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PLC Based Control of a Motor Test Bed and Torque Measurement

Master Thesis Report Submitted by

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I would like to thank Professor Bernd Altman for the opportunity provided to me to conduct my master thesis with him and stimulating spring where my practical experience has grown significantly. Despite my mechanical background, didactic and explanatory discussions about the thesis and reflected experience on each step of my thesis, made me more focused on my work and also gave me the courage to learn more and more. I would also like to thank Mr. Angerer for his technical support and enlightening comments to revise the approaches of practical works. Finally, I want to thank Mr. Manfred Kern and Mr. Jürgen Sonntag for the supportive ideas.

Abstract

In this master thesis, main focal point is to measure torque of a three phase induction motor with different torque sensors and understand the characteristics and behaviors of several process interface modules. Torque measurement is realized in three different ways. Burster8645 Torque Sensor (TS), optical reflective sensors and mechanical torque measurement equipment give torque values with different precision and ranges. On the other hand, by the help of process interface modules a detailed knowledge of signal processing for analog indicators and PLC modules is practiced. As a whole, motor test bed is equipped with many process interfaces and sensors to perform the desired process which are discussed in this document. As an outcome of this master thesis, handouts and other preparation documents for 'Lab Test No 5: Motor Test Bed' were written and revised.

Declaration

I hereby declare that all the work done in the master thesis is the result of my own ideas and knowledge. All the external sources and literature used in the thesis are mentioned in the references.

Mustafa Bektas

Weingarten, November 2014

Contents

Table of Figures

Symbols and Abbreviations

PLC	Programmable Logic Controller
VT	Voltage Transducer
CT	Current Transducer
CM	Current Monitor
SA	Signal Adaptor
FC	Frequency Converter
FFI	Field Frequency Indicator
CW	Clockwise
CCW	Counter Clockwise
RT	Resistance Transducer
ADC	Analogue to Digital Converter
Hz	Hertz
E_e	Irradiance
W	Watt
TG	Tachogenerator
OP	Operator Panel
IM	Induction Motor
PB	Push Button
DC	Direct Current
MSI	Motor Speed Indicator
TS	Torque Sensor

1 Introduction

Motor test bed was designed to combine all the ideas of an automation process, basically. It means, if the torque measurement is called as the process, motor test bed contains all the phases of this process. Firstly, a frequency converter is used to actuate induction motor. Generated rotation of the shaft of Induction Motor (IM) is coupled with a coupling that transmits the rotation to shaft of electrical brake. While the torque is generated, by the help of analogue indicators, operator can follow the values of Field Frequency, Motor Speed, Torque and Load Current. These indicators give chance to operator to modify or optimize the values. On the other side, adaptation of all needed signals to a Programmable Logic Controller (PLC) Moeller XC-100is achieved with several process interface equipment. These process peripherals are listed as Voltage Transducer (VT), Current Transducer (CT), Current Monitor (CM), Signal Adapter (SA) circuitry and a designed circuitry to see the effect of amplifier on Tachogenerator signal.

On another phase of this motor test bed, investigation of behavior of an optical reflex sensor, TCRT 1000, is done. Main objective of the investigation of optical sensor was to calculate the relation between sensing distance and reflection transition ranges which is taken on these sensing distances. The usage of optical reflex sensor is sensing the direction of rotation and measuring the torque with a principle that is based on counting an optical sensed signal by a high speed counter.

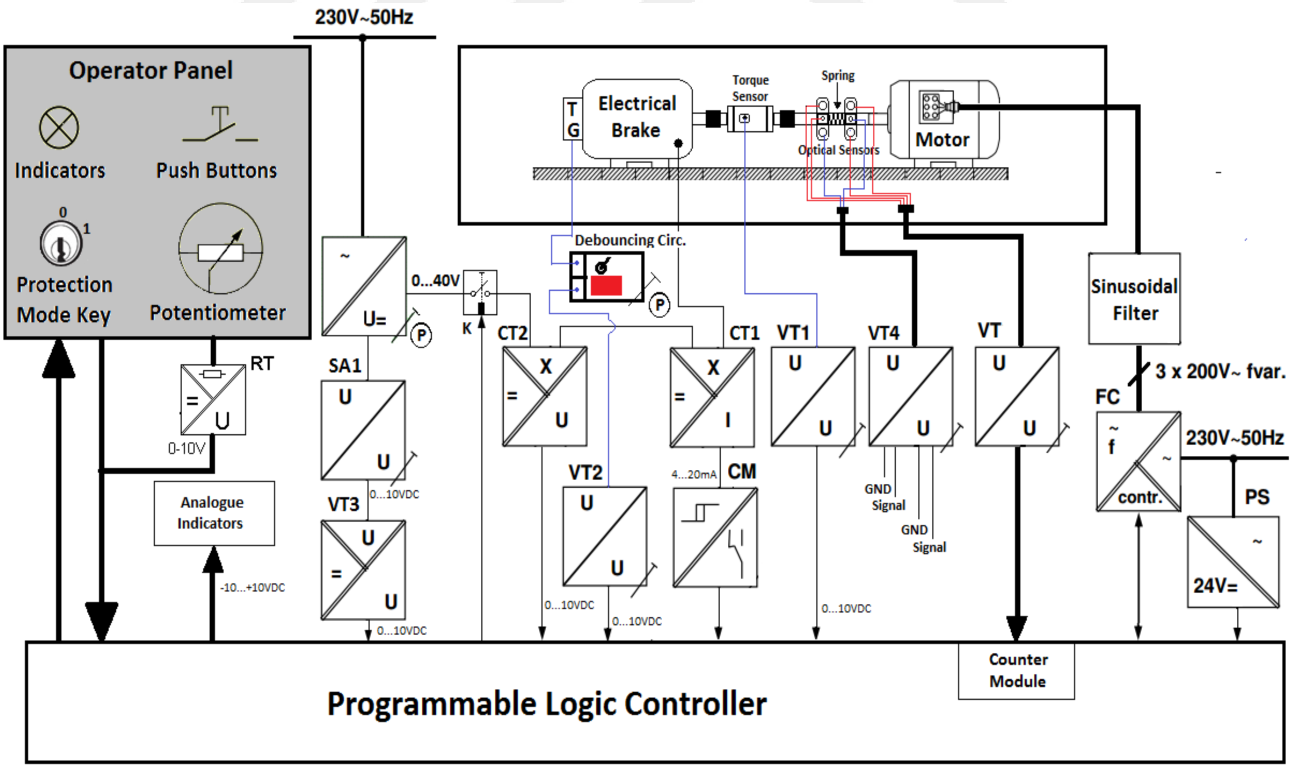


Figure 1-1 Motor test bed block diagram

2 Modifications and Practical Work based on Lab Test No 5 “Motor Test Bed V03”

In this section, modifications on motor test bed for the new lab test and solutions for hardware and software of test bed, will be described.

2.1 Modifications on Handout Part “5.1 First Steps”

In “5.1 First Steps” part, motor test bed is checked whether it is ready for the lab test. If system is not ready for starting, students or the users should check the protection cover and correspondent switches to enable Frequency Converter (FC), Protection Cover and Power ON.

In comparison to old version of test bed, new test bed an additional way to read out the field frequency .field frequency will be measured and read out with a speedometer and will be seen on the display of Frequency Inverter and simultaneously, it will be shown on the Field Frequency Indicator (FFI).An analogue double scale indicator is used to show Field Frequency. As shown in the figure given below, two double sides scale of 0…100% are present. A voltage of 0…+10 V DC is required to move the scale from 0…100% towards right side of the indicator. A voltage of 0…-10 V DC is required to move the scale towards left side of the indicator to show a value of 0…100%. The reason of using double side scale indicator is the motor direction in two sides, CW and CCW. So when motor is rotating in CW direction the scale indicates the respective value towards right side of the scale and vice versa.

Figure 2-1 Analogue double scale indicator

2.2 Modifications on Handout Part “5.2 Adapt Potentiometer P2 to PLC”

In “5.2 Adapt Potentiometer P2 to PLC” part, as it shown in the figure belowP2 potentiometer is adapted by the help of a Resistance Transducer (RT) to an analogue module of PLC. The output signal of RT module has a 0-10V value. Reference voltage value which is connected to analogue PLC module corresponds the field frequency that varies 0-100 Hz.

Terminal 62 of the FC gives a monitor voltage of 0-6V to monitor the field frequency of the FC. Signal which is taken from Terminal 62 is connected to analogue module of PLC and is scaled to give field frequency analogue indicator. Analogue indicator used has double sided scale of 0-100%, which means if the motor is rotating in right direction then the scale will indicate a value in between 0-100% on right side of the indicator which corresponds to 0-100Hz field frequency, whereas if the motor is rotating in left direction then the scale will indicate a value in between 0-100% on left side of the indicator which corresponds to 0-100Hz in left side rotation of the motor

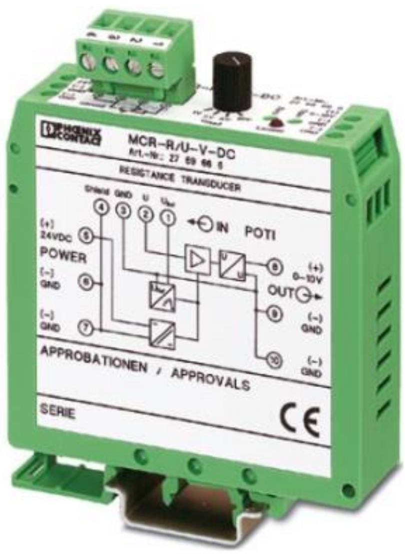


Figure 2-2 Resistance Transducer

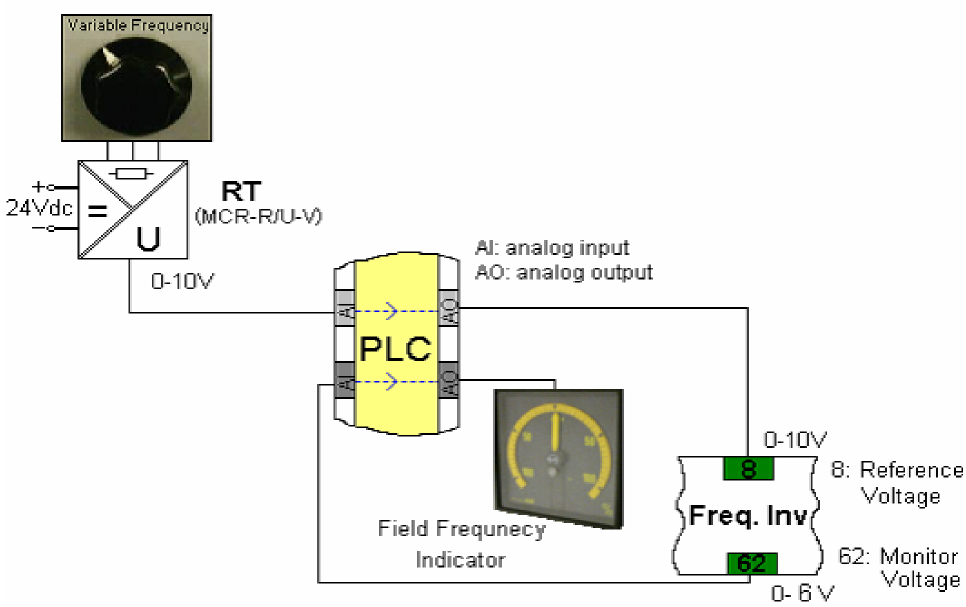


Figure 2-3 Field Frequency Monitor signal interface

Since the reference voltage source has four levels, any potentiometerbetween 100Ω and 20 kΩ can be connected. The measurement signal obtained at the center tap via a voltage divideris converted into an accurate analog signal.This analogue (0-10V) signal is directly connected to analogue module of PLC(XIOC-8AI-U1).After a program manipulation (Frequeny Feedback program),0-10 V signal is converted to bipolar (+/-10 V) signal.The reason of converting to bipolar signal is rotation of motor in CW and CCW direction.So these rotation values are indicated on FFI.

On RT module there are two screws to adjust zero(ZERO) and final point(SPAN) of the potentiometer.In motor test bed, potentiometer P2 has a working range with an alpha(α) angle between 0-280◦. These angle values correspond to 0-10V of field frequency indicator. In the figure shown below correspondant values are depicted. Output voltage of RT module can have a upper margin upto 11 V. Final value of potentiometer is adjusted by SPAN screw and the adjusment of beginning point is done by ZERO screw.[1]

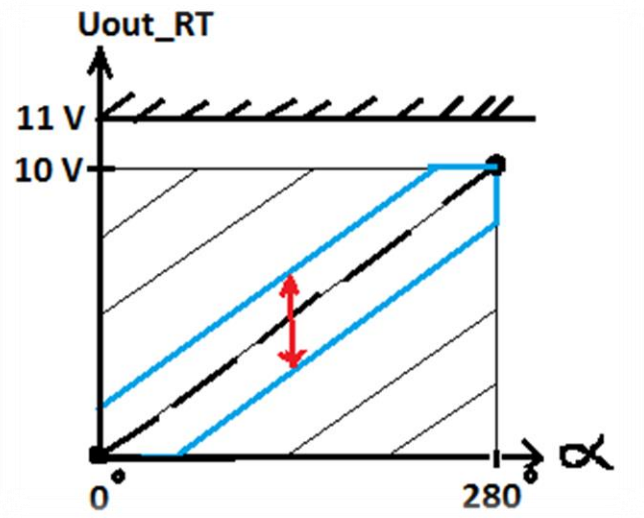


Figure 2-4 RT output voltage –potentiometer rotation angle

As it can be seen on the figure above, potentiometer has a dead zone in the beginning and final points. It means, when the operator starts to turn potentiometer, after first 5°-10° and when it approaches to last

5^o-10^o, potentiometer does not show any voltage changing as output. After adjusting zero and final point of potetiometer which correspond to indicated values on Field Frequency Indicator, operator can verify these limits on PLC software. This point is covered and used also in lab test handouts. ADC converter which is embedded in PLC analogue module helps us to convert the analogue values to digital ones. Specified ADC converter which is builded in PLC XC101, has a resolution of 12 bit. So k=12 bit, 2^k-1 formula gives a 4095 bit resolution to indicate as digital values. Operator can verify the adjusted zero and final points on RT module, by using the PLC configuration tree of PLC software. In easysoftCoDeSys PLC software,operator can check the "AT %IW10" physical adress on PLC Configuration Tree. This verification will give a precise adjusment for P2 potentiometer.

2.3 Modifications on Handout Part "5.4 Monitoring Load Current;Adjust Parameters of Current Monitor"

In "5.4 Monitoring Load Current; Adjust Parameters of Current Monitor CM" part, it is discussed that the load current and limits of the motor test bed regarding implementation of load current. In motor test bed, current monitor (CM) is used to limit the load current over a threshold value. Principally, electrical brake works on eddy current, which means magnetic force stops the motor. But as a disadvantage of using electrical brake is increasing temperature with the time. Because of this temperature changing, motor test bed has two interfaces to control the flow of the load and to limit this load when it exceeds threshold value.

One of the interfaces which is used to process Load Current is Current Transducer (CT) which works on Lenz Law principal. Switching behaviors and input-output specifications are configured by DIP switches.[2]One CT is configured to convert the input current of 0-5A flowing through the brake to a corresponding 0-10V. By the help of this module temperature of the load side is calculated. Calculation is based on the supplied voltage to module and current which flows through the brake.

CT2 module has a specific cycle time to sample the incoming data and giving the respective output voltage. For that reason, as it can be seen in the figure below, output voltage of the CT2 module reaches the level of stationary load current in two steps. Module has a sampling rate of approximately 270ms. This sampling rate also affect the switching points of output voltage. Switching points shift forward or backward regarding the internal specific cycle time and manually triggering of the Load ON/OFF pushbutton. With continuous triggering of the load brake which gives overlapping signals of output voltages, show the sampling characteristic of the CT2 module. This overlapping output voltages show approximately PT1 like step response. While the signals on the scope of oscilloscope are being sent to Excel as data and graphics, one special add-on from Tektronix company is used. By the help of this add-on for Excel, 2500 data points, which reflect the sampled points on oscilloscope, are directly shifted to Excel. The only problem that we will face, while we are using this add-on is to have a time scale on the excel graphs that is starting with minus values. This occurs because of the triggering points on the oscilloscope.[8]

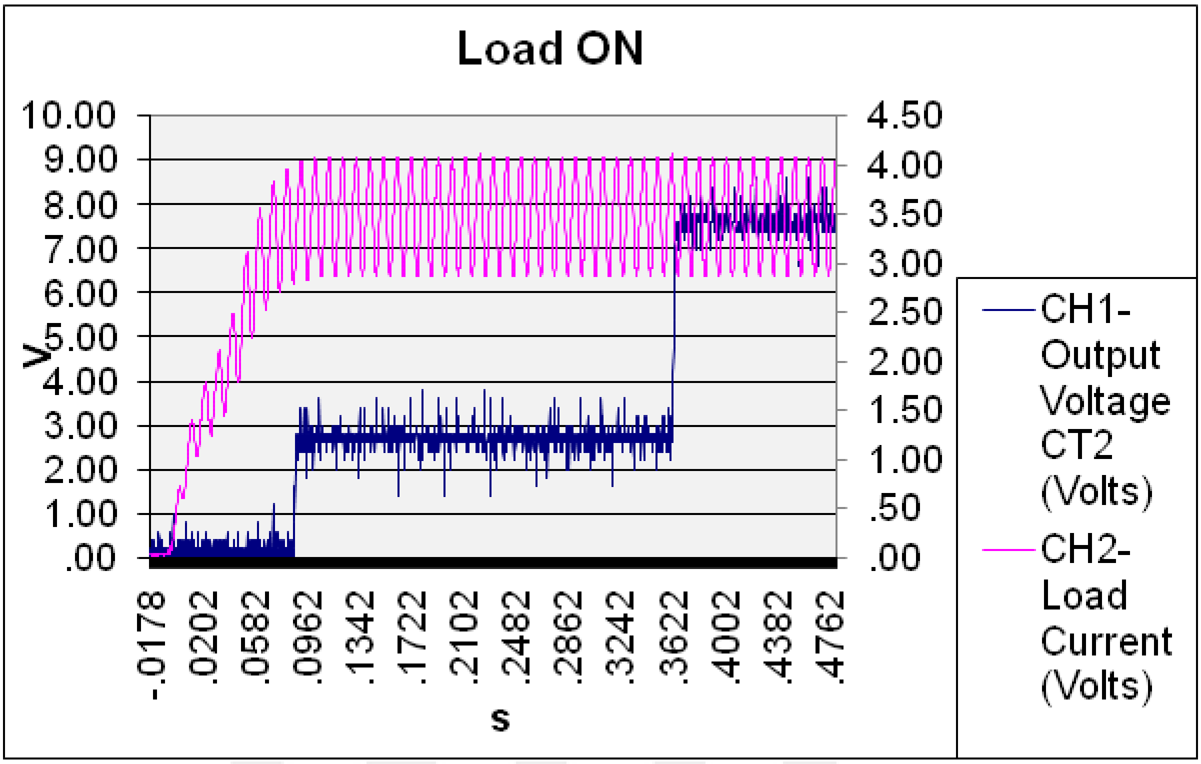


Figure 2-5 CT2 output voltage-load current (Load ON)

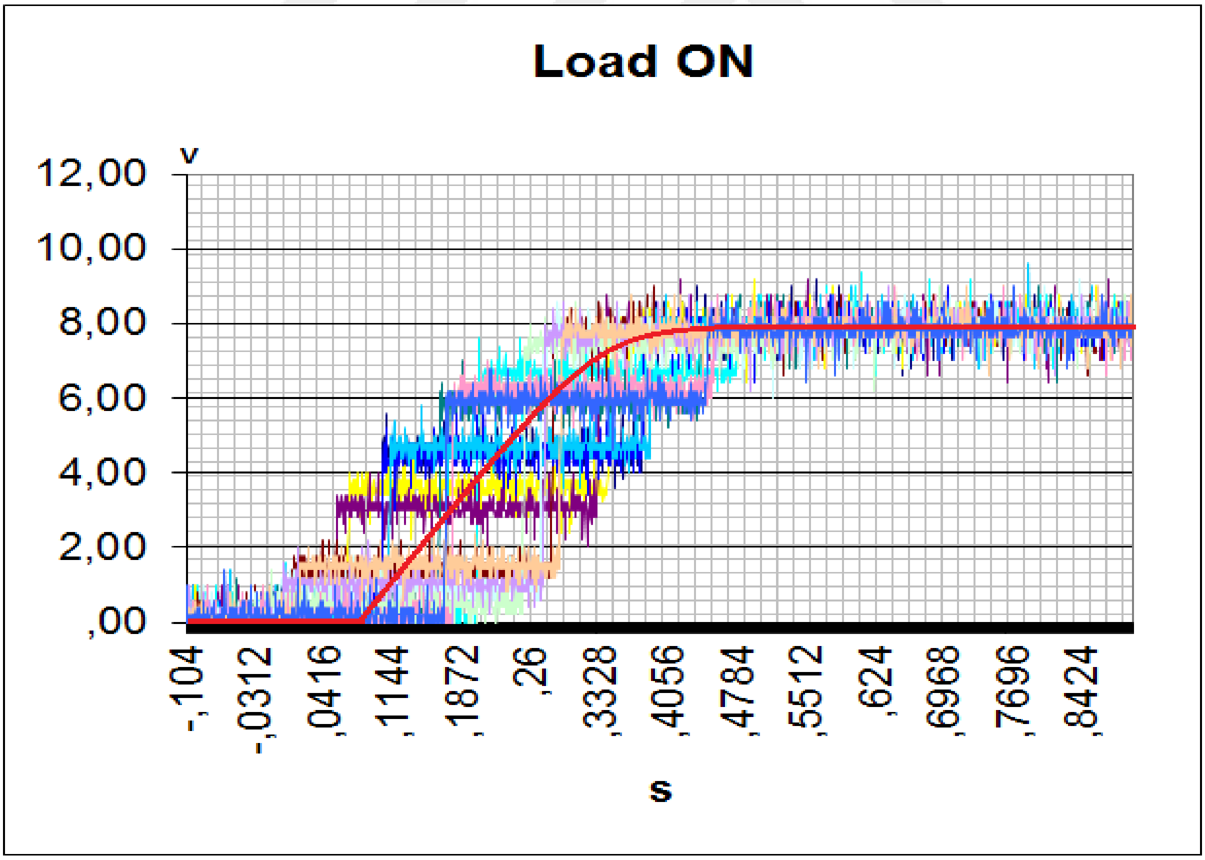


Figure 2-6 CT2 output voltage overlapping signals

As it is mentioned before, braking system of the induction motor works on eddy current principle. Energizing and de-energizing of the load shows a PT1 characteristic. Calculation of time constants is done as it shown below. Best fitting time constant is T=40 ms which is also given as a specification in data sheets of the current transducer module [2].

