



ELECTRICAL MAINTENANCE

ELECTRIC SYMBOLS AND STANDARDS

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ELECTRICAL MAINTENANCE

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1. OBJECTIVES

Following this presentation, which is (more or less) a "glossary" of terms and physical quantities, and a schematic representation of (almost) all elements an "electrician" is likely to come across, the attendant will be able to:

- Use basic physical quantities and physical units
- Relate symbols to the corresponding terms
- Identify all electrical symbols
- Differentiate a schematic representation on a plan
- Interpret combinations of symbols
- Define the symbols to be used depending on the type of electric diagram
- Explain the use of symbols on a plan
- Explain why representation standards are required
- Relate standards to symbols
- Satisfy symbolization by creating electric plans and diagrams
- Be familiar not only with the electrical field (specifically), but with related and similar families such as instrumentation, pneumatics, hydraulics, electronics, systems, etc.
- Be prepared to train non-electricians in electric schematic representation

2. GENERAL UNITS

Before considering the graphical representation of "electricity", let us reiterate units and terms which are used in electrics.

We will also review (the other courses) these units later, from an application point of view, for the time being, let us focus on representation.

2.1. BASIC SI UNITS

The quantitative study of formulas obtained by physicists or engineers implies the use of a consistent system of units.

The International system of units – or SI – is the universally adopted system in the field of electricity. It is based on seven basic units and two additional geometric units shown in the following table.

Physical quantities		SI units		Remark
Name	Symbol	Name	Symbol	
Length	l, d $x, y, \dots$	metre	m	
Mass	m	kilogram	kg	not to be confused with weight
Time	t	second	s	
Intensity of the electric current	I i	amps	A	
Thermodynamic temperature	T	kelvin	K	
Quantity of substance	n	mole	mol	
Luminous intensity	I_v	candela	cd	
plane angle	$\alpha, \beta, \gamma, \dots$	radian	rad	2π (rad) = 1 complete rotation
solid angle	Ω	steradian	sr	

Table 1: Basic units

2.2. DERIVED SI UNITS

All other units are derived from these basic units according to natural laws and geometric relations. A list of the main derived physical quantities and units used in electricity is shown in the following table.

Physical quantities		Derived SI units		Relations between units
Name	Symbol	Name	Symbol	
Force	F	Newton	N	$1 \text{ N} = 1 \text{ kg m/s}^2 = 1 \text{ W s/m}$
Torque (moment of a force)	$\frac{M}{T}$	Newton-metre	Nm	
Energy, work	$\frac{E}{W}$	joule	J	$1 \text{ J} = 1 \text{ Nm} = 1 \text{ W s}$
Power (active power)	P	watt	W	$1 \text{ W} = 1 \text{ J/s} = 1 \text{ V A}$
Reactive power	Q	reactive volt ampere	var	$1 \text{ var} = 1 \text{ V A}$
Apparent power	S	volt ampere	VA	
Pressure	P	pascal	Pa	$1 \text{ Pa} = 1 \text{ N/m}^2$
Electric load	Q	coulomb	C	$1 \text{ C} = 1 \text{ A s}$
Voltage, difference in potential	$\frac{V}{v}$	volt	V	$1 \text{ V} = 1 \text{ W/A} = 1 \text{ J/C}$
Electric resistance	R	ohm	Ω	$1 \Omega = 1 \text{ V/A}$
Electric capacity	C	farad	F	$1 \text{ F} = 1 \text{ C/V} = 1 \text{ A s/A}$
Inductance	L	henry	H	$1 \text{ H} = 1 \text{ Wb/A} = 1 \text{ V s/A}$
Frequency	f	hertz	Hz	$1 \text{ Hz} = 1 \text{ s}^{-1}$
Angular frequency	ω	radian/second	rad s^{-1}	$\omega = 2\pi f$
Magnetic flows	Φ	weber	Wb	$1 \text{ Wb} = 1 \text{ V s}$
Magnetic induction	B	tesla	T	$1 \text{ T} = 1 \text{ Wb/m}^2$
Magnetic field	H	ampere/metre	A/m	
Electric field	E	volt/metre	V/m	

Table 2: Derived SI units

2.3. PREFIXES

The major advantage of the metric system proposed during the French revolution was the addition of prefixes to units, corresponding to multiples and sub-multiples factored to 10.

A distance is expressed as **kilometre**, shortened to "km". This prefix corresponds to a multiplication of 1000, and the distance is stated as 37.2 km to give an example. In the same way, for a pencil lead with a diameter of 0.0005 m or 0.5×10^{-3} m, a sub-multiple of the metre can be used, i.e. the millimetre, shortened to "mm", corresponding to a sub-multiple of 1000, and making this diameter 0.5 mm.

Factor	Prefix		Example
	Name	Symbol	
10^{12}	tera	T	1 TJ = 10^{12} J
10^9	giga	G	1 GHz = 10^9 Hz
10^6	mega	M	1 MW = 10^6 W
10^3	kilo	k	1 k Ω = 10^3 Ω
10^2	hecto	h	1 hm = 100 m
10^{-1}	deci	d	1 dl = 0,1 l
10^{-2}	centi	c	1 cm = 0,01 m
10^{-3}	milli	m	1 mA = 10^{-3} A
10^{-6}	micro	μ	1 μ H = 10^{-6} H
10^{-9}	nano	n	1 ns = 10^{-9} s
10^{-12}	pico	p	1 pF = 10^{-12} F

Table 3: Prefixes

This systematically applies to all SI units and for far larger ratios.

To create names and symbols for multiples and sub-multiples as decimals of SI units, the prefixes shown in the above table are used.

2.4. RULES FOR THE NOTATION OF UNITS

The use of units in technical texts is governed by very strict spelling rules, defined by the ISO (International Standardization Organization), specifically in terms of the use of upper/lower case, punctuation and plurals:

- ✦ Symbols are not followed by the usual dot required for abbreviations. So this gives: "distance d equals 12 m".
- ✦ If the name is written in full, the unit will not vary. So this gives: "This motor has a power of 850 watt", without the plural "s".

However, in less technical texts, traditional grammar rules will take over in French: "This boat is 12 metres long", with an "s".

2.5. "NON-STANDARD" TECHNICAL UNITS

Some old units used previously to the application of the SI system are still in use, often due to custom, or often because the SI equivalent is not as "convenient".

Physical quantity	Unit		Relations between units
	Name	Symbol	
Distance	Ångstrom	Å	$1 \text{ Å} = 0.1 \text{ nm} = 0,1 \cdot 10^{-9} \text{ m}$
	Nautical mile		$1 \text{ nautical mile} = 1852 \text{ m}$
	Light year	ly	$1 \text{ ly} = 9.46 \cdot 10^{15} \text{ m}$
Volume	litre	lt	$1 \text{ lt} = 1 \text{ dm}^3 = 0.001 \text{ m}^3$
Angle	Degree	°	$1 \text{ rotation} = 360^\circ = 6.28 \text{ rad}$
	Minute	'	$1' = 60''$
	Second	''	$60'' = 1'$

Physical quantity	Unit		Relations between units
Time	Minute	min	1 min = 60 s
	Hour	hr	1 h = 60 min = 3600 s
	Day	d	1 d = 24 hr
Speed	Kilometres per hour	Km/hr	1 m/s = 3.6 km/hr
	Knot		1 knot = 1 nautical mile/hr = 1852 km/hr = 0,5144 m/s
Angular speed	Rotations per minute	rpm	$1 \text{ s}^{-1} = 1 \text{ rps} = 60 \text{ rpm}$ $3000 \text{ rpm} * \pi/30 \approx 314 \text{ rad/s}$
Mass	Ton	t	1 t = 1000 kg
Force	Kilopound	kp	$1 \text{ kp} = 9.81 \text{ N}$ This is the weight of a mass of 1 kg on the earth
Energy	Calorie	cal	$1 \text{ cal} = 4.1868 \text{ J}$ Heats 1 g of water by 1 °C
	Large calorie	Cal	1 Cal = 1 kCal = 1000 cal
	Kilowatt-hour	kWh	1 kWh = $3.6 \cdot 10^6 \text{ J}$
Power	Horse power	hp	1 hp = 735 W (metric)
Pressure	Bar	bar	1 bar = 100.000 Pa = 1 hPa
	Kilo per square cm	kp/cm ²	1 kg/cm ² = 9.81 N/cm ² = 98.000 Pa $\approx$ 1 hPa
	Atmosphere	atm	1 atm = 1.03 kp/cm ² = 1.01325 hPa $\approx$ 1 hPa
Temperature	Degrees Celsius	°C	Temperature difference: 1 °C = 1 K Reference: 0 °C = 273.16 K

Table 4: "Non-standard" technical units

2.6. IMPERIAL UNITS

Even English-speaking scientific environments have difficulty in using the SI system, and continue to use the imperial system, or the old US units.

They are based on units of length, mass and other divided by multiples of 12, 16 and other.

E.g. 1 mile (statute) equals 5280 feet; 3 feet equal 36 inches (1 foot = 12 inches).

Engineers often work in an international dimension, and you need to know the following units as a minimum:

Physical quantities	Name of the unit			Relations between units
	In French	In English	Symbol	
Length		mil	mil	1 mil = 0.001" = 25.4 μ m
	<i>Pouce</i>	Inch	" in	1" = 25.4 mm
	<i>Pied</i>	Foot	' ft	1' = 12" = 30.48 cm
	<i>Mille</i>	(statute) mile		1 mile = 5280' = 1609.3 m
	<i>Mille marin</i>	(nautical) mile		1 mile = 1852 m
Volume	<i>Gallon impérial</i>	Imperial gallon	UK gal	1 UK gal = 4.546 dm ³
	<i>Gallon US</i>	US gallon	US gal	1 US gal = 3.79 dm ³
Mass	<i>Once</i>	Ounce	oz	1 oz = 28.35 g
	<i>Livre</i>	Pound	lb	1 lb = 16 oz = 0.4536 kg
		Ton	ton	1 ton = 2240 lb = 1061.1 kg
Pressure	<i>Livre/pouce²</i>	Pound/square inch	lb/in ² psi	1 lb/in ² = 70,3 g/cm ² = 6.8948 kPa
Energy		British thermal unit	BTU	1 BTU = 252 kJ

Physical quantities	Name of the unit			Relations between units
Torque (*)	<i>Livre-pouce</i>	Pound-inch	lb-in	1 lb-in = 0.113 Nm
	<i>Livre-pied</i>	Pound-foot	lb-ft	1 lb-ft = 1.35582 Nm
Power	<i>Cheval</i>	Horsepower	hp	1 hp = 42.41 BTU/min = 745,7 W
Temperature	<i>Degré Fahrenheit</i>	Fahrenheit	°F	1 °F = 5/9 °C $\cong$ 0.56 °C 0 ...100 °C corresponds at 32 ...212 °F

(*): (*): When converting torque, gravity acceleration must be considered, i.e. $g = 9.8065 \text{ m/s}^2$, as the pound is a mass and not a force. Therefore, $1 \text{ lb-ft} = 0.13831 \text{ kgp}\cdot\text{m}$.

With the SI system: 1 French unit of horsepower (CV) = 735 W (or 736 W) while 1 horse power (HP) = 746 W

Table 5: Imperial units

3. CONTACT AND CONTROL DEVICE SYMBOLS

Even if you do not understand all of the terms and (therefore) their relation to the symbols, do not worry, you will be provided with an (almost) exhaustive list.

You can use this list in the future when attempting to 'decode' or create an electric diagram.

3.1. CONTACTS

Establishing a contact (in electricity) means closing an electric circuit, i.e. create a bridge between two sections of a circuit to enable the passage of the electric current.

3.1.1. Principle of contact

With a vehicle you:

- Start the engine = a) close the electric/electronic circuits
b) close the control circuit for the starter relay which will then close the (power) circuit between the battery and the engine/starter The 'starter key' has two positions.
- Stop the engine = open the ignition circuits, or the electric circuit (solenoid valve) for the fuel supply.

3.1.2. Types of contacts

You will come across the following types of contacts:

- **"Real"** contacts, i.e. those which establish a physical contact between the (two or +) poles in a device. Your car key, a switch on an ignition circuit, the push button in a starter circuit, the contactor supplying an engine, etc, are all examples of real contacts... They represent "hardware". *This is the type of contact we will look at below.*
- **"Virtual"** contacts, i.e. automated control systems, computers which open/close 'programmed' circuits. *In other words, "software" or digital systems. Refer to the chapter on 'Automated control systems'.*
- We could also mention the **"intermediary"**, i.e. electronic circuits (transistors, silicon controlled rectifiers, etc.) closing/opening circuits without 'physical separation'.

3.1.3. Representation rules:

Diagrams can be drawn without voltage, at ambient temperature and pressure. Action by contacts will lead to **contact movement to the right** (or upwards).

Contacts are shown in the 'rest' position, i.e. when there is no voltage and no action with two possible positions:

- NO for 'Normally open'
- NC for 'Normally closed'

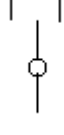
	Work contact Closing contact NO contact		Rest contact Opening contact NC contact		Two directional contact with no overlap
	Momentary contact which closes momentarily when the control device is activated		Momentary contact which closes momentarily when the control device is released		Momentary contact which closes momentarily when the control device is activated and released
	Early closing contact (closes earlier than the other contacts in the same set)		Early opening contact (opens earlier than the other contacts in the same set)		Two directional contact with middle opening position
	Delayed closing contact (closes later than the other contacts in the same set)		Delay opening contact (opens later than the other contacts in the same set)		

Table 6: Types of contacts

Momentary contact: contact which establishes or opens the circuit in a 'fugitive' manner (also known as a fugitive contact), i.e. for a "short moment". This 'transit time' is generally not adjustable, depending on manufacture, and represents a few dozen seconds. *(In the "software" version, with the automated control systems, it is easier to adjust this element)*

Early opening / closing contact: for a group of contacts, either in a relay closing/opening a certain number of contacts, this type of contact "reacts" more quickly (you know that it acts more quickly than the others).

When the relay coil is excited, the contact acts immediately, **before the others**. It can be used when you need locking in the engine starter sequences.

Delayed /closing contact: the contact opens or closes after the others and after the excitation of the relay coil commanding the group of contacts.

This type of contact must not be mixed up with time-delay contacts, mentioned below with the control devices

3.1.4. Other representations

The above symbols are used for the official representation of the new international system. Many other older types of symbols exist, and specific symbols for certain manufacturers.

You will most certainly come across unknown or even strange symbols. Often common sense is enough to recognise the functions of these symbols.



Figure 1: Other principles for the representation of contacts

With older (French) diagrams, the above representation was often used. The control devices were added according to the principle described in the following paragraph.



Figure 2: Representation of automated contacts

"Internal contacts" (software) of automated control systems are represented as shown (standardised).

However, "external contacts" (hardware), connected to input blocks are (generally) shown using traditional representation. See course on PLCs and automated systems.

However, contacts cannot exist alone, a control device must also be present.

A light switch (the switch next to the entrance door) is a contact equipped with a mechanical control device; A thermostat (in the corridor) is a contact equipped with a "heat device"; Travel stops are contacts equipped with 'control wobble sticks': time-delay contacts are (often) equipped with pneumatic delaying devices, etc.

With 'traditional circuits, the most frequent contact is NO or NC combined with a relay or a contactor which closes or opens a circuit depending on the status of the relay or contactor: 'rest' or 'excited'. In the following figure, the "instant auxiliary contact" unit consisting of 4 contacts (mixture of NO and NC) can be combined with the contactor in the following figure.

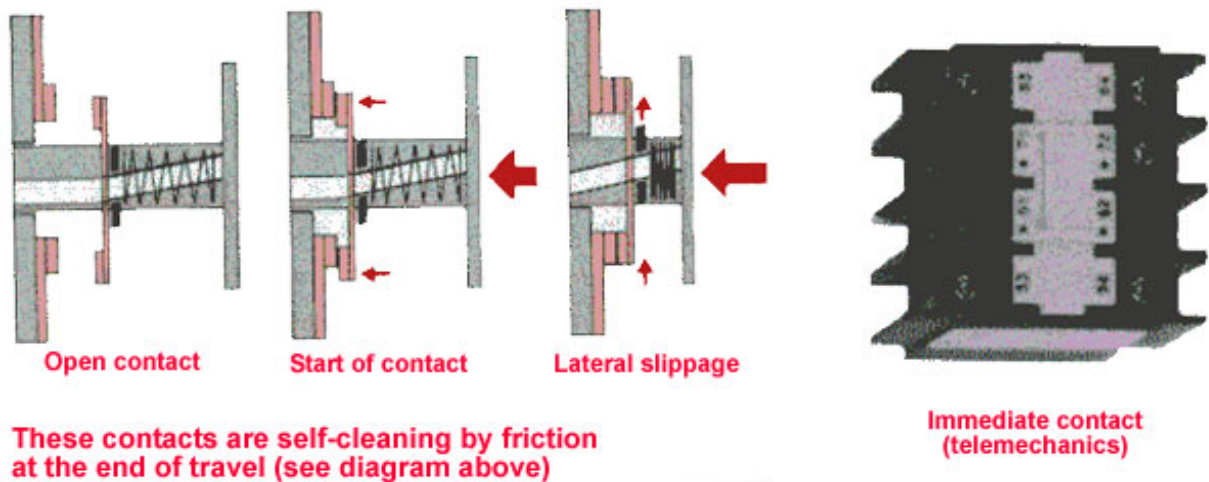


Figure 3: Principle of the auxiliary contact and telemechanics auxiliary contact unit

With another 'traditional' configuration, the contacts are part of the contactor (or relay).

