Chapter 10 Sensors, Safety, Analog and Troubleshooting

We now look outside the control panel at devices and methods of design that affect the design of the PLC and the overall project. Included in this chapter are sensors, a separate study of safety of the machine and the operator, machine vision, bar-code and RFID, analog signal acquisition, troubleshooting techniques and diagnostic circuits. We end the chapter with a short discussion of other 'stuff' and some articles on design and opinions about machine safety from some experts.

SENSORS

An important area is the discussion of sensors and sensor types. Many times the sensor and the application of the sensor are as critical to the success of a project as the PLC program. Web-sights such as www.sensorsmag.com, www.flowcontrolnetwork.com and www.globalspec.com provide search engines for information about various types of industrial sensor types.

A good website for an organization dedicated to instrumentation and sensor advancement is the International Society of Automation's website or www.isa.org. (ISA, 67 Alexander Drive, Research Triangle Park, NC 27709 USA)

Allen-Bradley lists a number of types of sensors in their website:

Automatic Float Switches
Connection Systems
Drum Switches
Encoders and Resolvers
Limit Switches
Liquid Level Switches
Photoelectric Sensors
Pressure Controls – General Industrial
Pressure Controls – Traditional Machine Tool
Proximity Sensors
Rotating Cam Limit Switches
Speed Switches
Temperature Control
Ultrasonic Sensors

Siemens likewise contains similar sensor types to Allen-Bradley and can offer sensors for most industrial applications. The following page(s) list only one type of Siemens sensor (for pressure). The list is rather long and shows the diverse nature of the sensor industry with each type of sensing requiring a great deal of investigation in order to provide the best possible device for the application at a competitive price.

Importance of Sensors

Sensors are important in the overall design of any control system and the engineer/technologist must be aware of their importance to have a successful control system. Cost is always a factor as well as safety and maintainability. Something as simple as level measurement is not always simple. With the example of sensing level in a tank, it can be seen that the methods and costs vary over a wide range. It is also important to consider whether temperature, humidity or other physical change will upset the device. Also to be considered are changes in density, composition, moisture and other physical characteristics. Accuracy and repeatability are also considerations. The factor that the material may or may not have to actually touch the sensor may need to be considered as well. Some powders are especially difficult to handle and sense. If the powder cakes or is chunky or granular, the sensor may require special techniques for sensing.

Devices such as tanks or silos with level control are an example of the sensors described that are chunky or granular. Level sensing in a tank may involve a number of different considerations including the following list. In the Liptak book "Process Measurement and Analysis", the author(s) divides the level selection guide into nine different categories:

Liquid
Liquid/Liquid Interface
Foam
Slurry
Suspended Solids
Powdery Solids
Granular Solids
Chunky Solids
Sticky Moist Solids

The number of different types of sensors is 21 from the same book with some of the types having a number of different sub-types. The list of methods to measure various physical continues to grow and increase in sophistication.

From Liptak's book, the following are methods used to sense level in a vessel.

Beam Breaker
Bubbler
Capacitance
Differential Pressure
Electromechanical Diaphragm
Displacer
Float
Float/Tape
Paddle Wheel
Weight/Cable
Gauges/Glass
Gauges/Magnetic

Inductive
Microwave
Radiation
Sonic Echo Sonar
Sonic
Ultrasonic
Thermal
Vibration

While the reader may quickly conclude that one of the sensor types is superior to another, the fact that so many different types are present suggests that different sensors may be useful for a specific type of application and be a failure in another application. Cost also is also of high importance in the selection of a sensor, especially if the number of sensors increases to a large number. Reliability and maintainability are also considerations for the purchaser.

Photo-eye Technology

Photo-eye technology has advanced greatly over the years and can be used to sense a great number of different devices. Used primarily to sense discrete devices, the photo-eye has been used to sense, among other things, the presence of an automobile in the garage door, effectively blocking the door from coming down on a moving or partially parked automobile. The figure below shows what would happen if a car were not protected by a photo-eye system. The car on the right would not be protected from an overhead garage door coming down on it if the photo-eye were not present. The car blocks the signal from the transmitter at left. The reflector does not see the light and the receiver responds with no light signal from the reflector. The light from the transmitter is unique in that another source such as a flashlight or the sun will not trigger a response other than from the photo-eye's own transmitter.

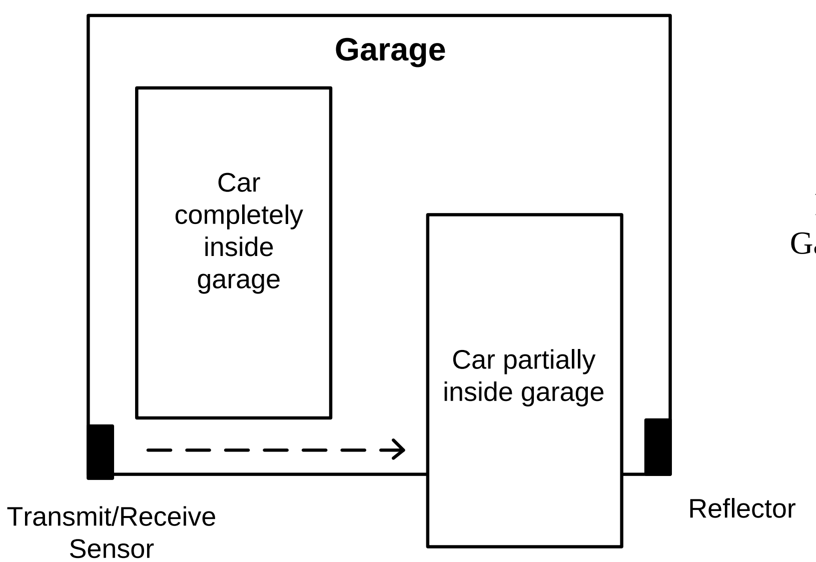
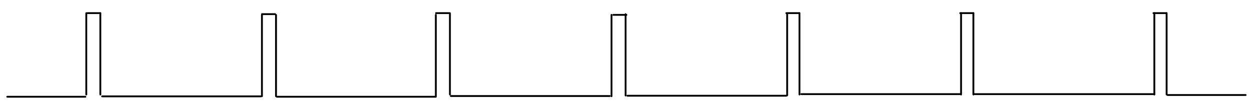


Fig. 10-1
Garage Door
Sensor

The following discussion of photo-eye types shows the breadth of usage for some types of sensors. The little photo-eye is not just used for the simple garage door application. They are useful in a number of very different types of applications with more applications being developed each year. The following discussion gives the reader some idea as to the specialization that even the simple devices can have. The photo-eye is ideal to study since it is useful over a range of applications and because it is relatively inexpensive. It does not have a high price tag but has many different types of modes with some having sub-modes of the various modes themselves. This gives a sophistication that is not present in the garage door photo-eye switch.

The infrared LED is pulsed at a rate from the transmitter and sensed at the receiver. Only the pulsed signals are accepted at the receiver. This blocks all other light sources which in prior years contaminated the photo-eye receiver. No longer does the afternoon sun change the signal sensed at the receiver.



(Pulsed signal from transmitter)

An Application of Photoelectric Devices

At the Banner Engineering website is a separate manual explaining the theory and practice of applying photoelectric devices to part sensing. Banner Engineering was innovative in their discovery of the modulated LED sensor for part sensing.

Included in their manual are discussions on sensing modes including:

- Opposed Mode
- Retro-reflective Mode
- Proximity Mode
- Diffuse Mode
- Divergent Diffuse Mode
- Convergent Mode
- Fixed-Field Mode
- Adjustable-Field Mode
- Fiber Optic Modes
- Ultrasonic Proximity Modes

The catalog also includes a number of applications with a suggested method of sensing the devices for the application.

A review of some of the concepts of infrared photoelectric sensing are reviewed below:

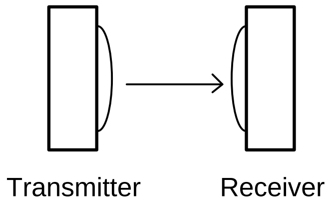


Fig. 10-2
Opposed Mode

In the opposed mode, emitter and receiver are housed separately. An object is seen when the beam breaks. A disadvantage to the opposed mode is that electrical power must be supplied to two separate locations, an added cost.

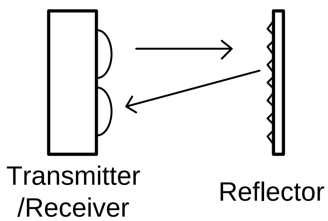


Fig. 10-3
Retro-reflective
Mode

In the retro-reflective mode, the emitter and receiver are housed in the same unit. A reflector is located opposite the emitter and reflects light back into the receiver. An object is seen when it breaks the beam as with the opposed mode.

Proximity Mode

In this mode, the sensor contains both emitter and receiver. Objects are detected when light is reflected from the object back to the receiver. The following four types of proximity mode can be used based on the device being sensed and the background around the device.

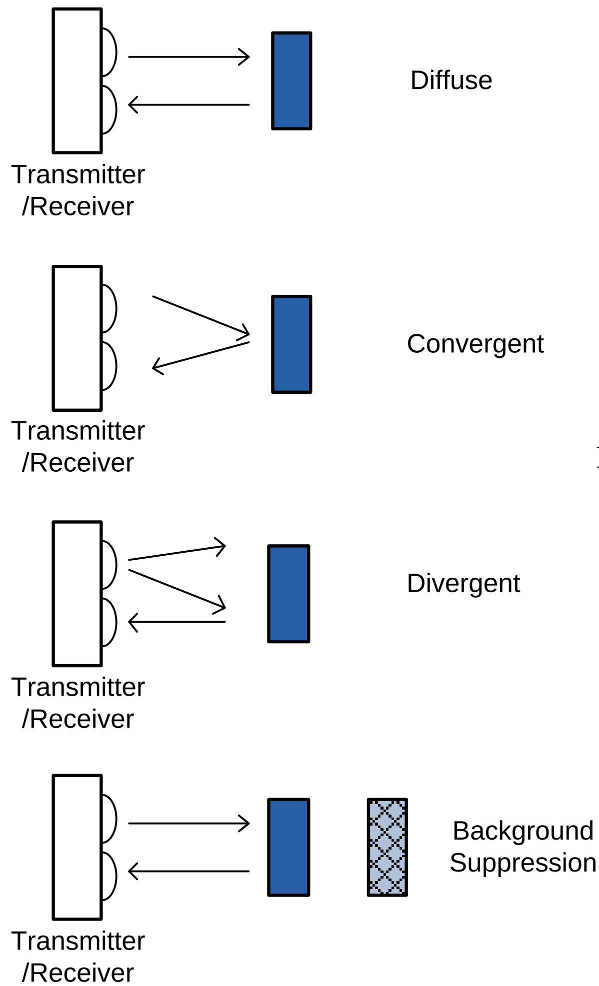


Fig. 10-4

The following definitions for range are described in the Banner manuals. The range for each mode is as follows:

Opposed mode:	Distance from emitter to receiver
Retroreflective mode:	Distance from emitter to reflector
Proximity mode:	Distance from emitter to object sensed

Also described for each sensor is a specific beam pattern and excess gain chart. These will be shown for various types of sensors. The beam pattern describes how the light falls around the object. A narrow beam pattern is usually desired over a more diffuse beam pattern although in some applications, a diffuse pattern is preferred. The excess gain describes a ratio of the amount of light at the receiver divided by the minimum light necessary to operate the sensor successfully.

Characteristics of the Various Modes:

Opposed Mode:

For the opposed mode, the excess gain graph on the left shows a linear response. The beam pattern shows a wide angle. Other characteristics of opposed mode include:

High reliability for opaque targets
A long sensing range (due to high excess gain)
In contaminated environments, good overall performance
Tolerant to misalignment

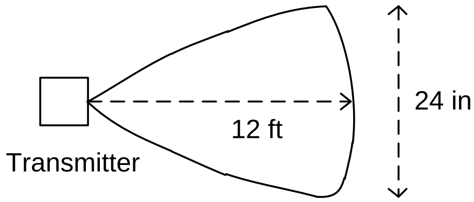


Fig. 10-5a
Beam Pattern of Opposed Mode

Retro-reflective Mode:

For the retro-reflective mode, the excess gain graph on the left shows a parabolic response. The beam pattern shows a wide angle similar to the opposed mode. Other characteristics of retro-reflective mode include;

Convenience in wiring and fitting into small spaces
A long sensing range (due to high excess gain)

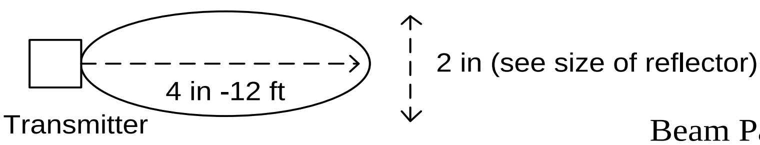


Fig. 10-5b
Beam Pattern of Retro-reflective Mode

Diffuse Mode:

For the diffuse mode, the excess gain graph on the left shows a gain linear over large distances and flat for smaller distances. The beam pattern shows a wide angle similar to the opposed mode. Other characteristics of the diffuse mode include:

Convenient in wiring and fitting into small spaces
Used in cases in which reflectivity is important

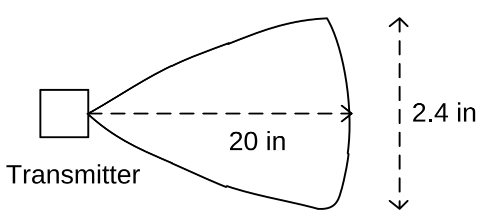


Fig. 10-5c
Beam Pattern of Diffuse Mode

Divergent Mode:

For the divergent mode, the excess gain graph shows a parabolic gain similar to the retro-reflective mode. The beam pattern is narrower than others discussed. Other characteristics of the divergent mode include:

Again, this mode is convenient for small space requirements
Good for detecting clear materials in close spaces
Good in detecting shiny objects or vibrating objects

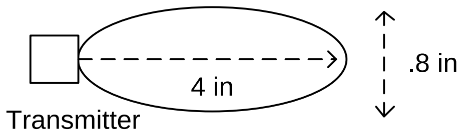


Fig. 10-5d
Beam Pattern of Divergent Mode

Convergent Mode:

For the convergent mode, the excess gain graph shows a very narrow range of detection allowed. The beam pattern is narrow and ranges from a few mm to no detection as distance increases. This can be useful if a background object is to be ignored. Other characteristics of the convergent mode include:

Useful for small space requirements, especially with round objects
Useful for objects with low reflectivity

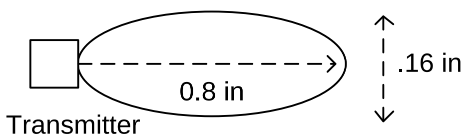


Fig. 10-5e
Beam Pattern of Convergent Mode

Background Suppression:

This mode is similar to the convergent mode in that the range of detection is limited. No beam pattern is given for this mode. Other characteristics of this mode include:

Backgrounds can be ignored
In the range of detection, high gains can be obtained
Targets of varying reflectivity may be detected

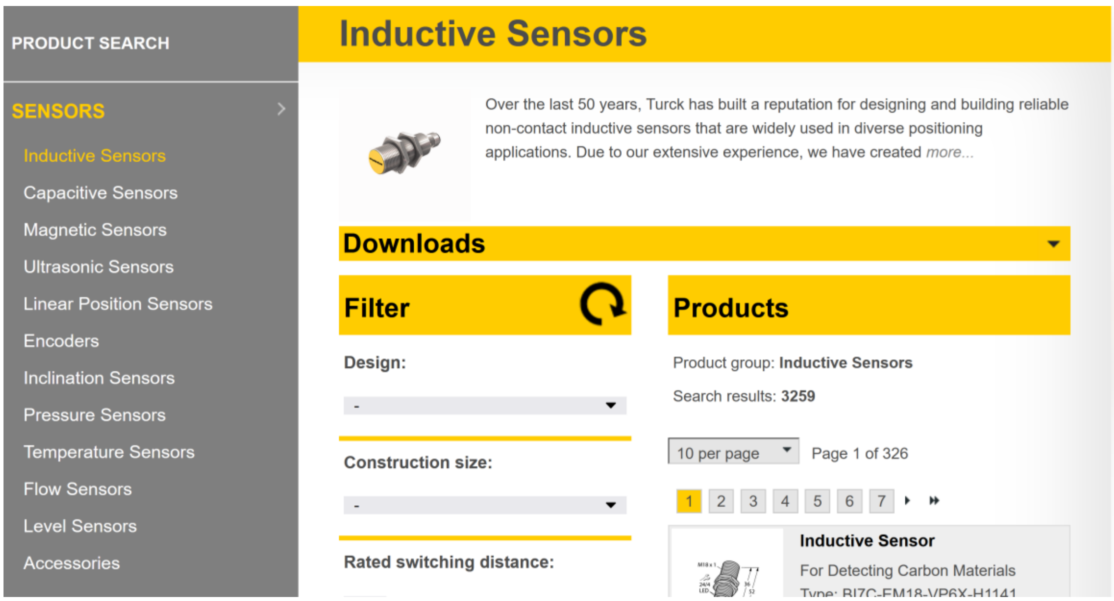
While the use of photo-electric sensors is not simple, a proper analysis usually gives a best fit of the type of sensor to be used.

Prox Switch

Another popular switch is the proximity switch. This switch can be found in a number of configurations, mostly though as the inductive prox switch.

This switch was invented to replace the limit switch, especially in cold climates when limit switches froze solid in winter. The prox switch has no moving parts and senses presence or absence of metal, ideal for sensing valve position in out-door tank farms.

See the list below of some of the various sensors offered by the Turck Company. Turck started as a prox switch manufacturer and branched into all the sensors seen here:



From the Turck Catalog:

“New this month, an Inductive Safety Sensor with two OSSD (output switching signal device) outputs. The sensors send switching signals to safety systems via their OSSD outputs. This is used to easily detect short circuits, overloads or cross-connections while simultaneously testing the shutdown capabilities. With SIL 2 and Performance Level D ratings, these sensors meet stringent functional safety requirements. The wide temperature range of -25°C to 70°C and IP67 rating make these ideal for use in safety-related applications such as compactors, machine covers, and monitoring of doors in safety zones.”

Machine Vision

A sensor that is costly but offers many benefits is the machine vision system. The Cognex vision system offers the complete system of vision inspection for industry. Their hardware and software offer the manufacturer an inspection system capable of solving many of the hard inspection problems.

The University of Toledo was given the opportunity to purchase Cognex equipment through a grant from the state of Ohio.We purchased eight Cognex 7802 vision systems. These systems gave the opportunity to explore the Cognex inspection process in depth. It was determined to use the hardware in classwork to inspect for the following:

PatMax Pattern Recognition
Histogram
Edges
Blobs

Cognex software may be used in either the online or simulate mode. In the simulate mode, an entire process may be built and tested without hardware. Both methods are acceptable to learn the software listed but with actual hardware, the hands-on learning of the 7802 system give students the experience of a real system complete with lighting or lack of lighting and how the part can be seen most clearly.

Introduction to the Cognex system is found in the EET 4450 tab on the hybridplc.org website.

RFID VS BARCODES: Advantages and disadvantages comparison

Manufacturers currently employ two forms of automated data collection: barcodes and RFID systems. There is much hype as to whether RFID will end up taking over the barcode industry. One data collection method is not essentially better than the other.

An application that barcode cannot do is the floating database of many transfer machines in which an operation is carried out at a station and the next station depends on the prior operation to successfully perform its operation. Each station must read the present status of the part (usually on a pallet) and then perform its operation and, if successful, write the new status on the rfid tag. The rfid tag then, at the end, has the entire history of the operations performed on the part written on the pallet tag.

This type of operation is not dependent on multiple plcs transferring information between each other. They only require the read-write communications capability to the rfid tag.

RFID tags can also be used in more harsh environments than the bar code tag. For example, the tags used on livestock are rfid tags placed in the ear of a calf or hog allowing the animal to be followed throughout their growth and eventual end in the rendering plant. The present RFID tags used in the livestock industry are low-frequency tags that are read at a radio frequency of 134.2 kHz (kilohertz). In the beef industry, the tags contain a 15- digit alpha-numeric (numbers and letters) code called the Animal Identification Number (AIN). This 15-digit AIN is also printed on the outside of the tag.

