The Programmable Logic Controller

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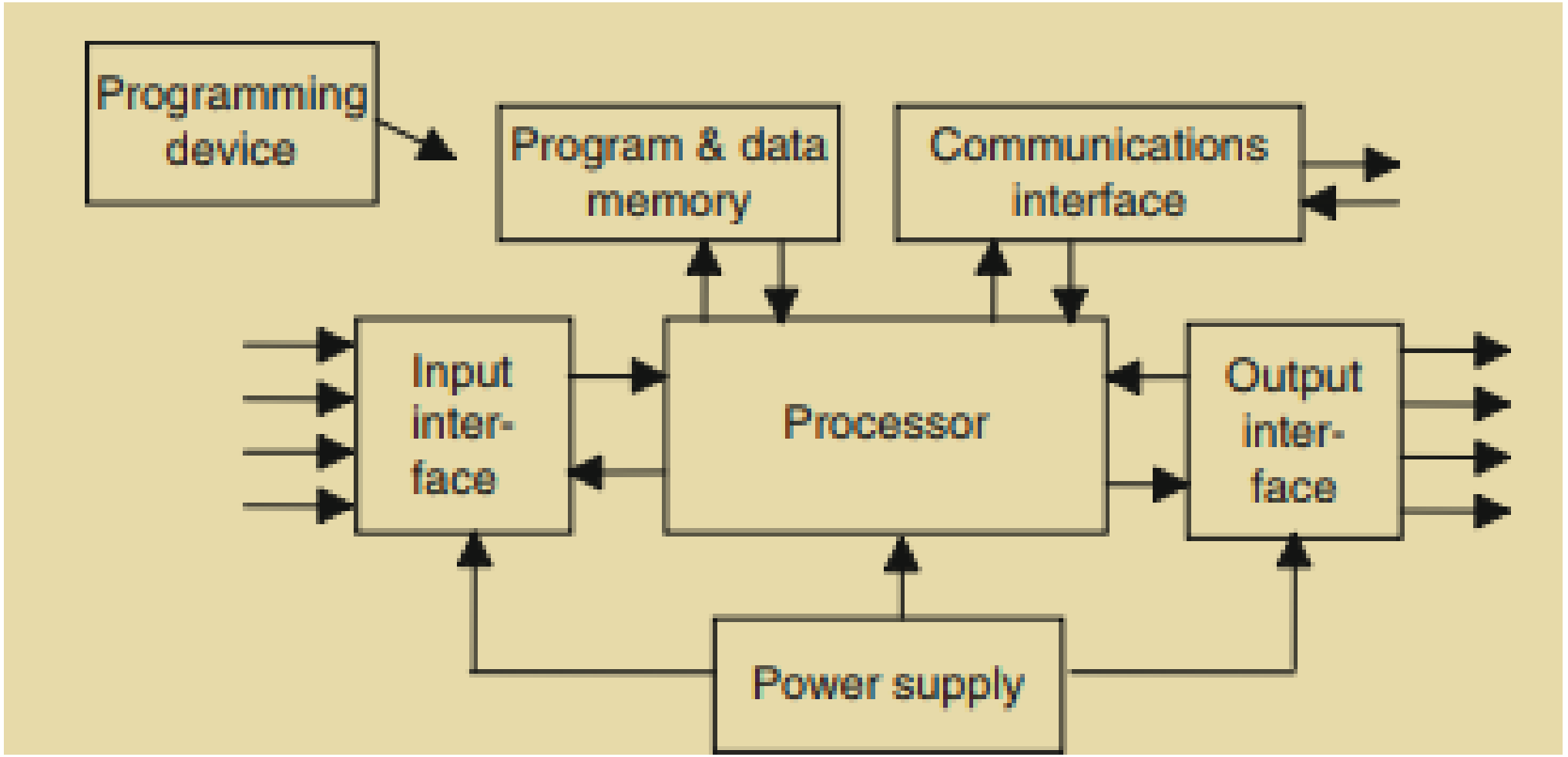
Introduction

- A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, and arithmetic in order to control machines and processes
- It is designed to be operated by engineers with limited knowledge of computers and computing languages.

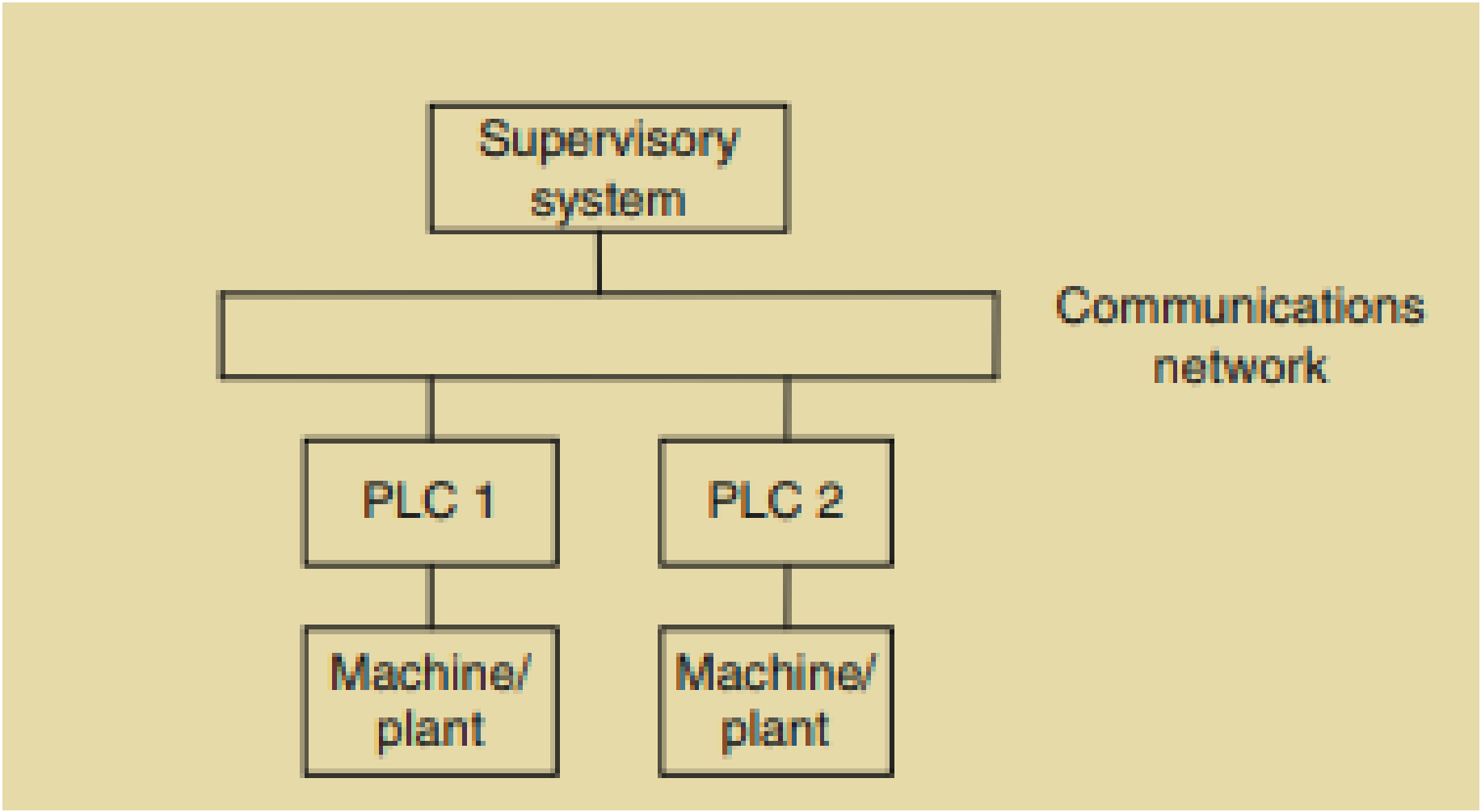
Introduction

- PLCs are similar to computers
- computers are optimized for calculation and display tasks.
- PLCs are optimized for control tasks and the industrial environment.
- Are rugged and designed to withstand vibrations, temperature, humidity, and noise
- Have interfacing for inputs and outputs already inside the controller
- Are easily programmed and have an easily understood programming language that is primarily concerned with logic and switching operations

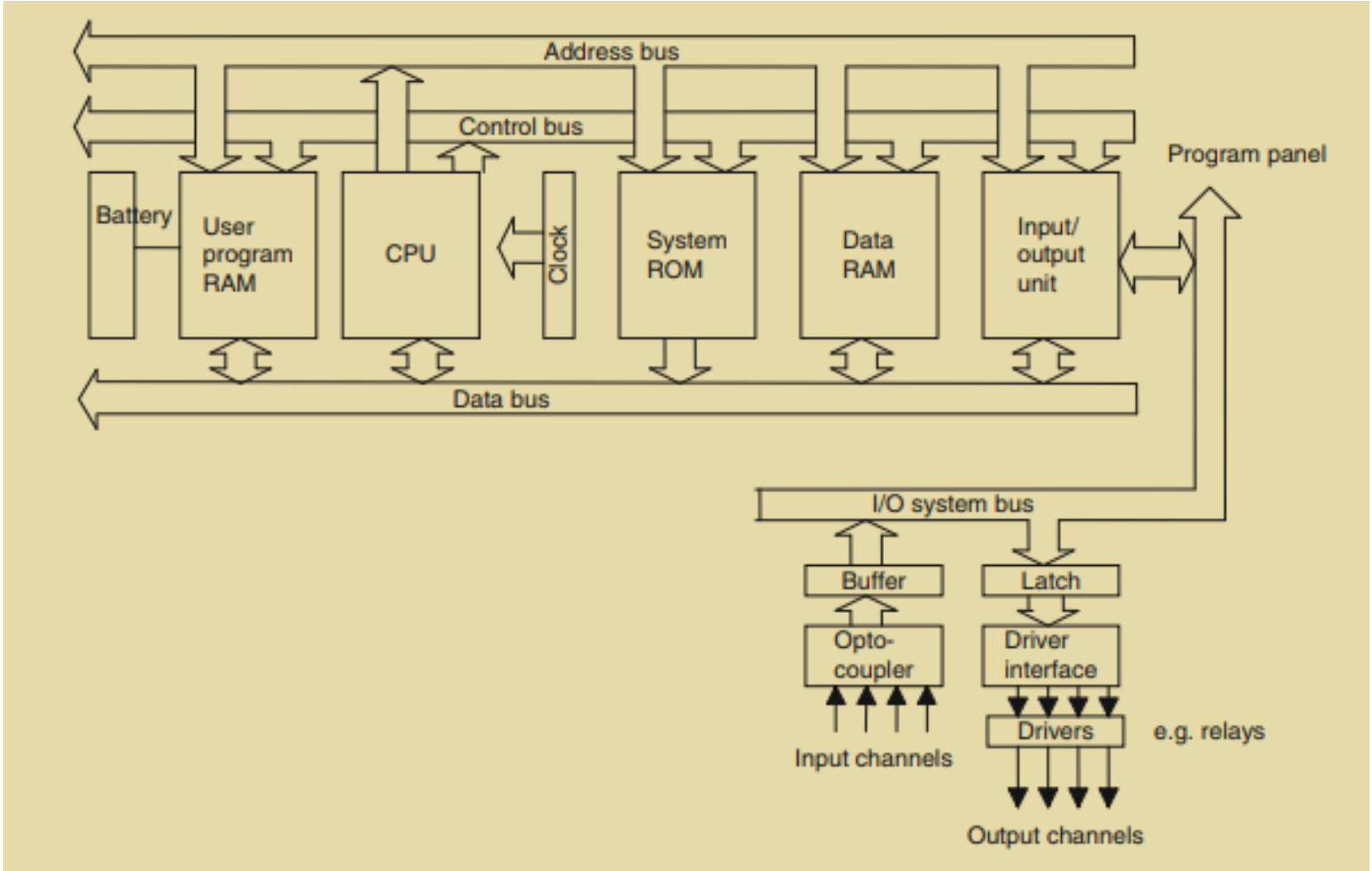
PLC system


Programming device
Program & data memory
Communications interface
Input inter-face
Processor
Output inter-face
Power supply

Basic communications model.



Internal Architecture



Internal Architecture

CPU

- An arithmetic and logic unit (ALU)
- Memory
- Control unit

Buses

- Data bus
- Address bus
- control bus
- system bus

Internal Architecture

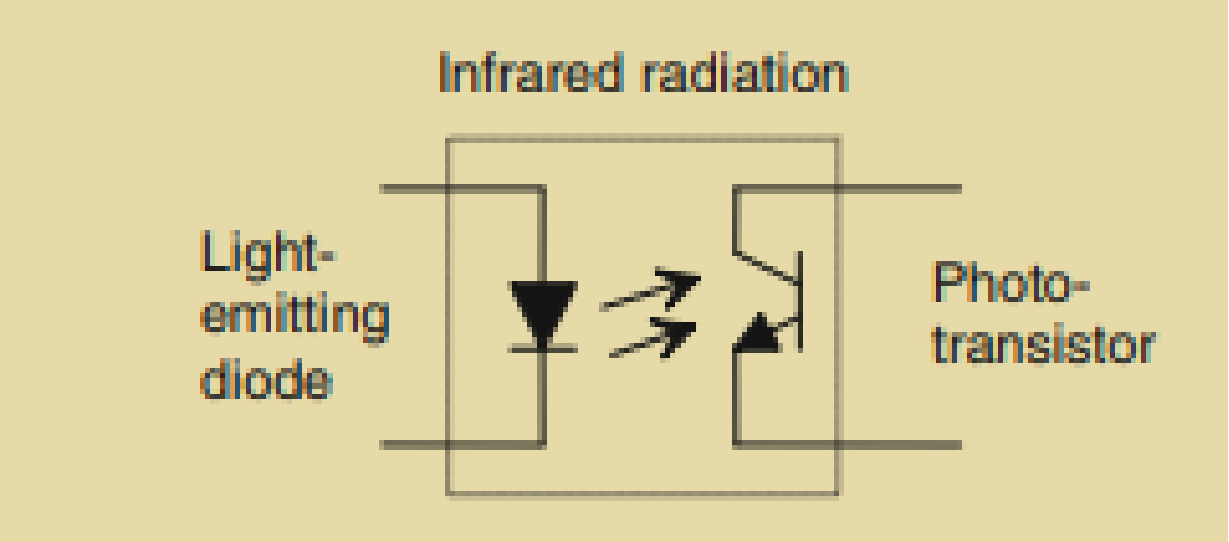
Memory

- System read-only-memory: gives permanent storage for the operating system and fixed data used by the CPU
- Random-access memory (RAM): is used for the user's program
- Random-access memory (RAM):a data table or register table. is used for data.
- Erasable and programmable read-only-memory (EPROM): is used to store programs permanently.