$$T_{02} = \frac{-t_{02}}{\ln(1-0.2)} \quad = \frac{-t_{02}}{\ln(0.8)} = -0{,}0082/\ln(0{,}8) = 37ms$$

$$T_{04} = \frac{-t_{04}}{\ln(1-0.4)} \quad = \frac{-t_{04}}{\ln(0.6)} = -0{,}0238/\ln(0{,}6) = 47ms$$

$$T_{06} = \frac{-t_{06}}{\ln(1-0.6)} \quad = \frac{-t_{06}}{\ln(0.4)} = 1{,}09 * 0.0495 = 54ms$$

$$T_{08} = \frac{-t_{08}}{\ln(1-0.8)} \quad = \frac{-t_{08}}{\ln(0.2)} = 0.62 * 0{,}0638 = 40ms$$

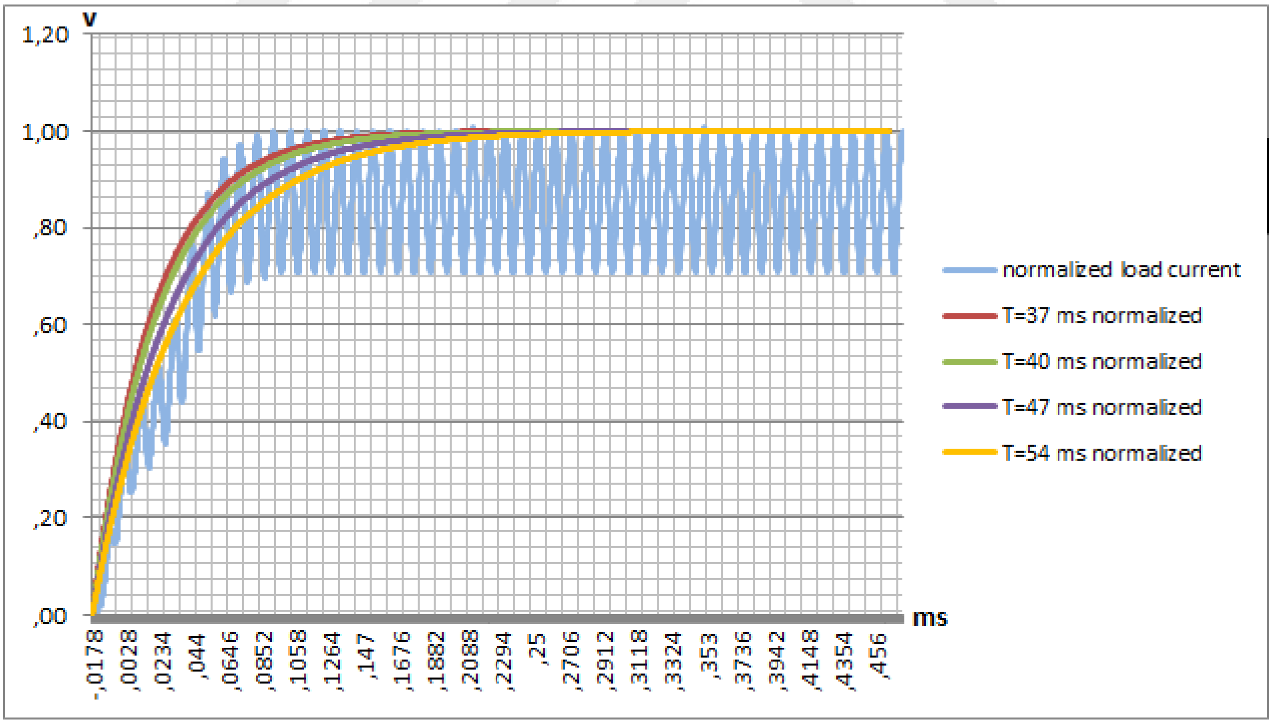


Figure 2-7 Load Current normalized signal – Step Responses

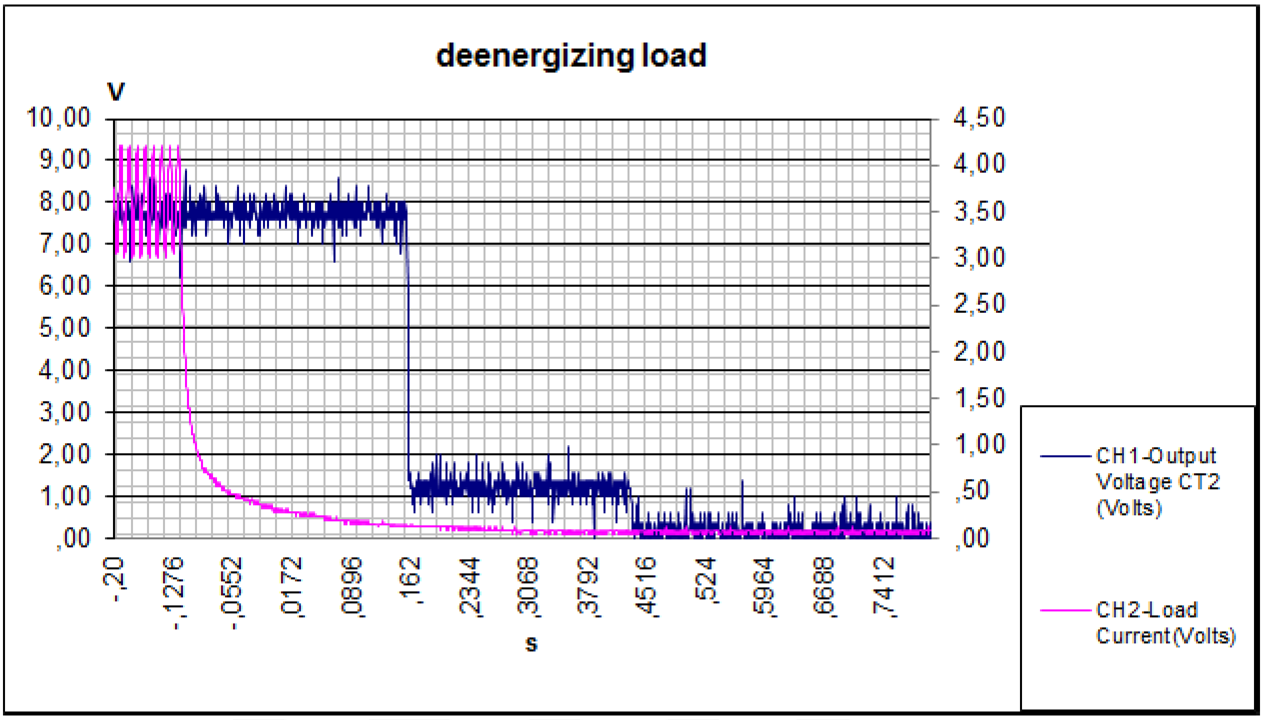


Figure 2-8 Load Current de-energizing-CT2 output voltage

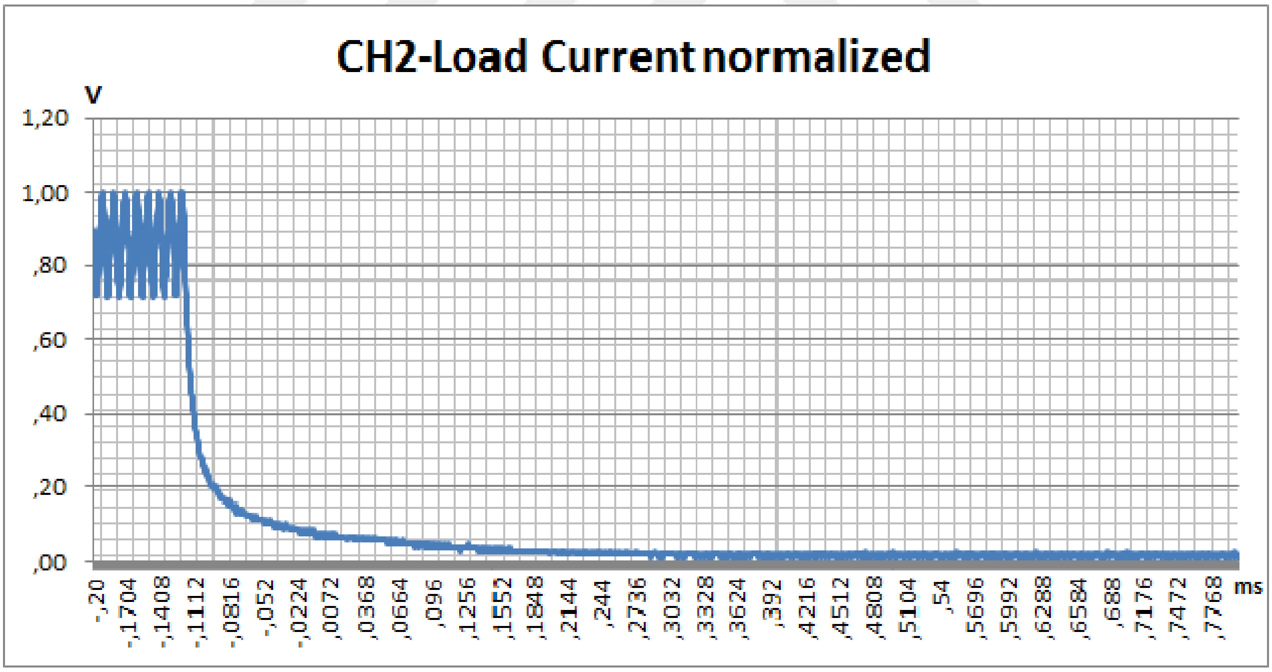


Figure 2-9 Load Current OFF normalized

Second Current Transducer (CT1) is configured to convert input current of 0-5A to a corresponding output live zero signal of 4-20mA. As seen in figure below, the live zero signals is given as an input to the Current Monitor (CM). CM output is a changeover contact which is changed when the input current exceed the set threshold current value.CM changeover contact is input to the PLC which will turn on the Load Exceed indicator on the operator panel (OP) to indicate the user that load has exceeded the set threshold value.CM threshold can be set by a screw by the user on top of the module. In PLC software "Enable/Disable" program stops the motor and inhibits motor to start in the case of "Load Exceed". In lab test, students are asked to adjust the threshold value to 10 %.

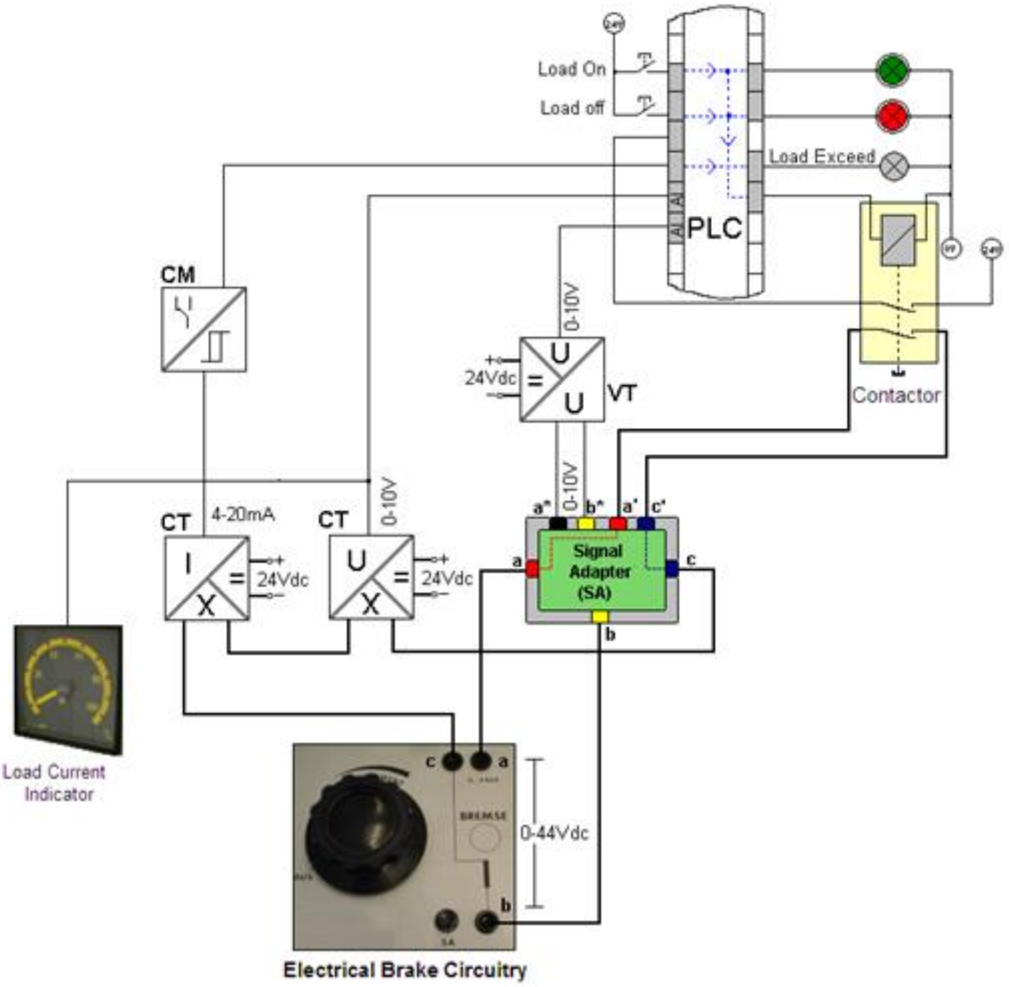


Figure 2-10 Electrical Brake Interface

2.4 Modifications on Handout Part "5.3 Adapt Tacho Generator to PLC"

In "5.3 Adapt Tacho Generator to PLC" part, the bipolar voltage signal of the Tachogenerator (TG) has to be converted into a unipolar voltage signal in the range 0 V to +10 V and, the superimposed ripple voltage has to be suppressed by filtering. Comparison to old version of motor test bed, new one has a circuitry that can be used as a switch with free bouncing (de-bouncing) effect. As it shown in the figure below, X2 and X3 ports of circuitry are the connections for Tacho signal and the signal which comes from amplifier circuitry(Amp1). S2 switch is used to select that, either to see just Tacho signal. In this mode of circuit, Motor Speed Indicator (MSI) shows the speed values of induction motor. In the other mode of circuitry, red button gives a 5V high pulse .By the help of this 5V ideal signal ,we can adjust Gain and Offset values of Amp1 ,so Time Constant (T=50 ms) can be determined. In the mode of "Amplifier (De-bouncing Button

Active)", motor speed indicator does not show any value. Hence de-bouncing circuitry has some more optimization to implement; actual situation of the circuitry is used for master thesis report.

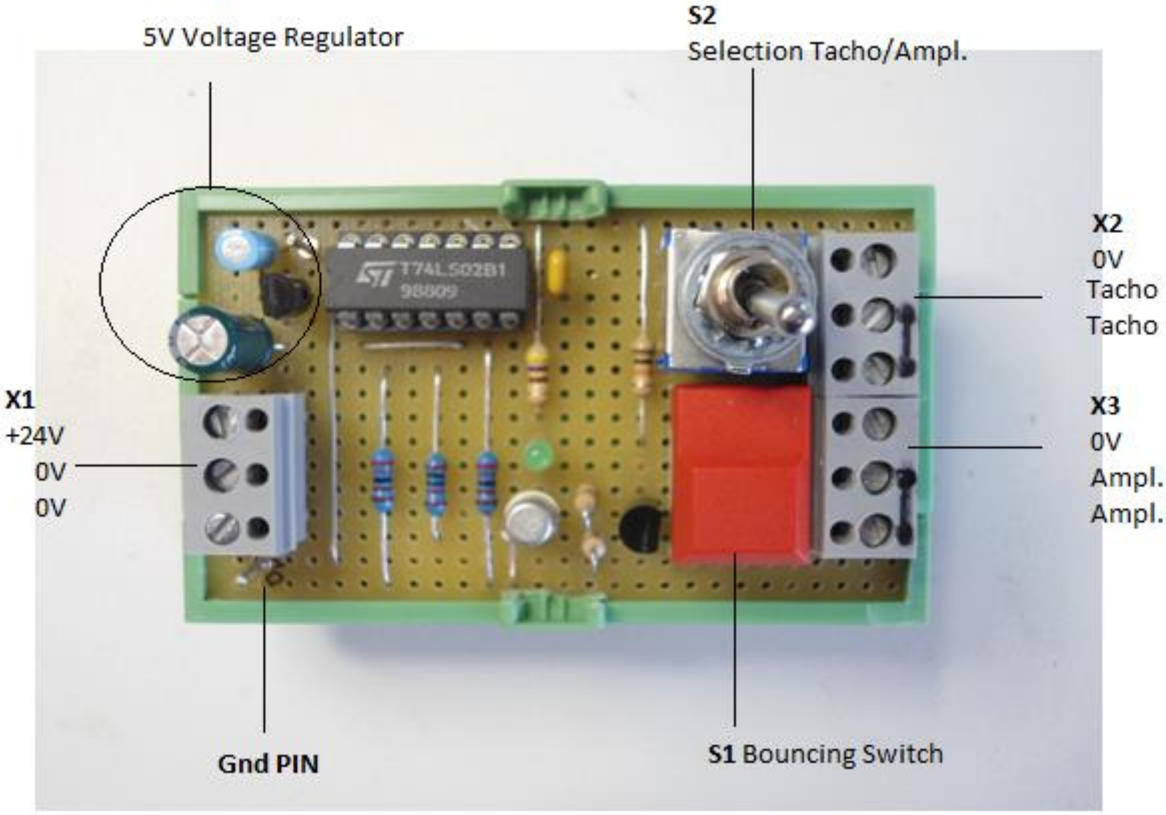


Figure 2-11 De-bouncing circuit

3 Investigation of Optical Reflective Sensor TCRT 1000

3.1 Principle of functioning of Optical Reflective Sensors

TCRT 1000 optical reflex sensor contains infrared-emitting diodes as a radiation source and phototransistors as detectors. Basically, emitted infrared light which is transmitted by a diode, encounters with a surface of an object that reflects the light. This reflected light is detected by a phototransistor and it causes a changing in the electrical signal. Transmitter and emitter is positioned on the same line, that avoids a direct light coupling. Transmitter of the optical reflective sensor emits radiation of a wavelength of 950 nm. The emitting and acceptance angles in the TCRT 1000 reflex sensors are about 45°.

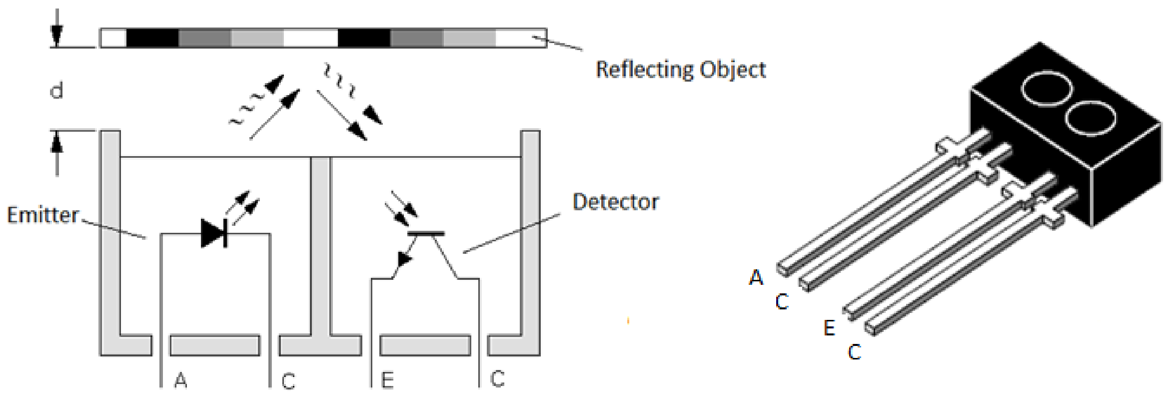


Figure 3-1 TCRT1000 optical reflex sensor with working principle

In the table below, reflection of different materials are listed. Table is taken from the data sheet of the sensor. [7] Table shows the relative collector current I_C (or coupling factor) of the reflex sensor for reflection on various materials. As a reference material white side of Kodak neutral card is stated. Reference conditions are the perpendicular positioning of reflex sensor to the surface and wavelength is 950 nm.