The standard for livestock readers is ISO 11784/11785. The functions of readers are to transmit and receive radio frequency signals, contain a control unit to execute commands, incorporate an interface to transfer data, and receive and respond to commands from a computer. Some readers only store the data (15-digit AIN) and require that the information will be manually downloaded to a computer. Other readers are able to send data directly to a computer or palm pilot.

The following give a review of one of the RFID tag systems from Siemens.

The following RF300 mode transponders can be used with the SIMATIC RF300 RFID system:

Transponder	Features
RF320T  	Small, compact, universal transponder. 20 byte EEPROM

The Machine Directive

The following is a link to the Machinery Directive for all equipment sold to Europe. Beyond that, we will discuss machine safety as it exists in the US.

Some of the directives are covered in an article by Linda Caron, Parker Hannifin, Jan 23, 2019

"The Directive mandates the use of commonsense safety strategies on machinery, such as the use of e-stop buttons, the removal of air in a machine to protect against unexpected movement where safe to do so and the addition of technical measures where risk cannot be designed out. Additionally, to meet enhanced safety levels on machinery, redundancy and monitoring must be included in the controls of the machine in accordance with EN ISO 13849-1, as well as validation of the system in accordance with EN ISO 13849-2."

She continues: "EN ISO 13849-1 provides safety requirements and guidance on the principles for the design and integration of safety-related parts of control systems (SRP/CS), including the design of software. EN ISO 13849-2 specifies the procedures and conditions to be followed for the validation by analysis and testing of the specified safety functions, the category achieved, and the performance level achieved by the safety-related parts of a control system (SRP/CS) designed in accordance with ISO 13849-1."

Smoke billows from fire following an explosion at the pesticide plant owned by Tianjiayi Chemical, in Yancheng City, Jiangsu Province, China on March 21, 2019. (Stringer/Reuters)

"Explosion at Chinese Chemical Plant Kills 47, Injures 640

BY REUTERS

March 22, 2019 Updated: March 22, 2019

SHANGHAI—An explosion at a pesticide plant in eastern China has killed 47 people and injured more than 600, state media said on March 22, the latest casualties in a series of industrial accidents that has angered the public.

The blast occurred on Thursday at the Chenjiagang Industrial Park in the city of Yancheng, in Jiangsu Province, and the fire was finally brought under control at 3.00 a.m. on Friday, state television said. Survivors were taken to 16 hospitals with 640 people being treated for injuries. Thirty-two of them were critically injured, it said.

The fire at a plant owned by the Tianjiayi Chemical Company spread to neighboring factories. Children at a kindergarten in the vicinity were also injured in the blast, media reported.

The cause of the explosion was under investigation.

Public anger over safety standards has grown in China over industrial accidents ranging from mining disasters to factory fires that have marred three decades of swift economic growth.

The Chinese regime has pledged to improve safety in factories, though explosions and other incidents are still commonplace.

In November, two people were killed and 24 others injured in an explosion at a machinery plant in the northern Chinese province of Jilin. And in the city of Ningbo, two people were killed in a factory explosion. In August, five people were killed in an explosion at an aluminum plant in the eastern city of Jiangsu.
In July, 19 people died in a blast at a chemical plant in the southwestern province of Sichuan.

By David Stanway. The Epoch Times contributed to this report."

Machine Safety in the US

NFPA 79 is a standard used by industry to define safety standards in machine control and a sample page is provided here for review:

"

ANNEX I 79–81

Annex H Minimizing the Probability of Control Function Failure

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

H.1 The following discussion is explanatory material on 9.4.1 General Requirements and 9.4.1.1.

H.1.1 The measures, and the extent to which they are implemented, either individually or in combination, depend on the safety requirements associated with the respective application.

H.1.2 General.

H.1.2.1 Measures to reduce these risks include, but are not limited to, the following:

(1) Protective devices on the machine (e.g., interlock guards, trip devices)
(2) Protective interlocking of the electrical circuit
(3) Use of proven circuit techniques and components *(see H.2)*
(4) Provisions of partial or complete redundancy *(see H.3)* or diversity *(see H.4)*
(5) Provision for functional tests *(see H.5)*

H.1.2.2 In general, only single failures are to be regarded. In the event of higher levels of risk, it can be necessary to ensure that more than one failure cannot result in a hazardous condition.

H.2 Measures to Minimize Risk in the Event of Failure. Use of proven circuit techniques and components measures to minimize risk in the event of failure include the use of proven circuit techniques and components. These measures include, but are not limited to, the following:

(1) Bonding of control circuits for operational purposes *(see 9.4.2.1)*
(2) One terminal of the control device (i.e., the operating coil) connected to the bonded conductor and all switching elements (e.g., contacts) connected to the non-earthed (grounded) side of the control supply *(see 9.1.4)*
(3) Stopping by de-energizing *(see 9.2.2)*
(4) Switching of all live conductors to the device being controlled
(5) Use of switching devices having positive opening operation *(see IEC 60947-5-1)*
(6) Circuit design to reduce the possibility of failures causing undersirable operations

H.3 Provisions for Redundancy.

H.3.1 By providing partial or complete redundancy it is possible to minimize the probability that one single failure in the electrical circuit can result in a hazardous condition. Redundancy can be effective in normal operation (i.e., on-line redundancy) or designed as special circuits that take over the protective function (i.e., off-line redundancy) only where the operating function fails.

H.3.2 Where off-line redundancy that is not active during normal operation is used, suitable measures should be taken to ensure that these control circuits are available when required.

H.4 Use of Diversity. The use of control circuits having different principles of operation or differing types of devices can reduce the probability of faults and failures giving rise to hazards. Examples include the following:

(1) The combination of normally open and normally closed contacts operated by interlocking guards.
(2) The use of different types of control circuit components in the circuit.
(3) The combination of electromechanical and electronic circuits in redundant configurations.
(4) The combination of electrical and nonelectrical systems (e.g., mechanical, hydraulic, pneumatic) can perform the redundant function and provide the diversity.

H.5 Functional Tests. Functional tests can be carried out automatically by the control system, or manually by inspection or tests at start-up and at predetermined intervals, or a combination as appropriate *(see also Sections 17.2 and 18.6)*.

Annex I Informational References

I.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

I.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70, *National Electrical Code®*, 2005 edition.

NFPA 70E, *Standard for Electrical Safety in the Workplace*, 2004 edition.

I.1.2 Other Publications.

I.1.2.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI B11-TR3, *Risk Assessment and Risk Reduction — A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools*, 2000.

I.1.2.2 EN Publications. CENELEC, 35, Rue de Stassartstraat, B-1050 Brussels, Belgium. CENELEC Online Info Service: Info@cenelec.org

EN 60204, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*, 2006.

EN 61010-1, *Safety requirements for electrical equipment for measurement, control, and laboratory use — Part 1: General requirements*, 2006.

I.1.2.3 IEC Publications. International Electrotechnical Commission, 3 rue de Varembe, P.O. Box 131, 1211 Geneve 20, Switzerland.

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance*, 1999-08.

IEC 60072-1, *Dimensions and output series for rotating electrical machines — Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080*, 1991-03.

IEC 60204-1, *Ed. 4.1 Safety of machinery — Electrical equipment of machines — Part 1: General requirements*, 2000-05.

IEC 60332-1, *Tests on electric cables under fire conditions — Part 1: Test on a single vertical insulated wire or cable*, 1993-04.

IEC 60364-4-1, *Electrical installations of buildings — Part 4-41: Protection for safety — Protection against electric shock*, 2001-08.

IEC 60417-1, *Graphical symbols for use on equipment — Part 1: Overview and application*, 2000-05.

IEC 60417-2, *Graphical symbols for use on equipment — Part 2: Symbol originals*, 1998-08.

"

Risk Assessment for Moving Equipment

In addition to NFPA 79, other standards are used for specific machine types. Use the following standard to begin evaluation of a risk assessment concerning moving equipment: ANSI/RIA R15.06 -1999. Other standards include:

(ANSI – American National Standards Institute)

(RIA – Robotic Industries Association)

Other Risk Assessment Standards include:

- ANSI B11.TR3 – Risk Assessment Technical Report
- EN 1050 – Principles of Risk Assessment
- IEC 61508 – Functional Safety
- ISO 13849 – Safety of Machinery – Safety Related Parts of Control Systems
- ISO 14121 – 2007 – Safety of Machinery – Risk Assessment
- IEC 62061 – 2005 – Functional Safety of safety-related electrical, electronic and programmable control system.

To design any system, a plan has to be generated to identify what it is that the system is supposed to do. If one were to design a safety system:

- The FUNCTIONS of the safety system has to be defined
  - The OBJECTIVE of the safety system function is to REDUCE RISK
  - The HAZARDS need to be defined for each MODE of OPERATION of the machine to meet the objective
- Functional requirements will be defined by sequencing of the machine, the requirements of the risk assessment, the types of components and subsystems within the system and the standards requirements

- The design of the functional aspects of the system can encompass:
  - Mechanical, Electronic and Fluid Power Guarding Systems
  - System, circuit and component performance requirements

- Safety Controls and Circuit Performance requirements are specified by Standards

- The Function of a safety system is to monitor and control conditions on a machine or process that are hazardous in themselves or, if no action were taken, may give rise to hazardous situations

- The Safety System runs in parallel with the Production System
  - Focus of Production System is Throughput
  - Focus of Safety System is Protection

- A Safety system is designed to protect (in the following order):
  - People
  - Environment
  - Machinery/Equipment

– A Safe Application is defined as a situation where the residual risk is **at or less than** the accepted risk.

This also means that **absolute** safety cannot be achieved. Each safety product must be applied as a whole to effectively reduce risk. Safety is the sum of its parts and safety is only as good as its weakest link. The complexity of the inputs (sensors) and outputs (actuators) and the flexibility of the control will determine the type of logic solver. The type may be stand-alone relay, modular relay or safety PLC.

What is Functional Safety?

Fig. 10-6

Functional safety can be described in the above pictures as to what is safe or unsafe. On the left, a machine is running and safe is a machine with enough guards with sensors in place to determine if the machine is indeed safe to run and capable of stopping if not safe. On the right a continuous process is determined to be fault tolerant or not based on a set of criteria. It may be unsafe to stop the process (process may blow up, set up, etc) and the safe mode is to maintain a safe control environment. If this means slowly ramp down a temperature, the control system must guarantee that this will happen in a predictable manner. Stopping in a continuous process is not always safe and may be very unsafe.

- There are a variety of standards for Machine Guarding
  - Federal Standards and Consensus Standards
  - Electrical Design Standards (NEC, NFPA, CSA, ISO, IEC)
  - Guarding Device Application Standards (ANSI, AMSE, ASSE, CSA, IEC, ISO)
  - Functional Standards (NFPA, ANSI, IEC, ISO, CSA)
  - Awareness Means Standards – Caution Warning Danger

- In the US, for employers with employees
  - OSHA is the Federal Enforcement arm driving safety performance requirements
  - OSHA can reference Consensus Safety Standards
    - ANSI, NFPA, ASME, etc.

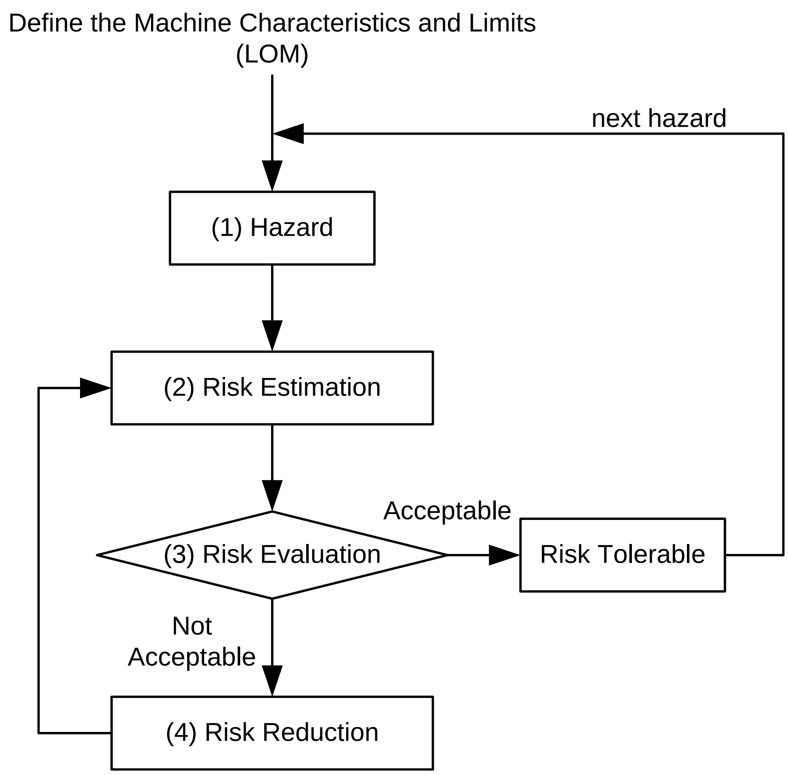
- In the US for Original Equipment Manufacturers
  - The litigious environment and the customer contract may drive conformance to various design standards (ANSI, ASME, ASSE, NFPA, OSHA, Corporate)

- Other parts of the world (CSA, AS, IEC, ISO, EN, CCC, etc.)
  - CE – European Union
  - Labour Ministries - Canada
  - Governmental Regulation
  - Drive conformance to standards by various techniques

This discussion of safety refers to machine safety as opposed to personnel safety from arc flash discussed in Chapter 9.

The Risk Assessment Team

A team is assembled to follow a process and determine if it is safe or unsafe. They follow a process described below for each hazard.



The BGIA Report, below, gives direction for analysis of machine safety in Europe. The organization is German but all of Europe uses the report for analysis of faults and design of systems to determine the safety state. In the BGIA Report, safety designs are given for various process types. There is a blend of the above assessment model and the BGIA designs for the design of a process for safe use. You may serve on a Risk Assessment Team. You will be held responsible for proper design and programming in the PLC for various controls the team deem necessary.

BGIA

Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

BGIA Report 2/2008e

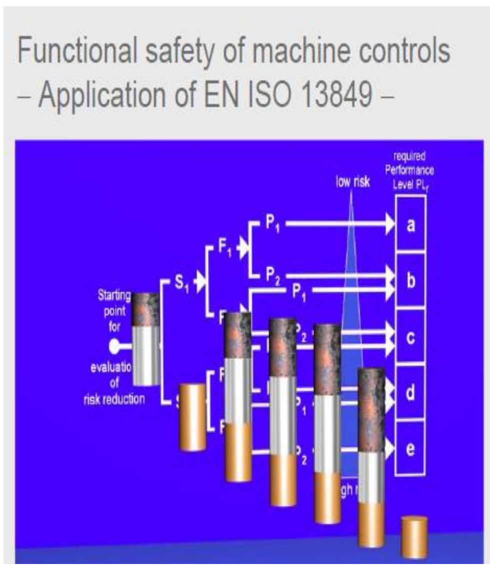


Fig. 10-7 BGIA Regulations
(German Insurance Corporation responsible for definition of EN ISO 13849)

Something tastes good around here.

Intrinsic Safety

From a recent Toledo Blade article:

“Two men died Friday upon being trapped inside a grain storage tank at The Andersons facility in South Toledo.

Firefighters responded shortly after 9 a.m. for a grain rescue at the facility, 125 Edwin Dr. near the I-75 DiSalle Bridge.

They and another man were inside the tank breaking up compacted grain in an effort to unplug a blocked hole, Dr. Barnett said. She had no information about the third man.”

Fig. 10-8 Andersons Grain Handling Facility

We learn from the above article that grain handling is an extremely dangerous job. We also learn that there are multiple ways that grain can cause damage. The first is concerned with the dangerous nature of grain to roll and move unexpectedly causing fatalities such as described above. The second concerns explosions that can occur, many times unexpectedly, due to grain dust and its explosive nature. This second concern is one described in the NEC’s Articles 500, 501 and 502 concerning hazardous materials and intrinsic safety.

An oil tank farm contains the same hazards, namely explosive materials. With oil and gasoline, the material is liquid rather than dust. Both can be dangerous. We could also discuss coal dust or other type of dust and its explosive nature.

The intrinsic safety sections of the NEC are descriptive in that they lay out the electrical protections that encompass the equipment at the site. The layout restrictions and areas around various types of equipment are in various NFPA documents.

Class I, II, or III describe the type of hazardous material. Divisions represent the distance from the source with Division 1 closest and Division 2 a distance from the source. Temperature is also considered.

The European directive is defined in IEC/EN 60079-10.

Burner Management

Burners are used for generating heat and are regulated by NFPA and IEC standards. Functional safety standards have changed and now allow the PLC to contain burner safety circuits. In the US, the industry standards are described by insurance as well as NFPA 85. In Europe, the IEC 61511 standard permits combining of control and combustion safeguarding in a single device, namely a safe PLC.

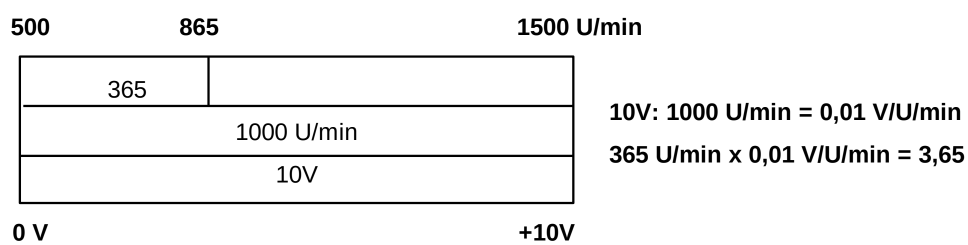
Analog Signals - Siemens

In contrast to binary signals that can assume only the two signal states "Voltage available +24V“ and "Voltage unavailable 0V“, analog signals -within a certain range- are able to assume any number of values. A typical example for an analog sensor is a potentiometer. Depending on the position of the rotary button, it is possible to set any resistance, up to the maximum value.

Examples of analog variables in control engineering:

- Temperature -50 ... +150°C
- Flow rate 0 ... 200l/min
- Speed 500 ... 1500 U/min
- etc.

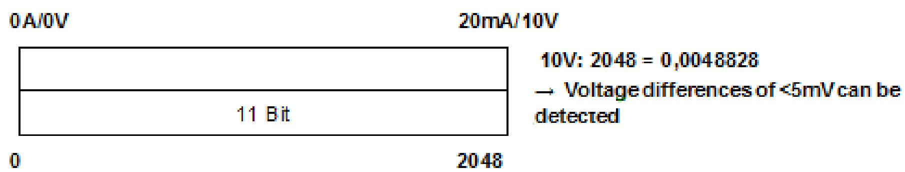
Using a transducer, these variables are changed into electrical voltages, currents or resistances. If, for example, speed is to be recorded, the speed range can be changed from 500 ... 1500 U/min to a voltage range of 0 ... +10V by using a transducer. For the measured speed of 865 U/min, the transducer would read out a voltage value of + 3.65 V.



These electrical voltages, currents and resistances are then connected to an analog module that digitalizes this signal.

Note:
Some analog modules are able to process different signal types in this case. This has to be set in the device overview. Please refer to the notes in the device manuals.

If analog variables are processed with a PLC, the voltage, current or resistance value that was entered has to be converted to digital information. This conversion is called analog-digital conversion (A/D conversion). This means, for example: the voltage value of 3.65V is stored in a series of binary digits as information. The more binary digits are used for digital representation, the higher is the resolution. If, for example, only 1 bit were available for the voltage range 0 ... +10V, information could be provided only as to whether the measured voltage was within the range of +5V ... +10V. With 2 bits, however, the range can be subdivided into 4 individual ranges; i.e. 0 ... 2.5/2.5 ... 5/5 ... 7.5/7.5 ... 10V. In control engineering, commercial A/D converters convert with 8 or 11 bits, whereby 8 bits provide for 256 individual ranges, and 11 bits a resolution of 2048 individual ranges.



The data types INT and REAL are very important in analog value processing since entered analog values are present as integers in the format INT. For exact further processing, only floating point numbers REAL can be used because of the rounding error at INT.