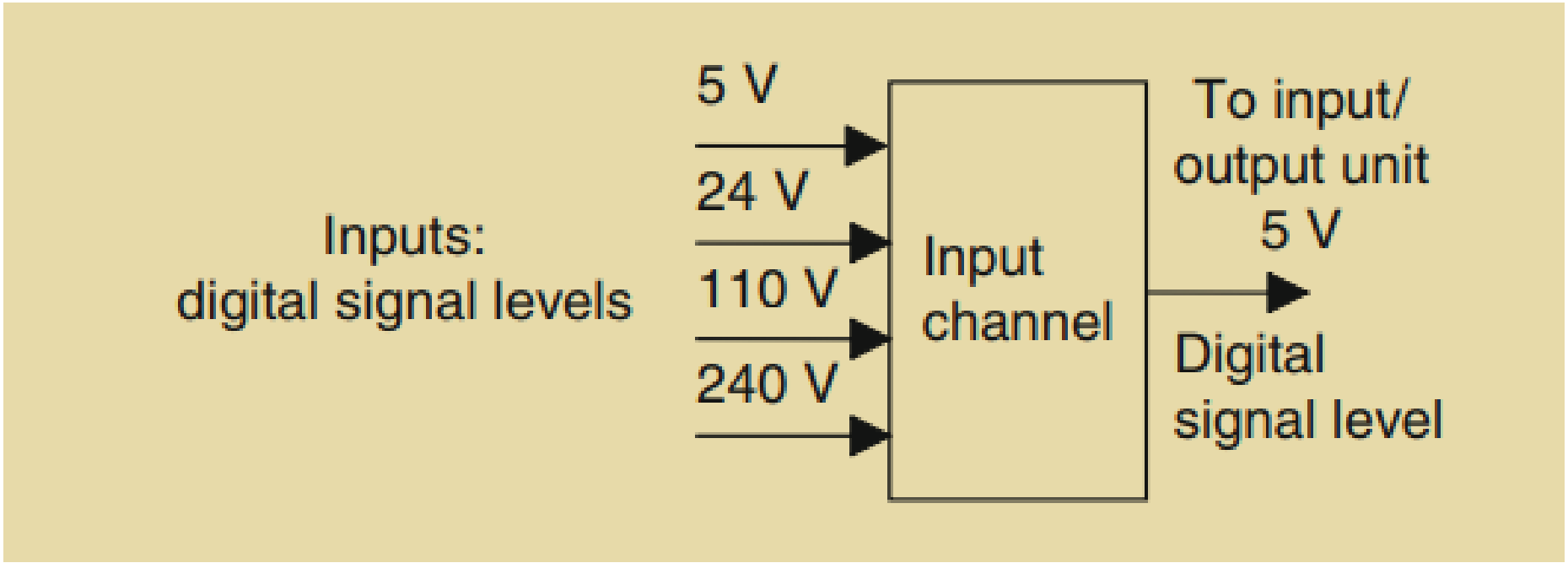
Input/Output Unit

Opto-Isolation

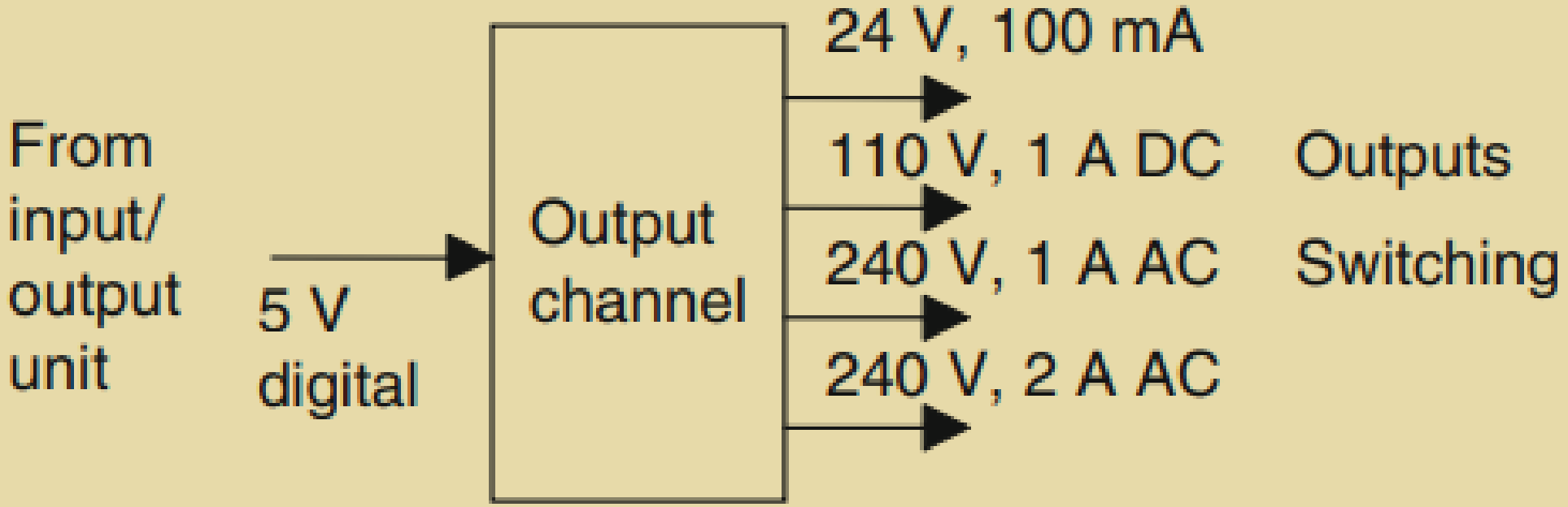
- provides the interface between the system and the outside world.
- Allowing for connections to be made through input/output channels to input/output devices
- provide isolation and signal conditioning functions



A range of inputs



A range of outputs



Types of outputs

Relay type:

- Allows small currents to switch much larger currents
- Isolates the PLC from the external circuit
- relatively slow to operate.
- Relay outputs are suitable for AC and DC switching.
- They can withstand high surge currents and voltage transients.

Types of outputs

Transistor type:

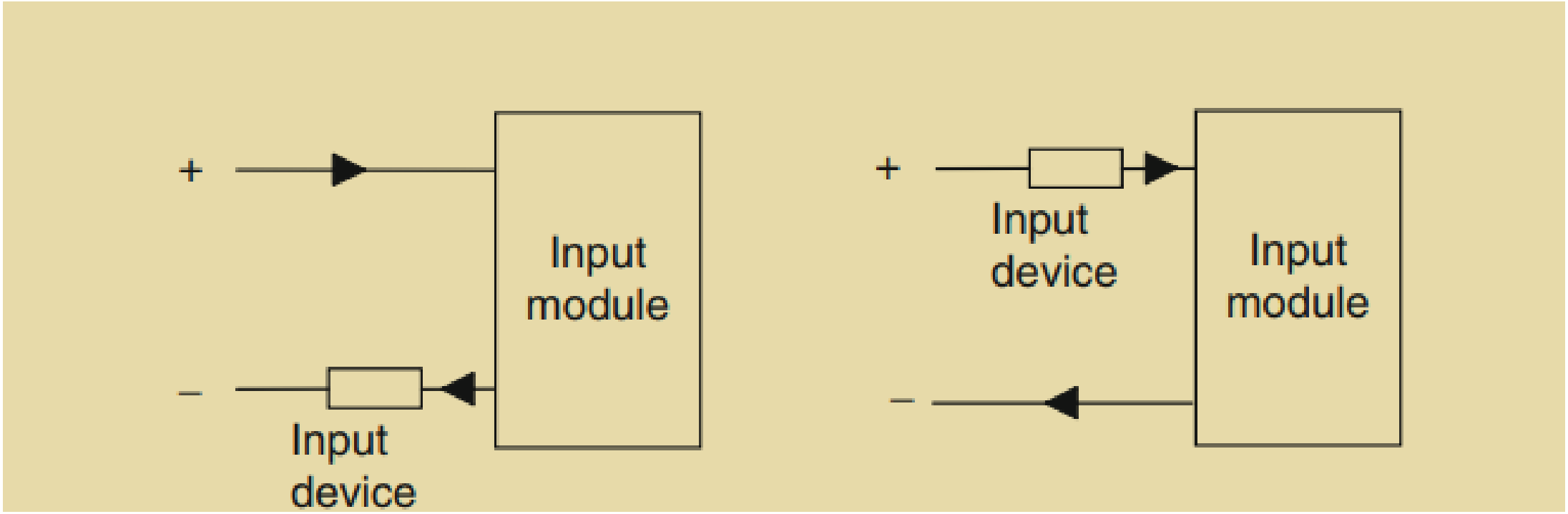
- Transistor to switch current through the external circuit.
- Considerably faster switching action
- Used for DC switching
- destroyed by overcurrent and high reverse voltage.
- For protection, either a fuse or built-in electronic protection is used.
- Optoisolators are used to provide isolation.

Types of outputs

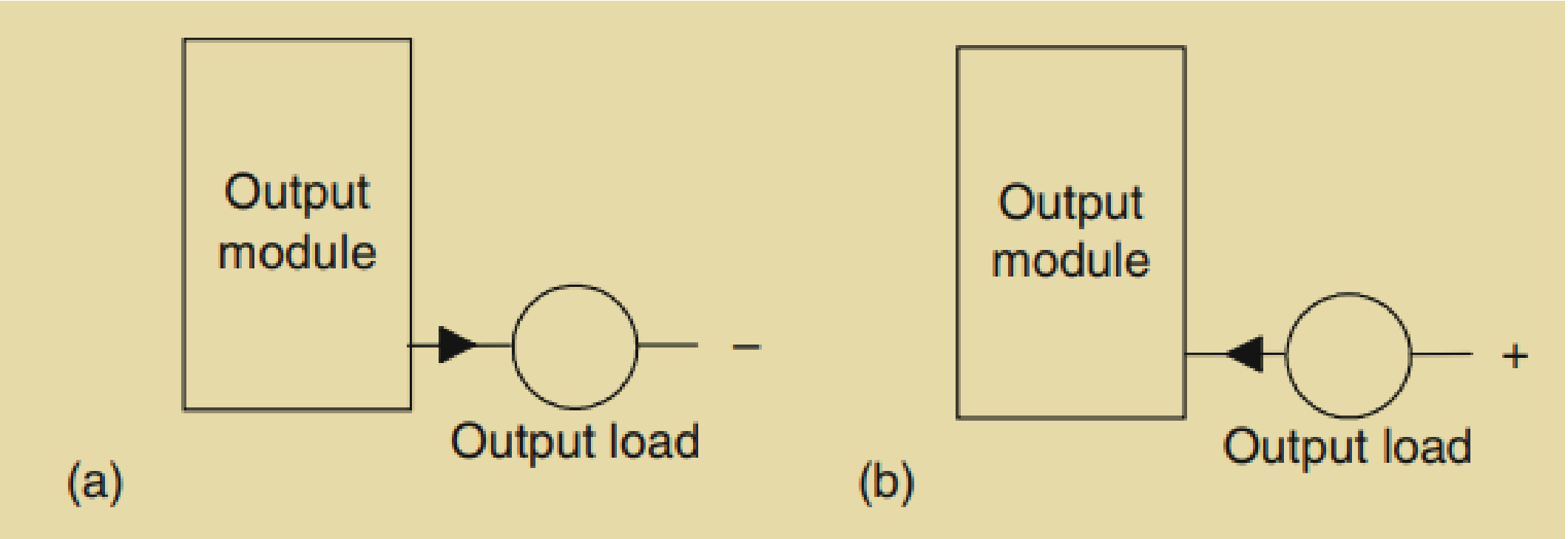
Triac outputs

- AC operation
- Very easily destroyed by overcurrent.
- Fuses are virtually always included to protect such outputs.
- Optoisolators are used to provide isolation

Sourcing and Sinking



Sourcing and Sinking



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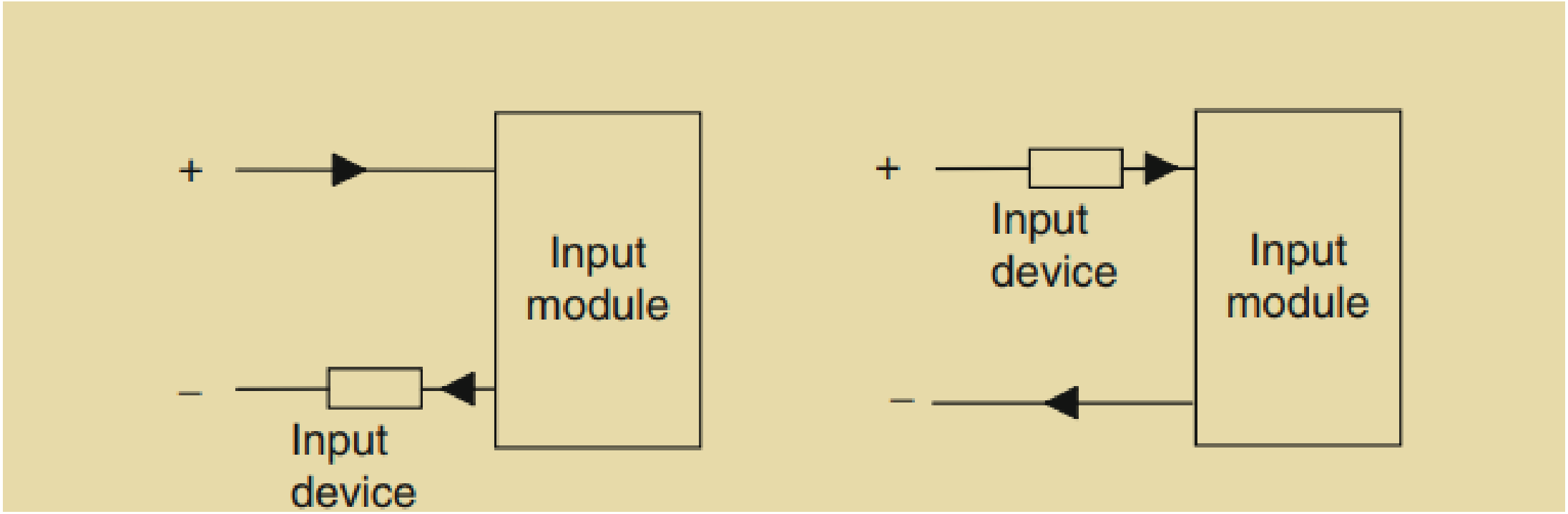