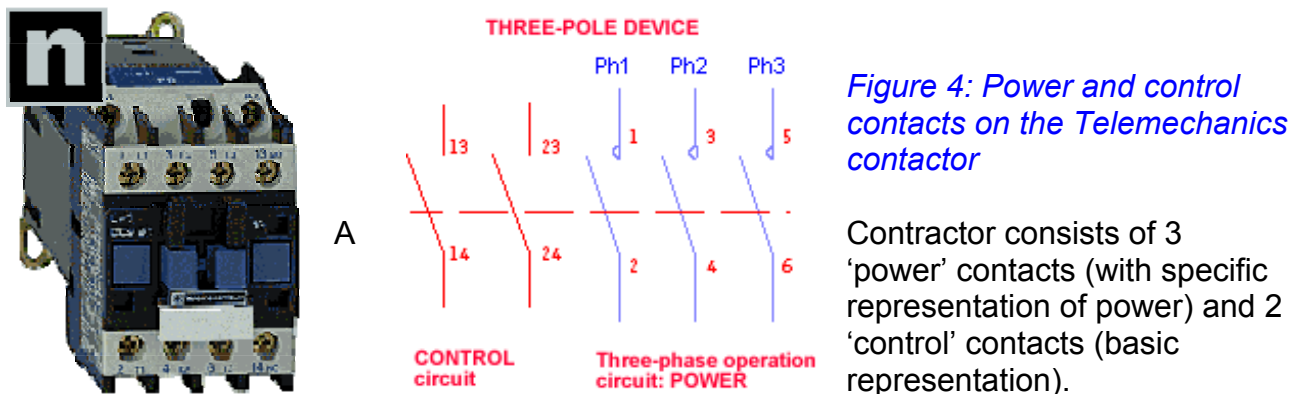


Figure 4: Power and control contacts on the Telemechanics contactor

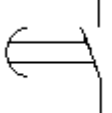
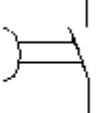
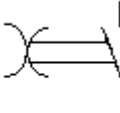
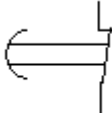
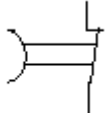
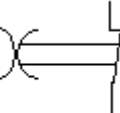
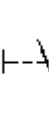
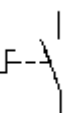
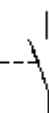
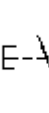
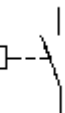
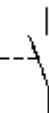
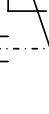
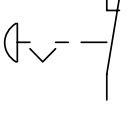
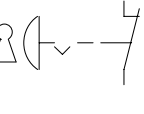
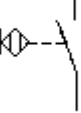
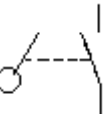
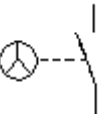
Contractor consists of 3 'power' contacts (with specific representation of power) and 2 'control' contacts (basic representation).

A contactor is a control device able to *establish or interrupt the passage of electricity*. For the moment, we will simply consider this function, i.e. the function of all contacts.

A contact can allow varying levels of current to pass depending on its size and design; This ability to cut off power defines disconnecter switches, switches, contact breakers, etc., which will be considered in other courses.

3.2. CONTROL DEVICES

The "principle" is added to "bare" contacts which then control this contact. The symbol added is (in theory) a logical schematic representation of the control provided.

	Work contact delayed at closing (attraction) NO delay 'on'		Work contact delayed at opening (fall) NO delay 'off'		Work contact delayed at closing and at opening NO delay 'on & off'
	Rest contact delayed at opening (attraction) NC delay 'on'		Rest contact delayed at closing (fall) NC delay 'off'		Rest contact delayed at closing and at opening NC delay 'on & off'
	Manual mechanical control (no automatic return)		Rotary switch (no automatic return)		Pull control (with automatic return)
	Push button (with automatic return)		Heat device control		Palm button
	NO + NC rocker (with automatic return in NC)		Emergency stop held in (with 'latch')		Emergency stop held in (key-type release)
	Proximity control		Touch control		Manual control with limited access (e.g. behind glass)
	Foot-operated control		Wobble stick control		Steering wheel control

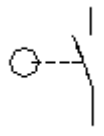
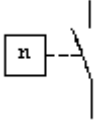
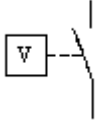
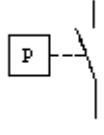
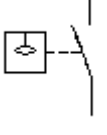
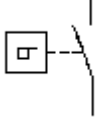
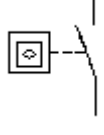
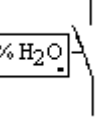
	Handle control		Roller control (end-of-travel contact)		Key-type control
	Electric motor control		Cam control		Timed control
	Rotation speed- based control		Linear speed-based control		Pressure-based control
	Liquid level-based control		Flow-based control		Event quantity-based control
	Temperature-based control (‘θ’ can be replaced by the activation value)		Humidity-based control		

Table 7: Types of contact control devices

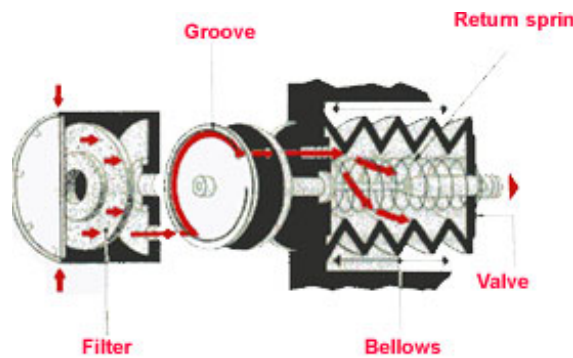
Note: all of the contacts shown in the above table (with the exception of timing at start-up and emergency stops) are ‘NO’.

The same clearly applies to ‘NC’ contacts, as rest position = closed contact for the control device.

While the contact ‘alone’ can be ‘subjective’, the contact with its control device is a very real object which can be shown, named and depicted.

3.2.1. Time-delay contact

The contact closes and opens after a delay, when the relay coil controlling the contacts is no longer excited or receives excitation.



*This must not be mixed up **with time-delay relay** when the delay concerns the "energisation" of the coil itself.*

*Figure 5:
Télémechanique's
time-delay contact*

Example of a time-delay contact combined with a relay or a contactor. Depending on the type, this contact (NO and/or NC) may be adjusted between a tenth of a second and hours or even days.

You will be able to do exercises on time-delay contacts (later in this course, and in the course on plans and diagrams). I have often seen many (beginners and experienced) electricians have difficulties in finding the right representation or the right interpretation for time contact sequences. *(This is also simpler with automated control systems...)*

Principle of time-delay contact:

The "umbrella" notion defines time-delay action, the closing and/or opening of the contact.

By "pulling" on the contact, and if you are on the 'open' side of the umbrella, you will obtain a 'resistance' and therefore a delay.

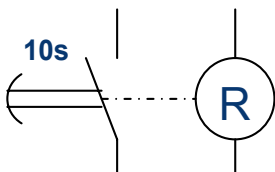


Figure 6: Work time-delay NO contact

When the relay coil 'R' is excited, the contact closes after 10 seconds.



Figure 7: Rest time-delay NO contact

When the relay coil **R** is excited, the contact immediately closes, 'no delay' applies. When the excitation of **R** stops, timing starts, the contact will open 5 seconds after cut-out of the **R** circuit.

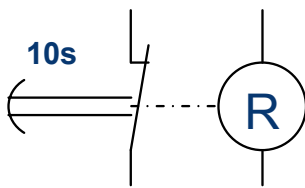


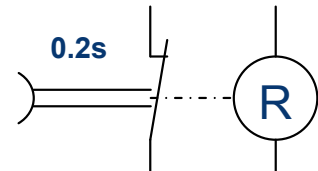
Figure 8: Work time-delay NC contact

When the relay coil 'R' is excited, the contact remains closed.... and opens after 10 seconds.

Should **R** be cut-out during these 10s, the contact will remain closed and timing will start with the renewed excitation of **R**.

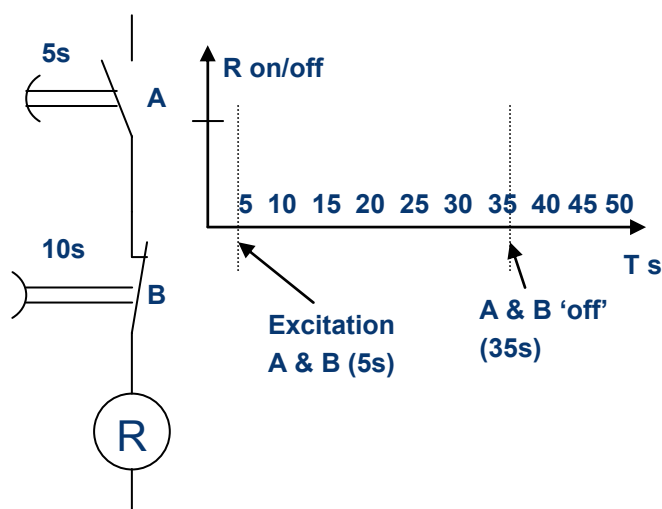
Figure 9: Rest time-delay NC contact

When **R** is excited, the contact will open..., immediately without timing. When the supply to **R** is cut, the 0.2 second delay will start, the contact will reclose after this period.

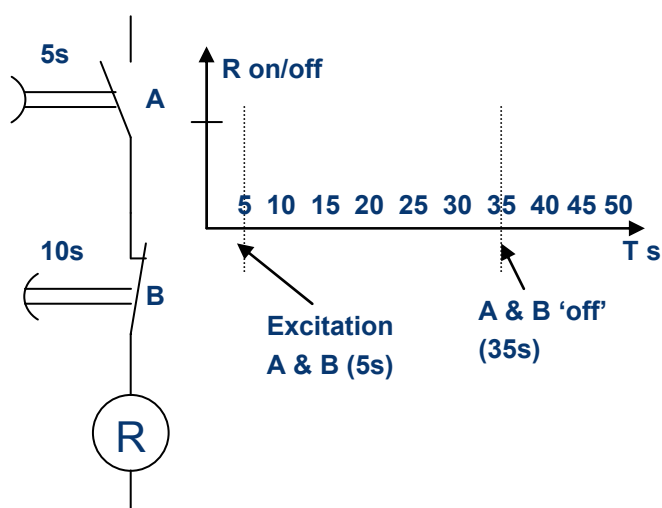


3.2.2. Time-delay contact exercises

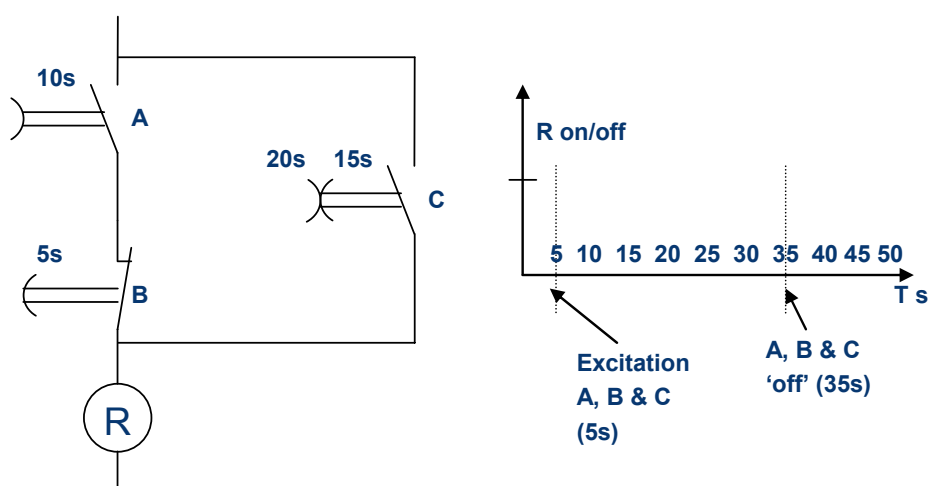
1. A and B are activated simultaneously after 5 seconds and released simultaneously after 35 s. Trace the 'On' excitation of R on the graph.



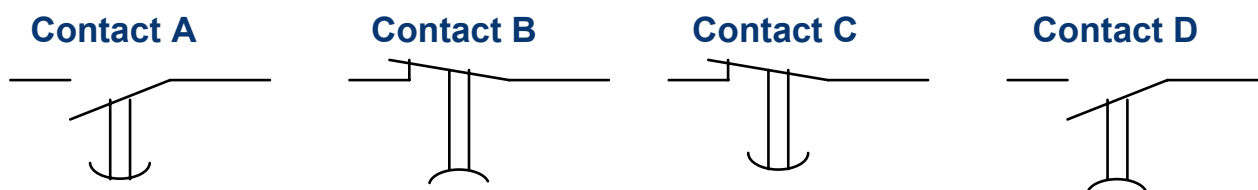
2. Same question as above, trace the excitation of 'R'



3. Let us add a contact for this exercise as, in practice, this type of assembly is very little used. A, B & C are activated simultaneously at t=5s and then released at t=35s. How does 'R' behave?



4. With a 'horizontal' representation, the contact is activated upwards (standard procedure), match the 4 definitions to the 4 symbols.



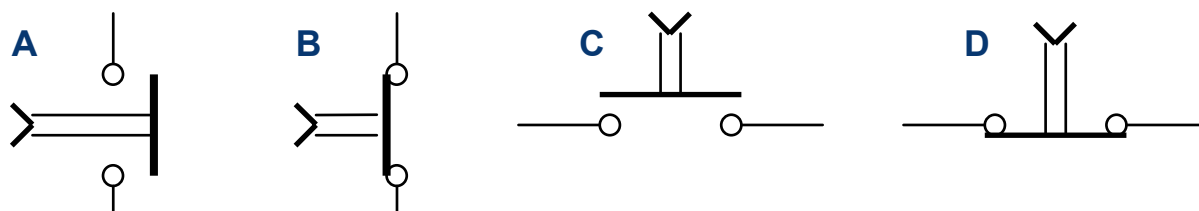
Definition 1: rest time-delay NC = contact ...

Definition 2: work time-delay NC = contact ...

Definition 3: work time-delay NO = contact ...

Definition 4: rest time-delay NO = contact ...

5. I found the following representation on an old diagram. Pay attention, the direction of activation does not appear to be indicated: downwards, upwards, to the left, to the right, you have to work it out and identify the 4 possibilities. Delay 'on' = work timing; delay 'off' = rest timing.



Definition 1: NC delay off = contact ...

Definition 2: NC delay on = contact ...

Definition 3: NC delay on = contact ...

Definition 4: NO delay off = contact ...

3.2.3. Contact with manual mechanical control

3.2.3.1. Push buttons

You must distinguish between 'traditional' push buttons, which automatically come back to their initial position and those which remain in the new position...(and 'pull' buttons).

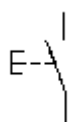


Figure 10: Automatic return push buttons

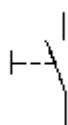


Figure 11: Static push buttons



Push buttons are mounted in "button terminals" of varying quantities and types.

The mechanical control will be on the front of the unit containing the NO or NC contacts. One control may activate 'x' contacts mounted in additional units.

Figure 12: Unit with 2 push buttons

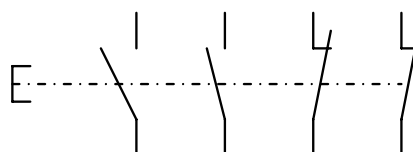


Figure 13: Push button activating 4 2 NO + 2 NC contacts

The function of the button is almost without limits. The button is used for the requested logic, with the preferred colour, text, symbol, etc.

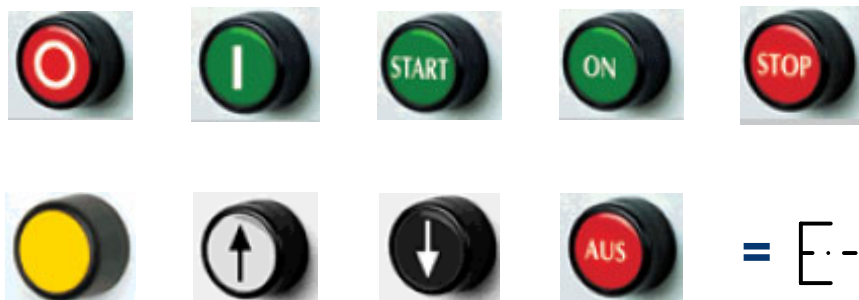


Figure 14: Unlimited functions for push buttons

Push buttons can also be lit, i.e. with an indicating lamp integrated in a separate circuit.



Figure 15: Aligned or overshooting standard illuminated B-P and symbol

Large palm button in the "impact zone" to ensure a direct hit in case of an emergency (also known as an 'emergency stop').



Figure 16: 40 mm emergency stop

3.2.3.2. Colours of push buttons and their meaning

According to IEC/EN 60073 (VDE 0199), IEC/EN 60204-1.

These are international standards, and not necessarily complied with on your site. You must check. Important: "screen" representations are different!

Colour	Meaning	Application examples
RED	Emergency	- Emergency stop - Fire fighting systems
YELLOW	Abnormal	Intervention to remove an abnormal situation or avoid unwanted modifications
GREEN	Standard	Start-up from a safe condition
BLUE	Mandatory	Reset
WHITE	No specific meaning assigned	- ON/Power (preferential) - OFF/No power
GREY		- ON/Power - OFF/No power
BLACK		- ON/Power - OFF/No power (preferential)

Table 8: Standard colours for push buttons

3.2.3.3. Colours of indicating lamps and their meaning

According to IEC/EN 60073 (VDE 0199), IEC/EN 60204-1

Specific standards may also exist for your site for indicating lamps...

Colour	Meaning	Explanation	Application examples
RED	Emergency	Warning of a potential danger or a situation requiring immediate action	Failure of the lubrication system • Temperature not within the specified safety limits • Essential equipment stopped via a protective device
YELLOW	Abnormal	Imminence of a condition critical	• Temperature (or pressure) not at standard value • Overload acceptable for a limited period • Reset
GREEN	Standard	Indication of safe working conditions or authorisation to continue operations	• Cooling fluid circulating • Automatic control of the boiler operational • Machine ready to start
BLUE	Mandatory	Condition requiring action by the operator	• Remove an obstacle • Switch to Forward
WHITE	Neutral	Other conditions: possible used whenever a doubt exists concerning the use of the colours RED, YELLOW and GREEN or to confirm	• Motor running • Indication of working modes

Table 9: Colours of illuminated push buttons and their meaning

For illuminated push buttons, refer to the two tables below. The first table must be used for push button functions.

3.2.3.4. Switches

Rotary switches are generally known as commutators, however a toggle switch (light switch next to the door) controls the starter circuit...

Rotary switches also exist (with automatic return).

