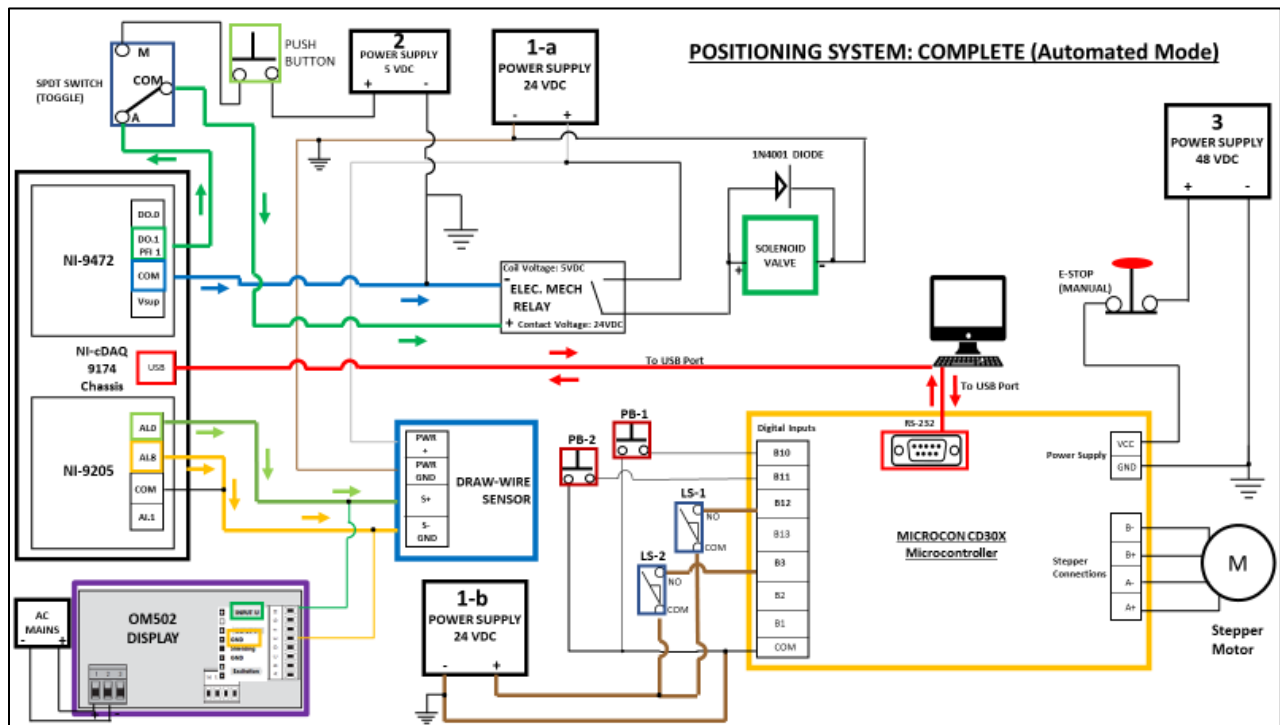


Figure 50: Automated positioning system: scheme

7 LabVIEW and its Application

LabVIEW is the short form of Laboratory Virtual Instrument Engineering Workbench. It can be defined as a system-design platform and development environment that enables combining various hardware types to facilitate testing and measurement. It is developed by National Instruments and is widely used in industrial setting for engineering measurements and testing.

The important part of the LabVIEW environment is the Virtual Instrument or VI where users can create their interface and then measure/test as per their requirements.

7.1 Need

One of the many things that the open-loop test stand lacks currently is the ability to be monitored or controlled remotely. Such a way of control can help improve operator efficiency and remove unnecessary physical interaction between the user and the test stand.

7.2 Objective

The assigned project requires an automated way of control. This can be realized via LabVIEW where the tasks of movement, measurement, actuation can be undertaken by the software and the user is only required to control/measure the occurring processes via LabVIEW.

This approach also allows for a more accurate and safer utilization of the test stand, eliminating the physical actuation of the movement or application/release of pneumatic brakes. This all can be realized via LabVIEW.

7.3 Present Scenario

At present, there is no application of LabVIEW in relation with the open-loop test stand.

7.4 Virtual Instrument

The part of the software where the user can create his/her tests/measurement programs is the virtual instrument. The virtual instrument can be divided into two distinct parts: -

- Front Panel: This is the part of the program with which the user interacts. Hence, all the interactive controls and process indicators together form the front panel.
 - Block diagram: This part can said to be the brains of the program. It contains the graphical code of the program. How a particular measurement executes in steps, what all parameters or functions are involved, and various other controllable factors exist in this part of the program.
-

7.4.1 Approach to program creation

Creating a complex program that involves a user interface to control parameters and to interact with the indicators can never be an easy task. So was also the case with understanding the creation of the program for our application.

However, a large chunk of the time to create a LabVIEW program was spent in increasing the knowledge about the software. This included literature survey, online-certification course on basics of LabVIEW, interacting and exploring the actual LabVIEW environment.

Once a sufficient understanding of at-least the basics and the necessary awareness on data acquisition was acquired, the development process for a LabVIEW program was started.

The approach taken was to consider each of the physical parts of the positioning system separately as an individual virtual instrument. This would help in troubleshooting in case some errors were found. Once, the testing of the available parts was done, the various VIs would be combined into a single program for an easy usage.

7.4.2 Draw-wire sensor Virtual Instrument

The draw-wire sensor has a function to output an analog voltage signal between 0-10 V in a total distance of 1250 mm. However, the sensor only inputs a voltage signal and does not automatically convert it into the distance moved.

Hence, the main task in creating a draw-wire VI was to be able to read the moved distance on the front panel. This is how the draw-wire sensor implementation into LabVIEW was realized.

7.4.2.1 Front Panel

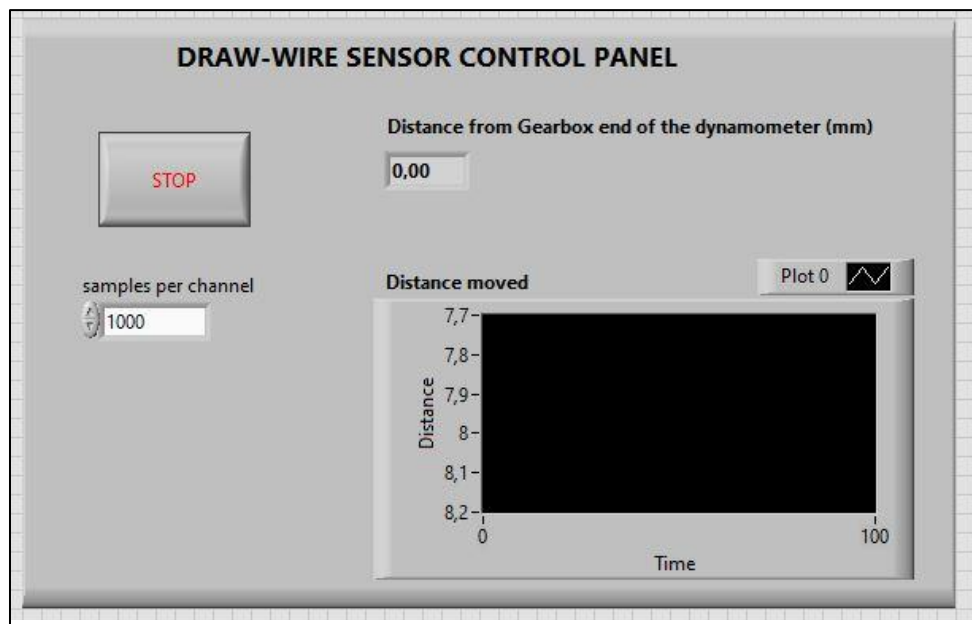


Figure 51: Draw-wire sensor front panel

The front panel for the draw-wire sensor contains three main interface objects: -

- Distance from the gearbox end of the dynamometer: This indicator displays the instantaneous distance the dynamometer has moved. This distance is referenced from the side of the test stand where the gearbox is attached. The total movable length of the test stand is 1005 mm. The scale for the sensor is up to 1250 mm.
- Distance moved graphical indicator: This indicator shows in real-time how the signal from the sensor has changed with respect to the movement. This just adds a visual representation of the value.
- STOP button: This button simply stops the loop which measures the signal.

7.4.2.2 Block diagram

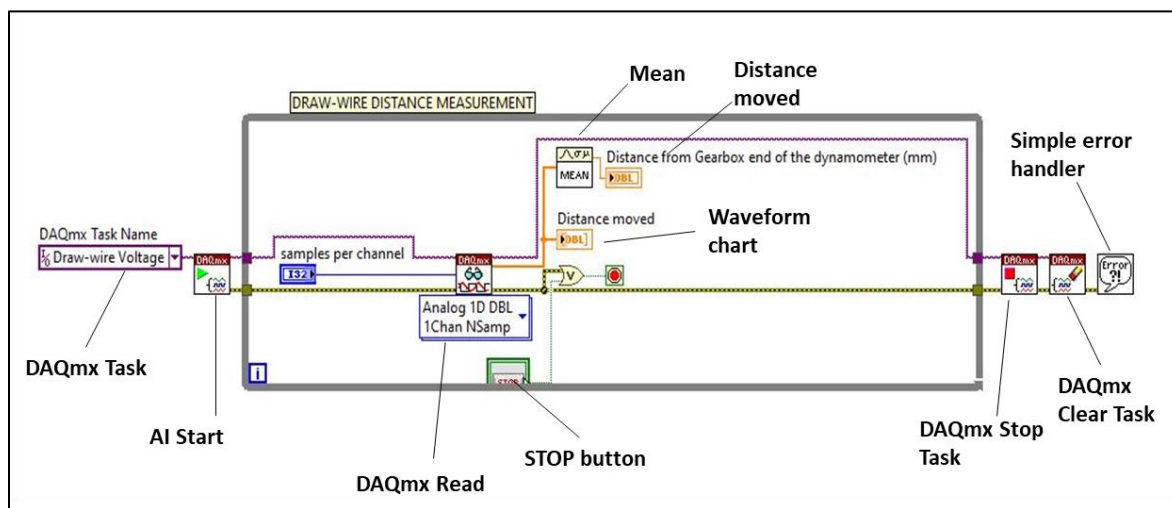


Figure 52: Draw-wire sensor block diagram

The block diagram contains the following components:

- **DAQmx Task:** This is a very useful way of creating a task in LabVIEW. The draw-wire sensor originally outputs an analog voltage signal of the range 0 – 10V. This signal when read by the data acquisition hardware and then displayed in the virtual instrument would show a voltage value based on the change in the distance. However, that's not what we require. This is where the DAQmx task comes into use. Through this we can create our own converted or interpreted logics to simplify the block diagram. In the DAQmx task settings, using the scaling feature, I converted the 0 – 10 V signal to the

distance. This would help in only showcasing the distance as the output, reducing the need for additional logics to convert the voltage signal.

- AI Start: This component of the diagram moves changes the state of the program from running to the beginning of the measurement.
- DAQmx Read: It reads the incoming analog input samples from the task. In our case, as only one device is connected to the measurement hardware, so only one channel is read. But as in continuous sampling we sample 100 samples for every change, the number of samples in the settings is N.

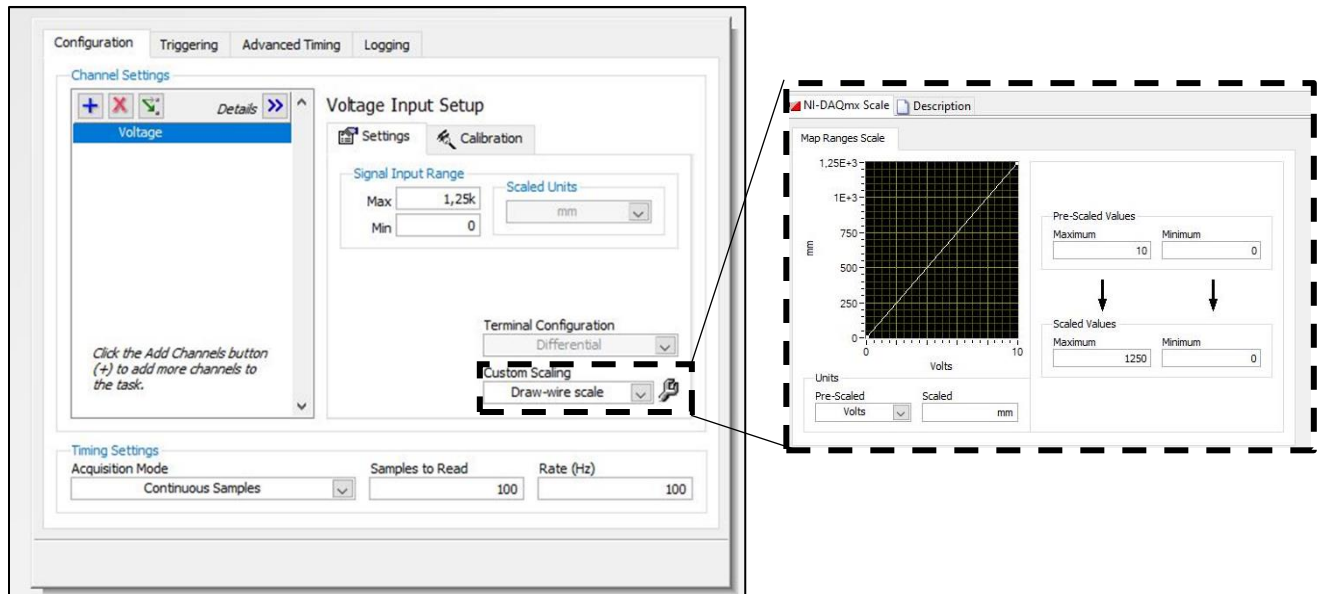


Figure 53: Scaling Voltage signal to distance (mm)

- Waveform chart: This displays a waveform in the front panel, as described already.
- Mean operator: This operator takes the instantaneous values from the measurement and then does a mean operation to single out a single value for every change in the signal. This helps in easy transformation of signal into a single value for every change in distance. This is then used to display the distance moved in the front panel.
- DAQmx Stop Task: This simply stops the task being measured and returns it to the initial state.
- Clear Task: This clears the task once the loop or the operation has been stopped.
- Simple error handler: This simply handles the errors, if any, encountered in the execution of the program and displays a dialog box explaining the error.