Kodak neutral card	
White side (reference medium)	**100%**
Gray side	20%
Paper	
Typewriting paper	94%
Drawing card, white (Schoeller Durex)	100%
Card, light gray	67%
Envelope (beige)	100%
Packing card (light brown)	84%
Newspaper paper	97%
Pergament paper	30-42%
Black on white typewriting paper	
Drawing ink (Higgins, Pelikan, Rotring)	4-6%
Foil ink (Rotring)	50%
Fiber-tip pen (Edding 400)	10%
Fiber-tip pen, black (Stabilo)	76%
Photocopy	7%
Plotter pen	
HP fiber–tip pen (0.3 mm)	84%
Black 24 needle printer (EPSON LQ-500)	28%
Ink (Pelikan)	100%
Pencil, HB	26%

Plastics, glass	
White PVC	90%
Gray PVC	11%
Blue, green, yellow, red PVC	40-80%
White polyethylene	90%
White polystyrene	120%
Gray partinax	9%
Fiber glass board material	
Without copper coating	12-19%
With copper coating on the reverse side	30%
Glass, 1 mm thick	9%
Plexiglass, 1 mm thick	10%
Metals	
Aluminum, bright	110%
Aluminum, black anodized	60%
Cast aluminum, matt	45%
Copper, matt (not oxidized)	110%
Brass, bright	160%
Gold plating, matt	150%
Textiles	
White cotton	110%
Black velvet	1.5%

Figure 3-2 Reflecting factor for different reflecting surfaces

3.2 Working Diagrams and Operation Range of Optical Sensor

As it shown in the figure below, collector current, I_C, is dependent on distance, A, which is measured from the surface of optical sensor to the object that will be detected. In the working diagram below, sensor shows a maximum point at a specific distance, A_o. At this point, optical coupling shows its highest effect . At larger distances collector current falls accordingly to its square. When the amplitude, I, has fallen not more than 50% of its maximum value, the operation range is at its optimum level.[7]

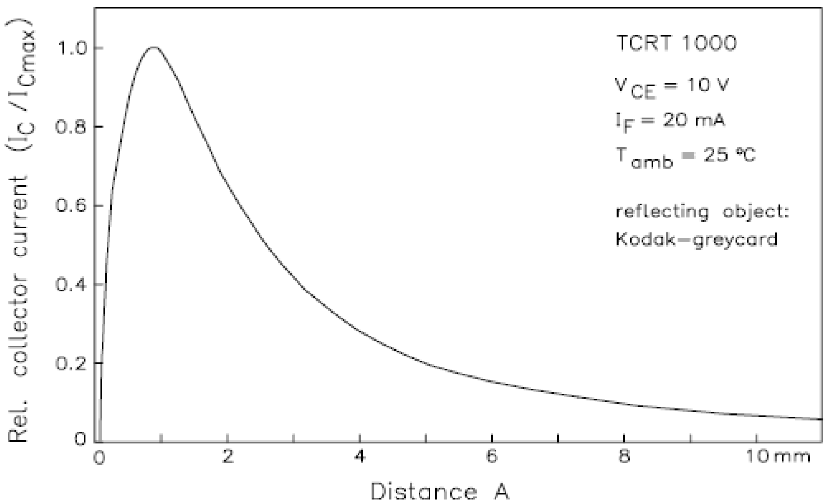


Figure 3-3 Working diagram of TCRT 1000

The behavior of the sensor regarding sudden changings as reflection over a displacement path is determined by two factors. These are defined as the resolution and the trip point. If a reflex sensor is following a reflecting surface with a reflection surge,changing of radiation, which is taken by the detector ,occurs gradually. As it depicted in the figure below,the surface,g, seen is covered by both transmitter and detector detection section. They determine range of radiation that is sensed by sensor. During the movement,this joint section g , is covered gradually by a dark/light reflection range. Accordingly with the change of reflection range, the collector current is also showing a transition from high to low values.[7]

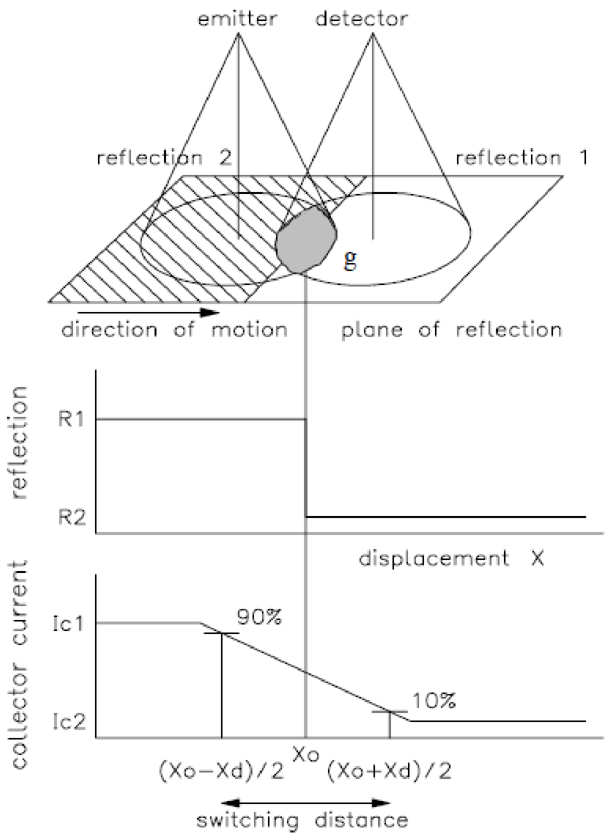


Figure 3-4 Reflection change and correspondent Collector Current values

When the sensor starts to detect a dark section on sensed path, collector current switches gradually to I_{C2}. That current changing occurs not at the point of X_0, but at the point of $X_0 + X_{d/2}$, displaced by $X_{d/2}$. Trip point is a point, that dark / light transition is fully detected by the sensor. This point is positioned between the points $X_0 + X_{d/2}$and $X_0– X_{d/2}$, around X_0. The displacement, X_d, therefore, corresponds to the width or the tolerance of the trip point. The section between 90 percent and 10 percent of collector current gives also Xd, practically. Displacement ,X_d ,can be described as switching distance , similarly to the switching time.

Resolution of the sensor is described as the ability to detect small objects. In the given example below ,the line with with width, d,has two dark/light sectionsthe switching distance $X_{d/2}$is, therefore, effective twice. As a condition to detect a line, width of line , d, should be greater than or equal to switching distance, X_d.(d ≥Xd) If the width of the line is less than the switching distance, Ic1 – Ic2,that is the processed current signal, becomes too small to implement and recognition of the object becomes uncertain. So switching distance , X_d, can also be called as the resolution of the sensor. The switching distance , X_d, is dependent on optical design of the sensor and the distance to the reflecting surface. Relative position of transmitter and detector axises also affect the switching distance.

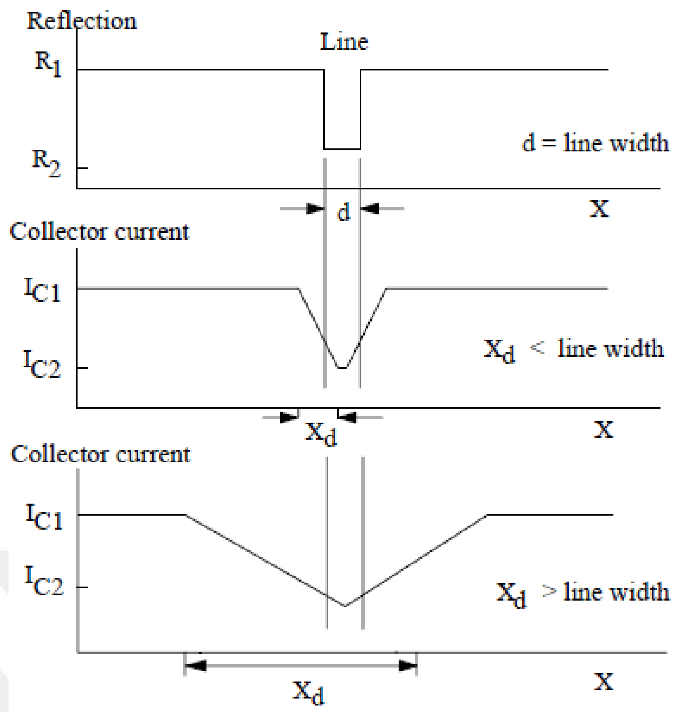


Figure 3-5 Reflection of a line of width d and corresponding curve of the collector current I_C

The switching distance, $X_{d,}$ is dependent on distance, A, that is respected to two different mounting position of reflex sensor. At position 1, axis of transmitter / detector is perpendicular to the separation line of dark/light transition. At position 2, axis of transmitter /detector is parallel to the dark / light transition as it shown in figure 3-6. In first position; sensor has a better resolution (smaller switching distances) in comparison to second position.

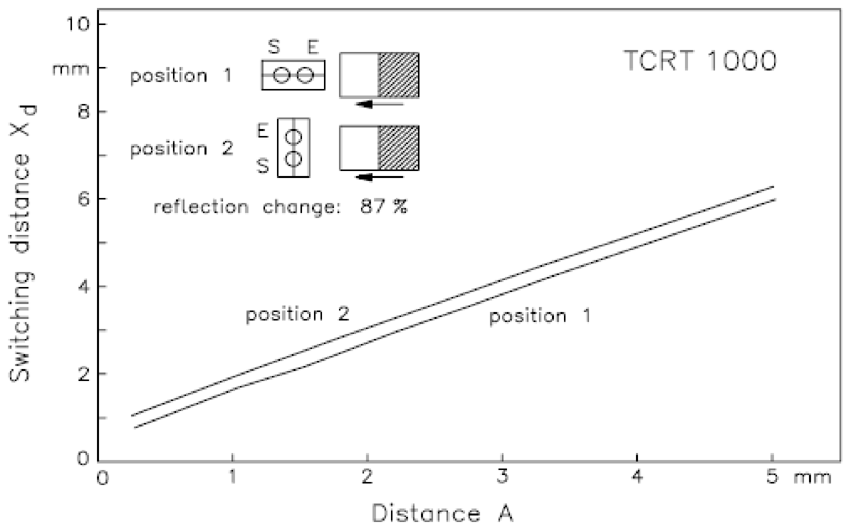


Figure 3-6 Positioning of the sensor TCRT 1000

3.3 Calculation of relation between Reflection Area of Sensor –Sensing Distance

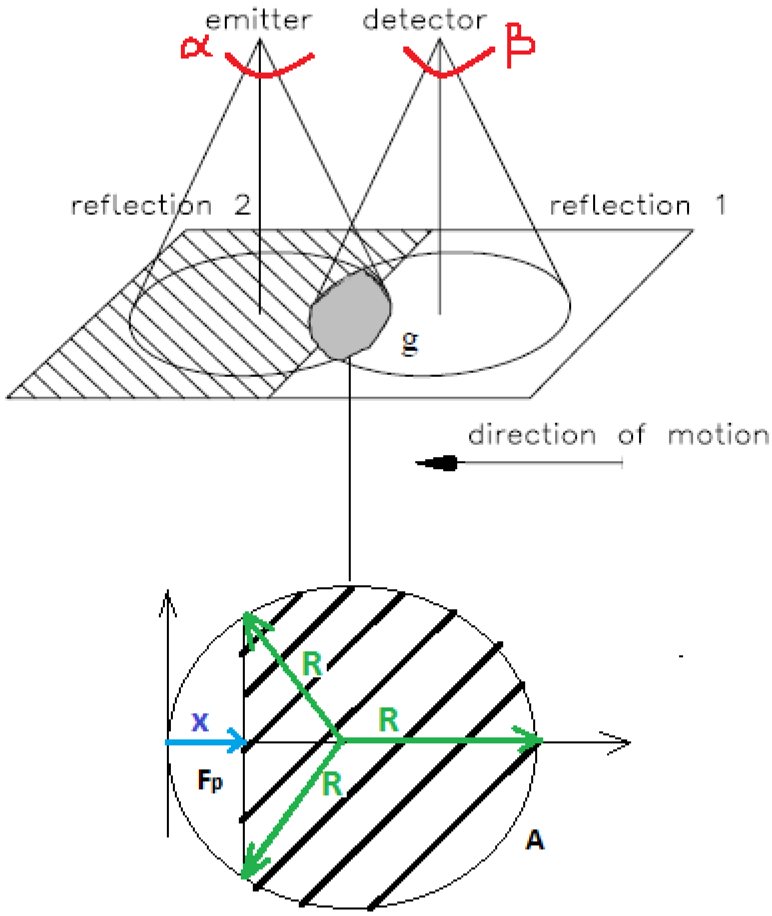


Figure 3-7 Relation between reflection area (A) – Switching distance (x)

Practically, this optical sensor was used to detect sense of rotation on the motor test bed. An optical tape which has four black and four white strips, is rolled on the mechanical coupling part on both motor and break side. While the induction motor is running, light that is reflected back from the white parts of optical tape, gives a signal. Used second optical reflex sensor also gives the same signal on the break (load) side. So when both of them is shown on one scope, the signals are located with a delay. By the help of this delay, sense of rotation can be detected.

As it can be seen in the figure above, the area which is jointly covered by reflections of emitter and detector has an elliptical form. In the following calculations, this reflection (footprint) area is assumed as a circle.

Diameter of reflection area is given by:

d = 2 * D * tan (45/2) (1)

R = d / 2

where

D is the sensing distance (mm)

d is the diameter of reflection area (mm)

R is the radius of reflection area (mm)

45^{o} angle that is used in the formula of diameter of reflection area is given as an optimal angle between emitter and detector. This is an advantage in short distance operation.

By using the radius of reflection area (footprint area, A), this reflection area itself can be found as follow:

$$\text{Footprint Area} = 2*((\pi * R^2 * \frac{\tan^{-1}(\frac{\sqrt{2*R*x-x^2}}{R-x})}{360}) - (\frac{(R-x)*\sqrt{2*R*x-x^2}}{2})) \quad (2)$$

where

R is the radius of reflection area (mm)

X is the switching distance that is depicted in figure above. (mm)

While we are deriving the formula (2), basically subtraction of a triangle area from a circle part is calculated. Finally, to find the light density on a specific concentrated foot print area can be calculated as follow:

$E_e = P / A$ (3)

where

E_e is the irradiance which is the power of electromagnetic radiation per unit area on a surface.(W /m^2)

P is the power of the light source. (W)

A is the footprint area (m^2)

In formula (3), the relation between distance to sensing surface and corresponding irradiance (radiation per unit area) can be seen. In the following gradually changing of transition of area is depicted.

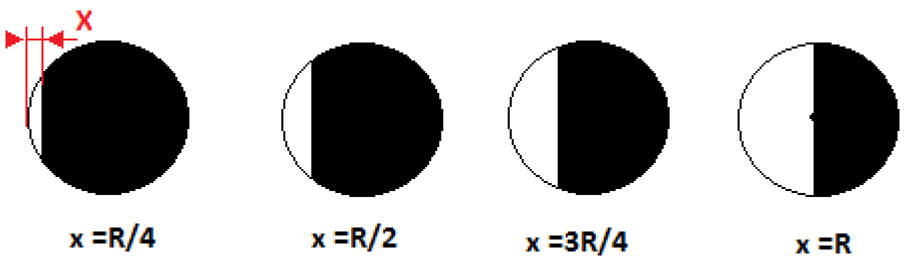


Figure 3-8 Transition of footprint area

As it drawn in the figure, the area which is covered by emitter and detector is changed by rotation of reflecting black-white strip. The effect of this transition is applied by square. It means, when we think the instantaneous point of x in time and if we make it bigger as twice, irradiance (radiation of light) or density of light on a specific area is changed by square.

Principally, as it is depicted in the figure below when sensing distance gets bigger irradiance (light density on a concentrated area approaches to zero. When x, switching distance, takes different values respected to R (radius of footprint area), irradiance shows different decreasing characteristics with distance. This decremental characteristic varies with bigger slopes of lines. Optimal detection point of sensor is 0.75 mm.

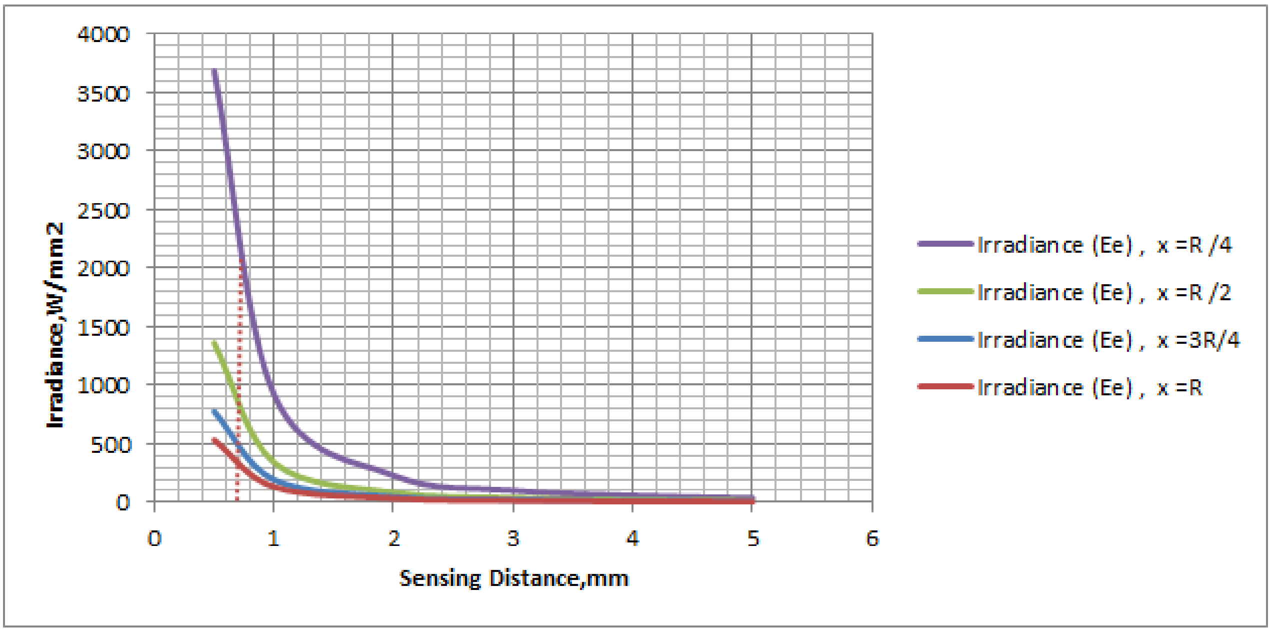


Figure 3-9 Relation between irradiance –sensing distance

In the following, we see the behavior of switching distance(x) respected to changing sensing distance (D).

Iterated values of x and D is based on an assumed threshold value (0.1). Sensing distance (D) varies between 0-5 mm.

