Diploma Thesis

Inductive Sensor System for Evaluation of Burrs and Edges

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Abstract

Nowadays, everything is heading towards automation. It is not just a trend as it saves time, money and most times gives best results. Quality control is such an example because it needs to be done fast and cheap several times along the production lines.

Several methods have been developed for such purposes each depending on both the nature of the process and the required accuracy. Inductive sensors were found as a solution for evaluating burrs and edge quality in industrial applications.

This paper presents the development of an application under LabVIEW 8.0 which stands as an interface and control tool for an automated quality control machinery. The mechanical stand consists of a Balluff inductive sensor, three motion axis driven by stepper motors and a National Instruments board which serves as an analog to digital (and vice-versa) converter. The application develops drivers for the motors and also tools for monitoring and pre-processing the input data. Data is then stored as a 2D image that can be further passed for subsequent analysis to specialized software (MATLAB for example).

În zilele de azi se doreste ca procesele tehnologice sa fie în marea parte automatizate. NU este doar un „trend" ci acest fapt conduce la economisirea resurselor bănesti, cât şi la reducerea timpului de productie, şi în majoritatea cazurilor conduce le cele mi bune rezultate. Cel mai bun exemplu care ilusteaza acest fapt este Controlol Calitaţii, deoarece necesita a fi executat cât mai rapid pentru a ţine pasul cu linia de producţie.

Câteva metode au fost dezvoltate în acest scop fiecare depinzând atat de natura procesului,cât şi de precizia impusa. Sensorii inductivi a fost consideraţi ca o solutie optimă pentru evaluarea calităţii şpanului şi a muchiilor în aplicaţiile industiale.

Această lucare prezintă o aplicaţie dezvoltată cu ajutorulu lui LabVIEW 8.0, care întradevar este utilizat ca intrefaţă şi instrument virtual pentru automatizarea mecanismului de control al calitaţii. Partea mecanică a proectului este alcătuită dintr-un sensor inductiv, produs de Balluff, trei axe de deplasare conduse de trei motoare pas-cu-pas şi o placa de achiziţie de la National Instruments care are rolul unui convertor analog-numeric (si vice-versa). Aplicaţia este dezvoltată atât pentru conducerea motoarelor, cât intrument pentru monitorizarea şi procesarea datelor obţinute de la sensor. Datele de intrare sunt salvate ca o imagine 2D care pot fi pasate mai departe software-lor specializate pentru analiza sunsecvenţiala (de exemplu MATLAB), în scopul obţinerii imagini 3D a piesei scanete.

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Chapter 1.

Deburring and Edge Finishing Technology

One dictionary defines a burr as "***a thin ridge or area of roughness produces in cutting or shaping meta***l". However, for engineers charged with removing burrs from manufactured parts, a process known as "***deburring***", this definition is inadequate [1].

What constitutes a "***burr-free***" part varies among companies and quality control departments. For some, it means having no loose materials at an edge. For others, it means having nothing visible to the naked eye or an edge condition that will not cause any functional problem in the next assembly process. Missing material or a hump of rounded metal at an edge may or may not be called a burr. The following is a reasonably complete list of the problems caused by improperly finishing edges:

- Cut hands is assembly or disassembly
- Interference fits in assemblies
- Jammed mechanisms
- Scratched mating surface that allow seals to leak.
- Increased wear on moving or stressed parts
- Electrical short circuits
- Unacceptable high-voltage breakdown of dielectric
- Irregular electrical and magnetic fields
- "Detuning" of microwave system

- Cut rubber seals and O-rings
- Excessive stress contamination
- Plating buildup at edges
- Paint thinout over sharp edges from liquid paints
- Edge craters, fractures, crumbling from initially nonsmooth edges
- Turbulences and nonlaminar flow
- Reduced formability
- Inaccurate dimensional measurement
- Clogged filters and parts from loose burr accumulation

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1.1.Fundamentals

The fundamental principles of burr technology rely on a few simple concepts. The first principle encompasses the following:

- Burr properties are a function of material properties, machining and blanking process, and part configuration.
- Acceptable deburring is a function of material properties, part configurations, acceptance standards, and deburring process parameters.
- Cost-effective deburring is a function of acceptable deburring quality, scheduled quantities, cycle time, and environmental, safely and health issues.
- All deburring processes have side effects

The second principle involves five basic approaches to reducing deburring costs:

- Improving product design
- Preventing burrs
- Minimizing burr properties
- Removing burrs during the machining and blanking cycle
- Developing or obtaining better deburring processes

The third principle recognizes that edge finishing and edge quality are two different aspects of deburring.

The fourth principle recognizes the vast number of processes and process variation used for deburring. Users have over 100 deburring and edge finishing processes from witch to choose.

The fifth principle recognizes that subtle tricks of the trade can produce major savings by eliminating the need for new machines, training, and maintenance of high-tech equipment. In deburring and edge finishing, innovations is the key to success.

1.2. Burr Properties

The first key to reduction edge issues is minimizing burr size. When burrs are small**,** deburring requires little thought and effort. If a burr is only $2.5 \times 2.5 \mu m$ it can be removed in a few seconds on any part using any process. In contrast, when a burr is $127 \times 127 \mu m$ and part tolerances are critical, carefully conceived approaches to removal are required. Figure 1.1[1] illustrates how manual deburring time increases as burr thickness increases for a simple shape on precision parts.
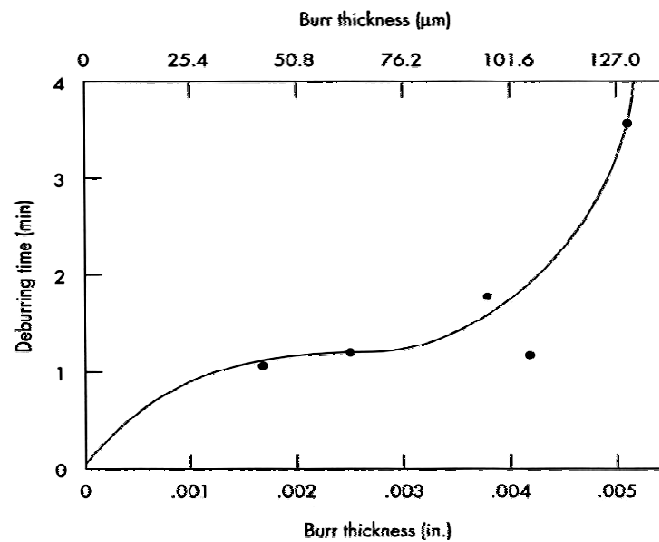
Figure 1.1. Hand-deburring time as a function of burr thickness on
precision miniature parts (Wick and Veilleux 1985)[1]

1.2.1. Material Properties

Two factors related to working material are directly linked to burr size:

(1) the ductility of the workpiece material

(2) the strain-hardening exponent of the material.

Large burrs cannot form in brittle materials. Since the material has little capacity for plastic deformation, large burrs cannot form.

Burr size is also a function of the strain-hardening exponent (or strain-hardening coefficient) (Datsko 1966). As the strain-hardening exponent increases, burr thickness generally increases, but the relationship is not usually directly proportional.

Deburring and Edge Finishing Technology

(The terms *strain hardening and work hardening*s are synonymous.). Table 1-1 [1] presents typical data on material properties related to burr size that are useful in estimating burr-forming tendencies.

Dull tools can significantly heat a part while being machined, causing normally small burrs to become monstrous. The underlying cause of these monster burrs is poor control of machining, but dull tools increase part temperatures, which further increases ductility and subsequently burr thick

Table 1-1 Material properties related to burr size [1]

Material	Yield strength (ksi)	Tensile strength (ksi)	Elongation (%)	Strain-hardening exponent	Burr tendency
Cost iron	55	80	6	0	Low
1020 steel	30	55	25	0.22	Medium
303 Se Stainless	60	180	50	0.56	High
Kovar	50	105	72	0.42	High
Hiperco 50	57	57	0.78	0	Low
BeCu	95	102	26	0.10	Medium
2024 Aluminum	11	27	20	0.15	Medium
Copper (soft)	10	32	45	0.50	High
4340 Steel	69	108	22	0.09	Medium
Vanadium	66	78	20	0.35	high

(Datsko 1966; Gillespie 1977a; Wick and Veilleux 1982)

1.2.2. Effects of Machining and Blanking Processes

Typical burrs are not the result of poor planning or poor engineering. They are a natural result of machining and blanking processes. Large burrs may be the result of poor planning. The cost of burr removal may be increased when certain machining or blanking processes are selected.

The geometry of cutters also plays an important role in burr production.

1.2.3. Effects of Part Configuration

A variety of strategies and some software exist for designing parts and processes so that burrs are less-costly problem. Part configuration affects the bottom line in three ways:

1. It defines geometry condition that do not produce burrs
2. It defines geometry condition that produce smaller burrs
3. It defines simple approaches to putting burrs where they can easily removed at the least cost.
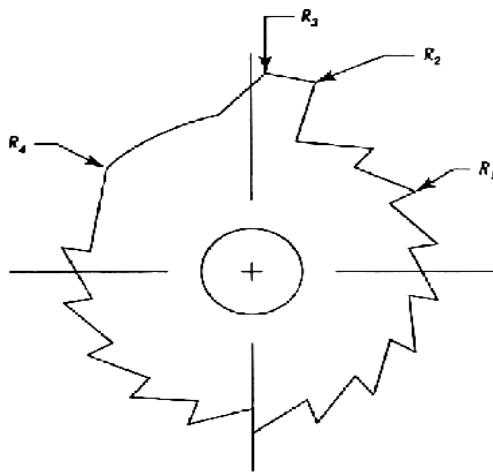
Radii produced on three edges of part while maintaining tolerance of radius R_2 on phosphor bronze:

Radius Feature	Edge angle (degrees)	Radius produced	
		(in.)	(μm)
R_1	60	.0018 ±.001	45.7 ±25.4
R_2	90	.0050 ±.001	127.0 ±25.4
R_3	125	.0113 ±.001	287.0 ±25.4
R_4	140	.0121 ±.001	307.3 ±25.4

Figure 1.2. Phosphor bronze ratchet and edge radii produced by centrifugal barrel finishing (Gillespie 1978) [1]

Part geometry affects not only burr size but also the ease of burr removal. Figure 1.2 [1] provides a simple analysis of the impact of angles. The ratchet wheel shown in Figure 1.2 has milled teeth; a blanked contour would involve similar deburring issues. Note that the angle at different teeth range from R_1 to R_4, and each angle is significantly different from the other. Mechanical deburring, such as tumbling process, work on each edge is for the same amount of time. Because of the angle differences, each edge after deburring will have a different radius, though it may not have had a burr initially. The centre hole will also have somewhat different radii than the other edges. If each edge begins with a different sized burr the final edge will have even more differences. These differences are the result of part-geometry effects. For some products, the differences in edge resultants are not critical. For critical application, the choice of deburring approaches becomes much more difficult.

1.3. Deburring Processes

Figure 1.3 [1] illustrates the most commonly used deburring processes. Unfortunately, no single machine or process produces all the required edge quality on every edge for every burr without side effects. Table 1-2 (see Appendix 1.1) outline the known deburring processes in use worldwide. Each process has a segment of the finishing business to witch it is particularly well suited. Some of the more common approaches, as well as some less common but novel approaches, are outline in the following section.
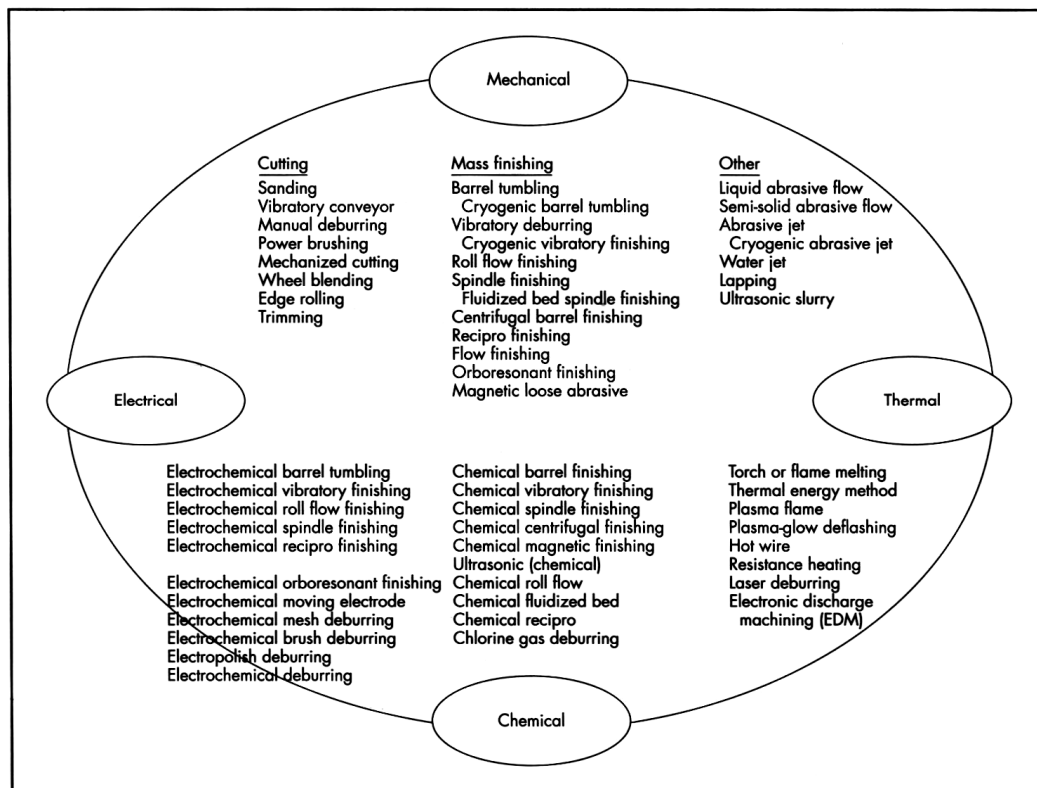

Figure 1.3.Principal deburring processes and their removal machines [1]

1.3.1. Deburring Process Parameters

Deburring and edge finishing processes can be improved by varying many of the parameters. Some processes have several adaptation or tooling changes that can significantly alter the results.

Consider vibratory deburring, as shown in Table 1-3 [1] (Appendix 1.1) witch shows key processes used on precision parts, users can adjust 12-15 variables to obtain the desired results, thus providing a great breadth of capability. The amount of time in a vibratory deburring machine is a one-dimensional variable- more time provides more deburring. In contrast, there are at least 29 different shapes of vibratory finishing media, and each shape affects part features differently.

1.3.2. Deburring Side Effects Influencing Process Selection

A critical factor in selection a deburring process is knowing how the deburring process itself affects dimensions, finishes, cleanliness, flatness, plating, soldering, welding, residual stresses, surface imperfection, corrosion rates, luster, and color. The challenge to manufacturing engineers is to remove burrs without adversely affecting part definition and function, to do it quickly at a reasonable cost, and to produce the desired edge definition at every edge. Table 1-4 [1] (see Appendix 1.1) outlines some of the predominant side effects of deburring processes such as part-size changes, edge breaks produced and their repeatability, and surface - finish results.

1.3.3. Burr Prevention

Some burr can be prevented, and this should always be considered before investing any resources for burr removal. Most users will find that although prevention is possible for some edges, is not for others, so some deburring will still be required. A basic tenet of deburring is *if you do not make the burr, you do not have to take it off*. Burr minimization is always possible and is one path used to reduce burr problems and expense.

1.4. Cost-Effective Deburring

The steps involved in reducing the cost of deburring are:

1. Design to minimize deburring coasts
2. Practice burr prevention
3. Minimize burr size
4. Improve deburring processes

As shown in Figure 1.4 [1], these elements are part of an interlocking puzzle to reduce overall costs.

Designing to minimize deburring costs require an understanding of how part geometry influences burr size and deburring costs and an understanding of what each edge contributes to and costs in part function.

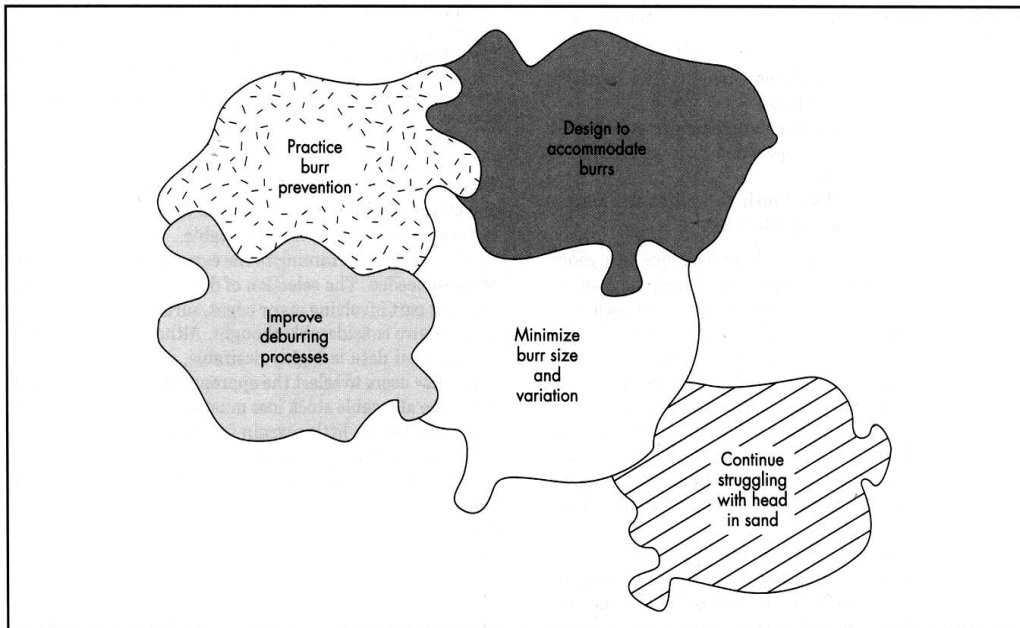*Figure 1.4. Key Elements in deburring technology (Gillespie 1972) [1]*

An understanding of how each edge affects product function and manufacturing costs is important in the design phase. Tables 1-5 and 1-6 [1] are checklists for qualitatively assessing the impact of each edge. If these checklists are carefully filled out by the engineer, the key issues will have been addressed. To use these checklists, each edge of a past is

marked with a number, and an assessment is made for each edge. The data support decision about the requirements of each edge.

Table 1-5 Designer's checklist for assessing edge function [1]

Edge function	Edge 1	Edge 2	Edge 3	Edge 4
None	X			
Clearance	X			
Meshing				
Cutting		X		
Electrical contact		X		
Minimize contact stresses			X	
Aesthetics				
Prevent cutting				
Reduce residual stresses				X
Reduce high-voltage breakdown				
Prevent microwave detuning				
Reduce plating buildup				
Prevent edge cratering, fractures, crumbling				
Reduce turbulence				
Reduce forming deformation				

Table 1-6. Designer's checklist for assessing edge concerns [1]

Would burrs:	Edge 1	Edge 2	Edge 3
Cut hands?	no	yes	
Cause an assembly interference?	yes		
Jam mechanisms?	yes		
Scratch mating surfaces?	yes		
Increase friction?	yes		
Increase part wear?	yes		
Short-circuit device?	no		
Cut wires?	yes		
Cause high-voltage breakdown?	no		
Disrupt magnetic/electric fields?	no		
Detune microwaves?	no		
Contaminate assembly?	no		
Clog filters and ports?	no		
Cut rubber seals?	yes		
Create stress concentrations?	yes		
Cause plating buildup?	no		
Cause paint buildup?	no		
Cause edge fractures/crumbling?	no		
Create turbulence/nonlaminar flow?	no		
Reduce sheet metal formability?	no		
Come loose during use causing other problems?	no		

Table 1-7 and 1-8 [1] (Appendix 1.2) provide specific details on the capabilities of the various deburring processes. The information in these tables, and in Tables 1-3 and 1-5, is provided because deburring requires knowledge of all of the following factors:

- Burr properties – thickness, height, and hardness in relation to part hardness
- Allowable dimensional changes in the part resulting from deburring operation
- Required edge radius
- Required final surface finish as well as the surface finish of the part before deburring

1.5. Inductive Sensor System for Evaluation of Burrs and Edge in Industrial Applications

1.5.1. Introduction

A burr often results by cutting or machining workpieces. The intensity of the burr formation depends, among other things, on the tool geometry (a drill, for example), the machining parameters, and the composition of the workpiece. Burrs present a number of problems. On one hand, there is a risk of personal injury, and on the other hand, burrs on parts used in motor vehicle transmission parts, for example, can affect the flow of oils and fluids or break off and cause premature wear. For these reasons a great deal of expense is devoted to deburring measures.

In order to address the problem of burr minimization, in 1999 the "Burr Minimization" industry workgroup of the automobile industry was formed. Members of this workgroup include leading automobile manufacturers as well as scientific institutions. In 2001, Balluff GmbH was invited to the workgroup as the sensor specialist, with the goal of developing an industrial measuring system that would be commensurate with the technical challenges [3].

1.5.2. Fundamentals of Burr Formation

1. Definition and Characteristics

DIN ISO 13715 defines a burr as "an overhanging, sharp workpiece edge" or as "a rough tear of material on an edge which remains after the mechanical processing or forming process" (Figure 1.5) [3]. Furthermore, with respect to burr heights on stamping, *DIN 9830* describes a burr as a generally thin, sharp workpiece overhang in a cut edge.
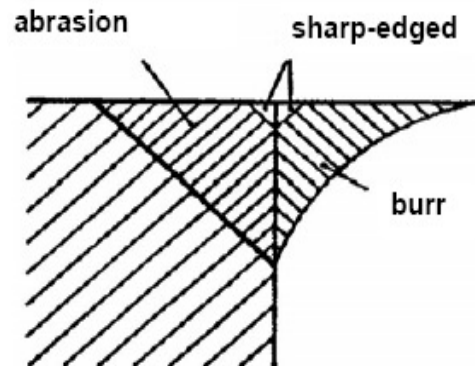

Figure 1.5. Edge condition per DIN ISO 13715 [3]

A comprehensive definition can be found in [Beier, 1999]: A burr is a body created on a workpiece surface during the production of a workpiece, which extends over the intended and actual workpiece surface and has a slight volume in comparison with the workpiece, undesired, but to some extend, unavoidable.

The basic terms are defined in [Beier, 1999]. As follows:

h: burr height
b: burr thickness
ϑ: edge angle
r_f: burr base radius
u: workpiece height
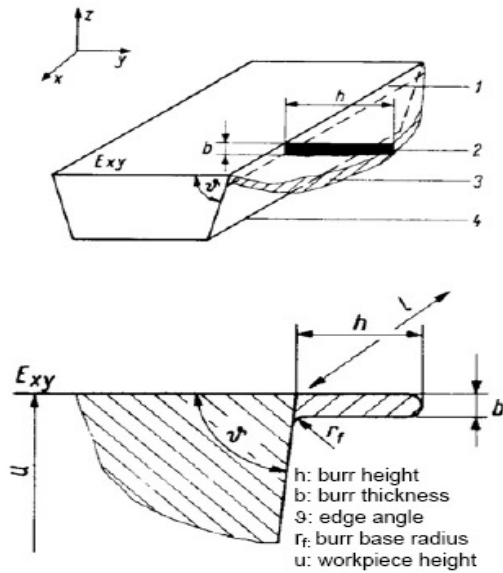
Figure 1.6.Burr Dimensions (Beier 1999 [3]

- Burr base profile (1): Geometric size of the presumed straight contact location burr/workpiece surface.
- Burr cross-section (2): Area created through a section vertical to the plane in which the burr base profile lies.
- Burr longitudinal profile (3): Curve resulting from the burr height h.
- Burr location (4): Geometric location of the burr base profile (inner/outer) with respect to the workpiece.

Burr dimensions are defined in Figure 1.6 [3]

2. Classification

From a production standpoint a burr can be classified in 5 various categories (Figure 1.7) [3].

Figure 1.7.Burr classification according to (Berger 2002) [3]

The first two types (burr type 1 and burr type 2) are characterized by the defined burr height and by the fact that burrs cannot detach due to their low height.

Burr type 3 results typically from dull tools or excessively high feed rates.

Rolled burrs such as occur with burr type 4 represent an even greater problem compared to type 3 burr. Burr type 5, the irregular burr, is especially difficult to measure due to its nonuniform structure, which can vary from bore to bore.

Burrs, flash, and related protrusions are formed by the six physical processes listed in Table 1-10 [1]. Burrs formed by the first three processes involve plastic deformation of the workpiece material. Solidification of material on the working edges, the fourth process, incomplete cutoff, occurs whet the workpiece is allowed to fall from the part before the cut is completed. Flash forms whenever the pressure on molten material is sufficient to force the material between the two halves of die or mold.

Table 1-10. Physical processes involved in the formation of burrs, flash, and related protrusions [1]

Process	Name of protrusion
1. Lateral flow of material	Poisson burr
2. Bending of material (such is chip rollover)	Rollover burr
3. Tearing of chip from workpiece*	Tear burr
4. Redeposition of material	Recost bead
5. Incomplete cut off	Cutoff projection
6. Flow of material into cracks	Flash
* A tear burr also forms in stamping operation when the punch tears the part from the stock	

1. Poisson burrs

A Poisson burr occurs whenever cutting edge extends past an edge of the working piece (Figure 1.8) [1]. It is the result of later deformation that occurs whenever a solid is compressed
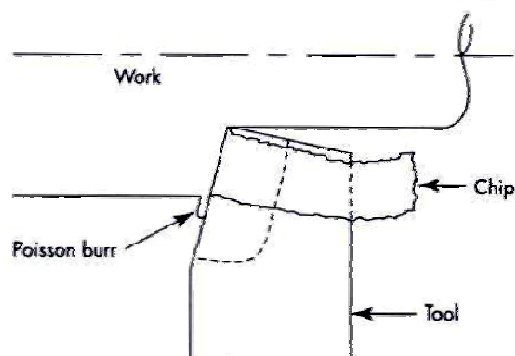
.