7.4.2.3 Testing

The part being already purchased and ready, it was possible to test the correctness and accuracy of the program. A sample picture of the test setup is displayed below.

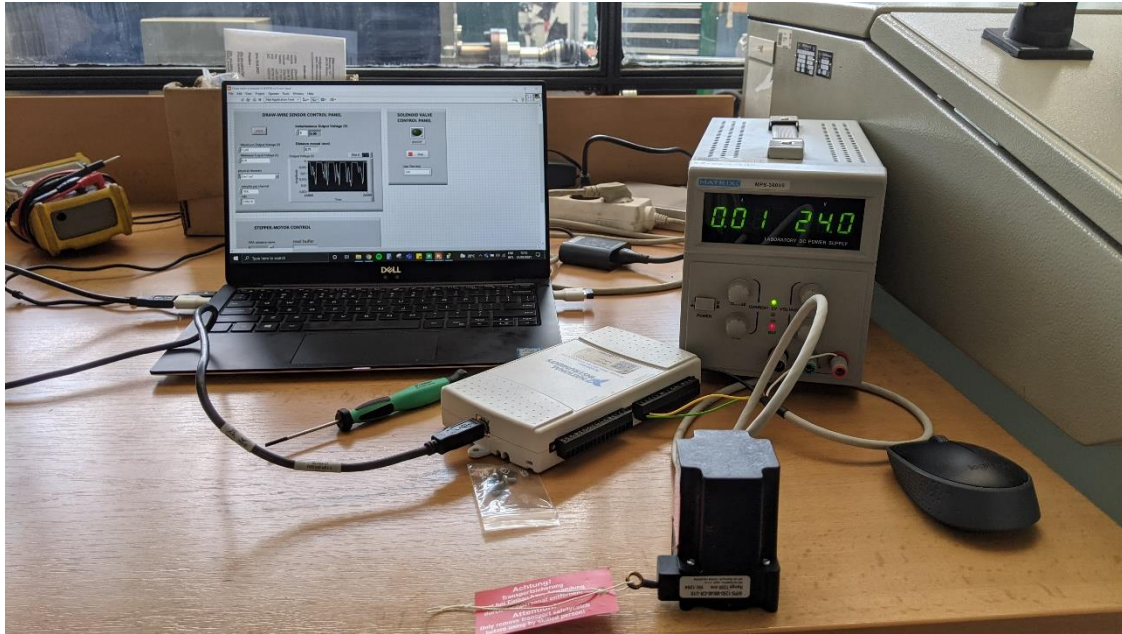


Figure 54: Draw-wire sensor testing with DAQ card

7.4.3 Stepper motor and limit switch virtual instrument

The stepper motor is controlled through its controller: MICROCON CD30x and then the controller communicates with LabVIEW.

The type of communication also differs in case of the stepper motor. As the hardware is not from National Instruments, the connection with the PC is made through a serial port.

Due to this reason, the type of communication within the virtual instrument also differs. The components in the VI are taken from the Serial library in LabVIEW. Also as the functioning of limit switch effects the stepper motor loop, hence they are described together.

7.4.3.1 Front Panel

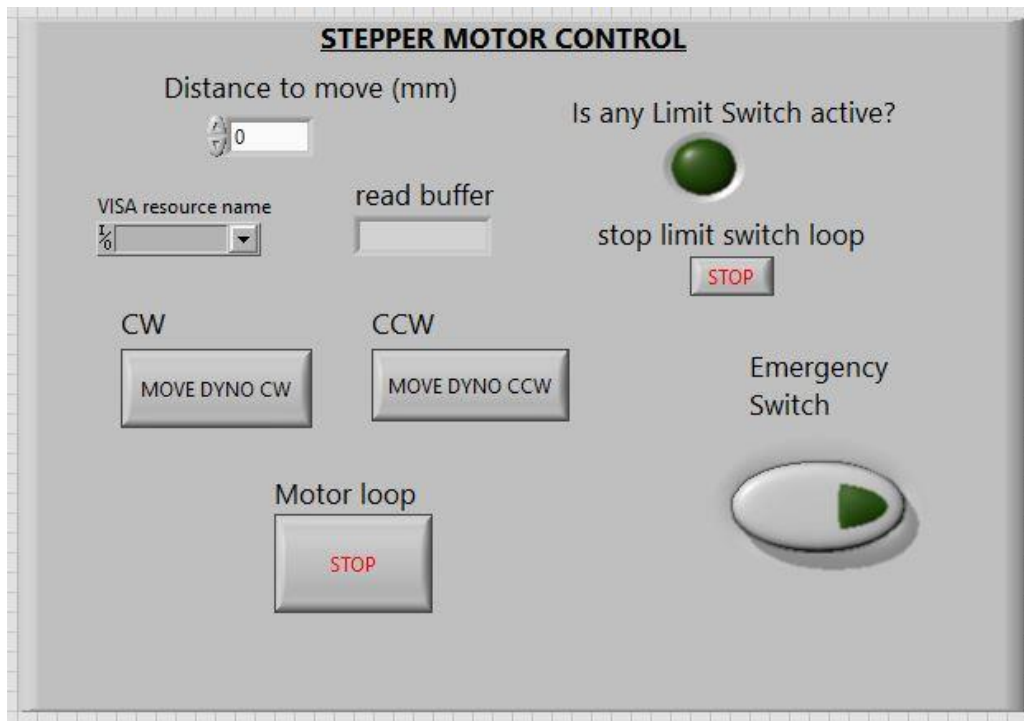


Figure 55: Stepper Motor front panel

The front panel mainly contains simple buttons to control the movement or to monitor the status of the limit switches. The main parts of the stepper motor front panel could be described as: -

- Distance to move: This control allows the user to input the desired distance to be moved (in mm) by the dynamometer.
-

- VISA resource name: This control allows the user to select the appropriate COM port for communication with the stepper. Being a program that uses a Serial communication, there isn't a way to pre-select the appropriate port before the program begins as in the case of other logics that use NI-hardware.
- Move Dyno CW: This button if pressed, would allow the dynamometer to move in the clockwise direction based on the distance input in the "Distance to move" control.
- Move Dyno CCW: This button moves the dynamometer in the counterclockwise direction based on the input distance.
- STOP motor loop: This button stops the loop of the stepper motor.
- Is any limit switch active: This indicator showcases the status of the limit switch. If a limit switch is active the indicator would be lit in green color.
- Stop limit switch loop: This button stops the limit switch monitoring loop.
- Emergency Switch: This switch when pressed, immediately instructs the stepper loop to stop the movement.

7.4.3.2 Block diagram

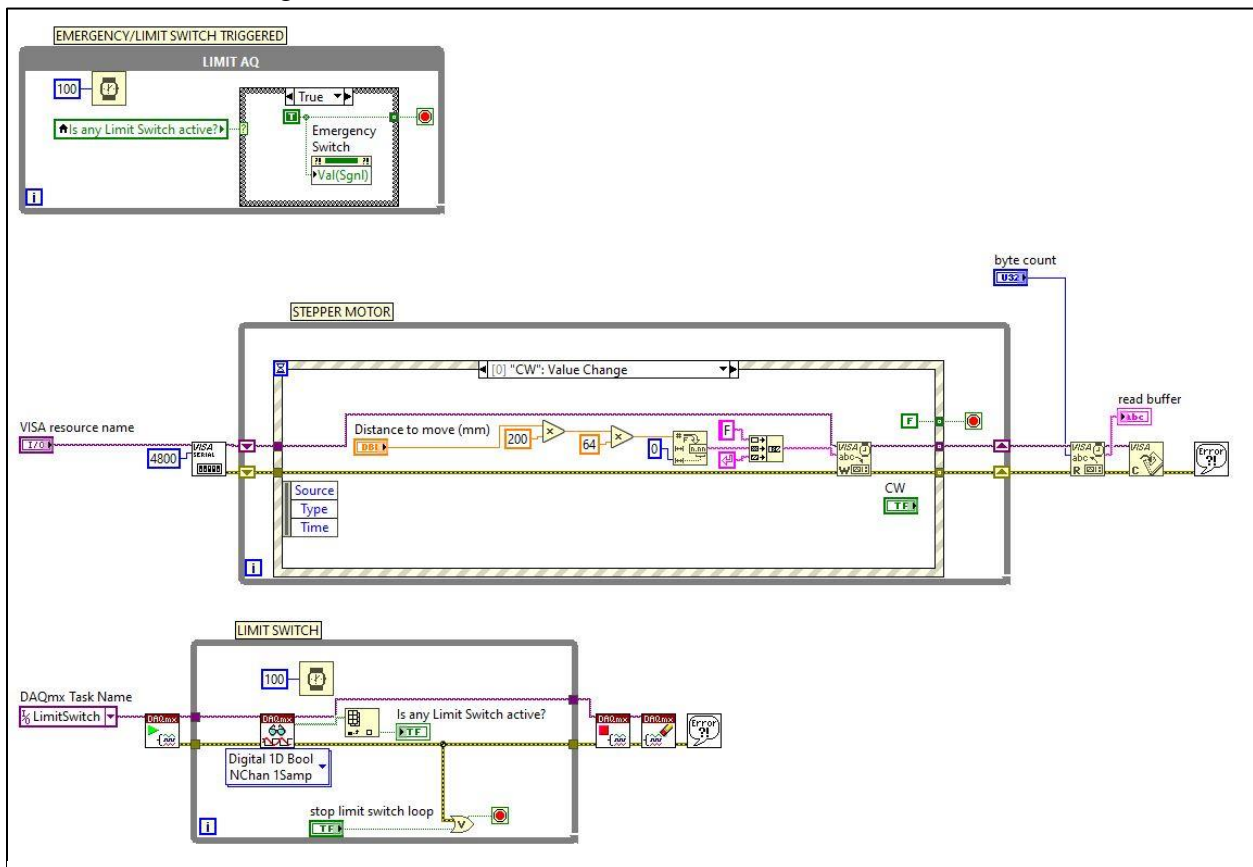


Figure 56: Stepper block diagram

The block diagram can be divided into three main loops: -

- Stepper Motor loop

The stepper motor loop runs in a while loop which has four event structures inside it: CW, CCW, Emergency Stop and STOP loop.

The clockwise movement event is taken as an example for explanation. This event handles all the necessary logics for the clockwise movement of the stepper.

- VISA Serial: This component of the block takes care of the initialization of the communication with the serial port. Settings crucial for the serial communication such as Baud Rate, Visa Resource, data bits, parity can be configured here. For our case the main settings need are the Baud Rate: 4800 and the visa resource (COM port)
- Logic to send the required distance movement specification: In this part of the program using the mathematical operators, a logic is devised to allow the user input of the distance (mm) to be converted in a form understandable by the stepper controller. The stepper controller understands ASCII commands written in the form of : Command-Argument-Carriage return.

FOR EXAMPLE: To move 5 mm, the logic would be

$5 \times 200(\text{Unit step size}) \times 64(\text{Stepping unit for the controller}) = 64000$. This number is preceded by a symbol for forward movement, F and at the end of the command comes the carriage return symbol \r.

Hence, the command to execute 5 mm movement in CW direction is: F64000\r

- VISA Write: This component of the block writes all the input values from the buffer into the device.
 - VISA Read: Reads the number of bytes and returns the value in read buffer.
 - VISA Close: Closes the session with the device.
 - Error handler: This is a simple error handler that displays any errors, if found during the execution of the program.
- Limit switch loop: The limit switch loop is a digital input loop. This checks continuously for a digital signal input. The way a digital signal can be generated by a limit switch is when, the contacts of the limit switch are closed. That means if the limit switch is actuated, a signal is received in the limit switch loop. This received signal can be observed in the Boolean indicator on the front panel by the user.
-

-
- DAQmx Start: The signal received from the task input is received by the DAQmx start component. This starts the measurement of the signal.
 - DAQmx Read: This component reads the incoming signal and can be used to interpret the data present in the signal.
 - Index array: To present the data in a form that can be represented by an indicator on the front panel, the data is converted into a Boolean form using the index array feature. After this, it can be connected to an indicator.
 - A stop button is placed along with the stop button of the loop. If any of the stop buttons are pressed, the loop shall stop.
 - At the end are the standard, DAQmx Stop and DAQmx Clear commands to stop the signal measurement and then clear the task after the measurement stops.
 - All the signal processing is done in a While loop so that the processing continues until the user presses the stop buttons or an error is detected.
- Emergency switch/limit switch trigger loop

This loop deals with the condition when either the limit switch is actuated or if the emergency switch on the front panel is pressed.