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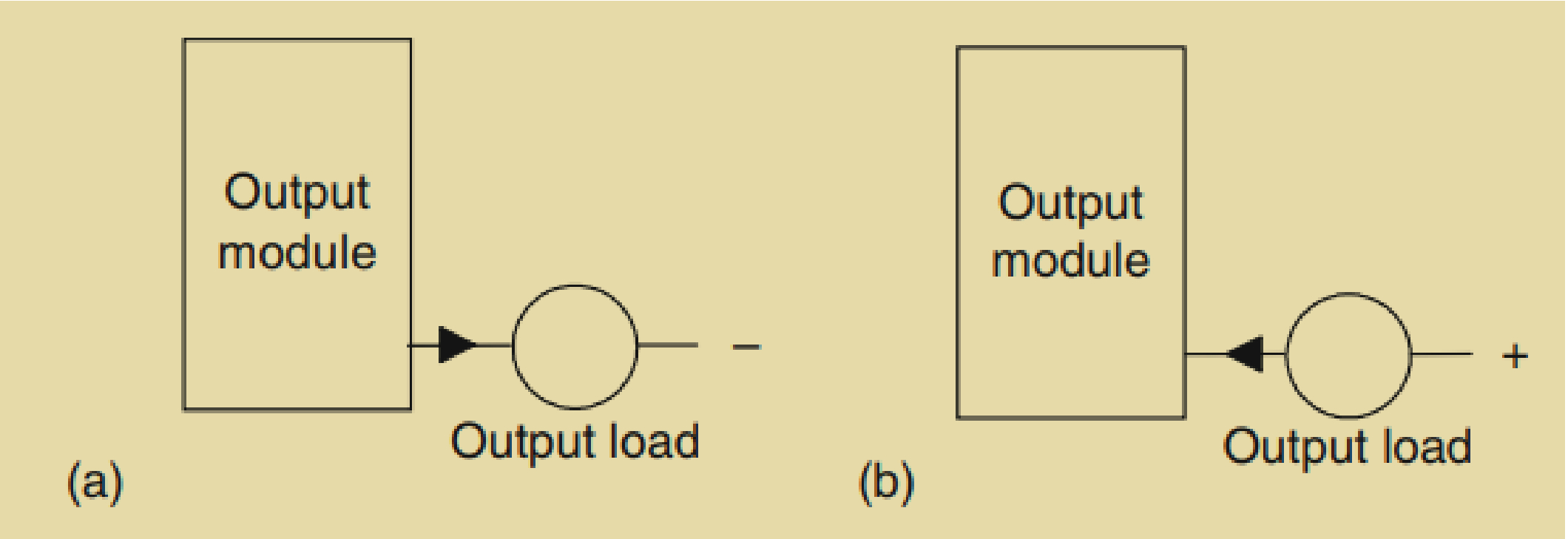


The IEC Standard

- Part 1: General definition of basic terminology and concepts.
- Part 2: Electronic and mechanical equipment requirements and verification tests for PLCs and associated equipment.
- Part 3: Programming languages. Five languages are defined: ladder diagram (LAD), sequential function charts (SFC), function block diagram (FBD), structured text (ST), and instruction list (IL).
- Part 4: Guidance on selection, installation, and maintenance of PLCs.
- Part 5: Software facilities needed for communication with other devices based on the Manufacturing Messaging Specification (MMS).
- Part 6: Communications via field bus software facilities.
- Part 7: Fuzzy control programming.
- Part 8: Guidelines for the implementation of PLC programming languages defined in Part 3.

Programming PLCs

- Handheld: Normally contains enough memory to allow the unit to retain programs while being carried from one place to another.
- Desktop consoles: are likely to have a visual display unit with a full keyboard and screen display.
- Personal computers: are widely configured as program development workstations.

Input/Output Devices

Performance of sensors:

Accuracy : The extent to which the value indicated by a measurement system or element might be wrong.

Example: A temperature sensor might have an accuracy of ±0.1C.

nonlinearity error: describe the error that occurs as a

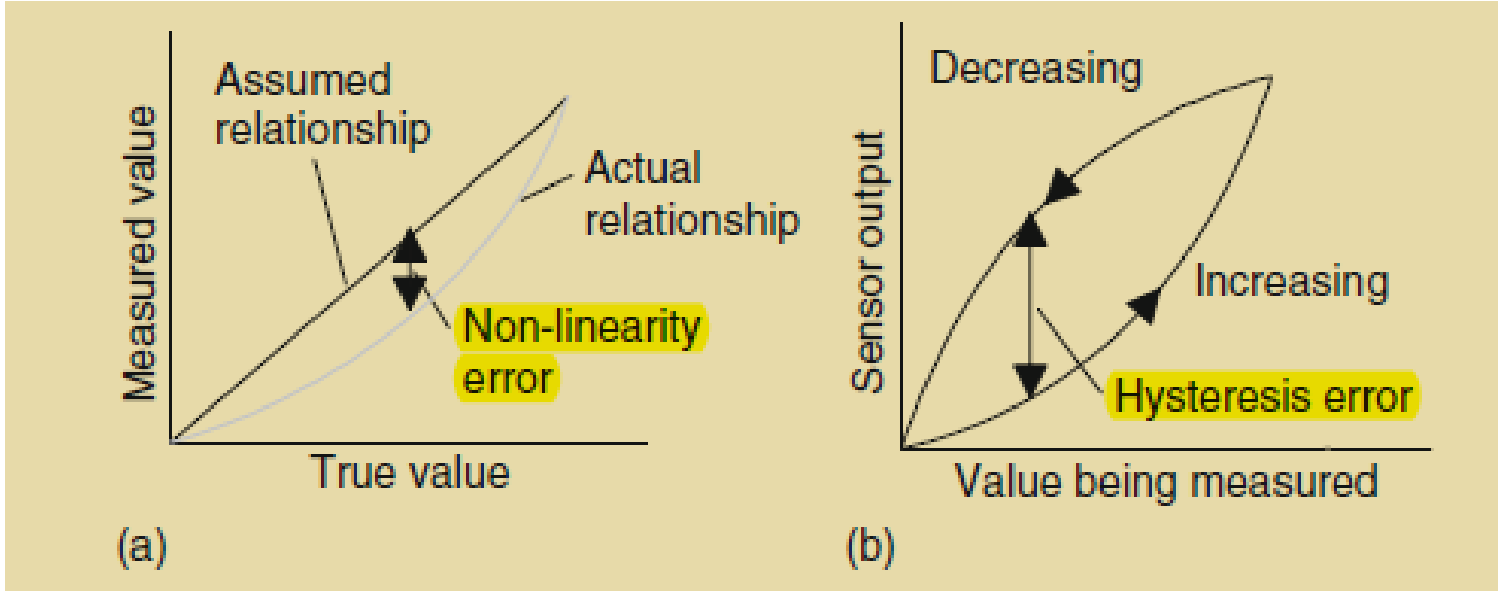
result of assuming a linear relationship between the input and output over the working range

A graph of output plotted against input is assumed to give a straight line.

Input/Output Devices

Hysteresis error:

used for the difference in outputs given from the same value of quantity being measured according to whether that value has been reached by a continuously increasing change or a continuously decreasing change.



Input/Output Devices

Range: the limits between which the inputs can vary.

Example: a resistance temperature sensor might be quoted as having a range of 200 c° to þ800 °C.

Repeatability: refers to the ability of a measurement system to give the same value for repeated measurements of the same value of a variable. Common causes of lack of repeatability are random fluctuations in the environment, such as changes in temperature and humidity.

Reliability :The probability that it will operate to an agreed level of performance for a specified period, subject to specified environmental conditions.

Input/Output Devices

Sensitivity: indicates how much the output of an instrument system or system element changes when the quantity being measured changes by a given amount, that is, the ratio ouput/input.

Example: a thermocouple might have a sensitivity of 20 mV/C and so give an output of 20 mV for each 1C change in temperature.

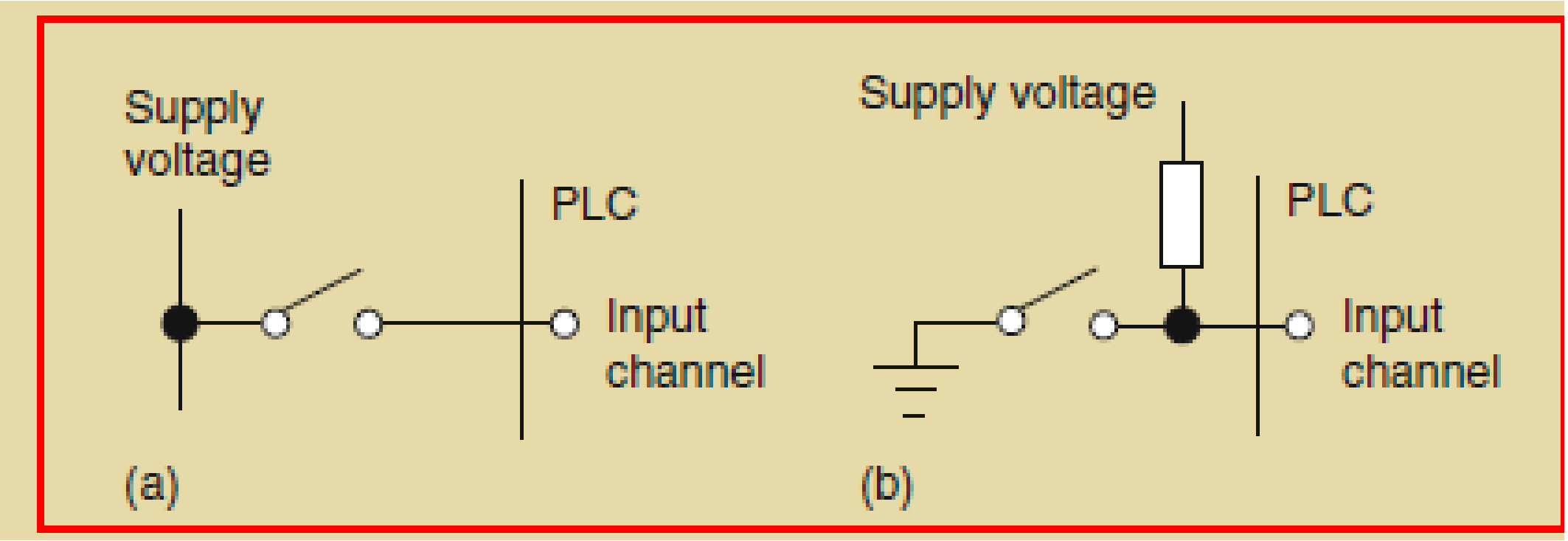
Stability :Its ability to give the same output when used to measure a constant input over a period of time.

Drift: describe the change in output that occurs over time. The drift may be expressed as a percentage of the full range output.

Zero drift: refers to the changes that occur in output when there is zero input.

Input/Output Devices

- Mechanical Switches: Generates an on/off signal or signals as a result of some mechanical input causing the switch to open or close



Input/Output Devices

- Switch indicate the presence of a workpiece on a machining table, the workpiece pressing against the switch and so closing it.
- The absence of the workpiece is indicated by the switch being open and its presence by it being closed.
- From figure a

Workpiece not present: 0

Workpiece present: 1

The 1 level might correspond to a 24 V DC input, the 0 to a 0 V input.

From figure b

The switch is open the supply voltage is applied to the PLC input;

when the switch is closed the input voltage drops to a low value.

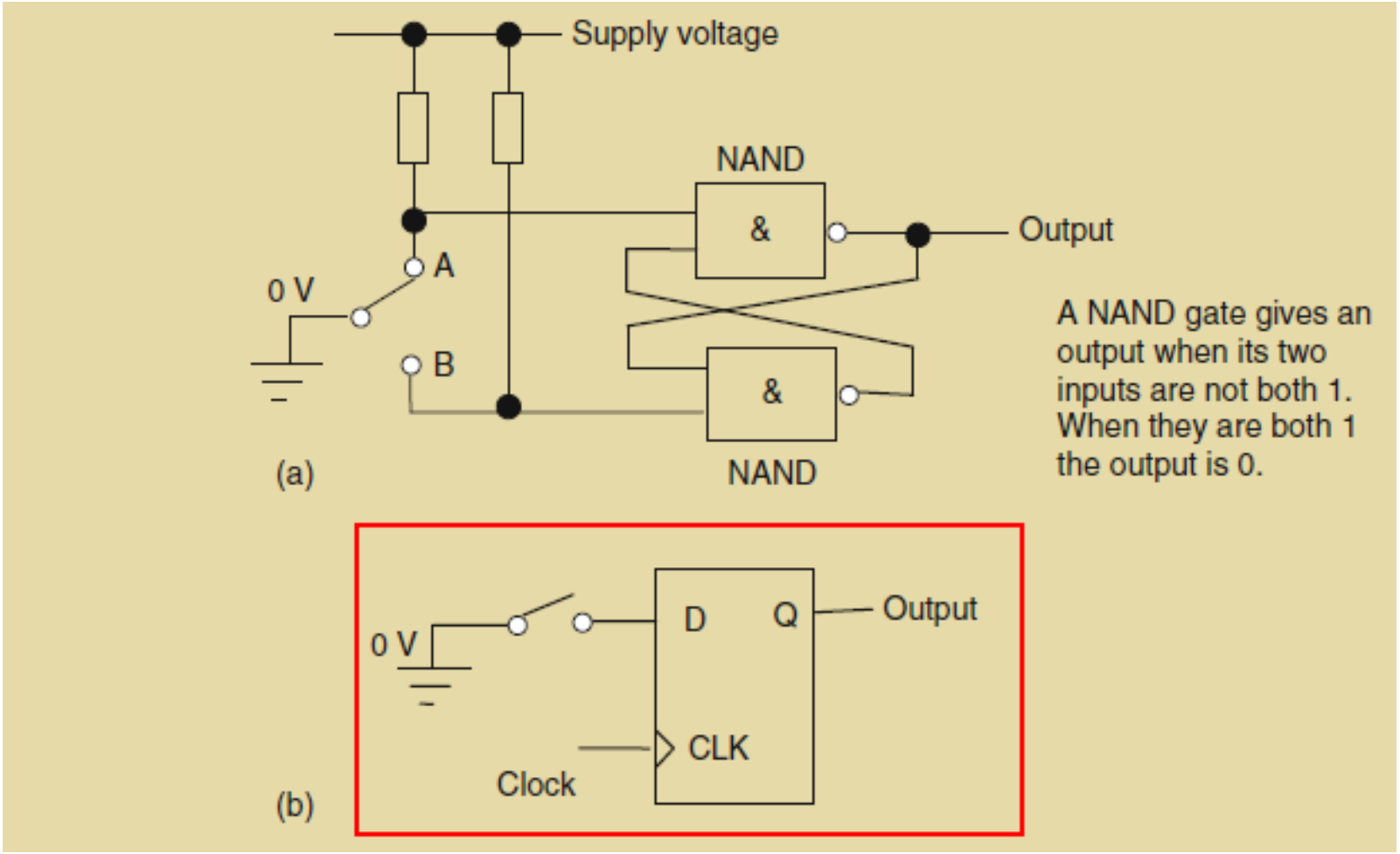
Workpiece not present: 1

Workpiece present: 0

Input/Output Devices

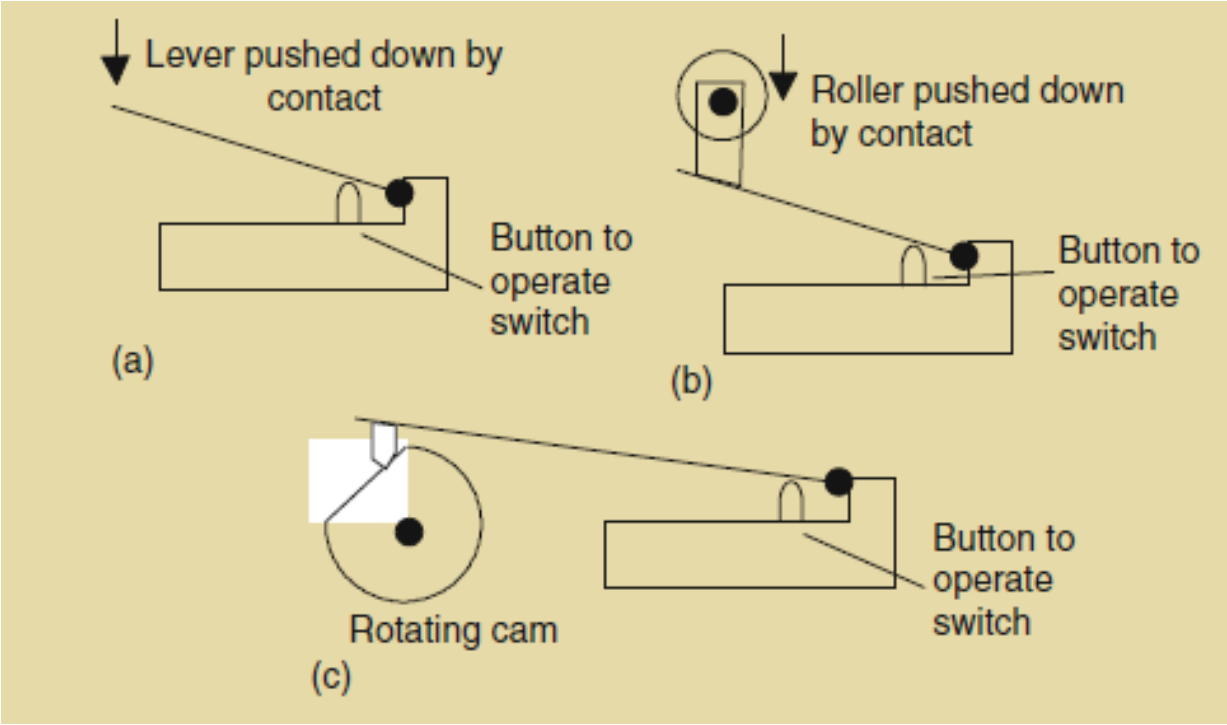
- Switches are available with normally open (NO) or normally closed (NC) contacts or can be configured as either by choice of the relevant contacts
- A problem with mechanical switches: Bounce

