PLUTO

Safety-PLC

Operating instructions

Hardware

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1 General

Pluto is a programmable safety system intended for safety applications where it is not accepted that faults in the control system leads to loss of a safety function. To achieve this requirement the system is designed with integral redundancy and monitoring. Unlike ordinary PLC systems, Pluto utilizes two microprocessors, which both control and monitor each safety function for correct operation. Each input to the system is separately connected to each processor, each having their own memory and executing their own program. The processors continuously compare the results with each other to ensure integrity of data.
Each safety output is connected to both processors and can not be set without both checking that the logic conditions in the application program are fulfilled.
Each Pluto unit has connections for CAN-bus and can be interconnected with other Pluto units. The degree of safety is the same over the bus as it is within each unit

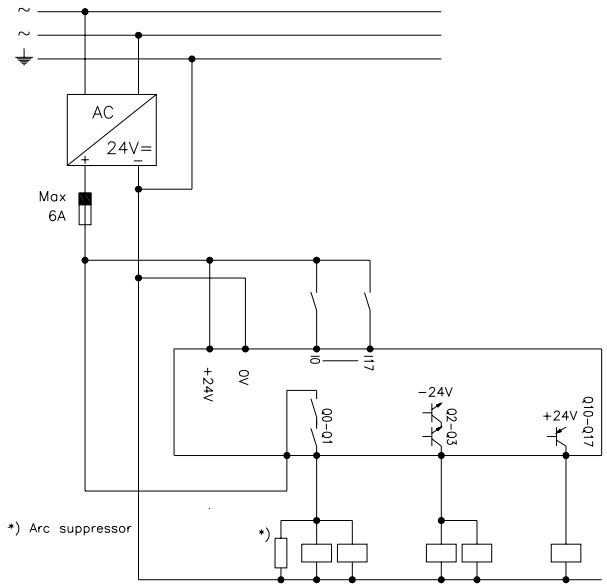
Pluto is primarily designed for fulfilling the demands of the EU Machinery Directive (98/37/EG) regarding safety of control systems and category 4 according to the harmonized standard EN 954-1. The system, however, can be used in other applications e.g. processing industry, furnaces, etc. which have similar requirements.

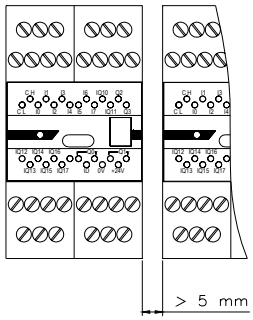
2 Enclosure

Pluto is constructed in a 45mm wide box for snap mounting on a DIN-rail in control cabinets or other suitable enclosures. External wiring is connected via screw terminals. To make it easy and to avoid incorrect connection when a unit is exchanged, the connector blocks are detachable so that individual wires do not have to be disconnected.

3 Electrical installation

The system is powered by 24V DC. For electrical safety reasons and in order to be able to detect safety critical earth faults in single channel circuits, the 0V terminal must be connected to protective bounding circuit. (see EN 60 204-1, 9.1.4).
The system is designed and tested for installation category II according to IEC 61010-1.
The system has internal over current protection (PTC) but should be protected by an external fuse of maximum 6A. Cables and connected devices such as sensors, pushbuttons, selector switches shall be isolated for 250V.



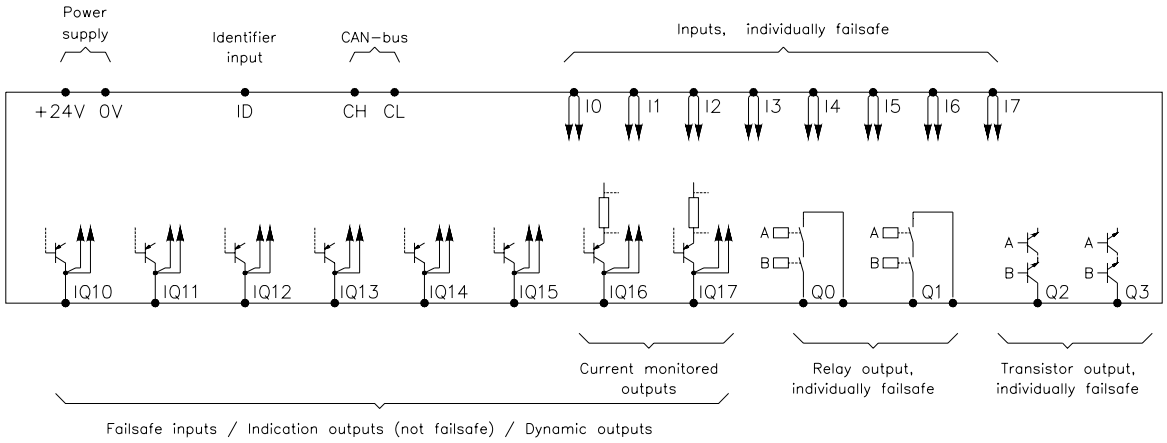


Min. 5 mm space between units.

The terminal blocks are detachable in order to simplify replacement. Note that the power shall be off during connection and disconnection

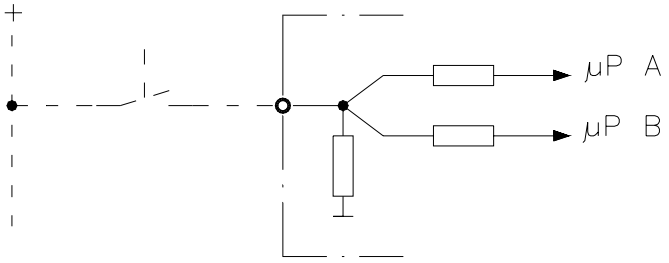
4 Inputs and outputs

In order to be as flexible as possible Pluto offers various combinations of different I/O: s.



4.1 I0 – I7 Digital failsafe inputs.

Each input is separately connected to both processors which, facilitating both single channel and dual channel safety devices.

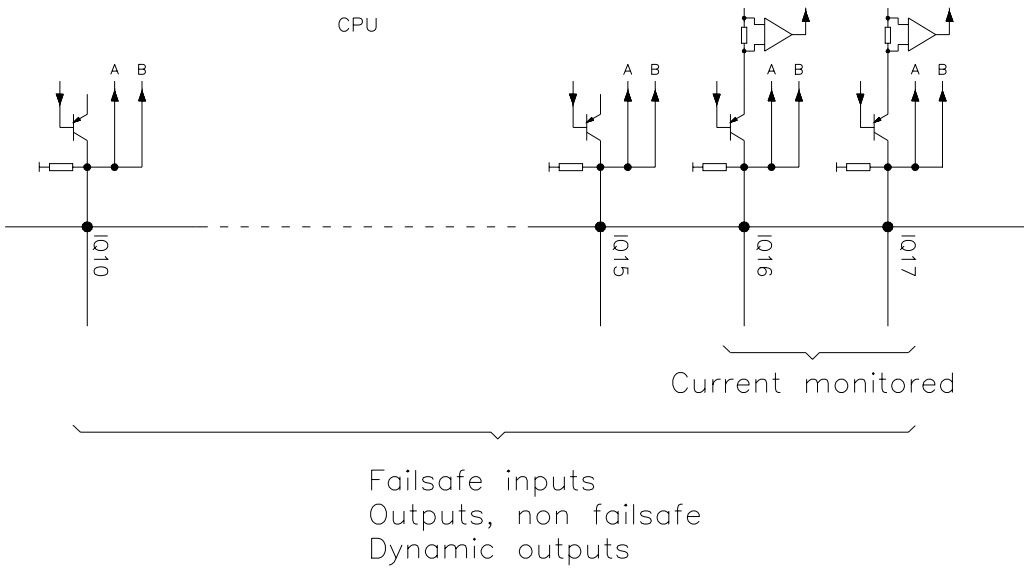


The inputs can be supplied by +24V or by the dynamic signal outputs A, B or C.