Specific commutator symbols (rotary)

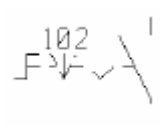
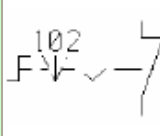
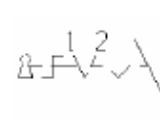
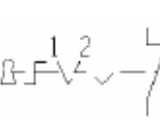
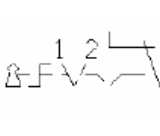
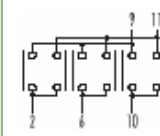
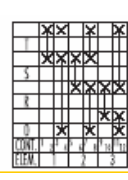
	NO contact with manual 2-position commutator + neutral point and 'latch'		NC contact with manual 2-position commutator + neutral point and 'latch'		NO contact with 2-position key-type commutator and 'latch'
	NC contact with 2-position key-type commutator and 'latch'		NO contact with 2-position key-type commutator + neutral point and 'latch'		NC contact with 2-position key-type commutator + neutral point and 'latch'
	2-position NC + NO contact with key + latch			And "logical" combinations with matrices for more complex situations	

Table 10: Contact rotary control devices (commutators)

The control section of the commutator (or **rotary selector** – an alternative name) may consist of a handle, crosshead, key, etc....



Figure 17: Different rotary selectors

The commutator may rotate 30°, 45°, 60°, or 90°, etc. left or right, as preferred.

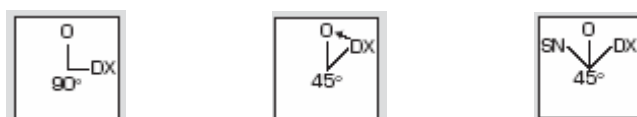


Figure 18: Different commutator positions

Commuters may have specific characteristics such as **measures, stepping, wafers, inverters, cams, a particular design, etc....**, and 'x' positions.

Simply "organise" the contacts behind the control device.

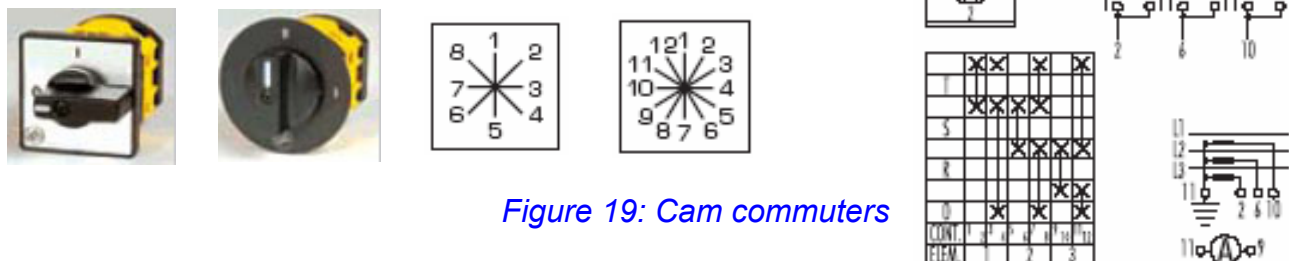


Figure 19: Cam commutators

A closing and opening logic is clearly required for the contacts combined with the control device in the case of cam commutators and wafer lay-up (stepping switches) and 'x' positions. You will do exercises (later) with commutators for voltmeters, ammeters, motor starters, etc. When a commutator controls a power circuit, it can also be called a switch....

Push-turn control devices also exist (*illuminated or other*), combining a push button with a commutator. I am never certain if I have to turn and then push or vice versa....

3.2.4. Automatic mechanical controls

The following are a few examples of controls which operate one or several contacts with a secondary action in addition to the human action (direct).

3.2.4.1. Travel stops (and similar)



Figure 20: Micro circuit breaker, limit switch, safety switch, etc...



Figure 21: Foot, wobble stick, yoke plate switches (contact)

"New" symbols can exist for control devices, certain manufacturers have their own representations. You must interpret the symbol shown on a diagram 'logically'.

However, if you create a diagram, try to use the "standard" symbols which are shown in the tables in this document.

3.2.4.2. Pressure switch, thermostat, humidistat, etc.

These are "systems" which activate a contact subsequent to a physical, chemical, electric, "event", etc.

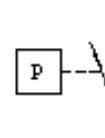
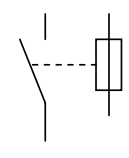
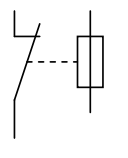
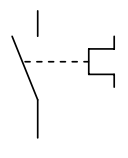
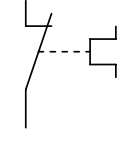
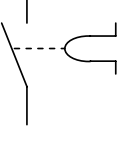
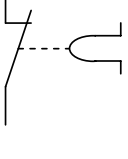


Figure 22: Thermostat, pressure switch and symbol

The contact is activated by a P, T, L, H, -based device. Simply change the letter in the symbol square.

3.2.4.3. Trigger contact

This contact relates to the symbol for the trigger system (electro-mechanical); A trigger system can activate several independent, but synchronised contacts, controlled by the trigger electro-mechanical system.

	NO contact activated by fuse melt		NC contact activated by fuse melt		NO contact activated by heat trigger
	NC contact activated by heat trigger		NO contact activated by magnetic trigger		NC contact activated by magnetic trigger

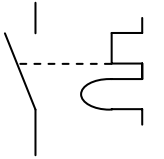
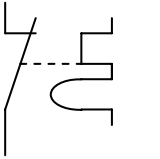
	NO contact activated by magnetic + heat trigger		NO contact activated by magnetic + heat trigger		
---	--	---	--	--	--

Table 11: Electro-mechanical control devices

Example: Auxiliary contact on a heat relay:

The intensity of the power circuit acts on the thermal element, which will activate the trigger contact in the power circuit due to thermal deformation.

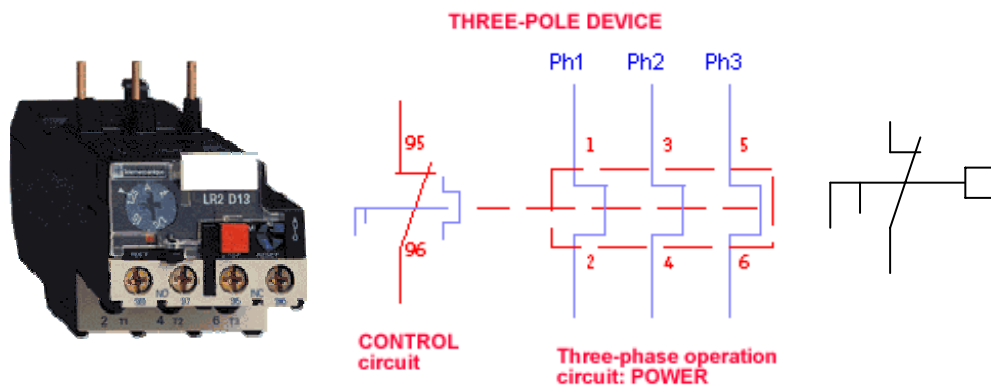


Figure 23: Sorting heat relay with diagram and symbol

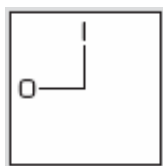
The  sign refers to the locking/securing “system”.

3.2.5. Exercises – contacts

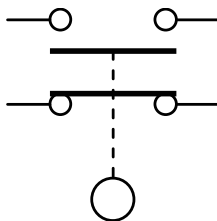
Not all symbols, and symbols with other representations/standard symbols have been listed above.

You must identify the following symbols and images, each symbol is defined in terms of contact type (and quantity), control device and additional devices (if existing).

6. Identify the next device and draw its symbol (it opens 1 contact and closes another in 2 separate circuits).



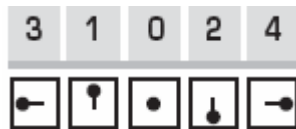
7. Define this symbol



8. Define this control device and draw the symbol (with a NO contact).



9. For this type of control device (joystick) and the control "signs" shown. How many positions are there? How many contacts (as a minimum) must be "coupled"?



10. Technical data for this device states:

- Setting of relative air humidity
- Inverter contact
- High commutation capacity
- Easy access to terminals

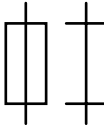
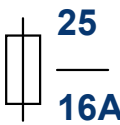
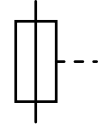
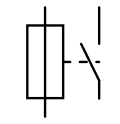
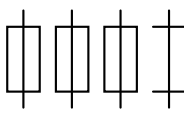
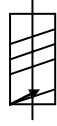
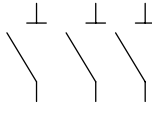
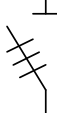
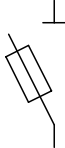
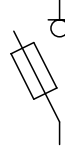
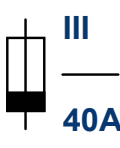
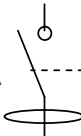
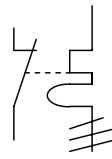
Give an alternative name. Draw the symbol.

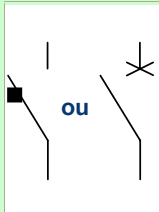
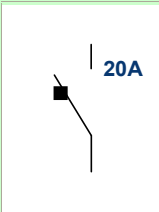
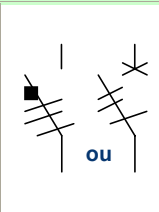
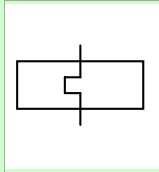
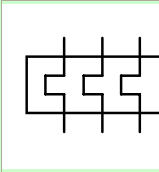
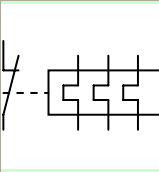


4. SYMBOLS FOR THE CREATION OF SCHEMAS

Control devices are (more or less) defined, let us consider what they control and add interconnections.

4.1. PROTECTION DEVICES

	Single-pole fuse overcurrent cut-out		Single-pole fuse overcurrent cut-out with neutral disconnect		Single-pole fuse overcurrent cut-out. 25 Amp. base and 16 Amp. fuse
	Fuse whose end remains on-load after melting		Striker fuse		Striker fuse with indication circuit
	Single-pole fuse overcurrent cut-out with neutral disconnect (single wire)		Three-pole fuse overcurrent cut-out with neutral disconnect (multiple wires)		Three-pole fuse overcurrent cut-out with neutral disconnect (single wire)
	Single-pole disconnect		Three-pole disconnect		Three-pole disconnect with single-wire representation
	Disconnecter with fuse		Load switch with fuse		Overcurrent cut-out with fuse Three-pole base and 40A fuses
	Differential switch 30 mA		Circuit breaker* Residual differential, sensitivity of 30 mA; In current = 25A		Three-phase heat magneto relay activating a NC auxiliary contact

	Automatic switch or circuit breaker**		Circuit breaker Nominal current 20A		Three-pole magneto-thermal circuit breaker Shown as single- wire
	Heat relay		Three-phase heat relay		Three-phase heat relay activating a NC contact

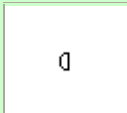
Distinctive symbols					
	Automatic trigger function		Circuit breaker function		Disconnecter function
	Switch function		Disconnecter-switch function		Contactor function
Important: a switch can act as a disconnecter, however a disconnecter cannot act as a switch - switch = cut-out (disconnection...) - disconnecter = 0 (zero) power					

Table 12: Protection devices

DDR (Residual differential circuit breaker) can also be represented in this way.

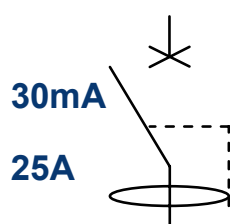


Figure 24: "traditional" symbol of a differential circuit breaker

** Circuit breakers (differential or other) are switches with an automatic cut-out function. Both devices (circuit breakers and switches) have a cut-out function, circuit breakers are (also) equipped with an "automatic" heat and/or magnetic trigger system.

4.1.1. Disconnecter switches

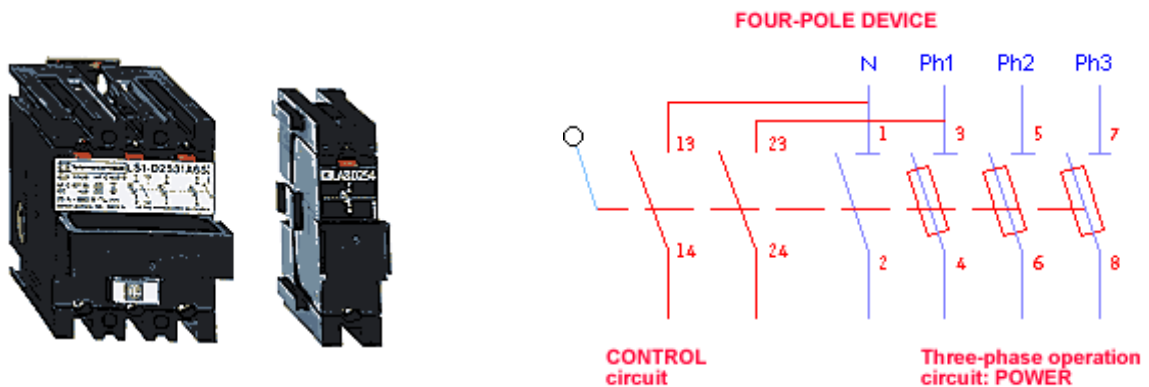


Figure 25: Four-pole disconnecter

This disconnecter has 3 phases + neutral point and can be equipped with a fuse, (*important, the fuse is not fitted to the neutral point*).

The representation shows the power contacts (3 + 1), 2 NO auxiliary contacts and the wobble-stick-operated manual control.

4.1.2. Power switch

Example of a 2-position four-pole switch with its representation symbol on the diagram.



Figure 26: Four-pole switch

Example of a safety four-pole disconnecter-switch with a **visible** load disconnection function and positive action for contacts.

- Double phase cut-out.
- Snap-on self-cleaning contacts.
- Device which may be equipped with auxiliary contacts.

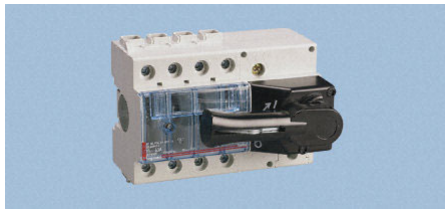


Figure 27: Four-pole disconnect switch

The switch may be handled on-load, and is not a disconnecter. It is (also) equipped with a fuse.



Figure 28: Three-pole switch with fuses

Create a symbolic representation (for a diagram) of the last 2 types of switches.



4.1.3. The circuit breaker

A course will be dedicated exclusively to circuit breakers, let us start by showing the relations between the device (image) and the symbol.

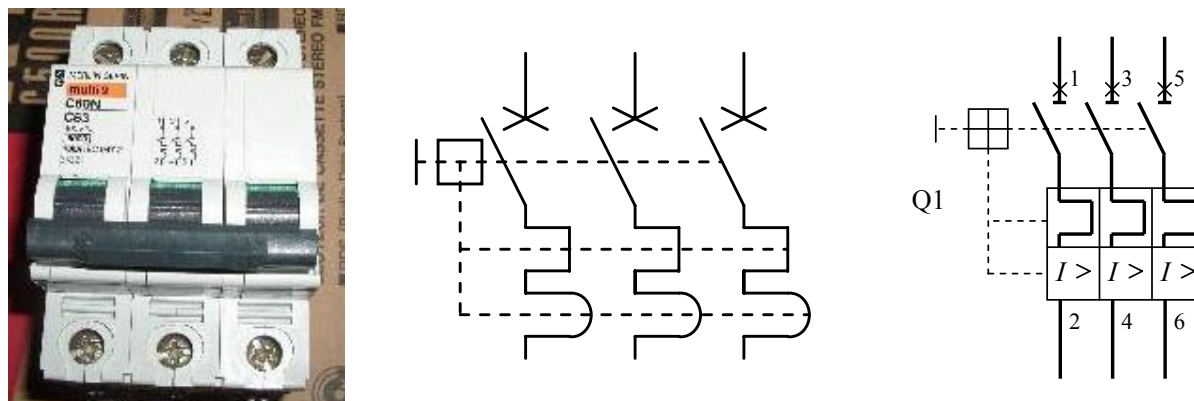
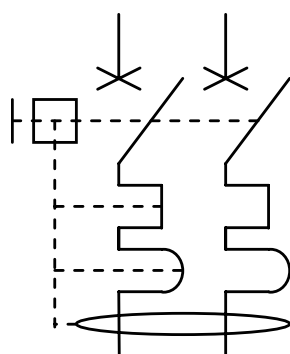


Figure 29: Three-pole circuit breaker and representations for diagrams



Take note of the diagram on the front of the devices. Almost all manufacturers supply this diagram.

A “test” button exists for circuit breakers with “differential units” as shown here. This button creates an artificial default

Figure 30: DDR - Two-pole circuit breaker with a differential unit

Auxiliary position and trigger contacts can be linked for almost all types of circuit breakers (physically and on a diagram).

4.2. SEPARATION DEVICES

Some protection devices can also act as separation devices (command/cut-out), e.g. remote controlled circuit breakers. The following table shows symbols for electrically controlled cut-out devices, relays (for control circuits in principle) and contactors (power circuits).

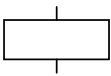
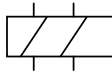
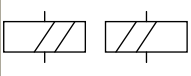
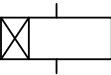
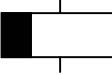
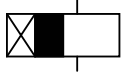
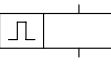
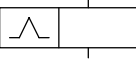
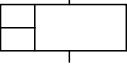
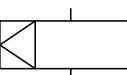
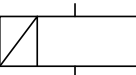
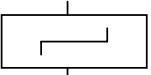
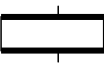
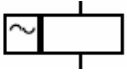
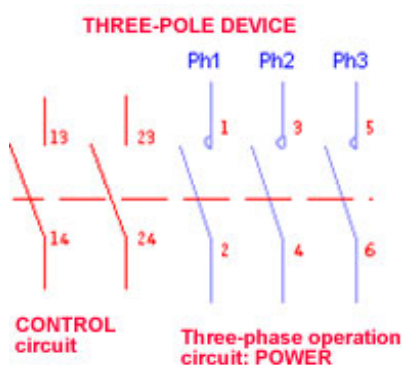
Relays and contactors					
	General symbols for relays and contactors		2-coil relay, simple diagram		2-coil relay, optional diagram
	Relay time delay at on		Relay time delay at off		Relay time delay at off and on
	Flasher relay		Fleeting relay		With quick acting coil
	Mechanical locking relay		Remanent relay		Step-by-step relay
	Polarised relay		Relay not AC-sensitive		AC relay

Table 13: Relays and contactors

4.2.1. The contactor

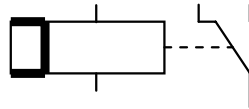
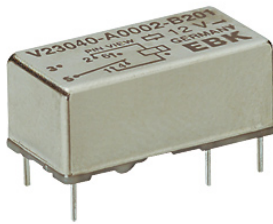


Represented without the coil on the diagram opposite - the contactor is aligned on the complete diagram.