Input/Output Devices



Input/Output Devices

Limit switch: applies to a switch that is used to detect the presence or passage of a moving part. It can be actuated by a cam, roller, or lever.



Limit switches actuated by (a) lever, (b) roller, and (c) cam.

Input/Output Devices

Liquid-level switches:

- To control the level of liquids in tanks.
- Essentially, these are vertical floats that move with the liquid level,
- The movement is used to operate switch contacts

Proximity Switches:

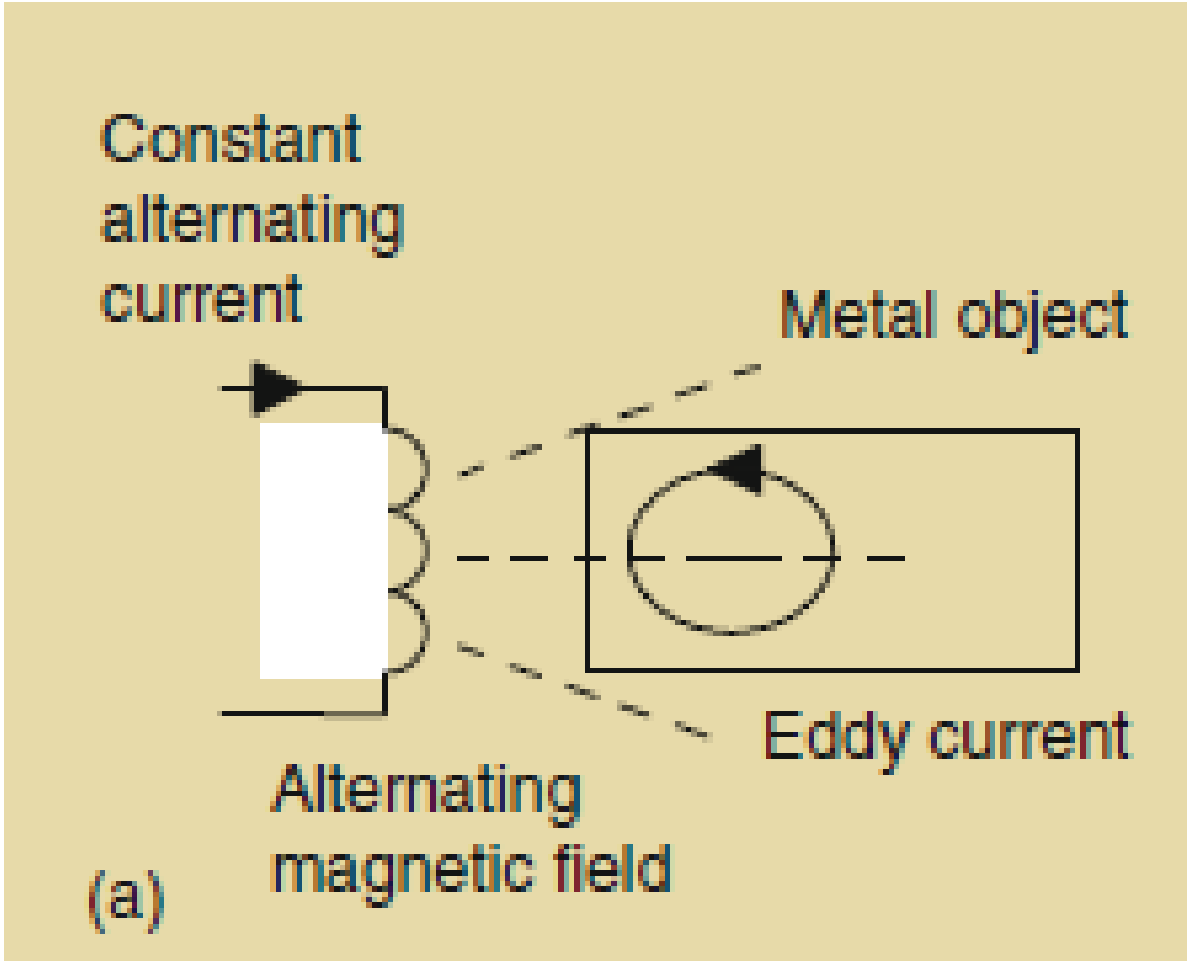
Detect the presence of an item without making contact with it.

Three types

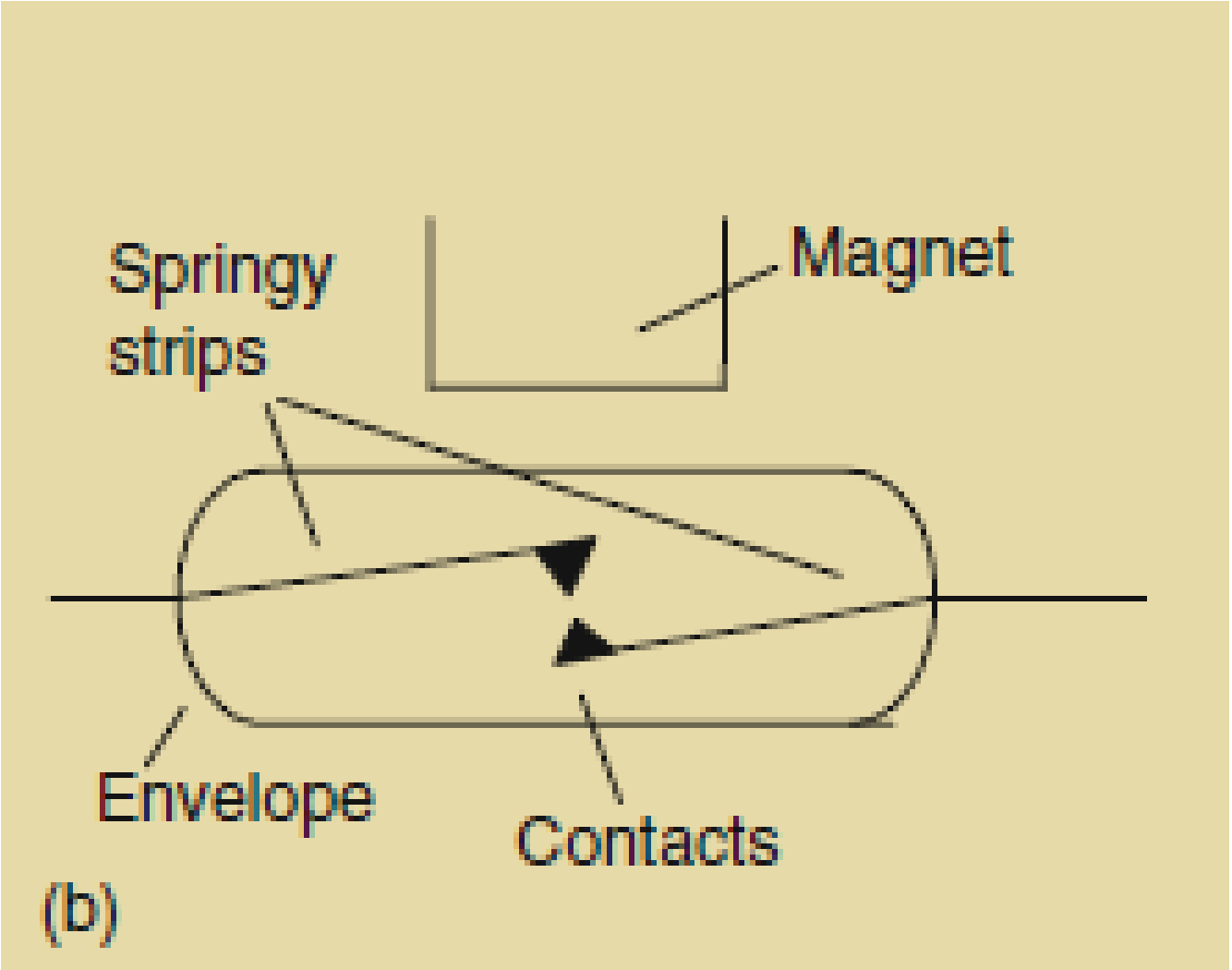
1. Eddy Current 2. Reed Switch 3. Capacitive

Kaman Precision Products - Eddy Current Technology.mp4

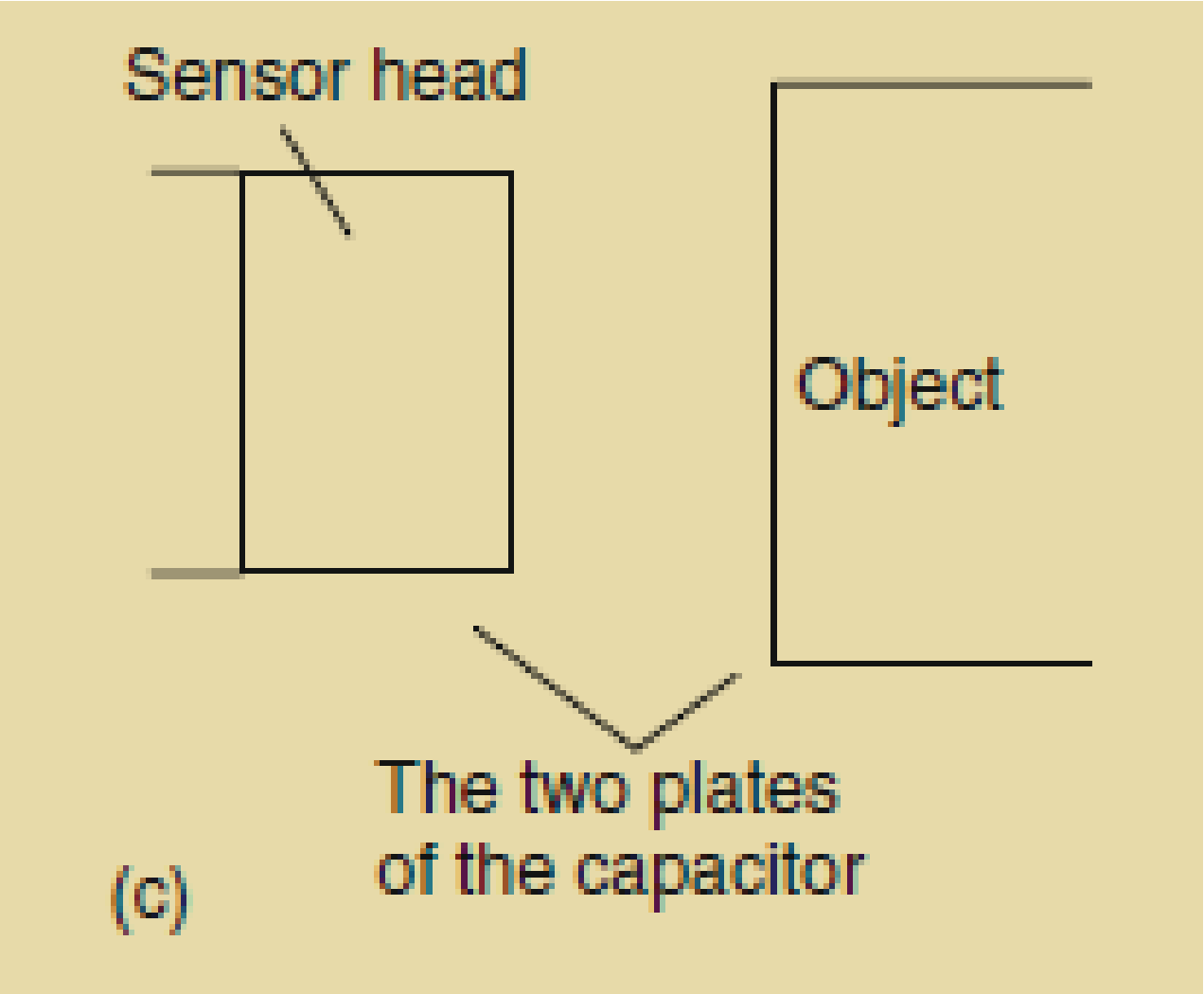
Input/Output Devices



Input/Output Devices



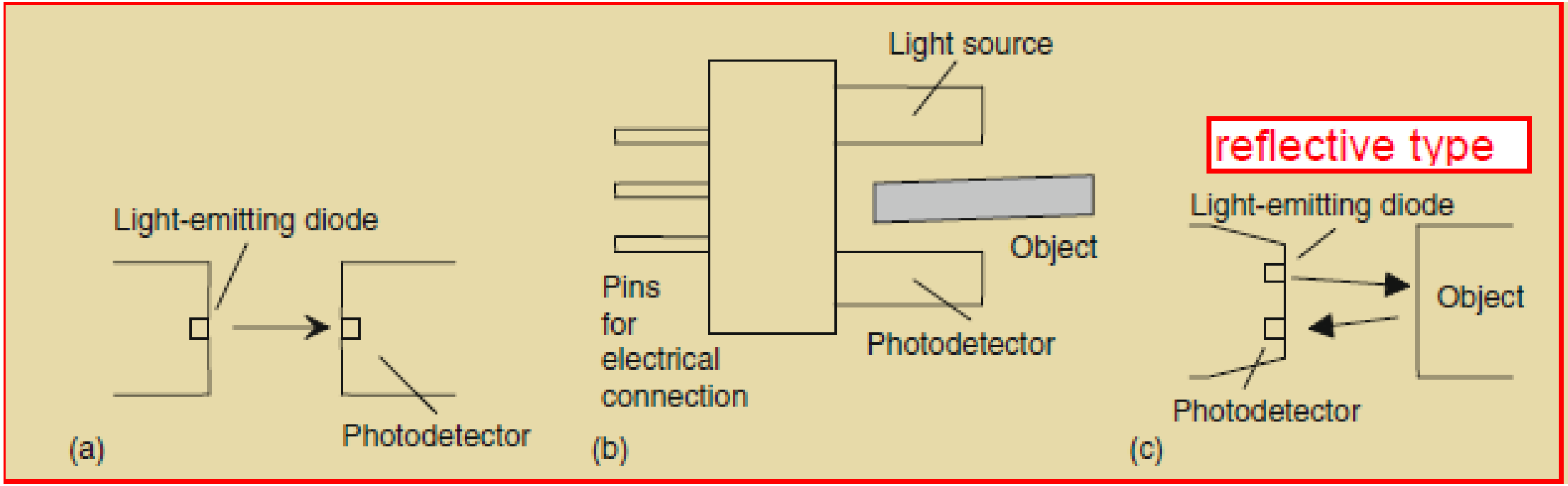
Input/Output Devices



Input/Output Devices

- proximity.mp4
- Capacitive Proximity sensor: between 4 mm and 60 mm
- Inductive :2 mm to 15 mm