Entering/Reading Analog Values

Analog values are entered in the PLC or read out from it as word information. The words are accessed with the following operands, for example:

%IW 64	Analog input word 64
%QW 80	Analog output word 80

Each analog value ("Channel") is assigned an input word or an output word. The format is INT, an integer. Addressing the input values or output values depends on the addressing in the device overview. For example:

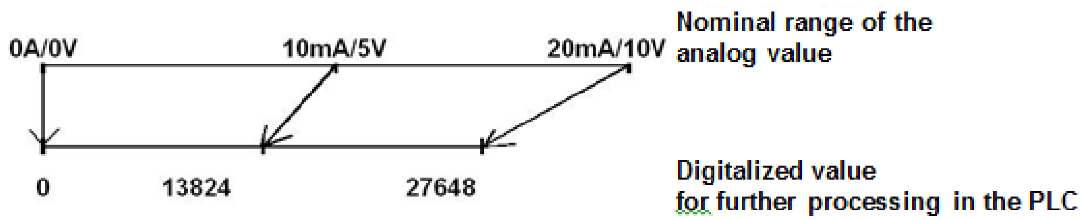
Device overview

Module	Slot	I address	Q addre...	Type	Order no.	Firmware	Comment
Control_tank	1			CPU 1214C DC/DC/DC	6ES7 214-1AE30-0XB0	V1.0	
DI14/DO10	1.1	0...1	0...1	DI14/DO10			
AI2	1.2	64...67		AI2			
AO1 x 12bit..	1.3		80...81	AO1 signal board	6ES7 232-4HA30-0XB0	V1.0	

Fig. 10-9
Analog Channel
Addresses

The address of the first analog input would be in this case %IW 64, that of the second analog input %IW 66, and that of the analog output %QW 80.

The analog value transformation for further processing in the PLC is the same for analog inputs and analog outputs. The digitalized value ranges look like this:



These digitalized values often have to be normalized through further processing in the PLC.

Normalizing Analog Values

If an analog input value is present as a digitalized value, it usually has to be normalized so that the numerical values correspond to the physical variables in the process.

Likewise, the analog output to the IO output word usually takes place only after the output value is normalized.

In STEP7 programs, computing operations are used for normalizing. That this is carried out as exact as possible, the values to be normalized have to be converted to the data type REAL, to keep rounding off errors minimal.

Sample Task: Level Monitoring of a Tank

For our program, we are programming the monitoring of a tank level. A sensor measures the level in a tank and converts it to the voltage signal 0 to 10V. 0V correspond to a level of 100 liters and 10V to a level of 1000 liters.

This sensor is connected to the first analog input of the SIMATIC S7-1200. This signal is now to be entered in the function FC1, and normalized.

Then, the following is to be programmed: monitoring for the maximum permissible level of 990 liters, and monitoring for the minimum permissible level of 110 liters.

Assignment list:

Address	Symbol	Data Type	Comment
%IW 64	AI_level_tank1	Int	Analog input level Tank1
%Q 0.0	Tank1_max	Bool	Indication > 990 liters
%Q 0.1	Tank1_min	Bool	Indication level < 110 liters

In the **Device Overview**, we can set the addresses for the inputs/outputs. Here, the CPU's integrated analog inputs have the addresses %I64 to %I67, and the integrated digital outputs the addresses %AQ.0 to %Q1.1 (→ Device Overview → AI2 → 64…67)

Since for modern programming we program with variables rather than with absolute addresses, we have to specify the **global PLC tags** here.

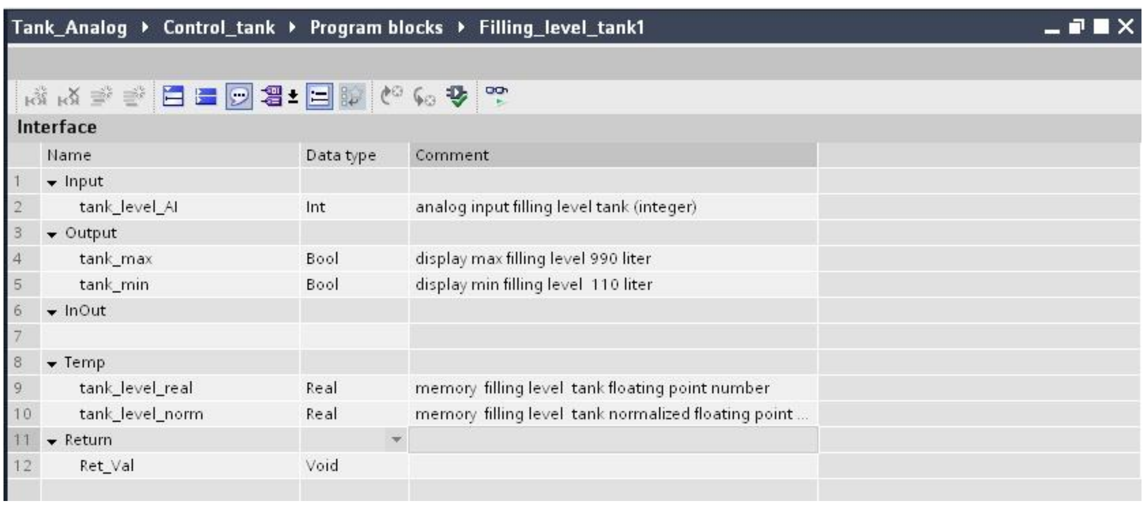
These global PLC tags are descriptive names and comments for those inputs and outputs that are used in the program. Later, during programming, we can access these global PLC tags by means of this name. These global tags can be used in the entire program in all blocks.

When declaring local variables, the following variables are needed for our example.

Input:

tank_level_AI	Here, the level sensor enters the analog value
Output:	
tank_max	Here, the status of the maximum indication is written to the output
tank_min	Here, the status of the minimum indication is written to the output
Temp:	
tank_level_real	This variable is needed to store an intermediate value
tank_level_norm	Here, a value for the level in the floating point format is provided, normalized to the range 100 to 1000 liters.

In this example, it is particularly important that the correct data types are used since in the following program, they are not compatible with the conversion functions used. For the sake of clarity, all local variables should be provided with sufficient comments.



	Name	Data type	Comment
1	▾ Input		
2	tank_level_AI	Int	analog input filling level tank (integer)
3	▾ Output		
4	tank_max	Bool	display max filling level 990 liter
5	tank_min	Bool	display min filling level 110 liter
6	▾ InOut		
7			
8	▾ Temp		
9	tank_level_real	Real	memory filling level tank floating point number
10	tank_level_norm	Real	memory filling level tank normalized floating point ...
11	▾ Return		
12	Ret_Val	Void	

Fig. 10-10 Analog Sensor Tag Table

After we declared the local variables, we can enter the program by using the variable names (variables are identified with the symbol '#'.) In FBD, for example, it could look like this:

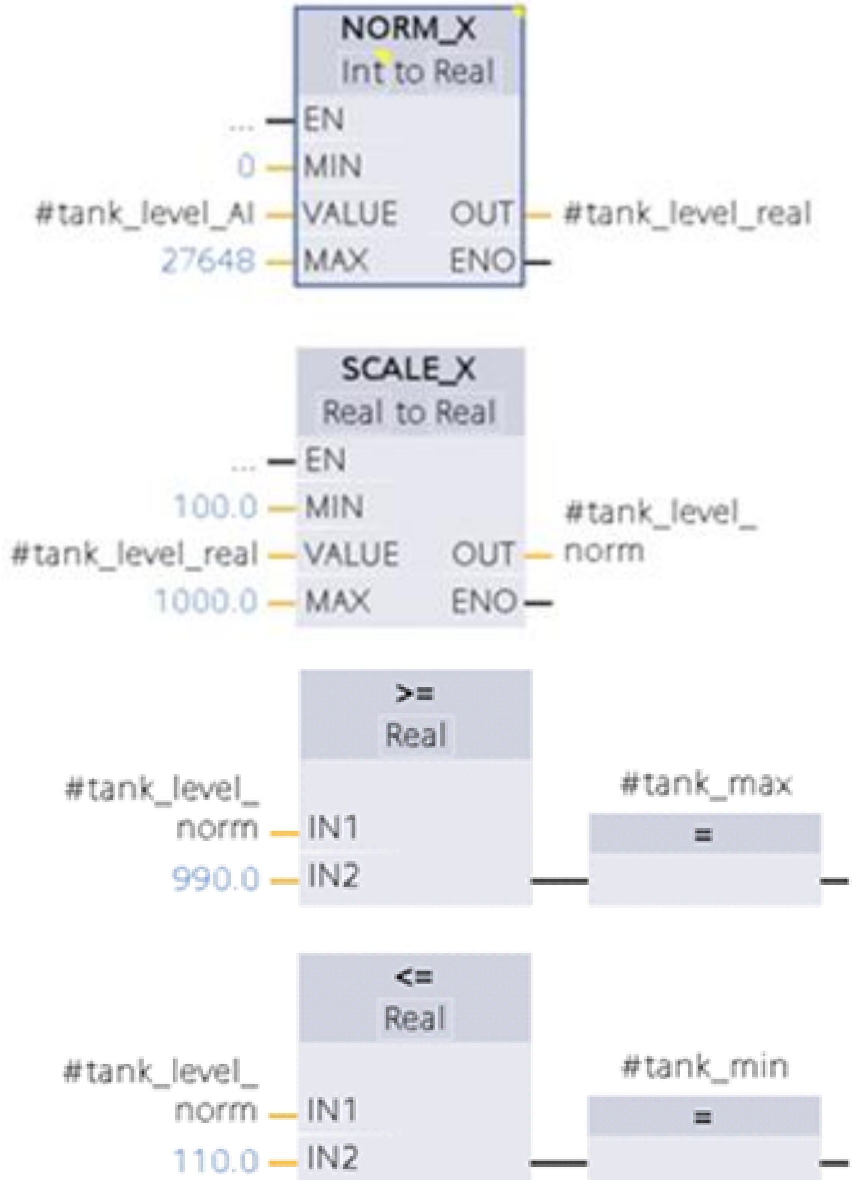
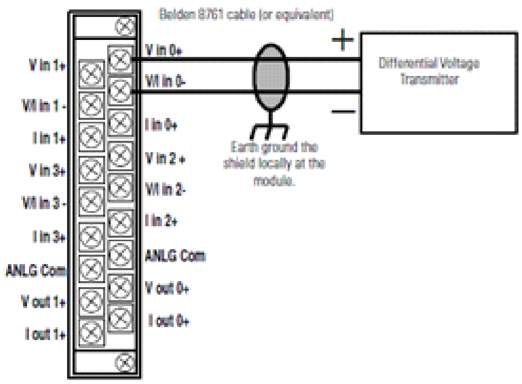


Fig 10-11   FBD Program to Read Analog Values

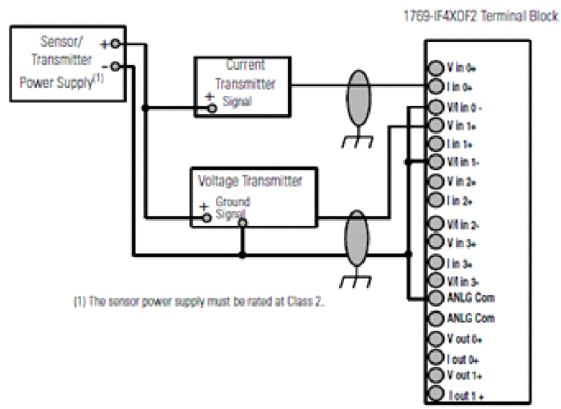
Analog Signals – Allen-Bradley

Allen-Bradley shows a number of wiring configurations for their analog input and output channels:

Differential Input Wiring Diagram



Single-ended Sensor/Transmitter Types Wiring Diagram



Mixed-input Transmitter Wiring Diagram

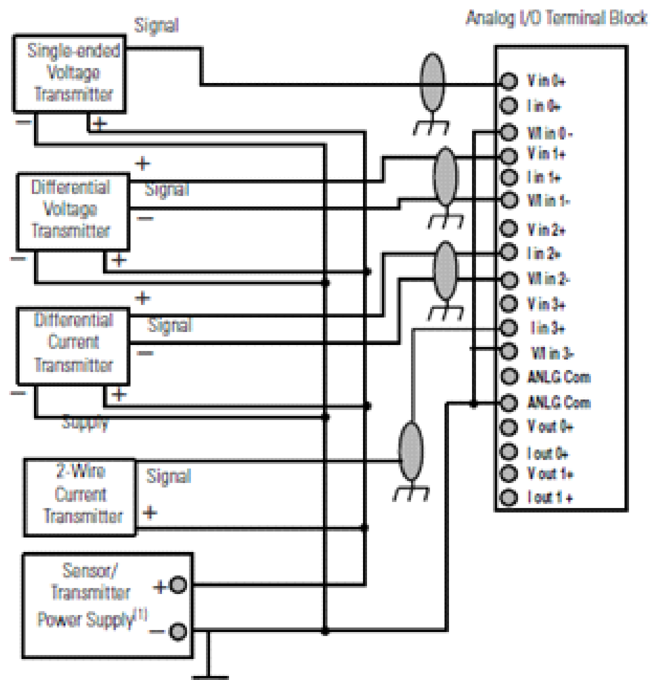


Fig. 10-12

(1) The sensor power supply must be rated at Class 2.

All analog I/O commons (ANLG COM) are connected in the analog I/O card of the packaged controller. The analog common (ANLG COM) is not connected to earth ground inside the packaged controller. Analog I/O channels are not isolated from each other. Use Belden 8761 (or equivalent) shielded wire. Under normal conditions, the drain wire and shield junction must be connected to earth ground via a panel or DIN rail mounting screw at the analog I/O removable terminal block end. Keep the shield connection to ground as short as possible. To ensure optimum accuracy, limit overall cable impedance by keeping your cable as short as possible.

Plan to place the packaged controller as close to your sensors or actuators as your application permits.

If multiple power supplies are used with analog inputs:

– the power supply commons must be connected
– do not exceed the specified isolation voltage

The embedded analog I/O does not provide loop power for analog inputs. Use a power supply that matches the input transmitter specifications. Differential analog inputs are more immune to noise than single-ended analog inputs. Voltage outputs (Vout 0+ and Vout 1+) of the analog I/O are referenced to ANLG COM. Load resistance for a voltage output channel must be equal to or greater than 1 KΩ. Current outputs (I_{out} 0+ and I_{out} 1+) of the analog I/O source current that returns to ANLG COM. Load resistance for a current output channel must remain between 0…300 Ω. Voltages on V_{in}+, V/I_{in}-, and I_{in}+ of the analog I/O must be within 0 to +10V DC of analog common.

Analog Outputs Wiring Diagram

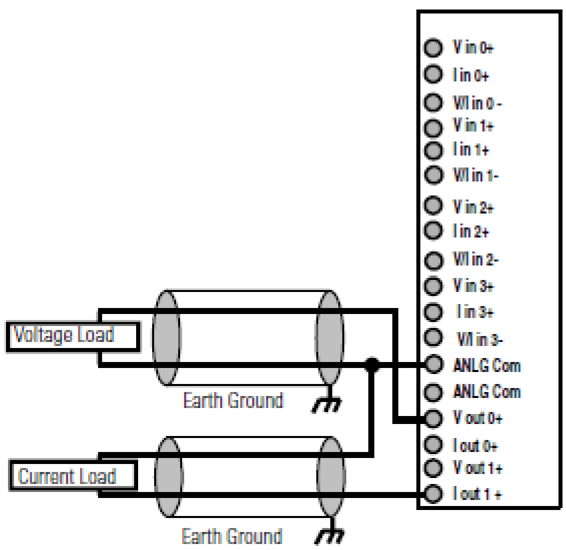


Fig. 10-13 Analog Output Wiring

Configure the Analog I/O

The analog I/O Module Properties dialog box lets you specify the analog inputs and outputs you want to enable in your application.

Configuration of the analog I/O is typically completed by using RSLogix 5000 software during the initial system configuration. To configure your analog I/O in RSLogix 5000 programming software, complete these steps:

1. In the I/O Configuration tree, right-click slot 3, Embedded IF4XOF2 Analog I/O and choose Properties.

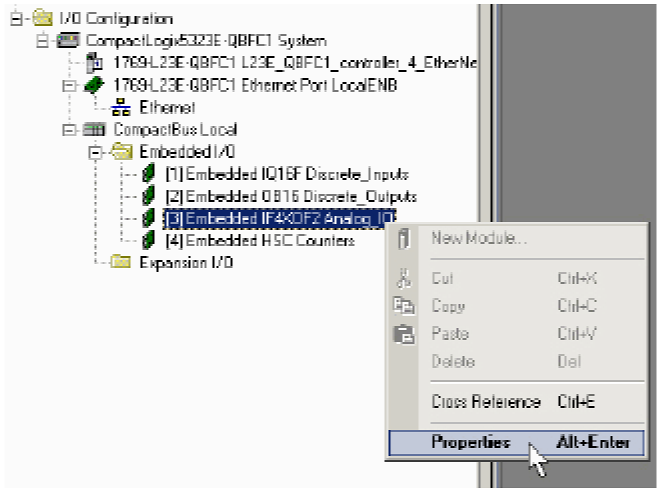


Fig. 10-14
Configuring the Analog Inputs

Tags specific to the use of the analog I/O are described here:

Analog I/O Tags:

Fig. 10-15   Input/Output Data File

Local:3:C	{...}	{...}		AB:Embedded_IF...
Local:3:C.Config0	2#0000_00...		Binary	INT
Local:3:C.Ch0ProgToFaultEn	0		Decimal	BOOL
Local:3:C.Ch0ProgMode	0		Decimal	BOOL
Local:3:C.Ch0FaultMode	0		Decimal	BOOL
Local:3:C.Ch0InputEn	0		Decimal	BOOL
Local:3:C.Ch1InputEn	0		Decimal	BOOL
Local:3:C.Ch2InputEn	0		Decimal	BOOL
Local:3:C.Ch3InputEn	0		Decimal	BOOL
Local:3:C.Config1	2#0000_00...		Binary	INT
Local:3:C.Ch1ProgToFaultEn	0		Decimal	BOOL
Local:3:C.Ch1ProgMode	0		Decimal	BOOL
Local:3:C.Ch1FaultMode	0		Decimal	BOOL
Local:3:C.Ch0OutputEn	0		Decimal	BOOL
Local:3:C.Ch1OutputEn	0		Decimal	BOOL
Local:3:C.Ch0FaultValue	0		Decimal	INT
Local:3:C.Ch0ProgValue	0		Decimal	INT
Local:3:C.Ch1FaultValue	0		Decimal	INT
Local:3:C.Ch1ProgValue	0		Decimal	INT

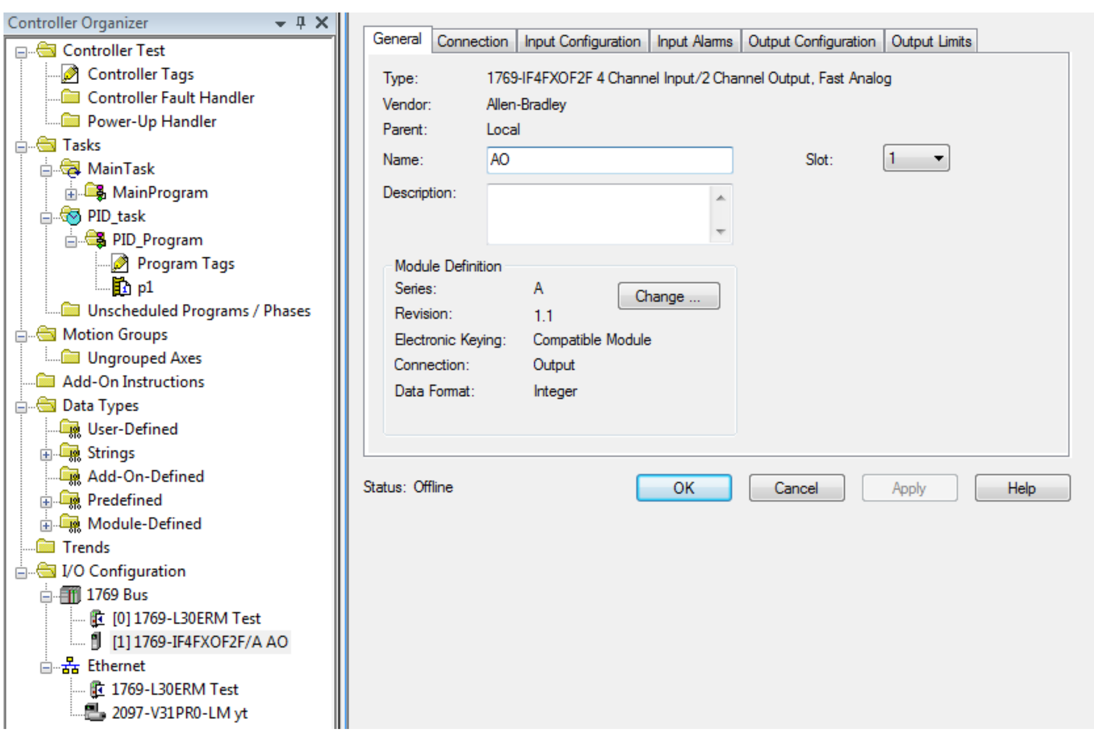
Fig. 10-16   Input/Output Data File

⊟ Local:3:I	{...}	{...}		AB:Embedded_IF...
⊞ Local:3:I.Fault	2#0000_00...		Binary	DINT
⊞ Local:3:I.Ch0Data	0		Decimal	INT
⊞ Local:3:I.Ch1Data	0		Decimal	INT
⊞ Local:3:I.Ch2Data	0		Decimal	INT
⊞ Local:3:I.Ch3Data	0		Decimal	INT
⊞ Local:3:I.InputRangeFlag	2#0000_00...		Binary	INT
Local:3:I.Ch0InputOverRange	0		Decimal	BOOL
Local:3:I.Ch1InputOverRange	0		Decimal	BOOL
Local:3:I.Ch2InputOverRange	0		Decimal	BOOL
Local:3:I.Ch3InputOverRange	0		Decimal	BOOL
⊞ Local:3:I.OutputRangeFlag	2#0000_00...		Binary	INT
Local:3:I.Ch0OutputOverRange	0		Decimal	BOOL
Local:3:I.Ch1OutputOverRange	0		Decimal	BOOL
Local:3:I.Ch0DataInvalid	0		Decimal	BOOL
Local:3:I.Ch1DataInvalid	0		Decimal	BOOL
⊞ Local:3:I.Ch0Readback	0		Decimal	INT
⊞ Local:3:I.Ch1Readback	0		Decimal	INT