4.2 IQ10 – IQ17 Digital failsafe inputs / Digital outputs (non failsafe)

This group of 8 terminals provides 4 different functions. Each terminal is connected to both processors and may therefore be used as a failsafe input.

Each terminal is also equipped with an output transistor which gives the user the option to configure it as either a failsafe input or non failsafe output. The outputs are intended for functions that do not require redundancy. E.g. indicators, status signals.



4.2.1 Dynamic signals.

3 of IQ10-IQ17 can be configured as dynamic outputs A, B or C for supplying inputs. When an output is configured as dynamic, a unique pulse train is generated. As a safety input can be configured just to accept this specific pulse train as the input condition, the system can detect external short circuit conditions. (See separate description).

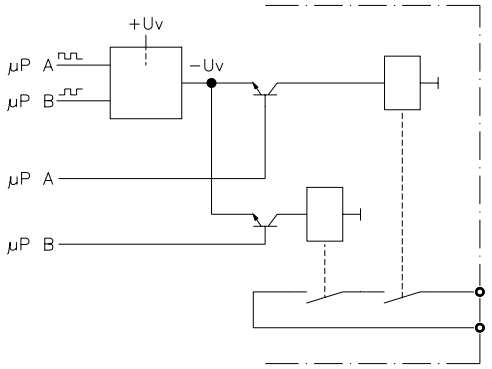
4.2.2 Monitoring of muting indicator:

IQ16-IQ17 has a function for monitoring of the output current when these terminals are used as outputs. The function is mainly intended for monitoring of muting indicators according to EN 61 496-1. In some applications it is necessary to indicate that a safety device is muted. By monitoring the current, the integrity of the filament of the light bulb is indirectly checked.

4.3 Failsafe output.

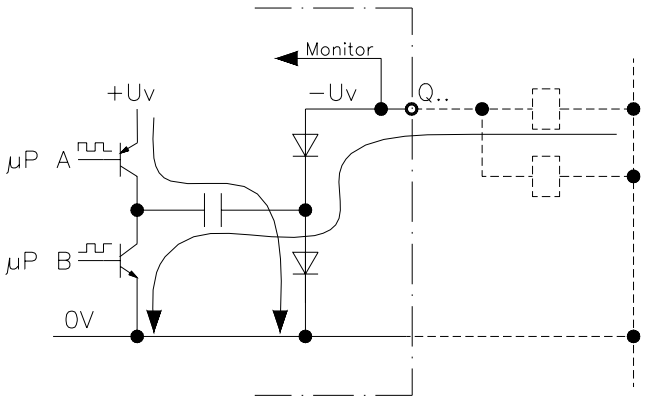
4.3.1 Q0 and Q1 relay output

Each potential free relay output is made individually ‘redundant’ by the use of two series connected relay contacts controlled by each processor. A single output can be used to individually control a safety function, however the outputs cannot detect short circuits in e.g. connection cables. In addition to the output relays being controlled by separate processors the power to the relay coils are generated by ‘charge’ pumps. (For description of function of ‘charge’ pump see section on failsafe solid state outputs).



4.3.2 Q2 – Q3 solid state outputs.

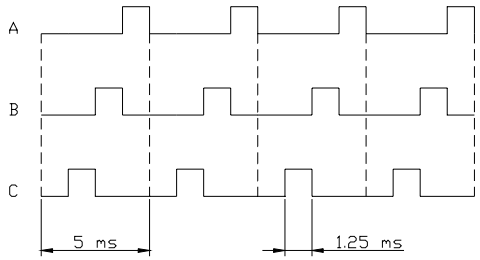
Each digital failsafe output is individually ‘redundant’ and can therefore be used to individually control a safety function. The nominal output voltage is –24V DC. The negative potential is due to the ‘charge’ pump principle used. The ‘charge’ pump is designed in such a way that the output voltage is generated by a capacitor which is charged and discharged by two transistors. The transistors switch alternately. One transistor switches to plus potential (+), charges the capacitor and then switches off. The other transistor then switches on discharging the capacitor to 0 Volts. During the discharge phase the capacitor ‘sucks’ current from the output making the output a negative voltage. This design principle requires that all components work and change state in the correct phase. A fault in any component leads to an immediate cessation of output current generation.
An advantage of using a negative output potential is that it is not normally present in a control system.Then the output is monitored, Pluto can detect short circuit between the output and a foreign potential.



5 Connection of inputs

5.1 Dynamic signals

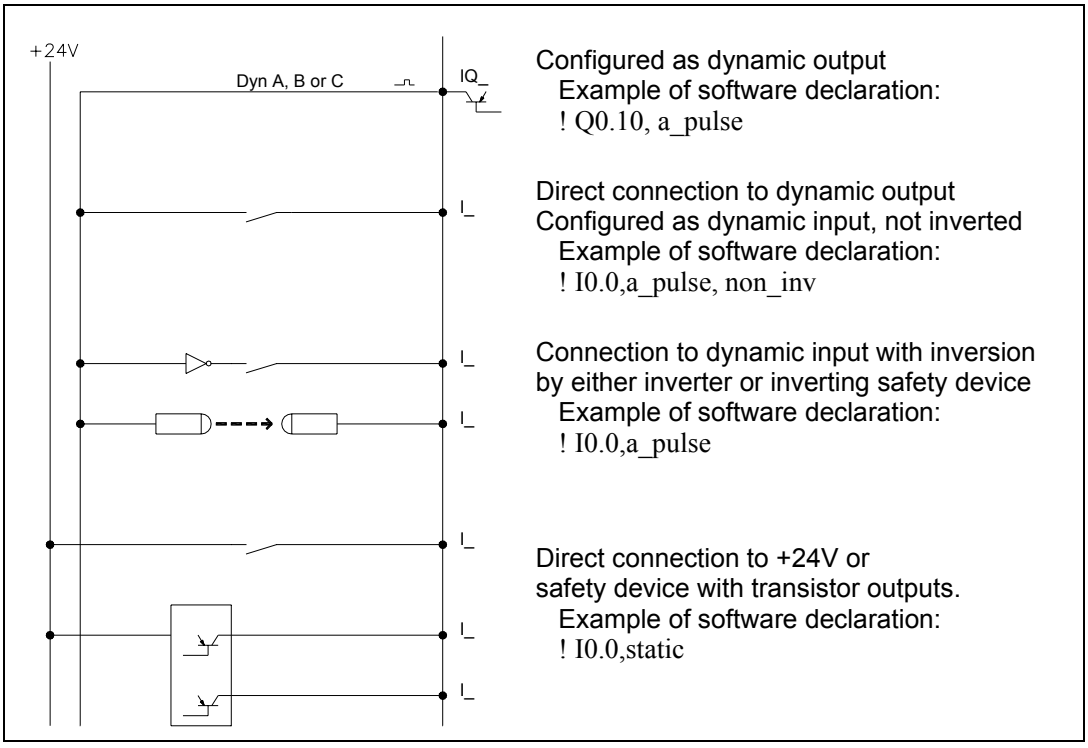
A maximum of three of the IQ10-IQ17 connections can be configured as dynamic outputs, and be used for voltage supply of the input devices. If they are configured as dynamic, each of them generates an unique pulse train as shown in the diagram bellow.



The system is intended for detection of different short circuits in external cabling, and dynamic monitoring of sensors. It enables the connections of devices such as the Jokab “SPOT” light beams, EDEN sensors etc. that inverts the input signal.
In the software a configuration of the inputs must be made to decide which kind of input signal each input shall accept as logic ‘1’. Other signals that do not match with the configured signal are regarded as ‘0’.

5.1.1 Connection of I 0 – I 7

I0-I7 can be connected to; A, B, C, A-inverse, B-inverse, C-inverse or +24V.
The diagram below shows possible connections and how they are configured in the software.
NOTE: The connections are only to show how devices can be electrically connected and are not to be taken as connections for any specific applications.