Figure 1.8.Poisson burr formed when cutting edge of tool extends past edge of workpiece [1]

2. Entrance burrs

When a cutting edge first intends a workpiece, as shown in Figure 1.9 [1], another type of burr may form. This entrance burr is material that had flowed opposite to the direction of the tool. It is similar to the ridge that forms around the indentation made by a Brinell hardness tester. Whenever a burr forms at this point depends on the workpiece properties and, probably, the shape of the cutting edge.
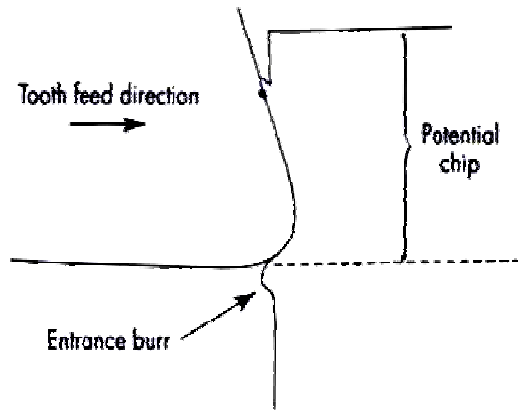
Figure 1.9.Cutting edge produces indentation burr as it enters workpiece [1]

3. Rollover burrs

When a cutting edge exit from a workpiece, a rollover burr normally occurs. This happens when banding the chip is easier than cutting it or fracturing the edge (Figure 1.10) [1]. the thickness of rollover burr (Figure 1.11) [1] in a continuous depth-of-cut process can be expressed by Equation (1.10):

Figure 1.10 and 11. Rollover burrs forms when the cutter nears the end of the cut [1]

$$h = t(\cos ecA - 1) \qquad\qquad (1.10)$$

where:

h - depth of plastic deformation, witch also is thickness of a rollover burr

t - depth of cut

A - shear angle, expressed approximately by the following equation:

$$A = \tan^{1}\left[(t/t_2)\cos B\right]/\left[1-(t/t_1)\sin B\right] \qquad (1.11)$$

Or

$$A = \tan^{-1}\left[\cos B\right]/\left[t_2/t - \sin B\right] \qquad (1.12)$$

where:

t_2 - chip thickness

B - Rate angle of cutting tool
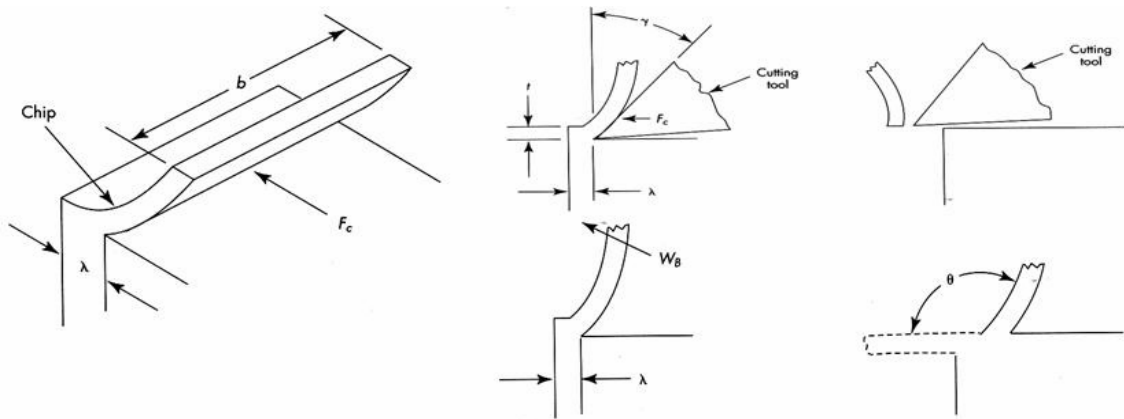
4. Tear burrs

Tear burrs form when chips are turn rather than sheared from the workpiece (Figure 1.12) [1]. Although such burrs can form in most cutting processes, they are easiest to produce in side-milling operation. The milling cutter tooth forces the chip up and forward. As it does so, the sides of the chip are torn from the workpiece. The tear burr is the torn portion remaining on the workpiece. In punch-press operation, the burr formed is basically a tear burr. In early research on this subject, the burr from blanking was called a *tensile burr*.
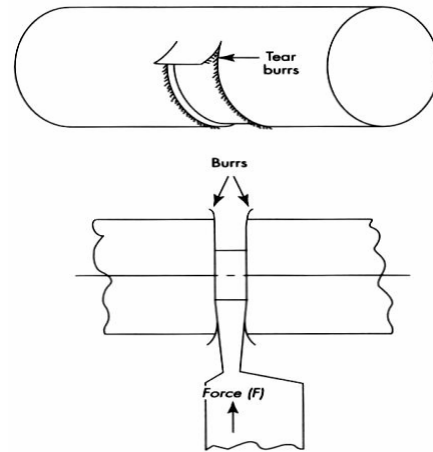
Figure 1.12. Tear burrs at sides of lathe groove cut [1]

Other types of burr formations are burrs produced by specific operations:

1. Burrs from Turning operations
2. Burrs from Drilling operations
3. Burrs from Milling operations
4. Burrs from Grinding operations
5. Burrs from Ball Broaching operations
6. Press working

Chapter 2.

Inductive Sensors

Inductive sensors plan an especially important role owing to their non-contact mode of operation, their robust industry compatible construction and the resulting high degree of reliability as well as for economic reasons.

Their non-contact mode of operation means that no actuation forces are required and direct contact with the object is avoided. The completely electronic design (no moving parts or contacts) functions without wear. The electronics are encapsulated and provide a high degree of protection against vibration and shock stress as well as dirt, dust and humidity, and as a result, the majority of these sensors can also be used in extreme conditions.

The principle of inductive proximity sensors is based on the interaction between metallic conductors and an electromagnetic alternating field. Eddy current[1] [13] fields are induced in the conductor, which remove energy from the field and reduce the

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[1] **An eddy current is the current is induced in little swirls ("eddies") on a large conductor (picture a sheet of copper).**

If a large conductive metal plate is moved through a magnetic field which intersects perpendicularly to the sheet, the magnetic field will induce small "rings" of current which will actually create internal magnetic fields opposing the change. This is why a large sheet of metal swung through a strong magnetic field will stop as it starts to move through the field. All of its kinetic energy will cause a major change in the magnetic field as it enters it which will induce rings of current which will oppose the surrounding magnetic field and slow the object down. In effect, the kinetic energy will go into driving small currents inside the metal which will give off that energy as heat as they push through the metal. [13]

To get rid of eddy currents, slits can be cut in metals so that large eddies cannot occur. This is why the metal cores of transformers are often assembled in small laminations with an insulator in between. This prevents AC energy from being lost to eddies generated within the magnetic core (which typically is also conductive because it is a metal like iron).

Now, sometimes eddy currents are a good thing. Mentioned above, eddy currents help turn kinetic energy quickly into other forms of energy. Because of this, braking systems have been created which take advantage of it. Adding a magnetic field around a spinning piece of metal will cause eddy currents in that metal to create magnetic fields which will slow the object spinning down quickly as long as the magnetic is strong enough.

height of the oscillation amplitude. This change is processed in the inductive sensor, which changes its output state accordingly.

The inductive sensor arrangement for detecting metal objects obscure in a surrounding medium includes a couple of field coils for making an alternating magnetic fluctuation by a sequential excitation with an AC-current and a couple of sense coils correspondingly mounted in every linked field loop in an orientation to the axes of every of supposed field coils such that effectively no voltage is induced in supposed sensor coils in an environment free of a metallic object. If a metallic object comes in the vicinity of the inductive sensor four trait voltage quantity sets are produced by the sense loop couple witch become topic of an algorithmic processing for defining a position and distinction criterion in respect to supposed obscure metallic object. The sensor arrangement has the benefit of a solitary point measurement resultant in an precise position discrimination for a obscure metallic object similar to a rebar in concrete.

An inductive proximity sensor comprises and LC oscillating circuit, a signal evaluator and a switching amplifier. (Figure 2.1) [5]. The coil of this oscillating circuit generates a high-frequency electromagnetic alternating field. This field is emitted at the sensing face of the sensor. If attenuating material nears the sensing face, eddy currents are generated in the case of nonferrite metals. In the case of ferromagnetic metals, hysteresis and eddy current loss also occurs. These losses draw energy from the oscillating circuit and reduce oscillation. The signal evaluator detects this reduction and converts it into a switching signal. (Figure. 2.2) [5] The terms "attenuated" and "unattenuated" are used to describe the two switching states of the inductive proximity sensors.
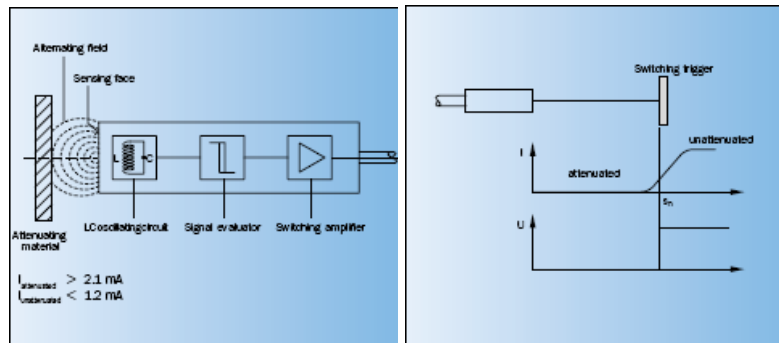
Figure2.1.Inductive proximity sensor makeup [5]   *Figure 2.2.Attenuated vb. unattenuated materials [5]*

Figure 2.3.Proximity sensor [5]

2.1. Inductive Ring Sensors

2.1.1. General description

Inductive ring sensors have been proved very well for the most different fields of application like assembly and supply machinery.

Due to the static working principle, they can be used as wire break detection and stow control.

Safety instruction

These instruments shall exclusively be used by qualified personnel.

The instruments are not to be used for safety applications, in particular applications in which safety of persons depends on proper operation of the instruments.

All technical specifications refer to the state of the art 12/05, they are subject to modifications. As typographical and other errors cannot be excluded, all data are given „without engagement".

2.1.2. Inductive Ring Sensors IR

The Ring Sensors have an scanning diameter from 6.1mm to 101.0mm with scanning resolution of 1.0mm to 10.0mm for different types of materials. In Figure 2.4 [4] is represented this type of sensors with theirs characteristics and the connection diagram. (more details about this sensors it can be found in the data sheet attached in the Appendix 2)

- Compact design
- Static operating principle
- High resolution
- Short response time
- Pulse stretching adjustable
- Insensitivity to dirt
- Metal connector
- High Protection class

Figure 2.4 Inductive ring sensors. Dimensions [4]

Application of a ring sensor

Figure 2.5.Wire Break Detection [4]

2.1.3. Wire Break Sensors IRDB

This type of inductive sensor has a scanning surface of only 4.0 mm to 6.1mm, but the resolution is the same. In Figure 2.6 [4] we have an overview of this kind of sensor with his connection diagram.

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- Compact Design
- Static operating principle
- High resolution
- Short response time
- Pulse stretching adjustable
- Insensitivity to dirt
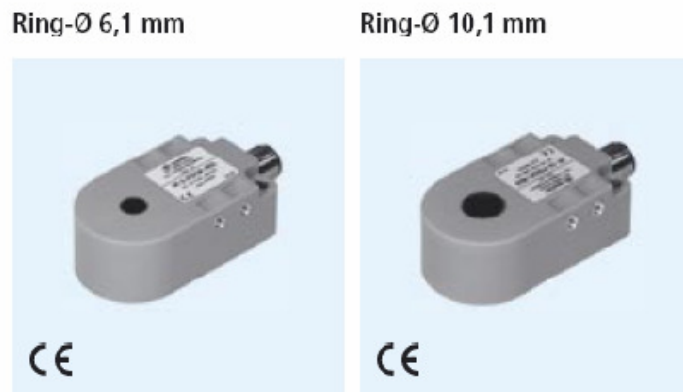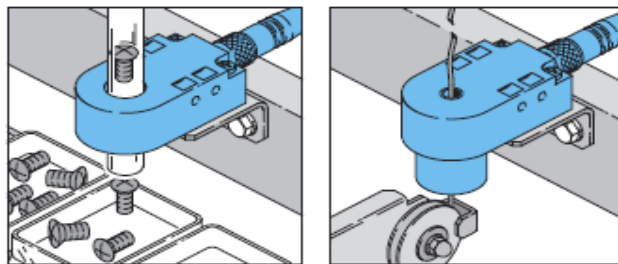- Metal connector
- High Protection class
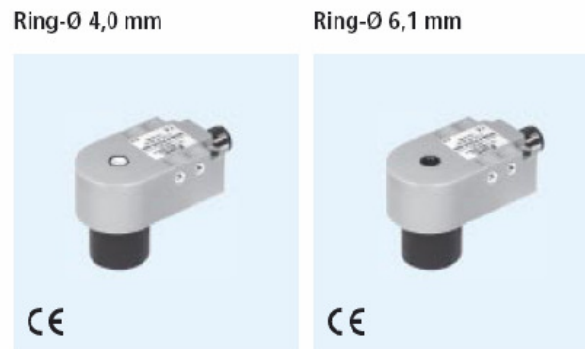
Figure 2.6. Wire Break Sensor IEDB. Dimensions [4]

2.2. Inductive Tube Sensor

- Compact design
- Static operating principle
- High resolution
- Low weight
- Slot for quick and safe mounting

Figure 2.7.Inductive tube sensor. Dimensions [4]
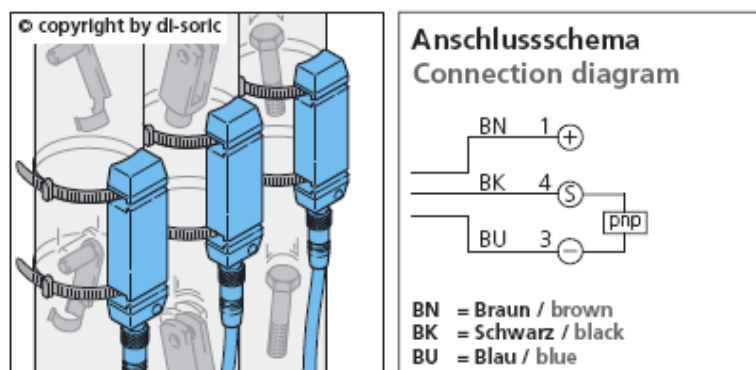
Figure 2.8.Parts detection in feed hoses [4]

Safety instruction

These instruments shall exclusively be used by qualified personnel. The instruments are not to be used for safety applications, in particular applications in which safety of per sons depends on proper operation of the instruments.

2.2.1. Inductive Sonde

The sensor used within the project was invented by the Balluff Company. The sensor was awarded 1st prize for innovative automotive technology in 2003 and was among the first 100 innovative products of the same year.

Figure 2.9. The Award wined by the inductive sensor [7]

More details about the sensor are presented in Chapter 3.

All Balluff inductive, capacitive, magnetic and optical sensors will interface with practically all PLC's available on the market. PLC[2] inputs are not much different than any other load that a sensor might operate. A relay or a motor starter needs a certain amount of voltage to activate and needs a source of power for the current it will draw at that voltage. To deactivate these loads, the voltage must be reduced to a low level. PLC inputs are no different. This is easier to understand when a mechanical switch is used as an input device. The mechanical switch connects the load to the source of power and disconnects it from the source of power. When a mechanical switch cycles, the load voltage goes from zero volts to full voltage and back to zero. The load current goes from zero to full current and back to zero. [6]

_____

[2] **A programmable logic controller, PLC, or programmable controller is a small computer used for automation of real-world processes, such as control of machinery on factory assembly lines. The PLC usually uses a microprocessor. The program can often control complex sequencing and is often written by engineers. The program is stored in battery-backed memory and/or EEPROM's. Unlike general-purpose computers, the PLC is packaged and designed for extended temperature ranges, dirty or dusty conditions, immunity to electrical noise, and is mechanically more rugged and resistant to vibration and impact. [13]**

_____

Chapter 3.

Hardware Considerations

In this chapter I will try to create an image of major hardware components used in this project, such as: Inductive Sensor, Data Acquisition Board (NI-DAQmx 6251), Front Panel (Control Panel delivered with NI-DAQmx) and a few details about the Electro-Mechanical Development of the project.

I will try to explain and present some details about them, how they are connected, what are their performance and characteristics are, how they work, and most important how I used them in this very one project. More details about this matter will be explained in every subchapter of Hardware Considerations (details how to connect the parts, how to use them, how to create a Task[1] for every cannel I have used in this application, Analog or Digital).

Block Diagrams which are mentioned in the future subchapters are functional parts of the application made for this project. They are parts of graphic programming in LabVIEW 8.0.

LabVIEW ties the creation of user interfaces (called front panels) into the development cycle. LabVIEW programs/subroutines are called virtual instruments (VIs). Each VI has three components: a block diagram, a front panel and a connector pane.

A more clear picture on this matter, see the next chapter called Software Considerations.

---

[1]   **What is a Task?...more details about this it can be found in Chapter 4 , subchapter 4,2 - Right now I'll mention just that we can create, customize, save multiple tasks, run, modify and duplicate them using two software came from National Instruments, VI Logger or Measurement and Automation (MAX).**
This matter will be explain in next chapter, where I'll address to main problem...*HOW TO?*

3.1. Inductive Sensor (Sonde)

Figure 3.1. Inductive Sensor and BIG P A065E Device [7]

The inductive sensor is based on the interaction phenomenon between a metallic conductor and a variable electromagnetic field (as shown in Figure 3.2). A current (Eddy) is induced in the conductor by an excitation coil; this current also creates an electromagnetic field. The sum of the two magnetic fields induces a tension in the sensor coil. This modification is caught by the inductive sensor coil, which changes correspondingly its output state.
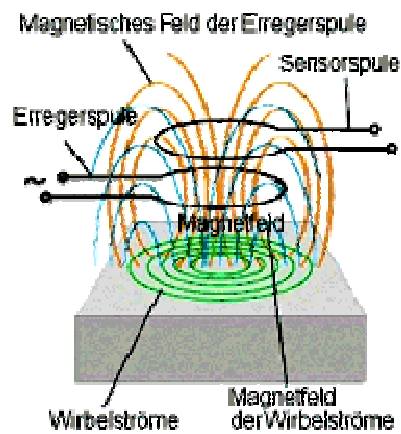

Figure 3.2.Operating principle of the inductive sensor

The sensor is delivered together with a device **BIG P A065E – Burr Probe Evaluation Unit** (Figure 3.1) [7], which permits the monitoring of the signal and of the temperature.

Figure 3.3 [3] represents the form of the electromagnetic field produced by the inductive sensor, in the proximity of a burred metal. Can be noticed the tendency of the field to close through the metal.
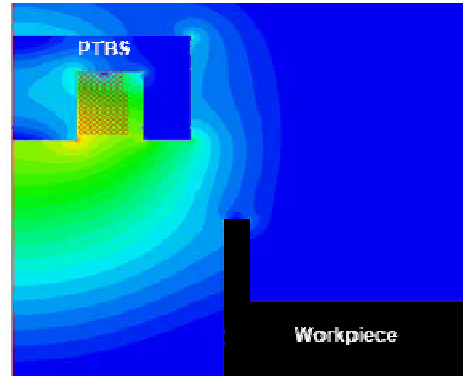
In Figure 3.4 [7] is represented the variation of the signal for a steel plate, which contains a hole without burrs and a burred one, both with the same diameter.

Figure 3.3. The form of the electromagnetic field in the proximity of the metal [3]

The distance *d* in Figure 3.4 is dependent of the magnetic properties of the scanned material. In the magnified portion seen to the right, it can be notice the influence of the 3 mm sensing spot. The resulting data from the sensor appears earlier then the actual beginning of the burr and it disappears a then the end of it.

This would not be a problem in determining the presence of a burr, but it represents a problem in getting qualitative, precise, information about the burr. One of the goals of this project is to realize precise 3D images of the holes. In order to accomplish this some data processing will be required. This processing will be done with the help of *MATLAB*.
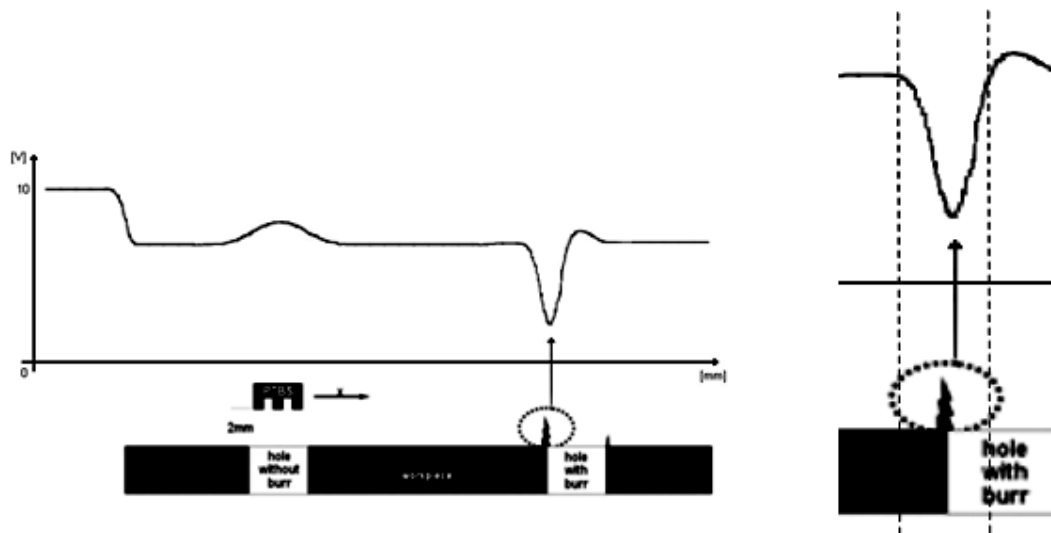

Figure 3.4. The variation of the signal for a steel plate

The mechanical dimensions and the electrical characteristics of the sensor produced by Balluff Company can be found in Appendix 3.1, which is the data sheet of the sensor and of the device which with it is delivered (BIG P-A065E).

3.1.1. Applied Electrodynamics Theory

For the specific working conditions of the inductive burr sensor system at very low magnetic field strength, the components of the system including the workpiece with or without burrs can be considered as isotropic, continuous and linear so that Maxwell´s equations (Griffith, 1989) may be simplified:

$$rotH = J + \frac{d}{dt}D \qquad \text{(Ampere's law) (3.1)}$$

$$rotE = -\frac{d}{dt}B \qquad \text{(Faraday's law) (3.2)}$$

$$divB = 0 \qquad (3.3)$$

$$divD = \rho \qquad \text{(Gauss's law) (3.4)}$$

where the vectors H, B, E and D represent the magnetic field strength, magnetic flux density, electric field strength and electric field density, respectively. The sources are the vector J representing the density of the conduction current and the scalar ρ giving the density of electric charges.

In isotropic mediums the vectors B and H are parallel each to other and the vectors E and D are also parallel each to other; in linear mediums they are also direct proportional each to other. These properties of the isotropic and linear mediums are described by the material equations:

$$B = \mu \cdot H \qquad (3.5)$$

$$D = \varepsilon \cdot E \qquad (3.6)$$

where μ is the magnetic permeability of the medium and ε is the electric permittivity.

In final solution are only describes position dependencies:

$$\Delta A + \varepsilon\mu\omega^2 \cdot A = -\mu \cdot J \qquad (3.14)$$

$$\Delta \varphi + \varepsilon\mu\omega^2 \cdot \varphi = -\frac{\rho}{\varepsilon} \qquad (3.15)$$

How we obtain this two equations is detailed explain in Appendix 3.2.

_____

3.1.2. Typical Structure of the PTBS (Primary Transducer of the Burr Sensor)

The representative structure of the PTBS is schematically illustrated in Figure 3.5 [3]. The essential element is a coil (1) made of massive copper conductor and placed in a ferrite pot core (3). The other mechanical components, e.g. the plastic coil body (2), and the plastic cap (4) with its sealing function, do not play a significant role in the system operation but do strongly influence the system performance.

Figure 3.5. Structure of the PTBS [3]

The workpiece to be inspected is figuratively represented by a target plate placed parallel to the active face of the PTBS.
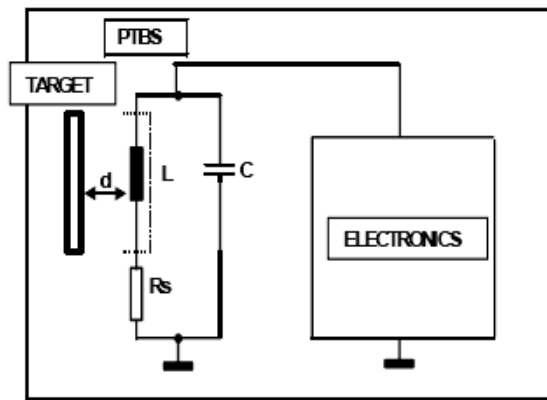
Figure 3.6. Equivalent diagram of the PTBS connected to the primary Electronics [3]

From a physical perspective, the PTBS in Figure 3.5 is essentially a coil with losses caused by the workpiece off variable distance d (see Appendix 3.1) to the coil (the evaluated loss) and also by components 1 and 3 (parasite losses).

From the variety of known equivalent diagrams, we have preferred the Jordan serial equivalent type.

The elements of this diagram are the inductivity L and the resistance R_S (the sum of all loss resistances in the coil, core, adjacent elements and target) and can be most easily determined by measurements or by the evaluation of simulation results.