⊟ Local:3:O	{...}	{...}		AB:Embedded_IF...
⊞ Local:3:O.Ch0Data	0		Decimal	INT
⊞ Local:3:O.Ch1Data	0		Decimal	INT

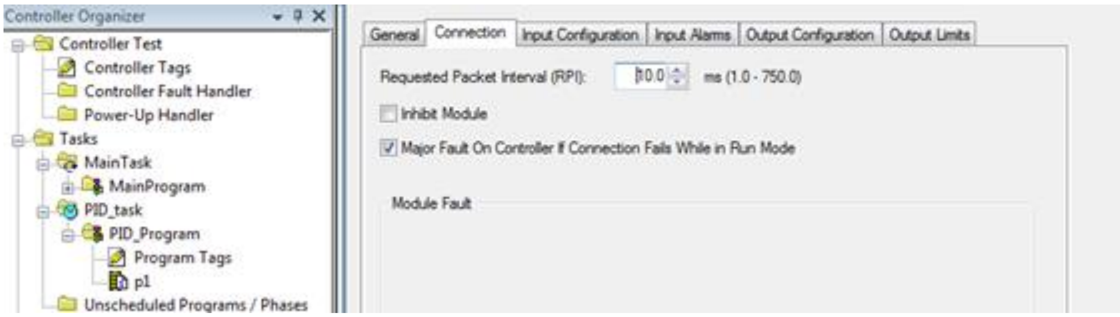
The analog card is chosen (1769-IF4FXOF2F/A). Then the following configuration appears:

Fig. 10-17 1769-IF4FXOF2F/A Configuration



The update time of the analog card is reduced from the standard 80 msec. down to 10 msec. or faster to successfully present new analog data to the PID block which is running at once each 100 msec.

Fig. 10-18 1769-IF4FXOF2F/A Configuration



Next, the Input Configuration is chosen and the inputs used are checked ‘enable’ and the Data Format is ‘Scaled for PID’. This gives input and output numbers ranging from 0 – 16383 for 4-20 mA signals.

Fig. 10-19 1769-IF4FXOF2F/A Configuration

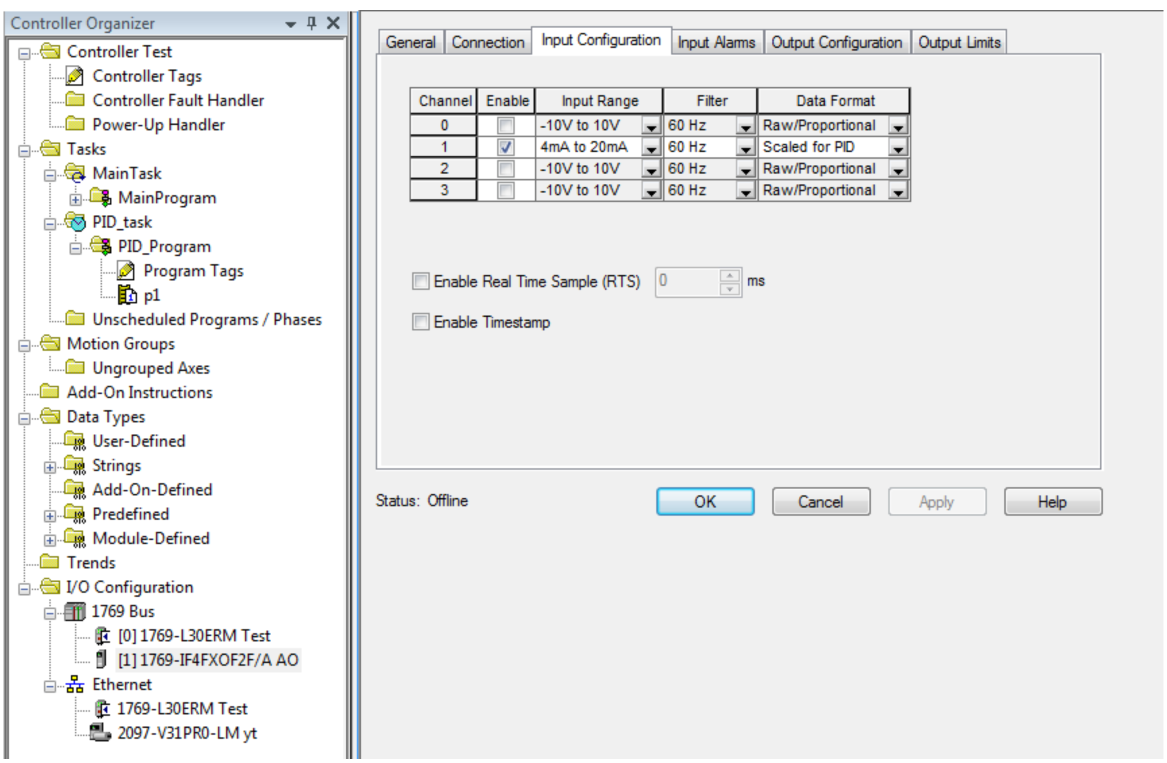
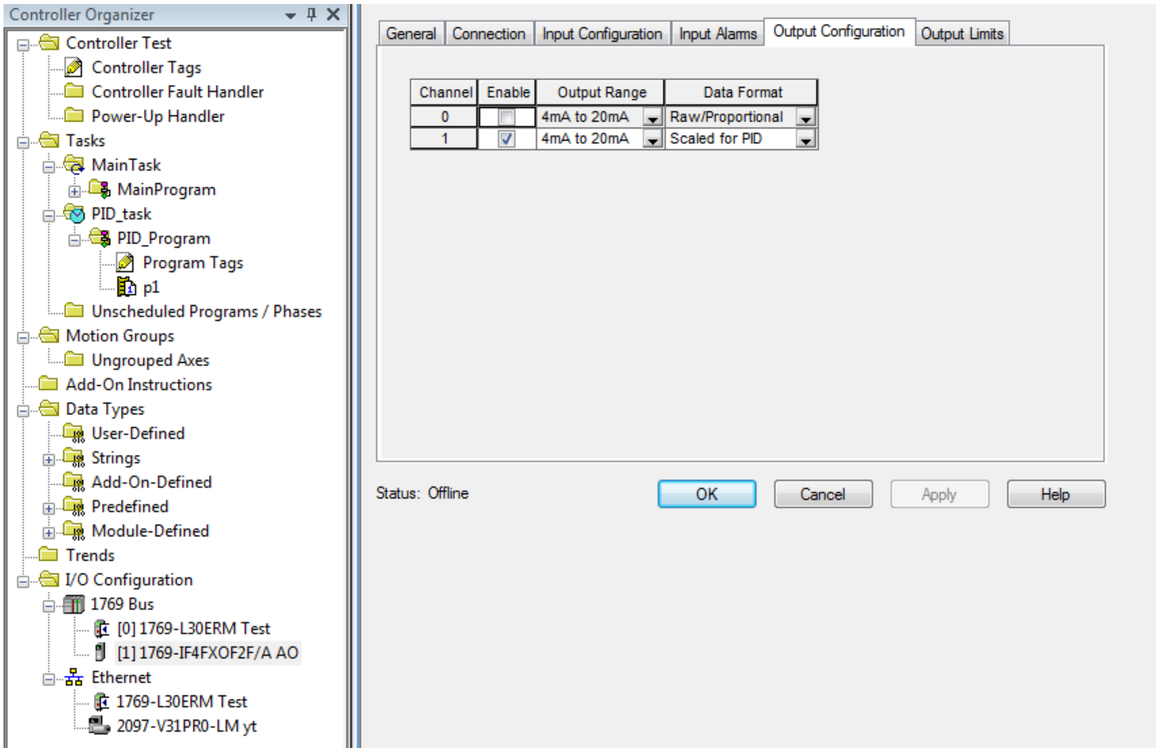


Fig. 10-20 1769-IF4FXOF2F/A Configuration



With this configuration, all analog points are read to and from the card in the range 0-16383 for a 4-20 mA signal. This gives an engineering range that can easily be scaled to any floating point number inside the PLC program.

Troubleshooting/Diagnostics

While both Allen-Bradley and Siemens have extensive diagnostics built into the software accompanying their plcs, the following description of diagnostics software will mainly focus on Siemens TIA software. The extent of this software is extensive and will be discussed here to an extent but will be needed by the software engineer more in the start-up phase of a project than in the classroom environment. Know that it exists and that you will at some future time need extensive portions of it to debug some difficult problems.

Test and online functions are introduced that you can test with the TIA_ Portal project 'Startup' in module M1, for example:

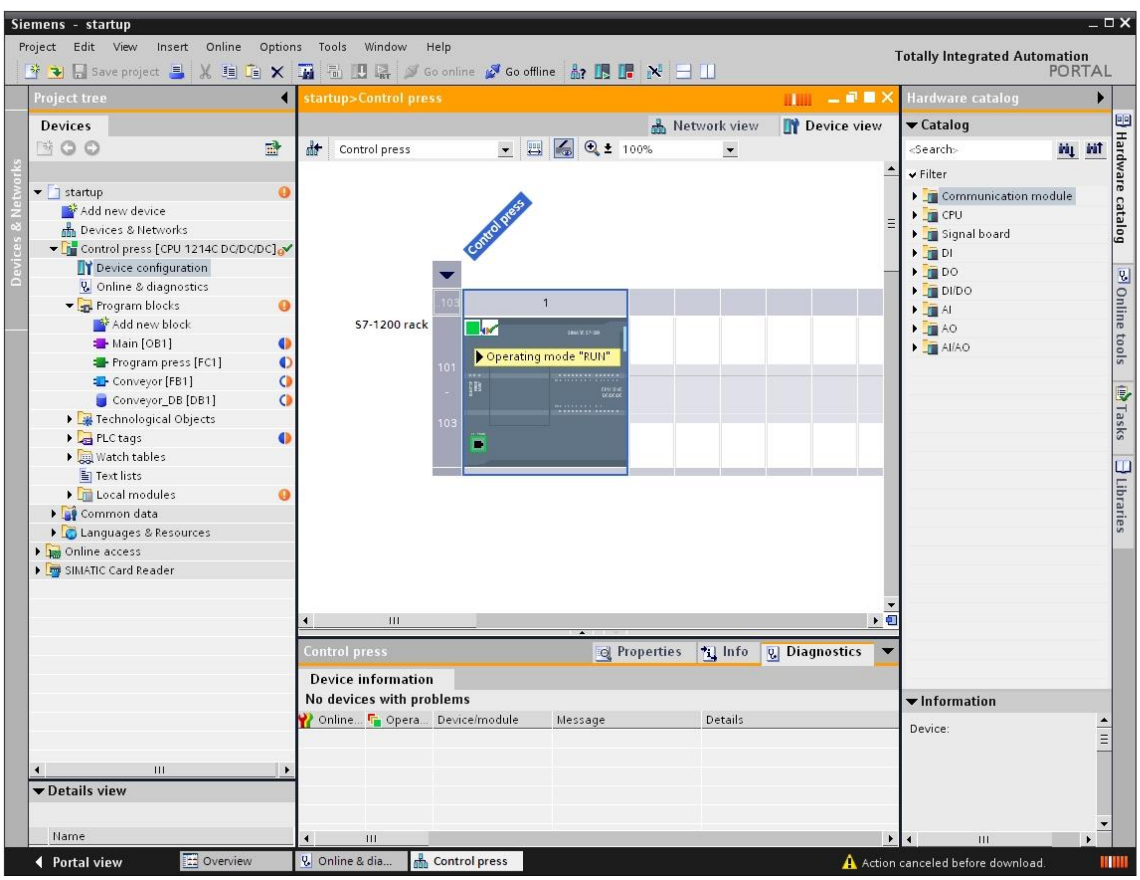
Next, select the **'PG/PC interface for online access'** and then click on **'Connect online'** (→ PG/PC interface for online access → Connect online)

Once we are connected to the CPU online, we can start and stop the CPU with the following buttons .

In project navigation, references regarding the diagnosis are already provided symbolically.

Device Diagnosis

If we open the 'Device configuration', under 'Diagnosis' we are informed about the status of the individual components (→ Device configuration → Diagnosis)



You can view details about the CPU if you click on it with the right mouse key, and then select **Online & Diagnosis** (→ Online & Diagnosis)

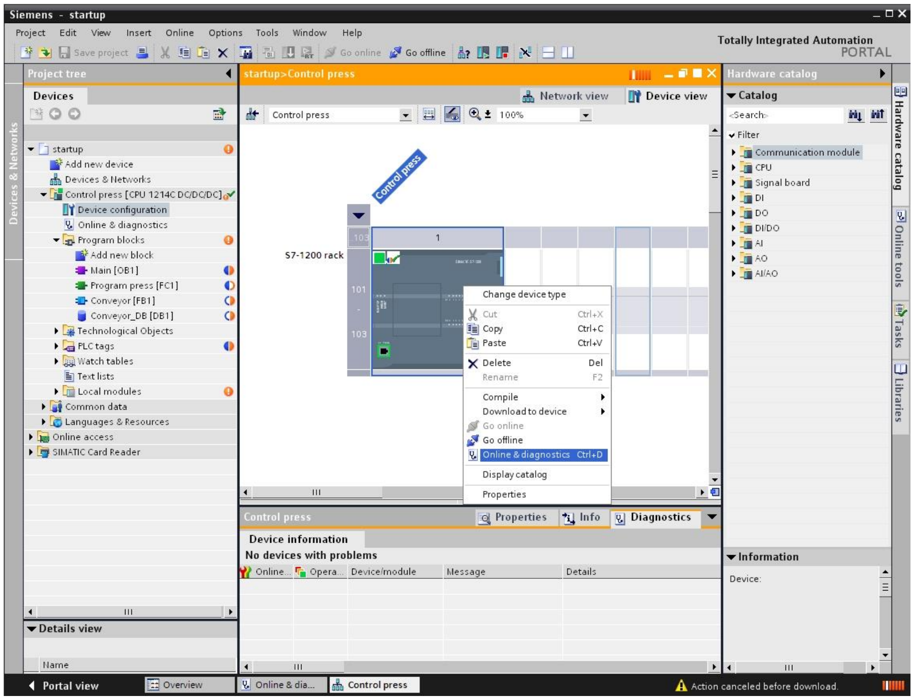


Fig. 10-21 CPU Status

On the right side, the following is displayed: an operator panel for the CPU, the cycle time and the memory capacity.

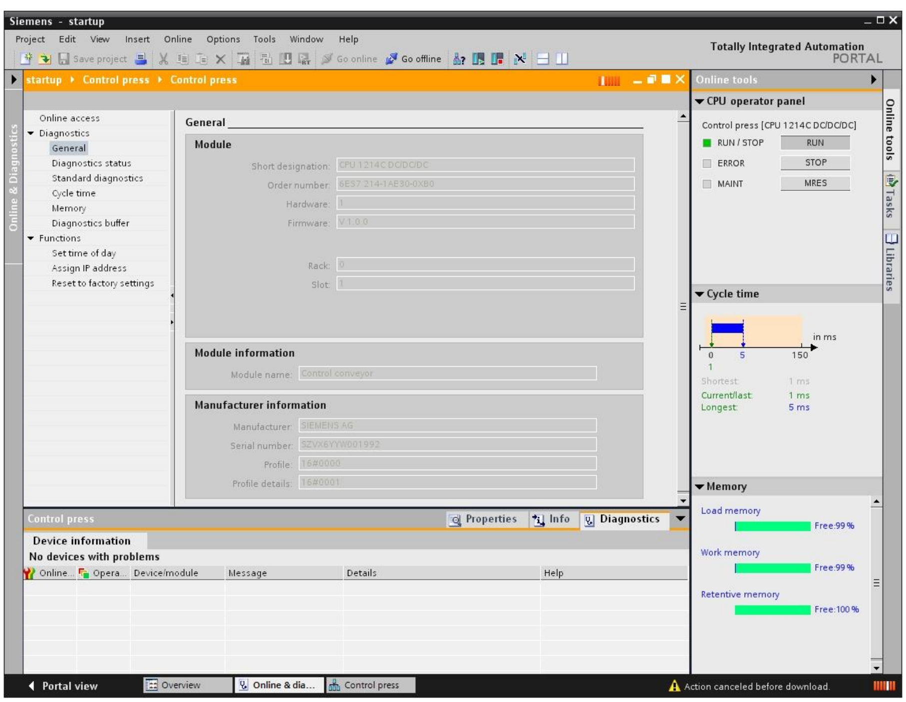


Fig. 10-22 CPU Status

General information about the CPU is available (→ General)

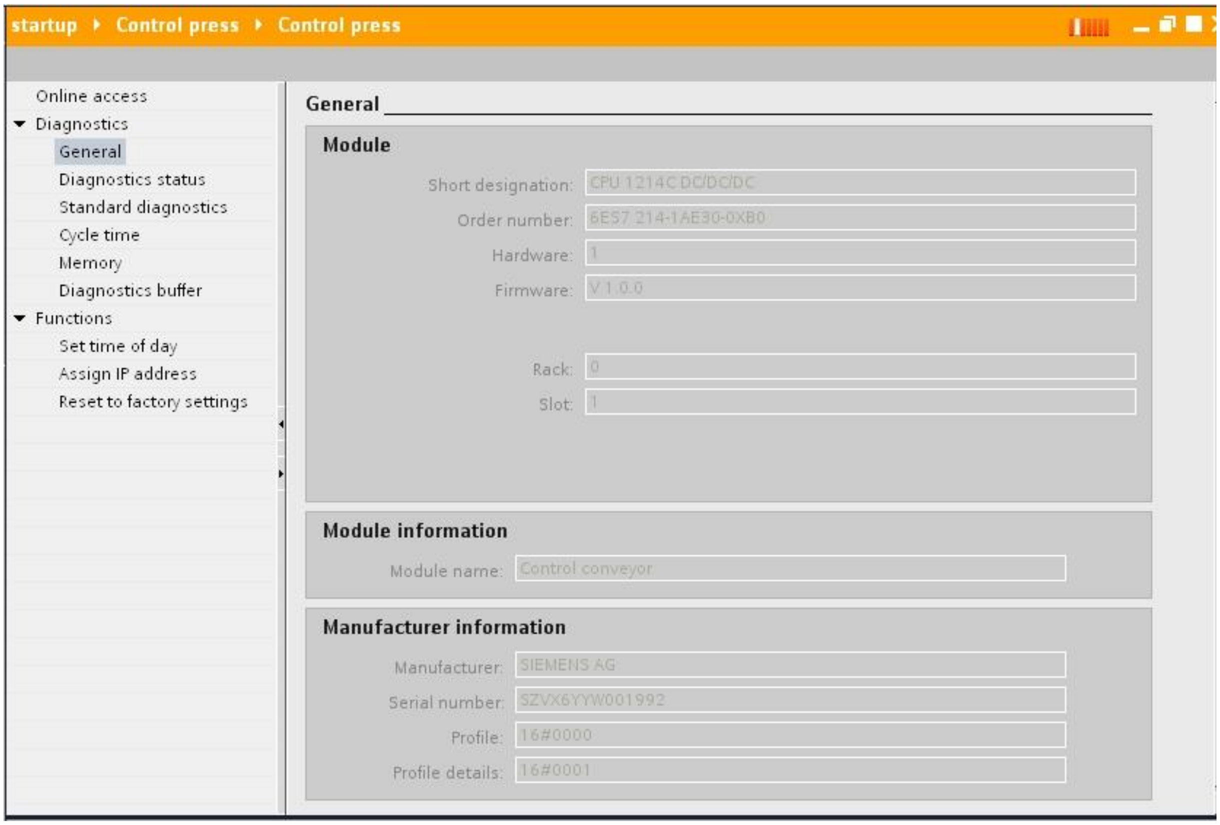


Fig. 10-23 CPU Status

If there is information regarding the diagnosis, it is displayed in the diagnosis status and in the standard diagnosis (→ Diagnosis status → Standard diagnosis)

