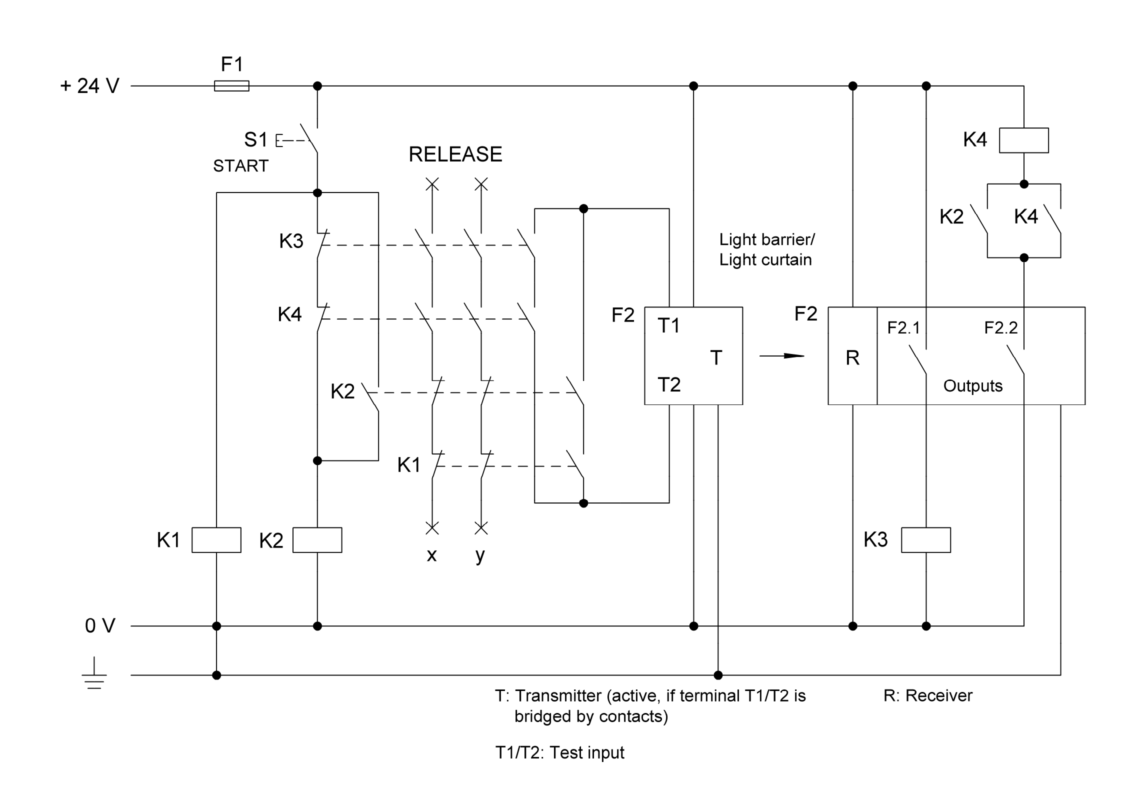
8.2.36 Processing of signals from a light barrier – Category 4 – PL e (Example 36)

Figure 8.60:
Electromechanical input of safety-related signals into the machine control system with reference to the example of a light barrier or light curtain

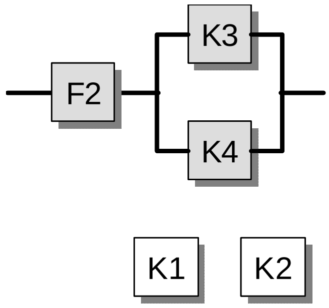


Safety function

- Safety-related stop function initiated by a protective device: sustained stopping of a hazardous movement in response to entry into a hazardous area or operator intervention at a hazardous zone, and start and restart interlock

Functional description

- Entry into a hazardous area or operator intervention at a hazardous zone is detected by the light barrier F2. The safety-related output signals from the light barrier (make contacts F2.1 and F2.2) de-energize the contactor relays K3 and K4, the coils of which are connected to the power supply in an offset arrangement. K3 and K4 then block the enabling signals x and y.
- For activation of the light barrier transmitter, actuation of the start button S1 first causes the test inputs T1 and T2 to be connected together by picking up of the contactor relays K1 and K2. K2 can pick up and latch in only once the contactor relays K3/K4 have dropped out. With the light path completed, K3 and K4 then pick up. K4 picks up and latches in only by means of the make contact of K2. With K3 and K4 picked up and the start button still depressed, the light barrier

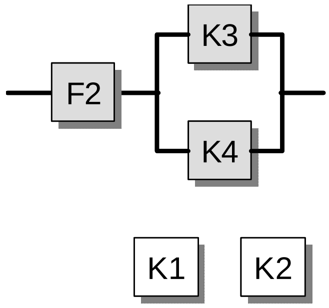


transmitter is activated and latched; the start button can therefore be released, and once K1 and K2 have dropped out, the enabling paths x and y are also closed. Following interruption of the light beam or in the event of breakdown and subsequent restoration of the voltage, the function of the start/restarting interlock prevents a valid enabling signal until K3 and K4 have picked up again following renewed pressing of the start button.