Therefor we obtain the following block diagram shown in Figure 3.6

3.1.3. Functional Block Diagram of the Electronics of the Burr Sensor

The functional block diagram of the burr sensor is shown in Figure 3.7 [3]. The front-end circuit has been integrated into an ***Application Specific Integrated Circuit*** (ASIC). The core of this part consists of an improved, very high performance oscillator followed by a precision rectifier.
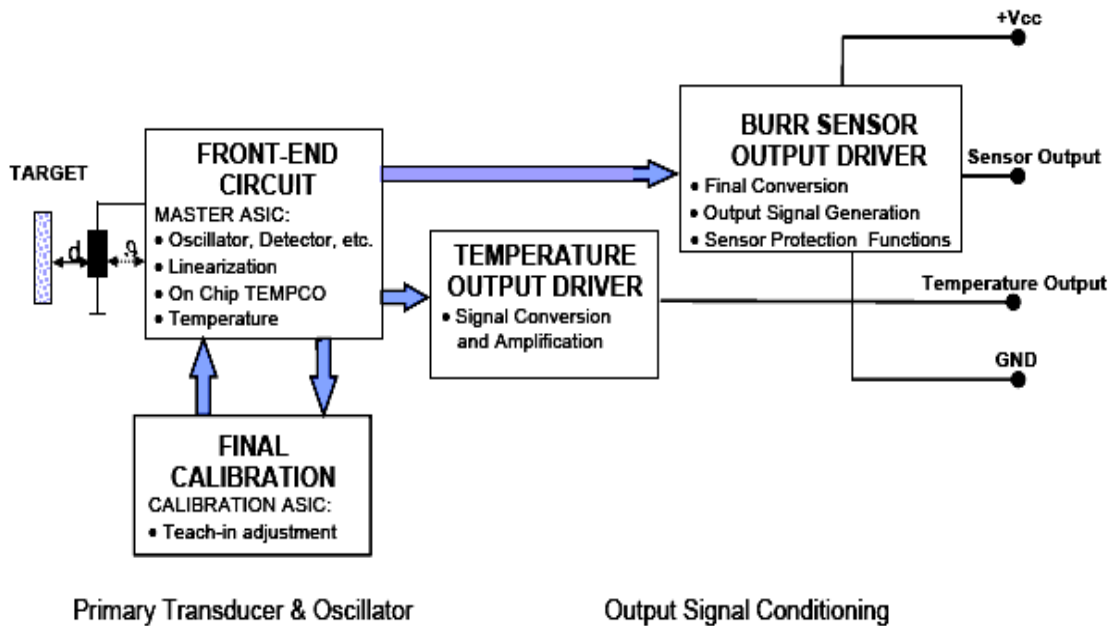
Figure 3.7.Functional Block Diagram of the Electronics of the Burr Sensor [3]

This stage converts the above mentioned oscillator output signal into DC voltage which represents the intermediate electrical burr sensor signal. The rectified signal, corresponding to the amplitude of the oscillator output voltage, is fed to the analog ASIC output. This ASIC output signal will be applied to an output driver which provides the final signal conversion and the sensor protections. The front-end ASIC also includes the integrated circuit for the linearization of the sensor characteristic. This compensates in the sensing range of the sensor the exponential gradient of the loss resistance R_P, by using a suitably adjusted reciprocal gradient of the excitation current [Fericean, 1996]. The final result is a linear relationship with the distance d over a wide range.

In addition to the linearity, the temperature behavior has also been optimized. This is mainly a function of the temperature drift of the sensor element, the resonance resistance of

the coil R_P. The temperature coefficients of the other system components are only of secondary significance.

The second step consists of active temperature compensation accomplished by the oscillator electronics. Here, an integrated compensation stage is used to linearly compensate the coil temperature drift over the entire temperature range.

This integrated compensation stage offers great advantages over traditional approaches using temperature-dependent resistors. Since the oscillator, linearization and temperature compensation are implemented on a single chip and the latter is located directly next to the sensor coil, the temperature gradients between all components are small.

On the other hand, the integrated temperature sensor of the compensation stage can be used externally for temperature measurements and additional temperature compensation tasks in applications with the burr sensor. The temperature output driver provides an amplification and conversion of the original signal and delivers a second signal of the burr probe.

3.1.4.   HOW TO…

…Operation and Structure.

…How is the Sensor connected to BIG P Device and how to monitor and acquire data from the sensor?

The burr sensor system under present discussion consists of a burr probe and the associated processing unit. The main components of the probe are a metal tube shaped like an endoscope with an active head in the front section and a flange used for fixing the probe. Depending on the application, the active head contains up to 3 inductive heads and the associated electronics.

The surface covered by the sensor has a 3 mm diameter. Within this project, the data related to the burrs will be extracted from the difference of two spots. Knowing that at a given time, for a spot, the sensor returns a certain value, in the next step (one step = 0,00625 mm, with micro stepping), the difference in the signal will give the quantity of existing (or not existing) burr.
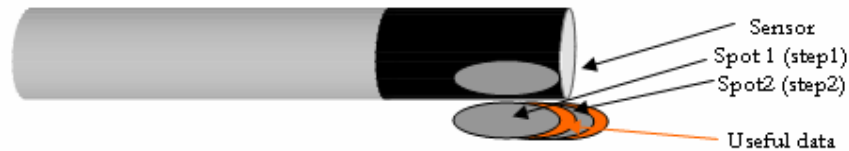
Figure 3.8. Burr Detection

…Connectivity

The block diagram for the probe electronics with one head is shown in Figure 3.7. The active head is supplied with power by the processor and provides several conditioned signals (0 …10 V). The main output signal is the burr signal, whose amplitude is a function of the damping of the inductive measuring head, thus providing information about the geometric characteristics of the burr. The electronics in the active head simultaneously make continuous temperature measurements.

The sensor is supplied with 24 VDC from an external power supply, as shown in Figure 3.9a. Switching the ON/OFF button we start monitoring, on the Analog Voltmeter placed on the BIG P device, output voltage produced by the sensor. We can also change sensitivity of the inductive sonde by clicking on the "Sensitivity High/Low Button".

Connection between Inductive Sensor and device is done with the 2 x M12 plugging (Figure 3.9a).

If we want to see how the burr signal evolve in time, i.e. to obtain amplitude – time characteristics, for monitoring evaluation in time of burr signal relative to the material type and the distance of the sensor from the workpiece, we use one of the Output Signals from the BIG P-A065E device, to be more precise from the pin no.1, where is the burrsignal (0..10V DC)(as shown in Figure 3.9 b)

Probe Input:

Pin Nr.	Signal
1	Burrsignal (0..10V)
2	nc
3	durchkontaktiert zu Output Signals – Pin 3
4	Rohrpotential RP (durchkontaktiert)
5	Temperatursignal T9 (3300mV typ. @ RT)
6	+24V
7	nc
8	GND

Output Signals:

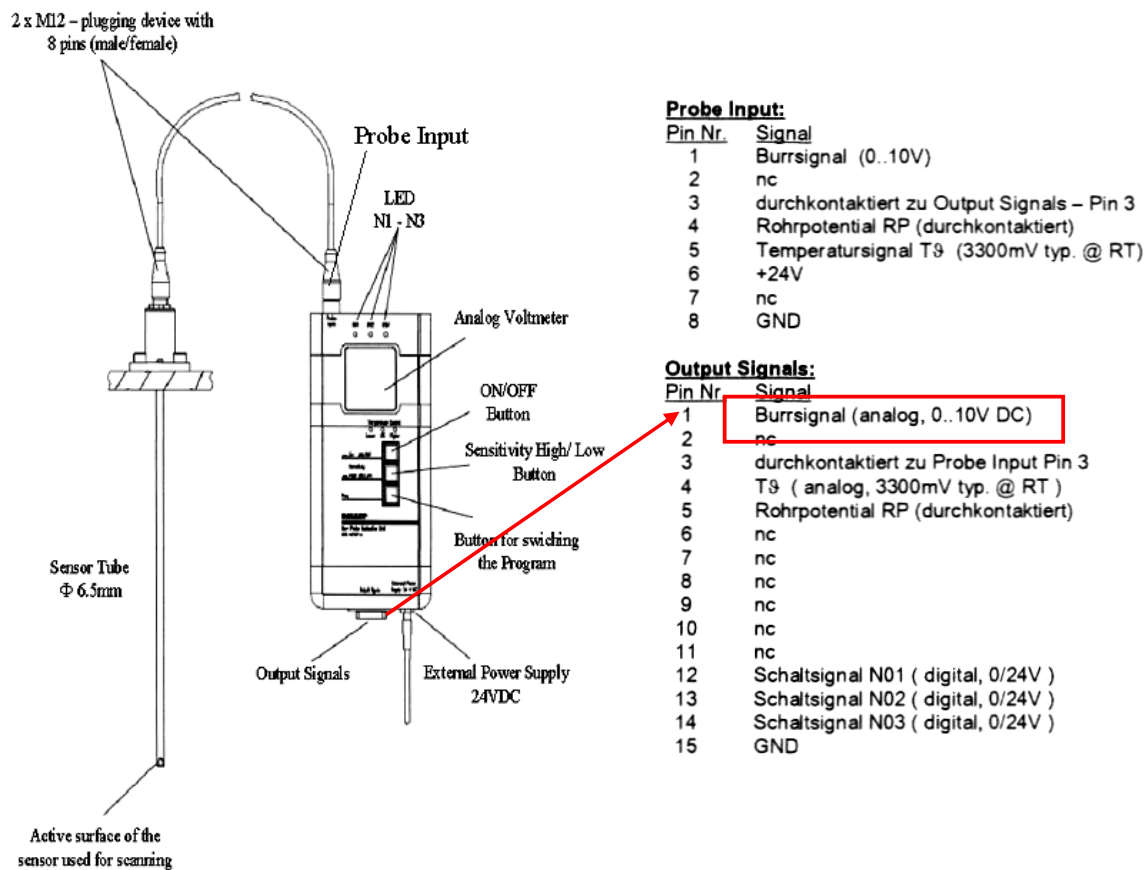| Pin Nr.	Signal
1	Burrsignal (analog, 0..10V DC)
2	nc
3	durchkontaktiert zu Probe Input Pin 3
4	T9 (analog, 3300mV typ. @ RT)
5	Rohrpotential RP (durchkontaktiert)
6	nc
7	nc
8	nc
9	nc
10	nc
11	nc
12	Schaltsignal N01 (digital, 0/24V)
13	Schaltsignal N02 (digital, 0/24V)
14	Schaltsignal N03 (digital, 0/24V)
15	GND

Figure 3.9

a.   Connectivity of Burr Sensor and the BIG P-A065E Device

b.   Probe Input and Output Signals [7]
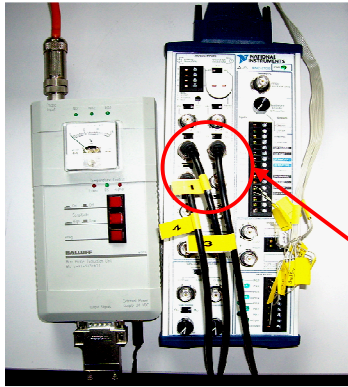
From this pin we used in this very one project a connector to rout the signal at the BNC connector on Differential Analog Input channel *AI2* on the Front Panel[2], as presented in Figure 3.10.

Figure 3.10.Connection between Front Panel and BIG P device

…Monitoring and Acquiring Data

Just for monitoring the evolution in time of the burrsignal from the inductive sensor I have used a few modules and simple functions in Labview 8.0. The signal will be read from the Analog Input channel, *AI2*, using a dedicated module, ***Read Channel*** (Figure 3.11 a) (witch is actually a VI = virtual instrument, Labview interface), and using ***Waveform Chart*** module (Figure 3.11b) the signal will be displayed on a single-plot, single-point waveform chart, as is shown in Figure 3.12, where we have a screen shot of the Front Panel of the Virtual Instrument made in Labview.

Figure 3.11.a.Read Channel b. Waveform Chart

For this matter I had to create a Task for the Analog Input channel using the second software came from National Instruments, Measurement and Automation. Now I will present how the Task is configured and which are the parameters that I used for this channel (Figure 3.13). More details about how to create, test, save and modify a Task are explained in the next chapter, Software Considerations.

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[2] **Front Panel (Control Panel) = BNC-2120 - is a desktop or DIN rail-mountable accessory you can connect to E Series, S Series, and waveform generation Multifunction DAQ devices. The BNC-2120 has a 68-pin input/output (I/O) connector that connects to your E Series, S Series, or waveform generation Multifunction DAQ device.**
   More details about device and what channels (Analog or Digital) I used in this project for monitories and acquiring data from the sensor, also signals for motor control (translation and rotation motor) , will be explain in next subchapter
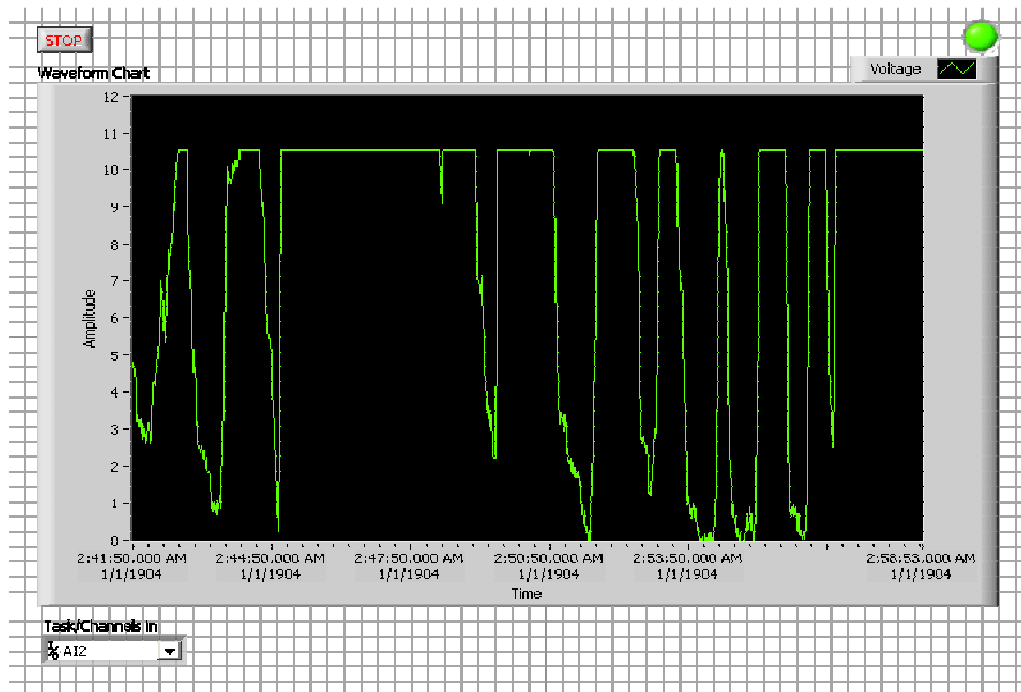
Inductive Sensor System for Evaluation of Burrs and Edges

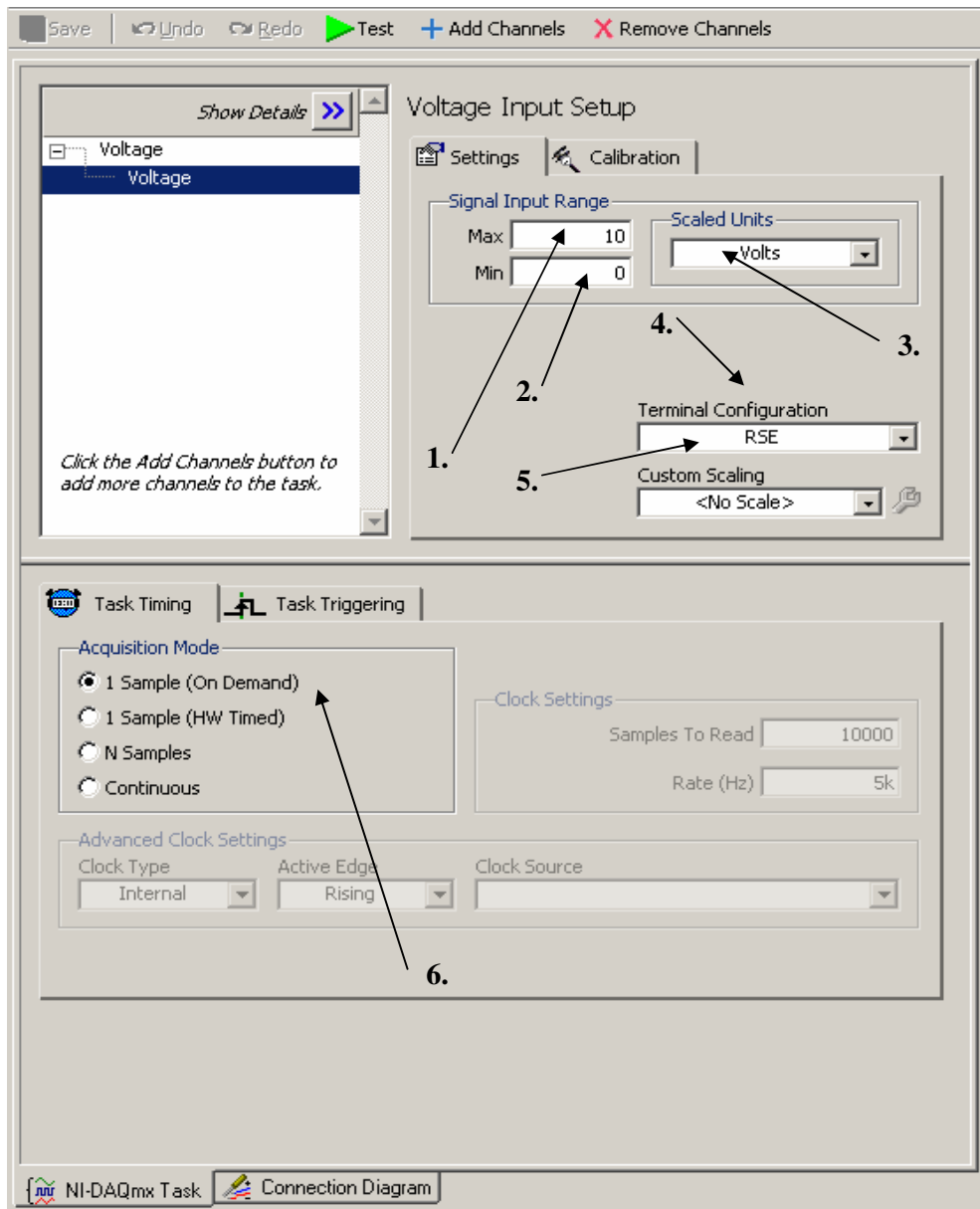*Figure 3.12. Example of how the burrsignal will look like in Labview*

Figure 3.13.Window for configuration

1. Max is the maximum value expected from your measurement after scaling.

2. Min is the minimum value expected from your measurement after scaling.

3. Units is the units used.

4. Terminal Configuration specifies the grounding mode used for the virtual channel

5. RSE—Measurement made relative to the ground.

6. Sample (On Demand) specifies that the task acquire one sample.

_____

A functional block diagram made with Labview for this very one application will look like the one presented in the Figure 3.14.
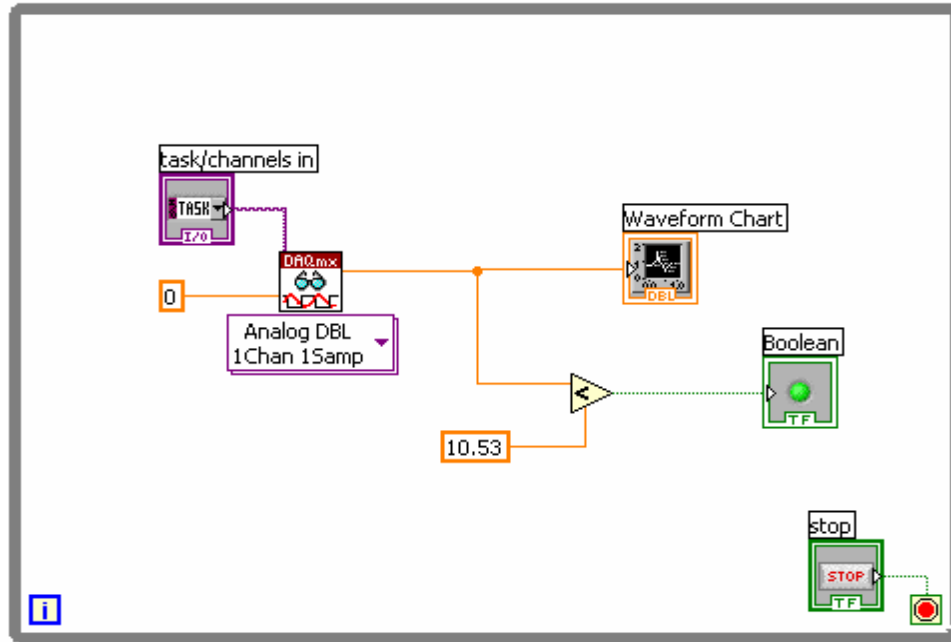

Figure 3.14.Functional block diagram of the presented application

For saving data, we used a specialised module, **Write to Measurement File**, from the Function Palette in Labview. This module is shown in Figure 3.15 along with the main signals that we need to connect to it.
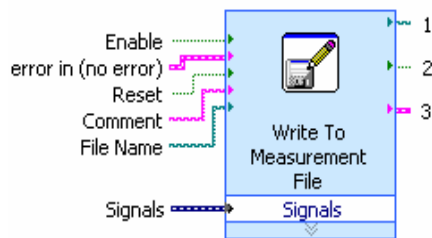

Figure 3.15. Saving module

Enable – is a signal that we need for starting the acquisition

Reset – signal for controlling data acquisition

File Name – choosing a name for the file where we save data

2 – Path where we save data

Signals – is the important signal, contains information about the process and what we want to save.

When we use this module a pop-up window will appear. Here we can configure our data format, we can chose what file format we need (text or binary), segment headers (One header per segment, One header only, No headers), and a few actions (see Figure 3.16 about more details).
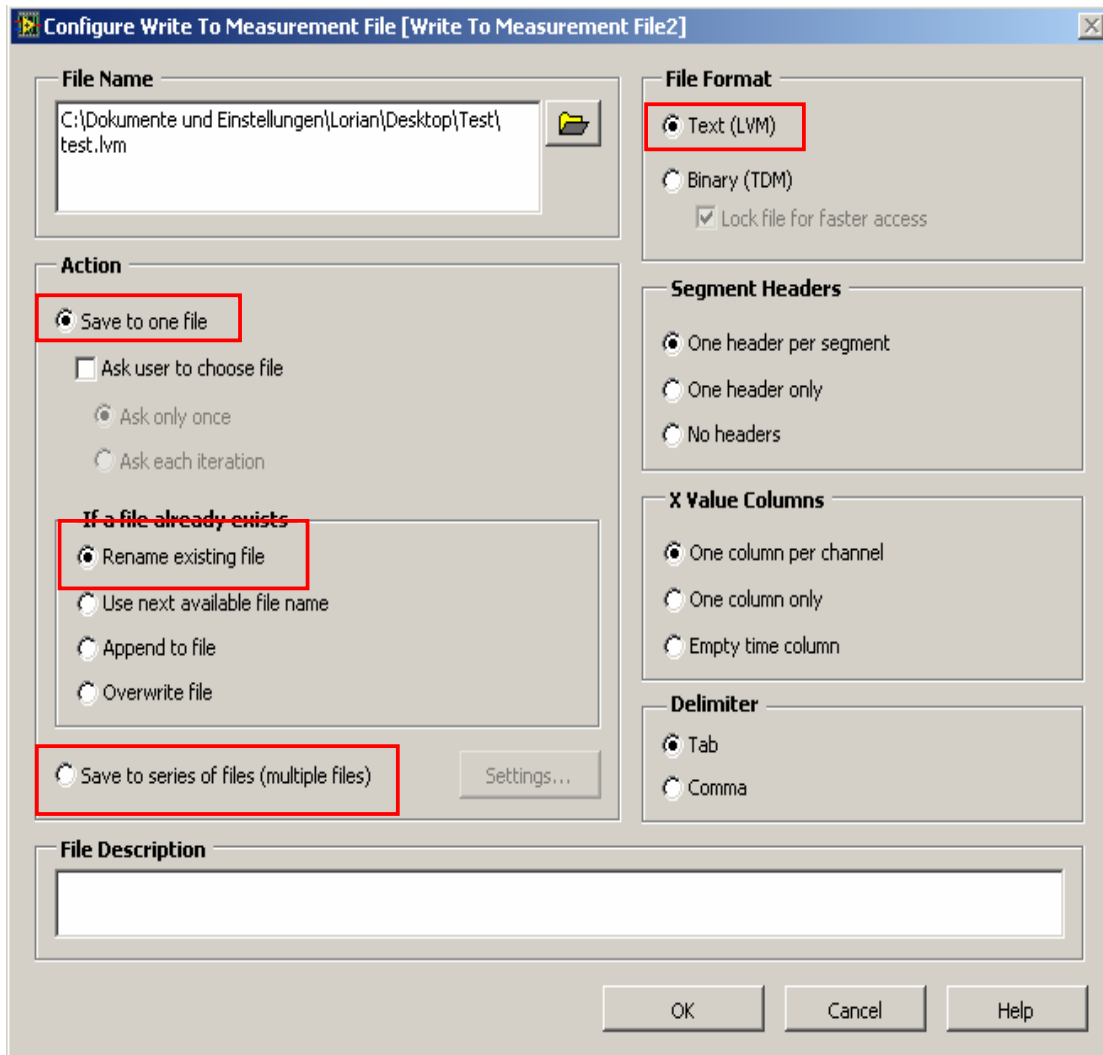
Figure 3.16.Configuration popup window for saving data

The highlighted elements of this pop-up are important because they determinate the quality of the saved data and the future uses of it: generating 3D models of the piece, or an intersection of the holes (see Figure 3.17). The image is then generated using MATLAB[3].