$E_e = P_e / F_P$,

$P_{RX} = A * E_e = A * P_e / F_p$

0.1 (Threshold) = P_{RX} / P_e => $A(x) / F_p = A(x, D) / F_P$

where

P_{RX} is the reflected power from a reflecting surface. (W)

P_e is the power of light source. (W)

F_P is the footprint area that enlarges gradually. (mm^2)

A is the total area that contains the footprint area. (mm^2)

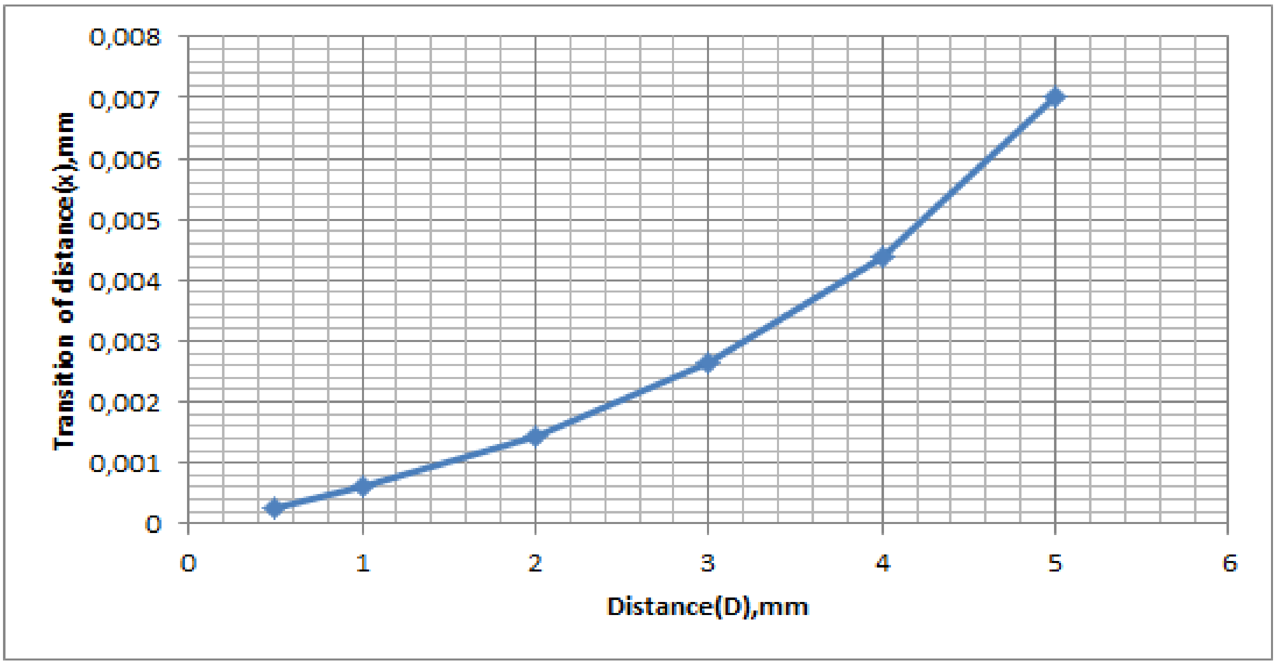


Figure 3-10 Transition of distance(x) – Sensing distance (D)

4 Output Signals of Lab Test

4.1 Current Transducer CT2 Output Signal

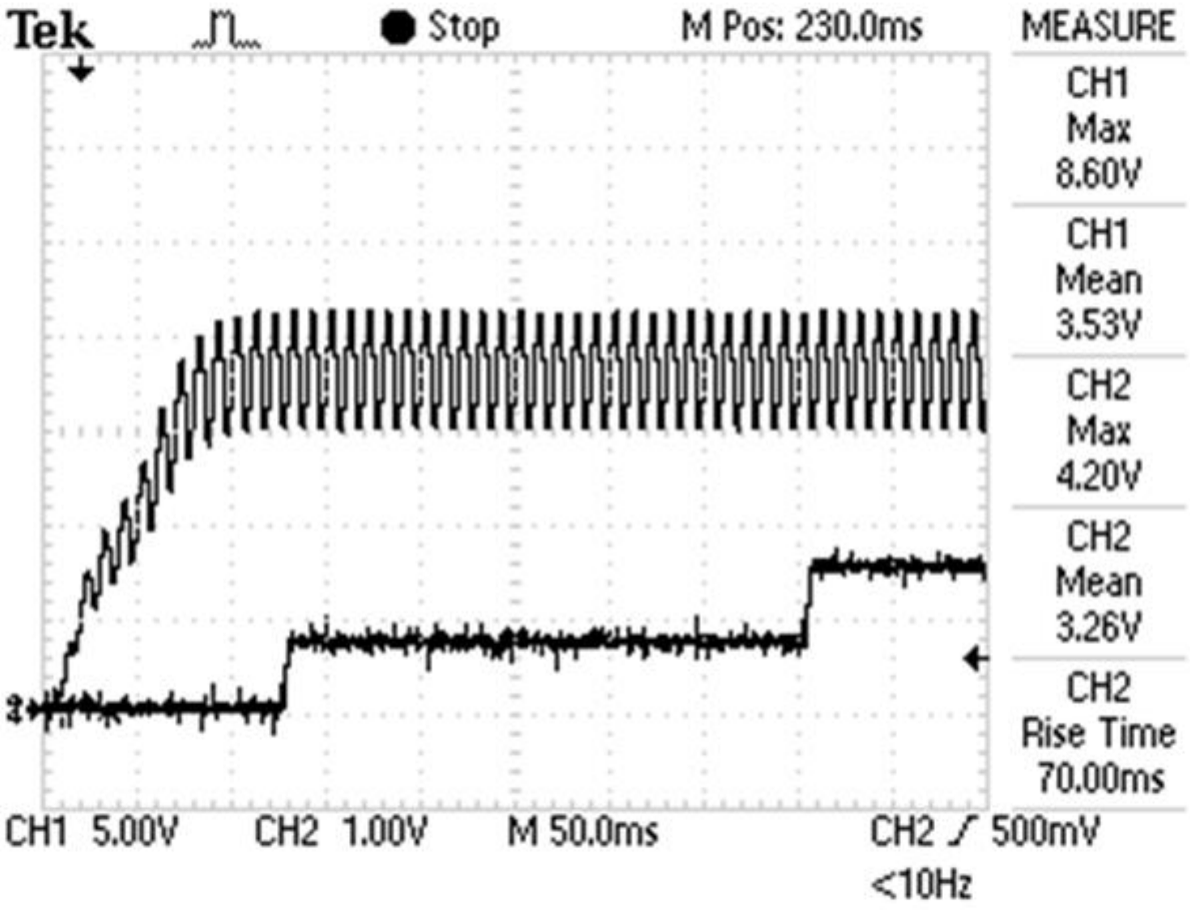


Figure 4-1 Output signal of CT2 (Load ON)

As it is seen in the figure above, when the max load current of the brake is applied, the correspondent module CT2 which adapts the signal for the PLC, gives an output of voltage. Current Transducer adapts the current value of the brake (0-5 A) to a voltage value that is given to analogue module of the PLC. While this scope is being sampled, triggering points are chosen that is so close to zero or the limit of oscilloscope scope. Because when the load of current reaches the stationary value, cycle time of CT2 or the sampling characteristic gives the output voltage in steps. As it is explained in the previous chapters, this special effect is seen because of the dynamic behavior of module.CT2 module has an internal cycle time of approximately 270ms.

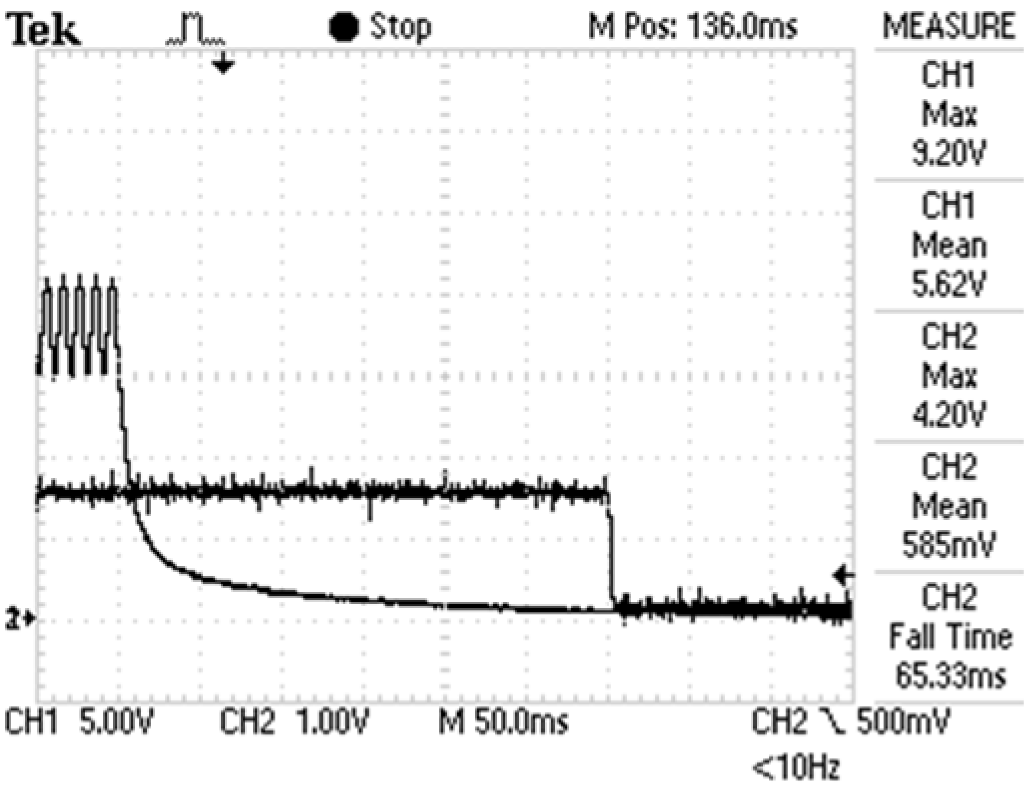


Figure 4-2 Output signal of CT2 (Load OFF)

4.2 Tachogenerator Output Signals

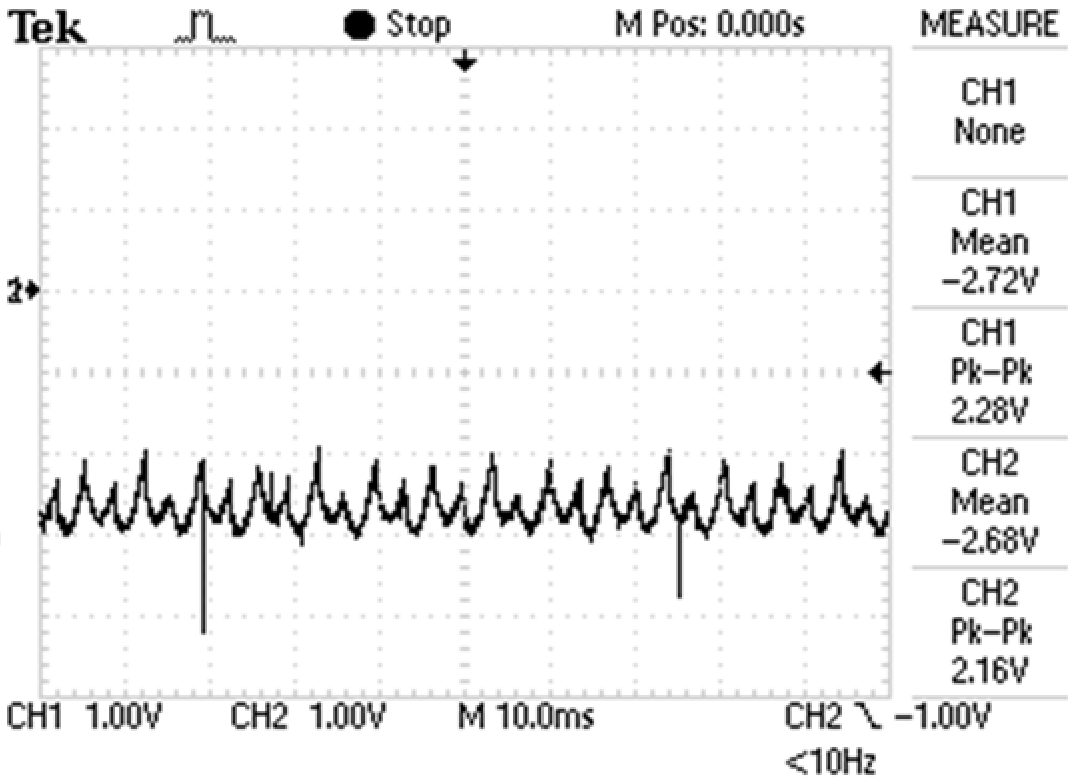


Figure 4-3 Identical amplified-normal TG signal

Tachogenerator (TG) gives a bipolar signal of ±2.85V at full speed (3000 rpm).The reason of having a bipolar voltage is the rotation of induction motor both CW and CCW direction. In the figure above, tachogenerator signal and amplified tachogenerator signal are depicted. As it can be seen on the scope, amplified signal and the normal tachogenerator signal are identical. This specific case is corresponding to lab test. In Lab test "Motor Test Bed", students are asked to adjust Gain and Offset of Amp1 such that input and output signals are identical. That means $K_{P1} = 1$ and $U_{off1} = 0$ V.Amp1 circuit is located on Voltage Transducer (VT4).

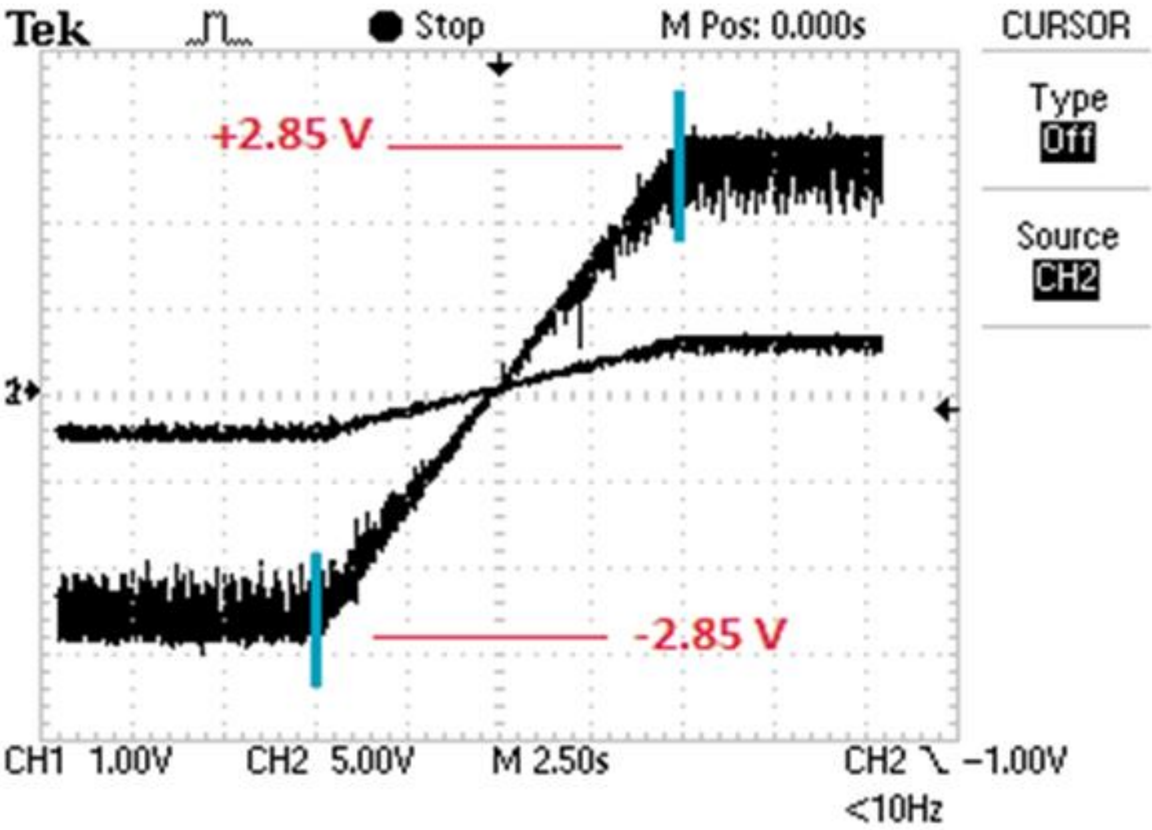


Figure 4-4 U_{TG}-U_{VT1} reversing max left to right

As it shown in the figure, in the beginning induction motor is rotating left (CW) direction and then it is reversed. So from left turning at full speed to right turning full speed takes time of 10s. On the other channel, output of VT1 is indicated. VT1 shows a changing between 0 to 10 which is an input value for PLC. This value is used for Motor Speed Indicator (MSI). 0-10 V analogue voltage value is converted by analogue to digital converter (ADC) which has a resolution of 12bit.

4.3 Torque Sensor Output Signals

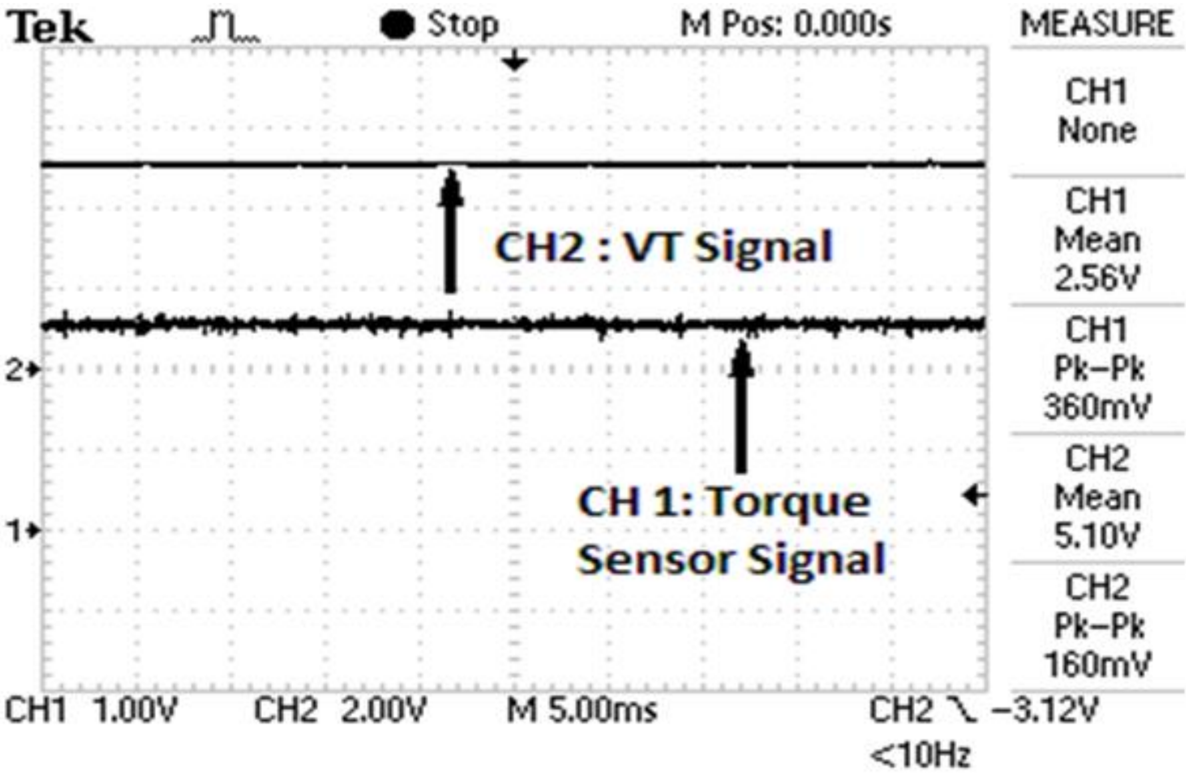


Figure 4-5 Torque sensor motor stopped

Burster 8645 torque sensor can measure up to 7.1 Nm. As it shown in this figure, when there is no load that is applied, sensor gives an output voltage of 2.5 V. Output working range of sensor is 0.5 - 4.5 V. So output values are used with the offset value as 2.5 ± 2V. Principally, that means when induction motor is turning right (CW), output voltage is bigger than 2.5 V and at fully reversed situation output voltage is less than 2.5V .As it expected, in the figures below firstly, induction motor is rotating right (CW) and torque sensor has an output voltage of 2.86 V. With the same characteristic, when the induction motor is rotating left (CCW), sensor has an output voltage of 2.23 V. So torque sensor gave us the expected values respected to 2.5 V offset.

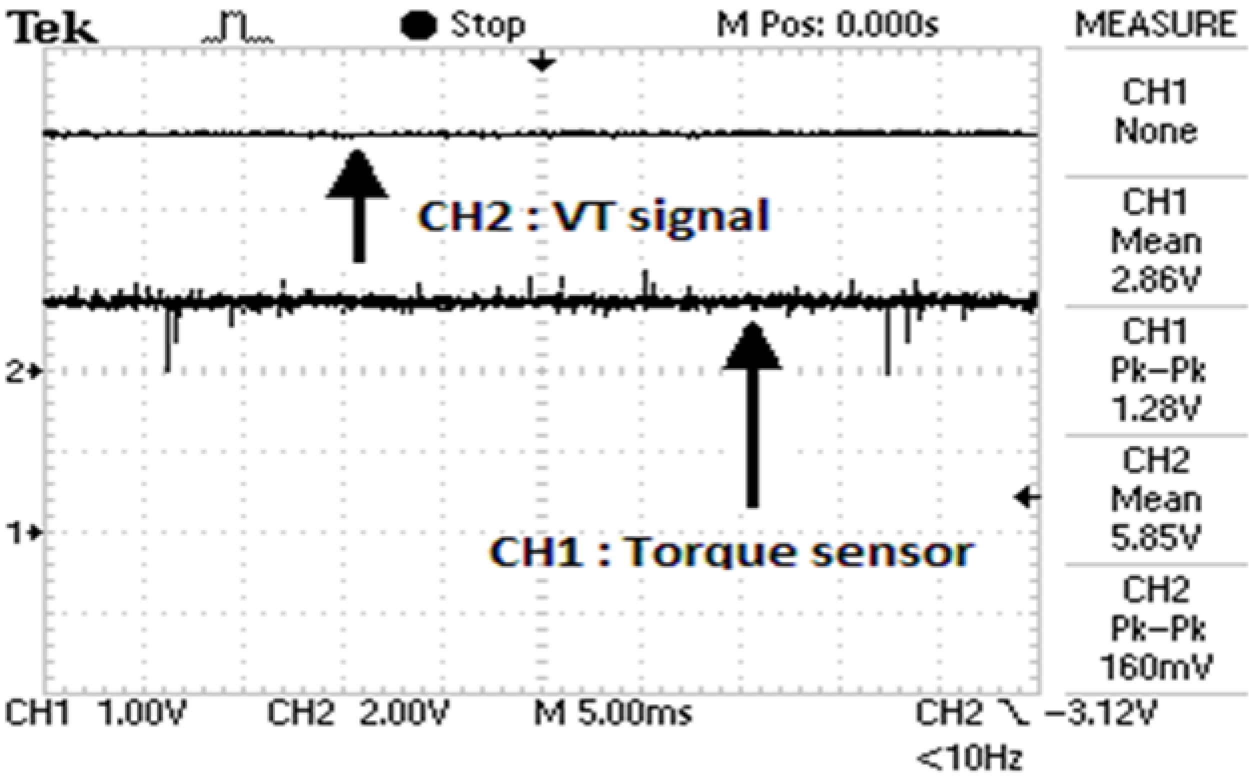


Figure 4-6 Torque sensor motor rotating right (CW)