The logic of use is to use the Boolean value of the limit switch from the limit switch loop as a local variable and use it as an input to the emergency loop. If this value is true, then the emergency switch press command is actuated that through the logic presses the emergency switch and stops the stepper motor loop.

In the true case, the loop monitors the signal value of the limit switch and the emergency switch on the front panel. If any of these are true/pressed, the stop case in the stepper is actuated.

7.4.4 Solenoid Valve Virtual Instrument

This virtual instrument deals with the processing of the signal for the solenoid valve. The setup for the solenoid valve uses NI- hardware for signal transmission. The function of the program for solenoid valve is to generate a 5V digital output signal to trigger the electromechanical relay. The solenoid valve is not attached directly to the PC but it is actuated through the electromechanical relay. This relay needs a 5VDC signal to be actuated that can be generated by LabVIEW through a NI-9472 Digital output data acquisition card.

7.4.4.1 Front Panel

The front panel of the solenoid valve is a very basic panel that displays the status of actuation of the solenoid. In case, the solenoid has not been actuated, the Boolean control is not lit. In case the solenoid gets actuated a green light appears in the Boolean control. The way of actuation itself is controlled by this Boolean control. A single press of the control actuates the solenoid. Another press turns the solenoid off.

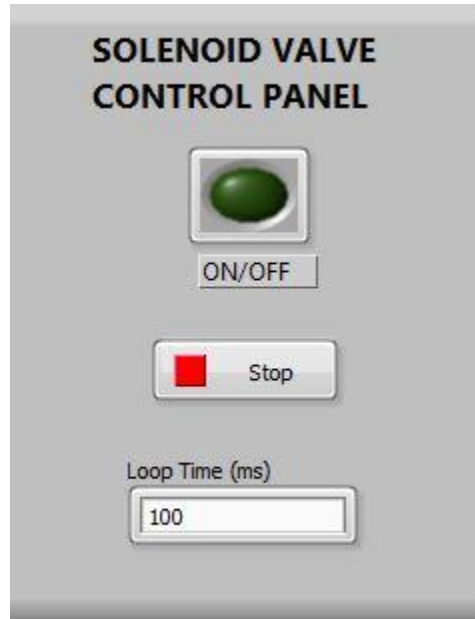


Figure 57: Solenoid front panel

7.4.4.2 Block diagram

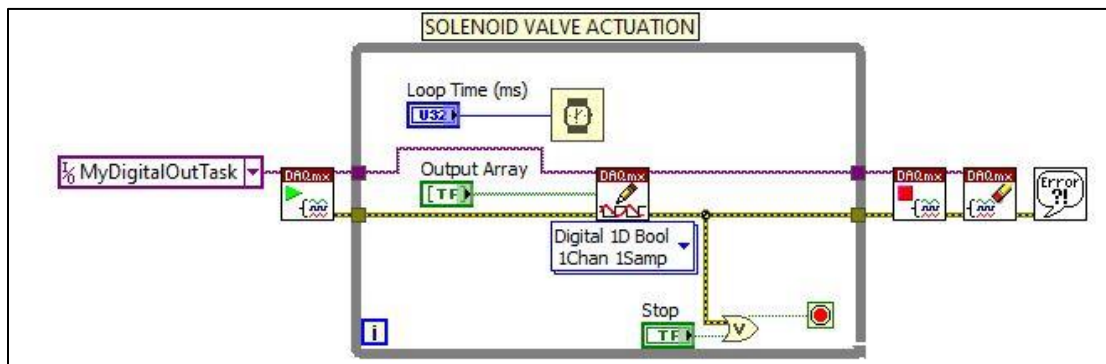


Figure 58: Solenoid valve - block diagram

The block diagram contains the logic behind the functioning of the solenoid valve control.

For the sample testing of the program, a digital output task was created to simulate the digital signal. The overall structure of the loop utilizes similar components from the DAQmx library. The digital output task creates a 5V signal that is fed to the DAQmx start to start the generation. This is fed to the DAQmx write to execute the signal. This is a single channel, single sample setting as we want to send a single 5V signal every time we press the Boolean control in the front panel to actuate/turn off the solenoid. Lastly, the DAQmx stop and DAQmx Clear components are used to close the task and clear the task.

As there was no physical part present to see the effect of actuation or triggering the accuracy of the virtual instrument can only be deduced from the ability to generate a 5V signal upon pressing of the Boolean control.

7.5 Final Virtual Instrument

This section showcases the combined virtual instrument for the positioning system.

7.5.1 Front Panel

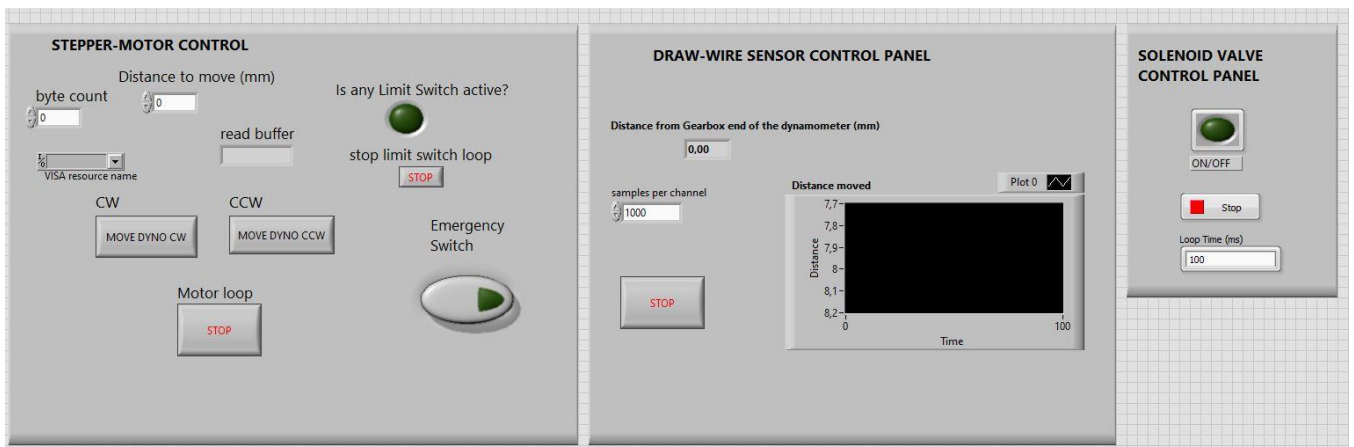


Figure 59: Positioning system Front Panel

7.5.2 Block diagram

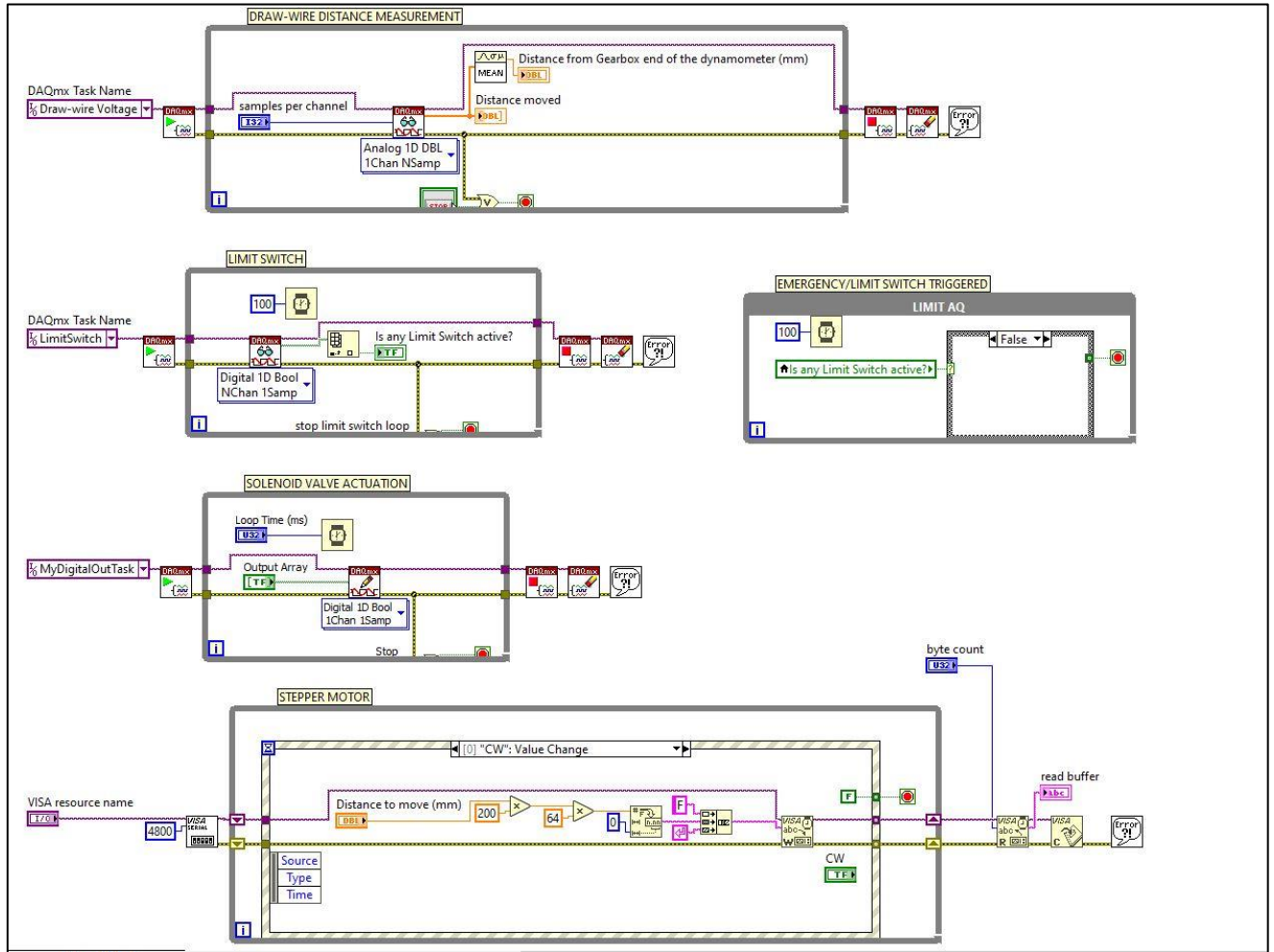


Figure 60: Positioning system block diagram

8 Mountings and changes to the test stand

This section describes the main changes suggested to the test stand. The suggested physical parts need to be mounted. Hence, to facilitate that, mountings are required to be designed and suggested in this section.

8.1 Draw-wire sensor

The draw-wire sensor takes care of the measurement of the distance and hence is a critical part of the system.

8.1.1 Mounting location

The draw-wire sensor must be installed at the gearbox end of the test stand. For reference of the distance measured, the side of the dynamometer that is facing the gearbox is considered the front of the dynamometer. Also, for the installation suggestion of mounting the draw wire sensor, the mounting is suggested to be done besides the gearbox stand.



Figure 61: Draw-wire mounting location recommendation

8.1.2 Material & Fabrication

The draw-wire sensor weighs 80 g and hence a lightweight solution for the mounting is suggested. The trend of using resins and plastic polymers has increased in the industrial applications. Hence, I suggest the usage of Acrylonitril Butadiene (ABS) as the choice of material. This material being lightweight and also sturdy enough to be used in an industrial environment is perfectly suitable for our application.

The fabrication can be done in-house utilizing the 3D printing technology.

8.1.3 Design and Assembly

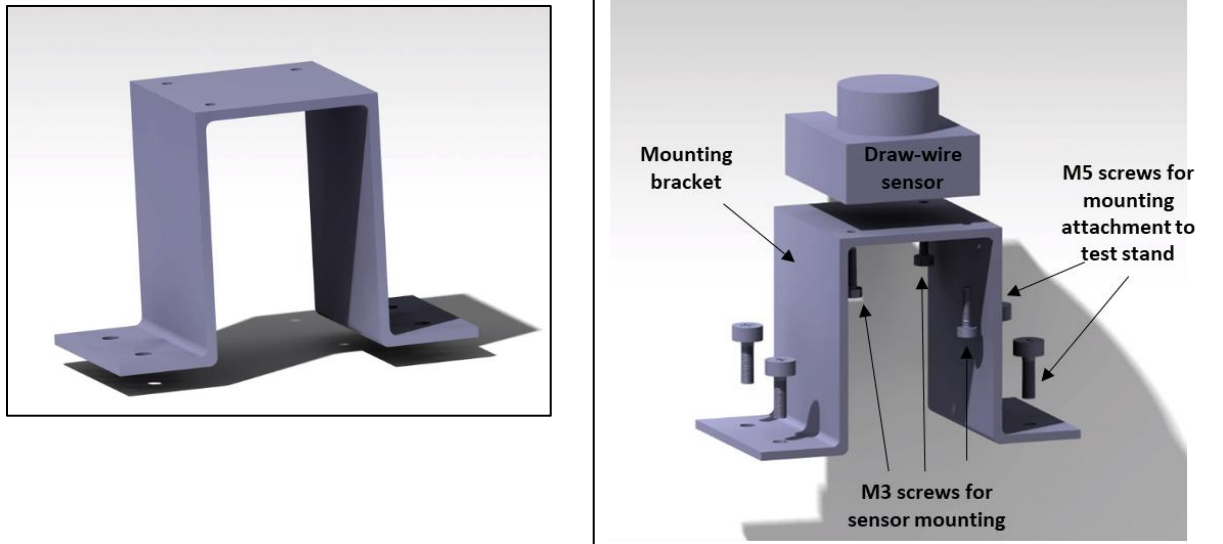


Figure 62: Design and assembly of draw-wire mounting bracket

It is a uni-body design with flat surfaces for mounting of the sensor and also the fixation of the mounting with the test stand. The dimensions and the tolerances are considered and marked in the drawings attached in the appendix of the master thesis.