_____

[3]   **The typical usages of MATLAB are algorithm evaluation, data acquisition simulation and processing, data visualization, graphical analysis and creation of a graphical user interface programs.**
A major advantage of the program is given by the possibility of arranging and processing the data in a 3D format.
_____

On the other hand, information generated by the inductive sensor can and will be used inside Labview for controlling the application (more precise scanning mode of the machine) and to know the exact position of the inductive tube at every moment in time, to know the position of the sensor had related to reference point, on the X- axe, and the angle on the rotation axe.
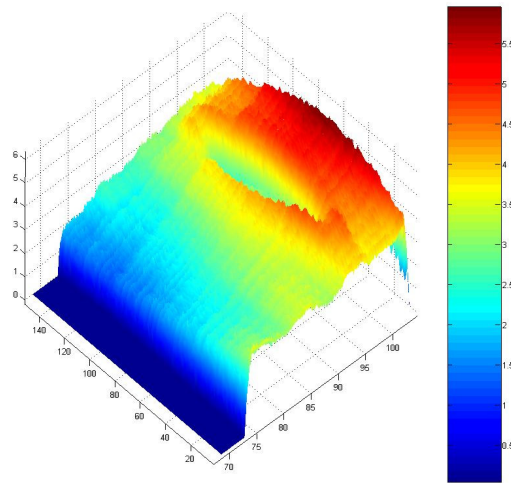
Figure 3.17. In the upper image, there are presented, in a 3D form, the data captured by a complete scan of a hole, using the inductive sensor.

After we configured the saving module and connected the signals that we need for correct acquisition of the information from the inductive sensor. The final solution made in Labview for this matter is shown in Figure 3.18.
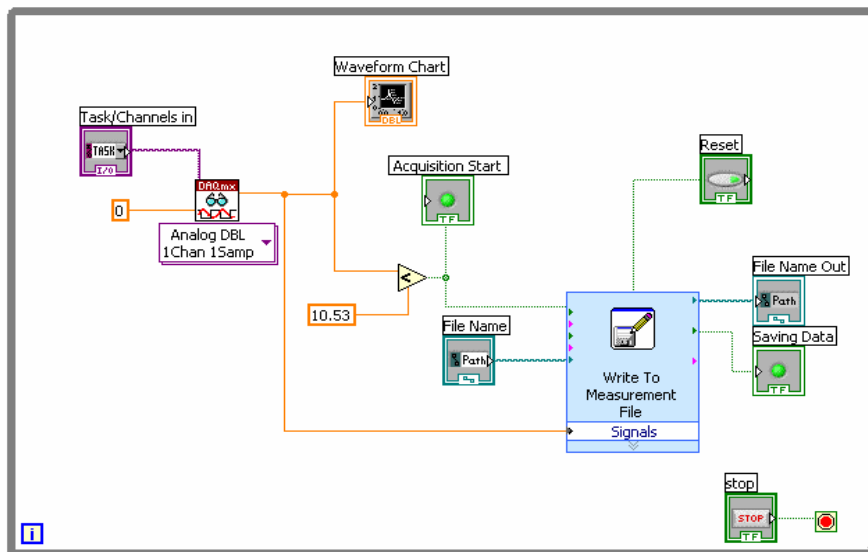

Figure 3.18.Routine for acquiring data from the had of the inductive sensor

…Temperature Output Signal

The conditioned output signal from the temperature sensing section represents a second probe output signal, and is used for monitoring temperature during the burr sensing process. To prevent collisions between the probe and workpiece, the probe outputs a third independent touch signal as soon as these components make contact.

Optimal work areas lie between $20°C$ and $30°C$. In this area a green Led will light up (Temperature Control LED (OK)). Outside of this domain a red LED for Lower level of the region will light up a second red LED for Higher Lever of this temperature domain.

The picture below shows how we can do this in Labview (Figure 3.21).

Monitoring the signal produced by the sensor we can see that it has an area of analog signal from 3.75V (3750 mV) to approximately 4V (4000mV), as we can see in Figure 3.19, when the sensor is working in the optimal area (the producer of the sensor recommends exactly 3300mV).
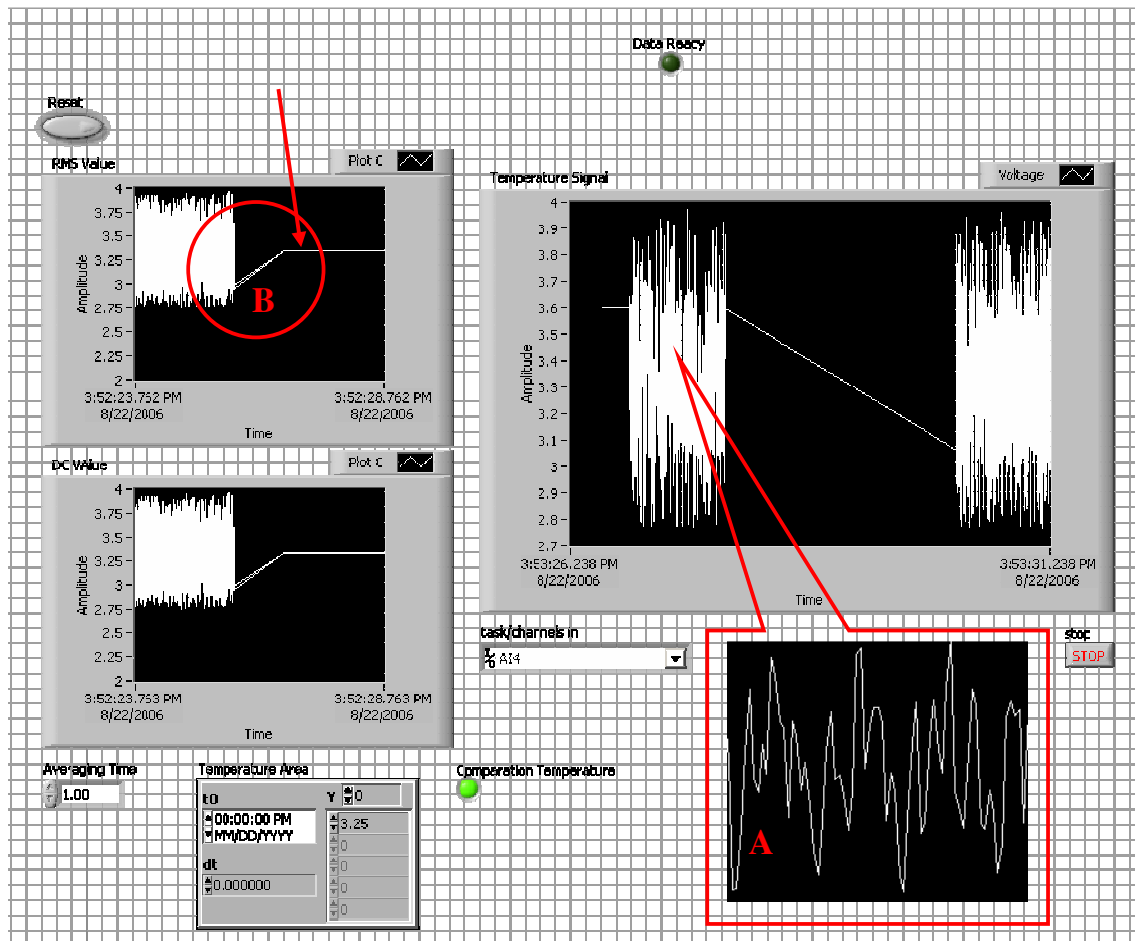

Figure 3.19.Temperature signal given by the inductive sensor

_____

Author: Dudic Lorian

In order to obtain from the signal given by the sensor (area A), a signal with the value approximately equal whit the one given by the Balluff Company (3.3V) (area B), we must calculate an average of the A signal, which is done in Labview as is shown in Figure 3. 21, with the modules inside of the area mark with C. This way we can get a signal of nearly 2.28 V (2280mV).
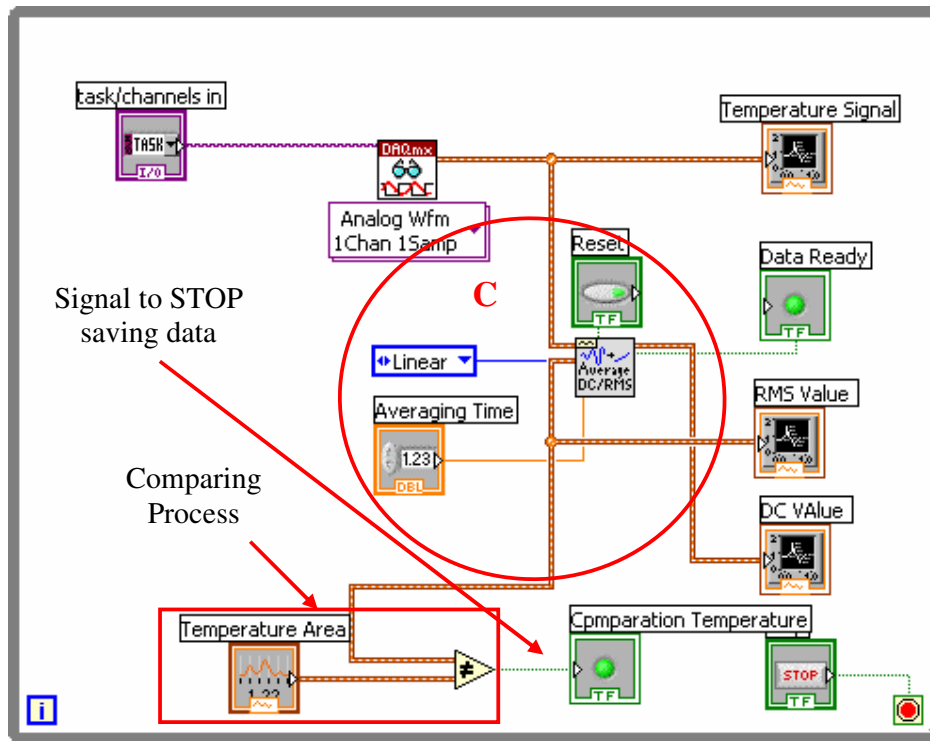
Figure 3.21.Monitoring and processing the Temperature Signal

We need to do this thing in order to adjust the data acquisition, to eliminate errors, and to eliminate data when the working temperature of the sensor is under or below given area.

When the working temperature is outside of the area, acquisition will be stopped, actually the data saving process stops (made in Labview as pointed in Figure 3.21), because we do not need information when the sensor is returning unusable data.

3.2.   Front Panel (Control Panel) – BNC-2120

3.2.1.   General Characteristics

The BNC-2120 is a desktop or DIN rail-mountable accessory you can connect to E Series, S Series, M Series (own very one data acquisition board) and waveform generation Multifunction DAQ devices.

The BNC-2120 has the following features:

- Eight BNC connectors for analog input (AI) connection with the following optional features:

  – Thermocouple connector

  – Temperature reference

  – Resistor measurement screw terminals

- Two BNC connectors for analog output (AO) connection

- Screw terminals for digital input/output (DIO) connection with state indicators

- Screw terminals for Timing I/O connections

- Two user-defined BNC connectors

- A function generator with the following outputs:

  – Frequency-adjustable, TTL-compatible square wave

  – Frequency- and amplitude-adjustable sine wave or triangle wave

The BNC-2120 has a 68-pin input/output (I/O) connector that connects to the E Series, S Series, M Series, or waveform generation Multifunction DAQ device. (For more details address to Appendix 3.3

Table 3-1.pinouts of the device

Front Panel BNC Connectors	Signal Description
AI <0..1>	Differential Analog Input channels 0 and 1[1].
AI <2..7>/AO <7..2>	Differential Analog Input channels 2 through 7[2] or Analog Outputs 7 through 2[3].
AO <1..0>	Analog Output channels 1 and 0.
PFI 0/AI START TRIG	Programmable Function Input 0/Trigger 1—As an input, this connector is either one of the PFIs or the source for the hardware analog trigger. As an output, it is the AI start trigger.
USER <1..2>	User-defined 1 and 2—Connected to USER 1 and USER 2 digital terminal blocks. This connector allows you to use a BNC connector for a digital or timing I/O signal of your choice.

[1] E Series and S Series devices only, reserved in waveform generation Multifunction DAQ devices
[2] When connected to E Series or S Series devices
[3] When connected to waveform generation Multifunction DAQ devices

3.2.2. HOW TO…

…Now I will present how the signals are connected to the Front Panel, on which cannel they are routed, how to create a virtual channel to measure and manage these signals and, the most important aspect why actually they are need.

…Connecting Analog Input

The BNC-2120 can be used to measure floating and ground-referenced AI signals. It can also measure temperature and resistance (as shown in Figure 3.22). This is already mentioned in the previous subchapter where is explain how to monitories, measure and acquire data from the Inductive sensor using the Analog Input. Here is pointed only the connectors which are used for this task are pointed here.

…Connecting Digital I/O

In this project, digital I/O are used for controlling the Stepper Motors, for managing their motion on the O_x, O_y and O_z axes, same the pins are used for monitoring the motion, to be more precise, one of the signals gives us the information about when the machine came to the end of the translation axe, in one direction or another. Signal characteristics and their connectivity to the BNC- 2120 device are represented in the following picture. (Figure 3.23)
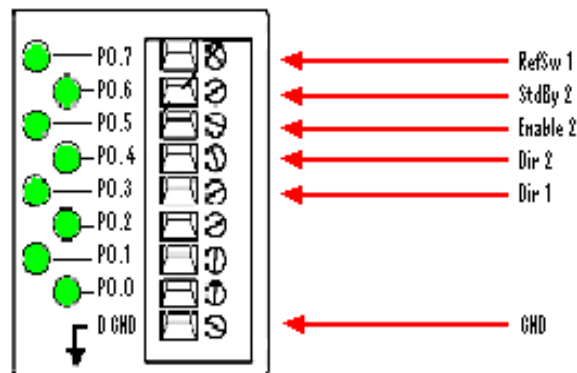

Figure 3.23.Connectivity of the Digital I/O

1. Reference switch, Overrun limit switch (RefSw)

Microswitches are used as reference or limit position switches. If installed and operated correctly, they can be used for referencing at a repeatability of ±1 step. The evaluation of this signal is not carried out on the stepper motor control board, but in the interface card connected upstream the system. An active H signal results in direct abortion of the step output. The only job of the control system is to carry the appropriate signal.

2. Standby (StdBy)

With the signal input unassigned (open), a motor current of approx. 50% of the set operating current results because of the internal pull-up resistor. An L signal (0 V) will enable the full, set motor current.

3. Output stage disable (Enable)

This is a signal input for disabling the power output stage, H signal when the output stage is active (Enabled), the L signal - output stage is disabled

4. Direction (Dir)

Is a signal input for defining the desired direction of rotation for the motor

H signal - positive direction of rotation of stepper motor (CCW)

L signal - negative direction of rotation of stepper motor (CW)

In order to solve this matter, it is recommended to do the following steps:

a. Generating a Digital Sample (Line)

Digital lines from our DAQ device can be used to generate a digital sample. This operation is based on software timing. Each line corresponds to a virtual channel in your task. All E and M Series devices support TTL (transistor-transistor logic) - compatible digital signals.

Common digital generation applications include controlling relays and driving external devices, such as a LED (as shown in Figure 3.23).

b. Acquiring a Digital Sample (Line)

We use the digital lines from the DAQ device to acquire a digital value. This acquisition is based on software timing. Each line corresponds to a virtual channel in the task.

c. Configure them in order to obtain desired results (Figure 3.24)

_____

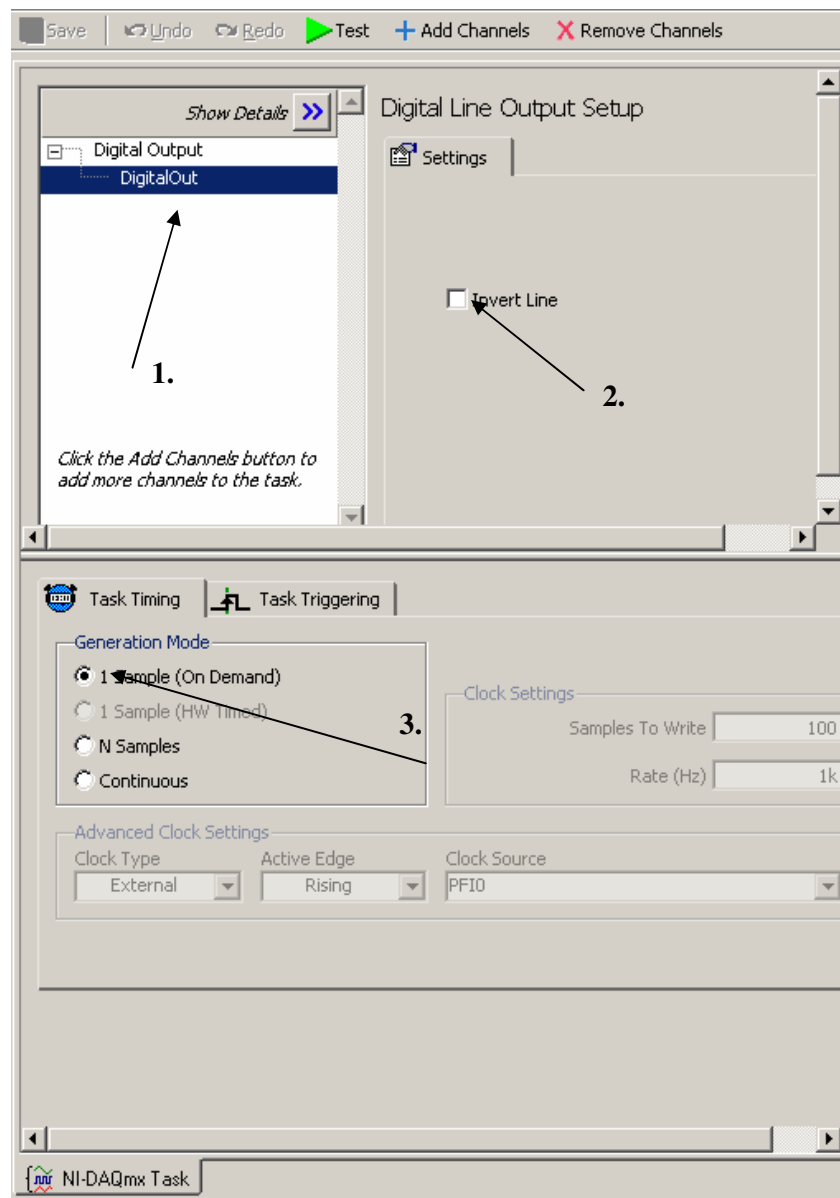Inductive Sensor System for Evaluation of Burrs and Edges

Figure 3.24 Configuration of the task

1. This is the list of virtual channels.

2. Invert Line reverses the polarity of the line.

3. Sample (On Demand) specifies that the task generate one sample.

…Connecting PFI (Programmable Function Interface)

M Series devices have up to 16 Programmable Function Interface (PFI) signals. In addition, M Series devices have up to 32 lines of bidirectional DIO signals.

Each PFI can be individually configured as the following.

- A static digital input
- A static digital output
- A timing input signal for AI, AO, DI, DO, or counter/timer functions
- A timing output signal from AI, AO, DI, DO, or counter/timer functions

Each PFI input also has a programmable debouncing filter. Figure 3.25 shows the circuitry of one PFI line. Each PFI line is similar.
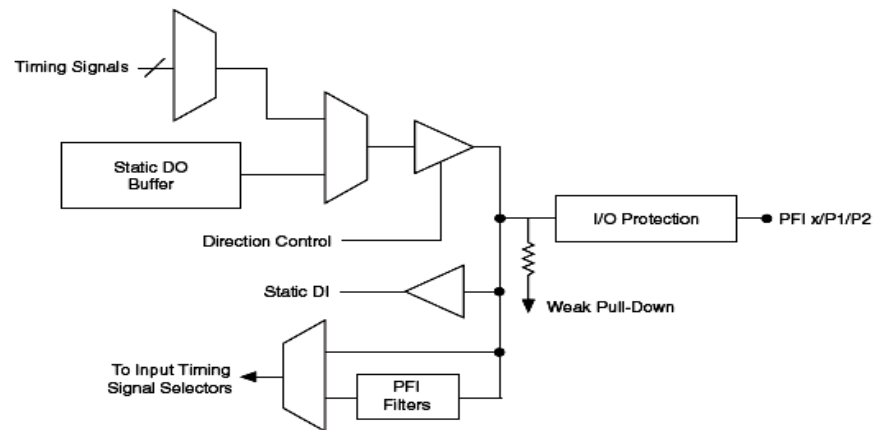

Figure 3.25 M Series PFI Circuitry

Specific function that were used in this application for Pulse Generation[4] are ***CTR0 OUT and CTR1 OUT (marked as a surface D in Figure 3.22) (output line form the counters on the DAQmx board).*** Reason that is chose hardware generation for the Clock[5] of the stepper motor is to be independently from the Application, because a task is running eparately from the main application. More details about counters and pulse generation it can be found in the subchapter, called NI-DAQmx 6251 in his subchapter named Counters.

---

[4] **Using a counter to output pulses is called pulse generation. Some measurement devices can generate TTL pulses from the counter/timer of the device. The pulse is either low (starts high, pulses low, and returns high) or high (starts low, pulses high, and returns low). A pulse can be used as a clock signal, a gate, or a trigger for other measurements and generations.**

[5] **The direct proportionality of clock frequency and motor speed or of the number of clocks and the motor rotation angle are an important criterion when using a stepper motor drive. With the stepper motor control 313112, each negative edge change at the Clk input results in a defined step angle motion of 1.8° in full-step mode, and 0.9° in half-step mode. The execution of the steps can be disabled using the signal input ClkEna**

Some inputs from the on-board counters are used, in order to detect and count every pulse separately on every rising edge.

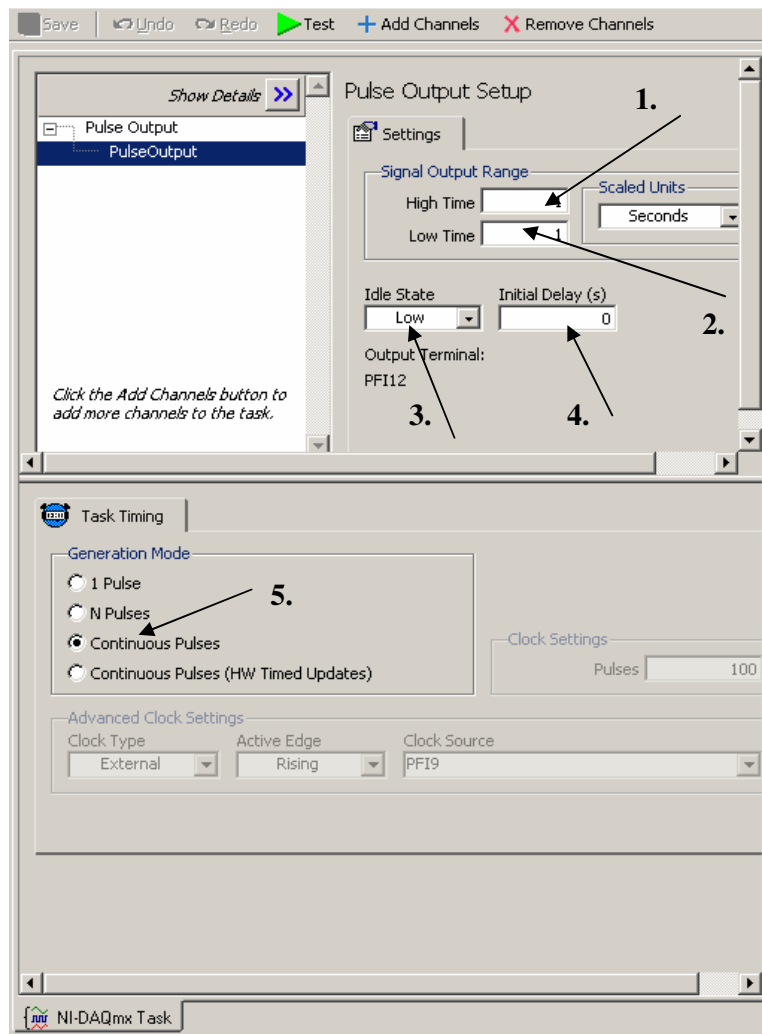Configuration of those two tasks will be illustrated in the next Figures.

Figure 3.26.Takc configuration for pulse generation

1. High Time - The amount of time the pulse is at a high level (5 V)

2. Low Time - The amount of time the pulse is at a low level (0 V)

3. Initial Delay - The amount of time the output remains at the idle state before generating the pulse

4. Idle State specifies the polarity of the generated signal:

   High - Terminal is at a high state at rest. Pulses move the terminal to a low state.

   Low - Terminal is at a low state at rest. Pulses move the terminal to a high state.

5. Continuous Pulses specifies that the task generate pulses until stopped.
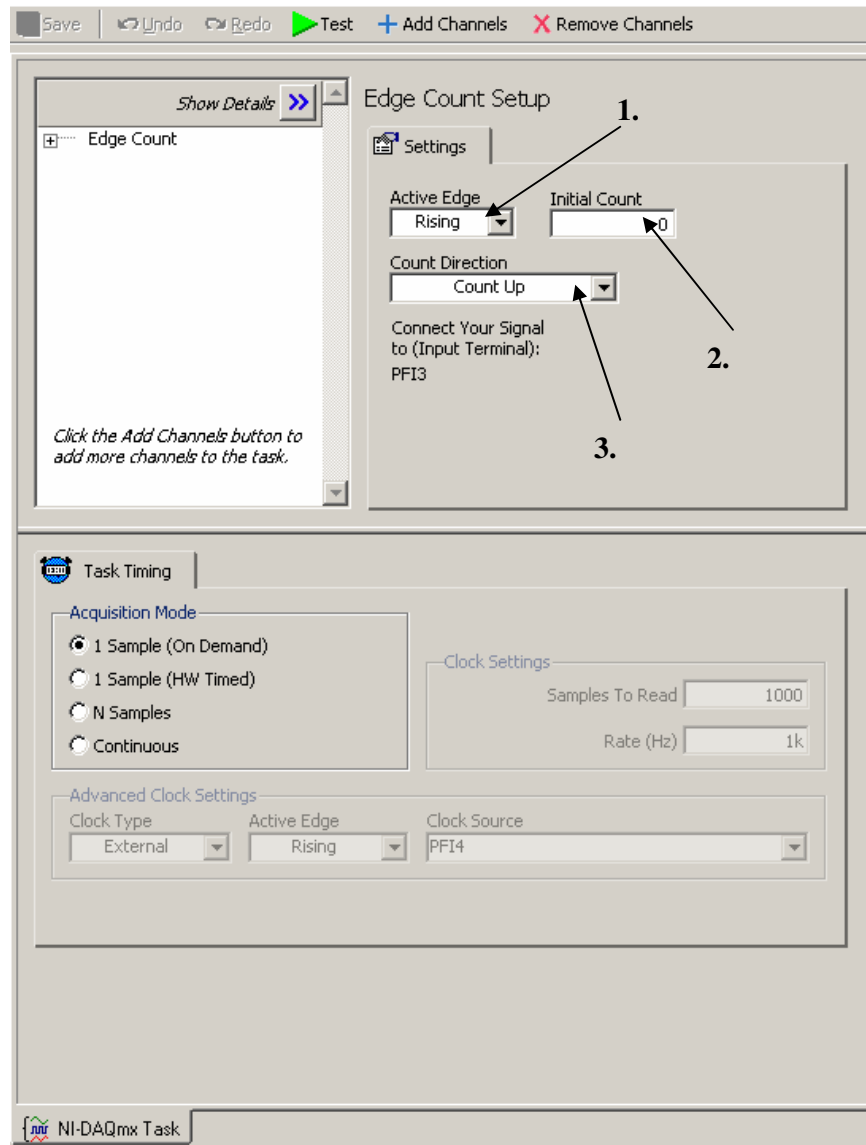
Figure 3.27.Task configuration for counting the pulses

1. Active Edge specifies on which edge of the signal to acquire samples or update the generation. If you are counting edges, **Active Edge** specifies on which edge of the source signal to count:

> **Rising**—Acquire samples, update generation, or count on rising edges.