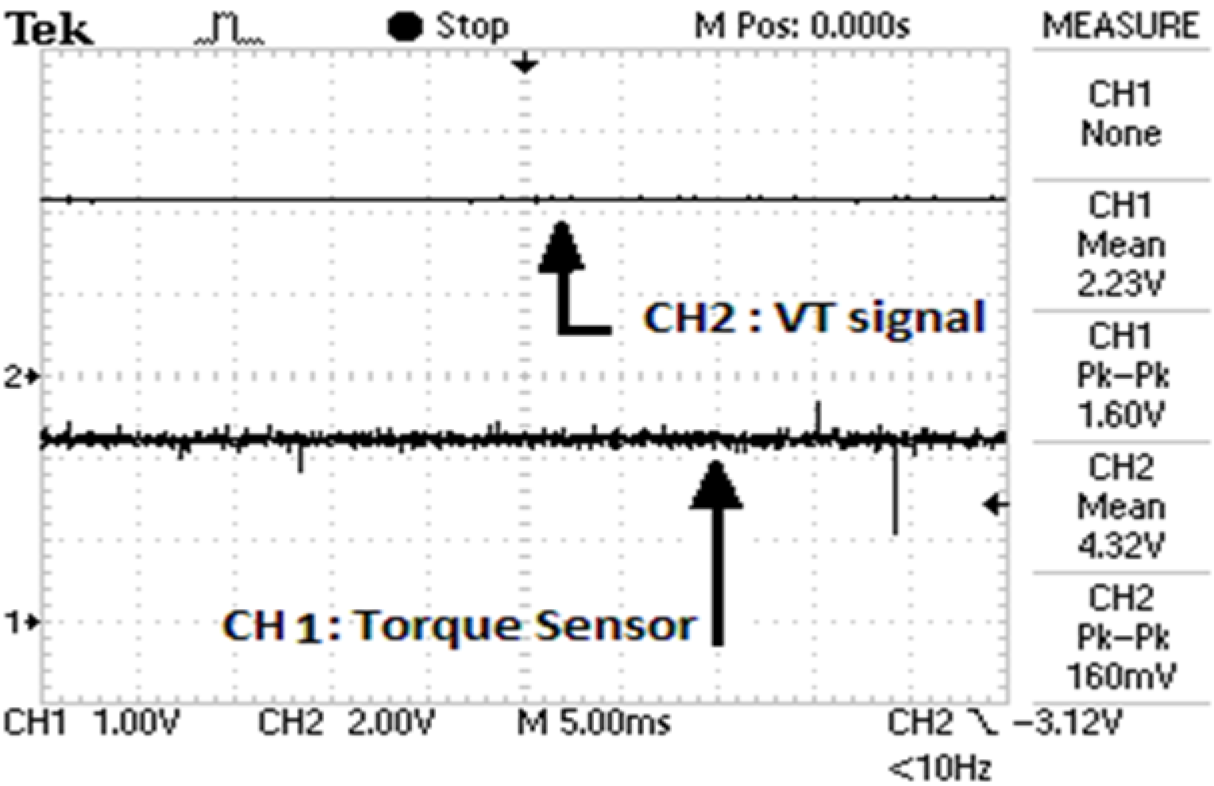


Figure 4-7 Torque sensor motor rotating left (CCW)

5 Future Work

- In the motor test bed, used coupling between motor and load side did not allow us to count the deflection of coupling by such an optical reflex sensor. On the other hand using a spring that has a less stiff torsional deflection coefficient creates more vibrations on itself and this cannot allow us to measure appropriate torque values. So as a solution with available structure of coupling a different type of optical sensor can be adapted to motor test bed.

- Optical reflex sensor TCRT 1000 gives a signal that has a triangular shape. So when this signal wanted to be adapted to high speed counter module, firstly it should be amplified by an amplifier circuitry. Then to get a rectangular shape signal, as a comparator circuit “Schmitt Trigger” can be used. By the help of this adaptation, high speed counter can count properly.

6 References

[1] RT module (Potentiometer Position Indicator) - MCR-R/… (-DC)

[2] Current transducers, MCR-S-1-5-UI-DCI – 2814634

[3] Prof. Dr. Ing. B. Altmann, Process Interface Equipment Lecture Handouts

[4] Prof. Dr. Ing. B. Altmann, Programmable Logic Control Lecture Handouts

[5] Prof. Dr. Ing. B. Altmann, Motor Test Bed Process Interface Lab

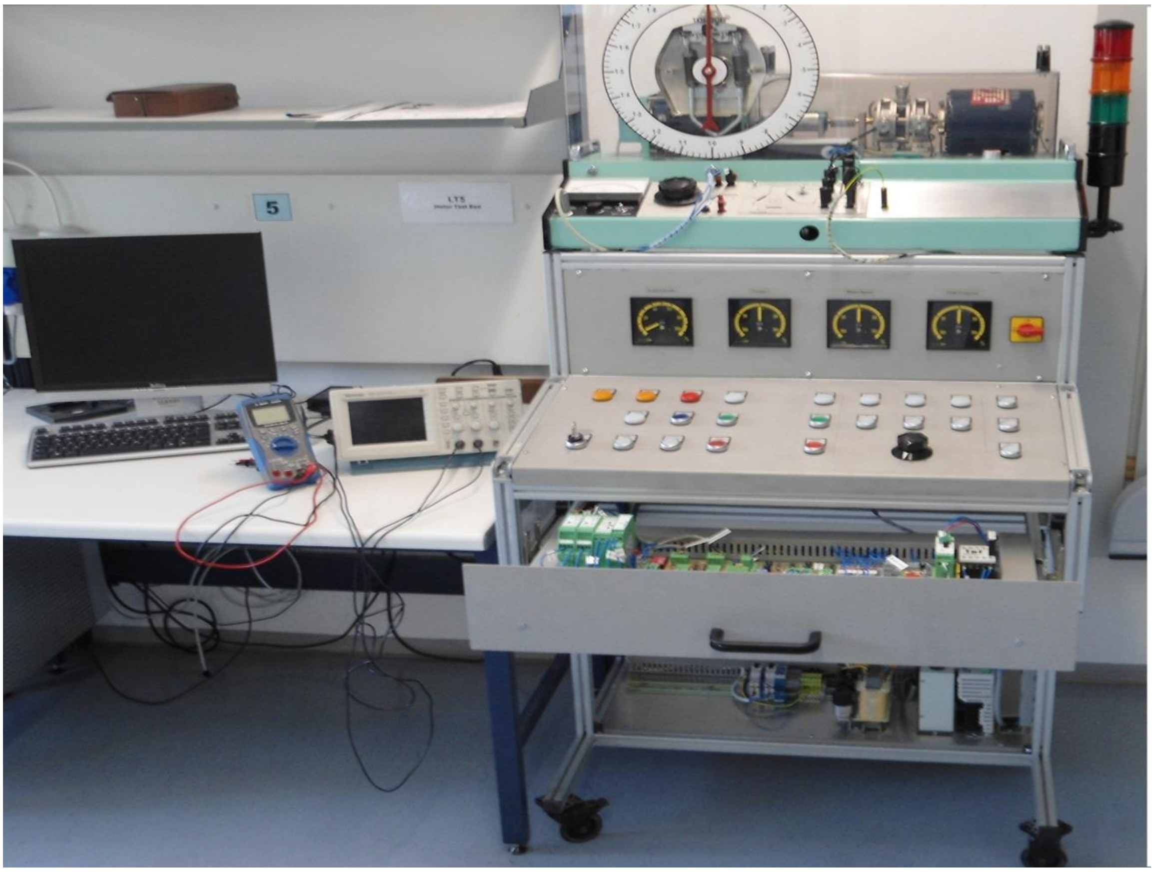
[6]TCRT 1000 optical reflex sensor datasheet, http://www.vishay.com

[7]http://www.tek.com/oscilloscope/dpo5034-0-software-1

7 Appendix

7.1 Lab Test No 5 : “Motor Test Bed V03” Handouts with results and Other Documents

Lab Test N° 5: "Motor Test Bed V03"



1 Required Equipment and Literature

• Motor test bed Version 03	
• Oscilloscope, connected to PC	Tektronix TDS 1012
• Tacho Hi Tester (speedometer)	
• Digital Multimeter	Metex M-3860D
• PC connected to lab printer via LAN	
• Software to capture picture from scope	WVW

2 Objective

The objective of this lab test is to configure and to investigate the interface equipment between a motor test bed and a PLC.

3 Introduction

In order to apply a mechanical torque to the motor, load ON button should be activated. This could be done manually Figure 1 (see attached power point slides) shows a total view of the LT5 test stand. On the test bed structure you find the motor test bed, which is composed of the drive unit (motor, torque meter, brake), the programmable logic controller

(PLC), interface modules, illuminated pushbuttons, and potentiometers as operator interface. The motor is driven by a frequency converter FC (DF4-120-037) which is located below the table. On the left side you see an oscilloscope for the investigation of dynamic signals. The oscilloscope is connected via RS 232 interface to a PC and allows printing out recorded run of curves on the printer in the LISA lab.

Start, Stop, right and left turning of the motor is controlled by manually operated pushbuttons of the operator panel (OP). Indicator lights show the actual status of the drive unit. The rotational speed may be continuously set by a potentiometer (P2). The variable resistance of the potentiometer is measured by a resistance transducer (RT) and applied as standardized analog voltage signal (0 to 10V) to the PLC. According to the setting of potentiometer P2 the PLC outputs an analog voltage (0 to 10V) to the frequency converter (FC) for applying an appropriate electrical field frequency to the asynchronous motor. The frequency of the high voltage output signal (3 phase 230V) of the converter may be in the range of 0...100 Hz. Right or left hand turning is controlled by a binary signal (Contact E4 at FC, see fig. 6).

A reflecting label is mounted on the shaft, which couples the motor to the brake. By this the rotational speed may be measured by a manual operated optical speedometer (fig. 33). Furthermore two optical reflex sensor is mounted to detect the sense of rotation. (Fig. 9) .

The rotational speed of the drive unit is indicated by a tachogenerator (TG) mounted to the axle at the end of the electrical brake. The bipolar analog voltage output signal of the tachogenerator (±2,9V) is converted into a standardized unipolar voltage signal (0...10V) by an adjustable voltage transducer (VT2) with integrated low pass filter and connected to an analogue input of the PLC.

by activating a push button at the operator panel. The mechanical torque is proportional to the current (0 to 3,5A) running through the brake which may be manually varied by the rotary knob P1 located at the basic body of the test bed.

The true RMS value of the break current is measured by a current transducer (CT2) and fed as analog voltage signal (0...10V) into the PLC. The standardized live zero current output signal (0…10V) of the CT1 is monitored by a loop powered current monitoring module (CM) delivering a binary output signal (metallic contact). The contact setting is adjustable to a certain threshold e.g. 10% of max break current. Only a closed contact at the CM output (load current less than 10% of max. value) allows the PLC to start the motor if the FC had been stopped.

4 Preparation (to be done at home prior to lab execution)

4.1 Read this description of LT5 including the attached power point slide
4.2 Perform the tasks given on slide 6 (internal representation of analogue signal)
4.3 Perform the tasks given on slide 13 (detection of rotating direction)
4.4 Perform the tasks given on slide 17 (adaptation of TG)
4.5 Perform the tasks given on slide 22 (current monitor)
4.6 Read for information detailed manuals provided on server (home/ doz /stud/altmann/pp/pp_lab…)

5 Test Procedure (to be done at LISA lab)

ATTENTION: The output terminals of the frequency converter connected to the ASM motor carry dangerous voltages. Don't touch these conductors!

5.1 First steps (fixed speed F3)

- Protection cover enable will be checked (It should be on **Enabled Mode : 0**)
- Ensure power switch set to OFF
- Turn **P1 (Load Brake)** to fully **CCW** (counter clock wise)
- Turn **P2 (Variable Frequency)** to fully **CCW**
- Load has to be turned **OFF**(no load)
- Turn power switch **ON**
- Check indicators at Operator Panel

- Select **F3** and motor turning **left**
- Check area of axles
- Press **Enable FC** on OP ~> **Motor starts turning left with fixed frequency F3**
- Check Field Frequency Indicator (**FFI**) $f_{3\_L\_FFI}$ = 40 Hz(40%,left side indicator)
- Read out indicated speed at Frequency Converter (**FC**) $f_{3\_L\_FC\_DISPLAY}$ = 40 Hz (negative)
- Measure rotational speed manually with **speedometer** $f_{3\_L\_Speedometer}$ = 19,87 Hz (r/s)
  and register readout (figs. 12 , 34)
- Command motor turning **Right** ~> **Reversing motor**
- Check Field Frequency Indicator (**FFI**) $f_{3\_R\_FFI}$ = 40 Hz (40%,right side)
- Read out indicated speed at Frequency Converter (**FC**) display $f_{3\_R\_FC\_DISPLAY}$ = 40 Hz
  (located on lowest part of test bed
- Measure rotational speed manually with speedometer $f_{3\_R\_Speedometer}$ = 19,8 Hz (r/s)
  And register readout (figs. 12, 34)

- Explain the lack of frequency:
  The asynchronous induction motor in motor test bed has 2 poles. The pole changing aspect with "Dahlander Circuitry" shows a reduction in field frequency comparison to stator field frequency. This affects to motor as "Slip".

- Turn **Load ON** and vary **P1** slightly ~> **Apply a torque of M = 0,2Nm**
  and measure the rotational speed $f_{3\_R\_0.2Nm}$= 19,09 Hz(r/s)
- Determine the decrease in frequency **Δf =** 0,71
- Increase the torque up to critical value and see what happens
- Set **P1** to fully **CCW** ~> **Release torque**
- Turn the **Load OFF**

- When motor has reached **F3**
  set **Load Brake ON** ~> **STOP motor by active braking**
  and measure the time to stop $t_{F3\_STOP\_BRAKE\_ON}$ =1,7 s
- Reversing time of the motor from left to right $t_{REVERSING\_L\_R}$ = 4,7 s
- When the motor is stopped, try to turn the axle manually (feel the braking torque)
- Set **Load Break OFF** (release brake) ~> **motor starts turning right**
- When motor has reached **F3**
  Disable Frequency Converter (FC) ~> **STOP motor by turning voltage OFF**
  and measure the time to stop $t_{F3\_STOP\_FC\_OFF}$ =3,6 s
- When the motor is stopped, try to turn the axle manually (feel the missing torque)

5.2 Adapt Potentiometer P2 to PLC (variable speed)

The potentiometer P2 (set point of motor speed) has to be adapted to PLC such a way, that its full deflection corresponds to the full range of motor speed.

Select Reference Voltage:

- Remove the connector of Resistance Transducer (**RT**)
- Measure resistance of Variable Frequency Potentiometer (**P2**) R_{poti2} = 0,825 kΩ
- Set selector of U_{ref} on top of **RT** to appropriate value (figs. 16,17) and plug in connector U_{ref} = 1 V

Adjust **Offset**:

- Turn **P2 to fully CCW**
- Adjust the **Zero** potentiometer of **RT** ,firstly **acoustically** (Sound of motor- getting higher or lower), then by **observation of**

The state of **motor** (running, slowing down or accelerating to max. speed)

And finally check the **zero point** on Field Frequency Indicator (**FFI**)

- Measure the corresponding Voltage at **RT output** U_{RT_min} = 0,002 V

Adjust **Gain**:

- Turn **P2 to fully CW**
- Adjust the **Span of** potentiometer of **RT**, firstly **acoustically** (Sound of motor- getting higher or lower), then by **observation of**

The state of **motor** (running, slowing down or accelerating to max. speed)

And finally check the **max point** on Field Frequency Indicator (**FFI**)

- Measure the corresponding Voltage at RT output U_{RT_max} = 10,35 V

Verification

- **Start motor** and **check the function of variable speed** setting (no fixed frequency is selected)

- Set **P2 to fully CCW** ~> **speed = 0?**
  read out the flowing values from **easySoftCoDeSys** PLC software(see **attachment** for PLC software) and Frequency Converter(**FC**):

  f_POTI = 2 f_FC = 2 Display of **FC** = STOP

- Set **P2 to fully CW** ~> **speed = max.?**
  read out the flowing values from **easySoftCoDeSys** PLC software(see **attachment** for PLC software) and

Frequency Converter(**FC**):

f_POTI= 4095 f_FC= 2448 Display of **FC** = 99,4 Hz

- Set Frequency Converter(**FC)** to **Disable** ~> **Stop motor**

5.3 Adapt Tacho Generator to PLC (variable speed, motor idle)

The bipolar voltage signal of the Tacho Generator TG has to be converted into a unipolar voltage signal in the range 0V to +10V and, furthermore, the superimposed ripple voltage has to be suppressed.

Basic Measurements:

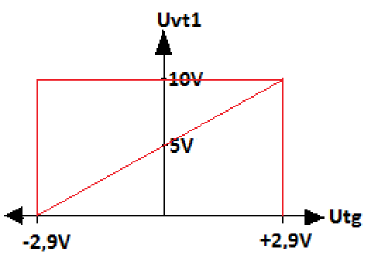
- Connect OSC: CH1 to TG at de-bouncing circuitry (fig.22)
- Connect OSC: CH2 to output of Amp 1at de-bouncing circuitry(fig.22)
- Assure Ground of OSC to be connected to 0V at de-bouncing circuitry (fig. 22)
- Select the jumper setting of Amp1 such, that the OPA operates as a pure DC amplifier (no capacitor connected)
- Start motor turning **left** and select **max. speed**
- Adjust Gain and Offset of Amp 1 such that input and output signals are identical.
  That means: K_{p1} = 1 and U_{off1} = 0V
  ~> OSC: CH1 and CH2 show identical signals (print out screen)
- Determine the mean value of TG voltage $U_{TG\_AV\_Lmax}$= -2.7 V
- Select motor turning **right** and **max**. speed
- Register TG output signal at full speed (print out screen)
- Determine the mean value of TG voltage $U_{TG\_AV\_Rmax}$= +2,7 V
- Explain the ripple of the superimposed TG voltage signal on printout
- Determine the frequency of the superimposed signal f_1 = 295 Hz(1 / 3.4s)
- Determine the peak to peak voltage of the superimposed signal U_{PP}= 1.12 V

Adjustments of low pass filter (Time Constant):

- Set the filter parameters of amp1 to appropriate values; T=R*C => R=5k / C=10µ
  insert jumper to connect the capacitor (T=**50ms**)
- Verify the effect of de-bouncing circuit (red button) (print out screen)
  Compare TG and amp1 signals (OSC : CH1 and CH2)
  Since de-bouncing circuitry has a small problem, it doesn't give a pure rectangle 5V when the user pushes to red button. Circuitry should be optimized.

Adjustment of measurement amplifier (DC signal adaptation):

- Adjust **Zero and Span** at Amp1such, that n_{min} ... n_{max} correspond to 0...10V
  Explain the steps how to proceed (remember: $U_{VT1}=K_{P1}\cdot U_{TG}+U_{off1}$):
  1).When motor stops (n = 0), U_{VT1} =5V offset value should be adjusted
  2) When motor is running to CW at max speed, U_{VT1} =10 V gain value should be adjusted
  3)When motor is running to CCW at max speed, U_{VT1} =0 V should be adjusted at VT2(amp1 circuitry)



- Verify some values:

Measured at:	max speed turning left	Motor stopped	max speed turning right
U_{TG}	-2,7 V	0 V	+2,7 V
U_{VT1}	0 V	+5 V (Offset)	10 V
f_TACHO at easySoftCoDeSys (see attachment)	410	2041	3686

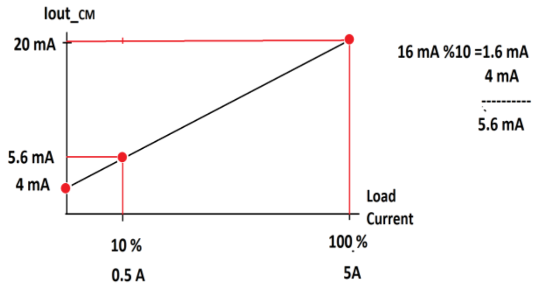
- Record U_{TG} and U_{VT1} while reversing from full speed left to full speed right (print out screen)
- Determine the time interval for this operation $t_{max\_R\_L}$= 10s
- Stop motor ; **Disable FC**

5.4 Monitoring Load Current; Adjust Parameters of Current Monitor(CM)

- Keep motor stopped
- Connect voltage probe (OSC: CH1) to output voltage terminal of **CT2** to measure DC voltage output signal of the current transducer
- Connect current probe (fig. 32) to OSC: CH2 to measure the load current of electrical brake in the conductor connected to terminal c of **CT2**
- OSC setting: CH1:5V / CH2:1V; Probe:10x / Time Base: 100ms; trigger: DC line; Auto trigger set measurement CH2: RMS
- Remove connector (fig.11: 5.5) and insert ampere meter (fig. 32) into current loop circuit (live zero signal) between CT2 and CM

- Turn the Load **ON**
- Set **P1 to fully CW** and record current signal and **CT2** output voltage (print out screen)
- Determine max. RMS load current by OSC: **CH2** I_{RMS_max} = 3,3 A
- Register corresponding current loop signal (read out ampere meter) I_{CT_max} = 16 mA

- **Reduce** load current down **to 10%** of previous max. value $I_{RMS\_10\%}$ = 330mA
- **Adjust threshold** of CM (fig. 28) to detect that value
- Measure adjacent current loop signal (read out ampere meter) $I_{CT\_10\%}$ = 5.57 mA
  and compare to calculated value of T19-1)



- Increase for **test** purposes the load current to more than 10% of max. value.
  LED of CM should now be illuminated.
- Select frequency F3 and motor turning right
- Try to start the motor (start of motor should be inhibited!)

