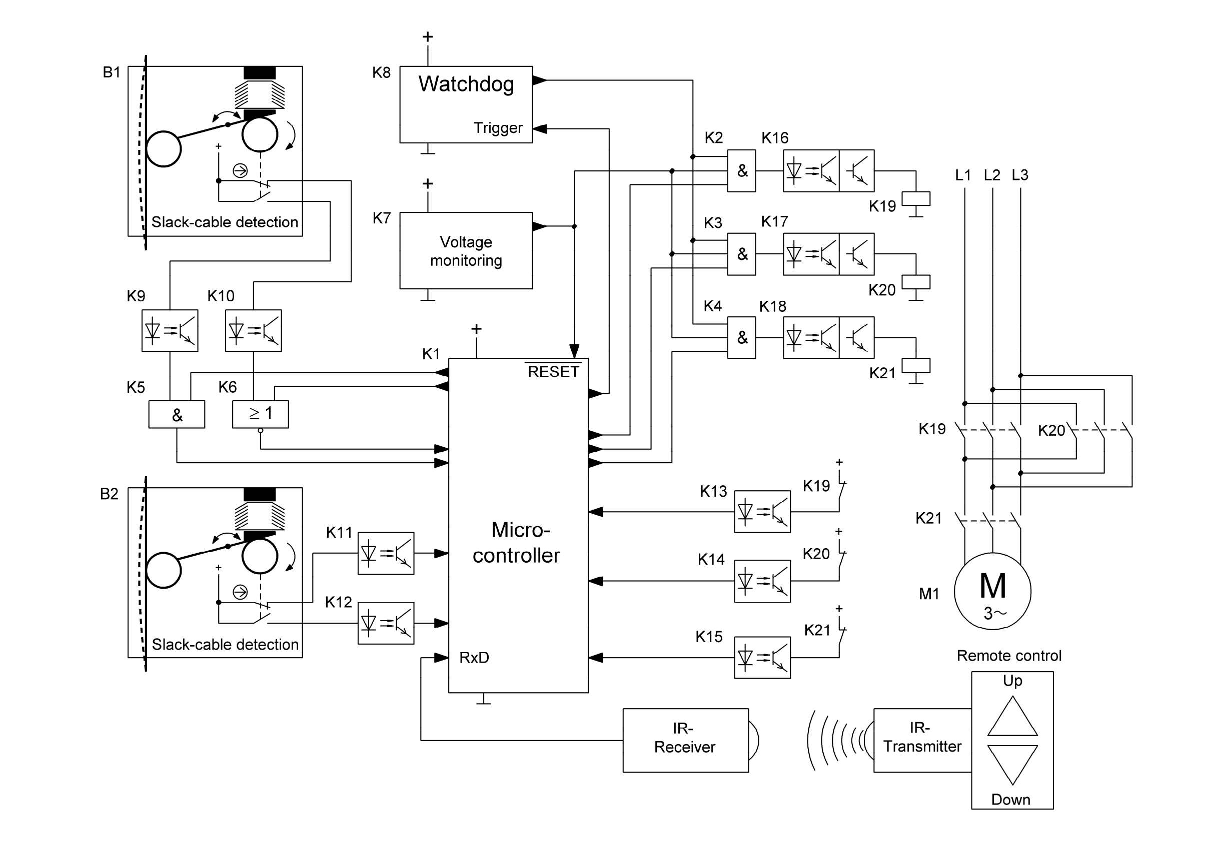
8.2.13 No-load sensing system for a hoist – Category 2 – PL d (Example 13)

Figure 8.25:
Combined electromechanical and programmable electronic control system for the prevention of no-load states on hoists

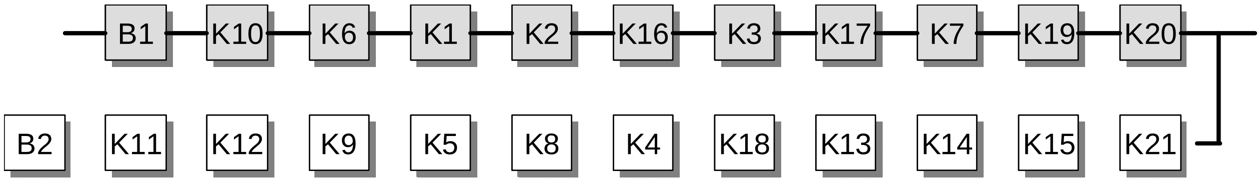


Safety function

- No-load/slack-cable detection: should a slack cable or suspension element be detected on a hoist, the downward movement is stopped (STO – safe torque off).