> **Falling**—Acquire samples, update generation, or count on falling edges.

2. Initial Count is the value to start counting from.

3. Count Direction specifies whether to increment or decrement the counter with each edge:

> **Count Up**—Increment the counter.

> **Count Down**—Decrement the counter.

> **Externally Controlled**—The state of a digital line controls the count direction.

For STC-based devices, port0/line6 controls the count direction for CTR and port0/line7 controls the count direction for CTR1.
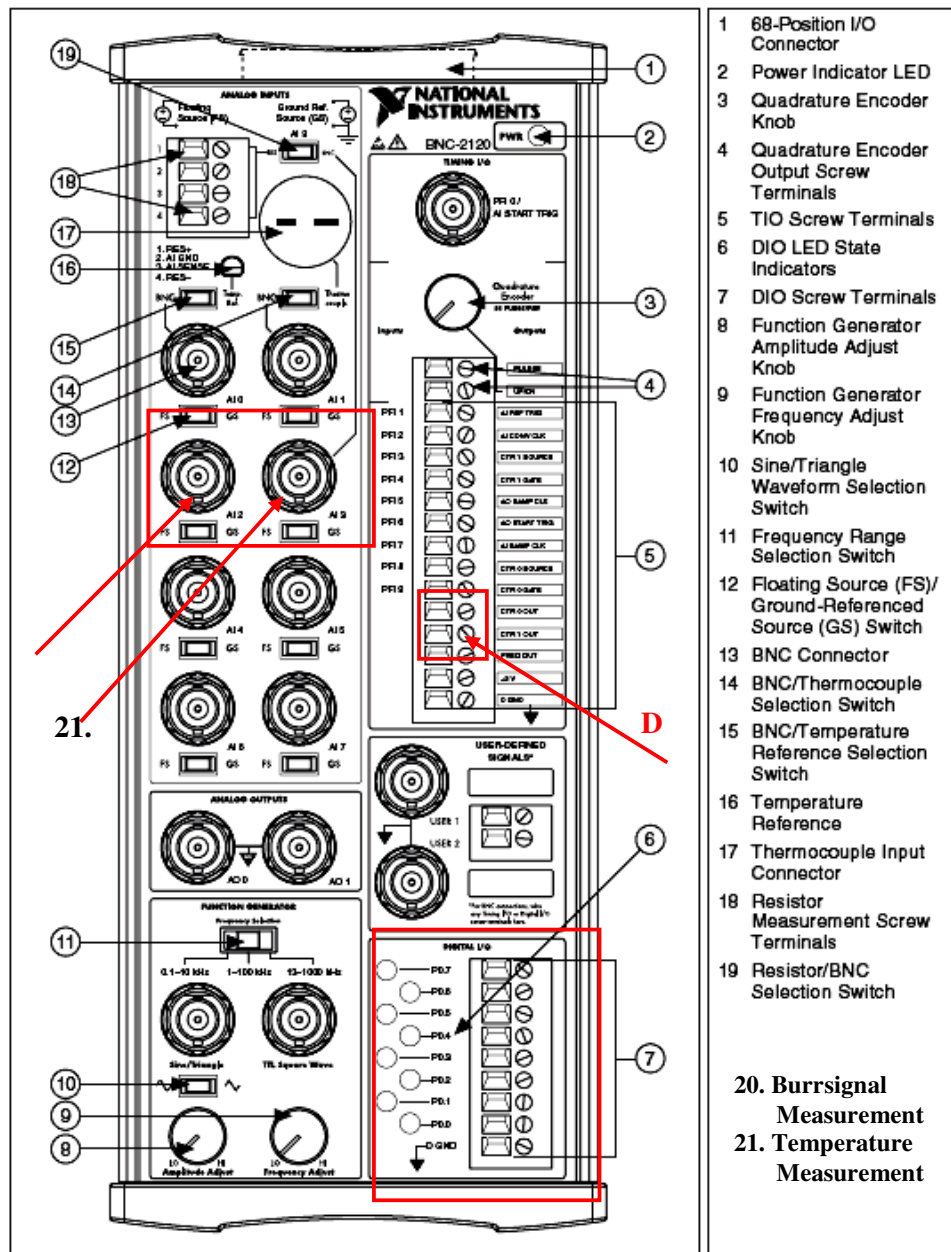

1	68-Position I/O Connector
2	Power Indicator LED
3	Quadrature Encoder Knob
4	Quadrature Encoder Output Screw Terminals
5	TIO Screw Terminals
6	DIO LED State Indicators
7	DIO Screw Terminals
8	Function Generator Amplitude Adjust Knob
9	Function Generator Frequency Adjust Knob
10	Sine/Triangle Waveform Selection Switch
11	Frequency Range Selection Switch
12	Floating Source (FS)/ Ground-Referenced Source (GS) Switch
13	BNC Connector
14	BNC/Thermocouple Selection Switch
15	BNC/Temperature Reference Selection Switch
16	Temperature Reference
17	Thermocouple Input Connector
18	Resistor Measurement Screw Terminals
19	Resistor/BNC Selection Switch

20. Burrsignal Measurement
21. Temperature Measurement

Figure 3.22.Connectors from the Front Panel (BNC-2021)

3.3. NI-DAQmx 6251

3.3.1. DAQ Hardware and Characteristics

DAQ hardware digitizes signals, performs D/A conversions to generate analog output signals, and measures and controls digital I/O signals. Figure 3.28 features components common to all M Series devices.
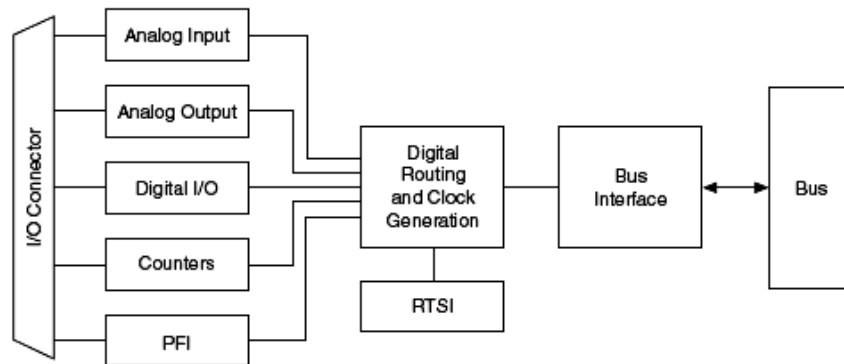

Figure 3.28.M Series Block Diagram

Some key features of this engine include the following:

- Flexible AI and AO sample and convert timing

- Many triggering modes

- Independent AI, AO, DI, and DO FIFOs

- Generation and routing of RTSI signals for multi-device synchronization

- Generation and routing of internal and external timing signals

- Two flexible 32-bit counter/timer modules with hardware gating

- Digital waveform acquisition and generation

- Static DIO signals

- True 5 V high current drive DO

- DI change detection

- Seamless interface to signal conditioning accessories

- PCI/PXI interface

_____

Signal Conditioning

Many sensors and transducers require signal conditioning before a measurement system can effectively and accurately acquire the signal. The front-end signal conditioning system can include functions such as signal amplification, attenuation, filtering, electrical isolation, simultaneous sampling, and multiplexing. In addition, many transducers require excitation currents or voltages, bridge completion, linearization, or high amplification for proper and accurate operation. Therefor, most computer-based measurement systems include some form of signal conditioning in addition to plug-in data acquisition DAQ devices.

3.3.2. Analog Input

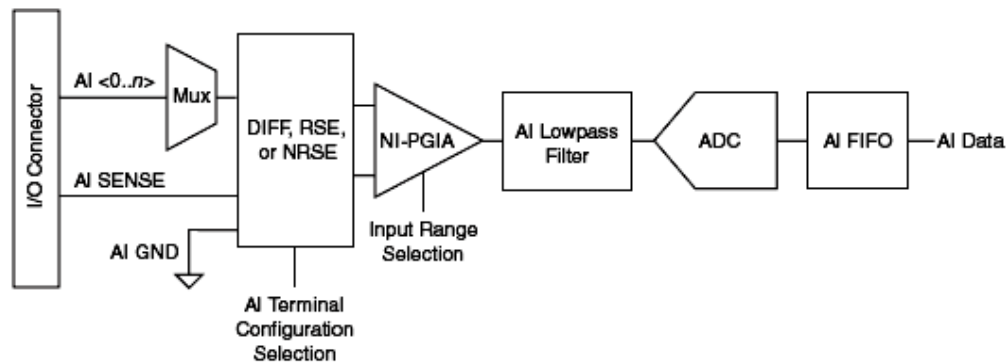Figure 3.29 shows the analog input circuitry of M Series devices.

Figure 3.29.Analog Input Circuitry

Analog Input Circuitry

a. I/O Connector

You can connect analog input signals to the M Series device through the I/O connector. The proper way to connect analog input signals depends on the analog input ground-reference settings.

b. MUX

Each M Series device has one analog-to-digital converter (ADC). The multiplexers (MUX) route one AI channel at a time to the ADC through the NI-PGIA.

c. Ground-Reference Settings

The analog input ground-reference settings circuitry selects between differential, referenced single-ended, and non-referenced single-ended input modes. Each AI channel can use a different mode (see Appendix 3.3).

d. Instrumentation Amplifier (NI-PGIA)

The NI programmable gain instrumentation amplifier (NI-PGIA) is a measurement and instrument class amplifier that minimizes settling times for all input ranges. The NI-PGIA can amplify or attenuate an AI signal to ensure that you use the maximum resolution of the ADC. M Series devices use the NI-PGIA to deliver high accuracy even when sampling multiple channels with small input ranges at fast rates. M Series devices can sample channels in any order at the maximum conversion rate, and you can individually program each channel in a sample with a different input range.

e. A/D Converter

The analog-to-digital converter (ADC) digitizes the AI signal by converting the analog voltage into a digital number.

f. AI FIFO

M Series devices can perform both single and multiple A/D conversions of a fixed or infinite number of samples. A large first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure that no data is lost. M Series devices can handle multiple A/D conversion operations with DMA, interrupts, or programmed I/O.

Analog Input Data Acquisition Methods

When performing analog input measurements, it either can perform software-timed or hardware-timed acquisitions. Hardware-timed acquisitions can be buffered or non-buffered.

Software-Timed Acquisitions

With a software-timed acquisition, software controls the rate of the acquisition. Software sends a separate command to the hardware to initiate each ADC conversion. In NI-DAQmx, software-timed acquisitions are referred to as having on-demand timing. Software-timed acquisitions are also referred to as immediate or static acquisitions and are typically used for reading a single sample of data.

_____

Hardware-Timed Acquisitions

With hardware-timed acquisitions, a digital hardware signal (ai/SampleClock) controls the rate of the acquisition. This signal can be generated internally on the device or provided externally.Hardware-timed acquisitions have several advantages over software-timed acquisitions.

- The time between samples can be much shorter.
- The timing between samples is deterministic.
- Hardware-timed acquisitions can use hardware triggering.

Hardware-timed operations can be buffered or non-buffered. A buffer is a temporary storage in computer memory for to-be-generated samples.

3.3.3. Digital I/O

M Series devices contain up to 32 lines of bidirectional DIO signals on Port 0. In addition, M Series devices have up to 16 PFI signals that can function as static DIO signals. M Series devices support the following DIO features on Port 0:

- Up to 32 lines of DIO
- Direction and function of each terminal individually controllable
- Static digital input and output
- High-speed digital waveform generation
- High-speed digital waveform acquisition
- DI change detection trigger/interrupt

Figure 3.30 shows the circuitry of one DIO line. Each DIO line is similar. The following sections provide information about the various parts of the DIO circuit.
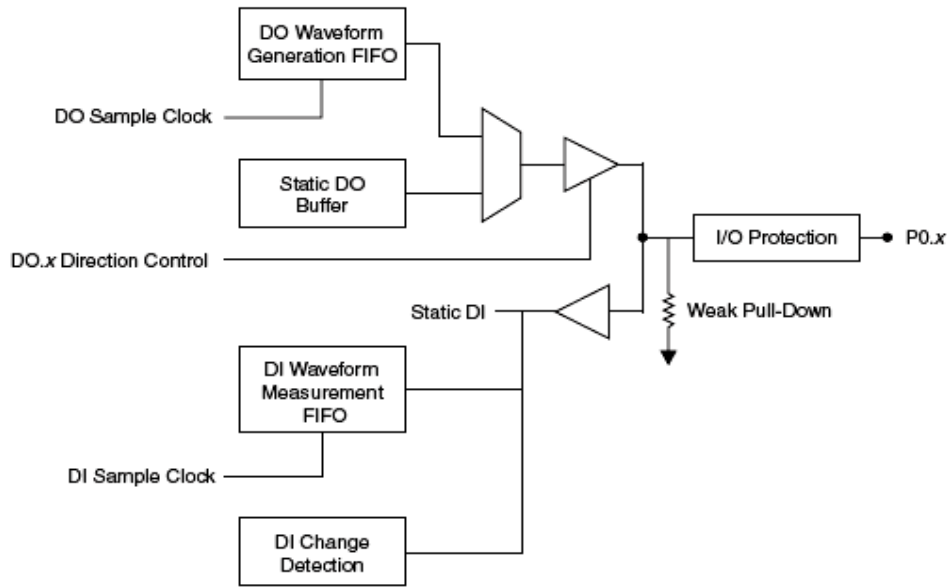
Figure 3.30.Digital I/O Circuitry

3.3.4. Counters

M Series devices have two general-purpose 32-bit counter/timers and one frequency generator, as shown in Figure 3.31. The general-purpose counter/timers can be used for many measurement and pulse generation applications.

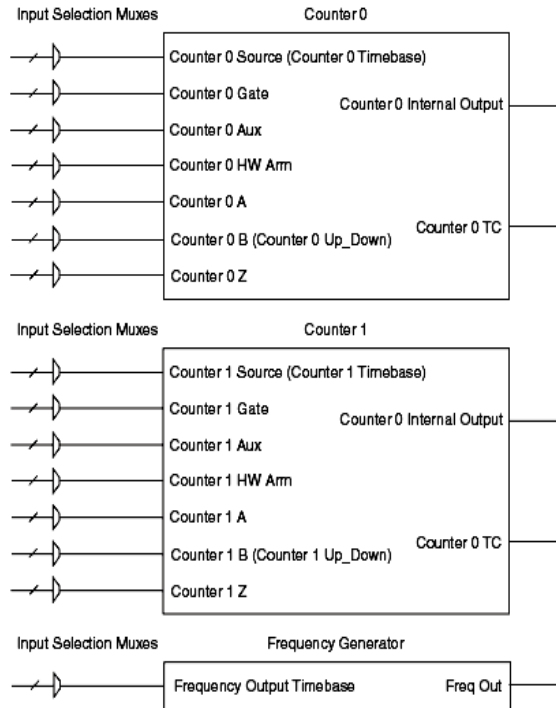The counters have seven input signals, although in most applications only a few inputs are used.

Figure 3.31.Counters

Counter Output Applications

1. Pulse Train Generation. Continuous Pulse Train Generation

This function generates a train of pulses with programmable frequency and duty cycle. The pulses appear on the Counter n Internal Output signal of the counter. A delay can be specified from when the counter is armed to the beginning of the pulse train. The delay is measured in terms of a number of active edges of the Source input. Also it can be specified the high and low pulse can be specified widths of the output signal. The pulse widths are also measured in terms of a number of active edges of the Source input. You can also specify the active edge of the Source input (rising or falling). The counter can begin the pulse train generation as soon as the counter is armed, or in response to hardware Start Trigger. You can route the Start Trigger to the Gate input of the counter. Also it can be used the Gate input of the counter as a Pause Trigger (if it is not used as a Start Trigger).

The counter pauses pulse generation when the Pause Trigger is active. Figure 3.33 shows a continuous pulse train generation (using the rising edge of Source).
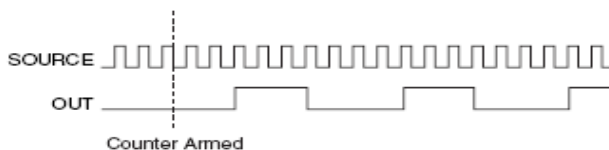

Figure 3.33.Continuos Pulse train Generation

Continuous pulse train generation is sometimes called frequency division. If the high and low pulse widths of the output signal are M and N periods, then the frequency of the Counter n Internal Output signal is equal to the frequency of the Source input divided by $M + N$

2. Frequency Generation

It can also generate a frequency by using a counter in pulse train generation mode or by using the frequency generator circuit.

a. Using the Frequency Generator

The frequency generator can output a square wave at many different frequencies. The frequency generator is independent of the two general-purpose 32-bit counter/timer modules on M Series devices.

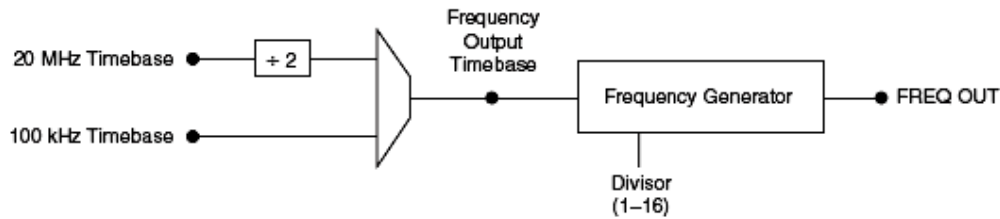Figure 3.34 shows a block diagram of the frequency generator.

Figure 3.34.Frequency Generator Block Diagram

The frequency generator generates the Frequency Output signal. The Frequency Output signal is the Frequency Output Timebase divided by a number you select from 1 to 16. The Frequency Output Timebase can be either the 20 MHz Timebase divided by 2 or the 100 kHz Timebase. The duty cycle of Frequency Output is 50% if the divider is either 1 or an even number. For an odd divider, suppose the divider is set to D. In this case, Frequency Output is low for $(D+1)/2$ cycles and high for $(D-1)/2$ cycles of the Frequency Output Timebase. Figure 3.35 shows the output waveform of the frequency generator when the divider is set to 5.
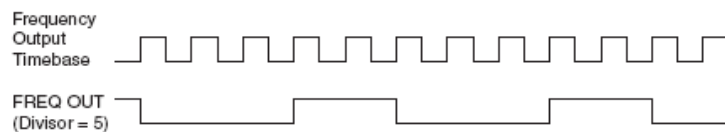

Figure 3.35.Frequency Generator Output Waveform

Chapter 4.

Software Considerations

Data acquisition is the sampling of the real world to generate data that can be manipulated by a computer. Sometimes abbreviated **DAQ** or **DAS**, data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include appropriate sensors that convert any measurement parameter to an electrical signal, which is acquired by data acquisition hardware.

Acquired data is displayed, analyzed, and stored on a computer, either using vendor supplied software, or custom displays and control can be developed using various programming languages such as BASIC, C, Fortran, Java, Lisp, Pascal.

How Data is acquired?

Transducers (most often **sensors**) convert measurable physical phenomenon into electric signals. Examples of tranducers include microphones for sound and photocells for light.

Signals may be digital or analog depending on the tranducer used.

Signal conditioning may be necessary if the signal from the transducer is not suitable for the DAQ hardware to be used. The signal may be amplified or deamplified, or may require filtering.

        DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc...) or cards connected to slots (PCI, ISA) in the mother board.

        Driver Software that usually comes with the DAQ hardware or from other vendors, allows the operating system to recognize the DAQ hardware and programs to access the signals being read by the DAQ hardware.

4.1. LabVIEW 8.0

        LabVIEW (short for *Lab*oratory *V*irtual *I*nstrumentation *E*ngineering *W*orkbench) is a platform and development environment for a visual programming language[1] from National Instruments. The graphical language is named "G". Originally released for the Apple Macintosh in 1986, LabVIEW is commonly used for ***Data Acquisition***, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various flavors of UNIX, Linux, and Mac OS. The latest version of LabVIEW is version 8.20. [11]

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[1]   **Visual programming language (VPL) is any programming language that lets users specify programs in a two-(or more)-dimensional way. Conventional textual languages are not considered two-dimensional since the compiler or interpreter processes them as one-dimensional streams of characters. A VPL allows programming with visual expressions, spatial arrangements of text and graphic symbols. Most VPLs are based on the idea of "boxes and arrows," that is, boxes or circles or bubbles, treated as screen objects, connected by arrows, lines or arcs (here a will mention a few VPLs: Circuit Maker, Hyperpascal, Prograph, PROTEL, LabVIEW). [13]**
Current developments try to integrate the visual programming approach with dataflow languages to either have immediate access to the program state resulting in online debugging (i.e. LabVIEW) or automatic program generation and documentation (i.e. visual paradigm). Dataflow languages also allow automatic parallelisation, which is likely to become one of the greatest programming challenges of the future.

Virtual Instrumentation is the use of customizable software and modular measurement hardware to create user-defined measurement systems, called virtual instruments (A program that implements functions of an instrument by computer, sensors and actuators. This can be a program written in the LabVIEW or in other programming language). 'Traditional' or 'natural' instrumentation systems are made up of pre-defined hardware components, such as digital multimeters and oscilloscopes that are completely specific to their stimulus, analysis, or measurement function. Because of their hard-coded function, these systems are more limited in their versatility than virtual instrumentation systems. The primary difference between 'natural' instrumentation and virtual instrumentation is the software component of a virtual instrument. The software enables complex and expensive equipment to be replaced by simpler and less expensive hardware; e. g. analog to digital converter can act as a hardware complement of a virtual oscilloscope, a potentiostat enables frequency response acquisition and analysis in electrochemical impedance spectroscopy with virtual instrumentation.

Leveraging commercially available technologies, such as the PC and the analog to digital converter, virtual instrumentation has grown significantly since its inception in the late 1970s. Additionally, software packages like National Instruments' LabVIEW and other graphical programming languages helped grow adoption by making it easier for non-programmers to develop systems.

The programming language used in LabVIEW, called "G", is a dataflow language[2]. Execution is determined by the structure of a graphical block diagram (the LV-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, "G" is inherently capable of parallel execution. Multi-processing and multi-threading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution.

---

[2]   *Dataflow* **language is a visual programming language that implements dataflow principles and architecture, and models a program, conceptually if not physically, as a directed graph of the data flowing between operations. Dataflow languages share some features of functional languages, and were generally developed in order to bring some functional concepts to a language more suitable for numeric processing.**

Programmers with a background in conventional programming often show a certain reluctance to adopt the LabVIEW dataflow scheme, claiming that LabVIEW is prone to race conditions. In reality, this stems from a misunderstanding of the data-flow paradigm. The afore-mentioned data-flow (which can be "forced", typically by linking inputs and outputs of nodes) completely defines the execution sequence, and that can be fully controlled by the programmer. Thus the execution sequence of the LabVIEW graphical syntax is as well-defined as with any textually coded language such as C, Visual BASIC, Python etc. Furthermore, LabVIEW does not require type definition of the variables; the wire type is defined by the data-supplying node. LabVIEW supports polymorphism in that wires automatically adjust to various types of data.

Graphical programming

LabVIEW ties the creation of user interfaces (called front panels) into the development cycle. LabVIEW programs/subroutines are called virtual instruments (VIs). Each VI has three components: a block diagram, a front panel and a connector pane. The latter may represent the VI as a subVI in block diagrams of calling VIs. Controls and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument. However, the front panel can also serve as a programmatic interface. Thus a virtual instrument can either be run as a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the given node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program (Figure 4.1).

The graphical approach also allows non-programmers to build programs by simply dragging and dropping virtual representations of the lab equipment with which they are already familiar. The LabVIEW programming environment, with the included examples and the documentation, makes it easy to create small applications. This is a benefit on one side but there is also a certain danger of underestimating the expertise needed for good quality "G" programming. For complex algorithms or large-scale code it is important that the programmer understands the special LabVIEW syntax and the topology of its memory management well.