- Set **P1 to fully CCW** and turn the Load **OFF**
- Remove ampere meter from current loop signal and insert bridge connector again (fig. 11).

Turn power off, shut down computer and clear table!

6 Report

The report should comprise the following:

- Lab test description
- Solutions of preparatory tasks
- Notes and measurement results of lab execution

Attachments

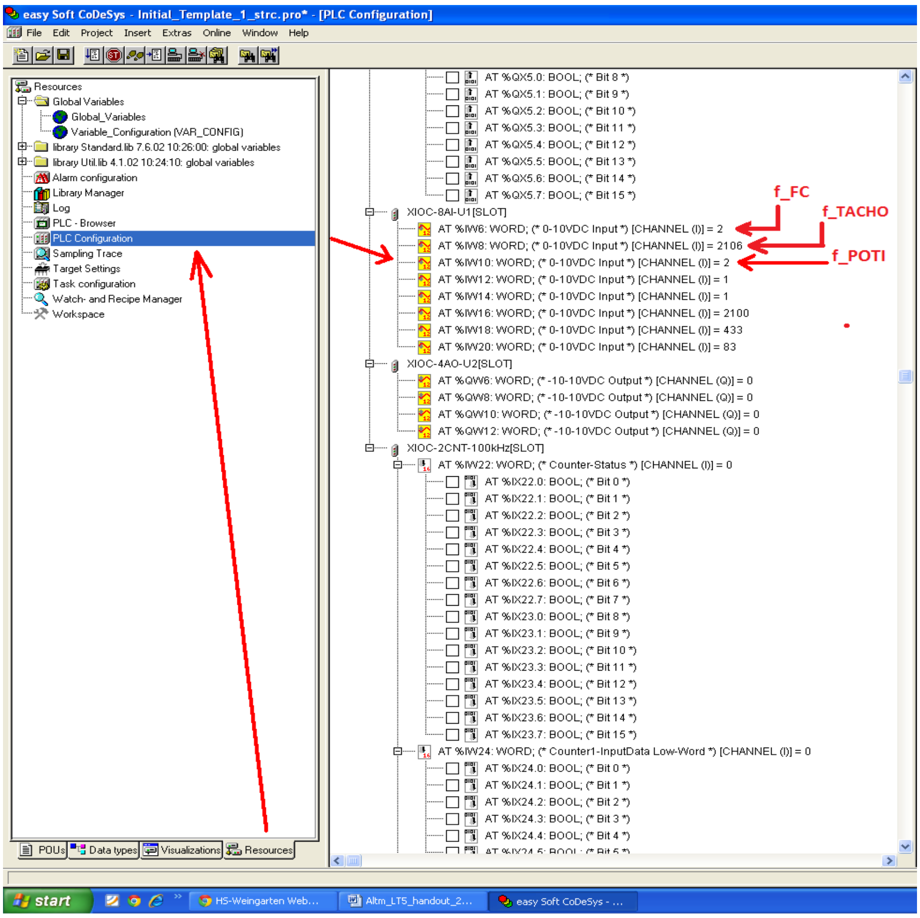
- Power point slides: Technical description and tasks to be prepared prior to lab execution
- Verification of setpoints of Poti2 through RT Module (1 page)

Verification of Setpoints of Poti2 through RT Module

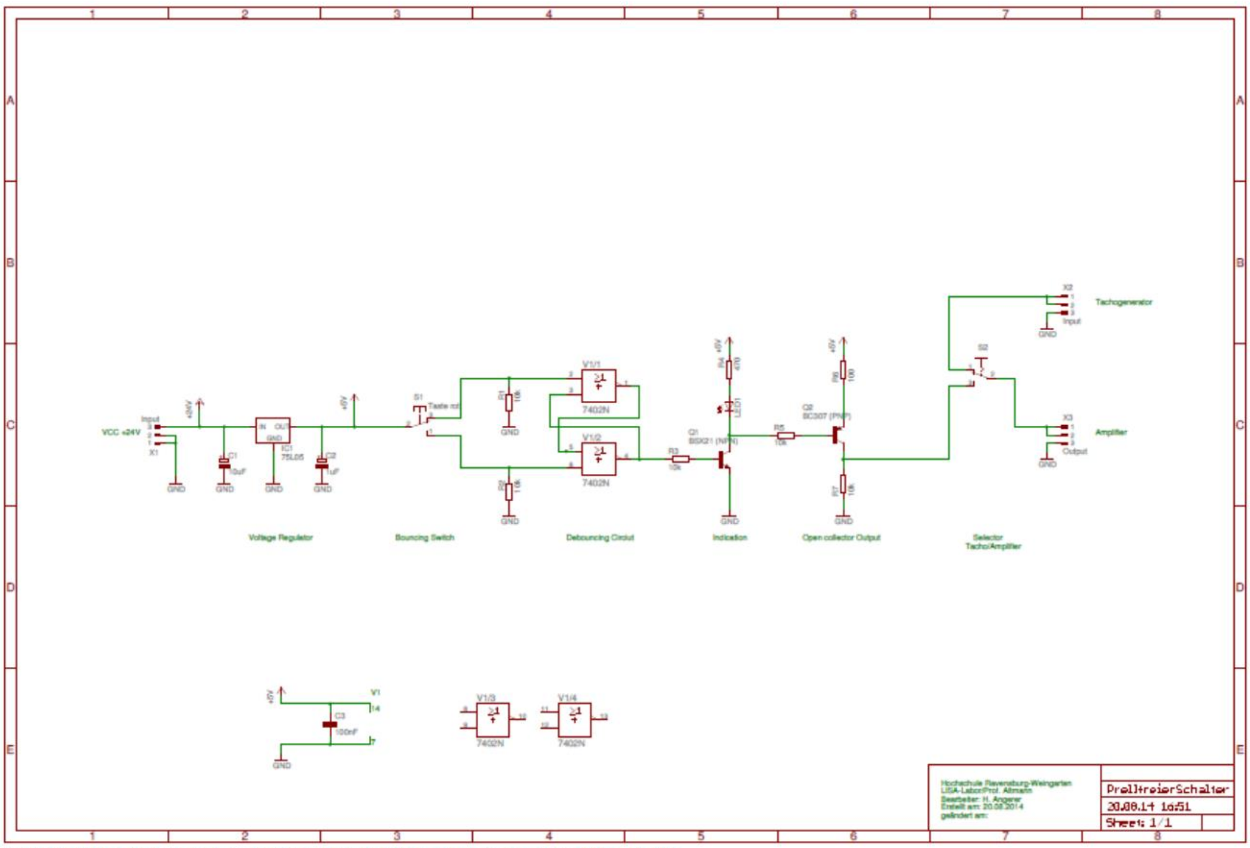
As it shown in this figure, easysoftCodeSys program show the configuration of PLC modules. In the Analog Input module(**8AI**), **RT**(Resistance Transducer) module corresponds to a physical address.(**AT %IW10**) .Here as we can see,the integer value of correspondent physical address varies between some upper and lower limit .This upper and lower limit is determined by the resolution of **ADC**(Analog to Digital Converter) of Analog PLC Module(**8AI**).Integer value varies between **0** to **4095**.

What's the resolution of **ADC**?

- To adjust the RT, zero and span screws on the module will be used.Adjustment will be done respected to integer values on **AT %IW10** physical address**.** It varies between **0-4095**.



7.2 Circuit Plan of De-bouncing Circuit



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7.3 Powerpoint Slides : Technical Description of Test Bed

Vorlesung Prozeßperipherie

LT5 Motor Test Bed | **Total View**

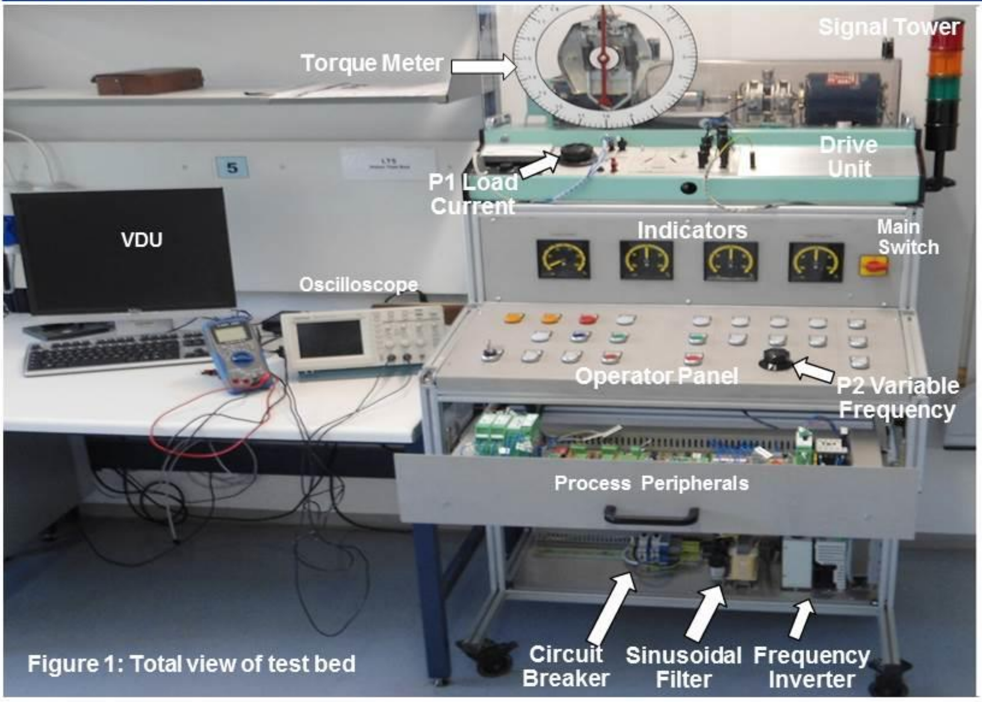


Figure 1: Total view of test bed

Vorlesung Prozeßperipherie

LT5 Motor Test Bed | **Control Board**

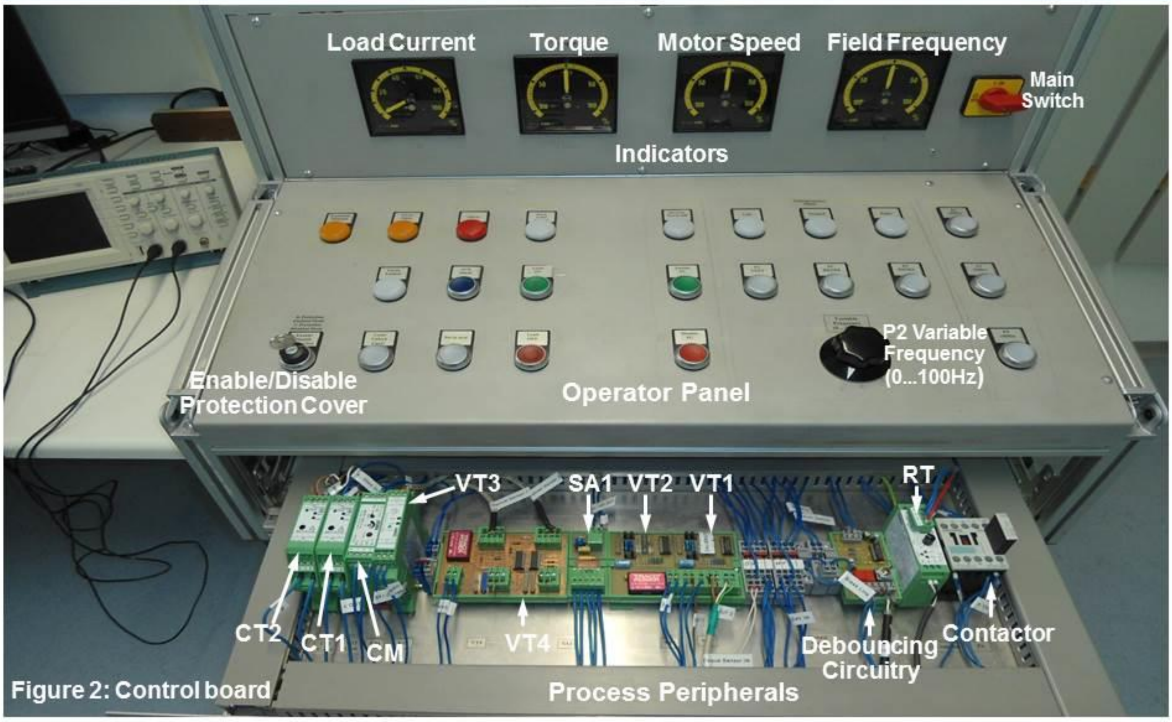


Figure 2: Control board

LT5 Motor Test Bed — Location of Components

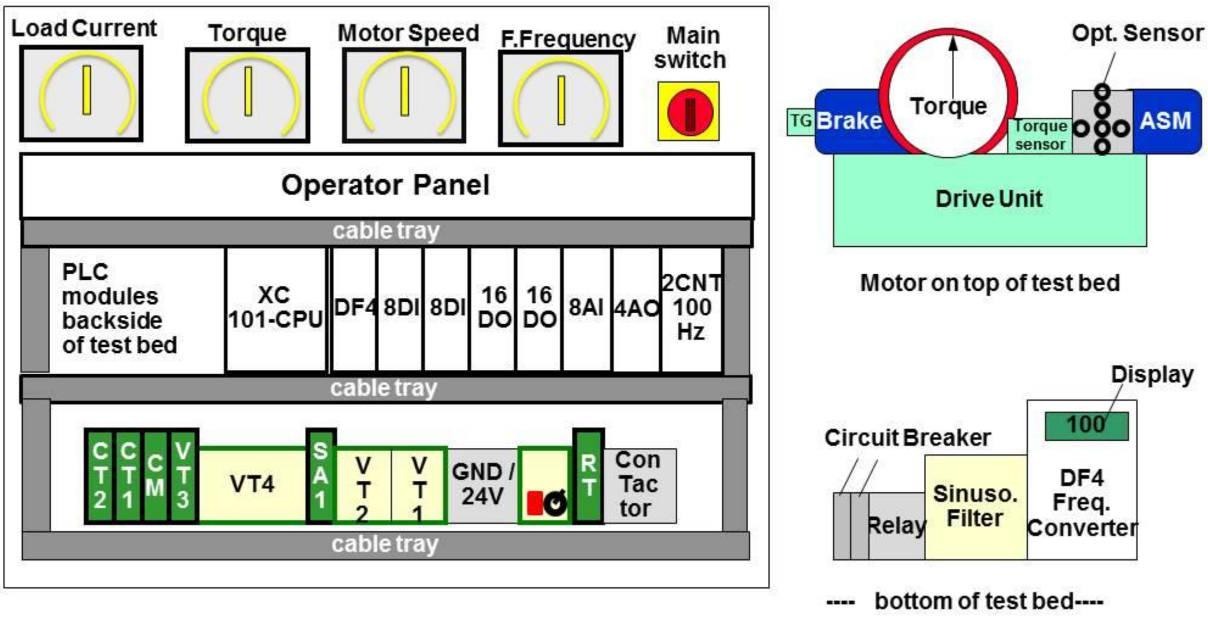


Figure 3: Location of test bed components

Vorlesung Prozeßperipherie

LT5 Motor Test Bed — Operator Panel

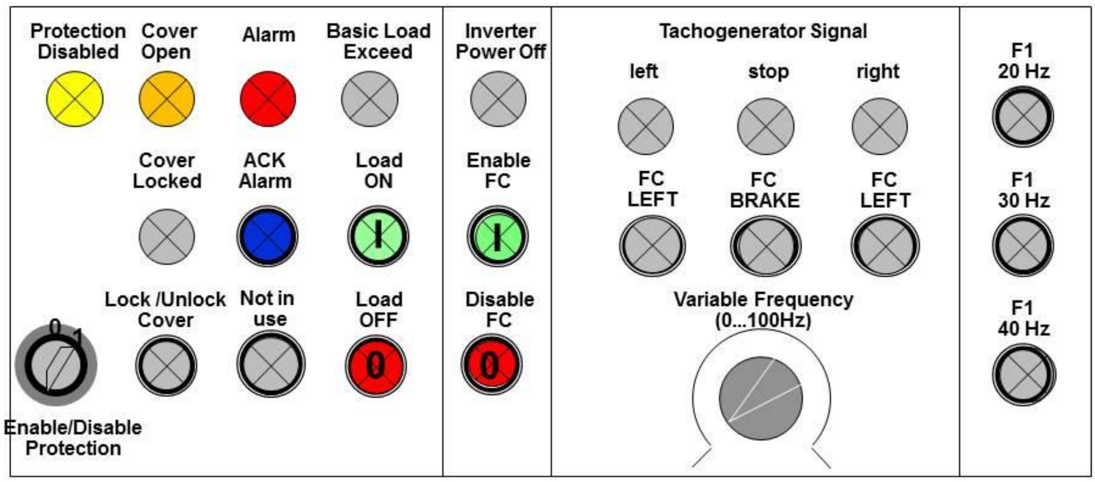


Figure 4: Operator Panel

LT5 Motor Test Bed — PLC

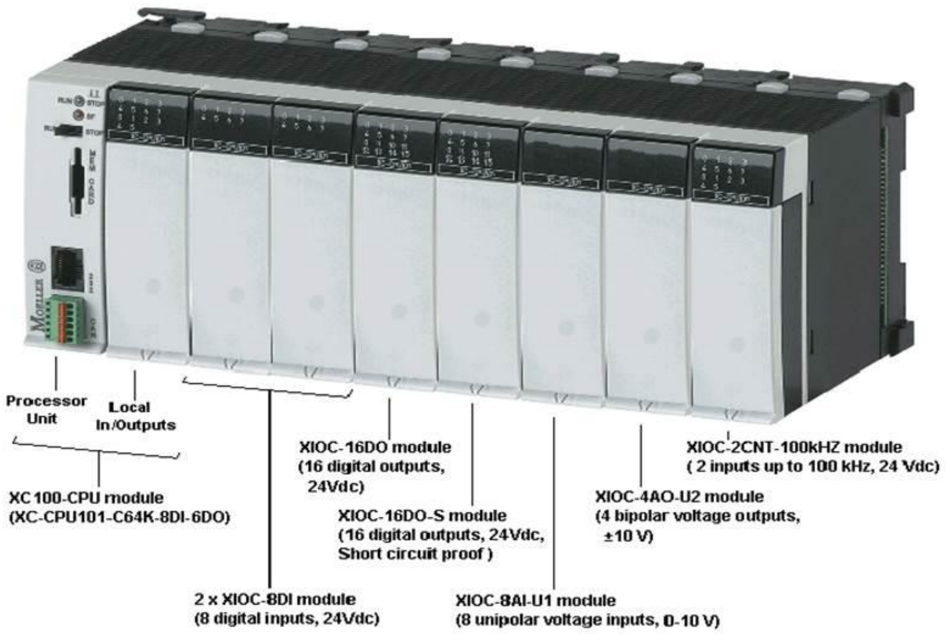


Figure 5: PLC Basic Module (Eaton Moeller XC101) and expansion modules(digital i/o ,analogue i/o,counter)

LT5 Motor Test Bed — Frequency Converter (FC)

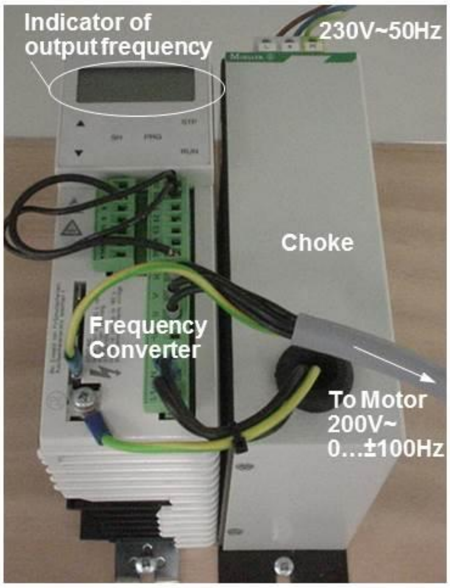


Figure 6: Frequency converter DF 4-120 (FC)

Binary interface to PLC (terminals at DF4-120)

E1 set:	F1 = 20Hz
E2 set:	F2 = 30Hz
E1 and E2 set:	F3 = 40Hz
E3 set:	DC brake active
E4 not set:	motor turning right
E4 set:	motor turning left
28 set:	enable converter
39:	GND to PLC GND

Analog interface to PLC (terminals at DF4-120)

7:	analog GND to PLC GND
8:	reference value of converter frequency 0..10V correspond to 0..100Hz (defined by setting of FC internal jumpers)
62:	monitor output signal of FC 0..6V correspond to 0..100Hz

Task to be prepared at home prior to lab execution:

T6-1) The monitor signal (62) is connected to analog module of the PLC (input range: 0...10V, 12bit converter). The FC is set to max. speed (F_{max} = 100Hz). Determine the PLC internal representation of the corresponding monitor signal as an integer value: (See the attachment for PLC configuration)