The assembly of the complete system includes: -

- 01 draw-wire sensor
 - 01 draw-wire sensor mounting
 - 03 M3 screws for the sensor attachment to the mount
 - 04 M5 screws for the mounting bracket
-

8.2 Stepper Motor

This is the most complex and critical part to be mounted on the test stand. The motor and the entire mounting assembly involve various individual parts.

8.2.1 Mounting Location

The stepper motor is to be mounted next to the input shaft of the gearbox.

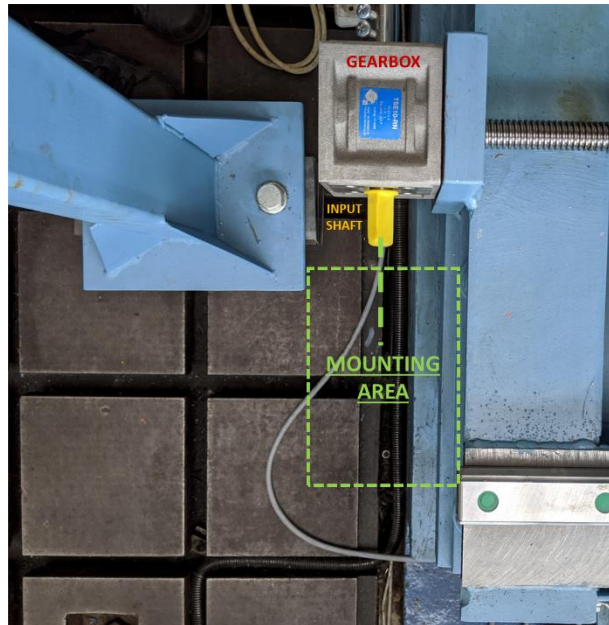


Figure 63: Stepper motor mounting location

8.2.2 Material and Fabrication

As the stepper motor is a heavier component that has to be attached to the mounting, hence the suggested material for the mounting should be an Aluminum alloy steel 6061 that allows lightweight yet strong mount to be fabricated.

The mounting should be prepared as a combination of two plates. One plate shall be the face plate for the stepper and the other shall be the face plate for the gearbox. These two face plates are then weld with other two thin plates to create a distance between the stepper plate and gearbox plate for the coupling of shafts. This arrangement of four plates together forms a mount.

8.2.3 Design and assembly

As described in the previous section, the design consists of two face plates and two weld plates (used on to create a space between face plates for coupling) placed perpendicular to the face plates.

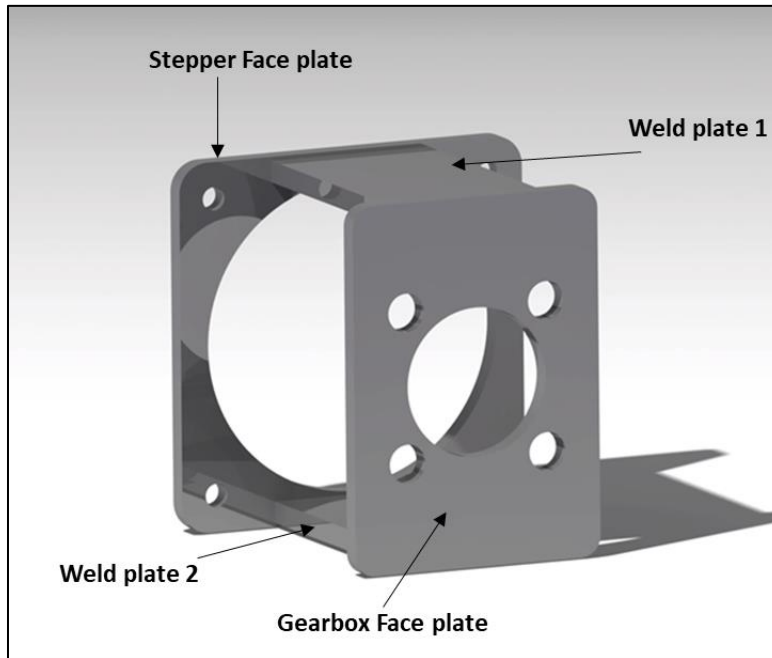


Figure 64: Stepper motor - gearbox connecting mount

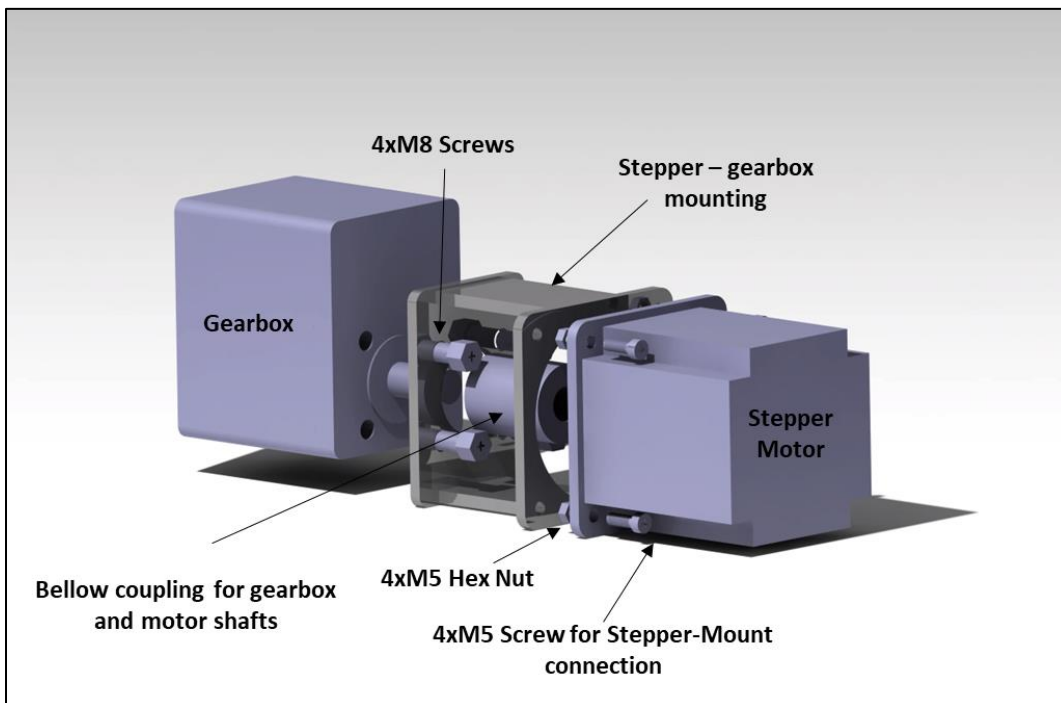


Figure 65: Stepper motor – gearbox mounting assembly

The assembly of the complete system includes: -

- 01 stepper motor
- 01 gearbox
- 01 bellow coupling
- 01 stepper motor – gearbox mount
- 04 M5 screws for the stepper attachment to the mount
- 04 M8 screws for the gearbox attachment to the mount

8.3 Solenoid valve and Limit switches

Solenoid valve's mounting does not require a special mount. It can easily be fitted in the existing panels in the Juliska laboratory. Various valves and other sensors are placed similarly in Juliska without the need of specific mounts. Also in the case of limit switches as they could not be procured in time, the final arrangement of their location wasn't agreed upon. Hence, this area comes into the future scope of the project.

9 Future work and conclusion

9.1 Future Work

The proposal of the positioning system could be improved in its automated control aspect. A few parts could not be purchased within the completion of the master thesis. Hence, their mounting and placement on the test stand could not be agreed upon. Although, the suggested program logics are quite simple to verify and the suggested connections for such parts are based on hardware documentation and data acquisition manuals, the presence of physical parts can allow further advancement of the program with even more complications in what the program can do.

The inter-dependence of the parts in the LabVIEW program could have been bettered. Although, the system does allow a very precise movement with a resolution of 1 mm and with the option to control the movement safely within the bounds. The proposed system provides a robust base for its further implementation on other test stands and equipment requiring similar control.

9.2 Conclusion

The proposed positioning system provides a convenient choice between manual and automated positioning of the dynamometer. The proposal extensively outlines and creates a blueprint of the entire system. The integration of the two systems together with an ability to switch between the two can be achieved with a few steps.

Right from the pneumatic braking to the linear movement control, every possible aspect of parts, their interaction in the circuit, electrical connections have been thought out. The proper mountings of the key parts are also suggested.

This presents a much higher improvement in the day-to-day operations of the dynamometer with a permanent solution to the utilization of the available resources.

It also promotes and provides the researchers and teaching staff with the ability to manage their work efficiently, to impart knowledge to the future generation. Thus, making it a success also on a social level.

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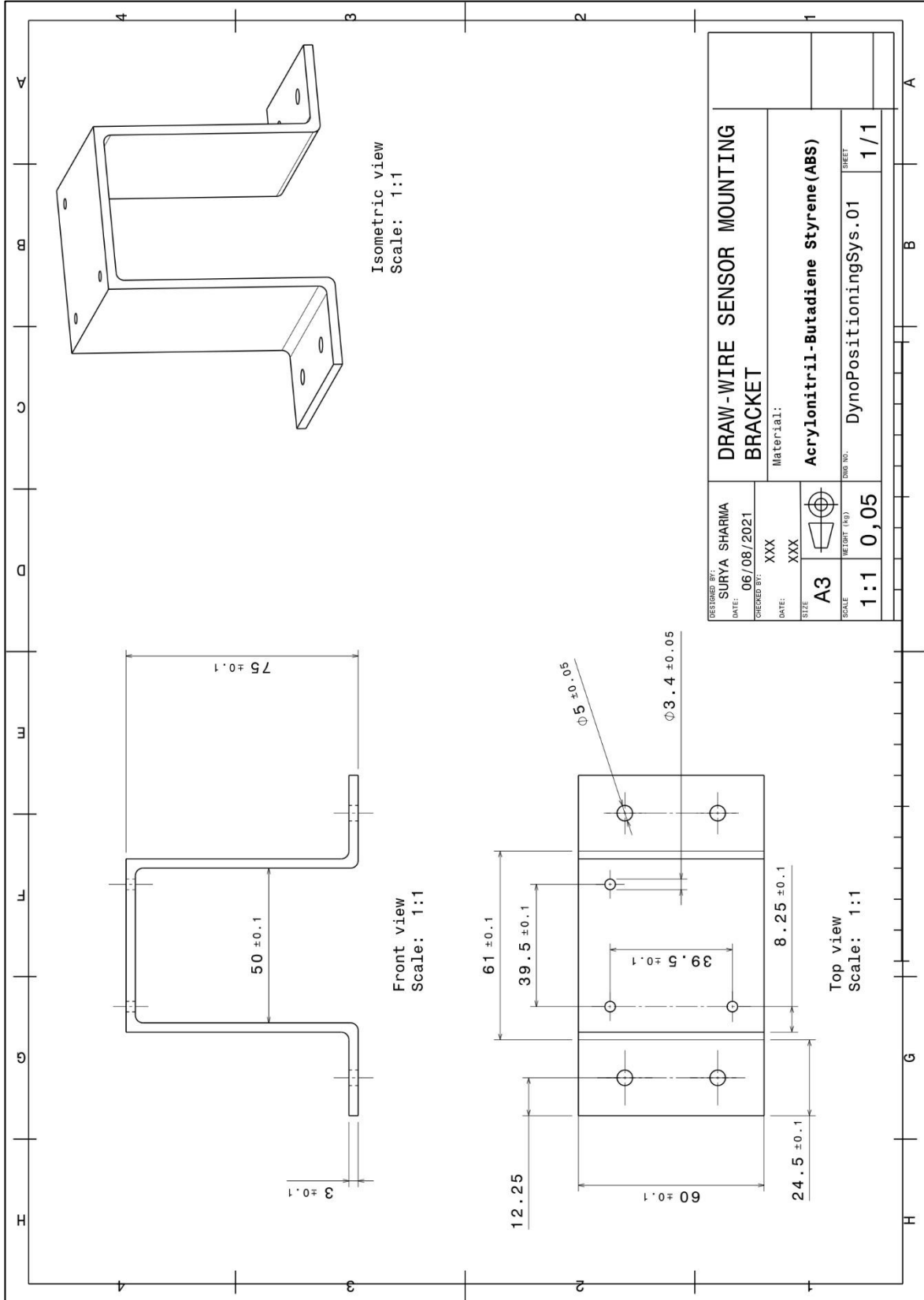
[OM18]