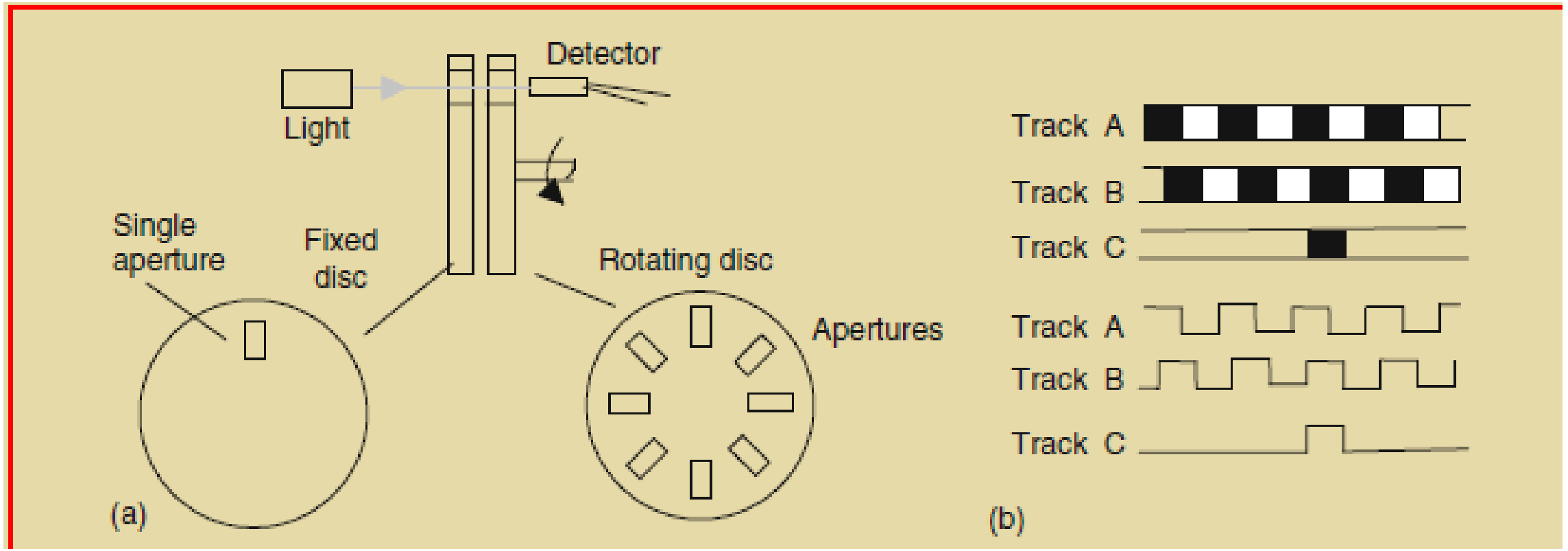
Photoelectric Sensors and Switches



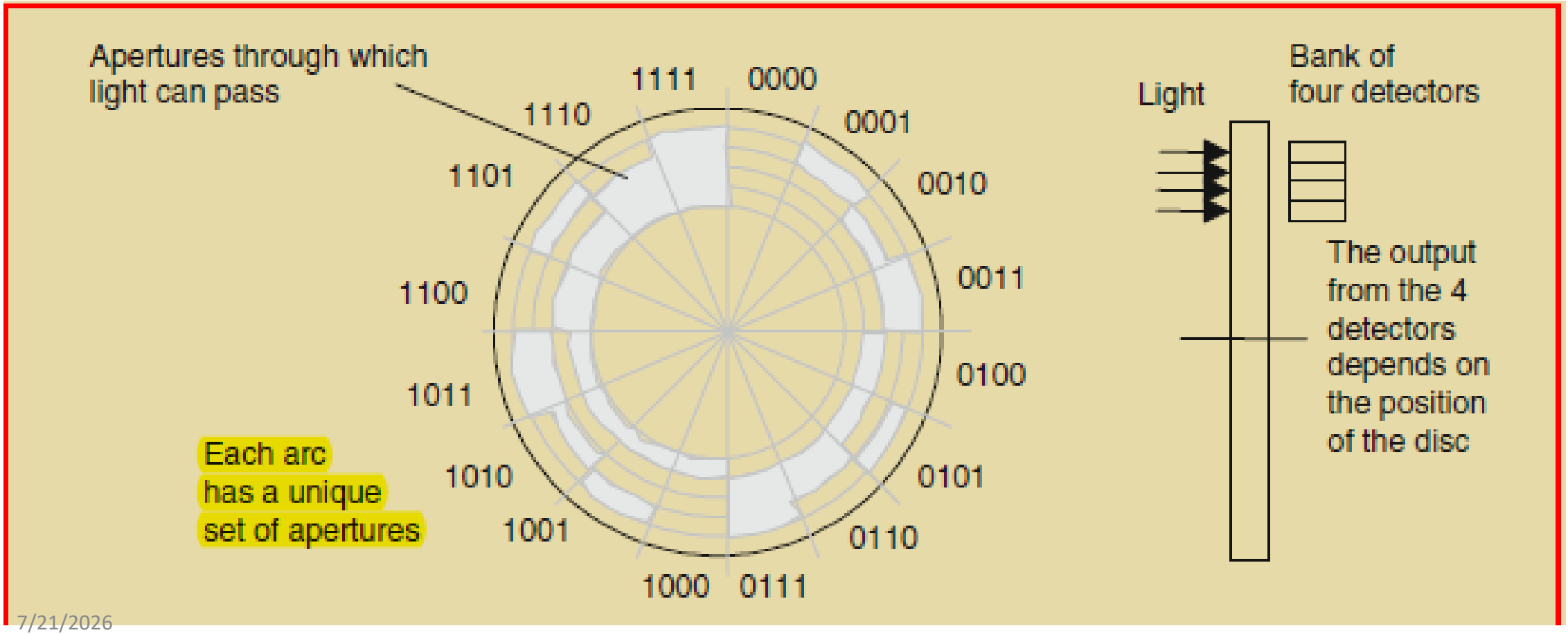
Input/Output Devices

- Photoelectric Sensors- The ML100 Series with PowerBeam™.mp4

Input/Output Devices



Input/Output Devices

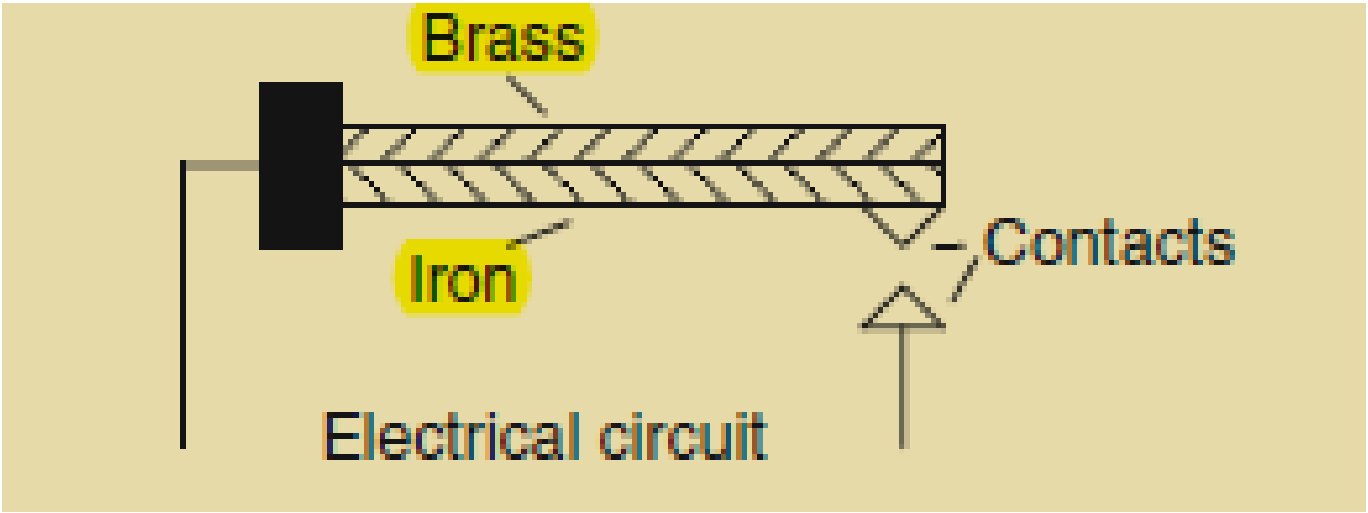


Input/Output Devices

Binary				Gray			
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	0
0	1	0	1	0	1	1	1
0	1	1	0	0	1	0	1
0	1	1	1	0	1	0	0
1	0	0	0	1	1	0	0
1	0	0	1	1	1	0	1
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	1
1	1	1	1	1	0	0	0

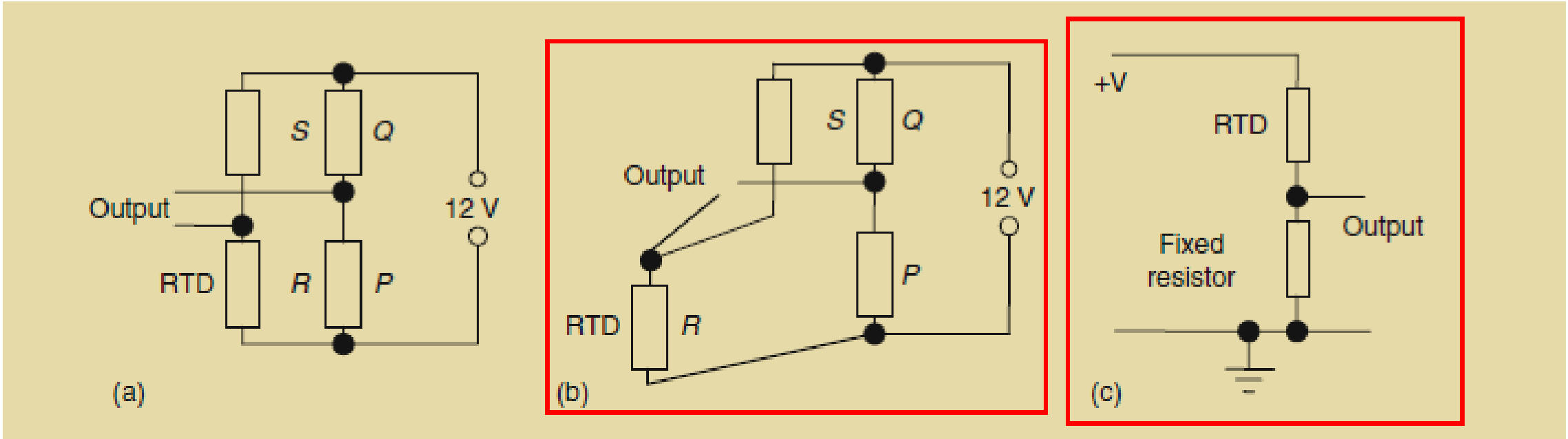
Input/Output Devices

Temperature Sensors: Bimetal element



Input/Output Devices

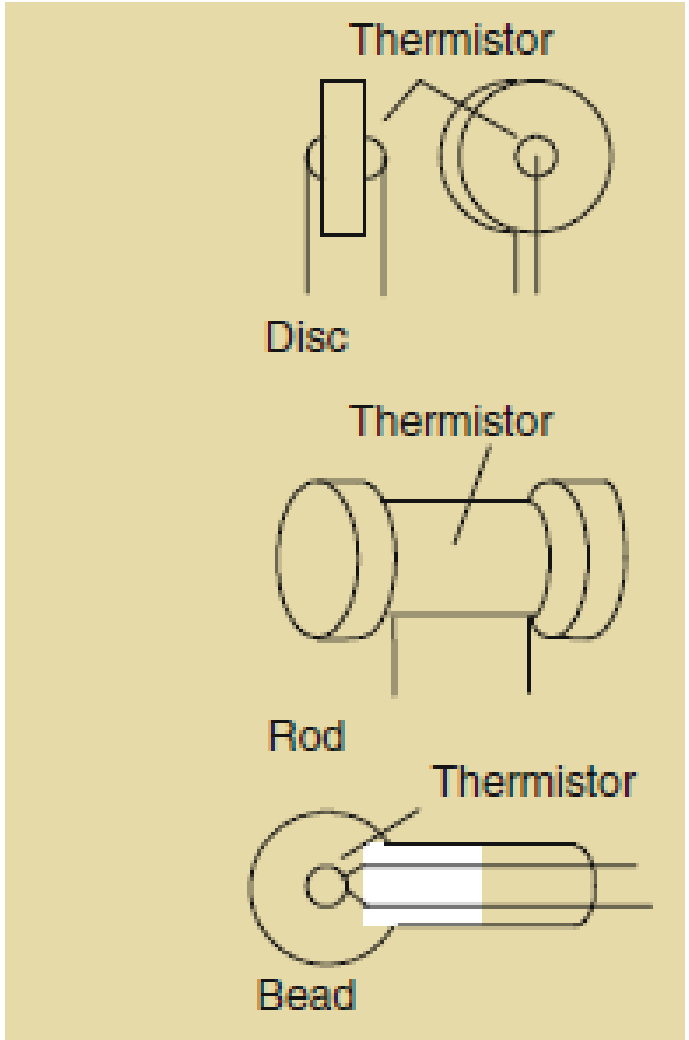
Resistive Temperature Detector(RTD):