Figure 31: Three-pole contactor with 2 auxiliary contacts

Contactors may be two, three or tetra-pole (or hexa-pole), the same symbol (representation) will be used irrespective of amperage.

4.2.2. Relays



Polarised relay for printed circuits with a change-over contact (double contact) for use in communication and data techniques, medical techniques, machine regulation and adjusting.

Figure 32: Example of a time-delay relay

When we think of a relay, we tend to think of a small contactor, which is almost right... Relays are like power-free circuits with low currents for control circuits.

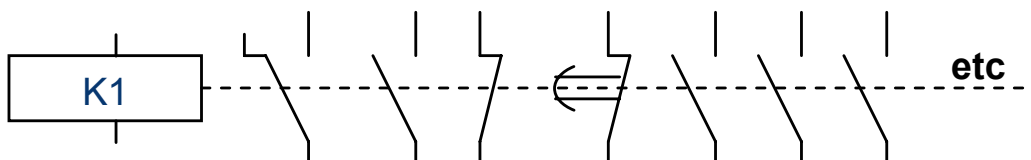
Relays activate between 1 (one) contact and 'x' contacts. *Relays on "lamp test" circuits have a multitude of NO contacts.* All types of 'auxiliary' or 'additional' contacts exist: NO, NC, times, transit, etc.

Caution: do not mix up the "particularity" of the contact with the "particularity" of the relay (coil) as shown below timing is applied at the contact and not at the relay.

A few examples (images) of auxiliary contacts to be fitted to relays or contactors are shown.



Figure 33: Example of a relay with multi-contacts and auxiliary contacts



4.2.3. Comparison of protection and cut-out devices

Establishment of a comparative table to "assess" the roles of protection and separation devices.

This aspect will be revised later on, we are only considering the symbols for the current time, however we have a general idea of 'standards' for use.

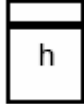
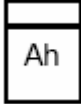
DEVICE	FUNCTION	ACTION	Interrupting capacity (IC)
DISCONNECTOR	SEPARATION	Manual control	N/A
DIFFERENTIAL	OPEN AND CLOSE AN ON-LOAD CIRCUIT 2 rest positions: open or closed	Manual control	ASSIGNED CURRENT
DISCONNECTOR	ON-LOAD CIRCUIT	Manual control	ASSIGNED CURRENT
FUSE	PROTECTION AGAINST SHORT CIRCUITS AND OVERLOADS	Automatic melt Cannot be reset	HRC (e.g.: 100 kA)
DIFFERENTIAL	PROTECTION AGAINST SHORT CIRCUITS AND OVERLOADS	Automatic cut-out Manual reset	$IC > C_{ci}$
CIRCUIT BREAKER DISCONNECTOR	DOUBLE FUNCTION (see below)	Automatic cut-out Manual reset	$IC > C_{ci}$
DIFFERENTIAL SWITCH	DOUBLE FUNCTION Circuit breaker + DDR	Automatic cut-out Manual reset	$IC > C_{ci}$ for the circuit breaker. Cut-out for the NDS by the DDR
CONTACTOR	OPEN AND CLOSE AN ON-LOAD CIRCUIT 1 rest position: open	Remote control	Min. IC: blocked rotor stator current
DIFFERENTIAL SWITCH	This device acts as a switch and a DDR differential unit. It is used if differential protection is required and if protection against overloads and short circuits is provided by a separate protection device.		

Table 14: Comparison of protection and separation devices

NB: The indications in the following table do not correspond to official definitions, but reflect the functions of the devices and their applications.

4.3. MEASUREMENT AND INDICATION DEVICES

This concerns measuring devices, lamps and indication devices.

Indicators, recorders and meters					
	Indicator		Recorder		Integrator (e.g.: electric meter)
Indicators and recorders <i>The device symbol is completed at the centre by one of the following mentions, letters or signs</i>					
A	Ammeter	Cos φ	Cos φ metre	Tx	Torquemeter
f	Frequency	Hz	Frequency meter	h	Hour
Z	Impedance	Ω	Ohmeter	λ	Wavemeter
φ	Phasemeter	n	Tachometer	t	Time
θ	Thermometer Pyrometer	varh	Varhour	var	Varmeter (active power)
VA	Volt-ampere meter	V	Volmeter	W	Wattmeter
Wh	Watthour				
	Oscilloscope		Differential voltmeter		Galvanometer
	Multimeter			Angular position or pressure indicator: - DC/ - induction	
Integrators, meters					
	Hourmeter, time meter		Ampere-hour meter		Watt-hour meter, active energy meter

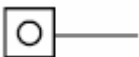
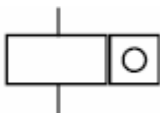
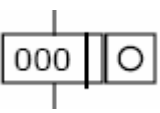
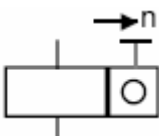
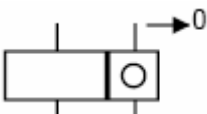
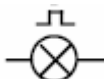
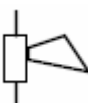
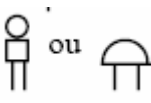
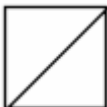
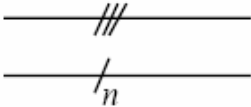
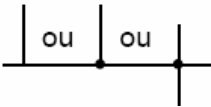
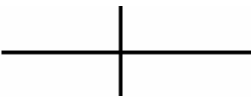
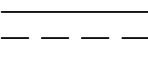
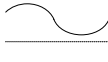
	Active energy meter measuring energy in one single direction		Varhour meter, reactive energy meter		
Meters: count a number of events					
	Distinctive symbol		Electric pulse meter		Electric pulse meter with digital display
	Electric pulse meter with manual n setting (reset if n = 0)		Electric pulse meter with electric reset		
Electric clocks					
	Clock, general symbol Secondary clock		Master clock		Contact clock
Lamps and indicators					
	Lamp, general symbol		Flashing light		Neon lamp (neon = red)
	Audio warning, horn		Bell		Siren
	Buzzer		Bell idem above, at 90°		Mechanical indicator

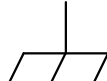
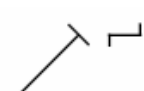
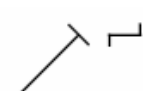
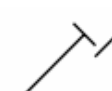
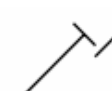
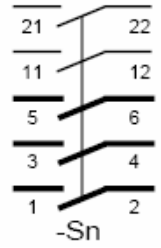
Table 15: Symbols for measuring and indication devices

4.4. CONDUCTORS

This concerns the interconnectors between the different symbols. They are quite simply lines, but rules apply...

The following representations are used when creating electric diagrams (next course).

General symbols for functional blocks					
Functional blocks are represented with a rectangle or a square with the symbol of the function concerned in the centre.					
	Functional block, general symbol		Converter (all types: e.g. rectifier, AC/DC)		Variable elements: e.g. speed regulator
	Direction of propagation of the energy or signal				
Connections between functional blocks and electric devices – Connecting lines					
	Electric connections		Three-phase, line with n channels		
	Electric contact: !!!: mandatory point for contact between 2 wires ⊥		Contact-free crossing.		
	Mechanical connection		3 phases – 50 Hz		
	Alternating current		Direct current		Inverted current
	Single-phase current		Multi-phase current (m phases)		

	Low frequency		Medium frequency		High frequency	
	Earth/ground		Connection to chassis		PE – connection point	
Variability						
	Linear doped variability		Non-linear doped variability		Linear intrinsic variability	
	Non-linear intrinsic variability		Predetermined adjustment		Automatic regulation	
doped: the variable depends on an external device. E.g.: resistance adjusted by an actuator intrinsic: the variable depends on the device itself. E.g.: resistance adjusted according to temperature)						
	Scaled variability		Constant variability		Constant variability	
						
	Main conductor Power circuit for diagrams thick line, one figure reference			Secondary conductor Control circuit for diagrams narrow line, one figure reference		
Nomenclature/References:						
L1, L2, L3, N, PE: three-phase network, neutral point, Earth connection						
Q* : disconnector (* = n°) S* : switch, commuter, push button F* : protection (fuse, circuit breaker, etc.) T* : transformer KM* : main contactor KA* : control relay M* : motor n: device number			 			

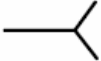
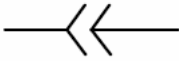
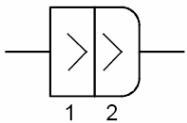
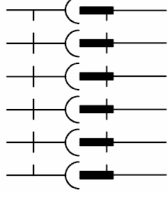
Conductors and connectors:					
	Male terminal		Female terminal		Plug and terminal
	Male terminal – control circuit		Female terminal – control circuit		Plug and terminal assembled
	Connector assembled 1) male mobile part 2) female mobile part			Multi-terminal and multi-plug connector	
	Closed connection bar (jumper)		Open connection bar		Shield latch, test point

Table 16: Conductors and connections between devices, for diagrams

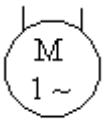
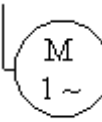
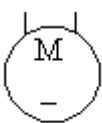
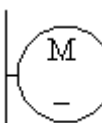
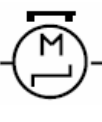


The "multi-connection" principle is often used in testing and when checking instruments (indicators, relay, recorders, etc.) for LV and HV panels.

Figure 34: Example of a multi-terminal connector

The particularity of "current" connectors (on the fixed connector, the female terminal) is that they do not cut-off circuits, an ammeter can be inserted or removed, while the circuit is maintained operational and closed (*split contact system*).

4.5. ELECTRIC MOTORS

<i>Symbols for electric motors for diagrams</i>					
	Single-phase asynchronous motor (short circuit rotor)		Single-phase AC commutator motor in series		Single-phase synchronous motor
	DC motor (general symbol) Or DC motor		Series-wound DC motor		Shunt DC motor
			Step-by-step permanent-magnet motor		Single-phase AC commutator motor
	Three-phase asynchronous motor with short circuit rotor (U, V, W) Or Three-phase motor with short circuit rotor (squirrel cage)		Three-phase asynchronous motor with short circuit rotor and 6 stator terminals 1 speed, U1, V1, W1 + U2, V2, W2 2 speeds, 1U, 1V, 1W + 2U, 2V, 2W		Three-phase asynchronous motor with ring (U, V, W + K, L, M) Or Three-phase wound rotor motor
<i>Functional symbols for motor starters</i>					
	Starter general symbol		Stepped starter		Regulating starter (regulator)
	Starter with automatic stop		Direct switching starter with contactor in both directions		Delta wye starter
	Autotransformer starter		Regulating starter with silicon controlled rectifier		Automatic starter general symbol

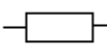
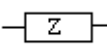
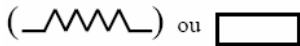
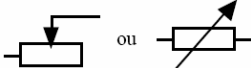
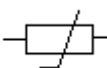
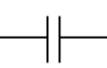
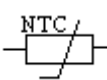
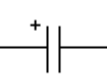
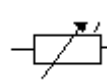
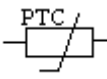
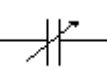
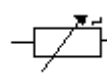
	Semi-automatic starter general symbol		Rheostatic starter		Series-parallel starter
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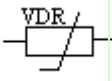
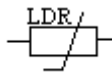
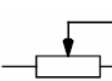
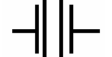
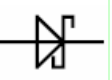
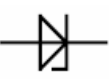
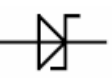
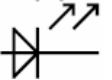
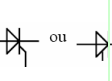
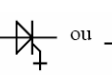
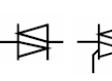
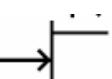
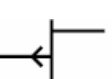
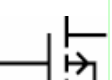
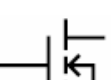
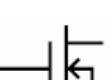
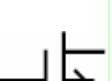
Table 17: Symbols for electric motors and motor accessories

Clearly, other types of schematic representation can exist, however, they would always be similar to the above. Understanding the meaning of a symbol is simply a question of applying logic.

4.6. ELECTRIC COMPONENTS

Other “elements” must be added to diagrams, e.g.:

Symbols for electric components for diagrams					
	Resistance (purely resistive)		Impedance		Inductance
		Variant for resistance			Variant for variable resistance
	Varistor general symbol		Capacitor		Inductance with core
	Negative temperature coefficient thermistor with non-linear variability (- θ can also be used)		Polarised electrolytic capacitor		Constant variation resistance
	Positive temperature coefficient thermistor with non-linear variability (+ θ can also be used)		Variable capacitor		Stepped variation resistance

	Thermistor with non-linear variability (U can also be used, depending on the voltage)		Photosensitive resistance		Potentiometer
	Coil (inductance)		Core coil		Piezoelectric element
Semi-conductor diodes					
	Shotky diode		Zener diode		Transil
	PN junction diode		Electroluminescent diode		Laser diode
Silicon controlled rectifiers					
	Silicon controlled rectifier		GTO (trigger blockable silicon controlled rectifier)		Diac (diode) Triac
Transistors					
	PNP two-pole transistor		NPN two-pole transistor		Transistors NPN darlington assembly
	Transistors PNP darlington assembly		Junction T. with N channel field effect		Junction T. with P channel field effect
	Enhancement mode MOS T., P channel		Enhancement mode MOS T., N channel		Depletion mode MOS T., N channel
	Depletion mode MOS T., P channel				

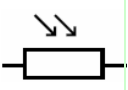
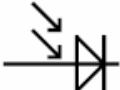
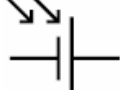
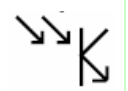
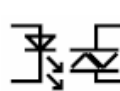
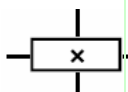
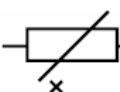
Photosensitive & magneto-sensitive devices					
	Photoresistance		Photodiode		Photovoltaic cell
	Phototransistor		Optocoupler with phototransistor		Optocoupler with phototriac
	Hall effect device		Magneto - resistance		

Table 18: Symbols for electric/electronic components

4.7. SOURCES OF ENERGY

4.7.1. Transformers

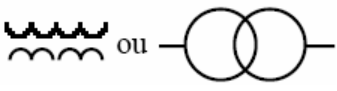
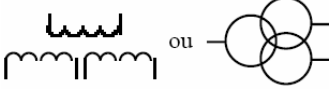
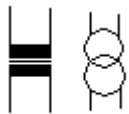
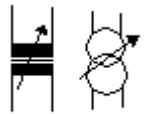
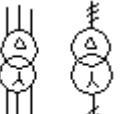
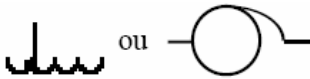
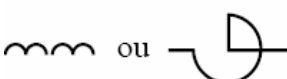
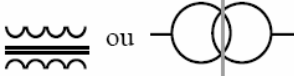
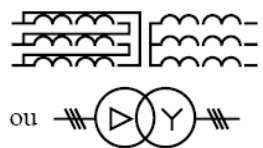
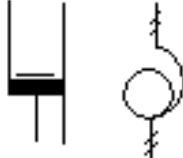
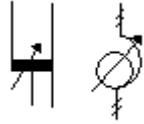
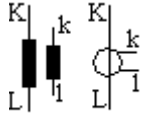
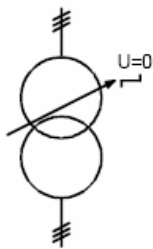
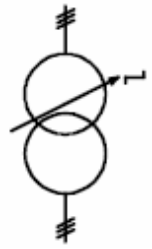
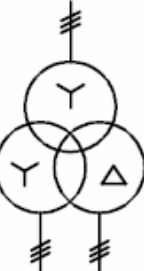
Transformers and self-transformers					
	Transformer with two windings		Transformer with three windings		
	single-phase transformer (either symbols)		single-phase transformer with adjustable synchronisation		three-phase transformer (e.g. delta wye)
	self-transformer		Inductance		
	Shield transformer		Three-phase transformer with delta wye synchronisation		
	single-phase self-transformer		single-phase self-transformer with gradual synchronisation		current transformer (primary KL, secondary kl; input k - kommen, output l - los).
	Current transformer, general symbol		Potential transformer, general symbol		3-phase transformer with 4 connection terminals
	3-phase transformer with voltage regulation (tap changer) non-operational		3-phase transformer with voltage regulation (tap changer) operational (power supplied)		3-phase transformer – 3 windings and indication of synchronisation

Table 19: Symbols for transformers and self-transformers

4.7.2. Generators and sources of current

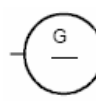
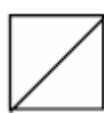
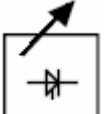
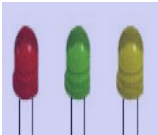
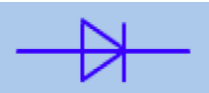
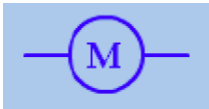
Sources of current and generation					
	source of voltage (ideal)		source of current (ideal)		source of trouble (default marking)
	fuel cell or accumulator component (add: + to the left and - to the right)		accumulator or fuel cell battery		photovoltaic cell
	AC generator (alternator). General symbol		DC generator		DC generator (alternative symbol)
Power converters					
	Converter general symbol		DC converter		Adjustable direct voltage rectifier
	Inverter		rectifier		Graetz bridge synchronisation rectifier
	Rectifier/Inverter		Silicon controlled rectifier power regulator		

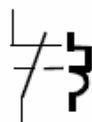
Table 20: Symbols for generators and sources of current

4.8. EXERCISES

11. Match the 10 images to the 10 symbols and add the corresponding names. You will need to find the names yourself!

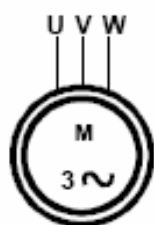
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12. Quiz – only one answer is correct



- ☐ Contact opening due to activation by a magnetic trigger
- ☐ Contact closing due to activation by a thermomagnetic trigger
- ☐ Contact opening due to activation by a thermomagnetic trigger
- ☐ Contact closing due to activation by a magnetic trigger

13. Quiz – only one answer is correct



- ☐ 3-phase induction motor, coil rotor
- ☐ 3-phase induction motor, squirrel cage
- ☐ AC motor, general symbol
- ☐ AC motor with 2 separate windings

14. Quiz – only one answer is correct



- ☐ Switch, general symbol
- ☐ NO (normally open) travel-stop contact
- ☐ Disconnecter
- ☐ Cut-out

15.: Quiz – only one answer is correct



- ☐ Load switch with fuse
- ☐ Disconnecter with fuse
- ☐ Circuit breaker with fuse
- ☐ Circuit breaker switch with fuse

5. SYMBOLS FOR THE TRACING OF DOMESTIC PLANS

You will not systematically come across these types of symbols when working for industrial actors, however, if you are (or intend to become) an electrician, it would be beneficial to have a basic understanding of the creation of domestic plans.