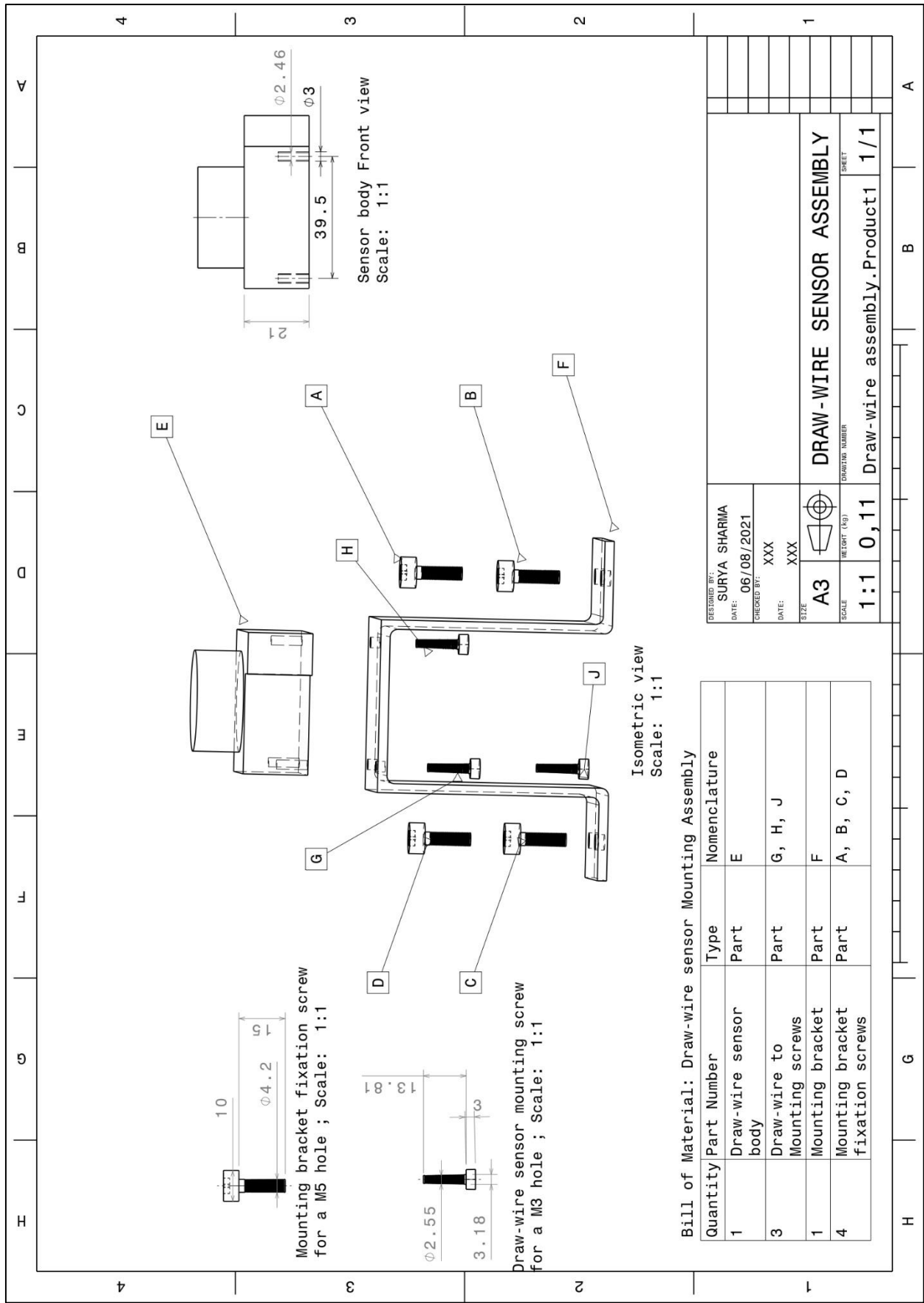
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Appendix



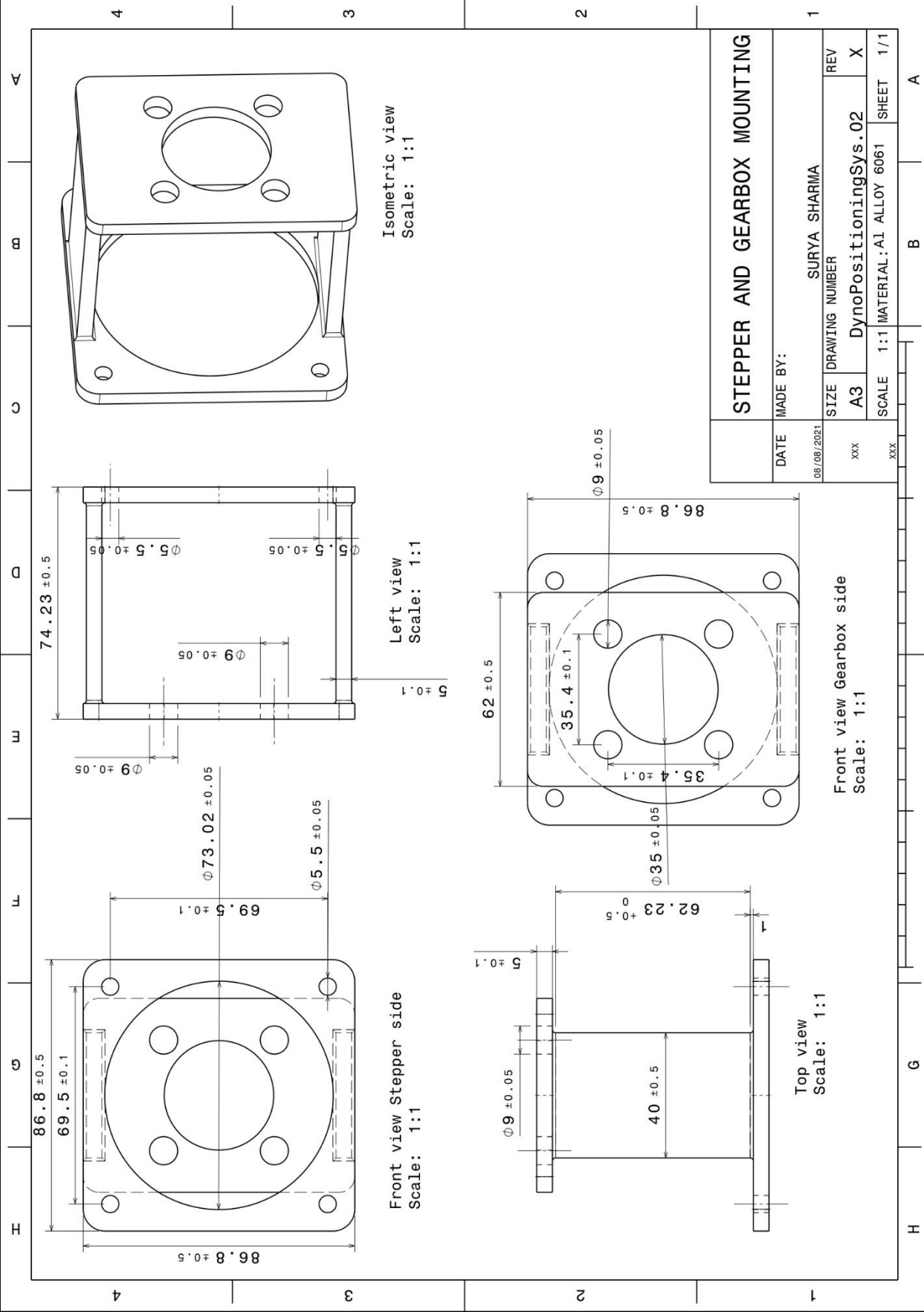


Bill of Material: Draw-wire sensor Mounting Assembly

Quantity	Part Number	Type	Nomenclature
1	Draw-wire sensor body	Part	E
3	Draw-wire to Mounting screws	Part	G, H, J
1	Mounting bracket	Part	F
4	Mounting bracket fixation screws	Part	A, B, C, D

DESIGNED BY: SURYA SHARMA	DATE: 06/08/2021	CHECKED BY: XXX	DATE: XXX	SIZE A3	SCALE 1:1	REVISION NUMBER 0,11	DRAWING NUMBER Draw-wire assembly.Product1	SHEET 1/1
------------------------------	---------------------	--------------------	--------------	------------	--------------	-------------------------	---	--------------

H	G	B	A
---	---	---	---



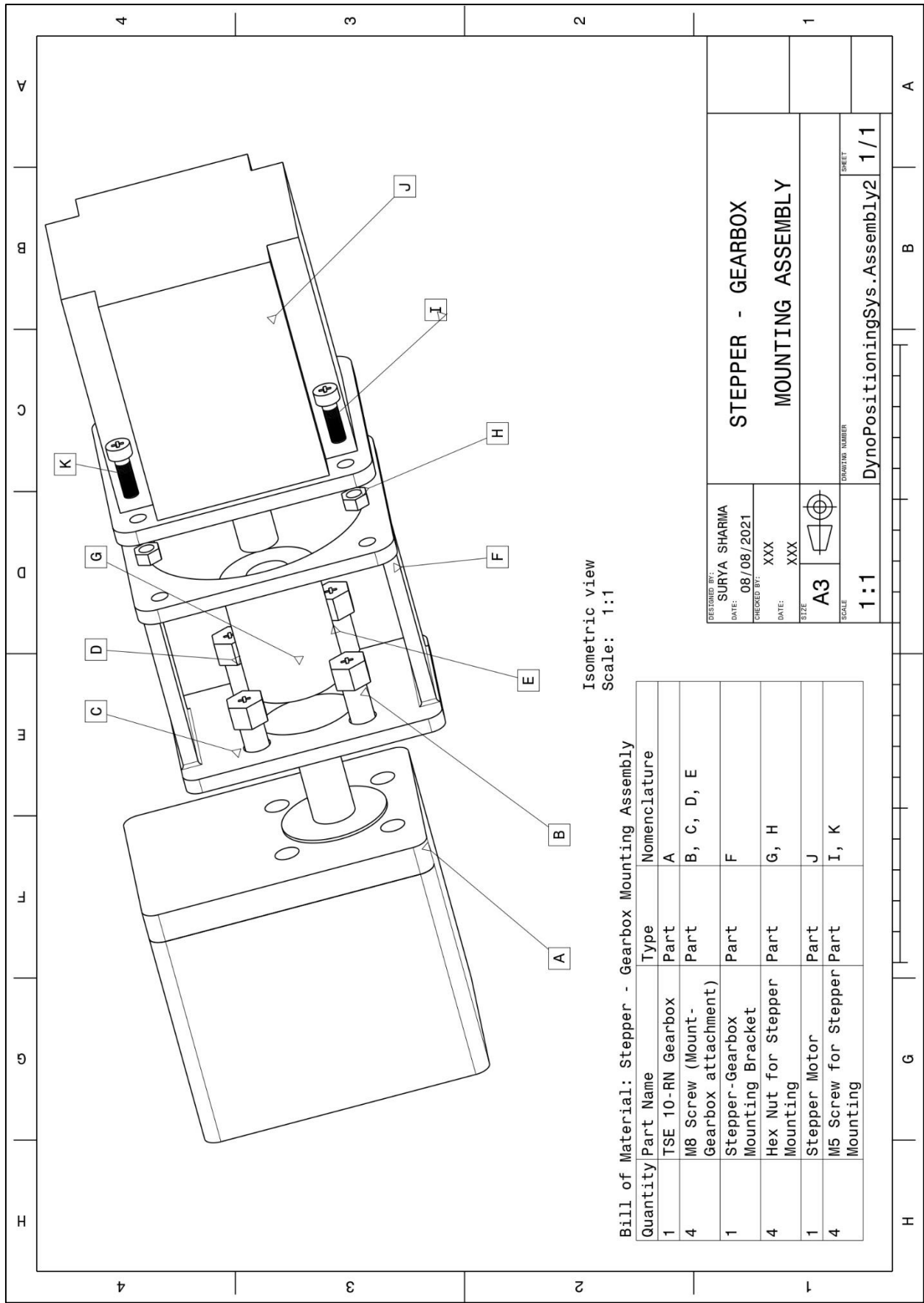
Isometric view
Scale: 1:1

Left view
Scale: 1:1

Front view Stepper side
Scale: 1:1

Front view Gearbox side
Scale: 1:1

Top view
Scale: 1:1



Isometric view
Scale: 1:1

Bill of Material: Stepper - Gearbox Mounting Assembly

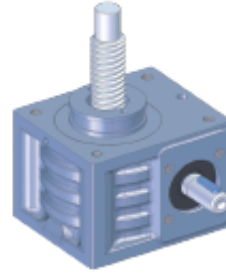
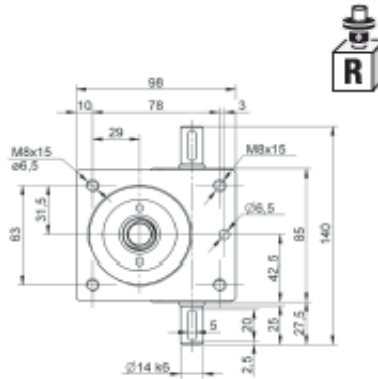
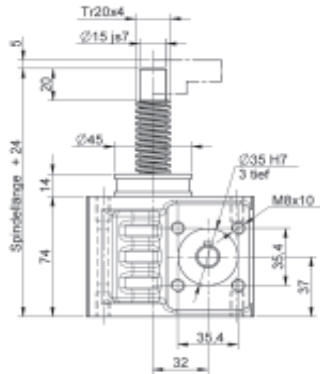
Quantity	Part Name	Type	Nomenclature
1	TSE 10-RN Gearbox	Part	A
4	M8 Screw (Mount-Gearbox attachment)	Part	B, C, D, E
1	Stepper-Gearbox Mounting Bracket	Part	F
4	Hex Nut for Stepper Mounting	Part	G, H
1	Stepper Motor	Part	J
4	M5 Screw for Stepper Mounting	Part	I, K

DESIGNED BY: SURYA SHARMA	DATE: 08/08/2021	CHECKED BY: XXX	DATE: XXX	 A3 <small>SIZE</small>	<small>DRAWING NUMBER</small> DynoPositioningSys.Assembly2	<small>SHEET</small> 1 / 1
STEPPER - GEARBOX MOUNTING ASSEMBLY						
<small>SCALE</small> 1:1						

GEARBOX



Spindelhubgetriebe, rotierend TSE10-RN/RL Screw jacks, rotating screw TSE10-RN/RL



Spindelhubgetriebe Screw jack TSE10-RN/RL		
Max. Last	Max. load	10kN (1t)
Max. Antriebsdrehzahl	Max. drive shaft speed	1800 min ⁻¹
Spindel	Screw	TR20x4

Versionen	Versions
Mit Sicherheitsfangmutter (SFM)	with safety trap nut (SFM)
Mit Kugelgewindtrieb (KGT)	with ball screw set (KGT)
Auf Anfrage lieferbar	available on request
Zweigängige Trapezspindel	double threaded screw
Rostfreie Spindel	stainless steel screw
Oberflächenbehandelte Spindel	surface-treated screw

Kalkulation des Antriebsmomentes für 1 Hubgetriebe | Calculation of the drive torque for 1 screw jack**

Bestell-Nr.	Untersetzung i	Verschub / Umdr. Antriebswelle	Antriebsdrehmoment*	Max. Antriebsdrehmoment	Durchtriebsdrehmoment **
Part no.	Ratio i	Feed rate / Input drive shaft turn	Input drive torque*	Max. input drive torque	Drive trough torque **
		[mm]	[Nm]	[Nm]	[Nm]
TSE10-RN	4:1	1	F[kN] · 0,46 + 0,26	10,5	42
TSE10-RL	16:1	0,25	F[kN] · 0,14 + 0,16	4,2	42
TSE10-RN, TR24x5	4:1	1,25	F[kN] · 0,56 + 0,26	10,5	42
TSE10-RL, TR24x5	16:1	0,31	F[kN] · 0,18 + 0,16	4,2	42

*Die Gleichung beinhaltet Wirkungsgrade, Untersetzungen und Sicherheit 1
 **Bei mehr als 6 Getrieben kontaktieren Sie bitte unsere Technik!

