EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání

MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

8. Fundamentals of logic control

8.1 Division, logical operations, relay logic

8.2 Contactless logic control, basic logic gates

8.3 Safety related parts of control systems

8.4 Safety relays, examples of applications

Doc. Ing. Stanislav Kocman, Ph.D.
March 2018

8.1. Division, logical operations, relay logic

8.1.1. Division of logic control

- manually operated: the simplest circuits with circuit breakers, contactors, switches…
- automatically operated: circuits realizing logical operations and controlled by internal or external components or devices
    - relay logic: circuits are realized using various types of relays wired in a fixed connection
    - logic module: using semiconductor logic gates in a fixed connection to realize logical operations
    - programmable logic controller (PLC): for more complex circuits, it provides flexible, ruggedized and easily programmable controlling. Output results must be produced in a response to input conditions within a limited time (https://en.wikipedia.org/wiki/Programmable_logic_controller)
    - single-board computer: embedded computer controller designed to do some specific operations (https://en.wikipedia.org/wiki/Single-board_computer)
    - microcontroller: small computer on a single integrated circuit used in automatically controlled products and device (https://en.wikipedia.org/wiki/Microcontroller)
- safety systems: ensure a protection against hazardous situations

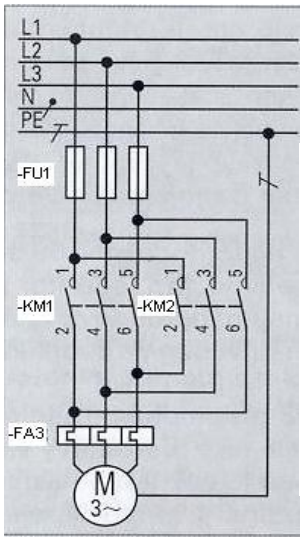
8.1.2. Logical operations

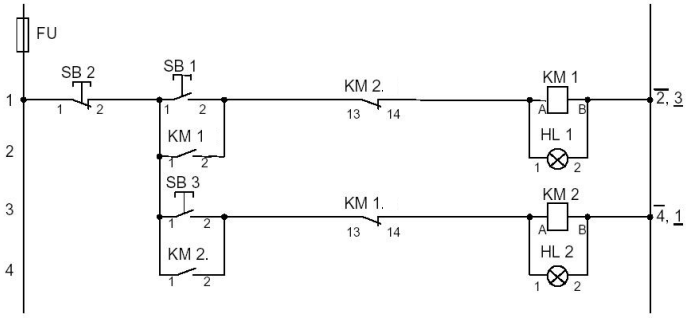
Some examples of operations in the area of drives with electrical motor are listed below:

- switch on
- start-up and controlled start-up
- speed adjusting or changing
- change of rotational or feed direction
- stopping
- braking and controlled braking
- light signaling and tone beep
- lockout

8.1.3. Relay logic

The circuits are realized using various types of relays (control, overload protection, time delay relay…), start and reset switches, light signaling, etc., wired in a fixed connection to realize some functions. The circuits consist of a power circuit (for the energy supply of a power device, e.g. electrical motor), and a control circuit with relays to ensure the logical operation of the power device (designed as a ladder logic diagram). An example of the reversible drive of asynchronous motor is shown in the figure (https://en.wikipedia.org/wiki/Relay_logic).



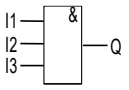
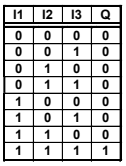
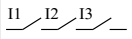
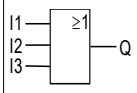
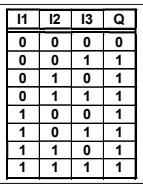
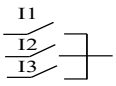
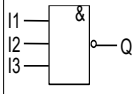
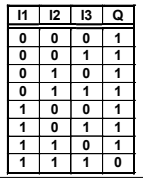
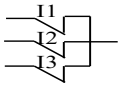
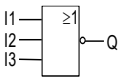
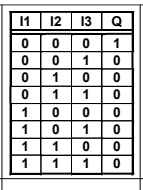
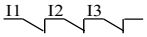
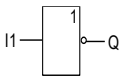
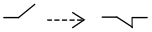


8.2. Contactless logic control, basic logic gates

8.2.1. Contactless logic control: logic module

Logic module is an intelligent logic module for small automation projects with easy installation and convenient programming. It enables to connect several hundreds of logic gates realizing both basic and special functions to replace a large number of conventional (relay) switching and control devices.

The basic logical functions are logical multiplication (AND), logical addition (OR), inverted logical multiplication (NAND), inverted logical addition (NOR) and inverter (NOT) (G. Rizzoni: Fundamentals of electrical engineering).