Configured as dynamic output
Example of software declaration:
! Q0.10, a_pulse

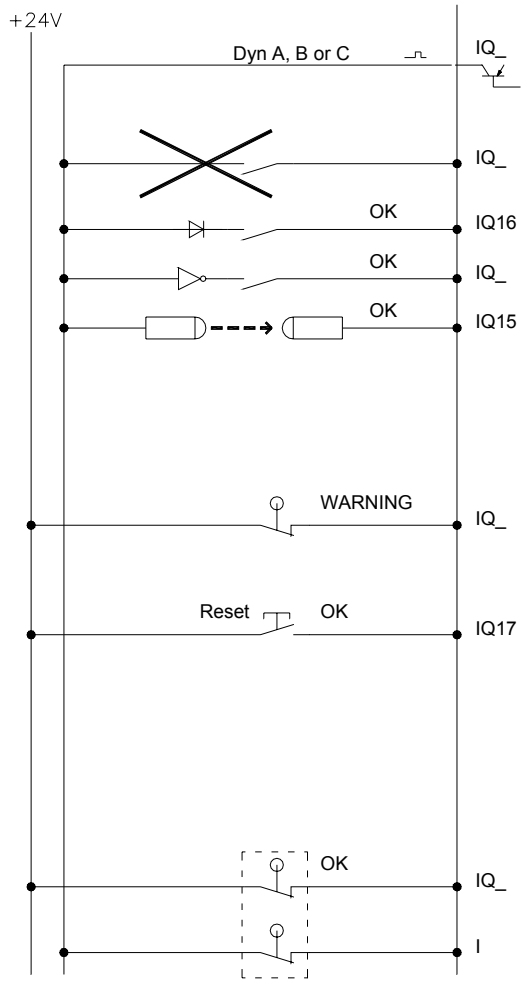
Direct connection to dynamic output
Configured as dynamic input, not inverted
Example of software declaration:
! I0.0,a_pulse, non_inv

Connection to dynamic input with inversion
by either inverter or inverting safety device
Example of software declaration:
! I0.0,a_pulse

Direct connection to +24V or
safety device with transistor outputs.
Example of software declaration:
! I0.0,static

5.1.2 Connection of IQ 10 – IQ 17

IQ10-IQ17 have some restrictions. If they are to be used as failsafe single channel inputs they must be configured as dynamic; A, A-inverse, B, B-inverse, C or C-inverse. For some two-channel devices also +24V can be used.



Configured as dynamic output

The system does not accept
a direct connection between
a dynamic output and another IQ terminal.
A component or device, blocking
current from input must be applied
Example of declaration:
! I0.15,a_pulse
! I0.16,a_pulse,non_inv (with diode)

IQ 10-17 connected to +24V
does not fulfil category 4
as stand alone input

IQ 10-17 connected to +24V
fulfils the safety requirements
used for reset, start etc.
Example of declaration:
! I0.17,static

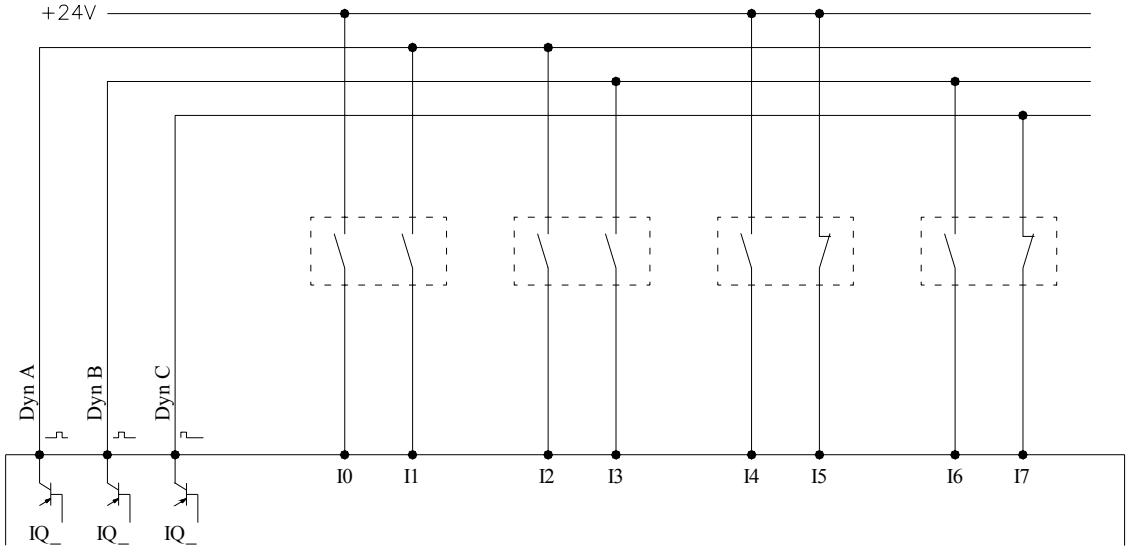
IQ 10-17 connected to +24V
fulfils category 4 by combination
with another dynamic input

NOTE:
The above connections are only to show how devices can be electrically connected and are **not** to be taken as connections for any specific applications.

6 Connection of safety devices

6.1 Dual channel systems

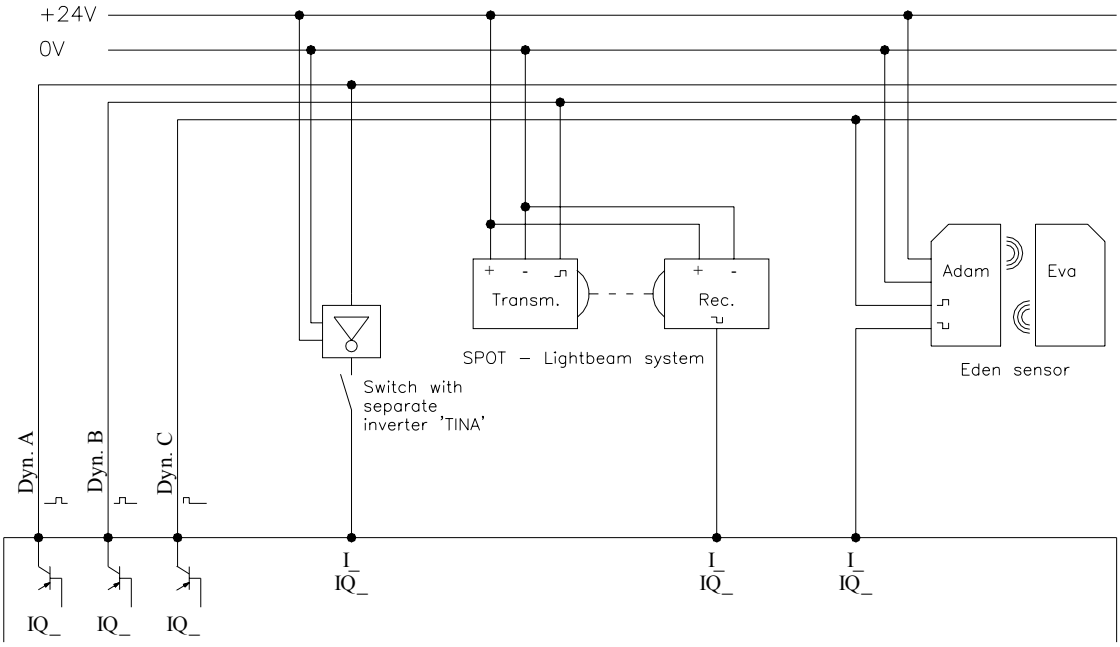
The classic way of making a failsafe system is to use two-channel devices. The system offers various possibilities for connection of such devices.



Dual channel inputs with detection of external short circuits

6.2 Single channel systems

Instead of using two-channel systems some applications can be made failsafe by using the principal of a dynamic single channel. By supplying electronic devices with dynamic signals a fault in the electronics will lead to a static on or off state at the input which will be detected immediately. By inverting the signal in or at the sensor, short circuits over the sensor are also detected.



Note: Serial connection is legal, but a short circuit of an even number of sensors is **not** detected.

A direct connection between two terminals of IQ10..17 is always detected. Detection of a short circuit between an output of IQ10..17 and an input of I0..I7 is **not** detected.