The most advanced LabVIEW development systems offer the possibility of building stand alone applications. Furthermore, it is possible to create distributed applications which communicate by a server/client scheme, which the inherently parallel nature of *G*-code makes easy.
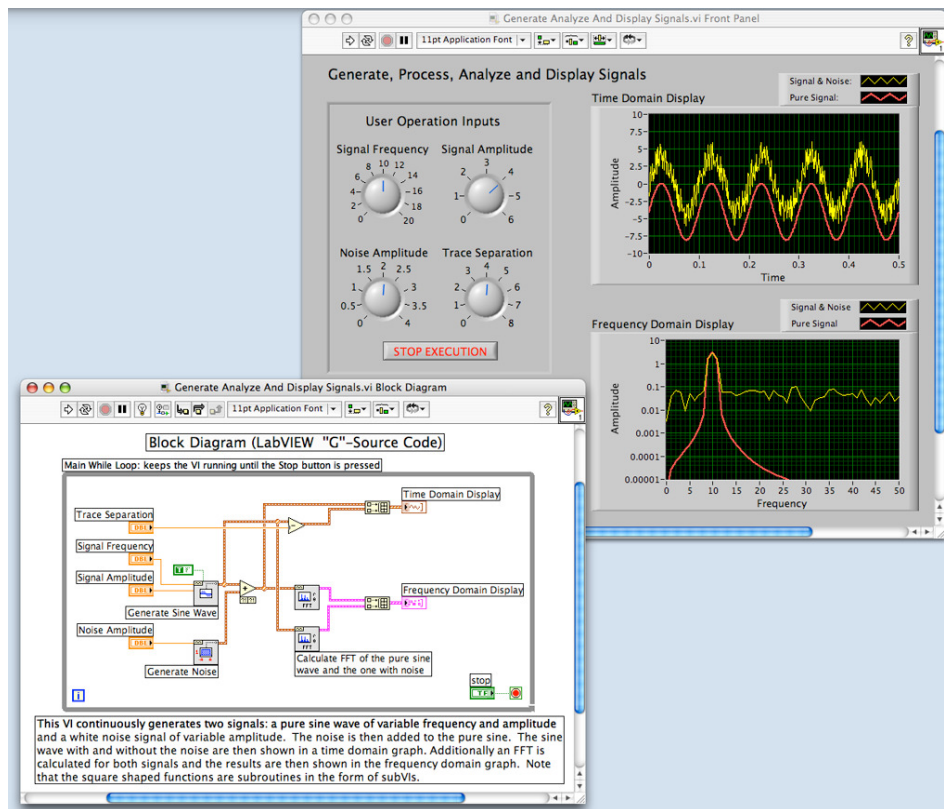
Figure 4.1.Screenshot of a simple LabVIEW program that generates, synthesizes, analyzes and displays waveforms, showing the block diagram and front panel. Each symbol on the block diagram represents a LabVIEW subroutine (subVI) which can be another LabVIEW program or a LV library function.

Benefits

One benefit of LabVIEW over other development environments is the extensive support for accessing instrumentation hardware. Drivers and abstraction layers for many different types of instruments and buses are included or available. These present themselves as graphical nodes. The abstraction layers offer standard software interfaces to communicate with hardware devices. The provided driver interfaces save program development time.

In terms of performance, LabVIEW includes a compiler that produces native code for the CPU platform. The graphical code is translated into executable machine code by interpreting the syntax and by compilation. The LabVIEW syntax is strictly enforced during the editing process and compiled into the executable machine code when requested to run or upon saving. In the latter case, the executable and the source code are merged into a single file.

Many libraries with a large number of functions for data acquisition, signal generation, mathematics, statistics, signal conditioning, analysis, etc., along with numerous graphical interface elements are provided in several LabVIEW package options.

A benefit of the LabVIEW environment is the platform independent nature of the *G-*code, which is (with the exception of a few platform specific functions) portable between the different LabVIEW systems for different operating systems (Windows, MacOSX and Linux).

4.1.1. LabVIEW Modules used in this Project [14]

Programming

1. Structures

While Loop

Repeats the subdiagram inside it until the conditional terminal, an input terminal, receives a particular Boolean value. The Boolean value depends on the continuation behavior of the While Loop. Right-click the conditional terminal and select **Stop if True** or **Continue if True** from the shortcut menu. You also can wire an error cluster to the conditional terminal, right-click the terminal, and select **Stop on Error** or **Continue while Error** from the shortcut menu. The While Loop always executes at least once. The iteration (**i**) terminal provides the current loop iteration count, which is zero for the first iteration.

Case Structure
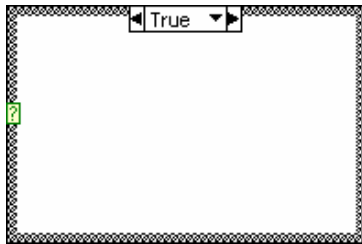
Has one or more subdiagrams, or cases, exactly one of which executes when the structure executes. The value wired to the selector terminal determines which case to execute and can be Boolean, string, integer, or enumerated type. Right-click the structure border to add or delete cases. Use the Labeling tool to enter value(s) in the case selector label and configure the value(s) handled by each case.

Measurement I/O

1. NI-DAQmx – Data Acquisition

DAQmx Global Channel Constant

Lists all virtual channels you create and save using the DAQ Assistant. Select **Browse** to select multiple channels. Right-click the constant and select **I/O Name Filtering** from the shortcut menu to limit the channels that the constant displays and to limit what you can enter in the constant.

DAQmx Create Virtual Channel

Creates a virtual channel or set of virtual channels and adds them to a task. The instances of this polymorphic VI correspond to the I/O type of the channel, such as analog input, digital output, or counter output; the measurement or generation to perform, such as temperature measurement, voltage generation, or event counting; and in some cases, the sensor to use, such as a thermocouple or RTD for temperature measurements. If you use this VI within a loop without specifying a **task in**, NI-DAQmx creates a new task in each iteration of the loop. Use the DAQmx Clear Task VI within the loop after you are finished with the task to avoid allocating unnecessary memory. Refer to Task Creation and Destruction for more information about when NI-DAQmx creates tasks and when LabVIEW automatically destroys tasks.

DAQmx Read

Reads samples from the task or virtual channels you specify. The instances of this polymorphic VI specify what format of samples to return, whether to read a single sample or multiple samples at once, and whether to read from one or multiple channels.

DAQmx Write

Writes samples to the task or virtual channels you specify. The instances of this polymorphic VI specify the format of the samples to write, whether to write one or multiple samples, and whether to write to one or multiple channels.

If the task uses on-demand timing, the default if you do not use the DAQmx Timing VI, this VI returns only after the device generates all samples. If the task uses any timing type other than on-demand, this VI returns immediately and does not wait for the device to generate all samples. Your application must determine if the task is done to ensure that the device generated all samples.

DAQmx Timing

Configures the number of samples to acquire or generate and creates a buffer when needed. The instances of this polymorphic VI correspond to the type of timing to use for the task.

2. Task Configuration

DAQmx Task Name Constant
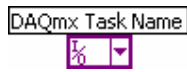
Lists all tasks you create and save by using the DAQ Assistant. You cannot use this constant to select multiple tasks. Right-click the constant, and select **I/O Name Filtering** from the shortcut menu to limit the tasks that the constant displays and to limit what you can enter in the constant.

DAQmx Create Task

Creates a task and adds virtual channels to that task if you specify them in the **global virtual channels** input. If you specify a **task to copy**, this VI duplicates the configuration of the specified task in the newly created task before it adds any additional global virtual channels.

If you use this VI within a loop, NI-DAQmx creates a new task in each iteration of the loop. Use the DAQmx Clear Task VI within the loop after you are finished with the task to avoid allocating unnecessary memory.

DAQmx Control Task

Alters the state of a task according to the **action** you specify.

If **error in** indicates that an error occurred previously, this VI executes normally if **action** is **unreserve** or **abort**.

DAQmx Start Task

Transitions the task to the running state to begin the measurement or generation. Using this VI is required for some applications and is optional for others.

If you do not use this VI, a measurement task starts automatically when the DAQmx Read VI runs. The **autostart** input of the DAQmx Write VI determines if a generation task starts automatically when the DAQmx Write VI runs.

DAQmx Stop Task

Stops the task and returns it to the state the task was in before the DAQmx Start Task VI ran or the DAQmx Write VI ran with the **autostart** input set to TRUE.

DAQmx Wait Until Done

Waits for the measurement or generation to complete. Use this VI to ensure that the specified operation is complete before you stop the task.

DAQmx Is Task Done

Queries the status of the task and indicates if it completed execution. Use this VI to ensure that the specified operation is complete before you stop the task.

DAQmx Trigger

Configures triggering for the task. The instances of this polymorphic VI correspond to the trigger and trigger type to configure.

Details about structure and properties of the simple modules and function witch are used in this project, such are Numerical, Boolean and File I/O it can be found in the Appendix4.
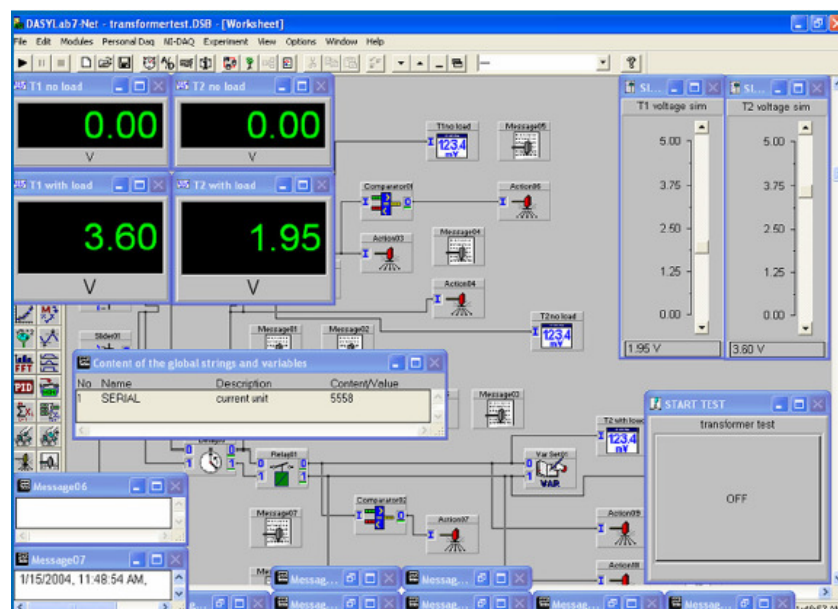
4.2. DASYLab

DASYLab is a data acquisition, process control, and analysis system which take full advantage of the features and the graphical interface provided by Microsoft® Windows™. DASYLab is an icon-based, data acquisition, control, and analysis software package that is easy to use, requires no knowledge of traditional programming languages, and allows the user to create very powerful PC based data acquisition interface programs.

DASYLab software uses a "graphical" approach to writing programs, which are called worksheets. The worksheet designer works in an environment that involves linking function module blocks together and creating logical data flow paths that define the operation of a given application.

The most important design requirements for DASYLab were the integration of the important measuring and control devices on the market, a truly intuitive operating environment which offers extensive help functions, a maximum signal processing speed, and the most effective graphical display of results.

The following graphic shows a typical DASYLab test application.

DASYLab offers real-time analysis, control, and the ability to create custom graphical user interfaces (GUIs).

Using DASYLab, a measuring, process control, or simulation task can be set up directly on your screen by selecting and connecting modular elements that can then be freely arranged. Even highly specialized tasks can be solved immediately on the screen, interactively and without difficulty. It is no longer necessary to find your way through lengthy and rigid menu structures.

Among the module functions provided are A/D and D/A converters, Pre/Post and Start/Stop Triggers, digital I/O, mathematical functions from fundamental arithmetic to integral and differential calculus, statistics, digital filters of several types, frequency analysis including various evaluation windows, signal generators for simulation purposes, scopes for the graphic display of results, logical connectors like AND, OR, NOR, etc., counters, a chart recorder, file I/O, timer, digital display, bar graph, analog meter and more.

With DASYLab it is now possible to achieve high signal input/output rates using the full power of the PC. Special buffers with large, selectable, memory address ranges enable continuous data transfer from the data acquisition device through to the software. DASYLab uses extremely sophisticated drivers to obtain realtime logging at a rate of up to 800 kHz and real-time on-screen signal display at a rate of up to 70 kHz (depending on the type of data acquisition device and graphics board installed).

4.2.1. LabVIEW vs. DASYLab

These are the reasons why we are using LabVIEW 8.0 over the DASYLab 6.0:

1. Much friendly interface
2. Easier to manage and control the application
3. Possibility to create a Virtual Instrument to control the Stepper Motors
4. Easier to generate the signals required by this application
5. Application is faster and much stable
6. We can acquire dates with less errors and can save it in any format we need

4.3. How To…

…What is actually a TASK?
…How to create a task using VI Logger or Measurement and Automation.

…Tasks in NI-DAQmx

A task is a collection of one or more virtual channels with timing, triggering, and other properties. Conceptually, a task represents a measurement or generation you want to perform. All channels in a task must be of the same channel type, such as analog input or counter output. With some devices, you can include channels from multiple devices in a task. To perform a measurement or a generation with a task, follow these steps:

1. Create or load a task. You can create tasks interactively with the DAQ Assistant or programmatically in your ADE such as LabVIEW or LabWindows/CVI.
2. Configure the channel, timing, and triggering properties as necessary.
3. Optionally, perform various task state transitions to prepare the task to perform the specified operation.
4. Read or write samples.
5. Clear the task.

If appropriate for your application, repeat steps 2 through 4. For instance, after reading or writing samples, you can reconfigure the virtual channel, timing, or triggering properties and then read or write additional samples based on this new configuration.

If properties need to be set to values other than their defaults for your task to be successful, your program must set these properties every time it executes. For example, if you run a program that sets property A to a nondefault value and follow that with a second program that does not set property A, the second program uses the default value of property A. The only way to avoid setting properties programmatically each time a program runs is to use virtual channels and/or tasks created in the DAQ Assistant.

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The following example illustrates how to perform a measurement with a task:

PROBLEM

Create an NI-DAQmx task to measure temperature in the range 50°C to 200°C using a J-type thermocouple that is wired to channel 0 on an M Series device configured as Device 1. Sample the temperature 10 times per second, and acquire 10,000 samples. Use LabVIEW or LabWindows/CVI to write your application.

SOLUTION

1. Call the Create Task function/VI and name your task myTemperatureTask.
2. Call the Create AI Thermocouple Channel function/VI.
3. Specify Dev1/ai0 as the physical channel for the device connected to the thermocouple signal.
4. Specify myThermocoupleChannel as the name to assign to your virtual channel.
5. Select the appropriate values for the thermocouple type and range inputs. NI-DAQmx applies these attributes to the virtual channel.
6. Call the Timing Sample Clock function/VI, specifying a **rate** of 10 Hz and a **sample mode** of finite.
7. Call the Start function/VI.
8. Call the Read function/VI, specifying **number of samples** as 10,000.
9. Call the Stop function/VI after the desired number of samples have been acquired.
10. Call the Clear function/VI.

You have now created a task called myTemperatureTask that uses a local virtual channel called myThermocoupleChannel.

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Software Considerations

…Creating a VI Logger Task for NI-DAQmx

VI Logger uses configurable tasks for datalogging and acquisition. You can create, customize, and save multiple tasks. When you use VI Logger with an NI-DAQmx device, you can work either in a simplified user interface or within MAX.

From the configuration tree, right-click *VI Logger Tasks* and select *Create New* to display the **Create New** dialog box, and then click the *Finish* button. A new VI Logger task named *My VI Logger Task 1* appears in the configuration tree and its settings display in the Task Attributes view of the VI Logger window, as shown in the following example (as shown in Figure 4.2). Then you can *Rename* Task by clicking on the Right-click to the task in the configuration tree.
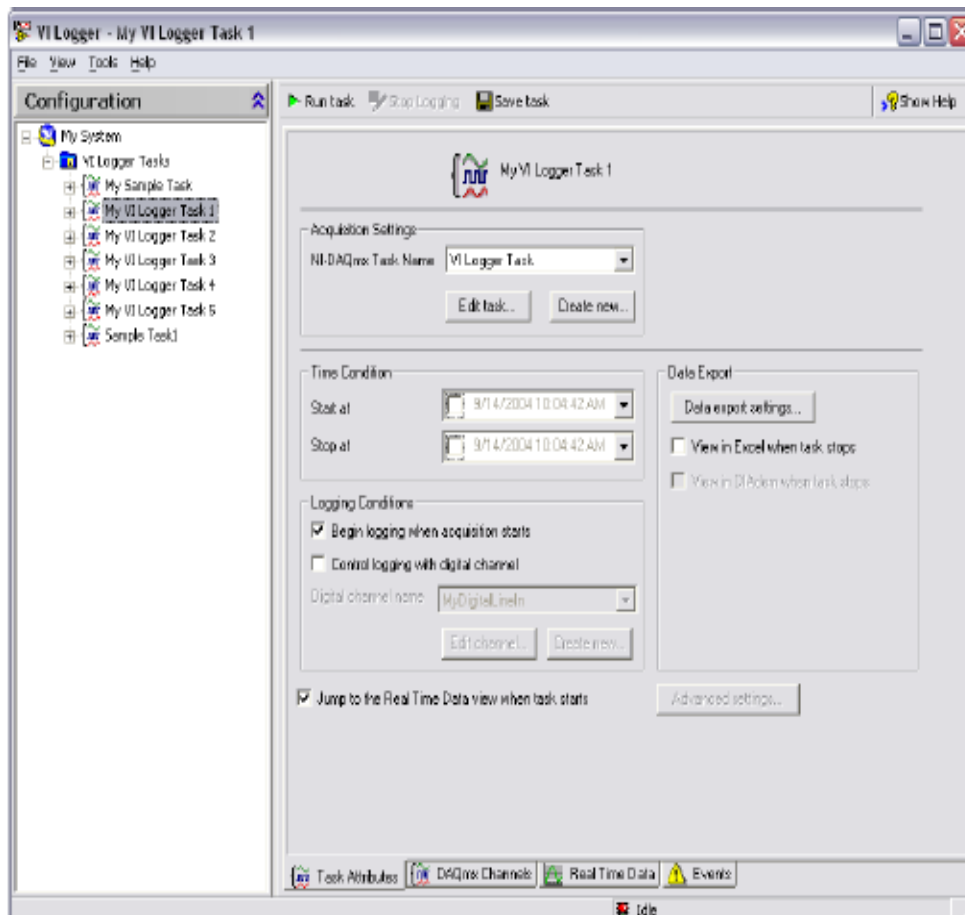
Figure 4.2.VI Logger Configuration Window

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Author: Dudic Lorian

In the ***Acquisition Settings*** section, click the ***Create new*** button to create an NI-DAQmx task. The DAQ Assistant launches and guides you through the following steps to create and configure an NI-DAQmx task.

For example click the ***Analog Input*** option to display analog input types. Chose a measurement type, such as Voltage, to select it. Select the channels to scan for data. Enter a name for the NI-DAQmx task. Click the ***Finish*** button. The DAQ Assistant displays task settings that you can configure, as shown in the following example (Figure 4.3). From the ***Task Timing*** tab, click the ***Continuou*s** radio button to select a continuous acquisition mode. This configures the NI-DAQmx task so you can stop a VI Logger task manually. From the Task Attributes view, you can click the ***Edit task*** button if you want to edit the NI-DAQmx task settings. For example, if you determine that a VI Logger task is acquiring data too quickly, you can edit the NI-DAQmx task settings to adjust the scan rate.
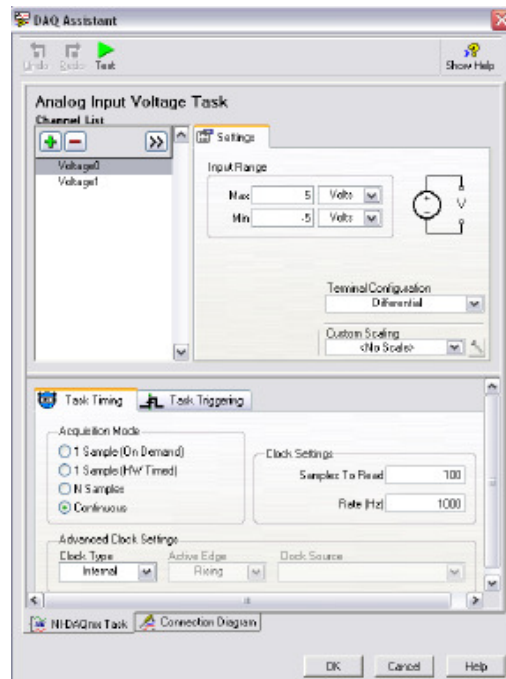
Figure 4.3.DAQ Assistant

…Setting up Channels to Acquire and Log Data

For each VI Logger task you configure, you can select which specific channels acquire and log data within that task. For doing that click the ***DAQmx Channels*** tab of the VI Logger window to display the DAQmx Channels view, as shown in Figure 4.4. The **Channel** column displays the channels you created in the DAQ Assistant for the NI-DAQmx device. To enable logging for each channel, place a checkmark in the **Log Enabled?** If a checkbox does not contain a checkmark, VI Logger scans the channel but does not log the data.
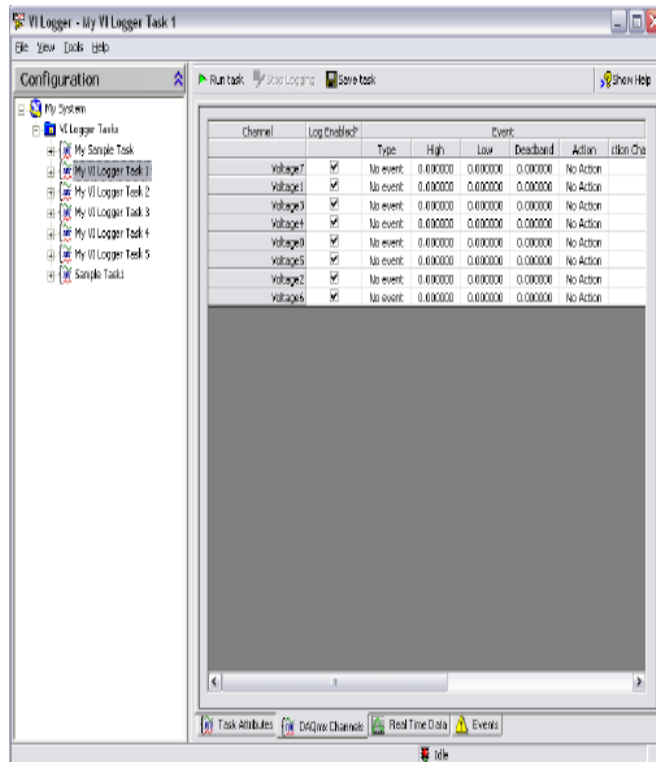
Figure 4.4. VI Logger Acquisition Settings

Chapter 5.

Summary and Conclusions

5.1. Conclusions

Beginning with fundamentals of the burr and the presentation of the burr difficulties and traditional burr inspection methods in industrial production, the paper continues with the description of the new inductive procedure and sensor system for the contactless burr detection, evaluation, and classification.

The Balluff burr sensor system integrates automatic burr detection within the production process. The system allows for unaffected part inspection by tough industrial conditions like residues of oil, lubricants, and other contaminants, and eliminates the need for redundant deburring and visual inspection. Thus, part quality in every area of production will be increased, and the part and component yields
will be improved.

The propose of the project was to create an experimental device for acquiring data with the Balluff inductive sensor and to process this data in order to get some qualitative information about the burrs around holes.

The first objective was to scan small holes, slightly bigger than the sensor. After developing in LabVIEW the necessary subroutines for data acquisition, some conclusions about the acquired signal were reached.

After managing to move all axes with the help of a Virtual Instruments made in LabVIEW 8.0, some data was acquired from different metals. This data had to be processed in order to make the burr visible. This processing was done using MATLAB.

In the future we plan to expand the variety of materials that can be scanned. Also, other types of junctions need to be identified and correctly evaluated from the quality point of view. A database can be then generated containing the parameters of the scanned material, the technological procedure that was used for processing the material and the results obtained after the analysis. All this information can be then correlated in order to obtain best matches between technology and materials.

5.1.1. Possible new directions

Milling machine head with sensor

Figure 5.1 shows a way of catching the sensor onto a head for the milling machine, this requiring also the modification of the sensor by removing the amplificatory part and mounting it aside.
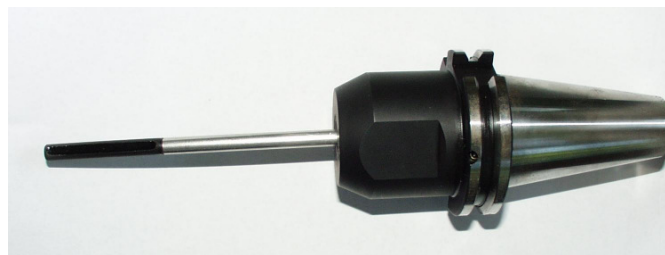
Figure 5.1.Milling machine head with sensor

For the device to be able to rotate, the data has to be transmitted through RF, the electrical power needed by the sensor being supplied through ring contacts. Using this type of attaching the sensor presents a high mobility and it can be implemented in any environment where a milling machine is present.

3 axis system or robotic arm with sensor

Sensor mounting locations
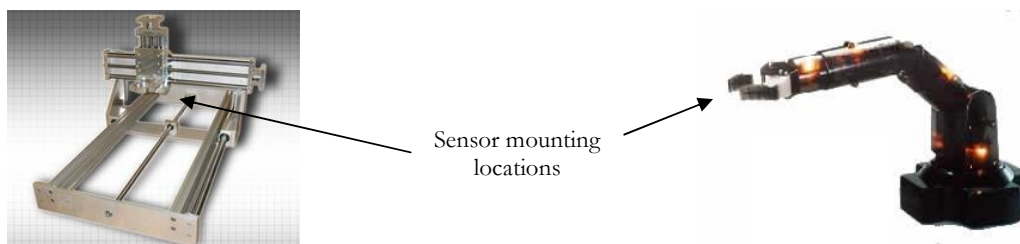
Figure 5.2.Other possibilities (3 axis- left, robotic arm- right)

Using a 3 axis device plus one mounted onto this one (for the sensor rotation), the performance can be the same as the one of the milling machine; using the robot arm, irregular surfaces can be scanned.

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Appendix 1.