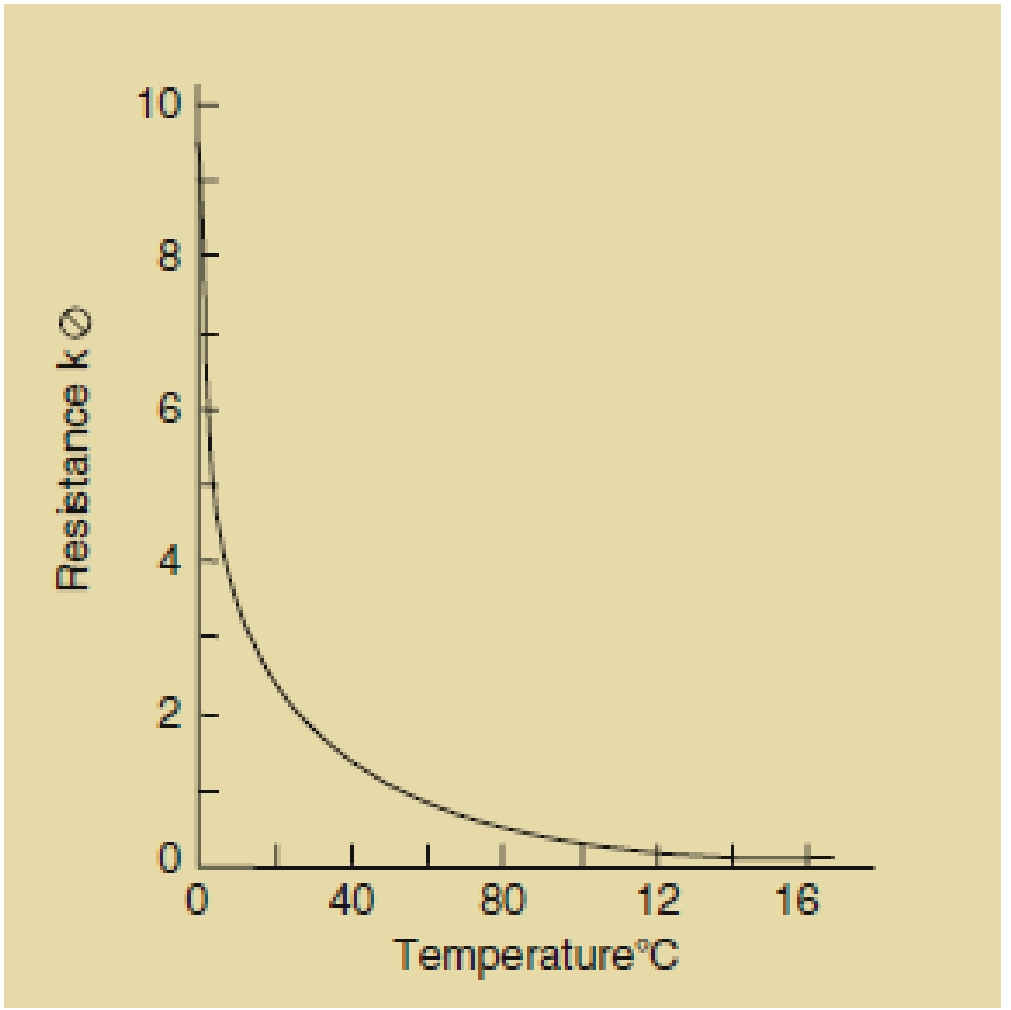


(a) A Wheatstone bridge, (b) a three-wire circuit, and (c) potential divider circuits.

Input/Output Devices

Thermistors:





Input/Output Devices

Thermodiodes and thermotransistors:

- The rate at which electrons and holes diffuse across semiconductor junctions is affected by the temperature
- Integrated package- LM35- which gives an output of 10 mV/C when the supply voltage is +5 V

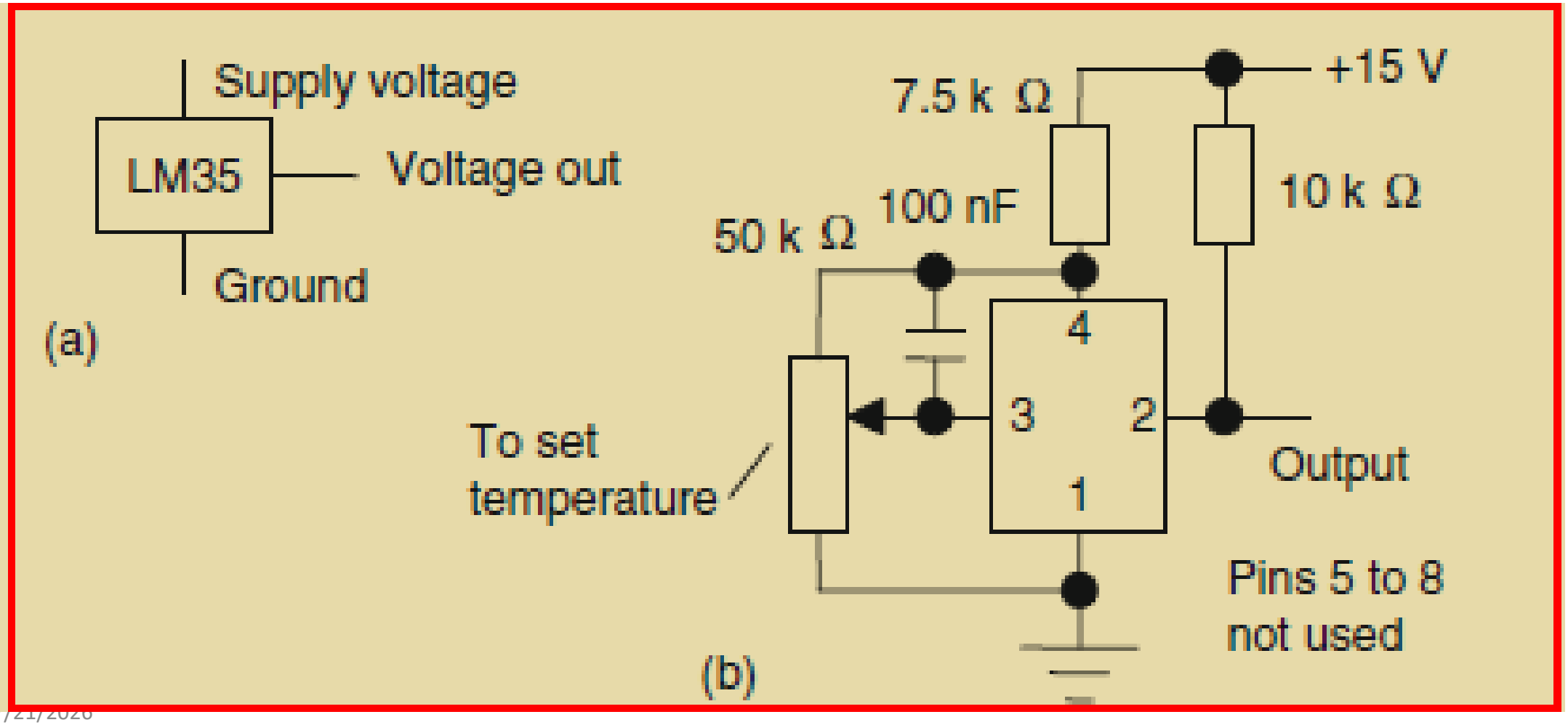
Advantages:

Cheap, Linear Response

Disadvantage:

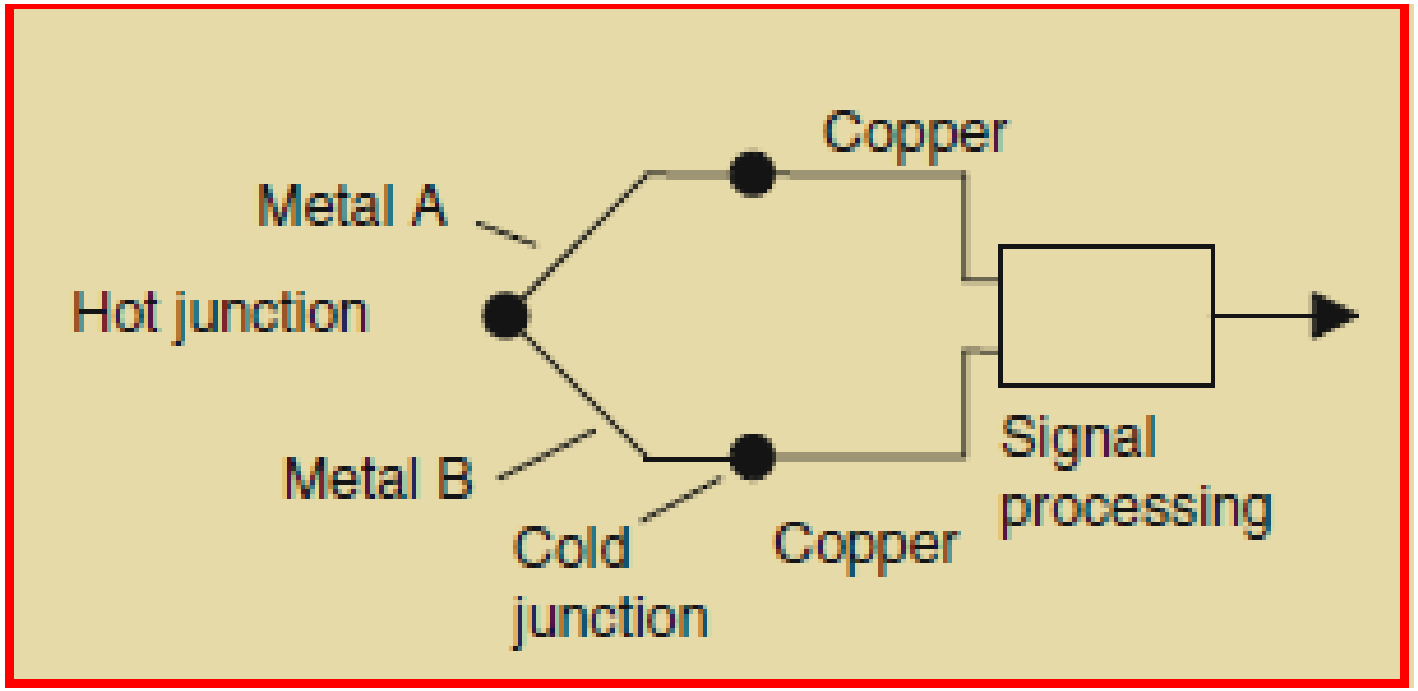
Limited Temperature range

Input/Output Devices



Input/Output Devices

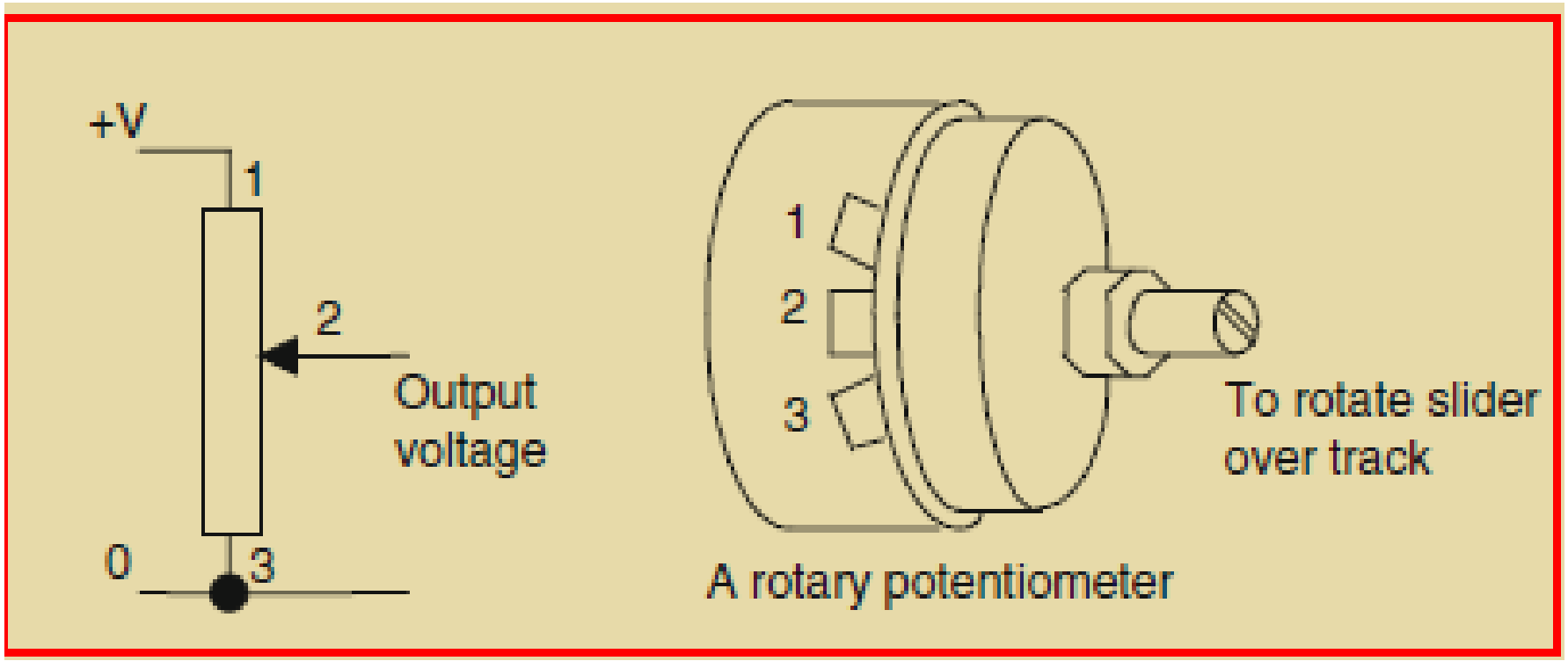
Thermocouple:



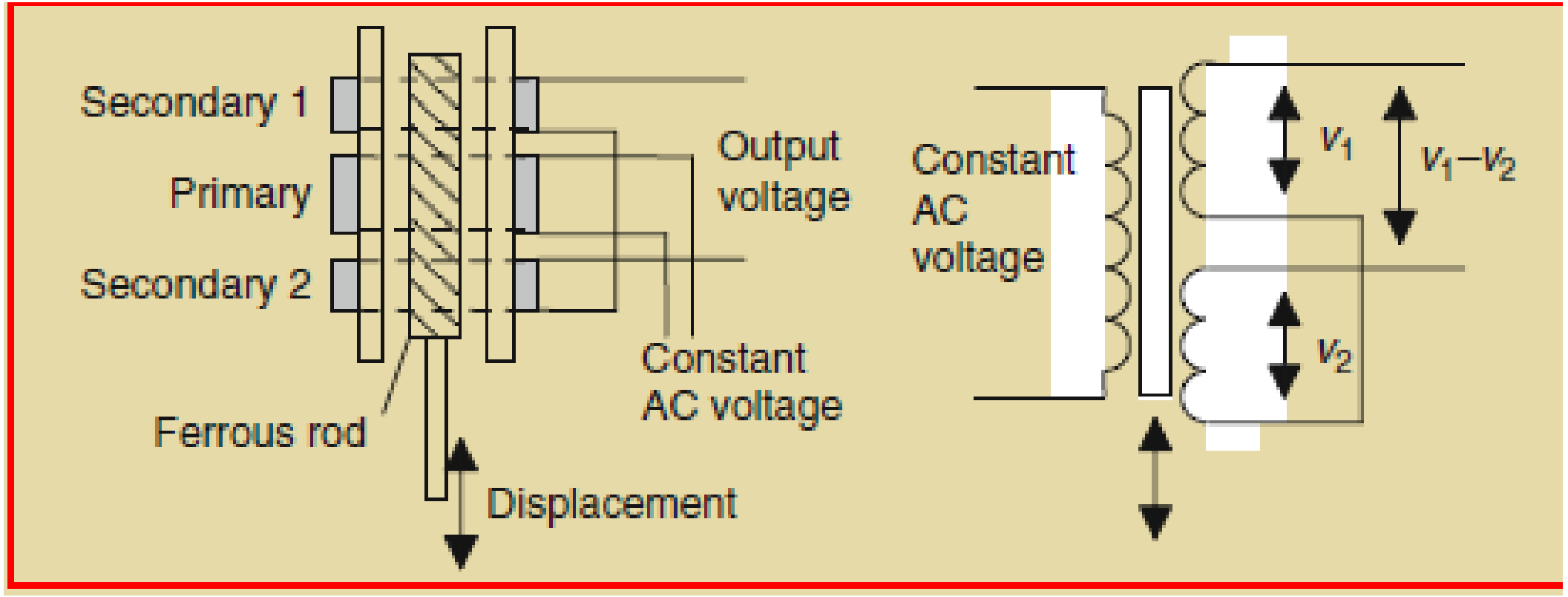
Input/Output Devices

Position/Displacement Sensors :

- linear and rotary potentiometers

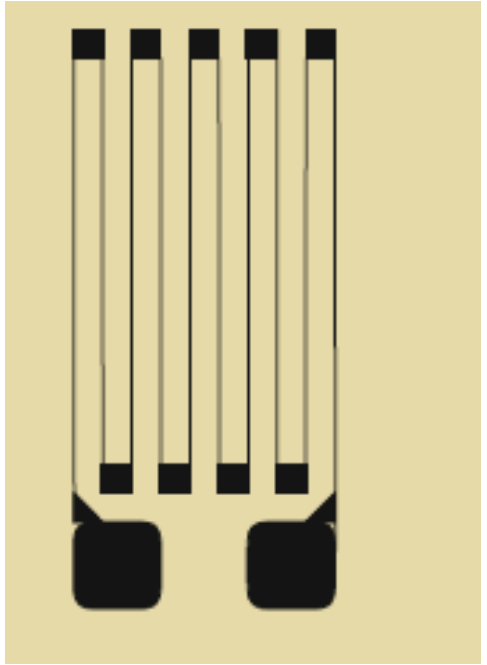


Input/Output Devices



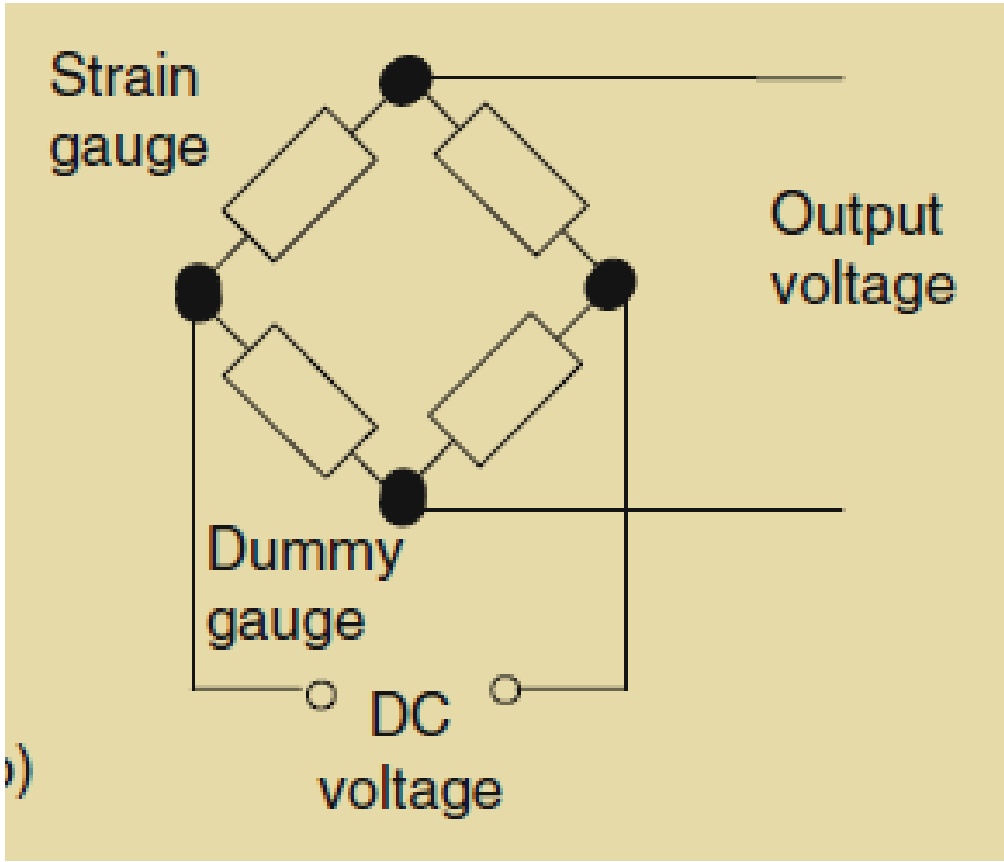
Input/Output Devices

- **Strain Gauges:** The fractional change in resistance is proportional to the fractional change in length, that is, strain
- Metal resistance strain gauges are in the form of a flat coil so that they get a reasonable length of metal in a small area.

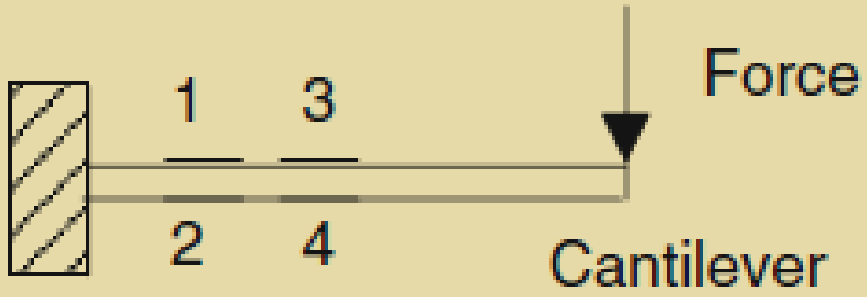


Input/Output Devices

- Temperature compensation

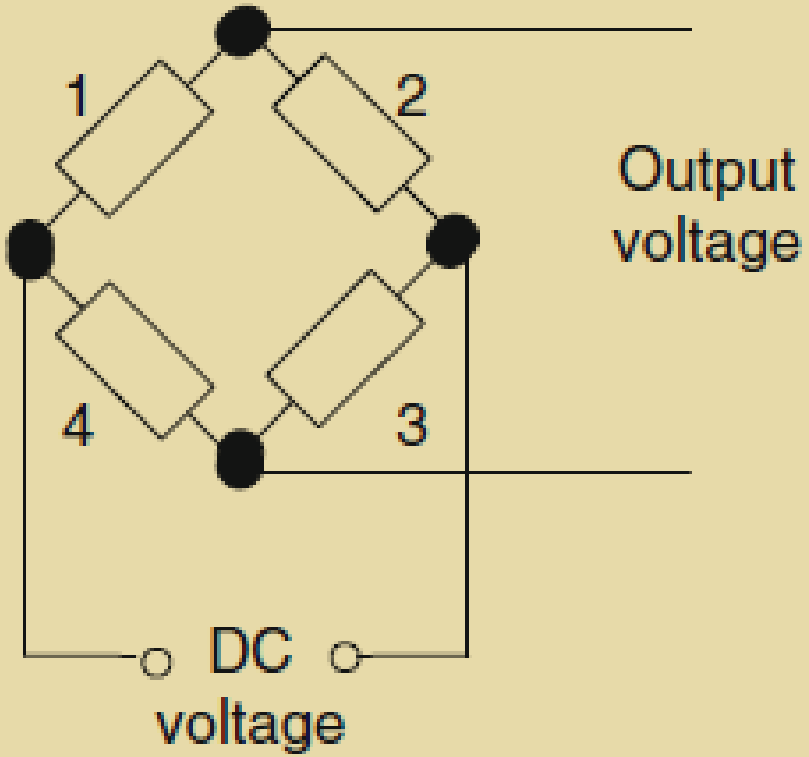


Input/Output Devices



4 strain gauges,
upper surface extended
and increase in resistance,
lower surface compressed

4 strain gauges, 2 for radial strain, 2 for circumferential strain



Input Devices

Pressure Sensors:

Liquid-Level Detectors:

Fluid Flow Measurement:

Smart Sensors:

- Integrated with the required buffering and conditioning circuitry in a single element
- Data converters, a processor and firmware, and some form of nonvolatile electrically erasable programmable read only memory

Output Devices

Relay:

The term latching relay is used for a relay whose contacts remain open or closed even after the power has been removed from the solenoid.

Directional Control Valves:

Output Devices

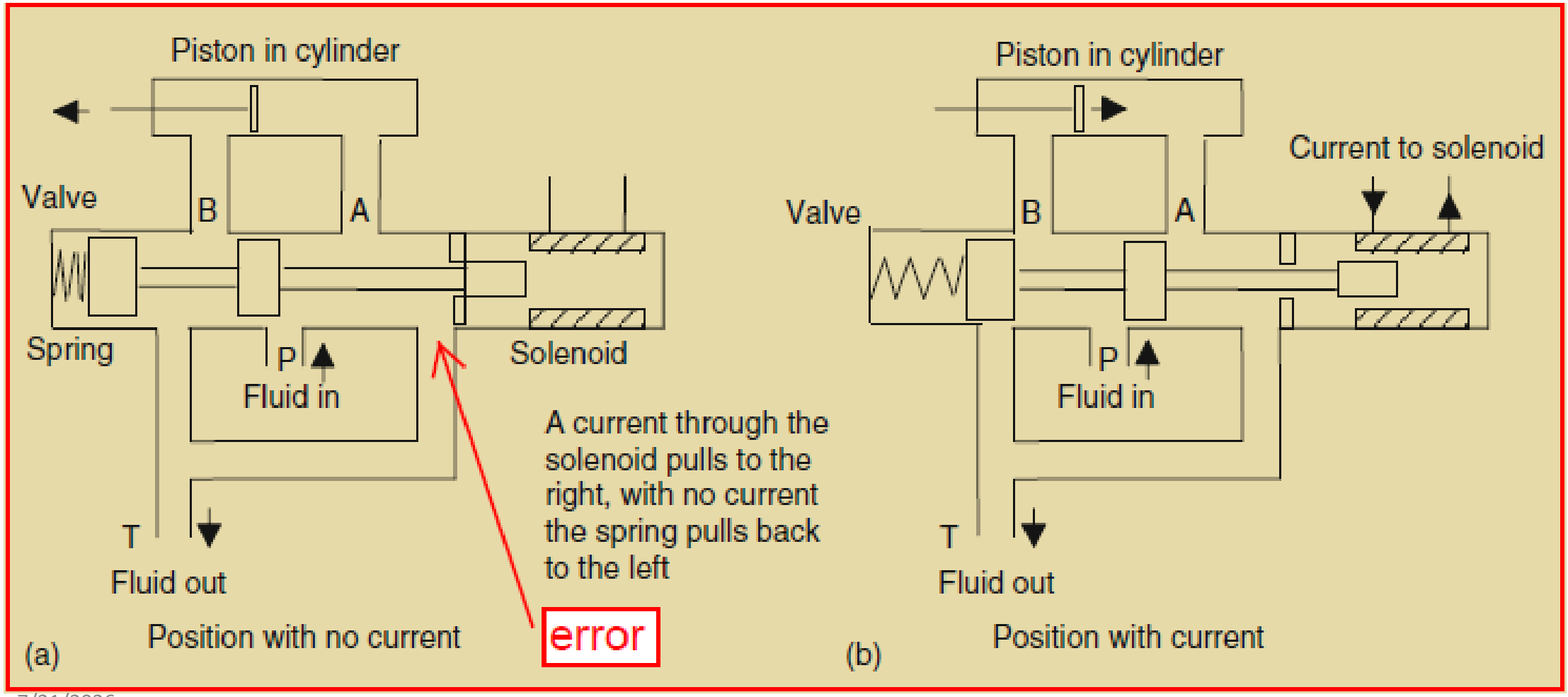
Solenoid as an actuator :Solenoid operated valve

The valve may be used to control the directions of flow of pressurized air or oil and so used to operate other devices, such as a piston moving in a cylinder.

spool valve: Control the movement of a piston in a cylinder.

Pressurized air or hydraulic fluid is input from port P,

Output Devices

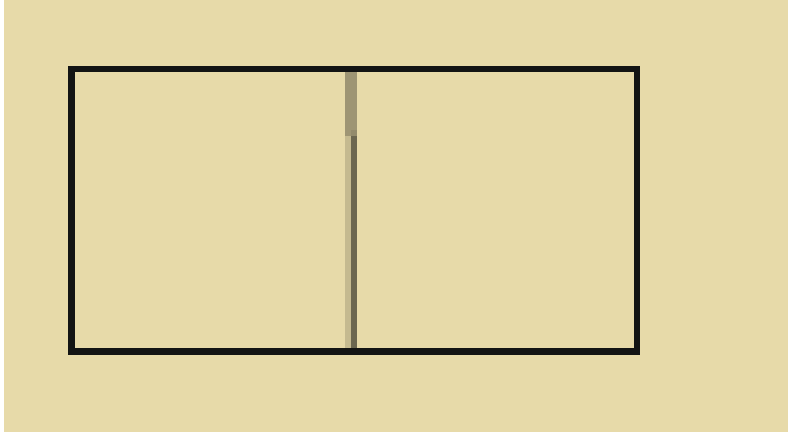


Output Devices

- Directional control valves :Described by the number of ports and the number of

control positions they contain.