- One make contact each on K3 and K4 is integrated both into the two enabling paths and into the input circuit for activation of the light barrier transmitter (test inputs T1/T2). Connection of the test inputs generates an internal start-up test within the device, for example by blanking of the light beam for a short defined period. On the receiver side, this test is logically evaluated as valid only within a narrow time window. Provided the start-up test is passed, the light barrier outputs are enabled. Conversely, in the event of an outage or fault, or interruption of the light beam, they are blocked.
- Faults in other components in the circuit (contactor relays, output contacts of the light barrier, start button) which in combination could result in the loss of a safety function are detected during the start-up/restarting test following an interruption of the light beam, and prevent renewed enabling.

Design features

- Basic and well-tried safety principles are observed and the requirements of Category B are met. Protective circuits (e.g. contact protection) as described in the initial paragraphs of Chapter 8 are implemented.
- The contactor relays K1 to K4 possess mechanically linked contact elements in accordance with IEC 60947-5-1, Annex L. The relay operating voltage of the contactor relays K3 and K4 must be greater than half the value of the power supply, so that simultaneous pick-up of K3 and K4 in the event of a short-circuit in the cable (connection in series results in the voltage being divided between the contactor coils) does not present a hazard, even in combination with other faults.
- The output signals from the light barrier F2 are routed in a cable, together with the supply conductors, from the electrical compartment of the receiver to the electrical compartment of the machine control system. Owing to application of the closed-circuit current principle and the principle of offset coils (K3, K4) in the earthed control circuit, all open circuits, earth faults and circuit-to-circuit shorts are detected immediately when the light barrier is in the activated state (among other things, by tripping of the fuse F1). A short-circuit which causes a single



output to be bridged is detected at the latest at the next interruption of the light barrier when the start button is subsequently actuated. Common routing of the output signals within a single cable is therefore permissible.

- The light barrier satisfies the requirements for Type 4 in accordance with EN 61496-1 and IEC 61496-2, and PL e.

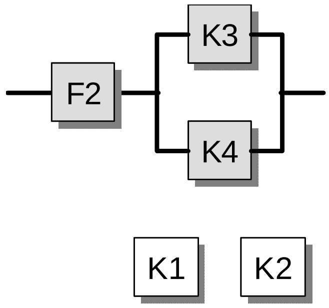
Remarks

- If the circuit is employed in applications in which the light barrier switches very infrequently, the possibility must be considered of the safety function being lost as a result of an accumulation of faults (two discrete undetected faults). Such loss may be countered by periodic testing.
- The manufacturer's information concerning the maximum switching frequency of the light barrier must be observed.

Calculation of the probability of failure

The probability of failure of the safety-related stop function, which is also shown on the safety-related block diagram, is calculated. If the contacts of the enabling paths x and y are processed further by the control system, the additional control components concerned, e.g. contactors, must be considered in the calculation of the probability of failure.

- The light barrier F2 is a standard safety component. The probability of failure of 3.0×10^{-8} per hour [E] is added at the end of the calculation.
- $MTTF_d$: owing to the unknown loads, the B_{10d} value for K3 and K4 is 400,000 cycles [S]. At 220 working days, 8 working hours per day and a cycle time of 120 seconds, n_{op} is 52,800 switching operations per year, and the $MTTF_d$ is thus 75 years. This is also the $MTTF_d$ value of each channel (“high”).
- DC_{avg}: the DC of 99% for K3 to K4 is derived from incorporation of the mechanically linked break contacts into the actuation circuit of K2. This also corresponds to the DC_{avg} (“high”).
- Adequate measures against common cause failure (75 points): separation (15), well-tried components (5), FMEA (5), overvoltage protection etc. (15) and environmental conditions (25 + 10)
- The K3/K4 subsystem corresponds to Category 4 with a high $MTTF_d$ per channel (75 years) and high DC_{avg} (99%). This results in an average probability of dangerous failure of 3.37×10^{-8} per hour. The overall probability of failure is



determined by addition of the probability of dangerous failure of F2 (3.0×10^{-8} per hour) and is equal to 6.37×10^{-8} per hour. This corresponds to PL e. The probability of failure of downstream power components may have to be added for completion of the safety function.

- The wearing elements K3 and K4 should be replaced at intervals of approximately seven years (T_{10d}).

More detailed reference

- EN 60204-1: Safety of machinery – Electrical equipment of machines – Part 1: General requirements (IEC 60204-1:2005, modified) (06.06). Section 9.4.3: “Protection against maloperation due to earth faults, voltage interruptions and loss of circuit continuity”

Figure 8.61:
Determining of the PL by means of SISTEMA