1. Deburring Processes

Table 1-2. Known deburring processes [1]

Process		Quantity in U.S.	Quantity worldwide
Abrasive finishing (A)[b]	Barrel tumbling (Al)	8,000	16,000
	Loose belt tumbling (A1A)	10	50
	Vibratory finishing (A2)	12,000	30,000
	Vibratory shaker mixer finishing (A2s)	15	30
	Roll-flow (centrifugal disk) finishing (A3)	300	500
	Centrifugal barrel finishing (A4)	1,000	2,000
	Spindle finishing (A5)	500	1,200
	Vibratory spindle finishing (A5a)	0	20
	Fluidized bed spindle finishing (A5a)	1	40
	Recipro finishing (A6)	0	5
	Orboresonant finishing (A7)	5	10
	Flow finishing (A8)	5	10
	Cascading media (A9)	35	50
Chemical loose abrasive finishing (AC)	Chemical barrel tumbling (AC l)	100	200
	Chemical vibratory finishing (AC2)	200	400
	Chemical roll-flow (centrifugal disk) finishing (AC3)	5	10
	Chemical centrifugal barrel finishing (AC4)	10	20
	Chemical spindle finishing (AC5)	0	0
	Chemical fluidized bed spindle finishing (AC5a)	0	0
	Chemical recipro finishing (AC6)	0	0
	Chemical orboresonant finishing (AC7)	0	0
	Chemical flow finishing (AC8)	0	0
Cryogenic loose abrasive finishing (ACRY)	Cryogenic barrel tumbling (ACRYL)	50	90
	Cryogenic vibratory finishing (ACRY2)	50	90
	Cryogenic vibratory shaker mixer finishing (ACRY2s)	0	0
	Cryogenic roll-flow (centrifugal disk) finishing (ACRY3)	0	0
	Cryogenic centrifugal barrel finishing (ACRY4)	0	0
	Cryogenic spindle finishing (ACRY5)	0	0
	Cryogenic fluidized bed spindle finishing (ACRY5a)	0	0
	Cryogenic recipro finishing (ACRY6)	0	0
	Cryogenic orboresonant finishing (ACRY7)	0	0
	Cryogenic flow finishing (ACRY8)	0	0
Magnetic loose abrasive finishing (AM)	Magnetic abrasive barrel finishing (Aml)	5	400
	Magnetic abrasive vibratory finishing (AM2)	0	0
	Magnetic abrasive spindle finishing (AM5)	0	5
	Magnetic abrasive cylindrical finishing (AM5a)	0	5
	Magnetic abrasive tube-ID finishing (AM5b)	0	5
	Magnetic abrasive ball finishing (AM5c)	0	5
	Magnetic abrasive special shape finishing (AM5d)	0	5
	Magnetic abrasive prismatic finishing (AM7)	0	5
	Mixed metal fiber magnetic finishing (AM8)	0	1
Chemical magnetic loose abrasive finishing (AMC)	Chemical magnetic abrasive barrel finishing (AMCL)	0	0
	Chemical magnetic abrasive vibratory finishing (AMC2)	0	0
	Chemical magnetic abrasive spindle finishing (AMC5)	0	0
	Chemical magnetic abrasive cylindrical finishing (AMC5a)	0	0
Chemical magnetic loose abrasive finishing (AMC)	Chemical magnetic abrasive tube-ID finishing (AMC5b)	0	0
	Chemical magnetic abrasive ball finishing (AMC5c)	0	0
	Chemical magnetic abrasive special shape finishing (AMC5d)	0	0
	Chemical magnetic abrasive prismatic finishing (AMC7)	0	0
Electrochemical loose abrasive finishing (EAC)	Electrochemical barrel tumbling (EACL)	0	0
	Electrochemical vibratory finishing (EAC2)	1	1
	Electrochemical roll-flow (centrifugal disk) finishing (EAC7)	0	0
	Electrochemical centrifugal barrel finishing (EAC3)	0	0
	Electrochemical spindle finishing (EAC4)	0	0
	Electrochemical fluidized bed spindle finishing (EAC4a)	0	0
	Electrochemical recipro finishing (EAC6)	0	0
	Electrochemical orboresonant finishing (EAC7)	0	0
	Electrochemical flow finishing (EAC8)	0	0

Process		Quantity in U.S.	Quantity worldwide
Lapping (A9)		10	20
Abrasive jet (AB1)		20,000	40,000
Cryogenic abrasive jet (ABCl)		5	0
Liquid hone abrasive flow deburring (AB2)		1	5
Abrasive flow finishing (AB3)		500	700
Abrasive flow orbital finishing (AB3O)		2	4
Abrasive flow stream finishing (AB3s)		1	2
Ultrasonic liquid deburring (AUl)		20	30
Ultrasonic abrasive flow deburring (AB3U)		1	2
Ultrasonic slurry finishing (AU2)		10	15
Chemical deburring (Cl)		20	40
EDM deburring (El)		1	2
Electrochemical deburring processes (EC)	Electrochemical deburring (salt) (ECl)	600	1,200
	Electrochemical rotary electrode (EC1R)	1	2
	Electrochemical deburring (glycol) (EC2)	50	90
	Electrochemical mesh deburring (EC5)	0	0
	Electrochemical moving electrode deburring (EC4)	0	0
	Electrochemical brush deburring (EC3)	0	0
	Electrochemical nonwoven abrasive magnetic finishing (ECM6)	0	1
Electropolish (EL3)		50	100
Manual deburring (Ml)		300,000	800,000
Mechanized cutting (M2)		10,000	20,000
Skiving (M2s)		50	100
Robotic deburring (M2R)		300	1500
Brushing (M3)		50,000	100,000
Buffing (M3b)		1,000	2,000
Wheel blending (M4)		300	600
Sanding (M5)		25,000	50,000
Vibratory conveyor deburring (M5a)		1	1
Abrasive chemical finishing (MC1)		1	5
Edge rolling (M7)		400	600
Edge burnishing (M8)		300	300
Edge peening (M13)		1,000	2,000
Trimming (press work) (M9)		800	1,600
Edge coining (M10)		100	150
Water-jet deburring (M6)		500	800
Ballizing (M11)		1	1
Tearing (M12)		10	50
Torch-cut deburring (T1)		500	3,000
Plasma deburring (T3)		50	60
Plasma-glow deburring (T5)		5	5
Thermal energy method (T2)		500	700
Hot-wire deburring (T4)		1	1
Hot-blade deburring (T4b)		100	200
Hot-tool deburring (T4c)		100	200
Resistance heat deburring (T6)		1	1
Laser deburring (T7)		1	5
Chlorine deburring (TC1)		0	0

Table 1-3. Key properties of commonly used deburring processes [1]

Process	Tooling	Batch or continuous process	Typical applications	Typical limitations
Abrasive flow	Simple	Batch or single part/load	Intersecting holes, irregular contours, drilled plates, fine finishes	Blind features not readily deburred
Abrasive blasting	None, or simple	Batch, single part/load, or continuous	External burrs, some fine work	Abrasive or metal particles beaten into surface, residual stresses
Barrel tumbling	None	Batch	External features	Part geometry, internal features not deburred
Bonded abrasive (sanding)	None	Single part/load or continuous	Flat surfaces, accessible edges	Internal features not deburred
Brushing	None	Batch, continuous or single part/load	External edges, internal holes, blind features	Large burrs in hard to reach areas
Centrifugal barrel	None	Batch	External features	Internal features not deburred
Chemical	None	Batch or continuous	Parts that can tolerate size changes	Can cause some pitting, limited to metals
Cryogenic vibratory	None	Batch or continuous	Plastic deflashing or thin flash on conductive metals	Not applicable for normal burrs or most metals
Edge coining	Yes	Single part/load	High-production parts whose edges are readily accessible	Limited to sheet metal parts
Edge rolling/ burnishing/skiving	Yes, simple	Continuous	Sheet metal strips/coils	Not applicable to individual components
Electrochemical	Yes, simple to complex	Single part/load	Holes, intersecting holes, slots, gears, intricate contours	Total part with complex shapes
Electropolish	Yes, contacts	Batch or continuous	High-volume, high-finish parts with thin burrs	Will not remove thick burrs without distorting dimensions
Hand (manual)	Yes, hand tools	Single part/load	Low-volume, any configuration and burr size	Time consuming, error prone
Magnetic abrasive	Yes	Single part/load	High-finish parts with small thin burrs	Normal burrs, each part requires its own setup
Mechanized cutting	Yes, fixtures, cutters	Batch, continuous, or single part/load	External burrs or high-volume internal work	Varying burr size or location
Robotic	Yes	Single part/load	External burrs, normal edge breaks	Intricate features, low-volume
Roll flow	No	Continuous or batch	External edges	Not applicable to internal features
Spindle finishing	No	Single part/load	External cylindrical parts	Not suited to internal features or prismatic parts
Thermal energy	Yes, simple	Batch	External thin burrs and some internal thin burrs	Not suited to heavy burrs, some metals, precision finishes
Vibratory	No	Batch or continuous	External edges of most parts	Not suited to internal features
Water jet	Yes, fixturing	Single part/load	Thin burrs, metal or plastic deflashing	Not suited for thick burrs, hard-to-reach areas

Table 1-4. Overview of key processes used on precision parts [1]

Process	Number of key variables	Typical burr thickness removed (µm)	Typical effect on part size (µm)	Typical edge break (µm)	Normal best repeatability of edge radii (µm)	Surface finish range (µm)	Typical part size (mm)	Typical part materials
Abrasive blasting	7–10	25–75	None	75–250	±75	1–7	up to 1–1,000	Zinc, steel,plastics; no soft metals
Abrasive flow	5–7	75	5	75–250	±38	0.4	20–500	All metals
Barrel tumbling	13–15	75	5	25–750	±25	0.2–0.8	20–300	All metals, plastics, rubber
Bonded abrasive (sanding)	8–12	25–75	2–50	75–500	—	0.8–1.6	50–500	All metals
Brushing	5–10	5–75	0–2	50–250	±50	0.4	20–500	All metals, ceramics, some plastics
Centrifugal barrel	14–15	5–75	0–12	75–500	—	0.05–0.8	1.5–200	All metals, ceramics, some plastics
Chemical	4–5	2–12	1–50	25	—	0.15–0.2	20–500	Some limit on metals
Cryogenic vibratory	15–16	—	—	—	—	—	20-200	—
Edge coining	4–5	2-12	0	—	—	—	10-100	—
Edge rolling/ burnishing/skiving	4–5	2-12	0	25–75	—	0.05–1.0	—	—
Electrochemical	5–6	7–127	0	50–250	±50	0.4	20–500	Metals other than titanium
Electropolish	5–7	2–25	5–12	25–125	±1	0.05	20–200	Many metals
Hand (manual)	20–50	5–75	0	50–250	±50	—	5–500	All metals, ceramics, plastics, rubber
Magnetic abrasive	5–10	5–25	1–12	5–40	—	0.1	50–200	Metals
Mechanized cutting	5–10	75–250	0	125–750	—	—	50–500	All metals, plastics
Robotic	5–10	75–250	0	125–750	—	—	50–500	All metals, plastics
Roll flow	10–15	25–125	1–12	75–750	±30	0.2–1.0	20–200	All metals
Spindle finishing	10–15	25–125	—	75–750	±30	0.2–1.0	20–200	All metals
Thermal energy	3–6	5–50	0–10	25–75	—	0.8–2.0	20–200	Many metals, a few plastics
Vibratory	12–15	25–125	1–12	75–750	±30	0.2–1.0	20–200	All metals, some plastics
Water jet	4–6	12–50	0	50–125	—	—	50–500	All metals, plastics

Note: Blanks indicate a lack of published data.

(Gillespie 1976)

2. Cost-Effective Deburring

Table 1-7. Typical processes for precision deburring of external metal edges [1]

Maximum allowable edge break (μm)	Allowable thickness change on external surfaces (μm)				Allowable thickness change repeatability (μm)		
	1.25	2.50	25.0	125	0.5	5.0	50
2.5	—	—	—	—	—	—	—
25	—	—	—	AB3	—	AB3	AB3
50	—	M2, M5, EC	AB3, M2, M5, EC	AB3, M2, M5, EC	EC	AB3, EC, M2, M5	AB3, EC, M2, M5
125	EC, M1–3, M5–8	EC, M1–3, M5	A, AM, AB1, AB3, E1, M1–5, M7, T1, T2	Most	EC, M1–3, M5	A, AB3, EC, M1–5	Most
250	E1, EC, M1–8	E1, EC, M1–M10	A, M, AB1, AB3, E1, M1–10, T1, T2	All	E1, EC, M1–8	A, AB3, EC, M1–5, T2	All

Note: Letters are codes for processes—see Table 1-3 for definitions. To use this table select the maximum edge break that a drawing allows and then move horizontally across the row that has that edge break or the next largest value. Move until you reach a column that has an allowable stock loss (part-thickness change). The processes shown in that cell will most likely yield acceptable effects on stainless steel parts having a surface finish requirement of 32 μin. (0.8 μm) or better (1 μm = 39.37 μin.). Data are based on complete removal of burrs having an initial thickness and height of 0.003 in. (76 μm). The last three columns provide an estimate of size-change repeatability for the various processes and conditions stated. Dashes indicate that no process will produce the desired result for the specified burr size, edge break, surface finish, part material, or stock loss. In this case the burr must be hand worked or machined to a smaller size before edge-finishing processes can provide complete burr removal.

Table 1-8. Typical processes for precision deburring of intersection holes [1]

Maximum allowable edge break (μm)	Allowable hole diameter change repeatability (μm)				Allowable hole diameter change (μm)		
	1.25	2.50	25.0	125	0.5	5.0	50
2.5	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—
50	EC1-2, T2	EC1-2, T2	EC1-2, T2	EC1-2, T2	—	EC1-2, T2	EC1-2, T2
125	EC1-2, T2	EC1-2, T2, M1	EC1-2, M1-2, T2, AB3, E1, M5	C1, EC1-2, EL3, M1-2, T2, AB3, E1, M5M2	EC1-2	EC1-2, T2, M1, M2	Most
250	EC1-2, M2, T2	E1, EC, M1-2	EC1-2, M1-2, T2,AB3,E1, M5	C1, EC1-2, 2, EL3, M1-2, 5, T2, AB3, E1, M5	EC1-2, M2	AB3, C1, EC1-2, EL3, M1-2, 5, T2	Most

Note: To use this table select the maximum edge break that a drawing allows and then move horizontally across the row that has that edge break or the next largest value. Move until you reach a column that has an allowable stock loss (hole-diameter change). The letters in that cell define the processes most likely to yield acceptable effects on stainless steel parts having a surface finish requirement of 32 μin. (0.8 μm) or better (1 μm = 39.37 μin.). The data are based on complete removal of burrs having an initial thickness and height of .003 in. (76 μm). Letters are codes for processes—see Table 1-3 for definitions. The last three columns provide an estimate of size-change repeatability for the various processes and conditions stated. Dashes indicate that no process will produce the desired result for the specified burr size, edge break, surface finish, part material, or stock loss. In this case the burr must be hand worked or machined to a smaller size before edge finishing processes can provide complete burr removal.

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2. Deburring Economics

Few examples of comparative deburring economics are published bellow. The following equations provide a reasonable estimate of costs using various processes. The equations use the following terminology:

C - deburring cost per part

C_D - depreciation cost per hour= machine cost per operating   hours

C_M - maintenance cost per hour of operation

C_L - labor cost per hour to run machine

C_p - cost of power used

C_A - cost of cleaning per hour after deburring (labor + material)

C_E - cost of media per hour = media cost x percentage of hourly attrition

C_C - cost of compound per hour

C_W - cost of water per hour

D_o - overload as percentage of labor rate

N - number of parts run per hour = n/t

n - number of parts run per cycle

t - time(hours) per cycle

C_g - cost of gas per cycle

C_b - cost of brush

C_B - cost of cleaning materials per hour

N_p - total number of parts run

N_{pl} - number of parts run for given quality of solution or tool life

C_t - total tool cost

C_s - total cost of solution

W - power used, in kilowatts (1hp=0.75kW)

K_1 - percentage of cycle time that operator actually spends controlling deburring operation

K_2 - percentage of cycle time that operator spends cleaning parts

For vibratory (loose abrasive) processes, use:

$$C = \left[C_D + C_M + WC_p + C_B + C_E + C_C + C_W \right] / N + \left[C_L(1+D_o)(K_1+K_2) \right] / N \qquad (1.1)$$

For thermal energy methods, use:

$$C = \left[C_D + C_M + C_L(1+D_o)WC_p + C_A \right] / N + C_g / n + C_t / N_p \qquad (1.2)$$

For brush deburring, use:

$$C = \left[C_D + C_M + C_L(1+D_o)WC_p + C_A \right] / N + C_b / N_{pl} \qquad (1.3)$$

For flame deburring, use:

$$C = \left[C_D + C_M + C_L(1+D_o)WC_p + C_A \right] / N + C_g / n \qquad (1.4)$$

For manual deburring, use:

$$C = \left[C_L(1+D_o) + C_A \right] / N + C_t / N_p \qquad (1.5)$$

For mechanical deburring, use:

$$C = \left[C_D + C_M + WC_p + C_A + C_L(1+D_o) \right] / N + C_t / N_p \qquad (1.6)$$

For chemical deburring, use:

$$C = \left[C_D + C_M + WC_p + C_A + C_L(1+D_o) \right] / N + C_s / N_p \qquad (1.7)$$

For electrochemical deburring, use:

$$C = \left[C_D + C_M + WC_p + C_A + C_L(1+D_o) \right] / N + C_t / N_p + C_s / N_{pl} \qquad (1.8)$$

For electro polish deburring, use:

$$C = \left[C_D + C_M + WC_p + C_A + C_L(1+D_o) \right] / N + C_t / N_P + C_s / N_{pls} \qquad (1.9)$$

Table 1-9. Typical costs of various processes (in US$ per unit) [1]

Cost item	Process			
	Vibratory	Thermal Energy Method (TEM)	Manual	Chemical
C_D	0.40	5.00	-	0.20
C_M	0.04	1.00	-	0.02
C_L	5.00	5.00	5.00	5.00
C_p	0.04	0.04	0.04	0.04
C_A	-	5.80	5.50	5.50
C_E	0.60	-	-	-
C_C	0.30	-	-	-
C_W	0.15	-	-	-
D_o	0.8	0.8	0.8	0.8
N	50	1,500	12	400
n	100	6	1	100
t	2	0.004	0.08	0.25
C_g	-	0.024	-	-
W	4	4	0	0
C_t	-	1,000	1,000	-
N_p	400,000	400,000	400,000	400,000
C_s	-	-	-	6,000
$CalculedC$	0.106	0.020	1.210	0.052
K_1	0.17	-	-	-
K_2	0.17	-	-	-
C_B	0.60	0.80	0.60	0.50

Note: This table assumes that no automatic load/unload is used

Appendix 2.

Induktive Ringsensoren / Drahtbruchsensoren

Inductive ring sensors / Wire break sensors

Allgemeine Beschreibung

Induktive Ringsensoren von di-soric haben sich bestens für die unterschied-
lichsten Einsatzbereichen in der Montagetechnik und in Zufahrautomaten
bewährt.
Durch die statische Funktionsweise können sie auch als Drahtbruchüberwa-
chung und Staukontrolle eingesetzt werden.

General description

Inductive ring sensors have been proved very well for the most different
fields of application like assembly and supply machinery.
Due to the static working principle, they can be used as wire break detection
and stow control, too.

Inhaltsverzeichnis | Table of content

Anwendungsbeispiele | Sample applications
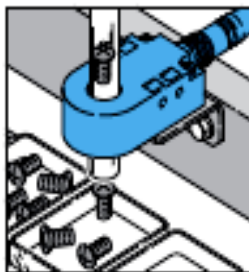
Teileerfassung im Zuführschlauch
part detection in hoses supply
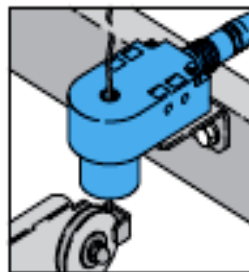
Drahtbruchkontrolle
Wire break detection

Sicherheitshinweis
Der Einsatz dieser Geräte muss durch Fachpersonal erfolgen.
Die Geräte sind nicht zulässig für Sicherheitsanwendungen, insbesondere bei
denen die Sicherheit von Personen von der Gerätefunktion abhängig ist.

Alle technischen Angaben beziehen sich auf den Stand 12/05, Änderungen
bleiben vorbehalten. Da Irrtümer und Druckfehler nicht auszuschließen sind,
gilt für alle Angaben „ohne Gewähr".

Safety instruction
These instruments shall exclusively be used by qualified personnel.
The instruments are not to be used for safety applications, in particular
applications in which safety of persons depends on proper operation of the
instruments.

All technical specifications refer to the state of the art 12/05, they are subject
to modifications. As typographical and other errors cannot be excluded, all
data are given „without engagement".

Induktive Ringsensoren IR ... | Inductive ring sensors IR ...

▪ di-soric

- ▪ Kompakte Bauform
- ▪ Statisches Arbeitsprinzip
- ▪ Hohe Auflösung
- ▪ Kurze Ansprechzeit
- ▪ Impulsverlängerung einstellbar
- ▪ Schmutzunempfindlichkeit
- ▪ Metallanschlussstecker
- ▪ Hohe Schutzart

- ▪ Compact design
- ▪ Static operating principle
- ▪ High resolution
- ▪ Short response time
- ▪ Pulse stretching adjustable
- ▪ Insensitivity to dirt
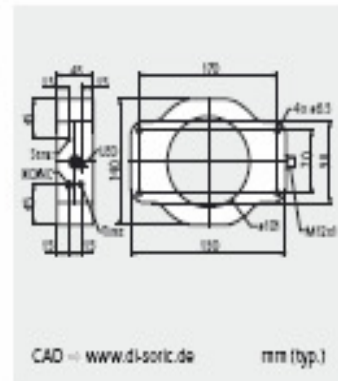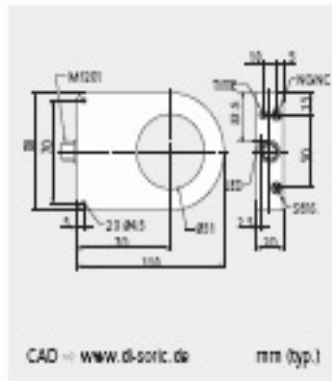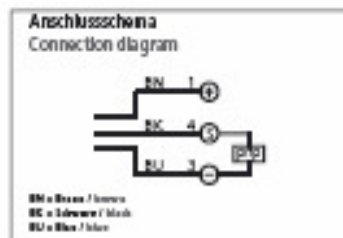- ▪ Metal connector
- ▪ High Protection class

Ring-Ø 6,1 mm

CE

Ring-Ø 10,1 mm

CE

Anschlussschema
Connection diagram

BN 1
BK 4
BU 3

BN = Braun / brown
BK = Schwarz / black
BU = Blau / blue

CAD – www.di-soric.de   mm (typ.)

CAD – www.di-soric.de   mm (typ.)
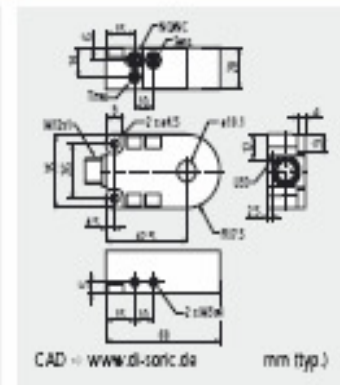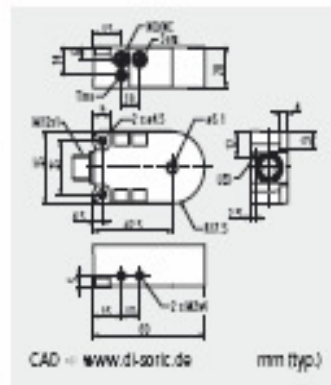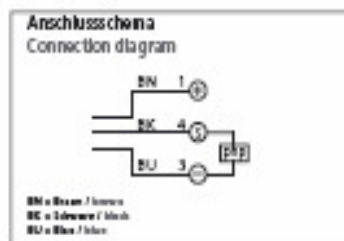
Technische Daten	Technical data + 20 °C, 24 VDC		
Ringdurchmesser	Ring-diameter	6,1 mm	10,1 mm
Auflösung (Stahlkugel)	Resolution (steel ball)	Ø 1,0 mm	Ø 1,5 mm
Betriebsspannung	Service voltage	10 ... 35 V DC	10 ... 35 V DC
Ausgang umschaltbar	Output switchable	pnp NO/NC	pnp NO/NC
Empfindlichkeitseinstellung	Sensitivity adjustment	Potentiometer	Potentiometer
Funktionsprinzip	Operating principle	statisch / static	statisch / static
Strombelastbarkeit	Maximum rating	200 mA	200 mA
Eigenstromaufnahme	Internal power consumption	< 11 mA	< 11 mA
Spannungsfall	Voltage drop	< 2,0 V	< 2,0 V
Impulsverlängerung	Pulse stretching	einstelbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms	einstelbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms
Teilegeschwindigkeit max.	Speed of parts max.	< 35 m/s	< 35 m/s
Ansprech- / Abfallzeit	Response / release time	< 0,5 ms / < 10 ms	< 0,5 ms / < 10 ms
Umgebungstemperatur	Ambient temperature	-25 °C ... +70 °C	-25 °C ... +70 °C
Isolationsspannungsfestigkeit	Insulation voltage endurance	1000 V	1000V
Schutzart	Protection class	IP 67	IP 67
Gehäusematerial	Casing material	Polyamid, Ring POM	Polyamid, Ring POM
Montageabstand zu Metall	Mounting distance to metal	> 5 mm	> 5 mm
Bestellbezeichnung	**Purchase order table**	**Typ / Model**	**Typ / Model**
Ausgang	Output		
pnp, NO / NC	pnp, NO / NC	**IR 6 PSOK-IBS**	**IR 10 PSOK-IBS**
Anschlusskabel	Connecting cables	VK...	VK...
(sep. Datenblatt)	(sep. data-sheet)		

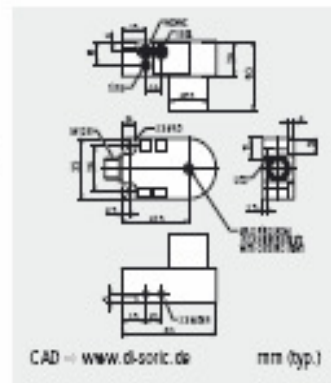## Induktive Ringsensoren IR ... | Inductive ring sensors IR ...