Who knows, perhaps one day you will work in the construction sector (which is a specialist area just like industrial electronics!!) or perhaps you will create an electric installation for your home, and in this case, you will need to understand the plans of the architect, etc.

Under all circumstances, references for domestic installations will be useful. These symbols are shown below, in case you should need them. You will also have a few examples of domestic installations in the course on "plans and diagrams".

I have (often) come across plans with the following symbols when constructing offices on industrial sites.

5.1. PIPING and CONDUCTORS

Piping and conductors on domestic wiring diagrams					
	Wall/ceiling duct		Visible laid piping on a wall		Piping embedded in a wall
	Airborne piping		Piping in a duct		Underground piping
	Floor duct		Rising piping		Descending piping
	Piping -> lighting holding point		Lighting holding point for wall		3-wire piping (number only if more than 3 conductors)
	Neutral conductor (N)		Protection conductor (PE)		Protection and neutral conductor (PEN)
	3 P, N, PE piping				

Table 21: Symbols for domestic piping and conductors

5.2. DEVICES

Domestic distribution devices include control devices, switches, two-way switches, push buttons, etc. located at entrance doors, in corridors.

These devices are represented as symbols.

Devices on domestic wiring diagrams					
	Single push switches (SA)		Dimmer switch		Single-pole pull switch
	Single-pole delay switch		Single-pole switch with Indicator		Two-pole switch
	Three-pole switch		Single-pole double switch (DA)		Single-pole commutator (two-way switches) (VV)
	Two-pole commutator		Double inverter, changeover switch		Push button illuminated push Button
	low current terminal (telecommunication) sheathed (TV)				

Table 22: Symbols for devices, for domestic diagrams

5.3. DEVICES/RECEIVERS

This concerns household equipment as well as motor receivers, among other elements.

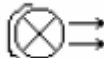
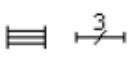
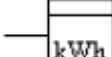
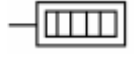
Lamps and receivers on domestic wiring diagrams					
	Lamp (general symbol)		Projector (General symbol)		Florescent light
	Spotlight with low divergence		Spotlight with divergence		Florescent light with 3 tubes
	Light with pull switch		Meter		Fixed household device (general symbol)
	Electric cooker		Electric oven		Microwave oven
	Fridge 3 stars = freezer		Ventilator		Dish washer
	Washing machine		Motor		Dryer
	Transformer		Heating		Water heater
	Storage heater (perhaps with a ventilator if a ventilator symbol is added)		Storage water heater		

Table 23: Symbols for lamps and receivers on domestic wiring diagrams

6. DENOMINATION STANDARDS

6.1. IDENTIFICATION - GENERAL

This concerns identification letters for electric equipment on the basis of DIN EN 61346-2:2000-12 (IEC 61346-2:2000) standards.

Many standards exist for symbols and we must attempt to "standardise these standards" for 'our' diagrams.

With the above reference, and unlike the identifications used until now, identification letters are now determined primarily on the basis of the function of the electrical equipment on the diagram. This leaves a certain degree of freedom when selecting the letter to be assigned to equipment.

Example for a resistance:

- Normal current limiter: R
- Heating resistor: E
- Measuring resistance: B

We could, for example, adopt a certain number of specific rules which partially differ from standards.

- The descriptions of connection terminals are not readable from the right.
- The second letter used to identify the function of the electric equipment is not indicated, e.g.: time-delay relay K1T > K1.
- Circuit breakers whose essential function is protection continue to be identified by Q. They are numbered successively from 1 to 10, starting with the top left circuit breaker.
- Contactors are now represented by Q and numbered successively from 11 to nn, e.g.: K91M > Q21.
- Control relays remain K and are numbered successively from 1 to n.

Identification appears at an appropriate location immediately next to the symbol. It establishes the relation between the equipment located in the installation and the different documents in the file (circuit diagrams, part nomenclatures, connection block diagrams, instructions).

Identification can also be fully or partially copied on or near to the equipment to simplify maintenance.

Equivalence between the old and new identification letters generally used for the selection of equipment are shown below, with an example of representation.

The new letters have already been used for a while for our diagrams.

6.2. Identification letters for electric equipment

6.2.1. IEC (DIN) standards

IEC 61346-2:2000 (DIN 61346-2:2000) standards.

Old identification letter	Example of electric equipment	New identification letter
B	Measuring transducers	T
C	Capacitors	C
D	Storage devices	C
E	Electric filters	V
F	Heat triggers	F
F	Pressure gauges	B
F	Fuses (thin, HH, signal)	F
G	Frequency converters	T
G	Generators	G
G	Gradual starters	T
G	Interruption-free supply	G
H	Lamps	E
H	Optical and acoustic signalling devices	P
H	Indicating lamps	P
K	Auxiliary relays	K
K	Control relays	K
K	Semi-conductor contactors	T
K	Power conductors	Q
K	Time relay	K
L	Inductances	R
N	Separation amplifiers, inverter amplifiers	T

Old identification letter	Example of electric equipment	New identification letter
Q	On-load cut-out disconnectors	Q
Q	protection circuit breakers	Q
Q	Motor circuit breakers	Q
Q	Delta wye circuit breakers	Q
Q	Disconnect switch	Q
R	Adjustment resistance	R
R	Measuring resistances	B
R	Heating resistor	E
S	Control auxiliaries	S
S	Push button	S
S	Limit switches	B
T	Voltage transformer	T
T	Current transformer	T
T	Transformers	T
U	Frequency converters	T
V	Diodes	R
V	Rectifier	T
V	Transistors	K
Z	EMC filters	K
Z	Attenuation and anti-interference devices	F

Table 24: Identification letters as per IEC 61346-2:2000-12 (DIN EN 61346-2:2000)

6.2.2. North American standards

Identification of devices in the United States and Canada according to **NEMA ICS 1-2001, ICS 1.1-1984, ICS 1.3-1986**.

Many diagrams are created in America or by the oil industry. Instrumentation and P&ID references are also identical. Consequently, it would be beneficial for you to be familiar with the US symbols and their meanings in English (with the French translation).

Three figures or letters can be added to the identification letters in the table below to differentiate devices with similar functions. If two or more identification letters are used, generally speaking, the first letter identifies the function.

Example:

The control relay which triggers the first function sequence = 1 JCR. The identification decodes as follows:

- 1 = order number
- J = Jog (sequencing) – equipment function
- CR = Control relay – type of equipment

Identification letter	ENGLISH Device or Function	<i>français</i> <i>Appareil ou fonction</i>
A	Accelerating	Accélération
AM	Ammeter	Ampèremètre
B	Braking	Freinage
C ou CAP	Capacitor, capacitance	Condensateur, capacité
CB	Circuit-breaker	Disjoncteur
CR	Control relay	Contacteur auxiliaire, contacteur de commande
CT	Current transformer	Transformateur de courant
DM	Demand meter	Compteur de consommation
D	Diode	Diode
DS ou DISC	Disconnect switch	Interrupteur - sectionneur
DB	Dynamic braking	Freinage dynamique
FA	Field accelerating	Accélération de champ
FC	Field contactor	Contacteur de champ
FD	Field decelerating	Diminution du champ (décélération)
FL	Field-loss	Perte de champ
F ou FWD	Forward	Marche avant
FM	Frequency meter	Fréquencemètre
FU	Fuse	Fusible
GP	Ground protective	Terre de protection
H	Hoist	Levage
J	Jog	Pianotage
LS	Limit switch	Interrupteur de position
L	Lower	Diminuer

Identification letter	ENGLISH Device or Function	<i>français</i> <i>Appareil ou fonction</i>
M	Main contactor	Contacteur principal
MCR	Master control relay	Contacteur de commande principal
MS	Master switch	Interrupteur maître
OC	Overcurrent	Surintensité
OL	Overload	Surcharge
P	Plugging, potentiometer	Potentiomètre ou connecteur
PFM	Power factor meter	Appareil de mesure du facteur de puissance
PB	Pushbutton	Bouton-poussoir
PS	Pressure switch	Manostat
REC	Rectifier	Redresseur
R ou RES	Resistor, resistance	Résistance
REV	Reverse	Marche arrière
RH	Rheostat	Rhéostat
SS	Selector switch	Sélecteur
SCR	Silicon controlled rectifier	Thyristor
SV	Solenoid valve	Électrovanne
SC	Squirrel cage	Rotor à cage (d'écureuil)
S	Starting contactor	Contacteur de démarrage
SU	Suppressor	Suppresseur
TACH	Tachometer generator	Génératrice tachymétrique
TB	Terminal block, board	Bornier, bloc de jonction
TR	Time-delay relay	Relais temporisé
Q	Transistor	Transistor
UV	Undervoltage	Sous-tension (sous le seuil)
VM	Voltmeter	Voltmètre
WHM	Watthour meter	Wattheuremètre
WM	Wattmeter	Wattmètre
X	Reactor, reactance	Inductance, réactance

Table 25: Identification letters for devices or functions as per NEMA ICS 1-2001

6.2.3. North American standards (bis)

Regulations also allow for the identification of devices as per class (class description) instead of the identification of devices using letters (device description) according to NEMA ICS 1-2001, ICS 1.1-1984, and ICS 1.3-1986.

This type of identification simplifies compliance with international standards. The identification letters used here are (partially) compliant with IEC 61346-1 (1996-03).

Identification as per class according to NEMA ICS 19-2002

Identification letter	Device or function	French Translation
A	Separate Assembly	Montage séparé
B	Induction Machine, Squirrel Cage Induction Motor Synchro, General Control Transformer Control Transmitter Control Receiver Differential Receiver Differential Transmitter Receiver Torque Receiver Torque Transmitter Synchronous Motor Wound-Rotor Induction Motor or Induction Frequency Converter	Machine asynchrone, rotor à cage Moteur asynchrone Synchro transmetteur en général Transformateur de commande Émetteur de commande Récepteur de commande Récepteur différentiel Émetteur différentiel Récepteur Récepteur de couple Transmetteur de couple Moteur synchrone Moteur à induction à rotor bobiné ou convertisseur de fréquence à induction
BT	Battery	Batterie
C	Capacitor Capacitor, General Polarized Capacitor Shielded Capacitor	Condensateur Condensateur en général Condensateur polarisé Condensateur blindé
CB	Circuit-Breaker (all)	Disjoncteurs (tous)
D, CR	Diode Bidirectional Breakdown Diode Full Wave Bridge Rectifier Metallic Rectifier Semiconductor Photosensitive Cell Semiconductor Rectifier Tunnel Diode Unidirectional Breakdown Diode	Diode Diode Zener bidirectionnelle Redresseur pleine onde Redresseur sec Cellule photoélectrique à semi-conducteurs Redresseur à semi-conducteurs Diode tunnel Diode Zener unidirectionnelle
D, VR	Zener Diode	Diode Zener

Identification letter	Device or function	French Translation
DS	Annunciator Light Emitting Diode Lamp Fluorescent Lamp Incandescent Lamp Indicating Lamp	Avertisseur Diode électroluminescente Lampe Tube fluorescent Lampe à incandescence Voyant lumineux
D	Armature (Commutator and Brushes) Lightning Arrester Contact Electrical Contact Fixed Contact Momentary Contact Core Magnetic Core Horn Gap Permanent Magnet Terminal Not Connected Conductor	Armature (collecteur et balais) Protection contre la foudre Contact Contact électrique Contact fixe Contact de passage Conducteur, âme Noyau magnétique Éclateur cornu Aimant permanent Borne Conducteur non raccordé
F	Fuse	Fusible
G	Rotary Amplifier (all) A.C. Generator Induction Machine, Squirrel Cage Induction Generator	Amplificateur rotatif (tous types) Alternateur Machine asynchrone, rotor à cage Alternateur asynchrone
HR	Thermal Element Actuating Device	Interrupteur à bilame
J	Female Disconnecting Device Female Receptacle	Dispositif de déconnexion femelle Connecteur femelle
K	Contactor, Relay	Contacteur, contacteur auxiliaire
FL	Coil Blowout Coil Brake Coil Operating Coil Field Commutating Field Compensating Field Generator or Motor Field Separately Excited Field Series Field Shunt Field Inductor Saturable Core Reactor Winding, General	Bobine Bobine de soufflage Bobine de freinage Bobine d'excitation Champ Champ de commutation Champ de compensation Champ générateur et moteur Champ à excitation séparée Champ série Champ shunt Inducteur Self à fer Enroulement en général
LS	Audible Signal Device Bell Buzzer Horn	Avertisseur sonore Sonnerie Ronfleur Klaxon
M	Meter, Instrument	Instrument de mesure
P	Male Disconnecting Device Male Receptacle	Dispositif de déconnexion mâle Connecteur mâle

Identification letter	Device or function	French Translation
Q	Thyristor NPN Transistor PNP Transistor	Thyristor NPN Transistor PNP Transistor
R	Resistor Adjustable Resistor Heating Resistor Tapped Resistor Rheostat Shunt Instrumental Shunt Relay Shunt	Résistance Résistance réglable Résistance de chauffage Résistance à prise Rhéostat Dérivation Résistance en dérivation pour appareils de mesure Résistance en dérivation pour relais
S	Contact Time Closing Contact Time Opening Contact Time Sequence Contact Transfer Contact Basic Contact Assembly Flasher Switch Combination Locking and Nonlocking switch Disconnect switch Double Throw Switch Drum Switch Flow-Actuated Switch Foot Operated Switch Key-Type Switch Knife Switch Limit switch Liquid-Level Actuated Switch Locking Switch Master switch Mushroom Head Operated Switch Pressure or Vacuum Pushbutton Switch Pushbutton Illuminated Switch, Rotary Switch Selector switch Single-Throw Switch Speed Switch Stepping Switch Temperature-Actuated Switch Time Delay Switch Toggle Switch Transfer Switch Wobble Stick Switch Thermostat	Contact Contact retardé à la fermeture Contact retardé à l'ouverture Contact à séquences Contact de commutation Rangée de contacts Signal clignotant Interrupteur Interrupteur avec et sans verrouillage Sectionneur Interrupteur à deux leviers Interrupteur à tambour Interrupteur commandé par le débit Interrupteur à pédale Interrupteur à clé Interrupteur à couteau Interrupteur de position Interrupteur à flotteur Interrupteur de verrouillage Interrupteur maître Interrupteur champignon Interrupteur actionné par la pression ou le vide Bouton-poussoir Bouton-poussoir lumineux Commutateur rotatif, commutateur à cames Sélecteur Interrupteur à un levier Inverseur de pôle Commutateur à gradins Contrôleur de température Minuterie – contact temporisé Interrupteur à bascule Inverseur Interrupteur à levier Thermostat

Identification letter	Device or function	French Translation
T	Transformer Current Transformer Transformer, General Polyphase Transformer Potential Transformer	Transformateur Transformateur de courant Transformateur en général Transformateur polyphasé Transformateur de tension
TB	Terminal Board	Tablette à bornes – Bornier
TC	Thermocouple	Thermocouple
U	Inseparable Assembly	Ensemble à montage et à raccordement fixe
V	Pentode, Equipotential Cathode Phototube, Single Unit, Vacuum Type Triode Tube, Mercury Pool	Pentode, cathode équipotentielle Tube photoélectrique, monolithique, Type à vide Triode Tube, cathode à bain de mercure
W	Conductor Associated Multiconductor Shielded Conductor, General	Câble, conducteur Câble normalisé Multiconducteur Blindé Conducteur en général
X	Tube Socket	Douille de tube

Table 26: Identification letters as per class according to NEMA ICS 19-2002

6.3. IDENTIFIERS- APPLICATIONS

You need to start by reading (or creating) the diagrams, however, we now need to move on to more hands-on elements, which you are (or will be) required to handle on a daily basis.