*The formula contains efficiencies, ratios and safety 1

**For more than 6 screw jacks please contact our technicians.

***Bei Anlagen mit mehreren Hubgetrieben das Antriebsmoment pro Einzelgetriebe errechnen und dann mit der Anzahl der Getriebe multiplizieren!

***In systems with multiple screw jacks calculate the input drive torque per single screw jack and then multiply with the number of screw jacks.

Anbauteile | Additional Parts => HGS64-HGS71



Antriebskomponenten | Drive parts => HGS72-HGS77



Motoranbau | Motor mounting => HGS78-HGS79



=> HGS25-HGS48



Bestell-Nr. Part no.	TSE	1:1/1	-5 / -4	N / L
Spindelhubgetriebe Screw jack	Baugröße Size	Version: S = stehende Spindel axial moving screw R = rotierende Spindel rotating screw	Vorschub Feed rate: N = Normal L = Langsam Slow	

Spindelhubgetriebe | Screw jacks

Angabe 2020 – Druckfehler, Maß- und Konstruktionsänderungen vorbehalten.
 2020 edition – No reserve the right to make dimensional and structural changes. We accept no liability for changes or printing errors.

HGS56

STEPPER MOTOR



Technické parametry krokových motorů řady SX34

Řada SX - příruba NEMA34

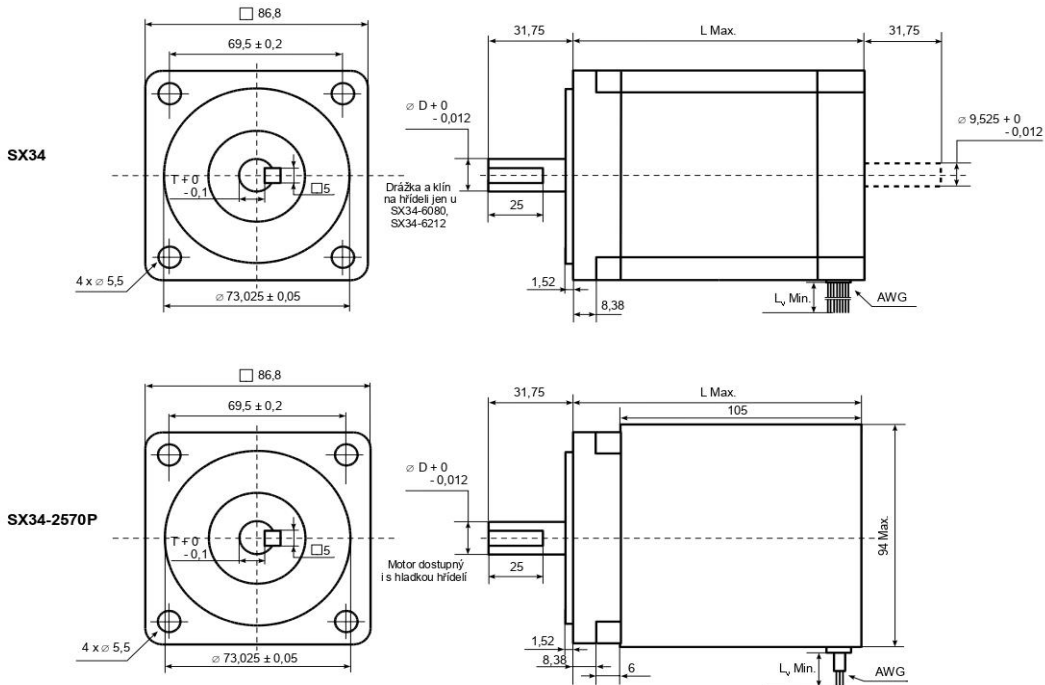
Typ	Statický moment (Nm) bipol. napájení, celokrok, jmen. proud v obou fázích	Jmenovitý proud (A) sériově / paralelní zapojení	Indukčnost (mH) sériově / paralelní zapojení	Odpor (Ω) sériově / paralelní zapojení	Moment setrvačnosti rotoru (kgm ² x10 ⁻³)	Hmotnost (kg)
SX34-2740	4	2,75 / 5,5	14 / 3,5	1,68 / 0,42	0,14	2,3
SX34-2570P	7	2,5 / 5	22,4 / 5,6	1,9 / 0,47	0,27	4
SX34-3080	8	3 / 6	22,4 / 5,6	1,9 / 0,47	0,27	3,8
SX34-4280	8	4,2 / 8,4	11,2 / 2,8	1,1 / 0,275	0,27	3,8
SX34-6080 / SX34-6080D	8	6 / 12	5,6 / 1,4	0,47 / 0,12	0,27	3,8
SX34-6212	12	6,2 / 12,4	9,6 / 2,4	0,66 / 0,165	0,4	5,3

D - motor s hřídelí na obě strany, P - provedení s ochranným zalitím a utěsněnou hřídelí

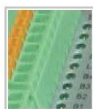
Délka kroku	1,8°
Tolerance kroku	± 0,1°
Izolační třída	NEMA B (130°C)

Rozměry (mm)

Typ	Hřídel		Délka		Vývody	
	D	T	L Max.	Délka vývodů L _v	Počet	Vinuti
SX34-2740	12,7	-	80	500	8	AWG20
SX34-2570P	12,7	9,7 (-)	120	500	8	AWG20
SX34-3080	12,7	-	118	500	8	AWG20
SX34-4280	12,7	-	118	500	8	TEFLON AF-200
SX34-6080	12,7	9,7	118	500	8	AWG20
SX34-6080D	12,7	-	118	500	8	AWG20
SX34-6212	15,875	12,875	156	2000	8	AWG20



STEPPER CONTROLLER-01



Programovatelné jednotky typu CD pro řízení krokových motorů

Programovatelné jednotky typu CD obsahují řídicí část realizovanou kontrolerem M1486 i výkonovou část pro bipolární napájení krokového motoru s pulsní regulací proudu.

Řídicí část jednotek je realizována kontrolerem M1486, který obsahuje:

- **programovatelné řízení krokového motoru** (délka dráhy, rychlost, zrychlení, mikrokrokování)
- **malý programovatelný automat** (vstupy/výstupy, smyčky, podmíněné skoky, čekací doby).

Standardně jsou jednotky osazeny kontrolerem M1486E1 s vnitřní pamětí pro povelů EEPROM 2 000 bitů. Povelů jsou uchovány v paměti i po vypnutí napájení, bez potřeby zálohování. V případě zájmu zákazníka o on-line řízení z nadřazeného systému po sériové lince bez potřeby zálohování je možné dodat jednotky osazené kontrolerem M1486B s pamětí RAM.

Kontroler je ovládán jednoduchými ASCII povelů po sériové lince. Povelů kontroleru jsou snadno zapamatovatelné, znakem povelů je vždy první písmeno anglického názvu povelů. Např. povel pro zadání rychlosti "Velocity" 500 kroků za sekundu: V500. Uživatel se tak nemusí zabývat složitým programováním, ale jednoduchým zápisem povelů (bližší viz str. 6, 7).

Řídicí část všech programovatelných jednotek typu CD je shodná, jednotky se liší pouze specifickými parametry výkonové části. Jednotky umožňují dělení celokroku - mikrokrokování, které výrazně omezuje oscilace jednotlivých kroků a rezonance při nízkých rychlostech. Realizace poháněného stroje či zařízení je díky jednoduchému ovládní velmi rychlá s možností pružného přizpůsobení případným změnám požadavků pouhou změnou povelového souboru.

Všechny jednotky typu CD mají pouze jedno napájecí napětí. Vzhledem k pulsní regulaci proudu není potřeba k napájení stabilizovaný zdroj, stačí jen transformátor a diodový můstek. Zdroj může obsahovat kondenzátor o kapacitě cca 4 700 μ F, ale vzhledem k použitým kondenzátorům na jednotkách (kromě jednotek CD30x, CD40x, CD6410M a CDZMP-Mini) není přídavná kapacita nezbytná. K modulu CDZMP-Mini je doporučeno použít přídavnou kapacitu 10 000 μ F. Pro napájení jednotek CD20M, CD30x, CD30M, CD34M, CD40x a CD40M je možné zvolit nestabilizovaný napájecí zdroj PS 20/30 s volitelným výstupním napětím 33 VDC a 44 VDC, pro napájení modulu CD6410M je určený zdroj PS 64 s výstupním napětím 64 VDC (bližší ke zdrojům viz str. 12 - 13).

CD30x, CD40x

- Jednotky velmi malých rozměrů včetně krytu a držáku pro uchycení na DIN lištu, CD30x - 105 x 57 x 47 mm, CD40x - 105 x 57 x 67 mm
- Uživatelské vstupy a výstupy (vyvedeny na zasouvací pružinové svorkovnice):
 - 10 galvanicky oddělených uživatelských vstupů**
Na svorkovnici jsou vyvedeny 2 společné katody a 10 anod vstupních diod optočlenů. Standardní úroveň vstupů 0; 24 V (7 mA).
 - 4 galvanicky oddělené uživatelské výstupy**
Výstupy jsou galvanicky odděleny optočleny. Na svorkovnici je vyveden 1 společný kolektor a 4 samostatné emitory výstupních tranzistorů optočlenů. Výstupní optočleny mají max. kolektorový proud 50 mA a max. napětí mezi kolektorem a emitorem 30 V.
- **Zvýšená ochrana proti rušení** - rozsáhlá zemní plocha, zcela galvanicky oddělený kontroler M1486
- **Možnost mikrokrokování** - plně využití 4 bit D/A převodníku pro další zvýšení plynulosti chodu motoru, možnost dělení kroku také osmi a šestnácti
- Možné připojení sériové linky volitelně přes konektor Cannon nebo přes svorkovnici
- Signalizace stavu vstupů, výstupů a napájení LED diodami
- Jednotky dodávány v provedení pro uchycení na DIN lištu



Momentové charakteristiky jednotek s vybranými krokovými motory - viz str. 19, 20, 25.

Parametry výkonové části		
	CD30x	CD40x
Napájecí napětí	12 - 48 VDC	12 - 48 VDC
Amplituda proudu	0,4 - 3,3 A	0,4 - 4 A
Nastavení proudu	v šestnácti stupních	v šestnácti stupních
Dělení celokroku	nastavení pomocí spínače SIP	nastavení pomocí spínače SIP
Doporučený počet mikrokroků na celokrok	4, 8, 16	4, 8, 16
Automatické snížení proudu po zastavení motoru	ANO	ANO
Možnost programového vypnutí koncového stupně	ANO	ANO
Momenty vhodných krokových motorů	1,2 - 8,5 Nm	3 - 8,5 Nm
Rozměry	105 x 57 x 47 mm	105 x 57 x 67 mm
Doporučený napájecí zdroj	PS 20/30	PS 20/30
Parametry řídicí části (podrobnější informace - viz str. 6, 7)		
Sériové rozhraní	RS232, galvanicky oddělená sériová linka	
Počet jednotek připojitelných na jedno sériové rozhraní	až 16	
Počet galvanicky oddělených uživ. vstupů / výstupů	10 / 4	

STEPPER CONTROLLER-02



Kontroler M1486

- PROGRAMOVATELNÝ INDEXER A SEQUENCER V JEDNOM OBVODU
- RYCHLOST AŽ DO 40 000 KROKŮ/S
- AŽ DO 64 MIKROKROKŮ NA CELÝ KROK
- OPTIMALIZACE VYUŽITÍ MOMENTU KROKOVÉHO MOTORU
- TŘI MOŽNOSTI PROPOJENÍ S VÝKONOVÝM ZESILOVAČEM: PULSY A SMĚR, DVOJITÝ D/A PŘEVODNÍK, DVA D/A PŘEVODNÍKY
- VÝKONNÝ SOUBOR VÍCE NEŽ 50TI POVELŮ
- DÉLKA DRÁHY AŽ 16 MILIONŮ KROKŮ
- VNITŘNÍ PAMĚŤ UMOŽŇUJE, ABY PŘEDPROGRAMOVANÉ POVELOVÉ SOUBORY BYLY PROVÁDĚNY OFF-LINE
- 21 UNIVERZÁLNÍCH VSTUPŮ/VÝSTUPŮ
- PROGRAMOVATELNÁ MAXIMÁLNÍ RYCHLOST, START/STOP RYCHLOST, ZRYCHLENÍ, TVAR PROUDU PŘI MIKROKROKOVÁNÍ
- PLYNULÉ ZRYCHLENÍ A BRZDĚNÍ
- SÉRIOVÝ VSTUP, AŽ 16 KONTROLERŮ MŮŽE BÝT PŘIPOJENO NA JEDEN PORT
- NÍZKOPŘÍKONOVÝ CMOS OBVOD, TTL KOMPATIBILNÍ
- POUZDRO 40PIN DIP NEBO 44PIN PLCC

Kontroler M1486 integruje v jednom obvodu plně programovatelné řízení krokového motoru i univerzální řídicí funkce (vstupy/ výstupy) a umožňuje tak realizovat kompletní řízení stroje či zařízení.