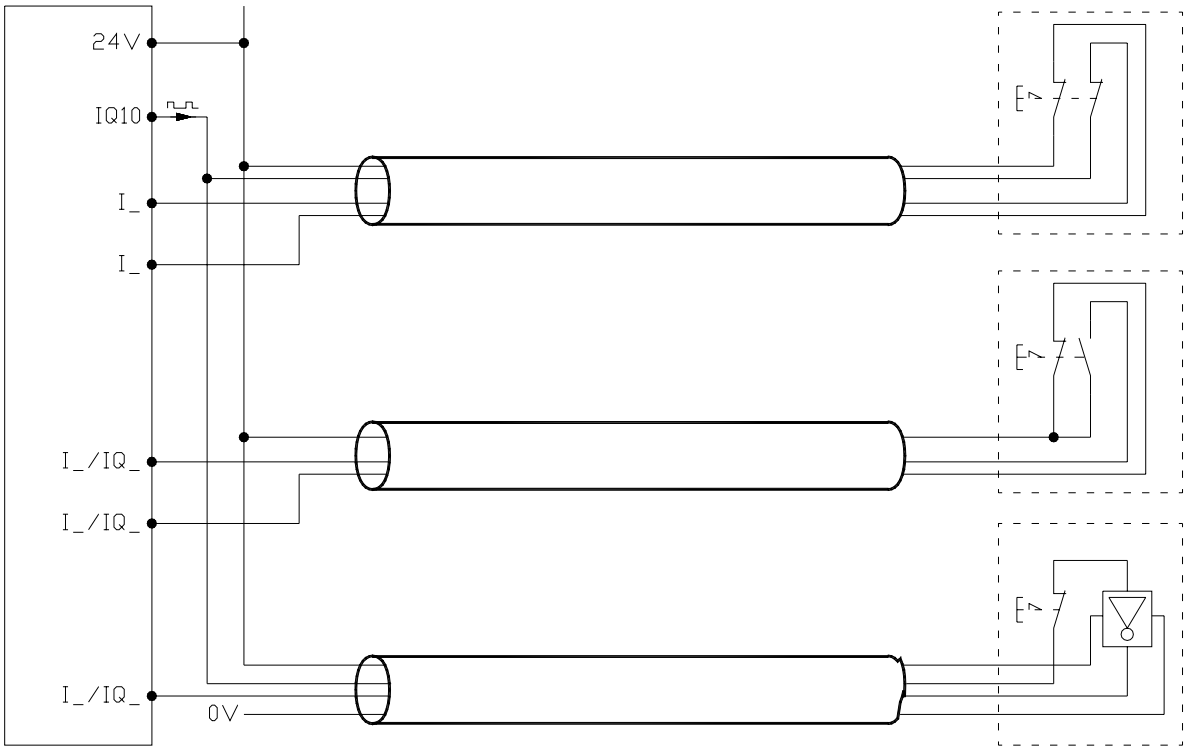
See Technical data for number of serial connected sensors.

6.3 Emergency stop

When emergency stop functions often remain inactivated for long periods of time, the function will not be monitored. It is therefore strongly recommended that emergency stop systems are periodically, manually tested and that this forms part of the maintenance instructions for the machine.

6.4 Monitoring of external short circuit

The system offers three main methods for avoiding that short circuits in input cabling leads to loss of safety function. The drawing below illustrates the different methods by which emergency stop buttons can be connected.



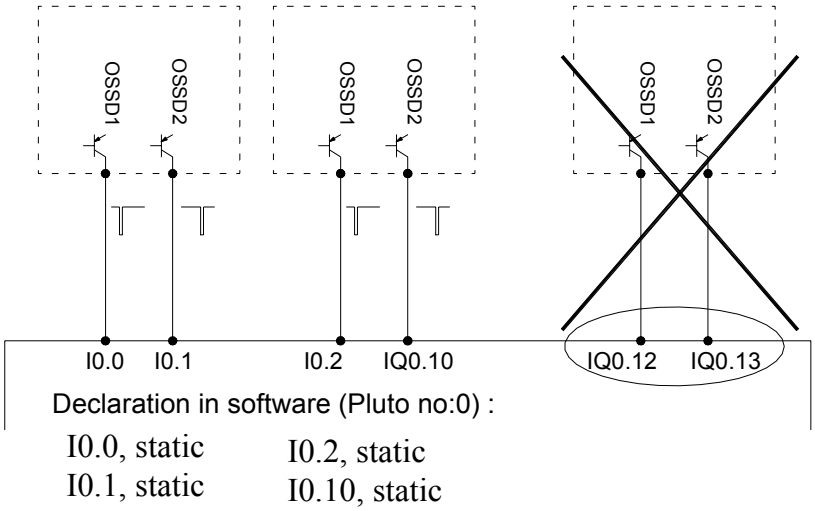
- The first button has two NC contacts supplied by one dynamic signal and +24V. The inputs are configured just to accept the expected signal and will therefore detect a short circuit between the channels as well as to other foreign voltage.

- The button in the middle has one NC and one NO contact supplied by +24V. The software requires that the inputs operate in opposition to each other. A short circuit in the connecting cable will have the effect that both inputs will at sometime during the cycle be ON, which the system does not accept.

- The last emergency stop button uses a short circuit proof single channel technique. A dynamic signal is converted by an inverter mounted close to the contact. The input is configured just to accept the inverted result of the supplied dynamic signal. A short circuit in the connecting cable will result in an incorrect signal being presented to the input which will not be accepted by the system.

6.5 Safety devices with transistor outputs

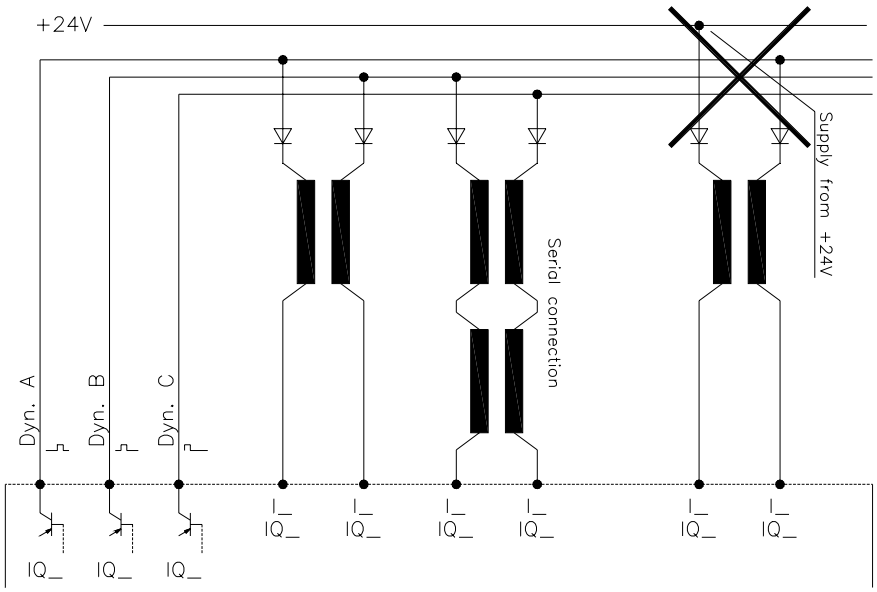
Certain safety devices on the market, i.e. light curtains, light beams, scanners, etc., are designed with dual monitored safety 24V DC transistor outputs. These devices monitor the output circuits by making short interruptions in the output signals.
Both channels can be connected to the system as static inputs, faults are detected by the safety device, instead of by the Pluto system. **But note that at least one of the inputs must be one of I0-I7.**
The short interruptions of the output signals are taken care of by the Pluto input filtering system.
A list of devices tested in conjunction with Pluto is available from Jokab Safety.