6.3.1. Electric command symbols

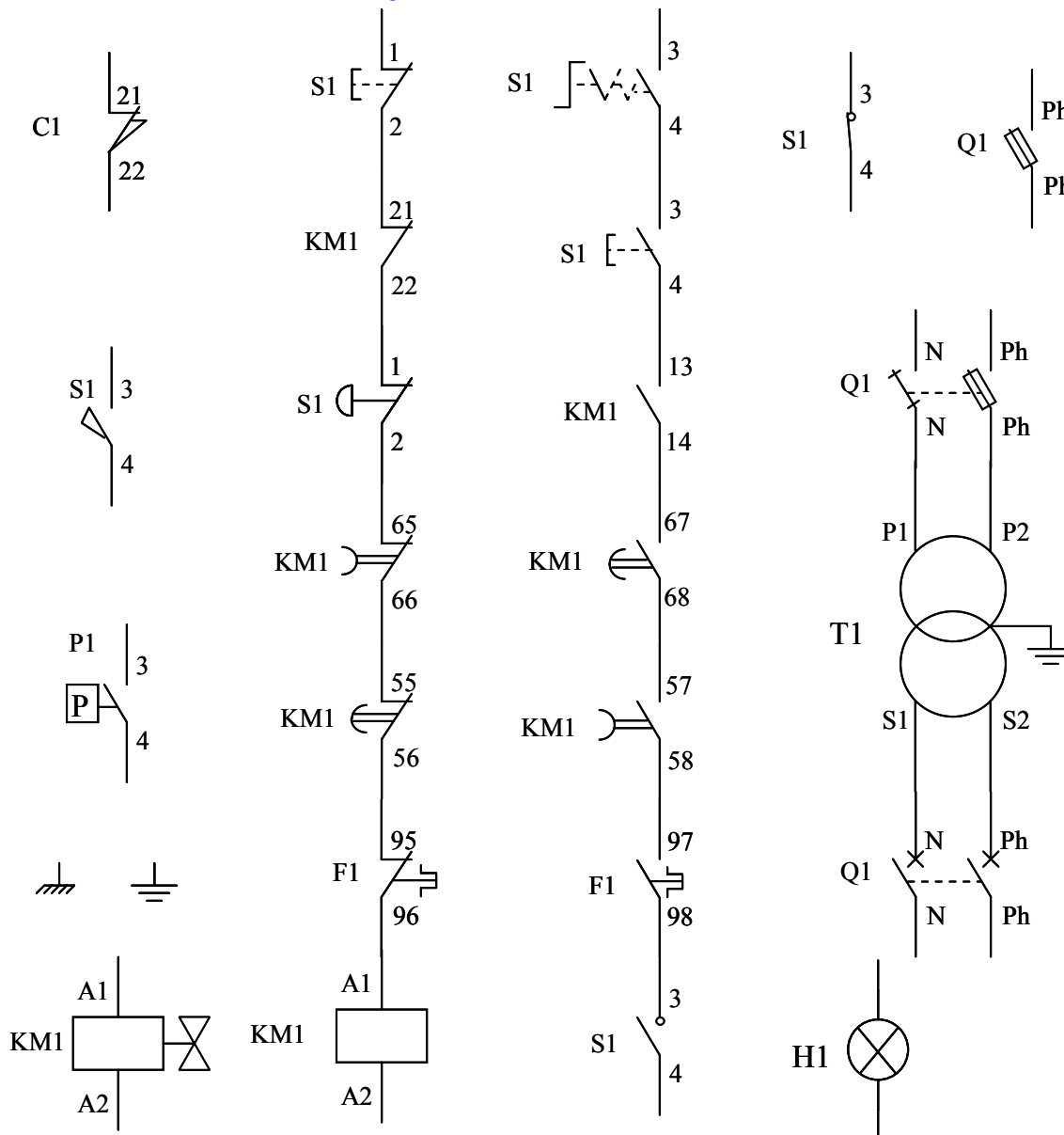


Figure 35: Examples of electric command symbols

The above is a random selection of symbols and identifiers. You need to identify, name, explain (or ask someone to explain) the details for the figures, letters and symbols.

Consider this paragraph as an exercise (no corrected version is available in this document).

6.3.2. Electric power symbols

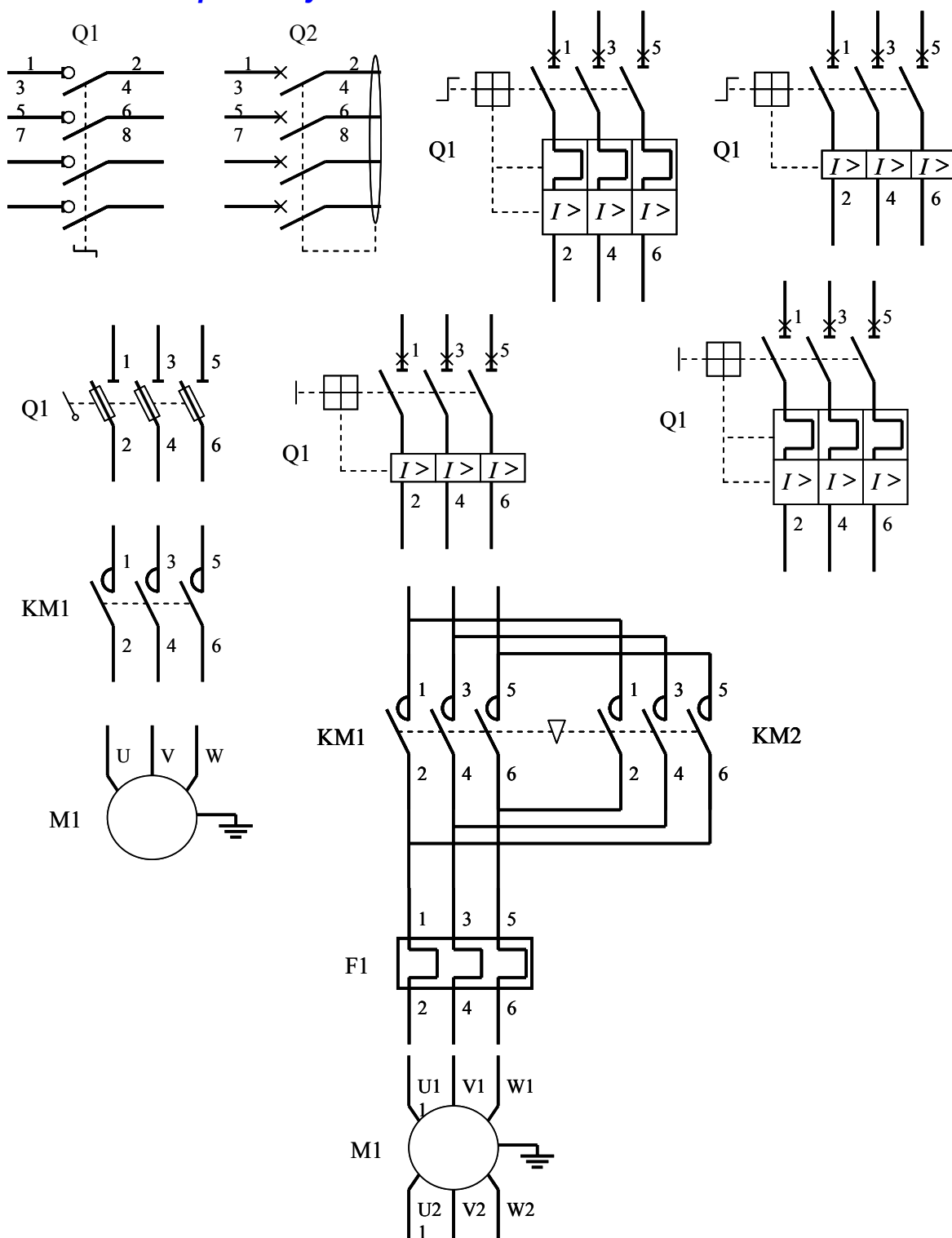


Figure 36: Examples of electric power symbols

Idem for "power": The above is a random selection of symbols and numbering. Describe the above.

7. PNEUMATIC SYMBOLS

The term electropneumatic is often used to refer to the combination of electric and pneumatic systems.

On sites, the instrument expert often "takes care of" pneumatic systems, however, electricians must be able to assist the former, or at least be able to interpret electropneumatic symbols and diagrams.

In terms of maintenance, mechanics, instrument experts and electricians work together, and the assignment of the different elements in this field (pneumatics) is not clear.

Replying "that is not my problem" when faced with an electric + pneumatic (and hydraulic) unit or interface is not constructive.

Everybody's input is required on a site, particularly that of electricians: so you need to learn pneumatic symbols (and the next chapter on hydraulic symbols).

You will also need this knowledge for P&ID's (which you must also be able to read).

7.1. SYMBOLIC REPRESENTATION IN PNEUMATICS

Please refer to the tables below...

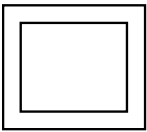
	Hydraulic oscillator		Pneumatic oscillator
	Electric motor		Internal combustion engine

Table 27: General symbols for pneumatic systems

7.1.1. Instruments and accessories

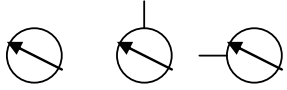
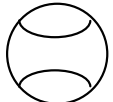
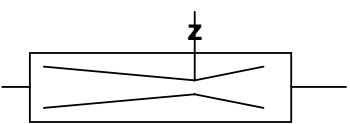
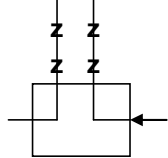
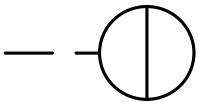
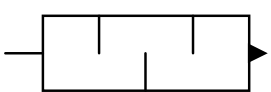
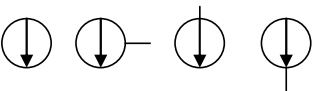
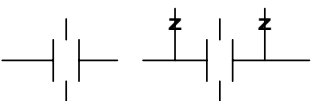
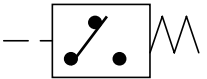
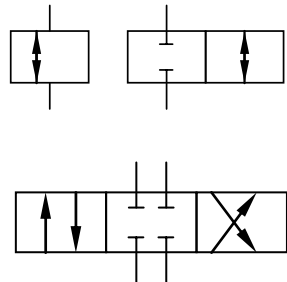
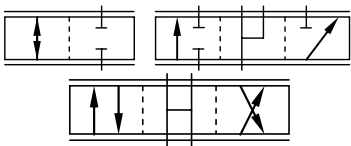
	Pressure gauge		Flowmeter
	Venturi		Pitot tube
	Liquid-level activated switch		Muting circuit
	Temperature gauges		Summer flowmeter
	Diaphragm (perforated plate)		Pressure switch
	Nozzle		

Table 28: Symbols for pneumatic instruments and accessories

7.1.2. Pneumatic valves/relays

	Inner blocked ports		Passages open to the inner section, indefinite positioning
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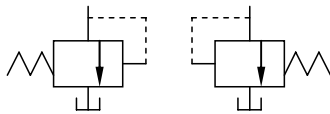
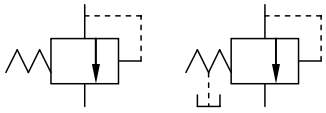
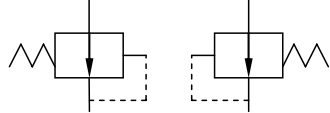
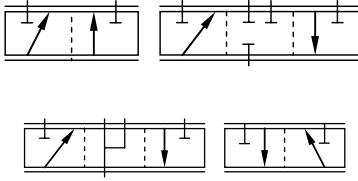
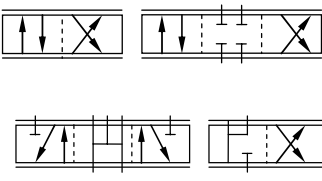
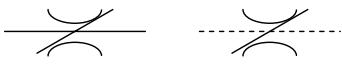
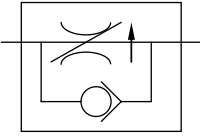
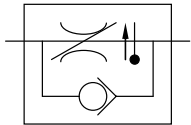
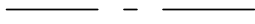
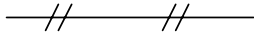
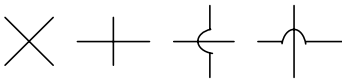
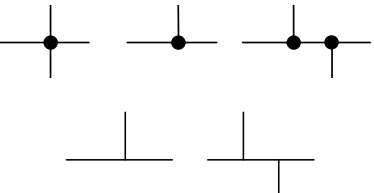
	All or nothing, two positions, with transition		Pressure limiter (PSV)
	Sequence		Pressure regulator
	Distributor, three channels		Distributor, four channels
	Adjustable flow regulator, not compensated		Adjustable pressure flow regulator, by-pass compensation
	Adjustable temperature and pressure flow regulator, by-pass compensation		

Table 29: Symbols for pneumatic valves and relays

7.1.3. Technical lines

	Container outline		Pneumatic line
	Crossing of lines		Connection of lines

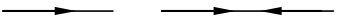
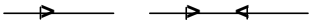
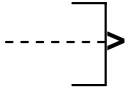
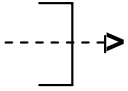
	Direction of the hydraulic flow		Direction of the pneumatic flow
	Non-connectable orifice		Connectable orifice

Table 30: Symbols for pneumatic technical ducts

7.1.4. Storage of energy and fluids

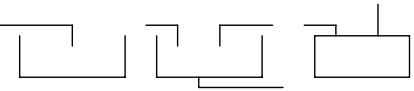
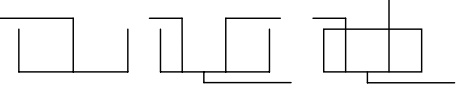
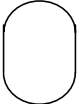
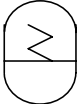
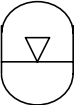
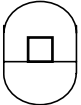
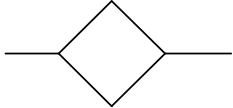
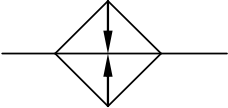
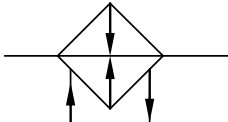
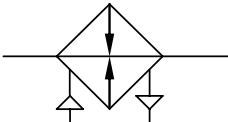
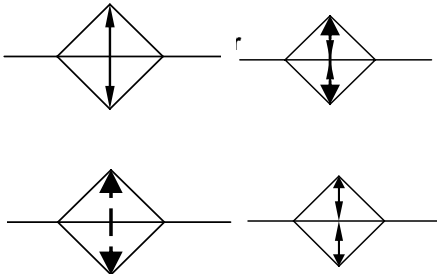
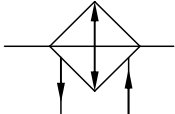
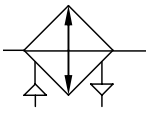
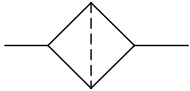
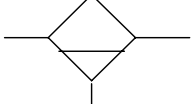
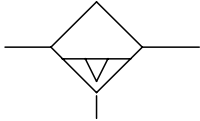
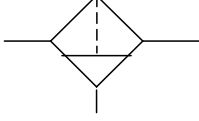
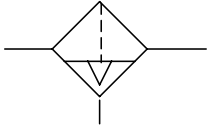
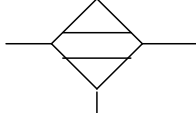
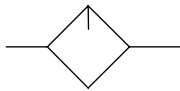
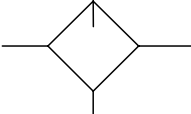
	Vented tank		Pressurized tank
	Vented/pressurised tank with connection ducts above the liquid level		
	Tank with connection ducts below the liquid level. Ducts arrive and leave under the tank when required due to the functioning of the circuit		
	Accumulator, basic symbol		Accumulator, spring loaded
	Accumulator, hydropneumatic		Weight loaded accumulator
	Air or other gas collector		Source of hydraulic energy
	Source of pneumatic energy		

Table 31: Symbols for the storage of pneumatic energy and fluids

7.1.5. Fluid conditioning

	Basic symbol		Heater basic symbol
	Heater liquid heating		Heater gas heating
		Cooler basic symbols	
	Cooler liquid cooling		Cooler gas cooling
	Filter liner		Separator manual draining
	Separator, automatic draining		Separator with filter, manual draining
	Separator with filter automatic draining		Dryer (chemical drying)
	Lubricator no draining		Lubricator manual draining

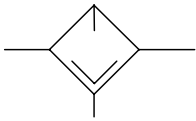
	Lubricator automatic draining		
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Table 32: Symbols for pneumatic fluid conditioning

7.1.6. Receivers with linear movements

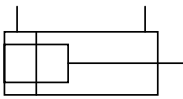
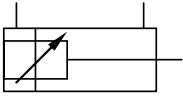
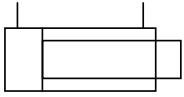
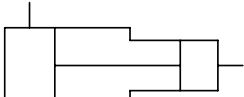
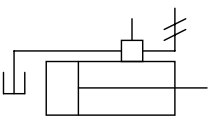
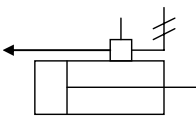
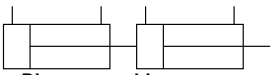
	Double-acting cylinder, reverse and forward with fixed attenuator		Double-acting cylinder, with adjustable attenuator
	Double-acting cylinder in which the diameter of the stem as compared with the diameter of the bore is significant in the functioning of the circuit		
	Amplified pressure		Hydraulic servo positioner
	Pneumatic servo positioner		Discrete positioner

Table 33: Symbols of pneumatic linear devices

7.2. TYPES OF PNEUMATIC SYMBOLS

Two main types of symbols are used for diagrams. Basic symbols and compound symbols. (see below) They are easy to distinguish.

The basic symbol is extracted from tables of symbols (above tables). Compound symbols consist of the combination of some of these symbols to form one single symbol.

Compound symbols represent several basic components which work together to execute a function.

This is shown below.

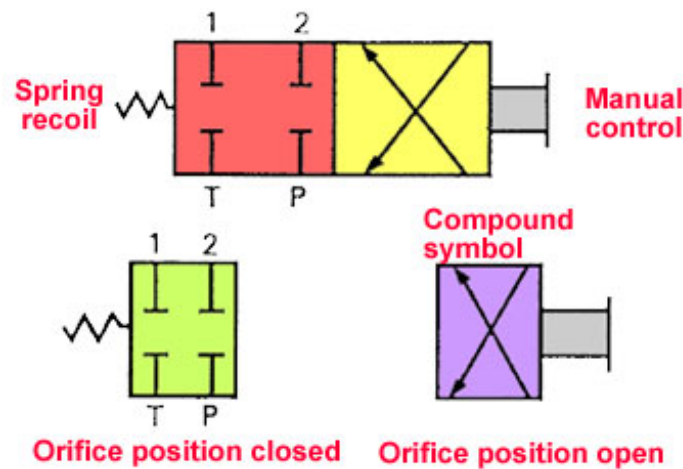


Figure 37: Compound symbol consisting of basic symbols

This figure shows four different basic symbols, each representing part of a hand-operated relay. The closed orifice, open orifice, return spring and manual control wobble stick symbols are shown.