- Example: 4/2 valve.
- The basic symbol used on drawings for valves is a square, with one square used to describe each of the control positions.
- Within each square the switching positions are then described by arrows to indicate a flow direction, or a terminated line to indicate no flow path

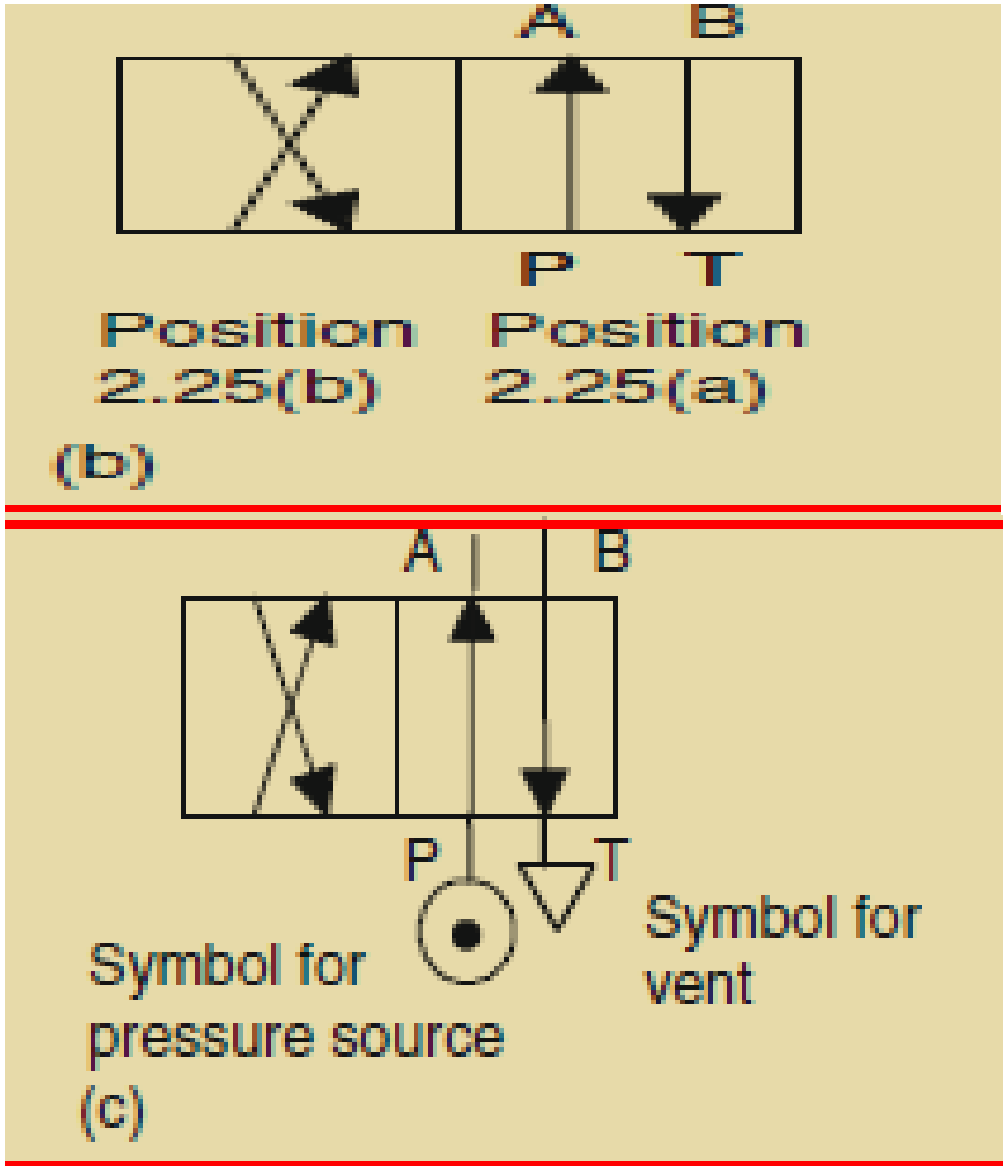


(a) The basic symbol for a two-position valve;

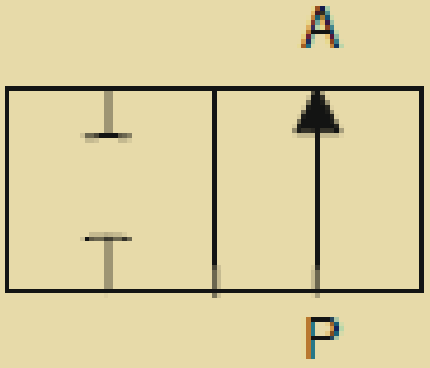
(b) the 4/2 valve

(c) external connections to the 4/2 valve.

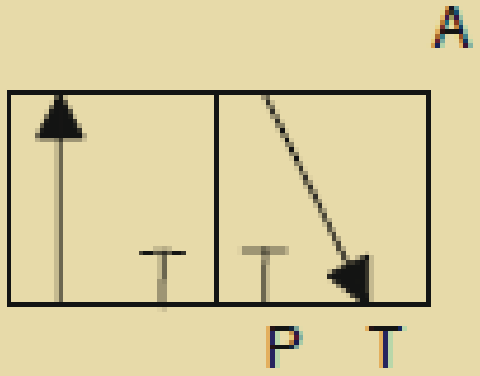
The P label is used to indicate a connection to a pressure supply and the T to an exhaust port.



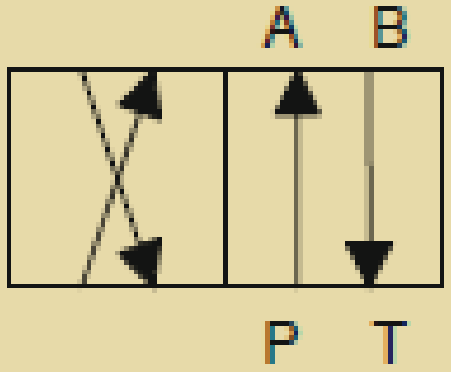
Output Devices



2/2 valve: flow from P to A switched to no flow.



3/2 valve: no flow from P to A and flow from A to T switched to T being closed and flow from P to A.

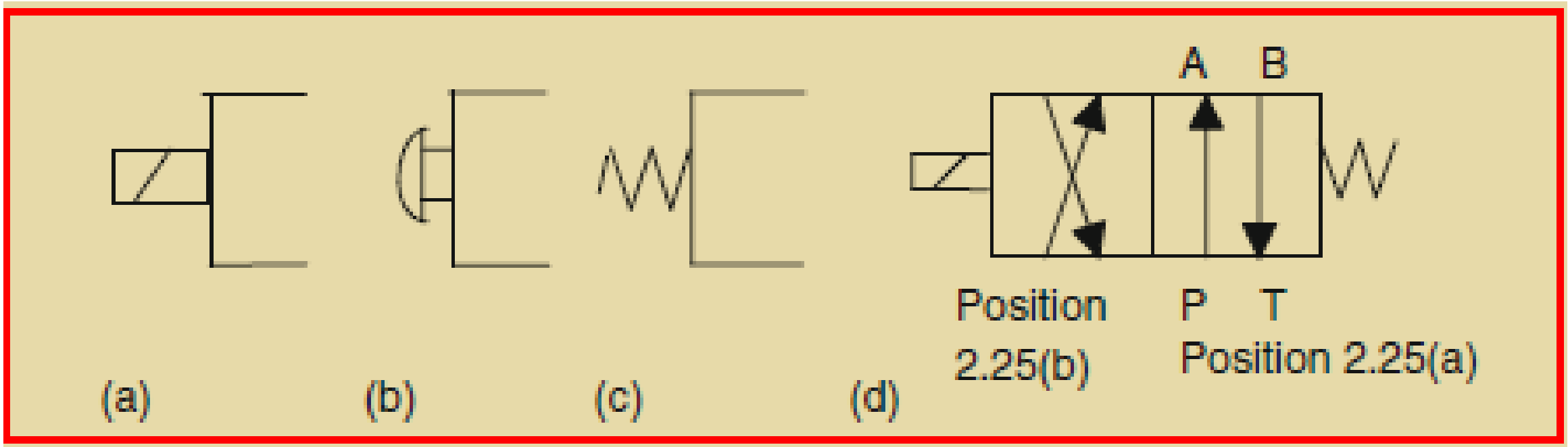


4/2 valve: initially flow from P to A and from B to T. Switched to flow from P to B and A to T.

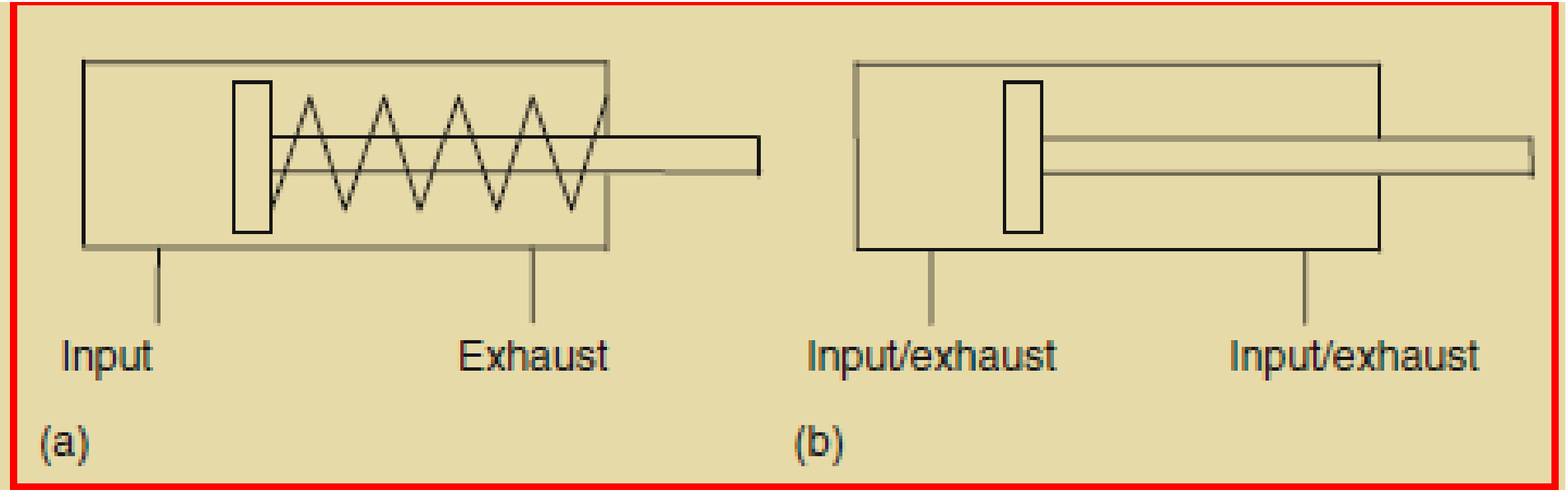
Output Devices

(a) solenoid, (b) push button, (c) spring operated,

(d) a spring and solenoid operated 4/2 valve.



Cylinders: (a) single acting, and (b) double acting.



Output Devices

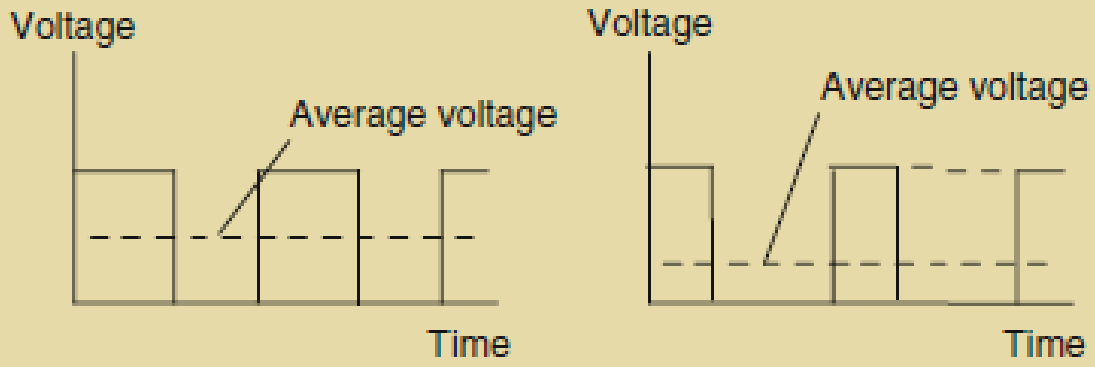
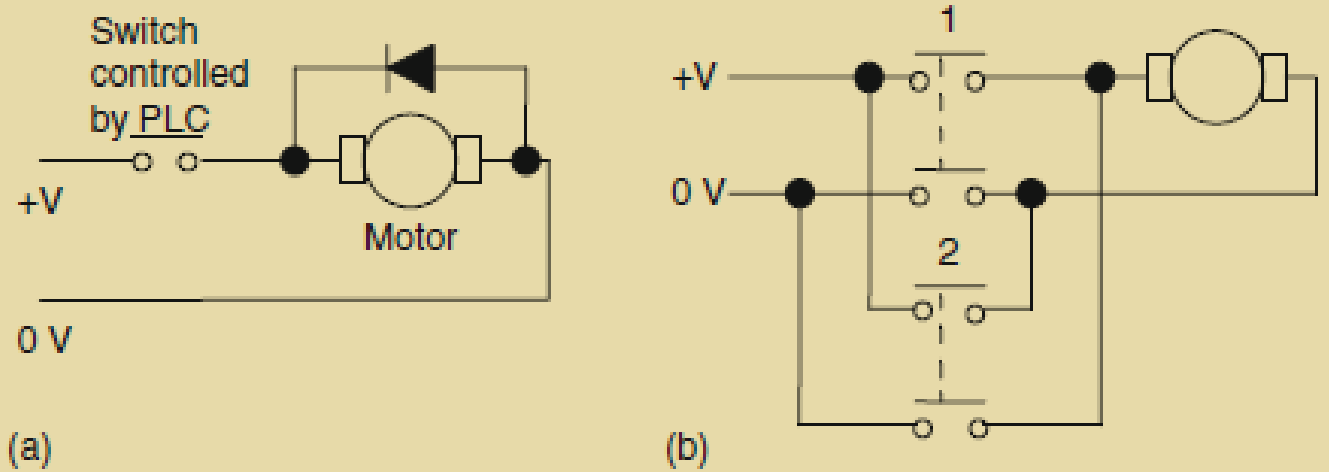


Figure 2.32: Pulse width modulation.



SCADA

Industrial Control System : 1. PLC

2. Supervisory Control and Data Acquisition.

3. Distributed Control System

distinguishes itself from the other two by being a multilocation, large distant sites.

supervisory control : closed-loop control

- It is a system which collects field data from dispersed field locations, transfers it to a central computer facility, and displays the information so gathered on the operator's panel (either graphically or textually).
- The operator sitting on the control panel (called Human-Machine Interface [HMI]) monitors and controls the entire system in real time as per the program inbuilt into the system.
- Depending on the sophistication and complexity of the software, control can be fully automatic or else can be initiated by operator commands.
- A SCADA system is an integration of data acquisition from different field devices at different locations, data transmission, centralized monitoring and display at a central location, and taking appropriate control actions on a real-time basis.

- Internet of Things (IoT) and cloud computing, which are of very recent origin, have drastically changed not only SCADA systems but also the whole gamut of monitoring, supervising, security, surveillance, and management of processes across varied industrial and commercial sectors.
- In a typical non-IoT-based SCADA system, data is stored in PLC memory addresses.
- But when a SCADA system is integrated with IoT technology, data may come from different sensors, controllers or databases.

- A SCADA system is a combination of hardware and software. Hardware: a Master Terminal Unit (MTU, which acts as the control server)
- communication equipment (like radio, cable, telephone line, or satellite)
- The communication hardware ensures communication between MTU and RTUs

Schematic of MTU and RTUs/PLCs via WAN.