NOTE: *At least one of the inputs must be one of I0-I7.*

6.6 Safety mats and safety edges

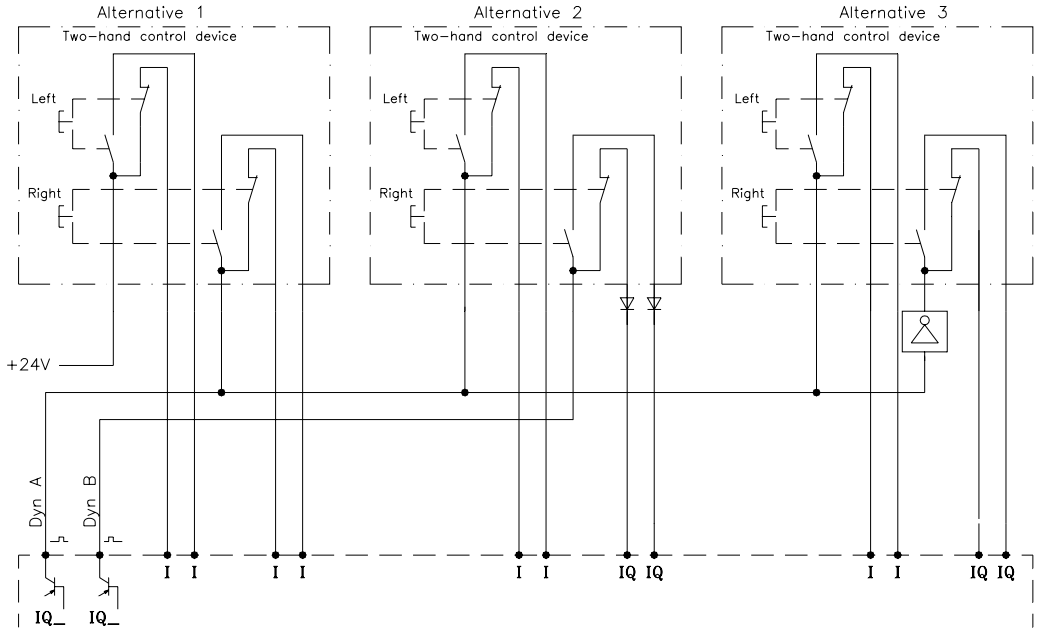
Safety mats and safety edges must be supplied by two different dynamic signals and connected to two inputs. By activation the two inputs will both get wrong input signal and give ‘0’ in the software as result. The programming can be made in the same way as for other dual channel functions.



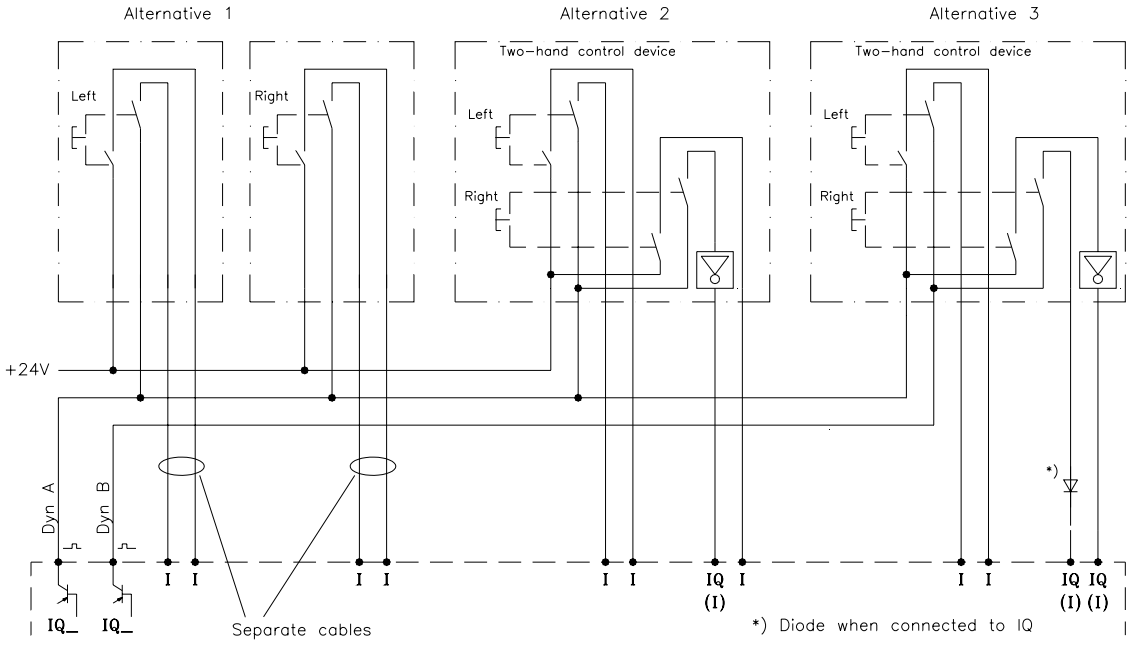
Examples of connections

6.7 Two-hand control

Two-hand control devices can be realized in many ways depending on the contact configuration in the two-hand device and which Pluto inputs are used. Below are some examples of solutions. All of the examples shown fulfil the requirements for type IIIC according to EN 574.



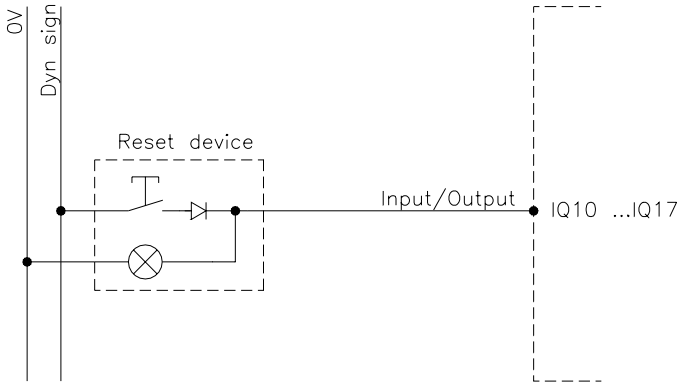
Examples of two-hand control with NO/NC + NO/NC contacts



Examples of two-hand control with 2 NO + 2 NO contacts

6.8 Illuminated push button function

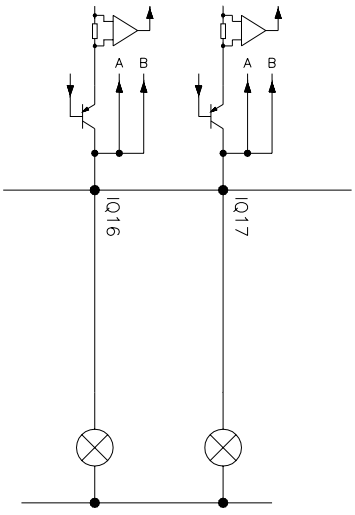
It is possible to connect both an indicator lamp and an input switch at the same time to terminals IQ10-IQ17. e.g. illuminated push button. A diode must be connected locally to the input device. The function is mainly intended for reset devices and reduces the number of IQ terminals used.



Note that the output voltage is a square wave of 24 V amplitude and the effective voltage to the indicator is reduced to a mean value of 75%. A filament bulb or LED designed for 24 VDC can be used operation can be used.

6.9 Monitoring of muting lamp

The system can measure the current in output IQ16 and IQ17. The function is intended for monitoring the current in a muting lamp, but other usage is not excluded. As the hardware for measuring the current is not fully redundant the function must be used in a dynamic way if used for safety functions. This means that the current must be read and evaluated both when the output is switched on and off.