They are combined into one single compound symbol for the hand-operated relay shown at the top of the figure.

Compound symbols are frequently used in diagrams for pneumatic and hydraulic systems.

Many diagrams/ engineering plans include a legend in list format or inserted in a corner. The legend shows the meaning of the symbols. The symbols used on this diagram are shown in the legend to confirm their meaning.

This procedure is useful when the operator uses symbols which differ slightly. As a general rule, symbols do not vary much.

7.3. IDENTIFICATION OF CONTROL ELEMENTS

Do not forget that this course is intended for operators and technicians working on oil production sites. The consideration of diagrams must be organised in view of operations, inspections, system repairs and procedures.

You must be able to start and stop a pneumatic system and be familiar with all of the operating procedures for this system.

You must be familiar with the operation of a system when running satisfactorily. You must also be familiar with events when a system is not running correctly, so that others can contact you for repair operations.

These elements can be learnt by working on the specific pneumatic and hydraulic systems used on the site. This course will enable you to learn the basics for pneumatic/hydraulic systems and their functioning.

You must collect all diagrams and go to the unit to see how "it" works on your site.

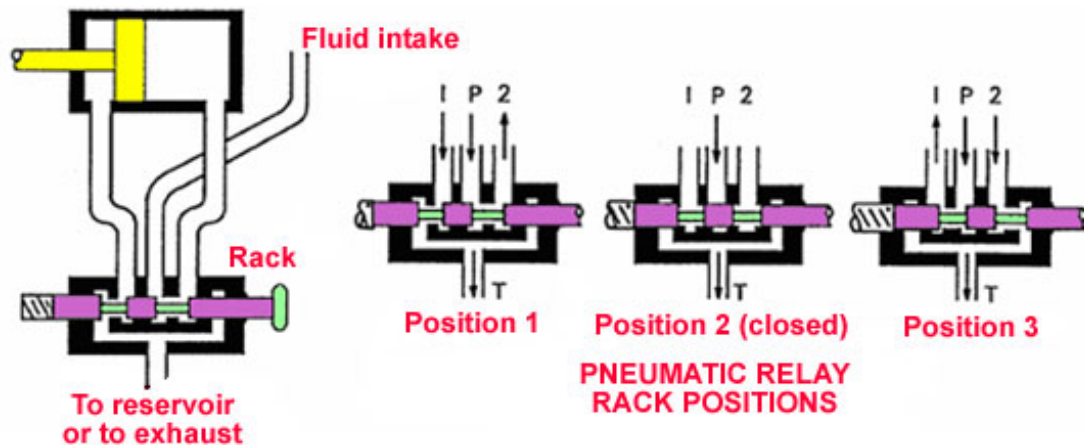


Figure 38: Example of the operation of a pneumatic distributor

7.4. CREATION OF SYMBOLS FOR RELAYS/VALVES

One of the optimum means of learning the meaning of symbols for pneumatic (and hydraulic, they are identical) relays/valves is to draw them. If you wish to represent a relay using a diagram symbol, you could draw the entire diagram yourself.

Start with a white symbol for a relay and add the positions of the components for this relay. Then add the operating mechanism. Complete the drawing by combining all of the sections in one single symbol (see example below).

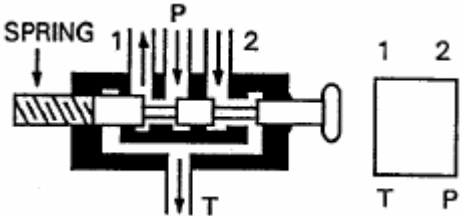
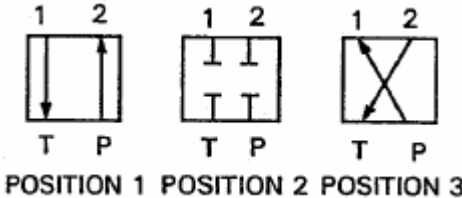
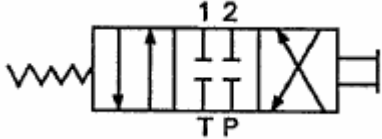
	Start with a basic symbol for a relay or valve.
	Add the orifices (ports) to the symbol, even if the valve/relay itself has three top orifices. The symbol always has 2 top ports and 2 bottom ports.
 POSITION 1 POSITION 2 POSITION 3	Indicate the direction of flow for all relay positions.
 SPRING MANUAL OPERATION	Add the operating mechanism to the symbol. This relay is activated manually with a spring return in the closed.
	Combine all the elements into one single symbol.

Figure 39: Creation of a relay symbol (pneumatic or hydraulic)

You have developed a symbol for a 4/3 relay (4 ports, 3 positions)

Standard symbols for cylinder types are shown in the following diagrams.

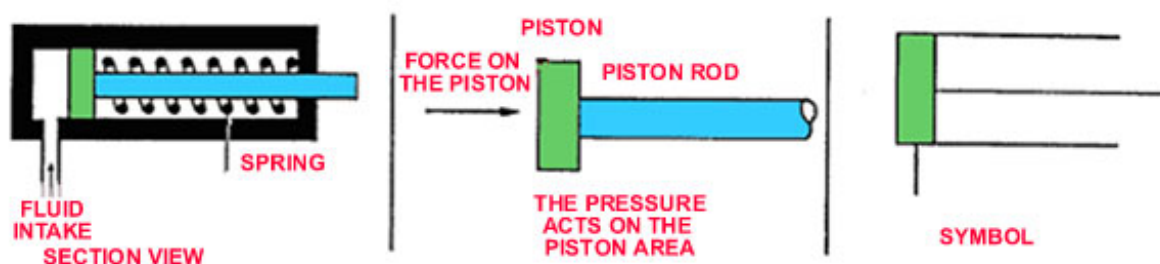


Figure 40: Symbol for a single action cylinder (pneumatic or hydraulic)

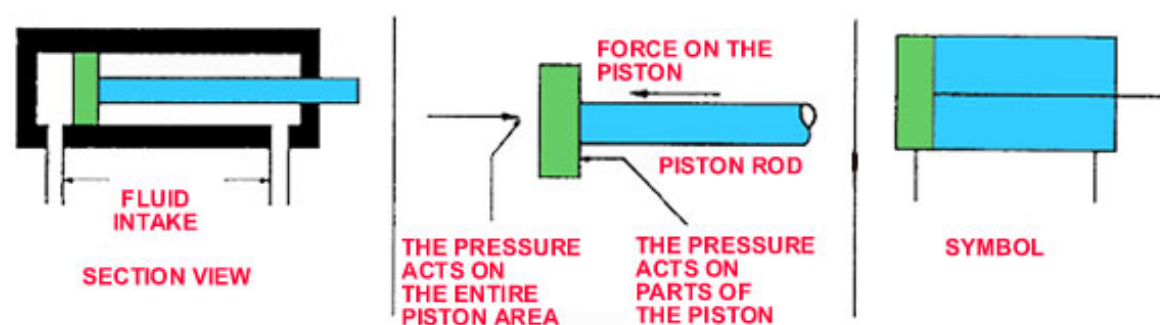


Figure 41: Symbol for a dual action cylinder (pneumatic or hydraulic)

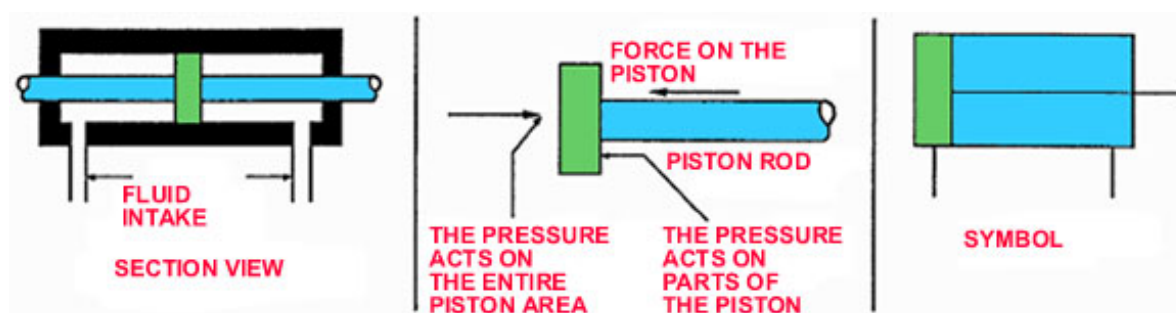


Figure 42: Symbol for a dual end cylinder (pneumatic or hydraulic)

8. HYDRAULIC SYMBOLS

We have already seen many principles with symbols for pneumatic systems. This section concerns specific hydraulic components.

8.1. UNDERSTANDING HYDRAULIC SYMBOLS

Symbols have been developed for systems activated by hydraulic fluids by the International Standardization Organization (ISO). As a site technician, you must be familiar with these symbols, as was the case for pneumatic symbols.

The most frequent symbols are shown in this chapter. Keep these documents for future use.

As you may be aware, several of the symbols used in pneumatic and hydraulic systems are identical or almost identical.

The differences are shown here, however revise the symbols on previous pages in parallel, as pneumatic and hydraulic diagrams must be understood using the same principles.

You will be fully familiar with the interpretation of the following diagrams at the end of this chapter.

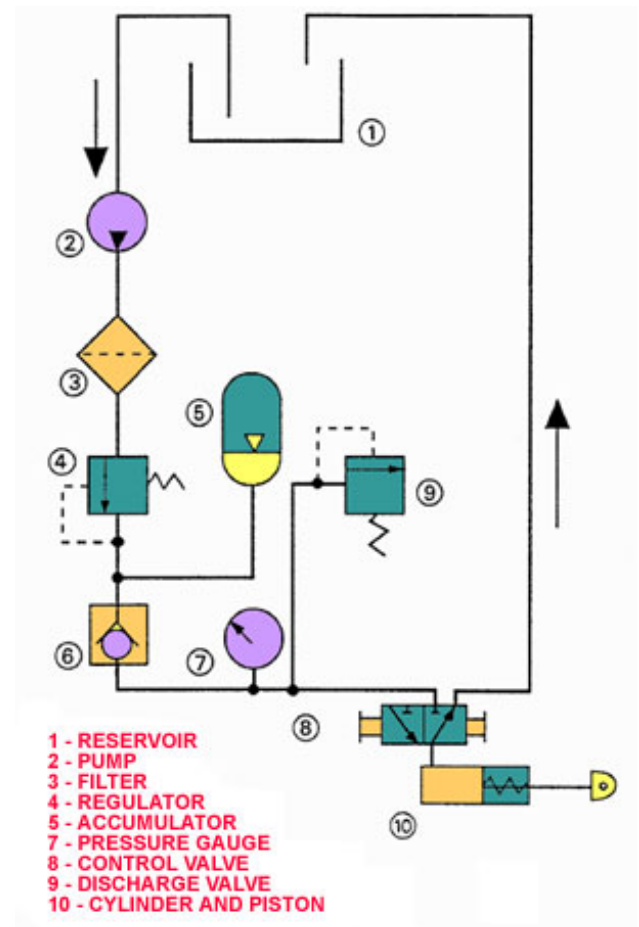


Figure 43: Standard hydraulic diagram

8.2. HYDRAULIC SYMBOLS FOR DIAGRAMS

This paragraph introduces the symbols for a range of hydraulic devices. Operators and technicians must be able to identify each individual representation, and work with sets of symbols for system diagrams.

A hydraulic system may include one single source of energy and one instrument using this energy, however it could also include many instruments.

To understand a hydraulic circuit diagram (relatively consequent), it is important to consider the different sections of the diagram and determine the energy flows per section. It will be easier to understand the entire diagram once you have understood the various sections (or portions) of the circuit.

8.2.1. Fluid duct symbols (lines)

A hydraulic system consists of hydraulic devices interconnected by pipes or tubes.

"Pipes" and "tubes" are sometimes listed as conductors or functional ducts, however they are generally listed as fluid ducts. To simplify, we will call them "ducts".

Functional ducts are the main fluid ducts in a hydraulic system. They are represented on diagrams as continuous lines.

Control ducts are usually far smaller than functional ducts. They generally support the same pressure as functional ducts. Control duct transmit pressurized fluids to internal devices. If the internal control device is operational, it enables the main device to operate. Control ducts are represented by dashed lines.

Evacuation ducts (vents) or drainage ducts are generally small. They only support low pressure. They are represented by dashed lines, however the dashes are shorter than for control ducts.

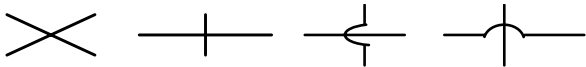
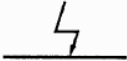
	Functional duct		Control duct
	Drain duct		
	Crossing of ducts		
	Connection of ducts		
	Hoses		Electric line
	Energy flow		

Table 34: Symbols for hydraulic fluid ducts

8.2.2. Restrictive devices

Restrictive devices are used in hydraulic systems to:

- Direct energy flows
- Control energy flows
- Measure energy flows

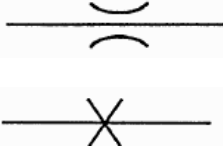
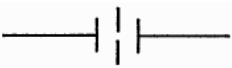
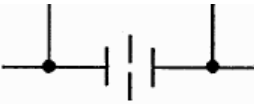
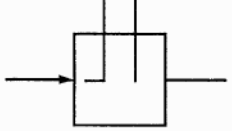
	Fixed restriction		Diaphragm (perforated plate)
	Diaphragm with pulse lines		Pitot tube
	Nozzle		

Table 35: Symbols of hydraulic restrictive devices

8.2.3. Quick coupling

Many hydraulic ducts must be frequently connected and disconnected. E.g. a hydraulic brake duct, connecting a tractor to a trailer. A quick coupling system is used on each "section" of the duct. These couplings have mechanical blocking devices, which are easy to connect and disconnect. A hose is used with this system.

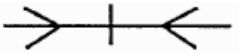
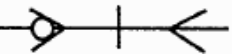
	Quick discoupling system		Quick discoupling system with check valve
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Table 36: Symbols of hydraulic quick discoupling systems

8.2.4. Cylinders

Cylinders and pistons can sometimes be used as linear motors. They receive the energy and drive the piston rod in a straight line to execute the work. This could also concern a source of energy if the piston rod is pushed by an external mechanical device. The piston will apply pressure on the fluid inside the cylinder. This pressure is transmitted into the system as energy.

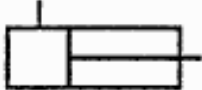
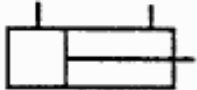
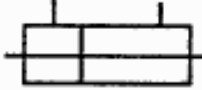
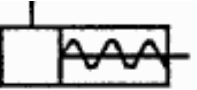
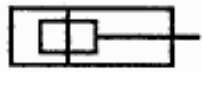
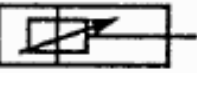
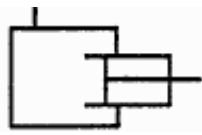
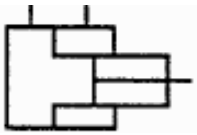
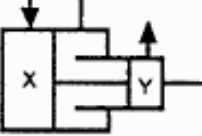
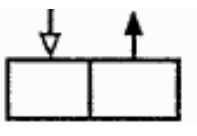
	Single-acting cylinder		Double-acting cylinder with stem
	Double-acting cylinder with two stems		Single-acting cylinder with pressure in one direction and spring return. <i>We could use the term 'double action': 1st fluid and 2nd spring</i>
	Cylinder with fixed attenuator		Cylinder with adjustable attenuator
	Single-acting telescoping (or telescopic system)		Double-acting telescoping
	Pressure multipliers		Air/oil pressure transformer

Table 37: Symbols for hydraulic cylinders

8.2.5. Hydraulic valves/relays

The basic symbol for a hydraulic relay is a rectangle known as a relay (or valve) envelope. The envelope is the relay body. Lines inside the envelope indicate the direction of the energy flow for input and output. Input and output orifices are known as 'ports'.

A relay is always represented on diagrams as found on the shelf. I.e. it is represented in its position prior to installation.

The relay is represented alone on the shelf.

This is because the relay is thus represented in its condition prior to use. This way, you can clearly identify what happens when the "power" is applied to the relay as electricity, pneumatic pressure, hydraulic pressure or a mechanical force.

If the relay is fitted with springs, it will not be compressed, therefore all items connected to a spring will remain in their initial position. This means that the relay is represented in its initial, or rest position.

A relay in a system is represented with the internal channels connected as would be the case for the shelf position.

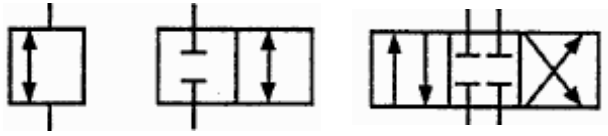
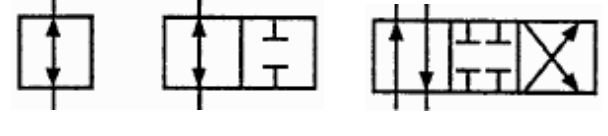
	Ports normally closed
	Ports normally open <i>Reminder: the left side (zone or symbol) is the "no supply" position for a 2-position relay and the middle zone is the "no supply" position for a 3-position relay</i>

Table 38: Symbols for hydraulic relays

8.2.6. Relay actuators

A control device such as a servomotor is a device which sets the valve to a given position. "Actuators" or servomotors can be electric, pneumatic, hydraulic, powered, sprung or manual. Sometimes a combination of different types of actuators is used for a valve.