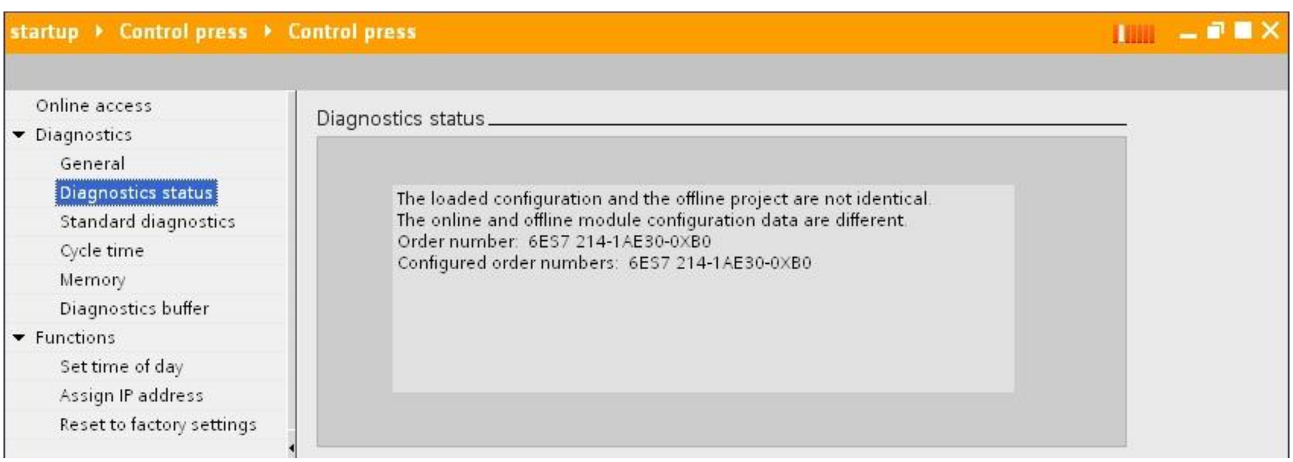


Fig. 10-24 CPU Status

In addition, information is provided about the cycle time of the processed program (→ Cycle time)

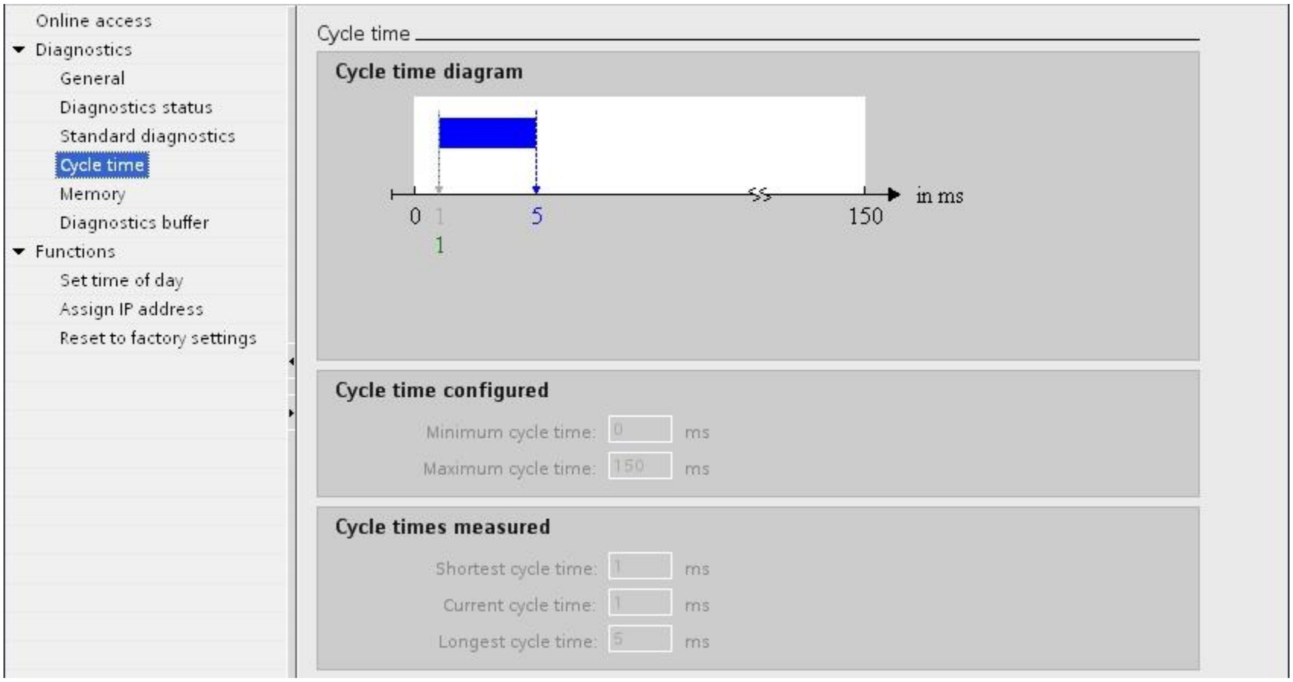


Fig. 10-25 CPU Cycle Time

Here, memory capacity is provided in detail (→ Memory)

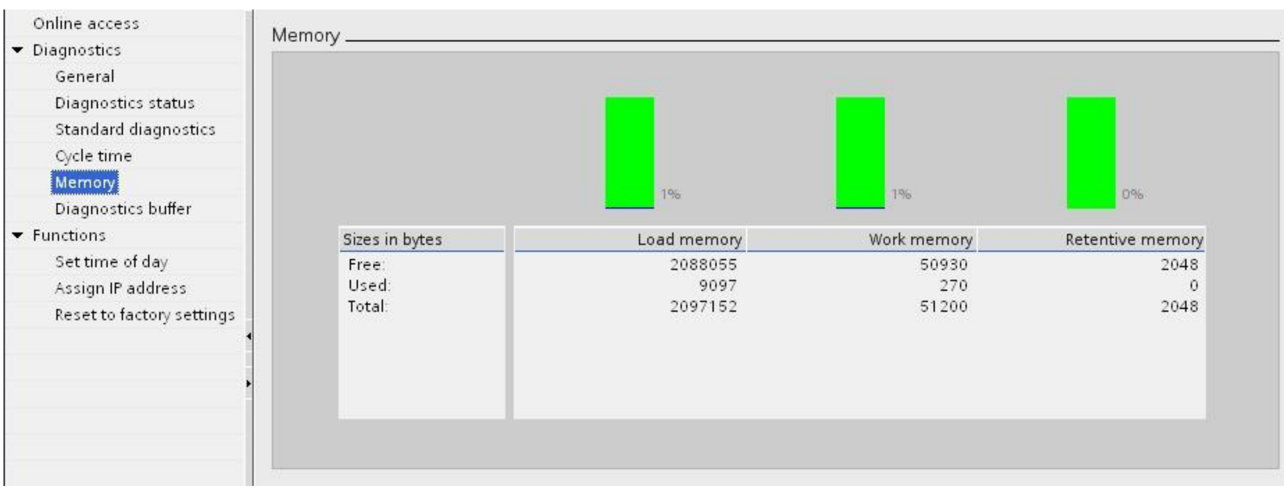


Fig. 10-26 CPU Memory Usage

The most important aid for error diagnosis is the diagnosis buffer (→ Diagnosis buffer)

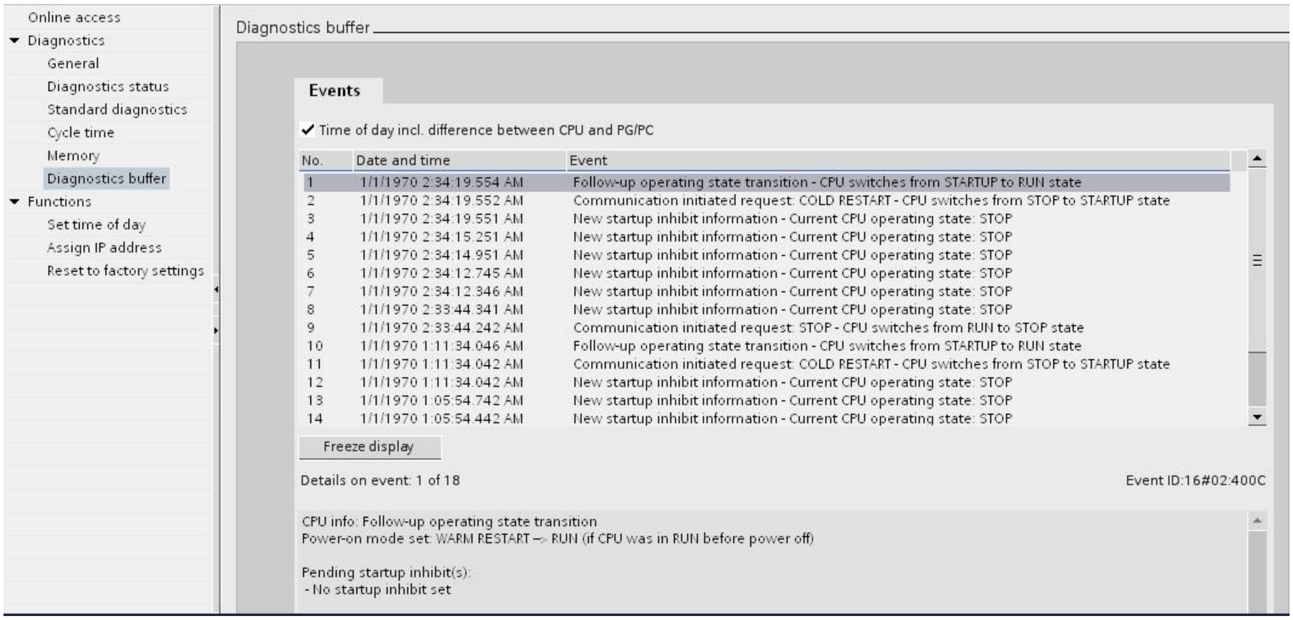


Fig. 10-27 Diagnostics Buffer

You can set the time under Functions (→ Functions → Set clock time)

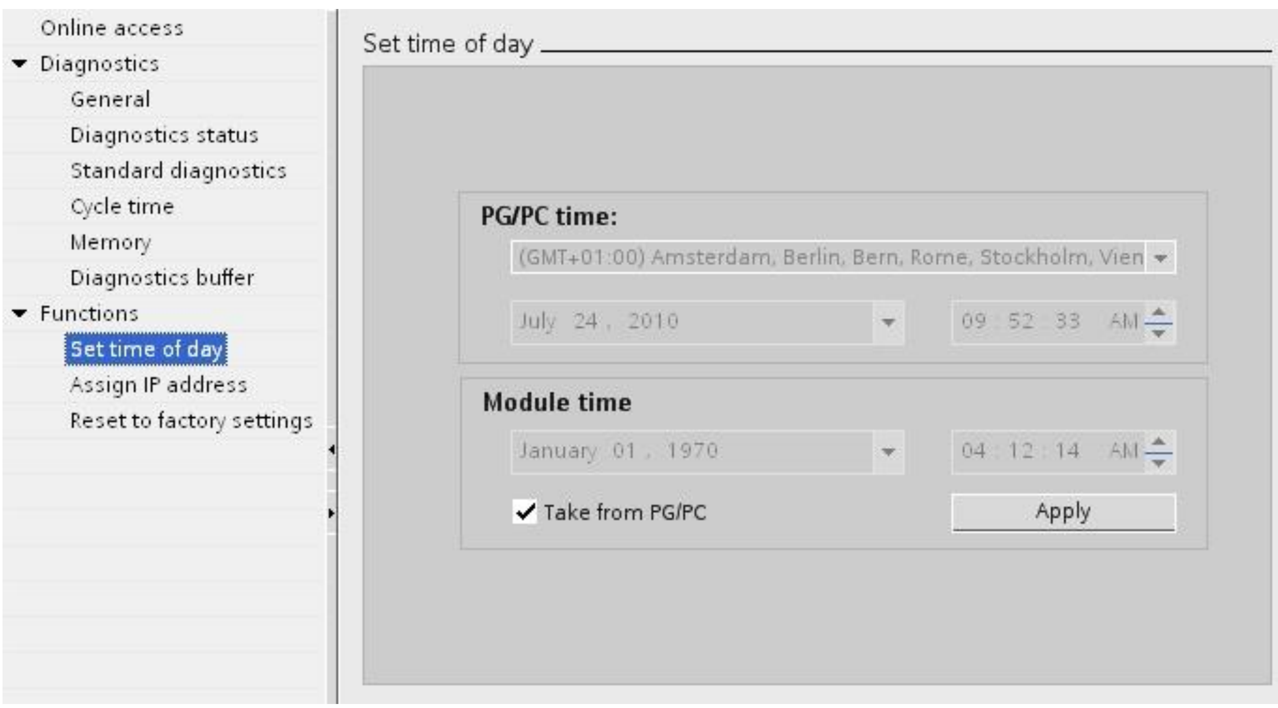


Fig. 10-28 Setting the Time of Day Clock

Also, the IP address can be assigned here (→ Assign IP address)

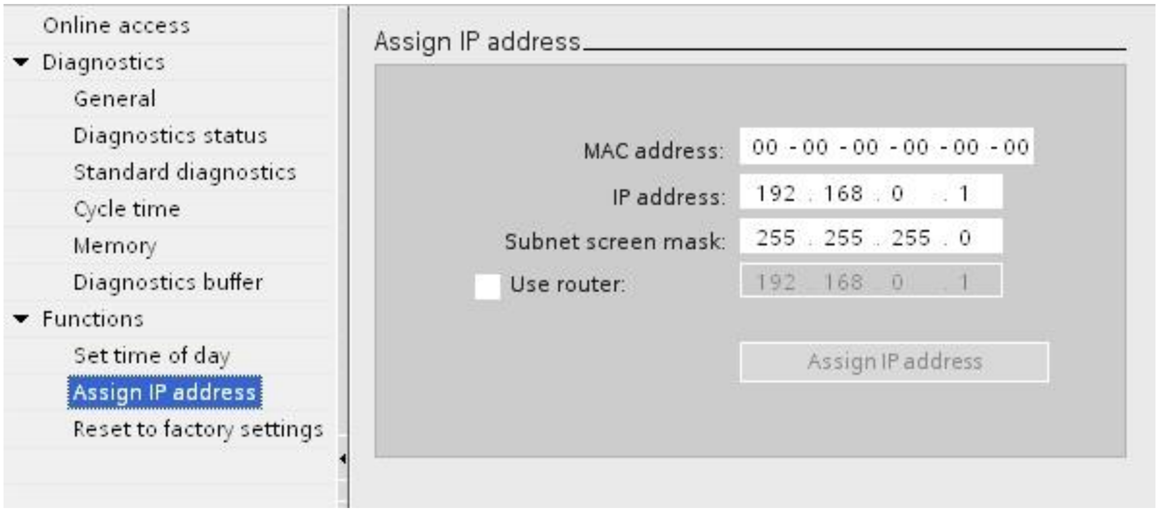


Fig. 10-29 Assigning an IP Address

Here, we can also perform a reset to the factory setting (→ Reset to factory setting)

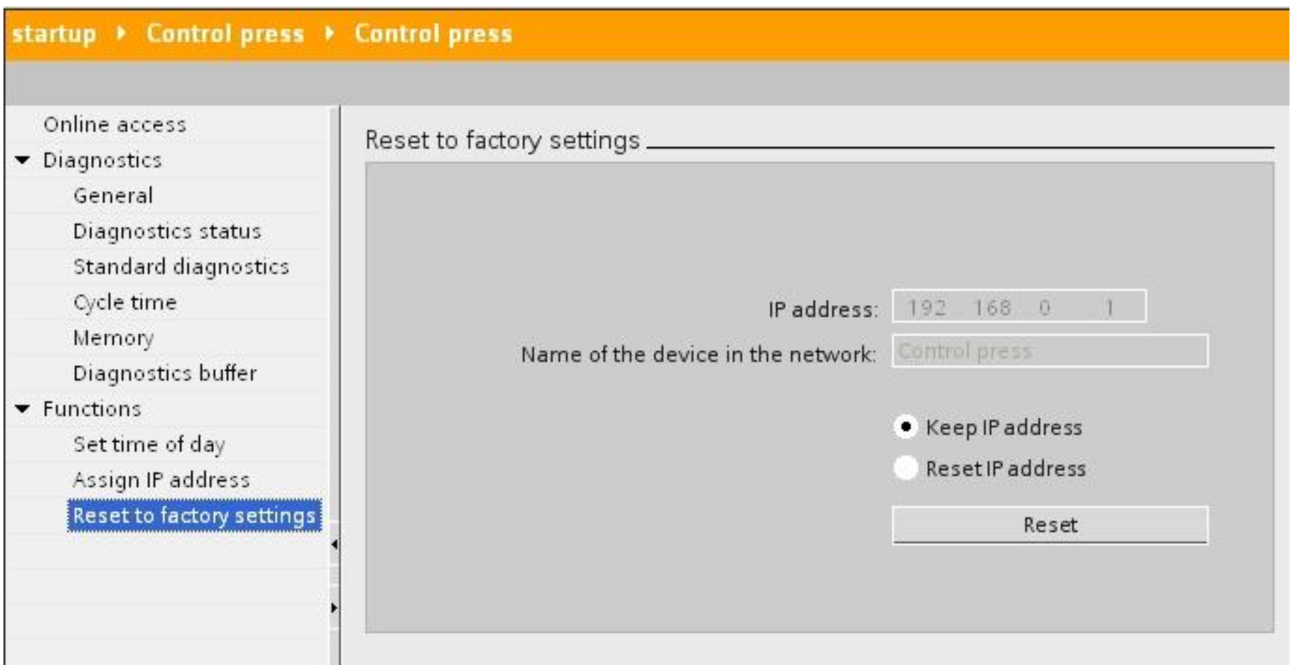


Fig. 10-30 Factor Reset of IP Address

Offline/Online Comparison

Often it is important to know whether the stored data matches the data loaded into the controller. To make the comparison, first select 'Controller Press' and then 'Compare Offline/Online' (→ Controller Press → Compare Offline/Online)