Výkonný povelový soubor

Všechny povelové obvodu M1486 jsou ASCII znaky (je možné použít jak velká, tak i malá písmena). Uživatel může použít běžné textové editory pro přípravu povelových ASCII souborů. Nové povelové jsou předávány prostřednictvím standardního sériového kanálu kompatibilního s rozhraním RS232. Až 16 kontrolerů může být zřetězeno při zadání adresy jednotlivých kontrolerů pro současně víceosé řízení. Přenosová rychlost může být vybrána ze čtyř rychlostí v rozmezí 1 200 až 9 600 bitů/s.

K dispozici je široká nabídka více než 50ti povelů, aby bylo možno realizovat požadavky kladené na řízení v různých aplikacích pouze povelovým souborem. Tyto požadavky často zasahují do oblasti programovatelných automatů - větvení povelového souboru podle stavu vstupů, čekání na zvolený stav vstupů, nastavování výstupů, opakování povelů ve smyčce, čekací doby. Proto je k dispozici i malý programovatelný automat, který je ovládán povelovým souborem a výše uvedené i další funkce realizuje. Realizace požadavku aplikace povelovým souborem je oproti hardwarovému řešení jednodušší, rychlejší a umožňuje snadné přizpůsobení v případě změny požadavků, což se v průběhu vývoje zařízení někdy stává.

Povelové jsou snadno zapamatovatelné, znak všech základních povelů je prvé písmeno anglického názvu povelu. Např. povel pro zadání rychlosti "Velocity" 500 kroků za vteřinu: V500. Uživatel se nemusí zabývat programováním, ale pouze jednoduchým zápisem povelů, které potřebuje, aby byly vykonány. Řízení s kontrolerem M1486 (např. jednotky typu CD) je proto vhodné i pro uživatele bez programátorských zkušeností.

Samostatný chod

Kontroler typu M1486E může být připojen k počítači či jinému nadřazenému systému vybavenému sériovým rozhraním pouze jednou za účelem nahrání povelového souboru. Pak může být trvale odpojen a pracovat v aplikaci zcela samostatně, řízení stavů uživatelských vstupů. Vnitřní paměť pro povelové EEPROM umožňuje uchovat povelové i po vypnutí napájení, bez potřeby zálohování. V případě nutnosti změny povelového souboru je možné kontroler znovu připojit k počítači a nahrát změněný povelový soubor.

Minimalizace dynamického zatížení motoru

Přesné a plynulé řízení rychlostí i v oblasti vysokých rychlostí využívá maximálně moment motoru a umožňuje tak použití menšího motoru a kompaktnějšího výkonového zesilovače. Z toho vyplývá nižší cena motoru a výkonového zesilovače či zvýšená momentová rezerva krokového pohonu v otevřené smyčce.

I když trojúhelníkový průběh rychlosti v závislosti na čase (konstantní zrychlení) je u dostupných řídicích jednotek pro krokové motory nejrozšířenější, tento průběh je velmi nevýhodný pro pásmo rychlostí, kde moment motoru klesá. Povel "Profile" umožňuje uživateli zadat zlom, ve kterém se lineární charakteristika mění na parabolickou při rozběhu a zpět při brzdění.

Mikrokrokování

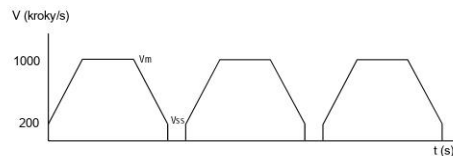
Kontroler umožňuje dělení kroku - mikrokrokování, které výrazně omezuje oscilace jednotlivých kroků a rezonance při nízkých rychlostech.

Počet mikrokroků na celokrok může být naprogramován od 1 do 64, zvláště pro oblast nízkých a zvláště pro oblast vysokých rychlostí, za účelem dosažení jak maximální rychlosti, tak i vysokého rozlišení při nízkých rychlostech.

Výstupem obvodu jsou digitální hodnoty proudu pro obě fáze krokového motoru. Standardní výstup Pulsy a Směr je také k dispozici.

Příklad uživatelského povelového souboru

S200..... "Start/stop" počáteční rychlost 200 kroků/s
V1000.... "Velocity" rychlost 1 000 kroků/s
A5000.... "Acceleration" zrychlení 5 000 kroků/s²
F39616... "Forward" dráha dopředu 39 616 mikrokroků
L3..... "Loop" následující povelové až po povel "End of loop" budou provedeny třikrát
R..... "Run" vykonaj pohyb se zadanými parametry
W250.... "Wait" čekej 250 milisekund
E..... "End of loop" konec smyčky



STEPPER CONTROLLER-03

Kontroler M1486



Numerická jednotka

Pro složitější aplikace je možné využít numerickou jednotku, která je součástí kontroleru M1486. Numerická jednotka je ovládána pomocí devíti povelů. Tyto povelů využívají interní proměnnou. Je možné zadat hodnotu interní proměnné buďto přímo povelům "Load" nebo pomocí univerzálních vstupů povelům "Query". Hodnotu interní proměnné je možné upravovat numerickými operacemi (součet, rozdíl, násobení, dělení). Je možné provést přesun z interní proměnné do registru a naopak. Hodnotu interní proměnné je možné použít jako parametr libovolného povelu. Pokud je zadána např. rychlost povelům "V" bez parametru, je jako parametr použita hodnota interní proměnné. Numerická jednotka tedy umožňuje zadání parametrů jednotlivých povelů (například rychlosti, dráhy, skoku na návštěji apod.) i při samostatném chodu pomocí univerzálních vstupů (formát binární nebo BCD) bez sériové linky. Většinu aplikací je možné vyřešit pouze několika povelů. Nabídka povelů je však široká, aby v případě potřeby bylo možné snadné řešení povelovým souborem a nebylo nutné používat hardwarové či externí řešení.



ZÁKLADNÍ ŘADA OBVODŮ M1486

Kontrolery s pamětí povelového souboru RAM

jsou vhodné pro aplikace on-line, kdy řídicí jednotka s tímto kontrolerem je připojena trvale k nadřazenému systému, který průběžně vysílá povelů po sériové lince a je potřebná rychlá komunikace, nikoliv zálohování.

M1486A

- vstupní paměť 96 bitů, paměť pro povelů RAM 864 bitů, rychlost do 20 000 kroků/s (M1486A2x do 40 000 kroků/s)

M1486B

- plně kompatibilní s M1486A, 48 návštějí, vstupní paměť 256 bitů, paměť pro povelů RAM 2 032 bitů

M1486B-NV

- kontroler s funkcí "změna rychlosti za běhu motoru", plně kompatibilní s M1486B

Kontrolery s pamětí povelového souboru EEPROM

jsou vhodné pro aplikace off-line, řídicí jednotka s tímto kontrolerem může být připojena k nadřazenému systému pouze jednou za účelem nahrání povelového souboru. Pak může být trvale odpojena a pracovat v aplikaci zcela samostatně, řízena stavy uživatelských vstupů.

M1486E1 - standardně používaná verze kontroleru

- kompatibilní s M1486A, 80 návštějí, vstupní paměť 256 bitů, paměť pro povelů EEPROM 2 000 bitů - povelů jsou uchovány v paměti i po vypnutí napájení, bez potřeby zálohování

- kontroler M1486E1 od verze 58 obsahuje ochranu zapsaných povelů do paměti před vlivem rušení

M1486E1-L4

- OTP verze obvodu M1486E1, povelový soubor v hranatých závorkách je možné nahrát pouze jednou - maximální ochrana proti rušení

M1486E4

- kompatibilní s M1486E1, 120 návštějí, vstupní paměť 256 bitů, paměť pro povelů EEPROM 8 000 bitů - povelů jsou uchovány v paměti i po vypnutí napájení, bez potřeby zálohování

PŘEHLED POVELŮ KONTROLERU M1486

POVEL	POPIS
\	"Reset" uvedení kontroleru do výchozího stavu
@ (Num)	"Address" zadané číslo návštějí se přiřadí této programové řádce
A (Num)	"Acceleration" zrychlení, rozsah = 1 až 65 000 kroků/s ²
B (Num)	"Backward" zpět, zadání dráhy v negativním směru, rozsah = 1 až 16 000 000
C (Num 1 to 21)	"Clear" nastav zadaný výstup do hodnoty logická nula, rozsah 1 až 21
C (Num 40 to 63)	"Clear" potlačení zadané přídavné funkce
C75	"Clear Kill" obnovení vykonávání programu
D	"Direction" směr, změna směru příštího pohybu
E	"End of loop" konec smyčky
F (Num)	"Forward" dopředu, zadání dráhy v pozitivním směru, rozsah = 1 až 16 000 000
G (Num)	"Go absolute" dráha zadaná absolutní polohou
G+	"Go positive" trvalý pohyb v pozitivním směru až do externího přerušení
G-	"Go negative" trvalý pohyb v negativním směru až do externího přerušení
H	"Home" vykonaj pohyb do výchozí polohy
I (Num)(Value)(Num)	"If" jestliže na zadaném vstupu je zadaná hodnota skoč na zadané návštějí ("H" High - logická jedna, "L" Low - logická nula)
J (Num)	"Jump" skok na zadané návštějí
K	"Kill" okamžitý přechod do brzděného režimu, přerušení vykonávání programu
L (Num)	"Loop" smyčka, opakování následujících instrukcí
M (Num)	"Microstepping" počet mikrokroků na celokrok v dolním pásmu rychlostí (až do 64)
N (Num)	"Number" výběr tvaru průběhu proudu při mikrokrokování
O (Num)	"One" čekej dokud zadaný vstup nebude mít hodnotu logická jedna
P (Num)	"Profile" rychlost, při které se lineární rozběhová charakteristika mění na parabolickou
Q (Num)	"Qualification" počet mikrokroků na celokrok v horním pásmu rychlostí (1, 2, 4)
R	"Run" vykonaj pohyb s aktuálními hodnotami parametrů
S (Num)	"Start/stop" rychlost start/stop; rozsah = 16 až 1950 kroků/s
T (Num 1 to 21)	"Turn on" nastav zadaný výstup do hodnoty logická jedna, rozsah 1 až 21
T (Num 40 to 63)	"Turn on" zapnutí zadané přídavné funkce
U (Num)	"Upload" vyšší hodnotu čítače absolutní polohy či hodnotu interní proměnné
V (Num)	"Velocity" maximální rychlost
W (Num)	"Wait" čekej zadaný počet milisekund; rozsah = 1 až 16 000 000
X (Num)	"indecX" volba kontroleru
Z (Num)	"Zero" čekej dokud zadaný vstup nebude mít hodnotu logická nula
["Disable" odklad provedení následujících povelů
]	"Enable" provedení předchozích povelů
((Num)	"Seek negative" jdi na limit v negativním směru
) (Num)	"Seek positive" jdi na limit v pozitivním směru
= (Num)	"Equal" přiřazení zadané hodnoty čítači absolutní polohy
: (Num)	"Load" ulož zadanou hodnotu do interní proměnné
? (Num)	"Query" načti data na specifikovaných vstupech a ulož do interní proměnné
! (Num)	"Order" zapsi hodnotu interní proměnné na specifikované výstupy
+ (Num)	"Add" přičti zadanou hodnotu k interní proměnné
- (Num)	"Subtract" odečti zadanou hodnotu od interní proměnné
/ (Num)	"Divide" dělení interní proměnné zadanou hodnotou
* (Num)	"Multiply" násobení interní proměnné zadanou hodnotou
> (Num)	"Move to register" přesun dat z interní proměnné do zadaného registru
< (Num)	"Move from register" přesun dat ze zadaného registru do interní proměnné
' (Num)	"Subroutine" podprogram
. (Num)	"End of subroutine" konec podprogramu

Všechny dodávané typy jsou ve verzi 2x s možností použití 24 MHz krystalu. Veškerá činnost kontroleru je tak zrychlena na dvojnásob. Pro spolehlivý zápis do EEPROM bez ohledu na verzi kontroleru s pamětí EEPROM je však vhodné použít 12 MHz krystal. Podrobný uživatelský manuál je součástí dodávky kontroleru M1486.