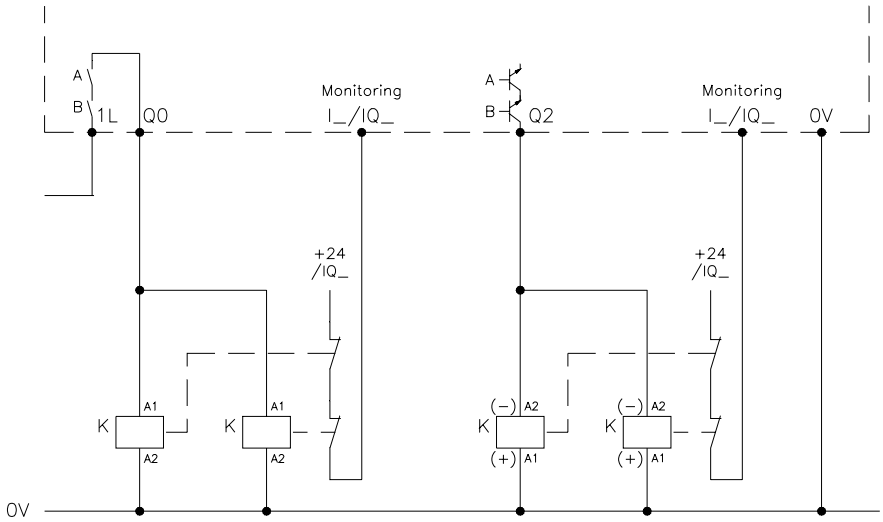


7 Connection of outputs

Below are examples of output connections that give different degrees of protection against short circuits. When and where they can be used depends on the kind of machine application (risk) and the electrical installation.

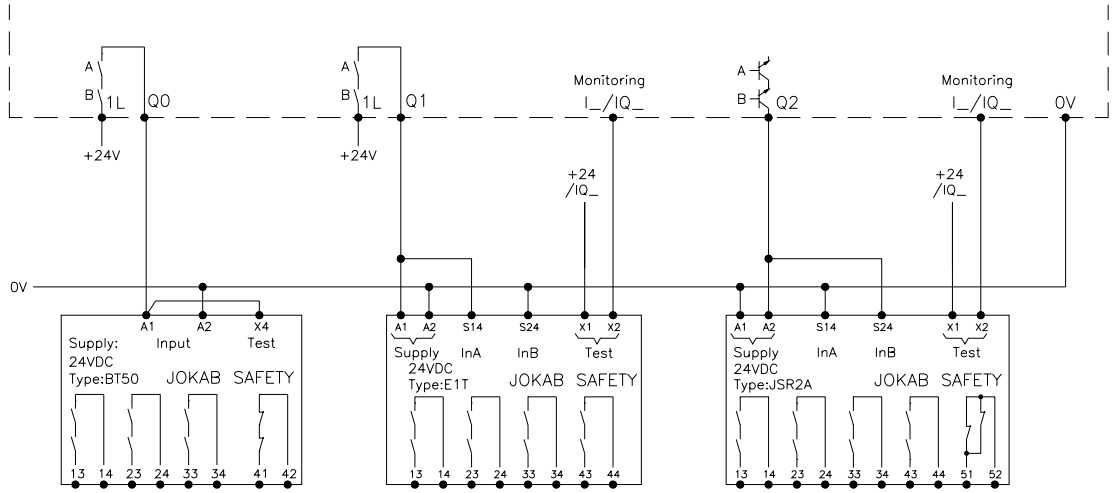
7.1 Connection examples

Output examples 1: Connection and monitoring of contactors.



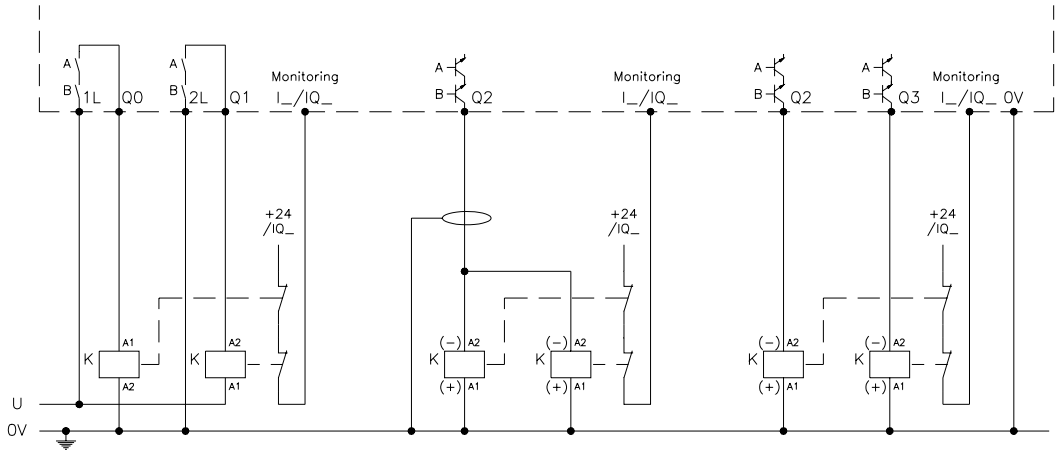
A fault in a contactor will not lead to the loss of the safety function and is monitored then the NC-contacts are connected to an input.
Note. Some short circuits from +24V and –24V can switch on both contactors and lead to loss of the safety function.
The example connections can be used where the highest safety integrity level is not required and the risk for short circuits is low or can be excluded e.g. inside a control cabinet. Example of application is automatic machines where safety function is used by setting, adjustment etc.

Output examples 2: Contact expansion with Jokab Safety expansion relays and safety relay



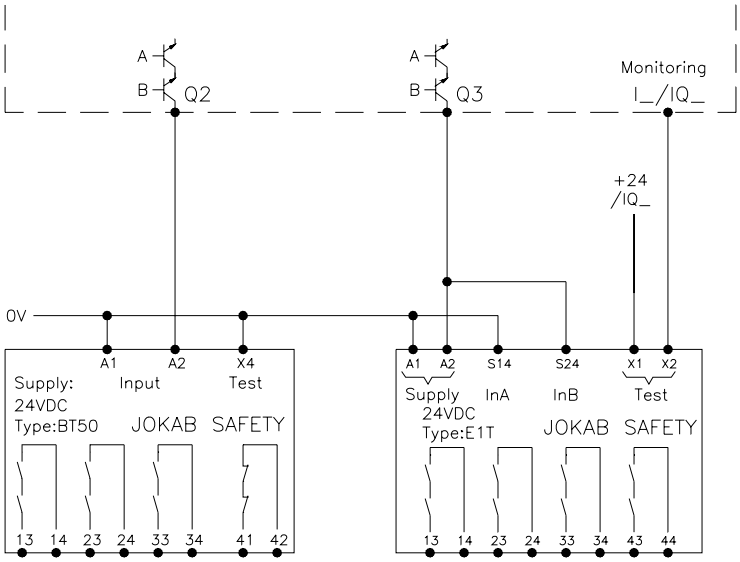
The examples give the same degree of safety and have the same advantages and disadvantages as output examples 1 and can be used for the same type of applications.