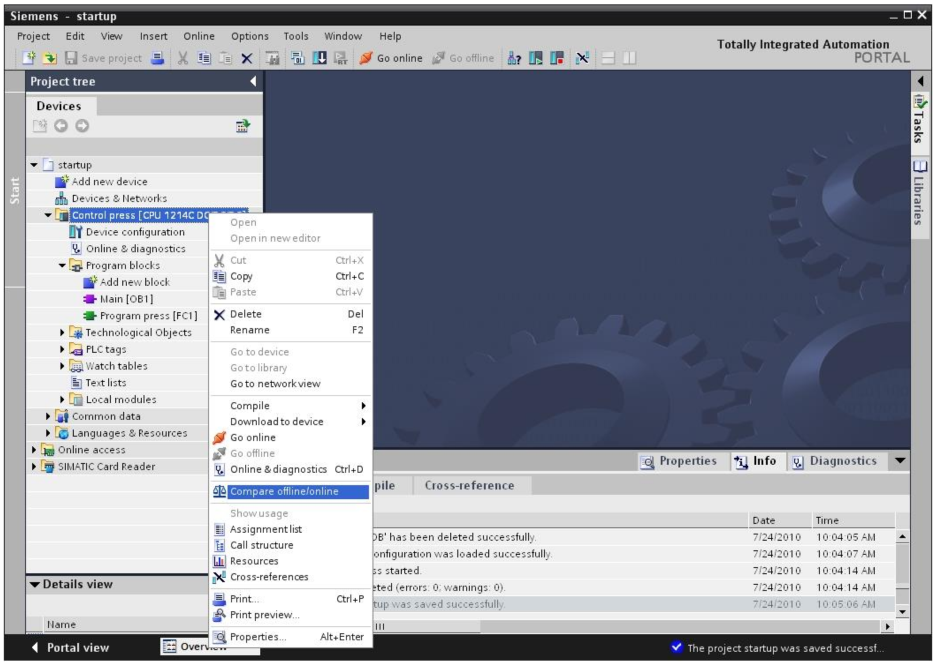


Fig. 10-31 Compare Online/Offline

If block differences are displayed , you can **’Start detailed comparison** (→ Program Press → Start detailed comparison)

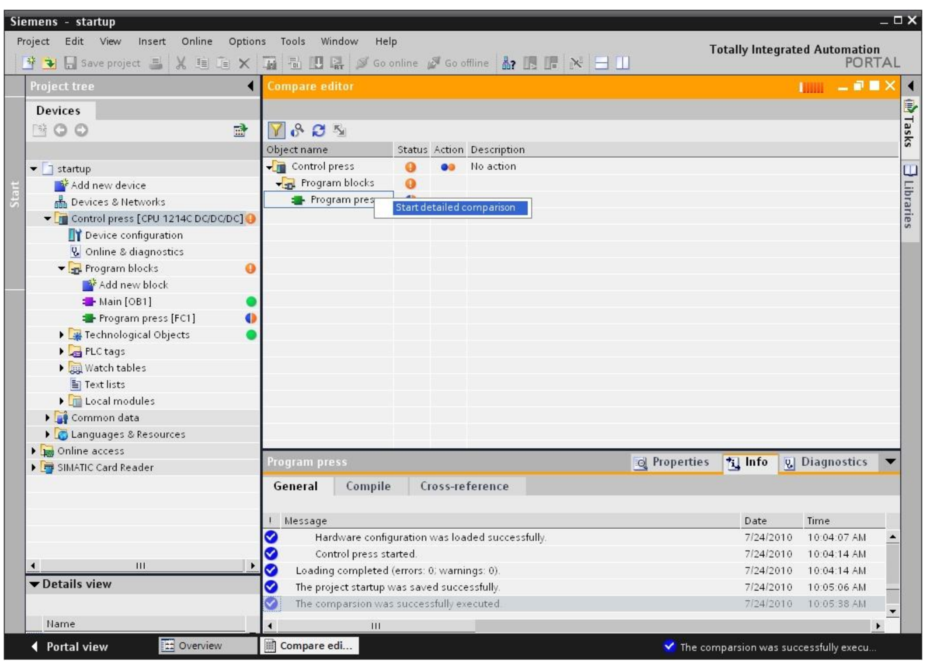


Fig. 10-32 Detailed Comparison

The block is displayed online and offline and references to differences are highlighted (→ Comparison result)

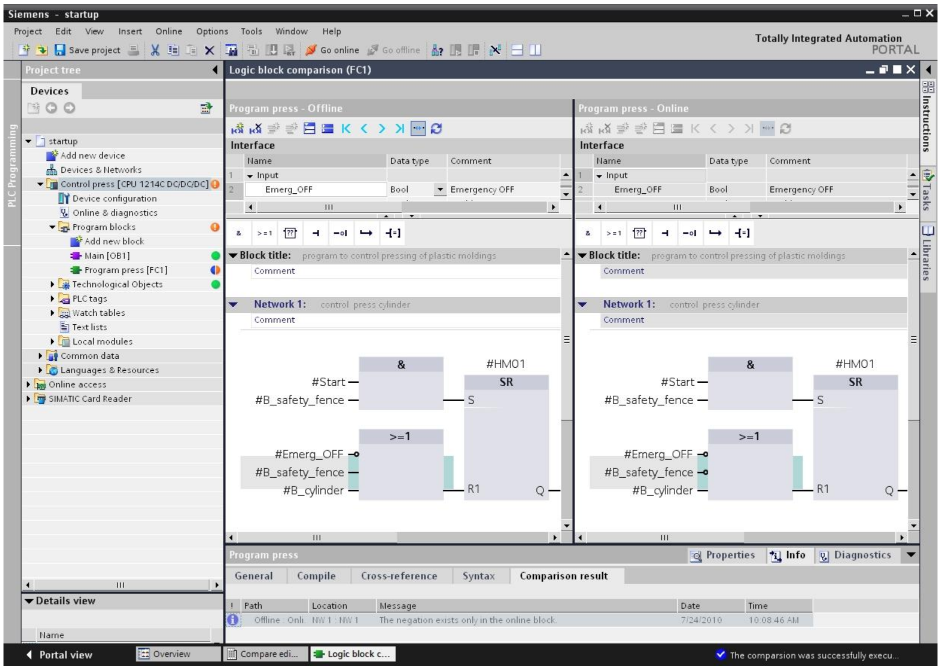


Fig. 10-33   Online/Offline Compare

While Allen-Bradley troubleshooting techniques are not discussed in this section, many similar methods exist within RSLogix 5000 to accomplish a similar set of tasks. The need to duplicate the entire list is not needed. Suffice it to say that A-B can accomplish the same task with a similar set of steps to those of Siemens.

Diagnostics Programs - First-Out Detectors

What happens when an input in a string of inputs turns off and the operator is potentially confused as to which input is at fault. A first-out system of fault detectors is used to detect the fault.
Occasionally, a second fault must be captured as well as the initial fault. The second output to turn on requires one-shot leading edge information and the fact that the first fault has occurred.

Faults are programmed as part of a larger diagnostic program that is added after the program is running the process. Fault display programs are found at the end of other large programs or in separate files. Fault programs are integral to the process while the diagnostic programs are traditionally not. Care must be taken to plan the development of the diagnostic program in such a way so that as the control program is changed, the diagnostic program is easily changed. One of the greatest complaints of ladder logic is that when a change is made in one area, chances are great that other parts of the program are being affected as well, but no one knows really how until the program is exercised in a real-time environment.

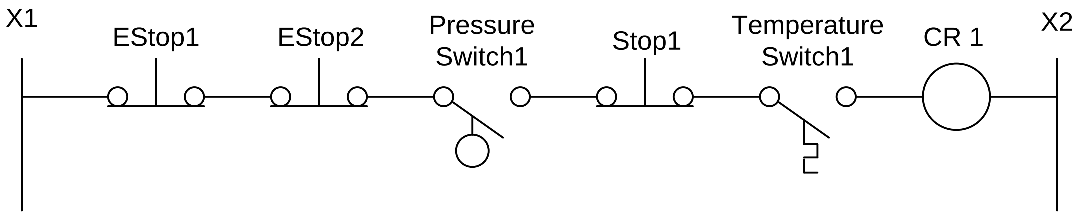


Fig. 10-34 Permissive String

To add a diagnostics program to this permissive string, either the programmer must wire to one or more of the input nodes or provide a second contact for each of the input devices. While considerably more wire may be used with the second approach, it is preferred since the two circuits are isolated. If the sequence of failure is important after the initial contact turns off, then the second approach must be used.

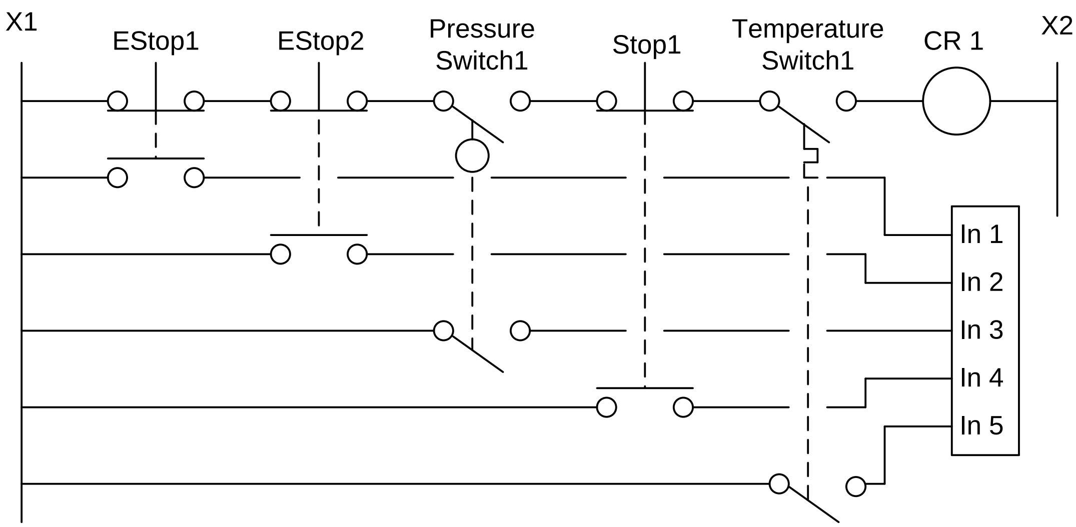


Fig. 10-35 Diagnostics Wiring of Permissive String

Use of Solid State Permissive Strings

Solid-state devices may be used in permissive strings but with some reservations. For example, there are two-wire proximity switches that directly replace limit switches. However, if used in a series of devices, they take a short time (usually 100 msec) to warm up after sensing power. Their response is therefore not immediate.

A symbol for the proximity switch is:

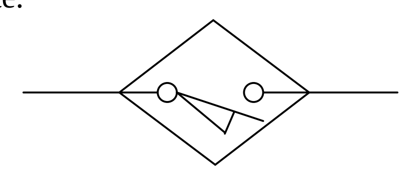
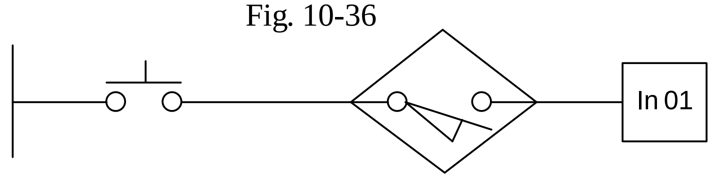


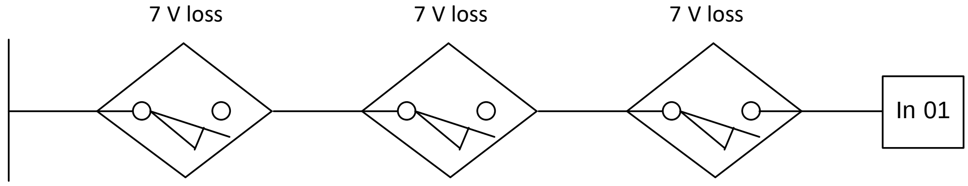
Fig. 10-36

Care must be taken to ensure that the following circuit will not cause unwanted results. The prox switch will take about 100 ms to warm up after the button is pushed. Then it will be able to turn on to report presence of a part.



Also, since these devices "borrow" some voltage from the source voltage to operate, the inclusion of more than two or three of these devices may drop the sense voltage at the PLC to an unacceptably low level.

Fig. 10-37



Total of 21 V loss may be too much to allow In 01 to turn on if VAC = 110 and turn -on voltage = 90 V.

If both selector switch positions are wired to PLC inputs, one input is energized when HIGH is energized and the other is energized when LOW is energized. Both positions are rarely needed. The circuit below is an example using both switch positions as PLC inputs.

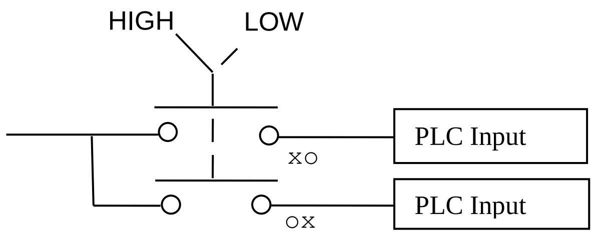


Fig. 10-38

However, if both positions are wired to independent limit switches which indicate a valve's position, then both positions are used. For instance, one limit switch shows the valve position fully open and the other shows the valve fully closed. There is a third position when both limit switches are off and the valve is moving between the end-of-travel positions. A fourth position may also be programmed with both inputs on. This position is an obvious error since both positions cannot be achieved at the same time.

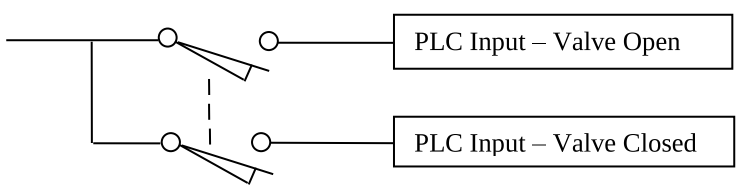


Fig. 10-39

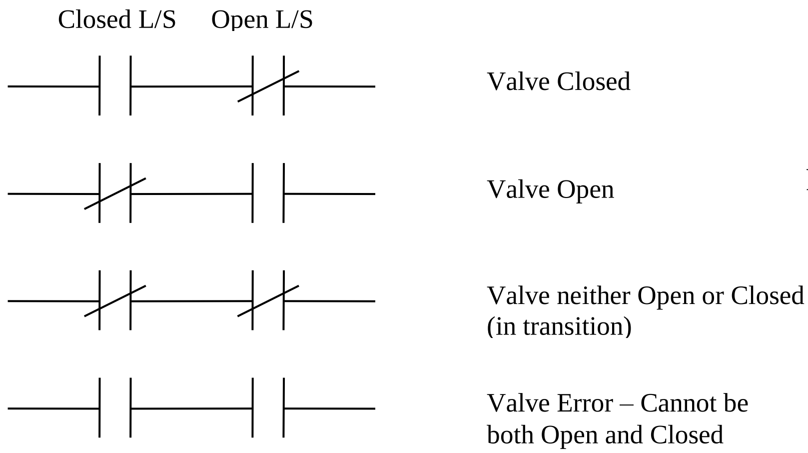


Fig. 10-40

The only error condition is when both valves report as closed. This is impossible since the valve cannot show both open and closed at the same time. Notice both switch positions are used in each evaluation. In general, if inputs are available, they are to be used. Before PLCs became popular, wired logic devices usually did not include both switch positions in switched logic. The PLC makes the task easier to include all available switch positions in logic to determine actual switch positions. Less wiring is involved with the PLC since all logic is included in the program.

This example is one of a group of diagnostics problems first mentioned in Chapter 5 and reviewed here:

Diagnostics and Error Handling

Diagnostics and error handling may be programmed in conjunction with the logic controlling the action of the process. For example, the level can never be above the high level switch but not at the middle level. This is not possible. But, the switches in fact may be in this position. The programmer may choose to add this logic to the control program and if a failure occurs, shut down other control logic.

Error monitoring methods can be categorized. Two main categories of diagnostic monitoring are:

Pair Monitoring
Time Monitoring

Pair monitoring has to do with combinations that are impossible to naturally occur but should be monitored. Time monitoring gives the process enough time for an action to occur and then shut off. The period of time should exceed any normal time for a particular action but should not be so long that a great deal of damage could occur. Judgment should be used for these times.

For the process above, the following table lists several diagnostic examples:

Fault Indicator	Realization of Monitoring	Monitoring Category	Possible Faults
Level above high but not at middle level	Logic statement for:	Pair Monitoring	Broken wire at middle level, hanging sensor at high level
Fill valve V1 too long open	Timer	Time Monitoring	Broken wire at V1, V1 damaged, High level fault No juice
Temp too long below 80	Timer	Time Monitoring	Heater fault, Wire fault
Temp too long above 80	Timer	Time Monitoring	Wire fault, welded contacts on heater relay

Table Types of Diagnostics

Other Stuff

The following is a scan-dependent program and placement of the logic is critical for outcome of the logic:

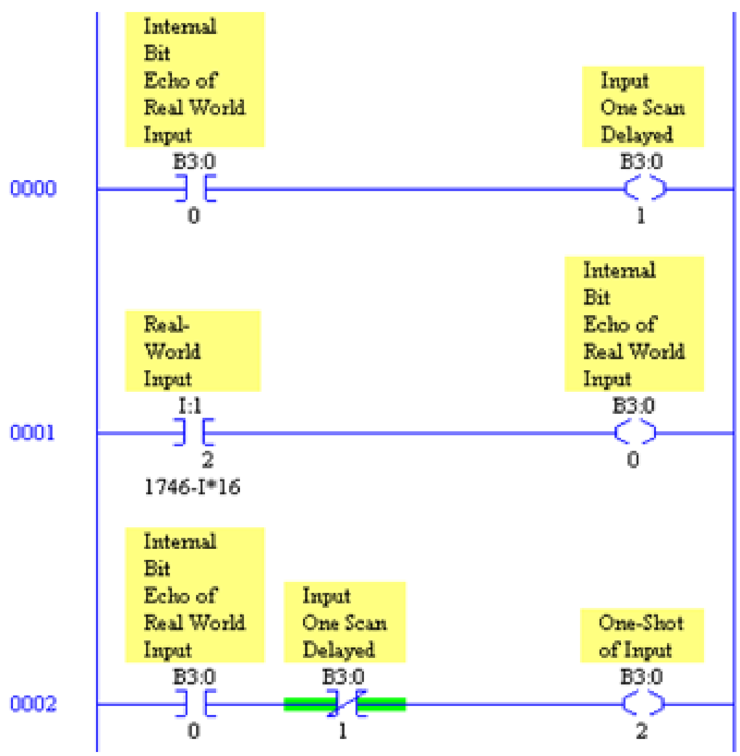
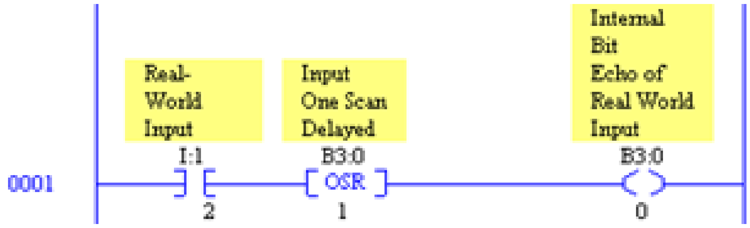


Fig. 10-41
One Shot Created without using OSR Instruction

When the input I:1/2 is energized, B3:0/0 is set. Notice, however, that it is not the first of the three rungs. The first rung in the sequence is the rung that follows the second rung by one scan. The one-shot B3:0/2 is created by use of the input and the **not** of the delayed input to create a bit for use as a one-shot. The modern equivalent of this circuit using the OSR instruction is:



Many times, scan-dependent programs use a chart to describe the actions of the various bits and the sequential functions as they happen. See the table below for the scan-to-scan results of Input I:2/1 turning on and for each of the coils: B3:0/0, B3:01 and B3:0/2.

	Scan 1	Scan 2	Scan 3	Scan 4	
B3:0/0	0	1	1	1	
B3:0/1	0	0	1	1	
B3:0/2	0	1	0	0	Signifies One Shot
I:2/1	0	1	1	1	

So, the one-shot can be built from logic without the [OSR] function. Don't sell your stock in [OSR]'s yet, however. Use them instead of the code above. Simply put, it is best to use the instruction for establishing a particular function than by creating that function through other means.