Functional description

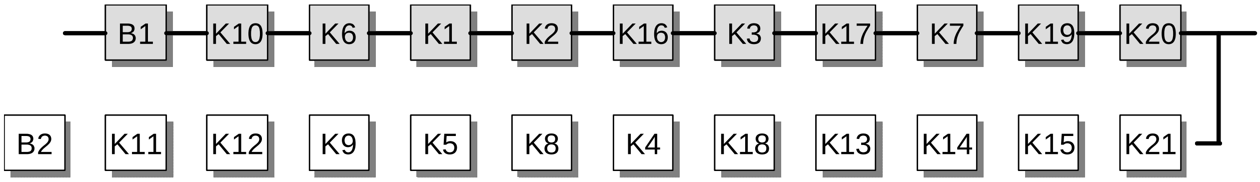
- Hoists driven by electric motors are widely used in studio and stage applications. During downward movement, the cable may become slack should the load stick or tilt or come to rest on other objects. In such cases, a risk exists for example of the obstruction suddenly giving way, the load slipping and consequently, danger arising for persons in the hazardous area.
- Upward and downward movements of the hoist can for example be controlled by means of an infrared remote control. This function is not evaluated here; it must, however, always be implemented with consideration for safety.



- In order for the hoist to be prevented from falling in the event of breakage of one suspension element, the load is borne by two suspension elements. A slack-cable switch B1/B2 with a break contact element/make contact element combination is fitted to each suspension element.
- The microcontroller K1 evaluates the switching states of the slack-cable switches B1 and B2. Via logic gates K2/K3 and optocoupled transistor amplifiers K16/K17, K1 also controls the contactor relays K19 and K20 for the upward and downward movements of the hoist.
- The switching states of the contacts of the slack-cable switches B1 and B2 are evaluated by the microcontroller K1 and tested for plausibility. For testing of the inputs used on the microcontroller, forced dynamics is employed on the signals from the slack-cable switch B1. This involves the microcontroller forcing a temporary signal change via the logic gates K5 and K6, in order to ascertain whether the inputs are still able to transmit the signal change. Forced dynamics of the signals of one slack-cable switch is sufficient.
- Self-tests of the integrated units such as ALU, RAM and ROM are performed in the microcontroller K1. The voltage monitor K7 detects faults in the supply voltage. Faults in the microcontroller are detected by temporal monitoring of the program sequence in the watchdog K8. The components K19 to K21 for control of the hoist's upward and downward movements are monitored by means of readback – decoupled by optocouplers K13 to K15 – in the microcontroller. Should a fault be detected, the hoist is shut off at a higher level by the component detecting the fault via the contactor relay K21, actuated by logic gate K4 and decoupled by optocoupler K18. If the watchdog K8 is not retriggered in time by the microcontroller K1, the movement of the hoist is stopped from K8 via all logic gates K2 to K4.

Design features

- Basic and well-tried safety principles are observed and the requirements of Category B are met. Protective circuits as described in the initial paragraphs of Chapter 8 are implemented.
- A slack cable is detected redundantly for both suspension elements via the two slack-cable switches B1 and B2. These switches contain position switches with direct opening action in accordance with IEC 60947-5-1, Annex K.
- A stable arrangement is assured for the operating mechanism of the slack-cable switches.
- K19 to K21 possess mechanically linked contact elements to IEC 60947-5-1, Annex L.



- The software (SRESW) for K1 is programmed in accordance with the requirements for PL d and the instructions in Section 6.3.