N_{FC100} =

Vorlesung Prozeßperipherie

LT5 Motor Test Bed

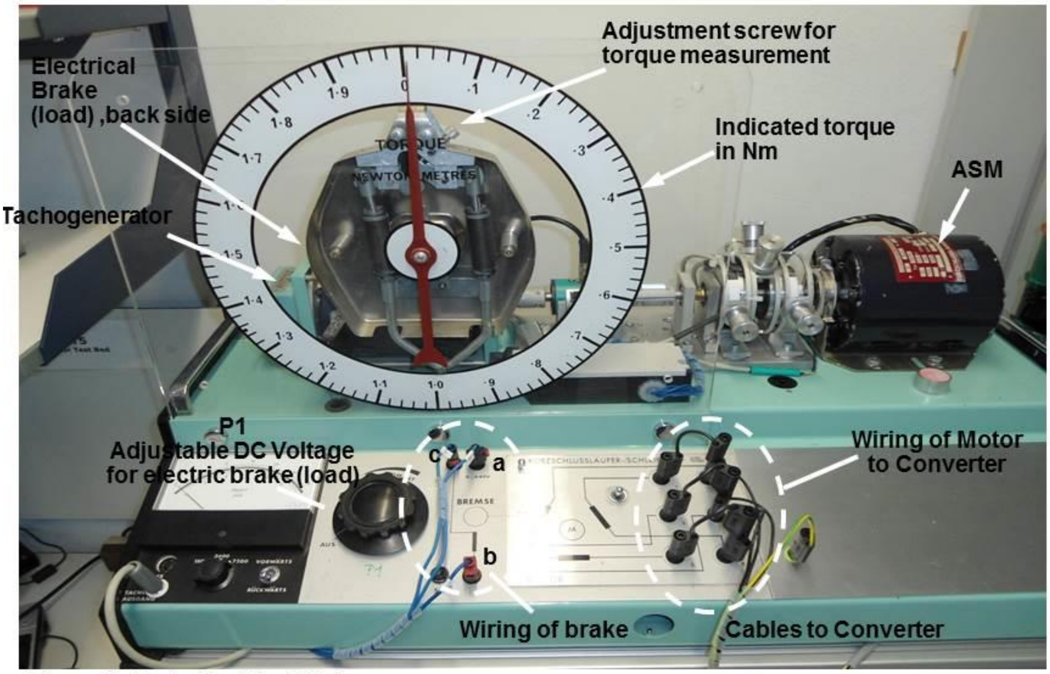
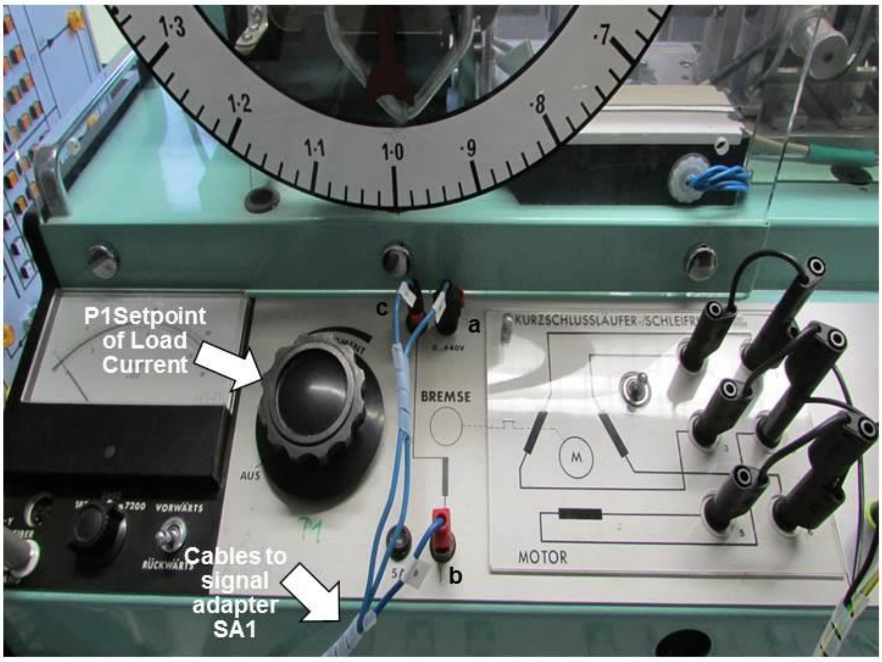


Figure 7: Motor Test Bed N° 2

Vorlesung Prozeßperipherie

LT5 Motor Test Bed Electrical Load (Adjustable)



$U_{\_}$ depends on setting of P1

~> variable rectified DC voltage Uab (Uab_av = 0 … 40V)

~> variable DC current I_L (I_L = 0 … 3,8A)

Load connected to rectifier, when contactor between a – c is closed

Electrical load circuit is totally potentially isolated

!!!!! (inductive load) !!!!!! Never remove cables between a – c, if P1 is not in fully CCW position!

Figure 8: Electrical load (break)

Vorlesung Prozeßperipherie

LT5 Motor Test Bed **Drive Unit**

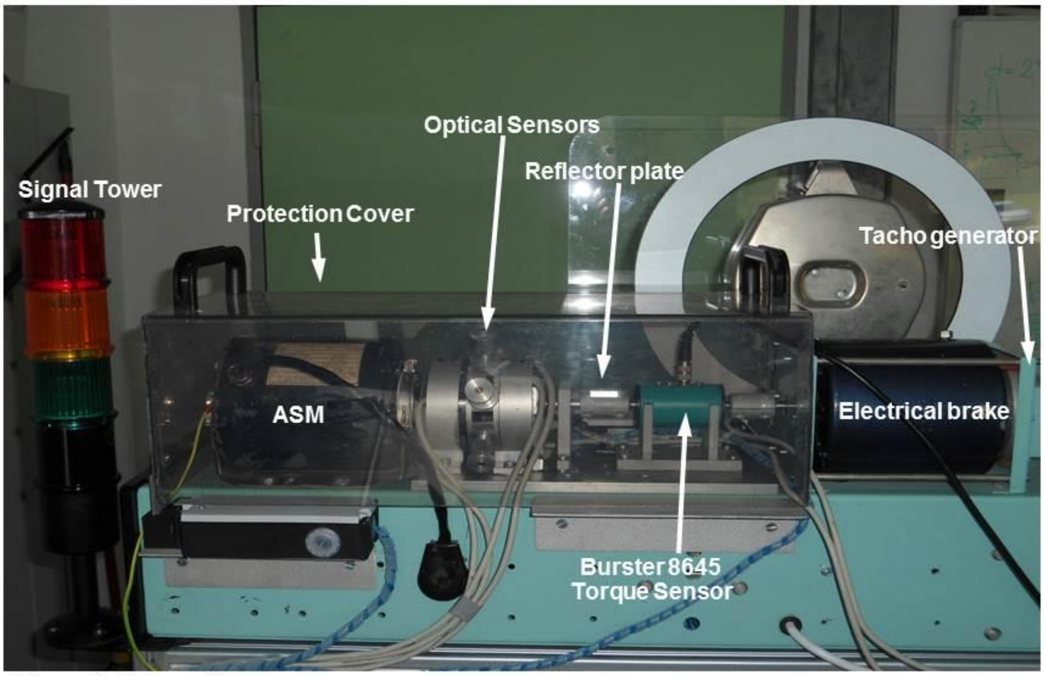


Figure 9: Drive unit

Vorlesung Prozeßperipherie

LT5 Motor Test Bed **Block Diagram**

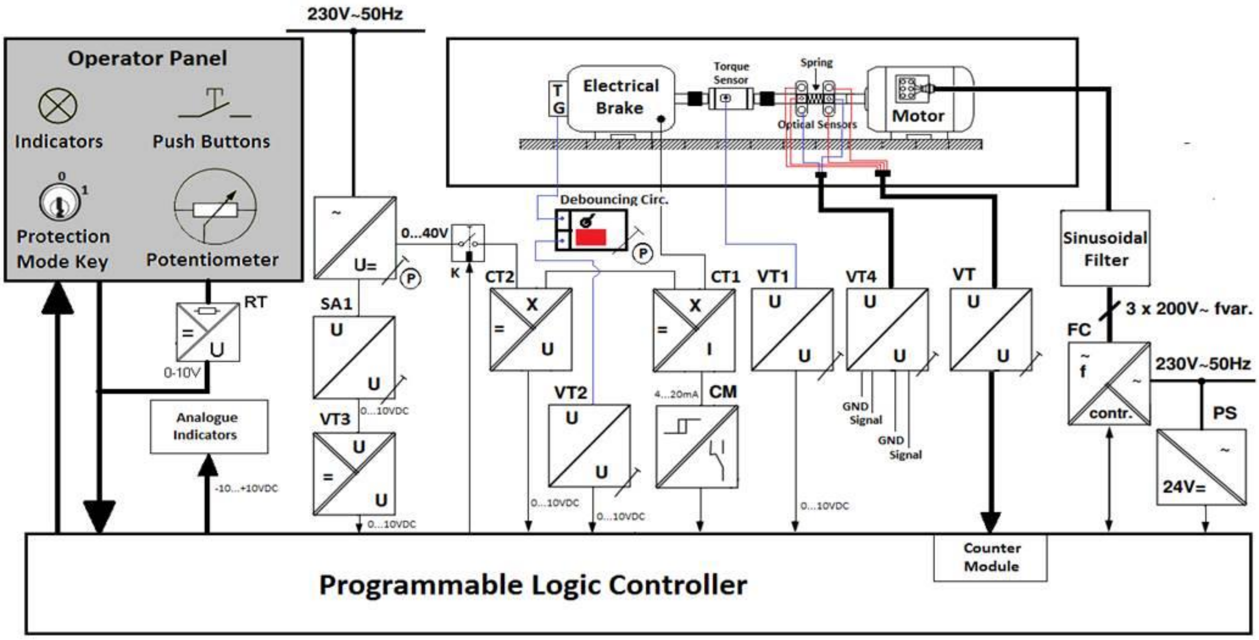


Figure 10: Block diagram

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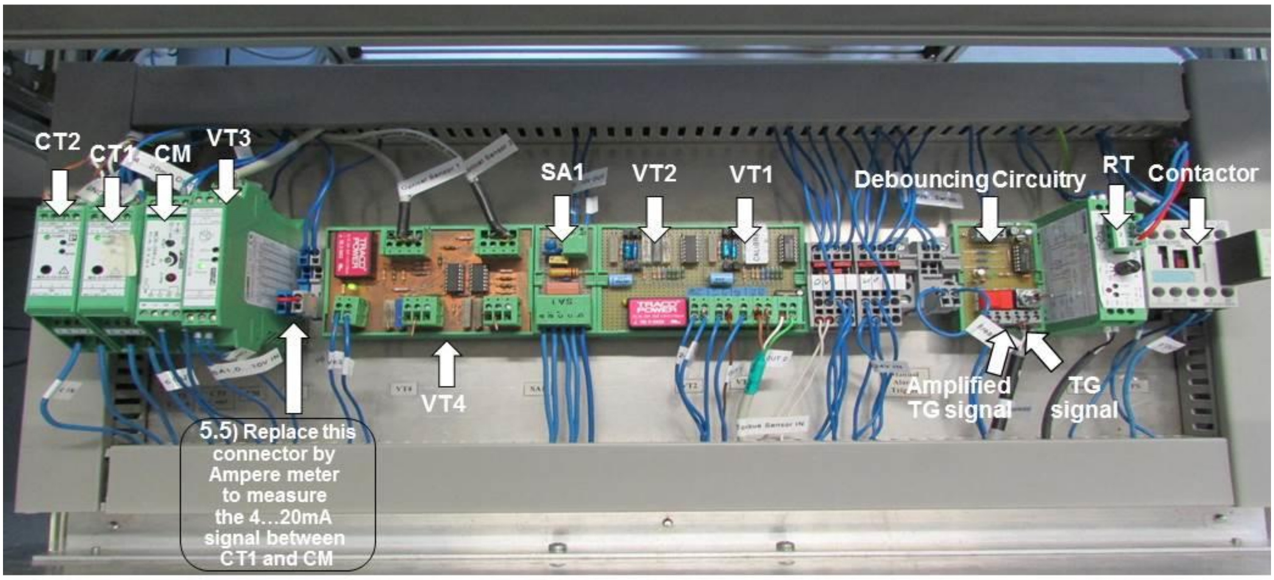
LT5 Motor Test Bed — Location of Interface Modules on Control Board



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LT5 Motor Test Bed — Measuring Rotating Speed

Light spot points at reflector plate

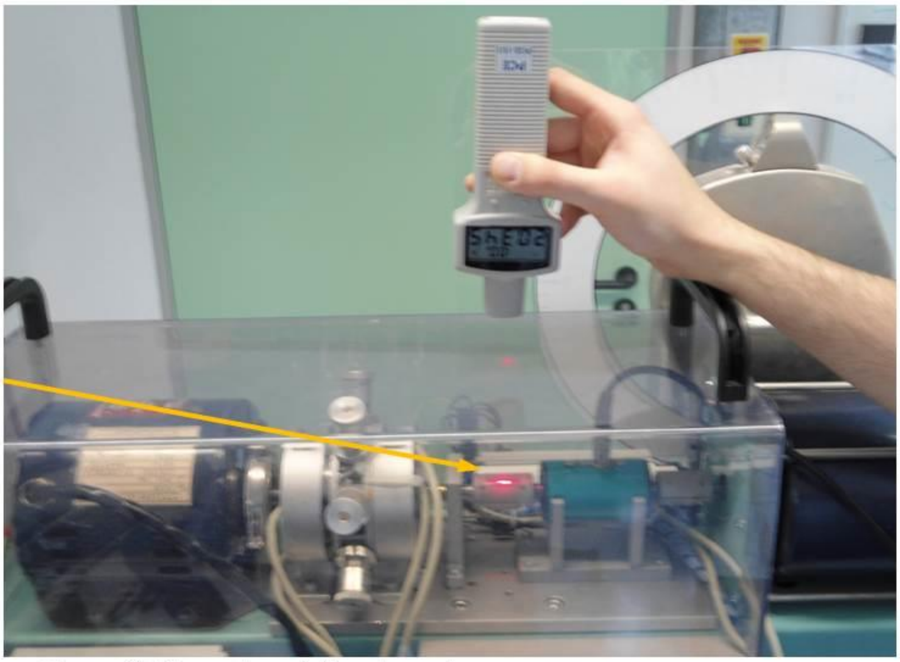
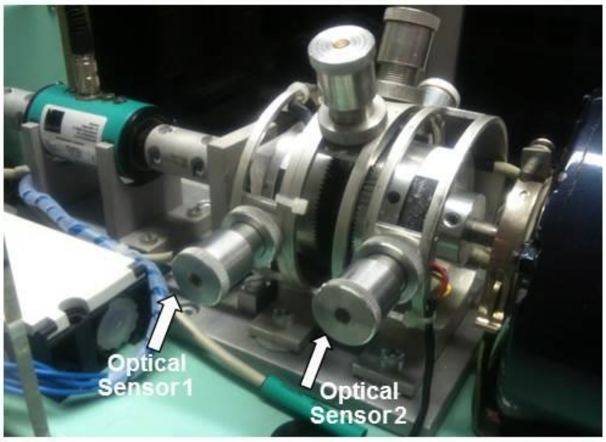


Figure 12: Measuring rotational speed

LT5 Motor Test Bed — Detection of R/L Rotation



Definition: Phase shift between Optical Sensor 1 And Optical Sensor 2 gives the direction of rotation.

Optical Sensor1 is used as reference and detects the rotational speed of motor .

Optical Sensor2 is used to detect the orientation of rotation.

<u>Tasks to be prepared prior to lab execution</u>

T13-1) Determine all possible angular positions α_i of OS2 such, that the output signal of OS2 is deferred by a quarter of the time period of the periodic output signal of sensor OS1.

T13-2) Draw a timing diagram showing the output signals of OS1 and OS2 if n > 0 and n < 0.

T13-3) Determine a logic circuit to detect right or left hand turning of motor

LT5 Motor Test Bed — Potentiometer Position Indicator (RT)

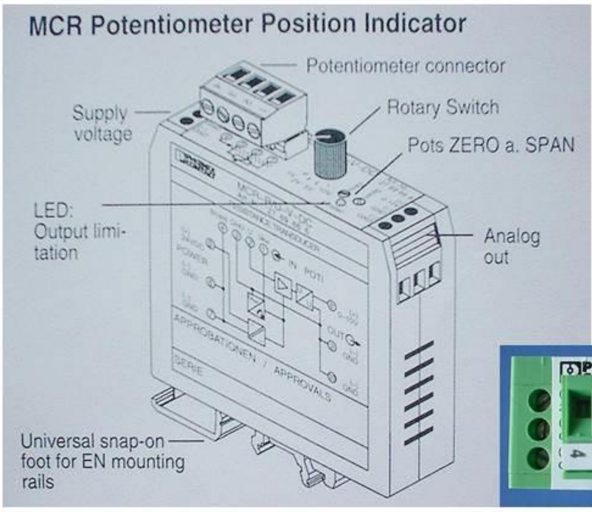


Figure 16: Resistance transducer (RT)

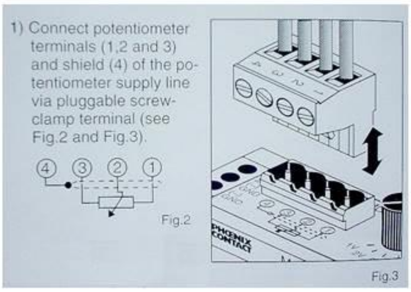


Figure 18: Connecting potentiometer

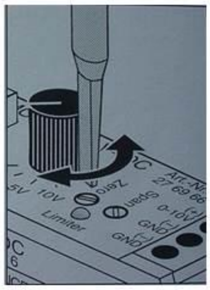


Fig. 19: Adjusting Zero and Span

Figure 17: Top view

The potentiometer position indicator detects the position of the potentiometer slider and converts it into a standard voltage output signal 0..10V.
The output voltage has to be calibrated by adjusting Zero and Span.

Select the reference voltage as follows:

R = 100Ω… 2kΩ	~> Uref = 1V	I =10…0,5mA
R = 400Ω… 4k Ω	~> Uref = 2V	I = 5…0,5mA
R = 1k Ω…10k Ω	~> Uref = 5V	I = 5…0,5mA
R = 2k Ω…20k Ω	~> Uref = 10V	I = 5…0,5mA

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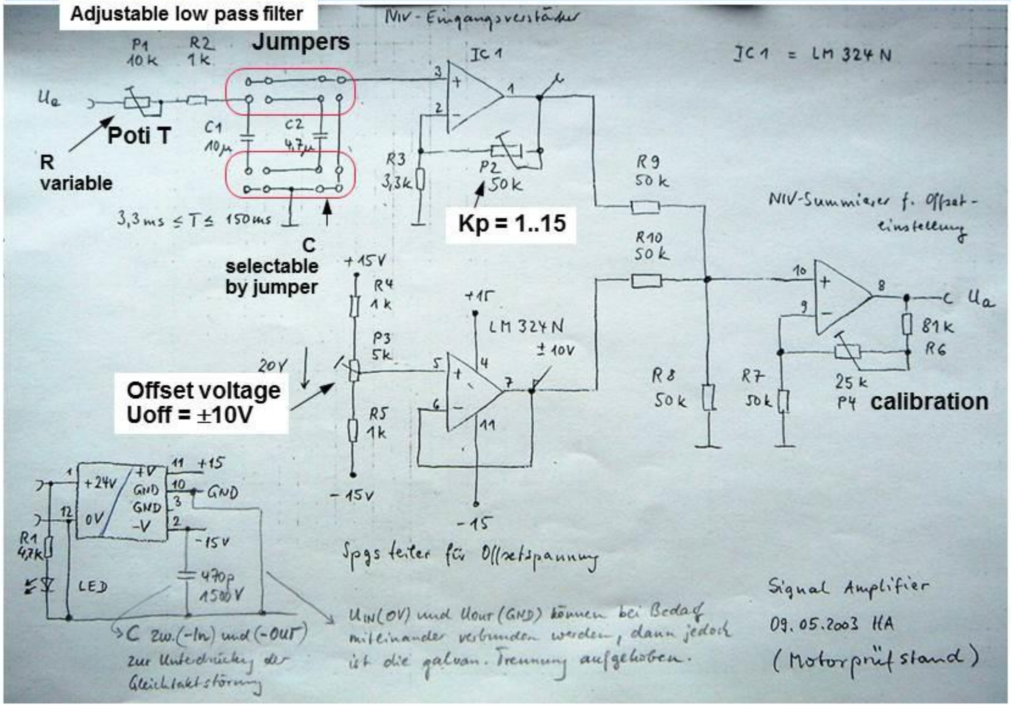
LT5 Motor Test Bed — VT2 Circuit Diagram



VT2 is composed of two signal amplifiers:
- Amp 1
- Amp2

Each of them comprises:
- Input filter with adjustable cut off frequency (fc=1...48Hz)
- DC amplifier with adjustable gain (Kp=1...15, pot P2)
- adjustable Offset voltage (Uoff=±10V; poti P3)

Gain and Offset are adjustable independent of each other

Adjusting cutoff frequency:
- input capacitance C selectable by jumpers
- input resistance R adjustable by poti P1