Use of scan-dependent code is necessary at times to accomplish a function or step from state in a program. To save a variable in a particular mode so that the variable may be used when the mode is turned off is a useful tool and is used in many programs.
Consider the one-shot's memory bit:

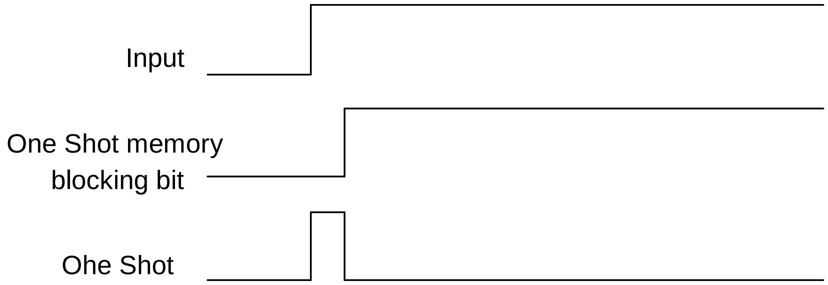


Fig. 10-42

While it is usually believed that the blocking bit is only useful as a memory bit to remember the last scan status of an input, it may also be used in logic. A characteristic of a one-shot is that it has fixed duration (one scan long) and then turns off. It is possible to have one-shots designed from the one-shot delayed memory bit. Signals can be chained together to create a number of one-shots.

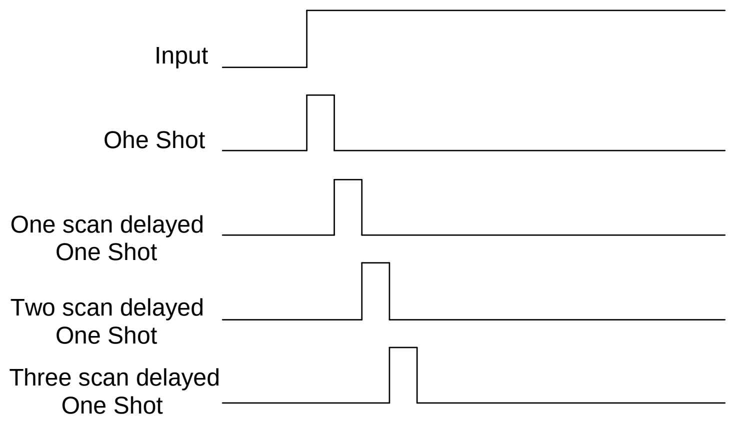


Fig. 10-43

A second example:

Create a small program that creates 4 one-shots that repeat as follows:

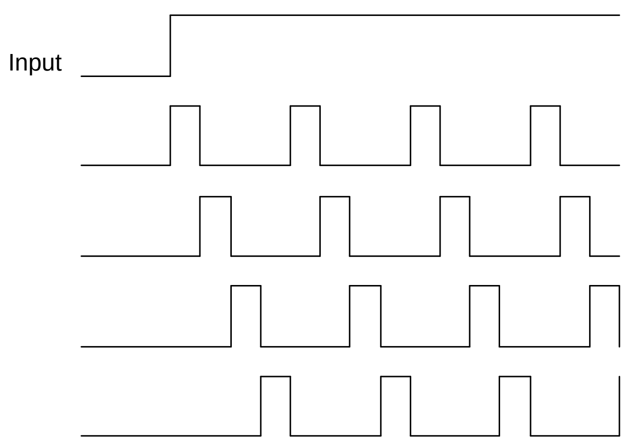


Fig. 10-44

Especially with the second example, try to create the repeating pattern using logic that climbs the ladder as opposed to logic using the OSR command. It will probably be easier to accomplish using this technique. This example will be left as an exercise to fill in the bits of the timing diagram.

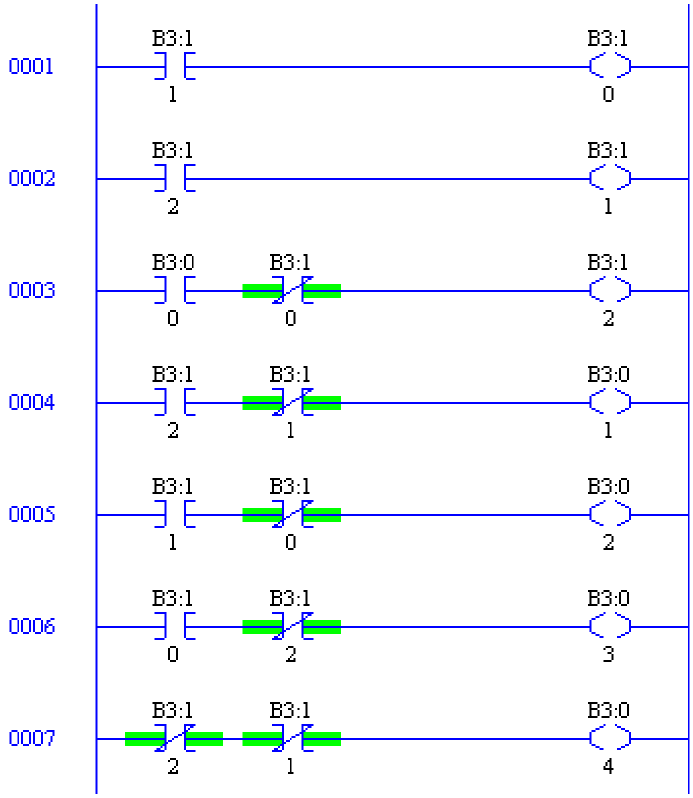


Fig. 10-45

The circuit above is similar to the ring counter or Johnson counter used in digital logic to control multi-step logic that repeats. Review a digital text for circuits that provide the logic for the ring or Johnson counter and compare them to the logic above. PLC logic is usually easier to implement than digital logic although the applications tend to differ and one would not use a ladder logic program when designing a piece of digital equipment for commercial use. The cost of the PLC would tend to be prohibitive.

Various types of automation are discussed in the following videos from RealPars:

What is Automation

What is Discrete Automation

What is Analog Automation

Also, see RealPars videos on:

photo-eyes

proximity switches

intrinsic safety

laser sensors

interlocks

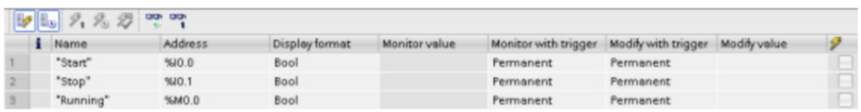
what really happens inside an industrial boiler.

More Diagnostics from the Siemens Easy Manual "

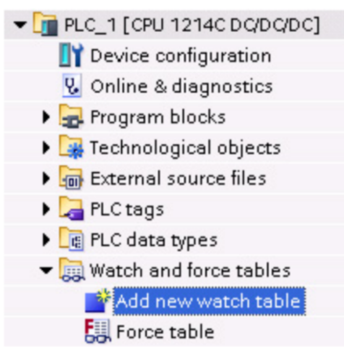
11.5 Using a watch table for monitoring the CPU

A watch table allows you to monitor or modify data points while the CPU executes your user program. These data points can be inputs (I), outputs (Q), M memory, a DB, or peripheral inputs (such as "On:P" or "I 3.4:P"). You cannot accurately monitor the physical outputs (such as Q0.0:P) because the monitor function can only display the last value written from Q memory and does not read the actual value from the physical outputs.

The monitoring function does not change the program sequence. It presents you with information about the program sequence and the data of the program in the CPU. You can also use the "Modify value" function to test the execution of your user program.



	i	Name	Address	Display format	Monitor value	Monitor with trigger	Modify with trigger	Modify value	
1		"Start"	%I0.0	Bool		Permanent	Permanent		
2		"Stop"	%I0.1	Bool		Permanent	Permanent		
3		"Running"	%M0.0	Bool		Permanent	Permanent		



To create a watch table:

1. Double-click "Add new watch table" to open a new watch table.
2. Enter the tag name to add a tag to the watch table.

To monitor the tags, you must have an online connection to the CPU. The following options are available for modifying tags:

- "Modify now" immediately changes the value for the selected addresses for one scan cycle.
- "Modify with trigger" changes the values for the selected addresses.

  This function does not provide feedback to indicate that the selected addresses were actually modified. If feedback of the change is required, use the "Modify now" function.

- "Enable peripheral outputs" allows you to turn on the peripheral outputs when the CPU is in STOP mode. This feature is useful for testing the wiring of the output modules.

The various functions can be selected using the buttons at the top of a watch table. Enter the tag name to monitor and select a display format from the dropdown selection. With an online connection to the CPU, clicking the "Monitor" button displays the actual value of the data point in the "Monitor value" field.

The following is found also in the same section of the Easy Book and discusses saving data in arrays that was previously loaded online and needing to be saved to the offline program. Explained is the snapshot function:"

11.7 Capturing the online values of a DB to reset the start values

You can capture the current values being monitored in an online CPU to become the start values for a global DB.

- You must have an online connection to the CPU.
- The CPU must be in RUN mode.
- You must have opened the DB in STEP 7.

Use the "Show a snapshot of the monitored values" button to capture the current values of the selected tags in the DB. You can then copy these values into the "Start value" column of the DB.

1. In the DB editor, click the "Monitor all tags" button. The "Monitor value" column displays the current data values.
2. Click the "Show a snapshot of the monitored values" button to display the current values in the "Snapshot" column.
3. Click the "Monitor all" button to stop monitoring the data in the CPU.
4. Copy a value in the "Snapshot" column for a tag.
   - Select a value to be copied.
   - Right-click the selected value to display the context menu.
   - Select the "Copy" command.
5. Paste the copied value into the corresponding "Start value" column for the tag. (Right-click the cell and select "Paste" from the context menu.)
6. Save the project to configure the copied values as the new start values for the DB.
7. Compile and download the DB to the CPU. The DB uses the new start values after the CPU goes to RUN mode.

Note

The values that are shown in the "Monitor value" column are always copied from the CPU. STEP 7 does not check whether all values come from the same scan cycle of the CPU.

"

Other sections of Ch. 11 of the Easy Book explain other important diagnostic helps features. They should be reviewed as needed.

Summary

In this chapter, there were a number of topics explored including sensors and sensor selection. Sensor selection can be very much a part of the control engineer’s job, especially during the start-up of a system incorporating sensors. The breadth of this topic is exhaustingly great.

Machine vision systems and RFID and bar-code systems also play in sensor selection. All have a prominent role in automation and automation systems.

Machine safety was also discussed. Standards for machine safety were reviewed. Risk assessment and implementation of functional safety was also discussed.

Intrinsic safety was introduced as a concern and methods for providing intrinsic safety to the explosive environment were discussed.

Analog signal handling was reviewed and program statements to provide signal conditioning were given.

Troubleshooting, diagnostics and diagnostic programming were also topics discussed in the chapter.

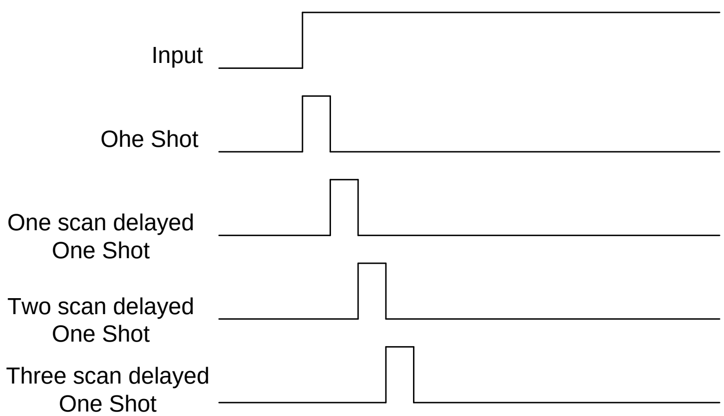
Whew!

Exercises

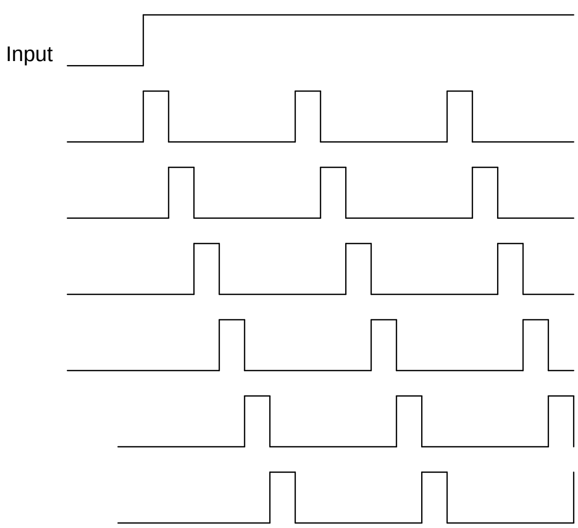
1. When dealing with machinery, continued motion and stopping are at issue. With a continuous process, stopping and _________ are at issue. Failsafe deals with _________ while fault tolerant deals with _________ _________.

2. "Good for detecting clear materials in close spaces
Good in detecting shiny objects or vibrating objects":
Name the type of photo-eye that has these characteristics:

3. Using both Siemens and A-B Ladder, write the program that will produce the following:



4. Using both Siemens and A-B Ladder, write the program that will produce the following:



What is this called?

5. The two pictures below may be labeled either **Fail Safe** or **Fault Tolerant**. Write in the appropriate response in the two boxes below.

Machinery

Continuous Process

6. Write the code to convert an input that is 0 to 10 V representing a signal 0 to 250 gal/min using both Siemens and A-B input channels.

7. How would one check for validity of the signal or an over-range/valid condition for Siemens? For A-B?

8. From lab 10.3, write the code to calculate calories using the two inputs for voltage and current.

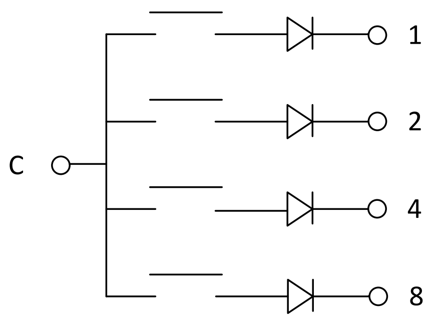
9. From lab 10.1, finish the code for a four-digit tws representing a number from 0-9999 with the diodes pointing to the right (true high representation).

10. Give a simple way to find the average scan time without writing a program.

11. How fast can the program of Lab 10.1 be safely executed?

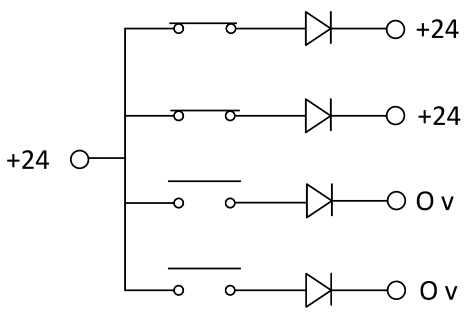
Lab 10.1 Multiplexers

Note: Lab 10.1 requires that code is executed too fast to be viewed on the on-line monitor. Timing diagrams will have to be drawn to successfully complete this lab. The figure below shows the thumbwheel switch as it is supposed to be used. This lab uses the same switch but is wired in the reverse direction due to the direction of the diodes.



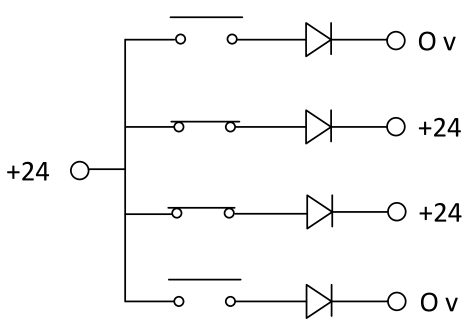
Display =
0000 = 0

The Thumb-Wheel Switch pictured at left shows a thumb-wheel switch as used in industry. The tws has been used in factories to enter numbers into computers and plc's. The switches show the number on the face and give the BCD bits shorted in the switch as the number is entered.



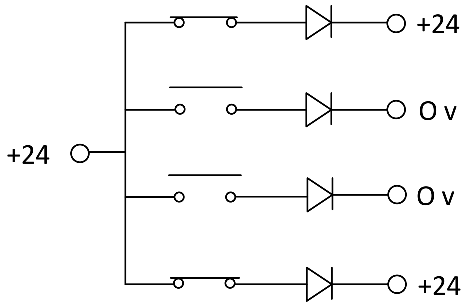
Display =
0011 = 3

For instance, if the number displayed is '3', the bits associated with the 1 bit and the 2 bit are shorted giving 24 V on these pins with 0 v on the 4 and 8 bit pins.



Display =
0110 = 6

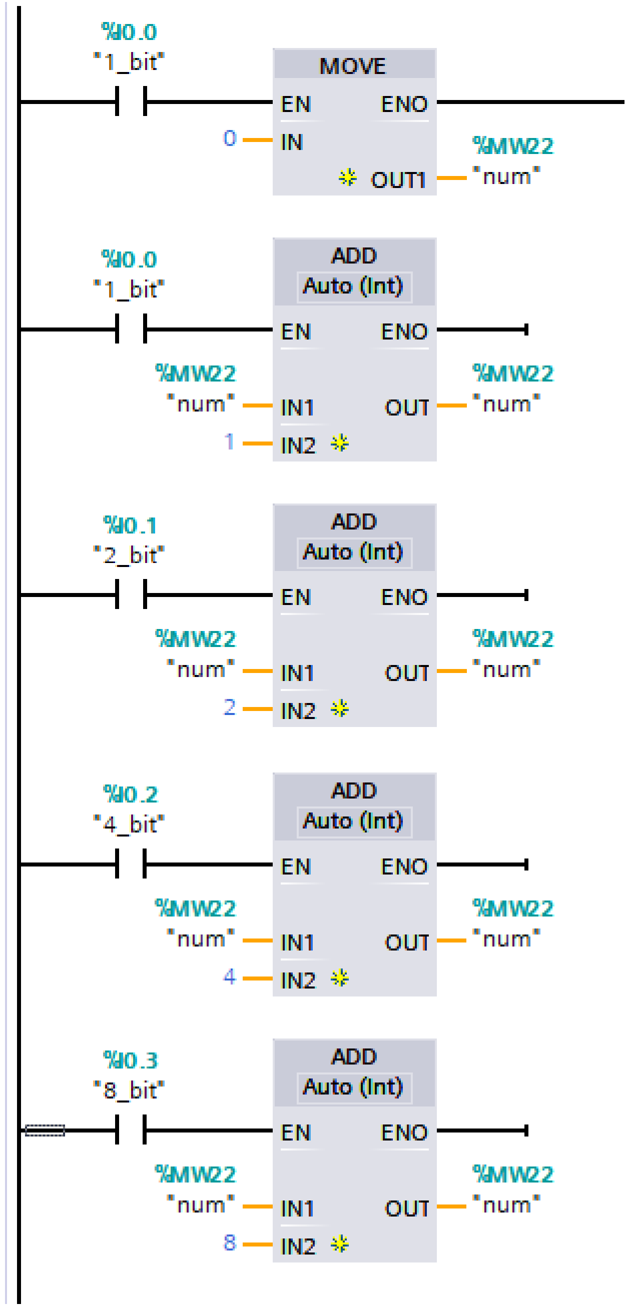
For instance, if the number displayed is '6', the bits associated with the 2 bit and the 4 bit are shorted giving 24 V on these pins with 0 v on the 1 and 8 bit pins.



Display =
1001 = 9

Likewise, if the number displayed is '9', the bits associated with the 1 bit and the 8 bit are shorted giving 24 V on these pins with 0 v on the 2 and 4 bit pins.

For the BCD (Binary Coded Decimal) number above, if the four inputs were connected to the Siemens processor's inputs I0.0, I0.1, I0.2 and I0.3 and the word representing the tws number was stored in the variable 'num', the following program would be generated to move this single digit into the integer number 'num'.



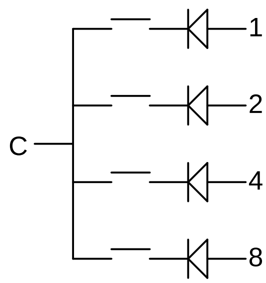
This lab requires the student to use the thumbwheel switches to enter a number from 0 to 9999 into an internal memory location (integer). The number is the one represented on the thumb wheel switches (TWS's) and can be changed. The internal memory location should be updated at least each half second.

With the tws above, we notice the diodes pointing to the right. This is the direction of positive current flow. We notice in the figures below the tws's with diodes shown in the reverse direction. This is due to the idea that tws's can be constructed with the diodes pointing either way. If pointing to the right, the wiring is for true high logic. If to the left, the wiring is for true low logic. However, one can still read the tws in the true low switch using true high logic if the bits are scanned one bit at a time through each tws. This is what is required in this lab assignment.

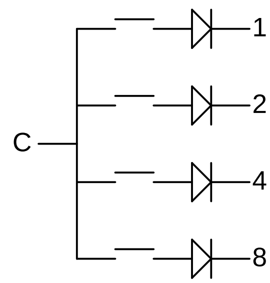
Allow only 4 inputs and 4 outputs to the PLC from the TWS's.