Remarks

- The draft version of DIN 15560-46, Section 5.1.2 requires at least two suspension elements in order to prevent a hoist and its load from falling.
- Visual inspections and maintenance of the suspension elements must be performed at suitable intervals.
- Parts of the circuit structure as shown are not explicitly designed to prevent possible hazards resulting from unintended movement of the hoist (unexpected start-up).
- The circuit structure used attains PL d for the safety function under consideration here, as is demonstrated by the calculation of the probability of failure. Use of the risk graph to determine the required Performance Level PL_r with the parameters S2, F1 and P1 results in PL_r c in accordance with DIN 15560-46, Section B.1.1.3.3, provided the hoist is operated under observation and only by skilled personnel. Should this not be the case, PL_r d is required.

Calculation of the probability of failure

- Components are summarized in blocks in Figure 8.23 in the interests of clarity. K9 to K15 each contain one optocoupler and two resistances. K16 to K18 additionally each contain a transistor for driving the downstream contactor relays.
- For application of the simplified procedure for estimation of the achieved PL, the components in the circuit are assigned to the blocks of the designated architecture for Category 2 as follows:

  I: B1

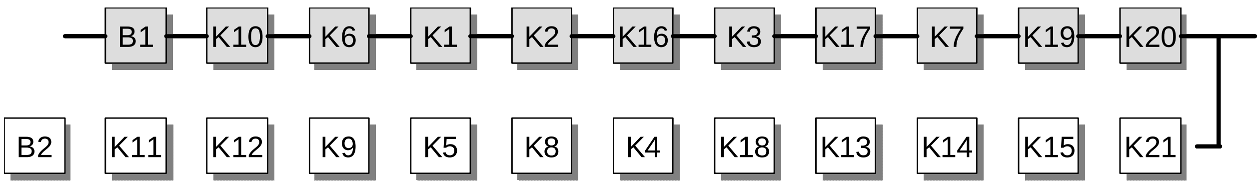
  L: K10, K6, K1, K2, K16, K3, K17, K7

  O: K19, K20

  TE: B2, K11, K12, K, K5, K8, K13, K14, K15

  OTE: K21

- $MTTF_d$: the $MTTF_d$ values required for the calculation are obtained from EN ISO 13849-1 [S], and from SN 29500-2 and SN 29500-14 [D]. The following values are substituted for B1 and B2: B_{10d} = 100,000 cycles [E], n_{op} = 10 cycles per year. For the contactor relays K19 to K21: B_{10d} = 400,000 cycles [S], n_{op} = 10 cycles per day on 365 working days. An $MTTF_d$ of 1,141 years [D] is substituted for the microcontroller K1. The following $MTTF_d$ values are



substituted for the electronic components [D]: 4,566 years for the watchdog K8, 5,707 years for the optocouplers K9 to K18, 22,831 years for the logic gates K2 to K6, 38,051 years for the voltage monitor K7, 45,662 years for transistors and 228,310 years for resistors. Summation of the failure rates for all components of the functional channel (blocks I, L and O) produces an $MTTF_d$ value of 288 years. This value is capped to 100 years ("High") in accordance with the requirements of the standard.

- The $MTTF_d$ of the test channel is produced by summation of the failure rates of all components of blocks TE and OTE. It is equal to 393 years and is thus greater than or equal to half of the $MTTF_d$ of the functional channel.
- DC_{avg}: the *DC* is 60% for B1, K10 and K6 owing to cross-checking of B1 and B2 in K1 with a low demand rate upon the safety function. The *DC* is 60% for K1 owing to temporal monitoring of the program sequence and self-tests of simple effectiveness. The *DC* is 99% for K2, K3, K16, K17, K19 and K20 owing to direct monitoring by means of mechanically linked contact elements. For K7, the *DC* is 0%. The averaging formula returns a result of 85% ("low") for DC_{avg}.
- Adequate measures against common cause failure (65 points): separation (15), overvoltage protection (15) and environmental conditions (25 + 10)
- The combination of the control elements corresponds to Category 2 with a high $MTTF_d$ per channel (100 years) and low DC_{avg} (85%). This results in an average probability of dangerous failure of 2.72×10^{-7} per hour. This corresponds to PL d.

More detailed references

- DIN 15560-46: Scheinwerfer für Film, Fernsehen, Bühne und Photographie – Teil 46: Bewegliche Leuchtenhänger; Sicherheitstechnische Anforderungen und Prüfung (Normentwurf) (06.07). Beuth, Berlin 2007
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