Figure 20: VT2 circuit diagram of Amplifier1

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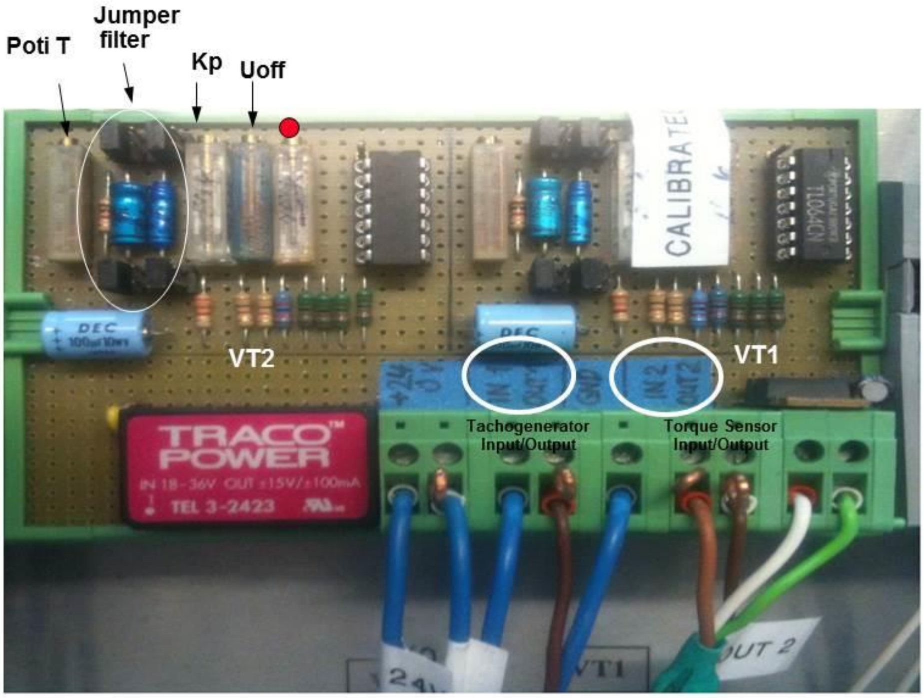
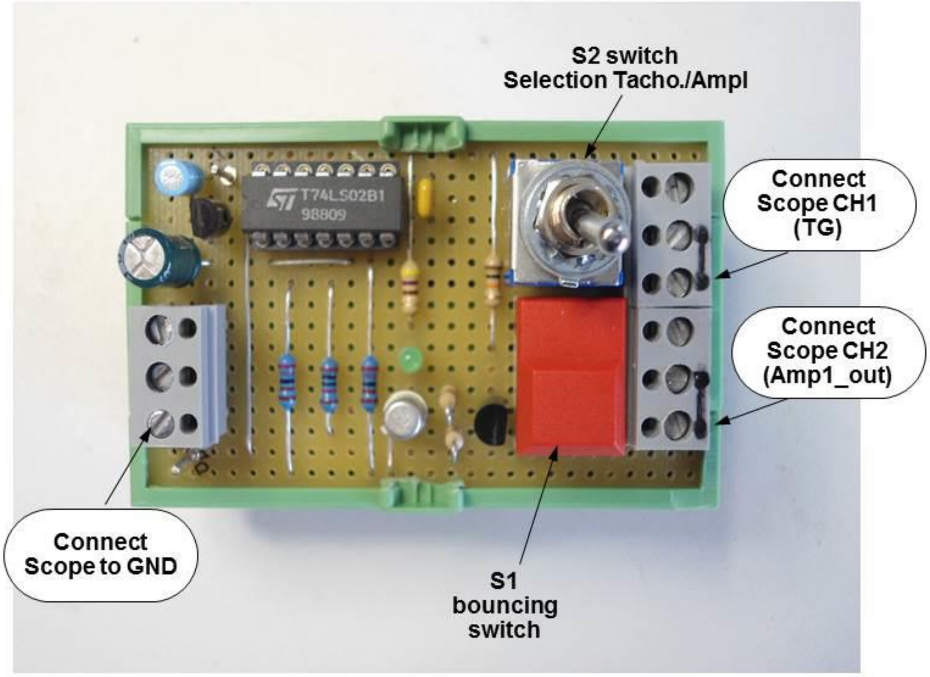
LT5 Motor Test Bed — Voltage Transducer Tacho-Generator (VT2)



In order to adapt the Tacho Generator signal to the PLC VT2 and to see some filter effects ,designed circuitry «debouncing (red button) circuitry» is used.

Figure 21: VT2

LT5 Motor Test Bed — Debouncing Circuit



By the help of debouncing circuit,user can verify the effect of Time constant.S1 switch (red button) gives a 5V high signal that can be comparable to amplified tachogenerator singal. S2 switch is used for mode of operation.When the switch is on the right side,tachogenerator signal is indicated on Motor Speed Indicator,when the switch is on the left side VT2 gain,offset values can be configured.

LT5 Motor Test Bed — Questions — TG – VT1

Amp1 operates as signal adapter to convert the TG signal from a bipolar (±2,9V) to a unipolar (0..10V) signal. Furthermore, the input stage of Amp1 is a low pass filter with adjustable cut off frequency to reduce the superimposed AC noise of the TG signal. Fig. 22 shows the TG signal at full speed turning right. When turning left at full, speed the TG signal looks identical except of negative voltage.

<u>Tasks to be prepared prior to lab execution at home:</u>

T17-1) Determine gain K_{p1} and offset U_{off1} of Amp1 such, that the input signal range of the TG signal (±2,9V) is converted to an output voltage range 0V $\leq$ Uout $\leq$ 10V:

K_{p1} = U_{off1} =

T17-2) Determination of parameters of the input filter The cut off frequency of the input filter should be f_c=30Hz. Determine the adjacent time constant:

T_c=

T17-3) Determine the jumper setting of Amp1 (fig. 20) to select an appropriate capacitor C and determine the adjacent input resistance R.

C= R=

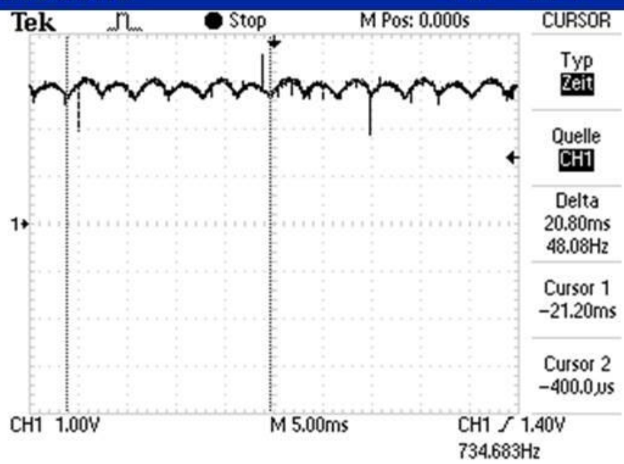


Figure 22: TG signal, turning right at max speed

LT5 Motor Test Bed — Optional Questions — TG – VT1

Optional Tasks

In order to determine the cut off frequency of the input filter the basic approach is as follows:

1) Determine the frequency f_1 of the basic harmonic of the input signal

2) Determine the amplitude $\hat{U}_{in\_1}$ of the basic harmonic of the input signal

3) Define the amplitude $\hat{U}_{out\_1}$ of the basic harmonic of the filtered signal

4) Calculate the cut off frequency of the filter

T18-1) Determine from fig. 22 the basic harmonic: f_1=

T18-2) Determine the amplitude $\hat{U}_{in\_1}$ of the basic harmonic from fig. 22 (Fourier analysis).
Hint: 6 ripples correspond to 1 total revolution of the axle!

T18-3) Calculate the cut off frequency f_c under the assumption of $\hat{U}_{out\_1}$=20mV: f_c=

T18-4) Determine the time constant T_c of the input filter
T_c=

T18-5) Simplified consideration. Instead of performing the Fourier analysis in detail, we assume as an approximation, that the peak to peak voltage U_{pp} of the TG signal equals twice the amplitude of the basic harmonic: $\hat{U}_{in\_1}= U_{pp}/2=$

T18-6) Calculate the cut off frequency f_c under the assumption of $\hat{U}_{out\_1}$=20mV: f_c=

T18-7) Determine the time constant T_c of the input filter
T_c=

T18-8) Compare the two results. Conclusion:

T18-9) The filter does not only reduce the noise, it effects furthermore the dynamic behavior of the measured speed signal.
If a command of reversing the direction of rotation is sent to the FC, the FC responds with a ramp signal: $r1(t)= 1Vs^{-1}\cdot t$.
How big is the time delay ΔT caused by the a.m. filter on response to this ramp signal (fig. 23)?

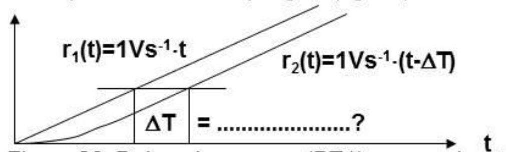


Figure 23: Delayed response (PT1) on ramp input

LT5 Motor Test Bed — ECD of Brake

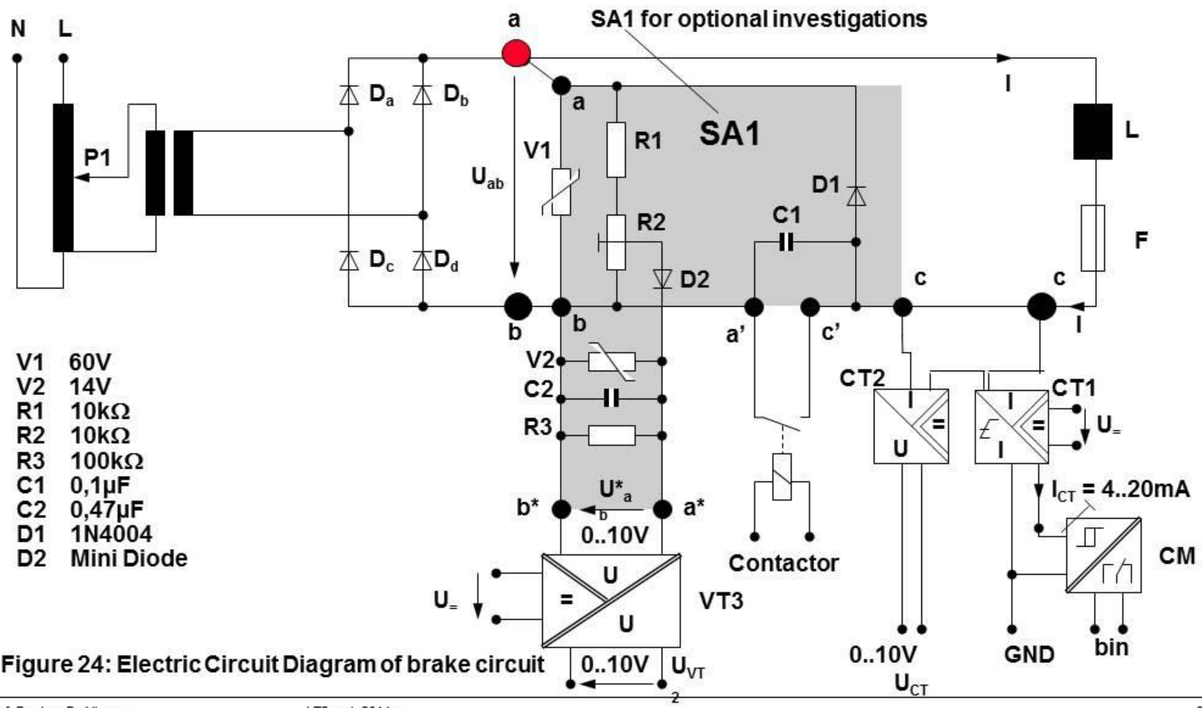


Figure 24: Electric Circuit Diagram of brake circuit

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LT5 Motor Test Bed — Current Transformer (CT)

Figure 25: Current transformer (CT)

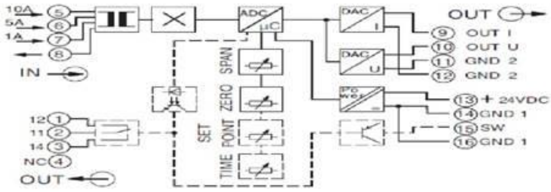

Figure 26: Block Diagram of Current Transformer (CT)

The current transformer is able to measure the true RMS value of input current in the range 0..5A and converts this into the output range 0..10V and 4..20mA.

Motor test bed contains two current transformers which has output range 0..10V or 4..20mA. The voltage output signal is available at terminals (10) and (11) and the current output signal at terminals (9) and (12).

The transformer performs potential isolation.
Measurement is based on Hall principle.

<u>Tasks to be prepared at home prior to lab execution:</u>

T20-1) Determine the output current I_1 of the live zero signal if the input current amounts to 10% of 3.0 A.

$I_1 =$

T20-2) Determine the corresponding load current ΔI_{in} if the live zero output current varies by $\Delta I_{out} = 1mA$?

$\Delta I_{in} =$

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LT5 Motor Test Bed — Current Monitor (CM)

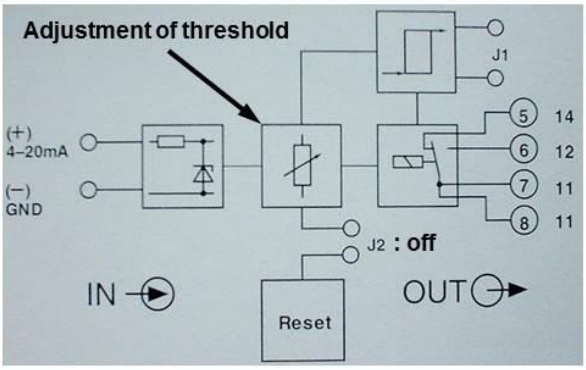

Figure 27: Block diagram of current monitor (CM)

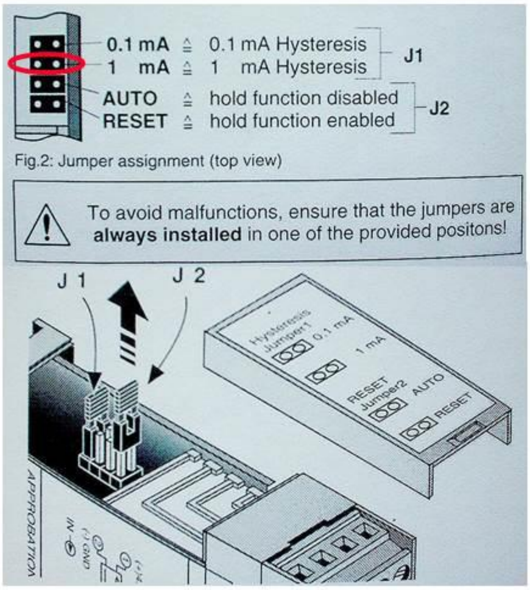

Figure 29: Jumper setting

Figure 28: Top view

Adjustment of threshold for contact activation
Set point range: 0..100% of input signal, hysteresis selectable by J1 (fig. 29)

LT5 Motor Test Bed — Oscilloscope

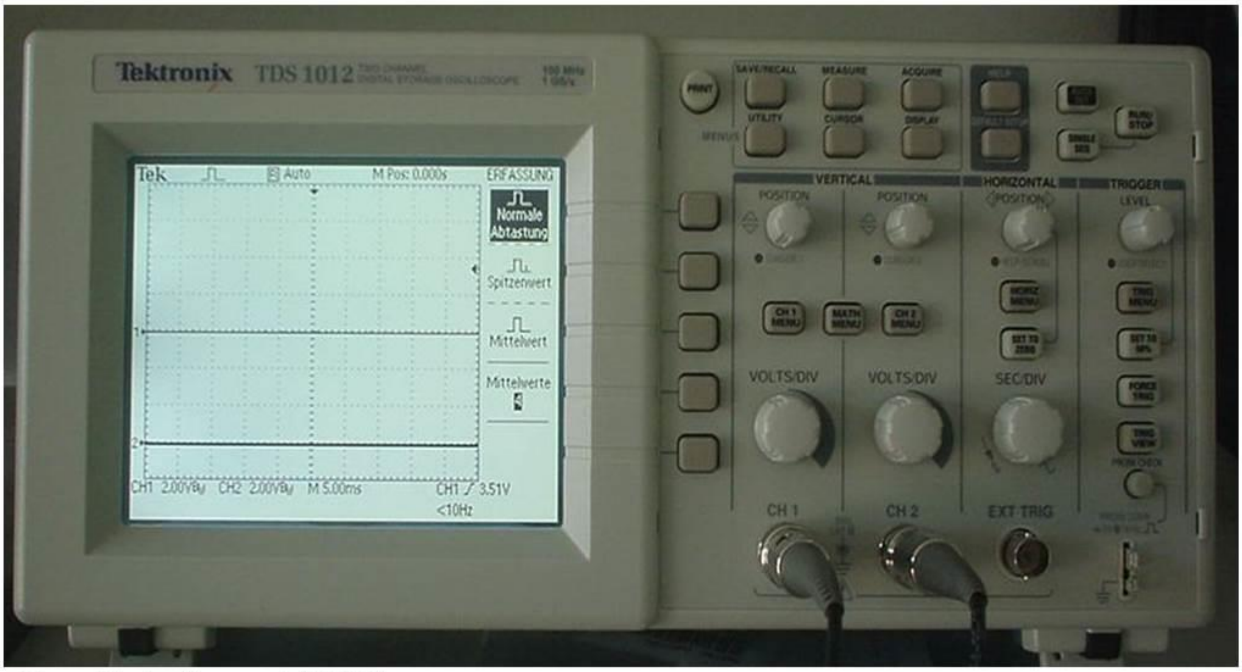

Figure 30: Oscilloscope TDS 1012

LT5 Motor Test Bed — Current Probe

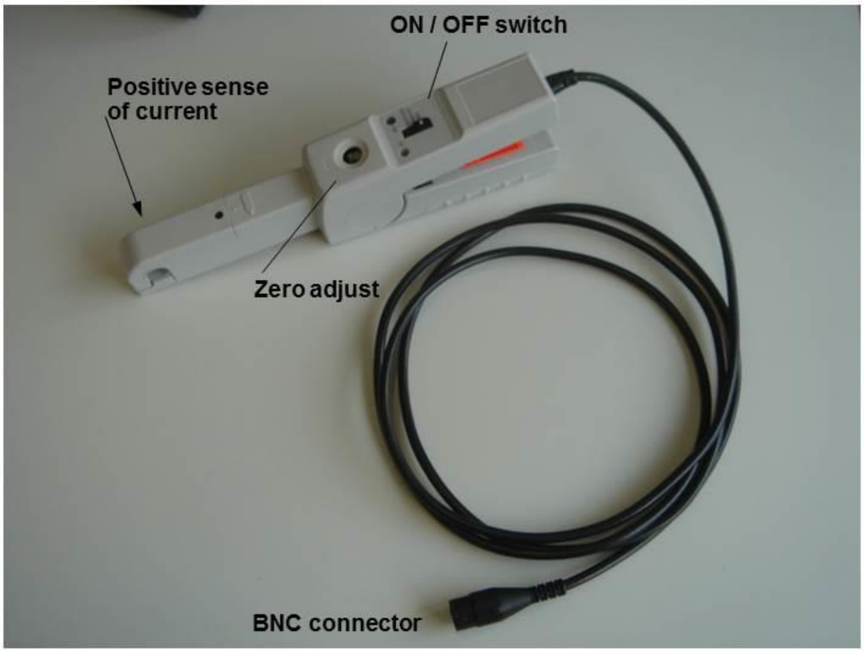

Figure 31: Current probe

Set sensitivity by ON / OFF switch to 100mV / A

Connect to channel 2 of scope

Set CH2 to 100mV / D

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LT5 Motor Test Bed — Speedometer

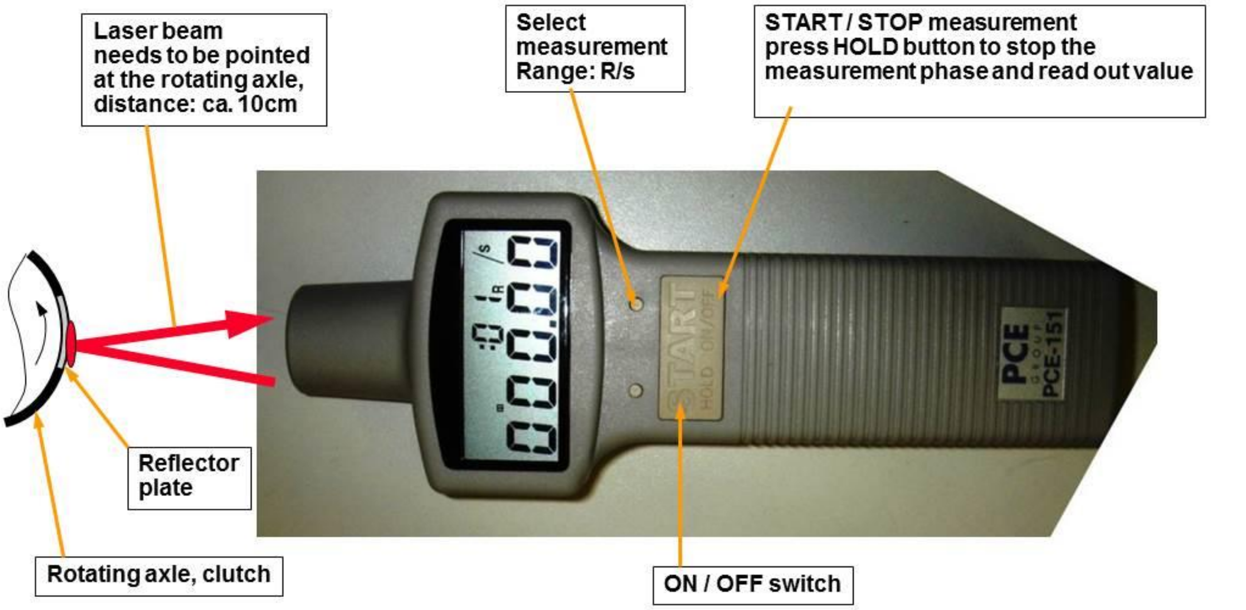

Figure 33: Measuring instrument for rotational speed

Prof. Dr.-Ing. B. Altmann LT5_ppt_2014s 26