Our TWS's:

To work correctly, the diodes should be reversed as follows: (do not do this, however)

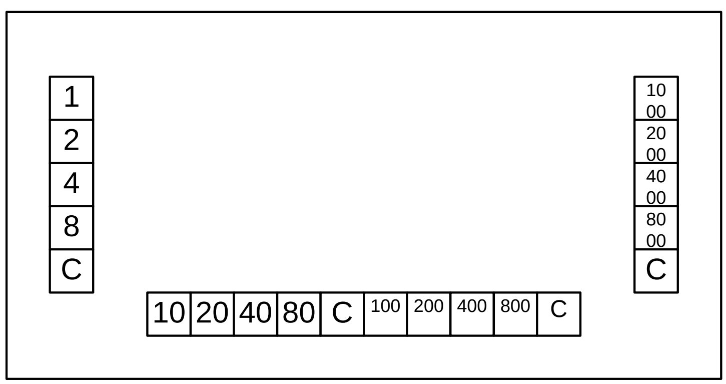


TWS with diodes installed



TWS with diodes reversed

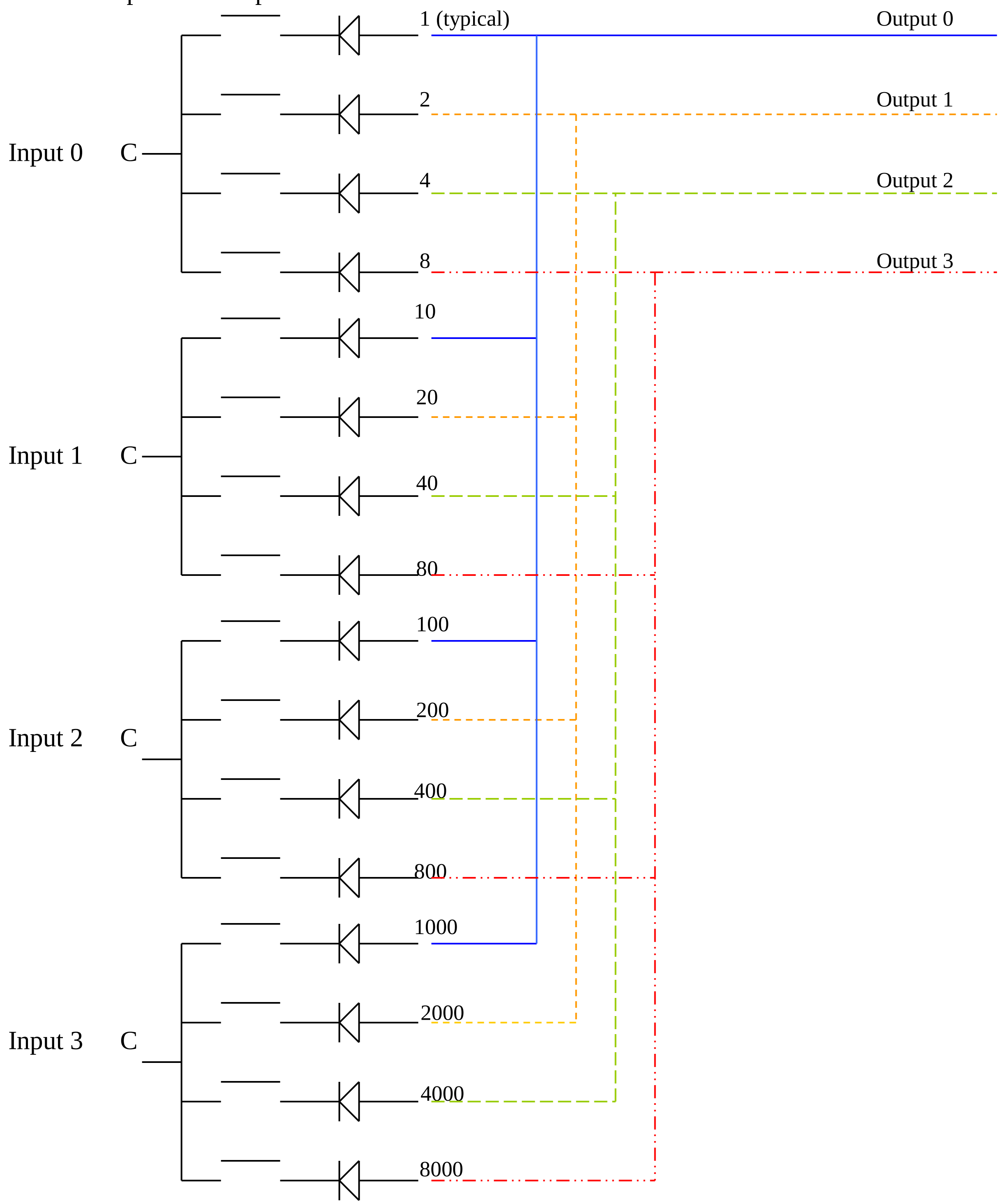
Wiring on the back of the TWS's is as follows:



Wiring Diagram Layout of Thumb Wheel Switches

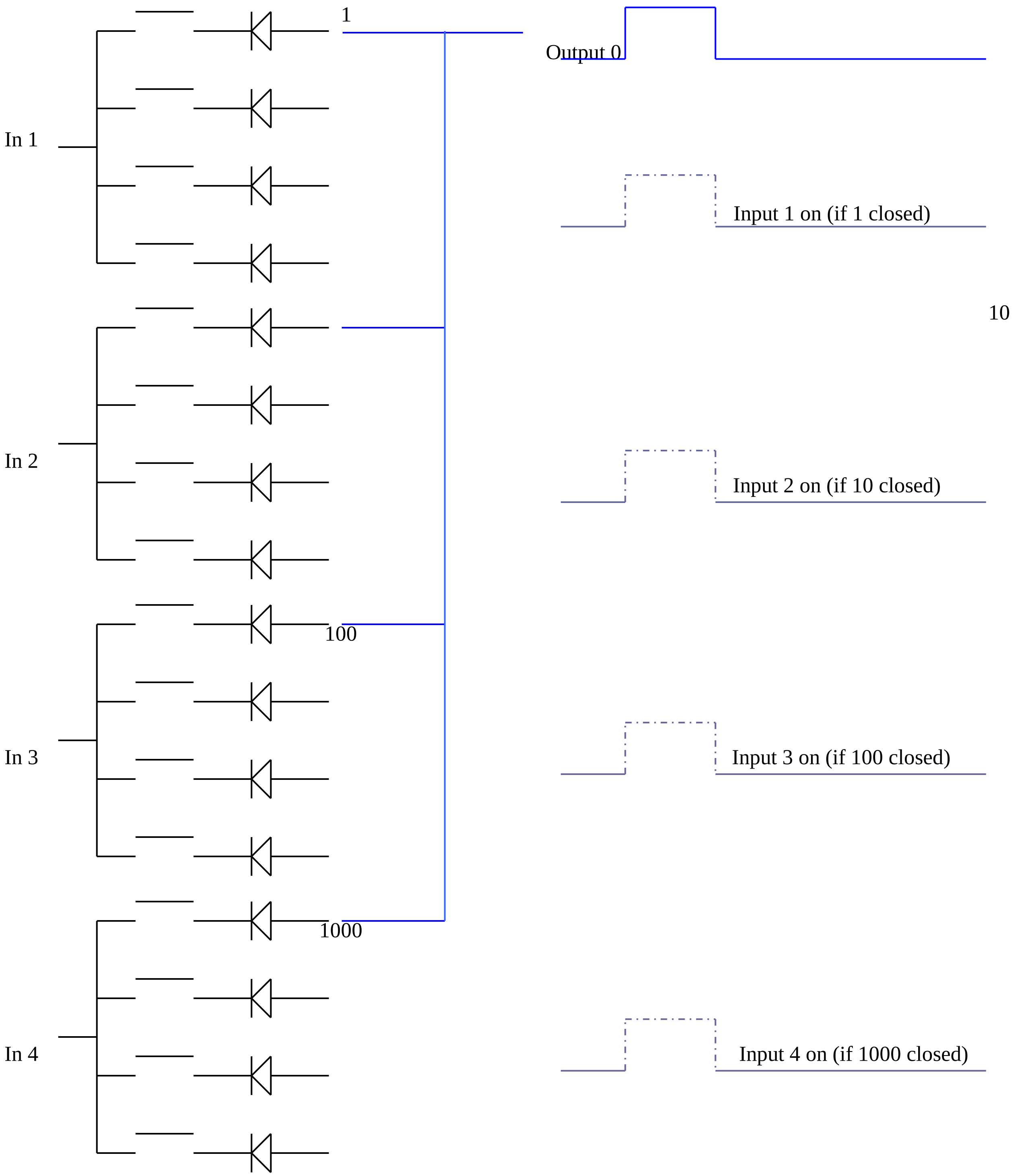
To complete lab 10.1, set up a timing diagram similar to the traffic intersection but with very short time durations. Hint: When reading from outputs through the TWS, tie the 1, 10, 100, and 1000 terminals together and read the result at an input. Four inputs are received, one from each common (C).

Wire the inputs and outputs as follows:



Thumb Wheel Switch Wiring Diagram

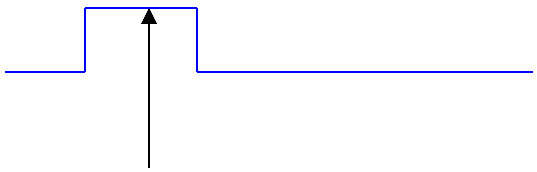
In order to see how the wired circuit and program work, follow as output 0 is turned on:



Thumb Wheel Switch Input Timing Diagram

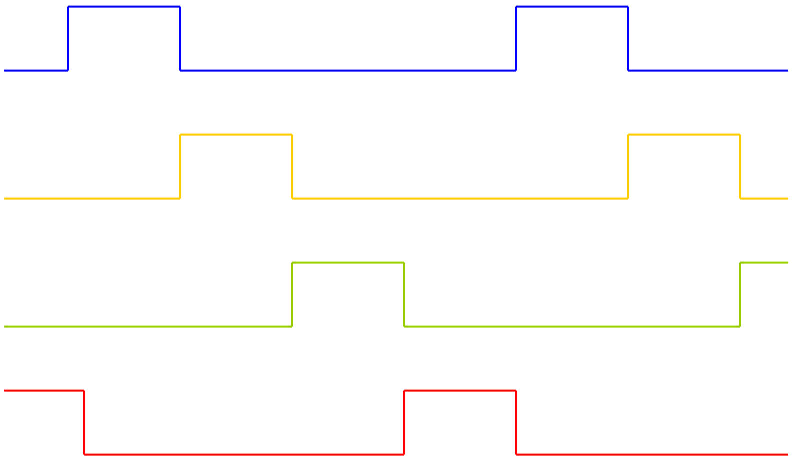
Note that care must be taken to not read inputs 1-4 immediately since the filter time for reading an input is not as quick as the time of a scan. A time delay must be introduced to read the input while the output is on.

Output 0



Read inputs 1-4 sometime after the filter time that is set for the processor. After Output 0 turns on and the inputs are read, output 0 can be turned off and the next input read. It is a good idea to read the inputs using a one-shot.

Repeat the timing chart so that the thumb-wheel switches can be read in as quickly as possible. Use a timing diagram similar to the one used for the traffic intersection but with much quicker times as follows:



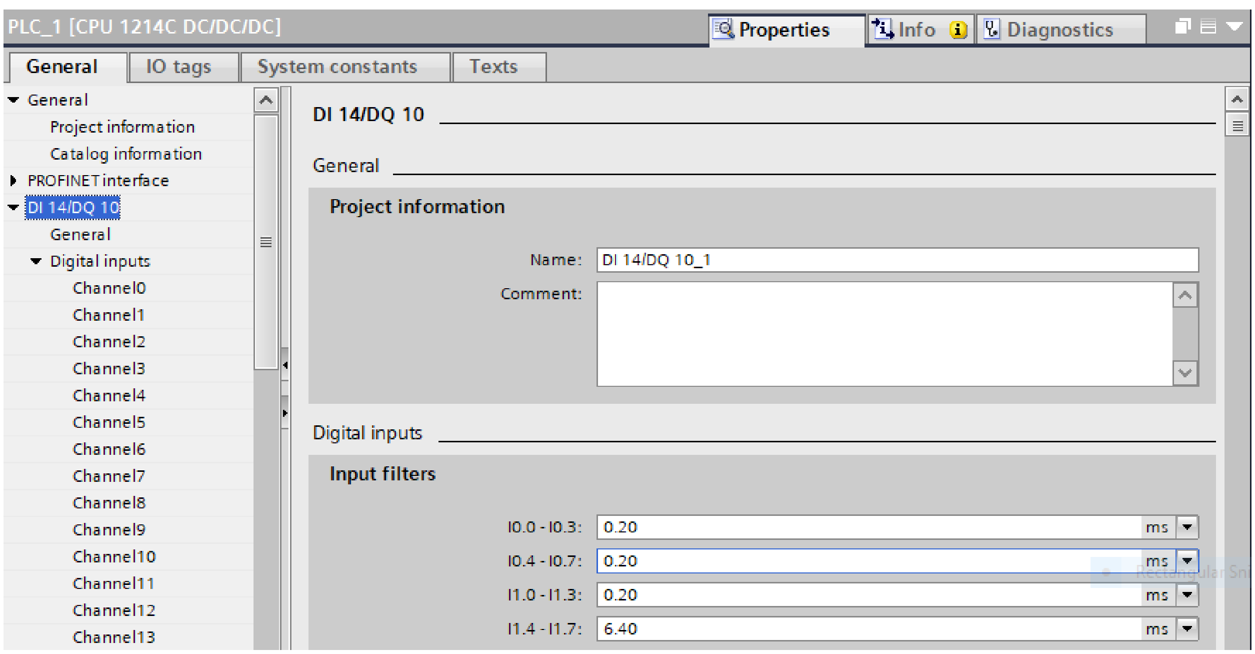
Timing Diagram of Repeating Outputs

Note: While these output waveforms move quickly, they are not one-shots and need to have time duration of 20-50 msec. Their duration must be long enough for the input signal to sufficiently settle and be longer than the filter time set for the input type.

An outline for the program for reading the 4 digit thumbwheel switch:

1. Clear a holding location for the completed number
2. Turn on Output 0
3. Delay a short time period (20 or 30 ms)
4. Read the 4 inputs. If input 0 =1 then add 1 to the holding location
   If input 1 = 1 then add 10 to the holding location
   If input 2 = 1 then add 100 to the holding location
   If input 3 = 1 then add 1000 to the holding location
5. Delay slightly and turn off output 0
6. Turn on output 1
7. Delay a short time period (20 to 30 ms)
8. Read the 4 inputs. If input 0 = 1 then add 2 to the holding location
   If input 1 = 1 then add 20 to the holding location
   If input 2 = 1 then add 200 to the holding location
   If input 3 = 1 then add 2000 to the holding location
9. Delay slightly and turn off output 1
10. Repeat for output 2
11. Repeat for output 3
12. Move the contents of the holding location to a second location for display in N7.

How quickly can an input be read? There is an input filter on these inputs by group. Input filters are shown in the figure below. The following shows the input I0.0-I0.3 changed to 0.20 msec to see a change:



Lab 10.2 Average Scan Time

Write a program to calculate the time of an average scan. Display the results in milliseconds in an integer location.

Lab 10.3 Calories from Bike

The bike has two inputs, one for current and one for voltage. Power is the instantaneous value V*I.

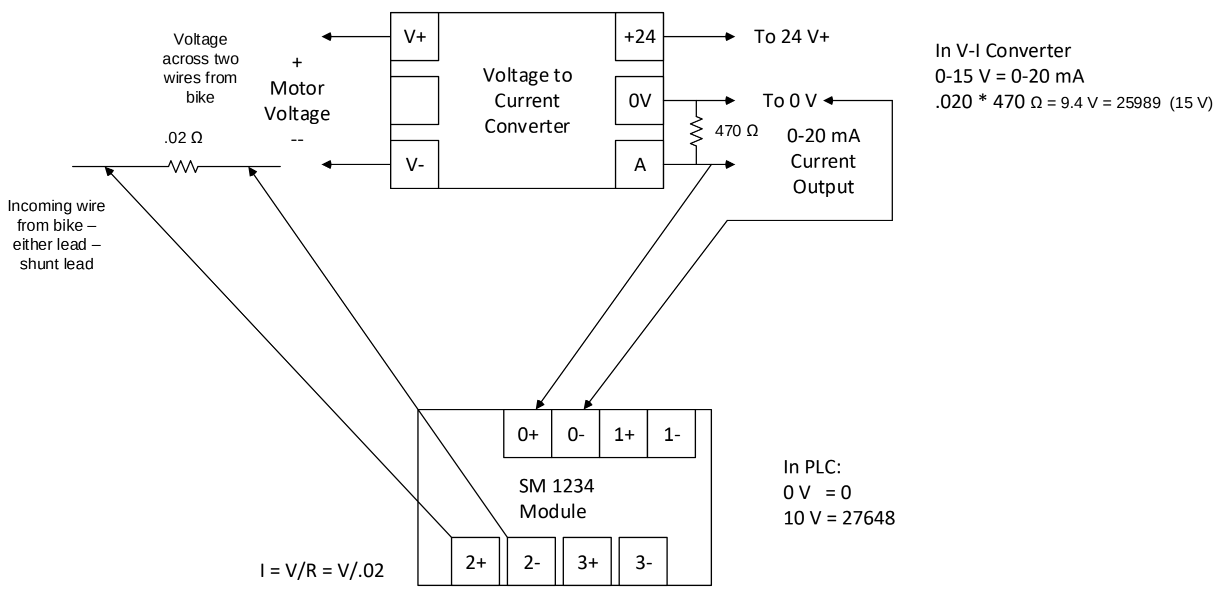
The relationship of power to energy is:

Power(Watts) = energy(Joules) / time(seconds)

and

1 Joule = 0.238902957619 calories

The current and voltage can be input to the PLC using the following diagram:



Create a display that denotes volts, amps, watts, joules and calories.

Details of the voltage voltage converter:

NOYITO Voltage to Current Module 0-2.5V 3.3V 5V 10V 15V 24V Voltage to 0-20mA 4-20MA Current 0/4-20mA Signal Generator Moudle (0-15V to 0-20mA)

Size: 0-15V to 0-20mA

- Voltage to Current module, can 0-2.5V / 3.3V / 5V 10V / 15V / 24V voltage conversion to 0-20mA / 4-20MA current signal output, by adjusting the voltage to adjust the size of the current. Can be used to generate the signal source, valve adjustment, inverter control, PLC debugging, instrumentation test, LED test, analog transmitter.
- Implement the industry standard voltage (0-2.5V / 3.3V / 5V 10V / 15V / 24V) into an industry standard current (0-10mA, 4-20mA).Drive capability MAX15mA, linear output, the output signal can be directly connected to the AD converter, with the AD function with the microcontroller connection.
- Using single-chip embedded technology. The module is small and easy to use in different places.
- Easy to operate, can be fine-tuned by potentiometer.
- Module working voltage: DC24V . 【Please see the product pictures on the left side of the page for the wiring diagram of the product.】

Product description

Size:**0-15V to 0-20mA**
Features:
Using single-chip embedded technology.
Implement the industry standard voltage (0-24V) into an industry standard current (0-10mA, 4-20mA).
Drive capability MAX15mA, linear output, output signal can be directly connected to the AD converter.
Can be connected with a microcontroller with AD function.
Easy to operate, can be fine-tuned by potentiometer.
Module operating voltage: DC24V

Pin Description:
24V: Operating power supply 24V DC +.
GND: 24V DC-.
P1: Adjustable potentiometer 1 pin;
VIN + (V + / P2): Input voltage 0-2.5V / 3.3V / 5V 10V / 15V / 24V DC- (OR adjustable potentiometer 2 pin).
VIN- (V- / P3): INPUT DC- (OR adjustable potentiometer 3 pin) 0V: Output current 0-20mA / 4-20MA.
Special Instructions:
The working voltage connected to V + and V-, cannot be reversed, so as not to damage the control panel and components. In the VIN terminal control voltage, the range is 0-5V, there is a corresponding output at the output current. The correspondence between voltage and current can be fine-tuned by adjusting the potentiometer.