Type	Symbol	Logic table	Relay logic
AND			
OR			
NAND			
NOR			
NOT			

Advantages of logic module over relay logic:

- small dimension
- low losses
- insensibility against environment
- higher switching rate and speed
- reliability is more
- reduced hard-wiring (it is easier to make changes in software than in hardware)
- cost effective control system

8.3. Safety related parts of control systems

The safety must be taken into account already from the design stage of an installation (e.g. drilling, press, turning machines, automatic welders…) and must be kept in mind at all stages in the life of a machine: design, manufacture, installation, adjustment, operation, maintenance and eventual scrapping. These priorities should be taken into account when a device is designed:

- take into account rules of safety work
- to protect hazardous situations on devices
- to identify the hazards
- to state hazardous zones
- device safe operation
- risks related to the potential hazard
- severity of the potential harm
- probability of occurrence

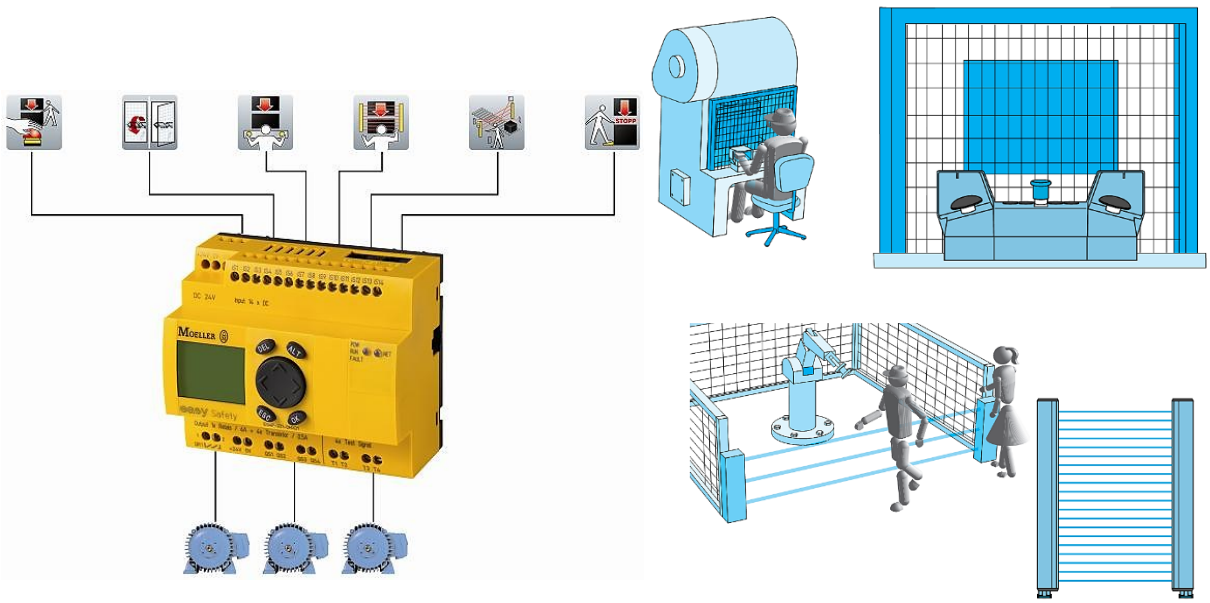
In the safety circuits a safety relay with force-guided contacts is used. They are mechanically linked together, so that when the relay coil is energized or de-energized, all of the linked contacts move together. If one set of contacts in the safety relay becomes immobilized (e.g. welded), no other contact of the same relay will be able to move. In the safety relay the off-state is kept by a cam, whereas in the standard relay by a spring, which is less safe (https://en.wikipedia.org/wiki/Relay#Force-guided_contacts_relay).

8.4. Safety relays, examples of applications

The safety relay ensures monitoring (by safety gate monitor) of a state of safety device connected to its input (e.g. emergency stop), secure safe stop or position and safety of persons. It consists of logic circuit (safety gate monitor), terminals for inputs and outputs, auxiliary contacts, safety contacts.

These devices with safety function can be used in safety circuits:

- interlock switches to detect the position of movable guards for control interlocking. Protective devices to permit tasks such as loading/unloading, cleaning, setting, adjustment.
- light curtains to detect approach to dangerous areas. For the protection of persons operating or working in the vicinity of machinery, by the stopping of dangerous movement of parts as soon as one of the light beams is broken.
- safety mats to detect persons. Used in front of or around potentially dangerous machines or robots and work by detecting persons stepping onto the mat.
- solenoid interlocks (powered guards) to prevent opening of guards. They are used on loads with high inertia i.e. where the stopping time is long and it is preferable to permit access only when the dangerous movement has stopped.
- two hand control stations and footswitches. Used to ensure the operator is standing away from the danger area when causing dangerous movements.
- emergency stop. Used in an emergency. It need to be robust, dependable, and available at all positions where it might be necessary to operate them (e.g. conveyor belt).



A basic principle and a structure of a safety relay (with redundant output and testing) is shown below.