Output examples 3: Short circuit protected



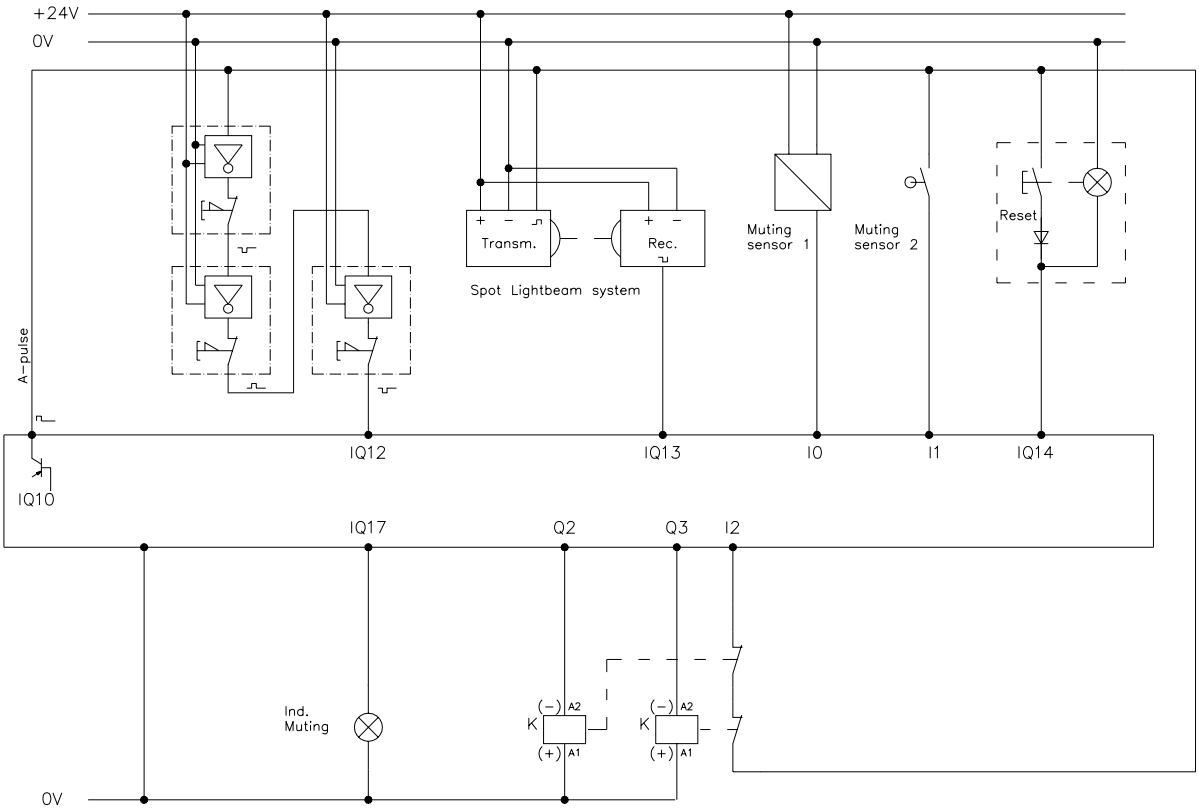
Connection and monitoring of contactors with protection against short circuit, for applications with very high demands on safety integrity level. (Category 4). In the example using output Q2 the conductor is protected with a shield connected to protective ground. Examples are applications for safeguarding the operator of manual operated machines like presses and press brakes.

Output example 4: Polarized safety relays



When using a safety relay for output expansion of output Q2 and Q3, the connection between the Pluto output and the safety relay is failsafe against short circuit from foreign +24V. This because it is operated by -24V and since the safety relay is polarized it cannot be switched on by +24V. As long as a -24V potential does not exist in the cabinet (which is not normally the case) the connection is failsafe.

8 Example of applications



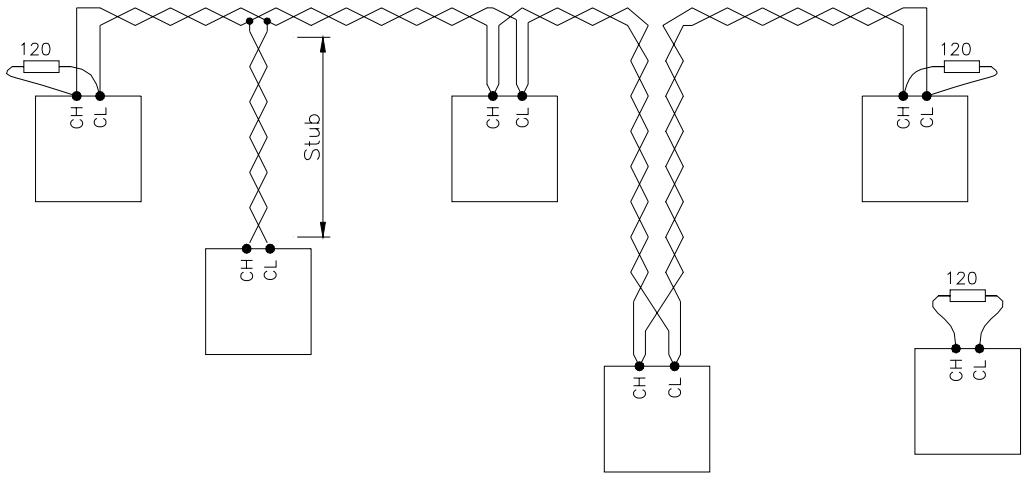
9 Bus communication

Up to 32 Pluto units can be interconnected with CAN-bus. Communication is achieved by connecting a twisted pair cable to the CH and CL terminals. When this connection is made the Pluto units can read each others I/O.

When the bus connected each Pluto unit executes its own individual program and operates independently, however it can read other units I/O.
An interruption of the bus connection results in the I/O in the unit with which communication is lost, being regarded as a '0' condition by other units on the bus. In this situation all units will continue program execution with the consequences of the fault being dependant upon the application program. For instance, if an emergency stop button connected to one unit is used by another unit as a condition for setting an output, the output will switch off if communications are lost. Outputs generated by I/O connected directly to a unit are not affected by interruption of communications.

9.1 Cabling

The maximum length of CAN-bus cabling is dependant on the transmission speed. At the default setting of 400 kbit/s the maximum total length is 150 meters. At each end of the bus a termination resistor of 120 Ω must be installed. When a Pluto unit is working alone and no bus-cable is connected, it must still be equipped with a termination resistor.
The bus connection should be made with a twisted pair cable to the CH and CL terminals. Due to EMC requirements bus cabling outside control cabinets must be shielded, one end of the shield being connected to a central earthing point.



Cable lengths:

Data Rate	**Trunk Distance**	**Stub length** Units connected on a Stub must not have termination resistors fitted.	
		Max single stub	**Accumulated stub length**
100 kbit/s	600 m	25 m	120 m
125 kbit/s	500m	20 m	100 m
200 kbit/s	300m	13 m	70 m
250 kbit/s	250m	10 m	50 m
400 kbit/s	**150m**	**6 m**	**30 m**
500 kbit/s	100m	5 m	25 m
800 kbit/s	60m	3 m	15 m
1 Mbit/s	<20m	1 m	5 m

9.2 Response time over the bus

As default the system works with the Baud rate set to 400 kbit/s and CAN-cycle to 20 ms. CAN-cycle 20 ms gives 10 ms extra response time for data over the bus (10-40 ms under fault condition). The records under Technical data for response time over bus etc. are related to this. To enable the use of longer cable lengths it is possible to change the baud rate to a lower value, but care must be taken as the buss can be overloaded. To avoid this over load there are two solutions: either to limit the amount of Pluto units connected on the bus or to increase the Bus cycle time which also increases the response time.
Note that “Bus cycle time” is individually set for each Pluto unit which means that it is possible to give variables of some Pluto units, better response times than others. It is also important to note that if an input in one unit controls an output in another, it is regarding the response time only relevant where the input is located. If the “Bus cycle time” in the unit with the output is changed it has no influence on the response time.

The table below is a guideline for selection of bus parameters.

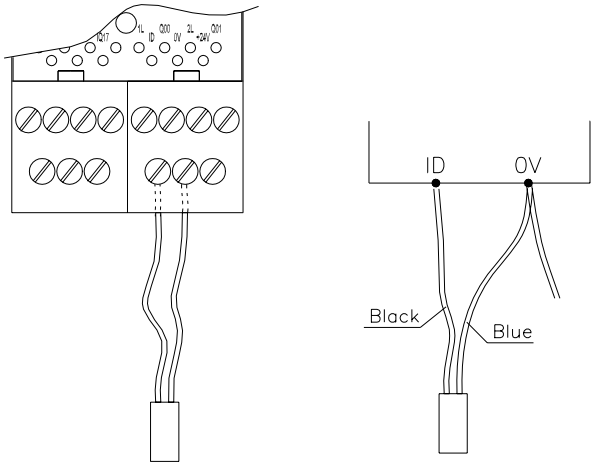
Baud rate **Bus cycle time**	100 kb/s	125 kb/s	200 kb/s	250 kb/s	**400 kb/s**	500 kb/s	800 kb/s
10 ms	3-4	4-6	8-10	12-14	18 - 25	25-32	32
20 ms	6-8	10-14	20-32	22-32	**32**	32	32
30 ms	12-18	15-21	20-32	25-32	32	32	32
40 ms	12-23	20-30	28-32	30-32	32	32	32

Possible number of units connected to the bus.