SOLENOID VALVE



General information

Item no.	161904
Device key	6012-C01,2FFMSGM81-2-024/DC-04* JB07+NA38
Item description	3/2-way-solenoid valve, direct acting
Program	V
Net weight	0.13 KG
CE	CEXX
Shipping time	6 Days
Statistical good	84818079

Explanation of device key

Typ (TYP_0009)	6012
Circuit function (WW)	C - 3/2-ways; normally closed; output A balanced
Orifice size (DN)	01,2 - 1,2mm (3/64")
Seal material (DWST)	FF - FKM
Material (WKST)	MS - brass
Port connection (LTA)	GM81 - G1/8 threaded port
Coil size (SG)	2 - 20 mm
Voltage (SP)	024 - 24 volts
Frequency (FR)	DC - DC
Power consumption (LEIS)	04 - 4 watt
Variable code 1 (VAR1)	JB07 - plug interface acc. form B (industrial form)
Variable code 2 (VAR2)	NA38 - Coil material insulation class H

Technical data

Pressure (bar) (min)	0
Pressure (bar) (max)	10
Pressure (max) by gas	10
Medium temperature (degree C) (min)	-10
Medium temperature (degree C) (max)	100
Ambient temperature (min)	-10
Ambient temperature (max)	55
KV value (M ³ /H)	0,045
QNN value (L/MIN)	48,00
Duty cycle (%)	100
Opening time (msec) (min)	7
Opening time (msec) (max)	12
Closing time (msec) (min)	7
Closing time (msec) (max)	12

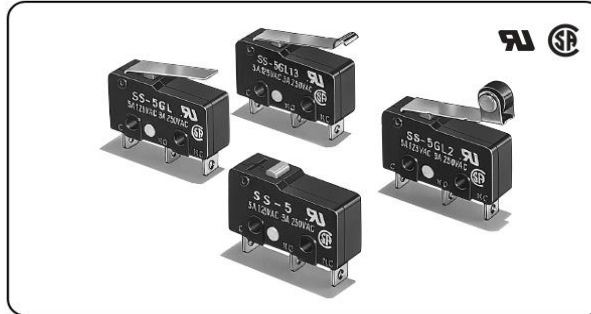
LIMIT SWITCH

SS

Subminiature Basic Switch

Subminiature Basic Switch Offers High Reliability and Security

- The OMRON's best-selling micro switches of a wide variety from 0.1A to 10.1A.
- A variety of models are available, with operating force ranging from low to high.
- Two split springs ensure a high stability and durability of 30,000,000 operations.
- 1 mm MIN Contact Gap Models available for Interlock applications




RoHS Compliant

Model Number Legend

- SS-**1** **2** **3** **4** **5** **6**
- 1. Ratings**
 10 : 250 VAC 10.1A
 5 : 125 VAC 5 A
 01 : 30 VDC 0.1A
 - 2. Actuator**
 None : Pin plunger
 GL : Hinge lever
 GL111 : Long hinge lever
 GL13 : Simulated roller lever
 GL2 : Hinge roller lever
 GL02 : Hinge roller lever
 (Roller material: Stainless) heat-resistant
 - 3. Maximum Operating Force (OF)**
 None : 1.47 N (150 gf)
 -F : 0.49 N (50 gf) (0.1 A, 5 A) Note. These values are for the pin plunger models.
 -E : 0.25 N (25 gf) (0.1 A)
 - 4. Contact form**
 None : SPDT
 -2 : SPST-NC
 -3 : SPST-NO
 - 5. Terminals**
 None : Solder terminals
 T : Quick-connect terminals (#110)
 D : PCB terminals
 - 6. Heat resistance**
 None : Standard (85°C)
 -T : Heat-resistant (120°C)

List of Models

●Standard Models

Actuator	Terminals	Contact Form	Maximum Operating Force (OF)	Ratings		
				10.1 A	5 A	0.1 A
Pin plunger 	Solder terminals	SPDT	1.47 N (150 gf)	SS-10	SS-5	SS-01
		SPST-NC		SS-10-2	SS-5-2	SS-01-2
		SPST-NO		SS-10-3	SS-5-3	SS-01-3
		SPDT		SS-10T	SS-5T	SS-01T
		SPST-NC		SS-10-2T	SS-5-2T	SS-01-2T
		SPST-NO		SS-10-3T	SS-5-3T	SS-01-3T
	Quick-connect terminals (#110)	SPDT	1.47 N (150 gf)	SS-10D	SS-5D	SS-01D
		SPST-NC		SS-10-2D	SS-5-2D	SS-01-2D
		SPST-NO		SS-10-3D	SS-5-3D	SS-01-3D
		SPDT		-	SS-5-F	SS-01-F
		SPST-NC		-	SS-5-F-2	SS-01-F-2
		SPST-NO		-	SS-5-F-3	SS-01-F-3
	PCB terminals	SPDT	1.47 N (150 gf)	-	SS-5-FT	SS-01-FT
		SPST-NC		-	SS-5-F-2T	SS-01-F-2T
		SPST-NO		-	SS-5-F-3T	SS-01-F-3T
		SPDT		-	SS-5-FD	SS-01-FD
		SPST-NC		-	SS-5-F-2D	SS-01-F-2D
		SPST-NO		-	SS-5-F-3D	SS-01-F-3D
	Solder terminals	SPST-NC	0.49 N (50 gf)	-	-	SS-01-E
				-	-	SS-01-E-2
				-	-	SS-01-E-3
				-	-	SS-01-ET
				-	-	SS-01-E-2T
				-	-	SS-01-E-3T
SPST-NO		0.49 N (50 gf)	-	-	SS-01-ED	
			-	-	SS-01-E-2D	
			-	-	SS-01-E-3D	
			-	-	-	
			-	-	-	
			-	-	-	
Quick-connect terminals (#110)	0.25 N (25 gf)	0.25 N (25 gf)	-	-	SS-01-E	
			-	-	SS-01-E-2	
			-	-	SS-01-E-3	
			-	-	SS-01-ET	
			-	-	SS-01-E-2T	
			-	-	SS-01-E-3T	
PCB terminals	0.25 N (25 gf)	0.25 N (25 gf)	-	-	SS-01-ED	
			-	-	SS-01-E-2D	
			-	-	SS-01-E-3D	
			-	-	-	
			-	-	-	
			-	-	-	

Separator (Sold Separately), Terminal Connector (Sold Separately) ➔ Refer to "Basic Switch Common Accessories"

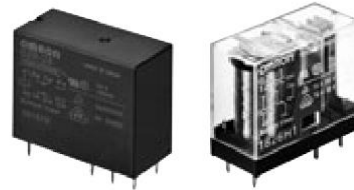
RELAY-01

G2R PCB Power Relay

The Best Seller G2R

- 1 General purpose power Relays of single-pole 10 A and double-pole 5 A.
- Safety-oriented design with dielectric strength of 5,000 V between coil and contacts, and surge resistance of 10,000 V.
- AC and DC types are both available for operational coils.

RoHS Compliant



Model Number Legend

G2R-□-□□□□-□□
1 2 3 4 5 6 7

1. Relay Function

None: Single-side stable
K : Double-winding latching

2. Number of poles

1: 1-pole
2: 2-pole

3. Contact Form

None: NO/NC
A : NO

4. Contact Type

None: Single
Z : Bifurcated contact

5. Enclosure rating

None: Flux protection
(T-type is an enclosed relay)
4 : Fully sealed

6. Terminal Shape

None: PCB terminals
T : Quick-connect
(upper bracket mounting #187)

7. Classification

None: Standard
E : High-capacity
H : High-sensitivity
U : For ultrasonically cleanable
Z : Full-wave rectifier

G
2
R

Model Configuration

Terminal Shape	Classification	Number of poles		1-pole		2-pole		Minimum packing unit
		Enclosure rating	Contact form	SPST-NO (1a)	SPDT (1c)	DPST-NO (2a)	DPDT (2c)	
PCB terminals	Standard	Flux protection	AC	G2R-1A	G2R-1	G2R-2A	G2R-2	100 pcs/tray
			DC	G2R-1A4	G2R-14	G2R-2A4	G2R-24	
		Fully sealed	AC	G2R-1AZ	G2R-1Z	–	–	
			DC	G2R-1AZ4	G2R-1Z4	–	–	
	High-capacity	Flux protection	AC	G2R-1A-E	G2R-1-E	–	–	100 pcs/tray
			DC	G2R-1A-H	G2R-1-H	G2R-2A-H	G2R-2-H	
	High-sensitivity	Flux protection	DC	G2RK-1A	G2RK-1	G2RK-2A	G2RK-2	50 pcs/tray
			DC	G2RK-1A	G2RK-1	G2RK-2A	G2RK-2	
	Double-winding latching	Flux protection	DC	G2RK-1A	G2RK-1	G2RK-2A	G2RK-2	50 pcs/tray
			DC	G2RK-1A	G2RK-1	G2RK-2A	G2RK-2	
Quick-connect	Standard	Unsealed	AC	G2R-1A-T	G2R-1-T	–	–	100 pcs/tray
			DC	G2R-1A-T	G2R-1-T	–	–	

Note 1. Full-wave rectifier and supersonic cleaner compatible models are also available. Refer to page 3.

2. Sockets for PCB terminal models are not provided.

RELAY-02

G2R

PCB Power Relay

■ Ratings

● Coil

Classification	Item Rated voltage	Rated current (mA)		Coil resistance (Ω)	Must operate voltage (V)	Must release voltage (V)	Max. voltage (V)	Power consumption (VA, W)
		50 Hz	60 Hz					
<ul style="list-style-type: none"> • Standard • Quick-connect • Fully sealed • High-capacity 	12 VAC	93	75	65	80% max.	30% min.	140% (at 23°C)	Approx. 0.9 (60 Hz)
	24 VAC	46.5	37.5	260				
	100/(110) VAC	11	9/(10.6)	4,600				
	200/(220) VAC	5.5	4.5/(5.3)	20,200				
<ul style="list-style-type: none"> • Standard • High-capacity • Bifurcated contact • Quick-connect • Fully sealed 	5 VDC	106		47	70% max.	15% min.	170% (at 23°C)	Approx. 0.53
	6 VDC	88.2		68				
	12 VDC	43.6		275				
	24 VDC	21.8		1,100				
	48 VDC	11.5		4,170				
	100 VDC	5.3		18,870				
<ul style="list-style-type: none"> • High-sensitivity 	5 VDC	71.4		70	70% max.	15% min.	170% (at 23°C)	Approx. 0.36
	6 VDC	60		100				
	12 VDC	30		400				
	24 VDC	15		1,600				
	48 VDC	7.5		6,400				

- Note 1. The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of +15%/-20% (AC rated current) or ±10% (DC coil resistance).
 2. AC coil resistances shown above are only reference values.
 3. The operating characteristics are measured at a coil temperature of 23°C.
 4. The "Max. voltage" is the maximum voltage that can be applied to the relay coil.

● Coil: Double-winding Latching Relays

Item Rated voltage	Set Coil		Reset coil		Must set voltage (V)	Must reset voltage (V)	Max. voltage (V)	Power consumption	
	Rated current (mA)	Coil resistance (Ω)	Rated current (mA)	Coil resistance (Ω)				Set Coil (mW)	Reset coil (mW)
5 VDC	167	30	119	42	70% max.	70% max.	140% (at 23°C)	Approx. 850	Approx. 600
6 VDC	138	43.5	100	60					
12 VDC	70.6	170	50	240					
24 VDC	34.6	694	25	960					

- Note 1. The rated current and coil resistance are measured at a coil temperature of 23°C with a tolerance of ±10%.
 2. The operating characteristics are measured at a coil temperature of 23°C.
 3. The "Max. voltage" is the maximum voltage that can be applied to the relay coil.

DRAW-WIRE SENSOR

Model	WPS-1000-MK46		WPS-1250-MK46	
Output	P		P/U/I	
Measuring range	1000mm		1250mm	
Linearity	wire pot. P25	±0.25% FSO	±2.5mm	±3.12mm
	Hybridpot. P10/U10/I10	±0.1% FSO	±1mm	±1.2mm
Resolution	wire pot. P25	0.3mm		0.4mm
	Hybridpot. P10/U10/I10		towards infinity	
Sensor element	wire/hybrid potentiometer			
Temperature range	-20 °C ... +80 °C			
Material	housing	plastic		
	draw-wire	coated polyamide stainless steel (ø 0.36mm)		
Wire mounting	eyelet			
Sensor mounting	mounting holes / mounting grooves			
Wire acceleration	approx. 5g			
Wire retraction force (min)	approx. 1N			
Wire extension force (max)	1.6N		1.5N	
Protection class	IP20			
Electrical connection	P10, P25	soldering tag		
	CR-P25/CR-U10/ CR-I10	integrated cable, radial, 1m		
Weight	approx. 80g			

FSO = Full Scale Output

Specifications for analog outputs on page 51.

Article description

WPS - 1000 - MK46 - P25

Output option:
P25: potentiometer
P10: potentiometer
CR-P25: potentiometer, integrated cable, radial, 1m

Model MK46

Measuring range in mm

WPS - 1250 - MK46 - P25

Output option:
P25: potentiometer
P10: potentiometer
CR-P25: potentiometer, integrated cable, radial, 1m
CR-U10: voltage, integrated cable, radial, 1m
CR-I10: current, integrated cable, radial, 1m

Model MK46

Measuring range in mm