- Kompakte Bauform
- Statisches Arbeitsprinzip
- Hohe Auflösung
- Kurze Ansprechzeit
- Impulsverlängerung einstellbar
- Schmutzunempfindlichkeit
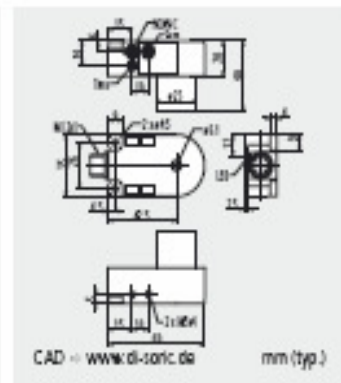- Metallanschlussstecker
- Hohe Schutzart

- Compact design
- Static operating principle
- High resolution
- Short response time
- Pulse stretching adjustable
- Insensitivity to dirt
- Metal connector
- High Protection class

Ring-Ø 15,1 mm

CE

Anschlussschema
Connection diagram

BN 1 +
BK 4
BU 3 −

BN = Braun / brown
BK = Schwarz / black
BU = Blau / blue

CAD – www.di-soric.de

mm (typ.)
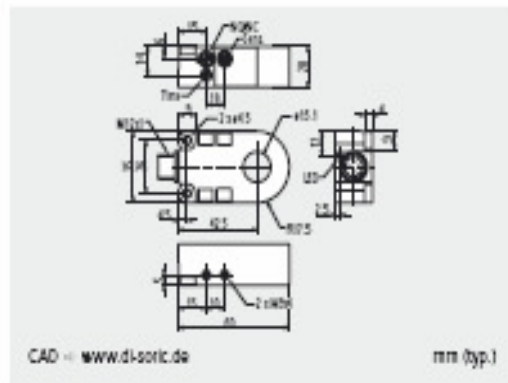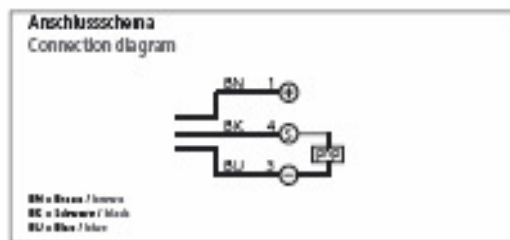
Technische Daten	Technical data	+ 20 °C, 24 V DC
Ringdurchmesser	Ring-diameter	15,1 mm
Auflösung (Stahlkugel)	Resolution (steel ball)	Ø 2,0 mm
Betriebsspannung	Service voltage	10 ... 35 V DC
Ausgang umschaltbar	Output switchable	pnp NO/NC
Empfindlichkeitseinstellung	Sensitivity adjustment	Potentiometer
Funktionsprinzip	Operating principle	statisch / static
Strombelastbarkeit	Maximum rating	200 mA
Eigenstromaufnahme	Internal power consumption	< 11 mA
Spannungsfall	Voltage drop	< 2,0 V
Impulsverlängerung	Pulse stretching	einstellbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms
Teilegeschwindigkeit max.	Speed of parts max.	< 35 m/s
Ansprech- / Abfallzeit	Response / release time	< 0,5 ms / < 10 ms
Umgebungstemperatur	Ambient temperature	-25 °C ... +70 °C
Isolationsspannungsfestigkeit	Insulation voltage endurance	1000 V
Schutzart	Protection class	IP 67
Gehäusematerial	Casing material	Polyamid, Ring POM
Montageabstand zu Metall	Mounting distance to metal	> 5 mm
Bestellbezeichnung	Purchase order table	Typ / Model
Ausgang	Output	
pnp, NO / NC	pnp, NO / NC	IR 15 PSOK-IBS
Anschlusskabel	Connecting cables	VK...
(sep. Datenblatt)	(sep. data-sheet)	

Appendix 2

di-soric
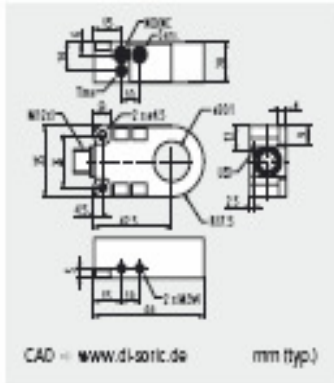
Ring-Ø 20,1 mm	Ring-Ø 25,1 mm	Ring-Ø 35,2 mm
CE	CE	CE
CAD → www.di-soric.de mm (typ.)	CAD → www.di-soric.de mm (typ.)	CAD → www.di-soric.de mm (typ.)
20,1 mm	25,1 mm	35,2 mm
Ø 2,5 mm	Ø 3,0 mm	Ø 4,5 mm
10 .. 35 V DC	10 .. 35 V DC	10 .. 35 V DC
pnp NO/NC	pnp NO/NC	pnp NO/NC
Potentiometer	Potentiometer	Potentiometer
statisch / static	statisch / static	statisch / static
200 mA	200 mA	200 mA
< 11 mA	< 11 mA	< 11 mA
< 2,0 V	< 2,0 V	< 2,0 V
einstellbar ca. 10 .. 150 ms / adjustable approx. 10 .. 150 ms	einstellbar ca. 10 .. 150 ms / adjustable approx. 10 .. 150 ms	einstellbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms
< 35 m/s	< 35 m/s	< 35 m/s
< 0,5 ms / < 10 ms	< 0,5 ms / < 10 ms	< 0,5 ms / < 10 ms
-25 °C ... +70 °C	-25 °C ... +70 °C	-25 °C ... +70 °C
1000 V	1000 V	1000 V
IP 67	IP 67	IP 67
Polyamid, Ring POM	Polyamid, Ring POM	Polyamid, Ring POM
> 10 mm	> 10 mm	> 30 mm
Typ / Model	**Typ** / Model	**Typ** / Model
IR 20 PSOK-IBS	IR 25 PSOK-IBS	IR 35 PSOK-IBS
VK...	VK...	VK...
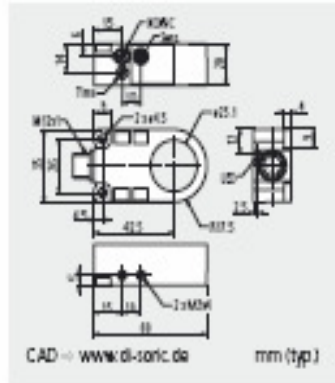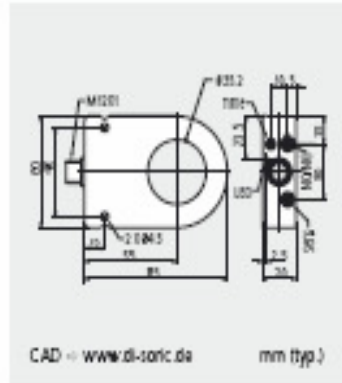
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Author: Dudic Lorian

Induktive Ringsensoren IR ... | Inductive ring sensors IR ...

- Kompakte Bauform
- Statisches Arbeitsprinzip
- Hohe Auflösung
- Kurze Ansprechzeit
- Impulsverlängerung einstellbar
- Schmutzunempfindlichkeit
- Metallanschlussstecker
- Hohe Schutzart

- Compact design
- Static operating principle
- High resolution
- Short response time
- Pulse stretching adjustable
- Insensitivity to dirt
- Metal connector
- High Protection class

Ring-Ø 51 mm

Ring-Ø 101 mm

CE

CE

Anschlussschema
Connection diagram

BN = Braun / brown
BK = Schwarz / black
BU = Blau / blue

CAD → www.di-soric.de   mm (typ.)

CAD → www.di-soric.de   mm (typ.)

Technische Daten	Technical data + 20 °C, 24 V DC		
Ringdurchmesser	Ring-diameter	51 mm	101 mm
Auflösung	Resolution	Ø 6,0 mm (Stahlkugel / steel ball)	Ø 10,0 mm (Stahlkugel / steel ball)
Betriebsspannung	Service voltage	10 ... 35 V DC	10 ... 35 V DC
Ausgang umschaltbar	Output switchable	pnp NO/NC	pnp NO/NC
Empfindlichkeitseinstellung	Sensitivity adjustment	Potentiometer	Potentiometer
Funktionsprinzip	Operating principle	statisch / static	statisch / static
Strombelastbarkeit	Maximum rating	200 mA	200 mA
Eigenstromaufnahme	Internal power consumption	< 11 mA	< 15 mA
Spannungsfall	Voltage drop	< 2,0 V	< 2,0 V
Impulsverlängerung	Pulse stretching	einstellbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms	einstellbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms
Teilegeschwindigkeit max.	Speed of parts max.	< 25 m/s	< 25 m/s
Ansprech- / Abfallzeit	Response / release time	< 1,0 ms / < 10 ms	< 1,0 ms / < 10 ms
Umgebungstemperatur	Ambient temperature	-25 °C ... +70 °C	-25 °C ... +70 °C
Isolationsspannungsfestigkeit	Insulation voltage endurance	1000 V	1000 V
Schutzart	Protection class	IP 67	IP 67
Gehäusematerial	Casing material	Polyamid, Ring POM	Polyamid, Ring POM
Montageabstand zu Metall	Mounting distance to metal	> 30 mm	> 60 mm
Bestellbezeichnung	Purchase order table	**Typ / Model**	**Typ / Model**
Ausgang	Output		
pnp, NO / NC	pnp, NO / NC	IR 50 PSOK-IBS	IR 100 PSOK-IBS
Anschlusskabel	Connecting cables	VK...	VK...
(sep. Datenblatt)	(sep. data-sheet)		

Author: Dudic Lorian

Appendix 2

Drahtbruchsensoren IRDB ... | Wire break sensors IRDB ...

di-soric

- Kompakte Bauform
- Statisches Arbeitsprinzip
- Hohe Auflösung
- Kurze Ansprechzeit
- Impulsverlängerung einstellbar
- Schmutzunempfindlichkeit
- Metallanschlussstecker
- Hohe Schutzart

- Compact design
- Static operating principle
- High resolution
- Short response time
- Pulse stretching adjustable
- Insensitivity to dirt
- Metal connector
- High Protection class

Ring-Ø 4,0 mm

Ring-Ø 6,1 mm

CE

CE

Anschlussschema
Connection diagram

BN 1
BK 4
BU 3

BN = Braun / brown
BK = Schwarz / black
BU = Blau / blue

CAD – www.di-soric.de   mm (typ.)

CAD – www.di-soric.de   mm (typ.)
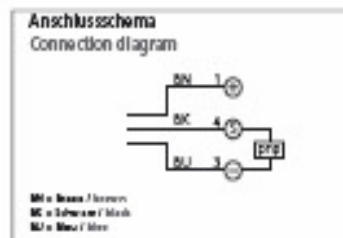
	4,0 mm	6,1 mm
	Ø 0,2 mm (Cu Draht / Cu Wire)	Ø 0,2 mm (Cu Draht / Cu Wire)
	10 ... 35 V DC	10 ... 35 V DC
	pnp NO/NC	pnp NO/NC
	Potentiometer	Potentiometer
	statisch / static	statisch / static
	200 mA	200 mA
	< 11 mA	< 11 mA
	< 2,0 V	< 2,0 V
	einstellbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms	einstellbar ca. 10 ... 150 ms / adjustable approx. 10 ... 150 ms
	< 35 ms	< 35 ms
	< 0,5 ms / < 10 ms	< 0,5 ms / < 10 ms
	-25 °C ... +70 °C	-25 °C ... +70 °C
	1000 V	1000 V
	IP 67	IP 67
	Polyamid, Ring POM	Polyamid, Ring POM
	> 5 mm	> 5 mm
	Typ / Model	**Typ** / Model
	IRDB 4 PSOK-IBS	**IRDB 6 PSOK-IBS**
	VK..	VK..

Author: Dudic Lorian

SENSORIK IN AKTION

di-soric

Sensorik-Komplettprogramm
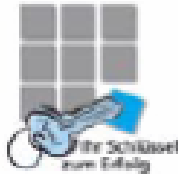
- Hochleistungs-Lichtschranken
- Einweg-Lichtschranken
- Reflexions-Lichtschranken
- Reflexions-Lichttaster
- Lasersensoren
- Lichtleitkabel-Verstärker
- Lichtvorhänge
- Gabel-Lichtschranken
- Winkel-Lichtschranken
- Rahmen-Lichtschranken
- Ring-Lichtschranken
- Kamerasensoren
- Farbsensoren
- Induktive und kapazitive Näherungsschalter
- Zylindersensoren
- Induktive Ringsensoren
- Etikettensensoren
- Ultraschallsensoren
- Kontaktsensoren
- Zubehör

Complete sensor program
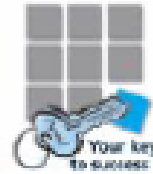
- High performance light barriers
- Through beam sensors
- Retro reflective sensors
- Diffuse reflective sensors
- Laser sensors
- Fibre-optic cables/-amplifiers
- Light curtains
- Fork light barriers
- Angled light barriers
- Frame light barriers
- Ring light barriers
- Camera sensors
- Colour detection sensors
- Inductive and capacitive proximity switches
- Cylinder sensors
- Inductive ring sensors
- Label sensors
- Ultrasonic sensors
- Contact sensors
- Accessories

www.di-soric.de

Appendix 2

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Appendix 2

Author: Dudic Lorian

Appendix 3.

1. Measurement data and the amplitude - distance characteristics

Increment (mm)	Steps	Increment x steps (mm)	Sensor Output for Steel (V)	Sensor Output for Aluminum (V)
0,01	0	0	0	1,3
0,01	5	0,05	0,1	1,6
0,01	10	0,1	0,31	1,94
0,01	15	0,15	0,52	2,33
0,01	20	0,2	0,73	2,74
0,01	25	0,25	0,95	3,18
0,01	30	0,3	1,2	3,65
0,01	35	0,35	1,46	4,05
0,01	40	0,4	1,73	4,53
0,01	45	0,45	1,96	4,98
0,01	50	0,5	2,27	5,42
0,01	55	0,55	2,5	5,84
0,01	60	0,6	2,76	6,32
0,01	65	0,65	3,07	6,8
0,01	70	0,7	3,41	7,26
0,01	75	0,75	3,72	7,72
0,01	80	0,8	4,03	8,15
0,01	85	0,85	4,36	8,6
0,01	90	0,9	4,7	9,06
0,01	100	1	5,03	9,46
0,01	105	1,05	5,36	9,9
0,01	110	1,1	5,66	10
0,01	115	1,15	6,01	10
0,01	120	1,2	6,36	10
0,01	125	1,25	6,71	10
0,01	130	1,3	7,04	10
0,01	135	1,35	7,38	10
0,01	140	1,4	7,71	10
0,01	145	1,45	8,09	10
0,01	150	1,5	8,46	10
0,01	155	1,55	8,78	10
0,01	160	1,6	9,14	10
0,01	165	1,65	9,48	10
0,01	170	1,7	9,8	10
0,01	175	1,75	10	10
0,01	180	1,8	10	10
0,01	185	1,85	10	10
0,01	190	1,9	10	10
0,01	195	1,95	10	10

Amplitude - distance characteristics

Steel plate characteristic

Aluminium 7,5 hole characteristic
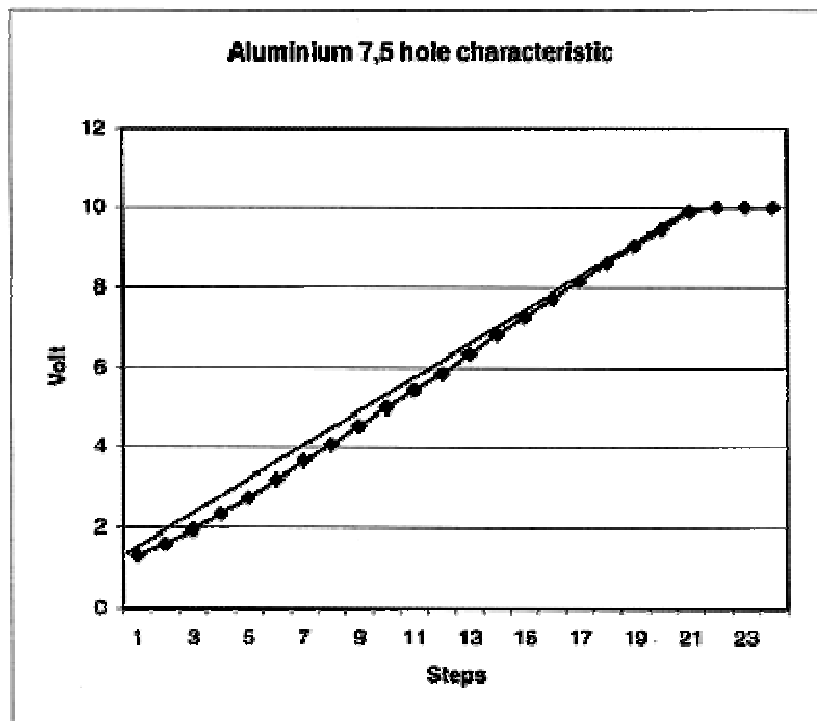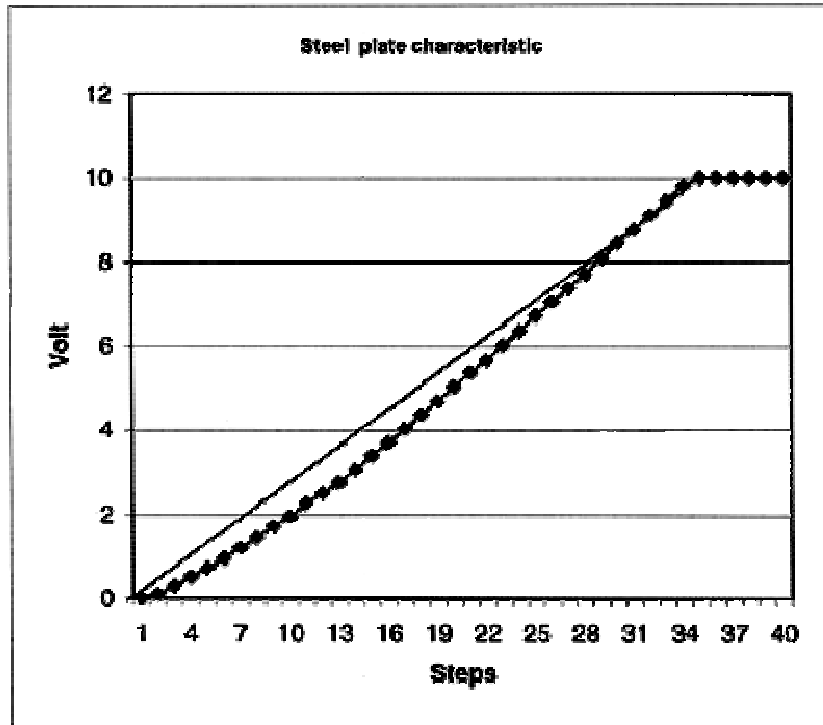
2. Applied Electrodynamics Theory. How was found final solution for the equations (3.14) and (3.15)

According to Equation (3.1) AC-currents and/or DC-currents flowing through metallic parts generate a solenoidal magnetic field. In contrast, only magnetic AC-fields having a time variation will induce an electric AC-field (3.2). Equation (3.3) stipulates that the total magnetic flux through a closed surface is always equal to zero, so that the magnetic field lines are closed. According to Gauss's law (3.4), the total electric flux through a closed surface depends on the contained sources, and the electric field lines are not closed. These physical interpretations of fundamental Maxwell´s equations make possible the understanding and the modeling of the phenomenon which characterize the behavior and the operation of the inductive burr sensor system.

Several methods of solving the Maxwell´s equations are known. A modern topical procedure uses an auxiliary theoretical vector A called magnetic vector potential and defined by:

$$rotA = B \tag{3.7}$$

If the equation (3.7) is inserted into (3.2) the result is:

$$rot(E + \frac{d}{dt}A) = 0 \tag{3.8}$$

which shows that the field $E + dA/dt$ is a nonsolenoidal field and therefore can be considered as the gradient of a scalar function φ according to the equation:

$$E = -grad\varphi - \frac{d}{dt}A \tag{3.9}$$

The scalar function φ is called scalar potential. The equations (3.7) and (3.9) can be applied in Maxwell´s equations (3.1) and (3.4). With simultaneous consideration of the material equations and of the Lorentz convention two independent equations result for the potential values:

$$\Delta A - \varepsilon \cdot \mu \cdot \frac{d^2}{dt^2}A = -\mu \cdot J \tag{3.10}$$

$$\Delta\varphi - \varepsilon \cdot \mu \cdot \frac{d^2}{dt^2}\varphi = -\frac{\rho}{\varepsilon} \qquad (3.11)$$

If the sources of any system to be solved are known and the electromagnetic properties of this system, represented by the parameters μ and ε, are specified, equations (3.10) and (3.11) can be solved for A and φ. If these primarily quantities are already known, there is no difficulty in obtaining the solution B, H, E and D by using the previous univocal equations (3.7), (3.5), (3.8) and (3.6). The method is universal and can be used for the analytical analysis of above mentioned systems, independent of their complexity.

A significant simplification can be made if the system sources are harmonic time functions.

$$X = X(p,t) \text{ and } \Phi = \Phi(p,t) \qquad (3.12)$$

where the variable t represents the time and p is the current point vector - are harmonic functions with the angular frequency ω:

$$X = X_{max} \cdot \text{Re}\{e^{j(\omega t + \alpha)}\} \qquad (3.13)$$

For this particular case the variable time can be eliminated in (3.10) and (3.11) we obtain equations (3.14) and (3.15).

Appendix 4.

1. Numeric

Numeric Constant

Use the numeric constant to pass a numeric value to the block diagram. Set this value by clicking inside the constant with the Operating tool and typing a value.

Add

Computes the sum of the inputs. If you wire two waveform values or two dynamic data type values to this function, **error in** and **error out** terminals appear on the function. You cannot add two time stamp values together. The dimensions of two matrices that you want to add must be the same. Otherwise, this function returns an empty matrix. The connector pane displays the default data types for this polymorphic function.

Multiply

Returns the product of the inputs. If you wire two waveform values or two dynamic data type values to this function, **error in** and **error out** terminals appear on the function. The connector pane displays the default data types for this polymorphic function.

Divide

Computes the quotient of the inputs. If you wire two waveform values or two dynamic data type values to this function, **error in** and **error out** terminals appear on the function. The connector pane displays the default data types for this polymorphic function.

2. Boolean

True Constant

Use this constant to provide a value of TRUE to the block diagram.

False Constant

Use this constant to provide a value of FALSE to the block diagram.

Not

Computes the logical negation of the input. If **x** is FALSE, the function returns TRUE. If **x** is TRUE, the function returns FALSE.

And

Computes the logical AND of the inputs. Both inputs must be Boolean or numeric values. If both inputs are TRUE, the function returns TRUE. Otherwise, it returns FALSE.

Not And

Computes the logical NAND of the inputs. Both inputs must be Boolean or numeric values. If both inputs are TRUE, the function returns FALSE. Otherwise, it returns TRUE.

Or

Computes the logical OR of the inputs. Both inputs must be Boolean or numeric values. If both inputs are FALSE, the function returns FALSE. Otherwise, it returns TRUE.

Not Or

Computes the logical NOR of the inputs. Both inputs must be Boolean or numeric values. If both inputs are FALSE, the function returns TRUE. Otherwise, it returns FALSE.

Exclusive Or

Computes the logical exclusive or (XOR) of the inputs. Both inputs must be Boolean or numeric values. If both inputs are TRUE or both inputs are FALSE, the function returns FALSE. Otherwise, it returns TRUE. The connector pane displays the default data types for this polymorphic function.

Not Exclusive Or

Computes the logical negation of the logical exclusive or (XOR) of the inputs. Both inputs must be Boolean or numeric values. If both inputs are TRUE or both inputs are FALSE, the function returns TRUE. Otherwise, it returns FALSE.

3. Comparation

Equal?

Returns TRUE if **x** is equal to **y**. Otherwise, this function returns FALSE. You can change the comparison mode of this function. If you compare two matrices, the default comparison mode is **Compare Aggregates**, and this function returns a scalar. You can compare an array or cluster of a data type to a scalar of the same data type and produce an array or cluster of Boolean values. The connector pane displays the default data types for this polymorphic function.

Not Equal?

Returns TRUE if **x** is not equal to **y**. Otherwise, this function returns FALSE.

Greater?

Returns TRUE if **x** is greater than **y**. Otherwise, this function returns FALSE. You can change the comparison mode of this function. You can compare an array or cluster of a data type to a scalar of the same data type and produce an array or cluster of Boolean values. The connector pane displays the default data types for this polymorphic function.

Less?

Returns TRUE if **x** is less than **y**. Otherwise, this function returns FALSE.

Select

Returns the value wired to the **t** input or **f** input, depending on the value of **s**. If **s** is TRUE, this function returns the value wired to **t**. If **s** is FALSE, this function returns the value wired to **f**. The connector pane displays the default data types for this polymorphic function.

4. Timing

Wait (ms)

Waits the specified number of milliseconds and returns the value of the millisecond timer. Wiring a value of 0 to the **milliseconds to wait** input forces the current thread to yield control of the CPU. This function makes asynchronous system calls, but the nodes themselves function synchronously. Therefore, it does not complete execution until the specified time has elapsed.

Wait Until Next ms Multiple

Waits until the value of the millisecond timer becomes a multiple of the specified **millisecond multiple**. Use this function to synchronize activities. You can call this function in a loop to control the loop execution rate. However, it is possible that the first loop period might be short. Wiring a value of 0 to the **milliseconds multiple** input forces the current thread to yield control of the CPU. This function makes asynchronous system calls, but the nodes themselves function synchronously. Therefore, it does not complete execution until the specified time has elapsed.

Tick Count (ms)

Returns the value of the millisecond timer. The base reference time (millisecond zero) is undefined. That is, you cannot convert **millisecond timer value** to a real-world time or date. Be careful when you use this function in comparisons because the value of the millisecond timer wraps from (2^32)−1 to 0.

5. File I/O

Write To Measurement File

Writes data to a text-based measurement file (.lvm) or binary measurement file (.tdm). Use the Read From Measurement File Express VI to read data from the generated measurement file. You also can use the Storage VIs to read

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