NOTE: The prolongation of response time for I/O over the bus is equal with the Bus cycle time.

10 Identifier

The identifier is an external component that can be connected to the ‘ID’ and ‘OV’ terminals. The circuit contains a unique ID-number that can be read by the system. In the PLC program the identifier number can be declared which connects the program so that it will only work together with the correct identifier. The use of identifier is voluntarily as long as a unit works alone, but if an identifier is connected to the unit and the PLC program is declared to work without, the program will not run.
The function gives a protection against a unit being exchanged by mistake. The identifier circuit should be securely fastened to the physical location of the unit by e.g. tie it together with other connection conductors.



Connection of identifier

When a number of Pluto-units are interconnected with the bus, identifiers are necessary. The units are numbered 0…31. In the application program it is necessary to declare which identifier number has to be connected to which Pluto unit (0…31). Example: ! id_pluto:01=023474526654

There are two types of identifier circuits available;
Pre-programmed: The number is programmed by the circuit manufacturer who guarantees that two circuits with the same number do not exist.
Programmable: The number can be programmed by the user.

Programmable identifiers can for example be used where it is required to deliver units with the same PLC program e.g. for a special machine or safety application.

11 Programming

The development of application programs (Pluto PLC program) is achieved using a standard PC computer using a specially developed high level language. Communication between the PC and the Pluto PLC is via a cordless Infrared (IR) link. This link facilitates program down loading and monitoring of inputs, outputs, memory, timers, etc. with the PC ‘on line’.

See separate programming manual for further information.

12 Cleaning

The front plate can be cleaned by a dry dust rag. The front plate can also be removed for cleaning or exchange.

13 Technical data

Supply

Nominal voltage	24 V DC
Voltage tolerance	-15%, +20%
Max interruption	20 ms
Power consumption at 24V	
Unit consumption	270 mA / 8,4 W
Failsafe outputs	0 – 1.8 A / 0-43 W
PLC outputs (non failsafe)	0 – 2.5 A / 0-60 W
Recommended external fuse	6 A
Installation category:	Category II according to IEC 61010-1

Failsafe inputs

I0 – I7	+24V (for PNP sensors)
IQ10 – IQ17	+24V (for PNP sensors) also configurable as non-failsafe outputs.
Logic ‘1’	> 12V
Logic ‘0’	< 8V
Current at 24V	
I0 - I3:	12 mA
I4 - I7, IQ10 - IQ17:	6 mA
Max. over voltage	30 V continuously
Filter time (standard)	5 – 10 ms, software

Safety output

Q2-Q3:	Solid state, -24V DC
Output voltage tolerance:	Supply voltage -1.5V at 800mA
Max. load / output:	800mA
Q0-Q1:	Relay output
Max voltage	250 VAC
Max. load / output	1.5 A

Outputs, non-failsafe

IQ10 - IQ17	Transistor +24V, PNP open collector (also configurable as failsafe inputs.)
Max load / output	800 mA
Max totally load IQ10-IQ17	2.5 A
Current monitoring IQ16, IQ17	
Range	0-1,0 A
Resolution	20 mA

Indication:

Input LED's	1 per input (Green). Controlled by processor
Output LED's	1 per output (Green). Controlled by processor
Indication of status and error	7 segment display

General

Enclosure	45 x 84 x 118 mm (w x h x d) DIN-Rail mounting

Response time of dynamic A or static input (+24V):

Relay output, Q0-Q1:	< 20,5 ms + progr. execution time
Solid state output, Q2-Q3:	< 16,5 ms + progr. execution time
Solid state output, Q10-Q17:	< 16,5 ms + progr. execution time

Response time of dynamic B or C inputs:

Relay output, Q0-Q1:	< 23 ms + progr. execution time
Solid state output, Q2-Q3:	< 19 ms + progr. execution time
Solid state output, Q10-Q17:	< 19 ms + progr. execution time

Program execution time	approximately 10µs / instruction
Software setting 'NoFilt'	Response times - 5 ms (5 ms less)

Extra response time over bus:

Normal condition	10 ms
Fault condition	10-40 ms

Q2-Q3 prolongation of response time under fault condition: <10 ms

Detection time

Shortest detectable pulse	10 ms
Ambient air temperature:	-10°C - + 50°C

Temperature, transportation and storage:
- 25 - +55°C

Humidity:
EN 60 204-1: 50% at 40°C (ex 90% at 20°C)

Degree of protection:

Enclosure:	IP 40 - IEC 60 529
Terminals:	IP 20 - IEC 60 529

Connection of sensors

Maximum number of serial connected sensors:

Eden	10-12
Spot 35	3-4
Spot 10	2
Tina	10-12

Maximum number of serial connected sensors with 100m cable:

Eden	10-11
Spot 35	3
Spot 10	1
Tina	10-11

Maximum cable length for inputs using dynamic signals (depending on capasitance):

Example 10x0,75 mm²	approx. 1000 meter

14 Appendix - Message and fault code list

Status messages

No:	Description
-	Power up
n	Run mode for station number 0-9. (*n* = station number)
P *n n*	Run mode for station number 10-31. (*nn* = station number)
L	Program load mode state. Flashing 'L', ready for self programming (program found in other unit)
H	Program execution stopped from PC computer.

User faults

No:	Fault and possible reason.	Reset action
E10	Dynamic output short circuited to foreign voltage.	Remedy of fault
E11	IQ_ for illuminated push button function. Missing diode	Remedy of fault
E12	Short circuit between two dynamic inputs	Remedy of fault
E13	Static output Q10…Q17 short circuited to 0V or Q2-Q3 overloaded	Reset button, power off/on
E14	Static output Q10…Q17 short circuited to 24V.	Remedy of fault
E15	Power supply below 18V	Reset button, power off/on
E16	Power supply above 30V	Reset button, power off/on
E17		
E18	CAN-bus fault. (Short circuit, termination resistor, etc.)	Remedy of fault + reset button
E19	Other unit same station ID on Can-bus	
E20	PLC-program not loaded	Load of program
E21	PLC-program CRC-error	Re-load with valid PLC-program
E22	Identifier problem. External identifier can not be read.	Power off/on
E23	Unmatched ID. Identifier doesn't match declaration in program.	Exchange of identifiers or re-declaration of identifier in program.
E24	Erroneous PLC-code. Invalid PLC-instructions.	Reload with valid code.
E25	For version A16. Non existing output used in program.	
E26	Baud rate conflict. Unit programmed for other baud rate than current buss baud rate.	Reprogramming or reboot
E27	Wrong checksum for unit member in common program	Reprogramming or reboot

I/O faults

No:	Fault and possible reason.	Reset action
E 40	Error output Q0 - Q3.	Remedy of fault + reset button.
E 41	Error output Q2 or Q3. Overload or foreign voltage.	Remedy of fault + reset button.
E 42	Error output Q0 or Q1. (No answer from relay monitoring.)	Remedy of fault + reset button.
E43	Error output Q0 or Q1. (Self test of transistors)	Power off/on
E45	Analogue functions not calibrated	System must be calibrated
E49	Error calibration values, analogue functions	Recalibration

CPU faults

No:	Fault and possible reason.	Reset action
E50	a/b twin input data diff	Power off/on
E51	a/b twin output data diff	Power off/on
E59	Calibration analogue functions CRC fault	Power off/on
E60	twin self test monitoring	Power off/on
E61	Timer IRQ monitoring	Power off/on
E62	Internal serial communication	Power off/on
E63	Boot-flash CRC	Power off/on
E64	OS-flash CRC	Power off/on
E65	Plc-flash CRC	Power off/on
E66	5 volt under/over voltage monitoring	Power off/on
E67	CPU-test error	Power off/on
E68	Ram-test error	Power off/on
E69	Scan cycle time over run	Power off/on
E70	System, sum of system and stack monitoring	Power off/on
E80	Undefined self-test error	Power off/on