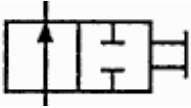
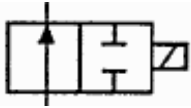
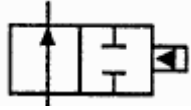
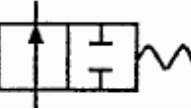
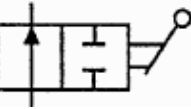
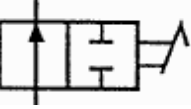
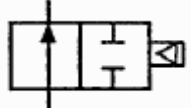
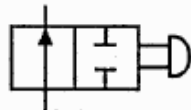
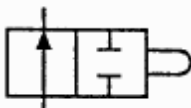
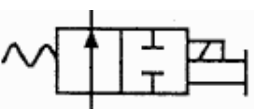
	Manual		Solenoid valve
	Hydraulic		Spring
	Lever		Pedal
	Pneumatic		Push Button
	Plunger		Hydraulic, spring return
	Direct reversing motor		Solenoid valve manual priority spring return

Table 39: Symbols for hydraulic relay actuators

8.2.7. Hydraulic pump symbols

The basic symbol for a pump is a circle. Ducts outside of the circle are not part of the symbol. This concerns connection ducts. Dark triangles indicate the direction of the energy flow. With hydraulic systems, fluid flows are not as significant as energy flows. The energy circulates when the compression pressure is applied to the system.

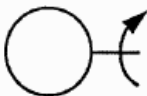
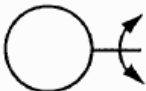
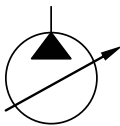
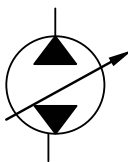
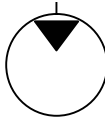
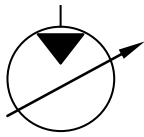
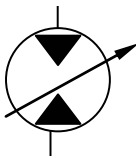
	Basic pump		The shaft rotates in one direction
	The shaft rotates in both directions		Fixed displacement pump. The energy circulates in one direction
	Fixed displacement pump. The energy circulates in both directions		Variable displacement pump. The energy circulates in one direction
	Variable displacement pump. The energy circulates in both directions		

Table 40: Symbols for hydraulic pumps

8.2.8. Hydraulic motor symbols

The basic circle used for pumps is also used for rotary hydraulic motors. Dark triangles still indicate the direction of the energy flow. Triangles are next to the opposite side of the circle, unlike pumps. The energy flow moves away from the pump and towards the motor.

	Fixed displacement motor. The energy circulates in one direction		Fixed displacement motor. The energy circulates in both directions
	Variable displacement motor. The energy circulates in one direction		Variable displacement motor. The energy circulates in both directions

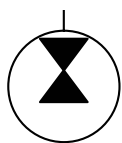
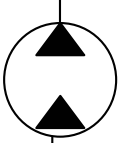
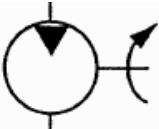
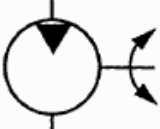
	Motor in one direction, pump in the opposing direction		Motor or pump in one direction only
	The shaft rotates in one direction		The shaft rotates in both directions
	Limited rotation motor		

Table 41: Symbols for hydraulic motors

8.2.9. Safety Valves

All pressurised systems have a means of avoiding overpressure. A pressure relief valve (PSV) is used to correct overpressure. With pneumatic systems, the gas is generally evacuated into the atmosphere. With hydraulic systems, the liquid is evacuated into a storage tank or returns to the reservoir.

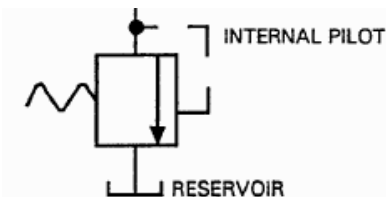
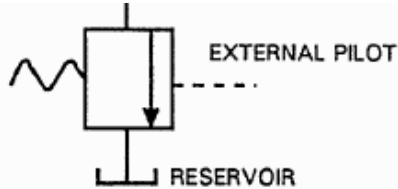
	Pressure relief valve (PSV)
	Relief valve (external control)

Table 42: Symbols for hydraulic relief valves

8.2.10. Flow conditioning valves

Hydraulic systems use different types of valves to control flow.

Check valves are used to control the direction of the flow or stop/start operation.

Regulation valves allow a specified quantity of fluid to pass.

Regulators control the pressure of the hydraulic fluid.

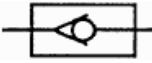
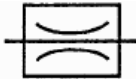
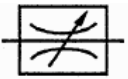
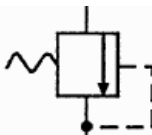
	Manual sectioning valve		Pressure-controlled sectioning valve		Check valve
	Fixed flow regulating valve		Variable flow regulating valve		Pilot-controlled pressure regulator

Table 43: Symbols for hydraulic flow conditioning valves

8.2.11. Reservoir

Three types of reservoirs are used in hydraulic systems.

I.e.:

- Vented reservoirs
- Pressurised tanks
- Non-pressurised tanks

Drainage ducts in hydraulic systems generally flow to vented reservoirs.

An example of a pressurised tank is use with actuators (servomotors) for process valves (process).

Pressure relief valves (PSV) can "evacuate" into a non-pressurised tank.

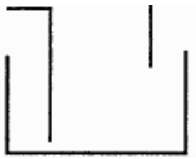
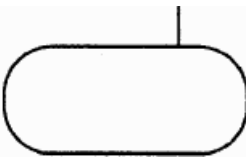
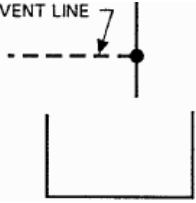
	Vented reservoir with connection duct		Pressurised tank
	Drainage air duct leading to a vented reservoir		

Table 44: Symbols for hydraulic reservoirs

8.2.12. Motor devices

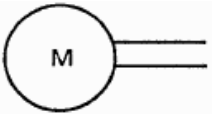
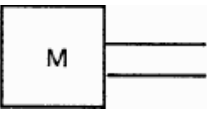
	Electric motor		Internal combustion engine
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Table 45: Symbols for hydraulic motor devices

8.2.13. Indicators

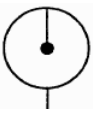
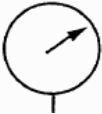
	Thermometer		Pressure gauge
	Flowmeter		Summoter flowmeter

Table 46: Symbols for hydraulic indicators

8.2.14. Accumulators

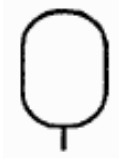
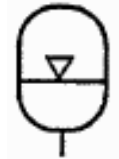
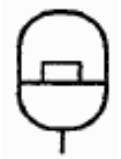
	Basic accumulator		Spring-loaded accumulator
	Accumulator, hydropneumatic		Weight loaded accumulator

Table 47: Symbols for hydraulic accumulators

8.2.15. Fluid conditioning

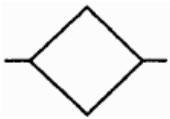
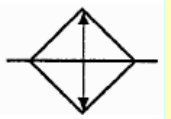
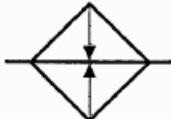
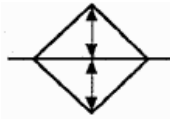
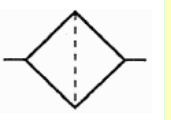
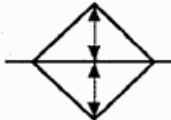
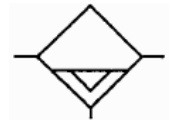
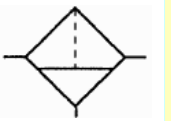
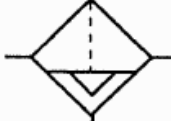
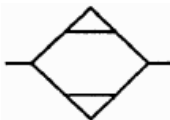
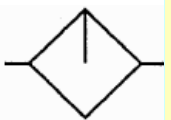
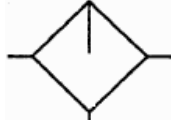
	Basic envelope		Cooler		Heat exchanger
	Temperature controller		Filter liner		Separator with manual drain
	Separator with automatic drain		Separator and filter with manual drain		Filter separator with automatic drain
	Dryer		Lubricator, no draining		Lubricator, with draining

Table 48: Symbols for hydraulic fluid conditioning

9. OTHER SYMBOLS

9.1. ELECTRONIC - LOGIC SYMBOLS

We are now considering details, you may feel that this is a "specialisation" focusing on instruments and systems, however, if you find yourself facing a motor starter cabinet with regulators, a back-up supply cabinet (ASI or UPS), simply changing the 'electronic' will not be enough, you will need to understand the diagrams for these boards, *the plans and dossiers are (almost) always provided by the vendor free of charge*. And being able to understand these diagrams, well, it could help....

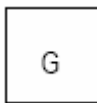
9.1.1. Telecommunications

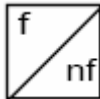
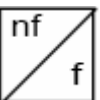
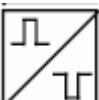
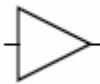
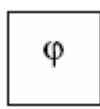
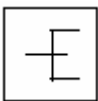
Commutation and peripheral equipment

Transducers					
	Microphone		Telephone receiver		Loud speaker
	Transformer head (general symbol)		Flow head		

Table 49: Symbols for telecommunications transducers

9.1.2. Telecommunications - transmissions

	Antenna, general symbol				
Signal generators					
	Signal generator (general symbol)		Generator of a sinusoidal wave		Adjustable frequency sinus wave generator

	Generator of a sawtooth wave		Pulse generator		Noise generator
Converters					
	Converter general symbol		Frequency converter $f_1 > f_2$		Frequency multiplier
	Frequency divider		Pulse inverter		
Amplifiers					
	Ampli general symbol 1		Ampli general symbol 2		Adjustable amplifier
Network devices					
	Attenuator, fixed attenuation		Filter general symbol		High-pass filter
	Low-pass filter		Band-pass filter		Rejector filter
	Low signal booster		High signal booster		Dephaser
Limiters/ Terminations/Modulator, demodulator/Concentrator					
	Limiters (general symbol) Symmetric surge suppressor		Termination		Mod., demod. (general symbol)

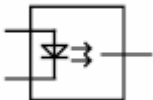
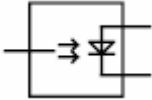
		Left to right concentrator with m input circuits and $n < m$ output circuits			
Optical fibers					
	Optical fiber		Light emitter for optical fibre system		Receiver

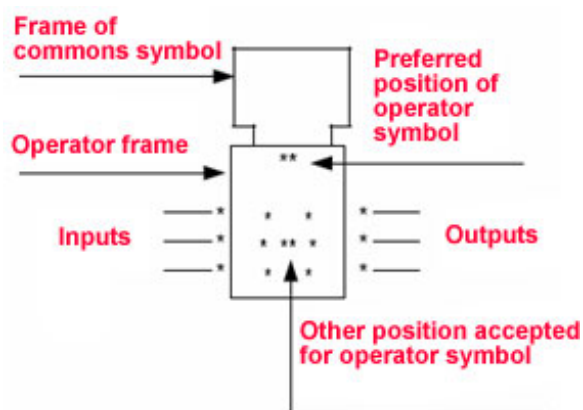
Table 50: Symbols for transmissions

9.1.3. Binary logic operators

9.1.3.1. Creation of symbols

The symbol consists of one or several frames completed with distinctive symbols.

Figure 44: Creation of a symbol with binary logic



9.1.3.2. Combination of symbols

To reduce the space required on the diagram, separate symbols, representing basic operators, can be backed as follows:

- there is no logical relation between two symbols if the separation line is parallel to the direction of the information.
- there is a logical relation between the symbols on either side of the separating line if this line is normal to the direction of the information.

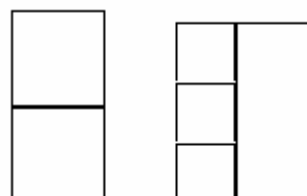
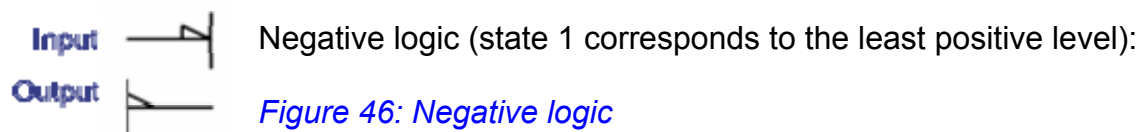


Figure 45: Example of the combination of symbols with binary logic

9.1.3.3. Type of logic



NB: these symbols are sometimes used to indicate logic negation.

The absence of a symbol implies positive logic (where state 1 = most positive level).

9.1.3.4. Distinctive signs for input and output

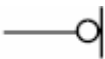
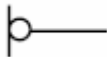
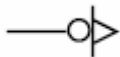
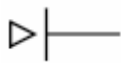
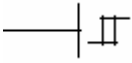
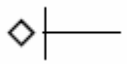
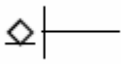
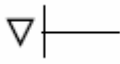
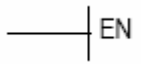
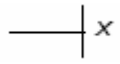
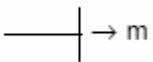
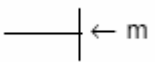
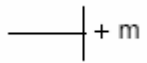
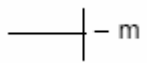
Distinctive signs for input and output					
	Logic negation at input External state 0 ► internal state 1			Logic negation at output Internal state 1 ► external state 0	
	Dynamic input (first issue) First issue ► internal state 1			Dynamic input (last issue) Last issue ► internal state 1	
	Deferred effect on output		Amplified output		Limited input (hysteresis)
	Open circuit output.		Open collector output.		3-state output (high impedance)
	Validation input (ENable) EN Ø► high impedance output state			"x" type transfer input("x" = D, J, K, R, S, T)	
Serial log offset input:					
	- right offset, m positions			- left offset, m positions	
Meter input					
	- increment of m for each pulse			- decrement of m for each pulse	

Table 51: Logic input and output

9.1.3.5. Fundamental combinations for operators

Fundamental combinations for operators					
&	AND	≥ 1	OR	1	YES
(NO = YES symbol with negation at output)					

Table 52: Fundamental combinations for operators

9.1.3.6. Complex combinations for operators

Complex combinations for operators			
$\geq m$	Logic limit (m at least) (output = 1 $\leftrightarrow$ n° of input at state 1 $\geq m$)	$> n/2$	Logic majority (output = 1 $\leftrightarrow$ majority of input at state 1)
$= m$	"m and only m" limit (output = 1 $\leftrightarrow$ m input from n at state 1) (OR exclusive if m = 1)	mod2	Modular addition 2 (logical odd parity) (output = 1 $\leftrightarrow$ n° of input at state 1 is odd)
=	Logic identity (output = 1 $\leftrightarrow$ all input in the same state)	2K	Digital parity
2K + 1	Digital odd parity		

Table 53: Complex combinations for operators

9.1.3.7. Phantom operators

A phantom operator is created by the interconnection of output from a certain number of operators to ensure that AND or OR operations are executed without the use of another operator ("cabled AND" or "cabled OR").

Conventionally, if no distinctive symbol is indicated, the phantom operator is considered as an OR.

Phantom operators			
	AND phantom		OR phantom

Table 54: Phantom operators

9.1.3.8. Complex sequential operators

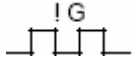
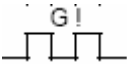
Complex sequential operators					
	Retriggerable monostable		Non-retriggerable monostable		Astable
	Astable synchronised at start-up		Astable synchronised at stopping		

Table 55: Complex sequential operators

9.1.3.9. Transfers and transfer groups

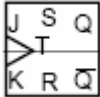
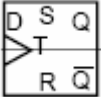
Transfers and transfer groups					
	Bistable transfer general symbol		JK transfer, with resetting to 0, to 1		D transfer with resetting to 0, to 1
	Phase memory (automated control system)	CTR	Meter	CTRm	M stage meter
CTR DIVm	M down meter	REG	Log		

Table 56: Transfers and transfer groups

9.1.3.10. Delay operators

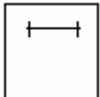
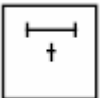
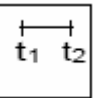
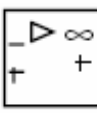
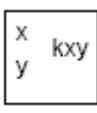
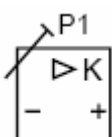
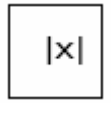
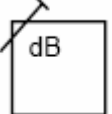
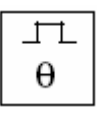
Delay operators			
	Delay operator, general symbol		Variable delay
	Identical delay for the 2 transition phases		Delay with indication of values

Table 57: Delay operators

9.1.4. Analog operators

Analog operators					
	Analog signals		Digital signals		Summation
	Integration		Differentiation		K gain amplifier
Inverting inlet Non-inverting inlet  Non-inverting outlet		Operational amplifier			Integrator K/P
	Differentiator K.p		K gain summer		Multiplier
	K gain amplifier inverter adjusted for P1		Digital - analog converter		Analog - digital converter
	Two-directional connection operator, functional contact controlled by digital input ("controlled switch"): passage of the signal in both directions if logic input = 1				Voltage regulator
	One-directional connection operator, rest contact controlled by digital input: passage of the signal in one single directions if logic input = 0				Dephaser
	Absolute value		Primer		Keyway
	Adjustable attenuator		Conversion from parameter x to voltage		Monostable, long pulse

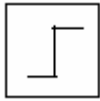
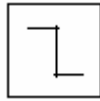
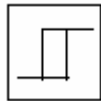
	Triangular signal generators		Galvanic isolation via an optocoupler		Symmetric surge suppressor
All-Or-Nothing comparator (TOR):					
	non-inverter		inverter		Comparator at limit, version 1
	Comparator at limit, version 2		Maximum value sensor		

Table 58: Analog operators

9.1.5. Resistance colour code

While we are considering "electronics" we could take a look at colour symbols for components.

9.1.5.1. Nominal value

This is the reference value shown on the component in coded format.

9.1.5.2. Tolerance

This is the interval of possible values for the actual value of the resistance. This tolerance is expressed in % of the nominal value.

Example: $100\text{ k}\Omega \pm 5\% = (95\text{ k}\Omega \text{ R } 105\text{ k}\Omega)$.

9.1.5.3. Standardised values

Not all resistance values exist and, generally speaking, they are not manufactured to demand. The values proposed by manufacturers are shown in various standardised lists (The figure indicates the number of values in the series):

- E3 series, tolerance $\pm 40\%$,
- E6 series, tolerance $\pm 20\%$,
- E12 series, tolerance $\pm 10\%$,
- E24 series, tolerance $\pm 5\%$,
- E48 series, tolerance $\pm 2\%$,
- E96 series, tolerance $\pm 1\%$,
- E192 series, tolerance $\pm 0.5\%$,

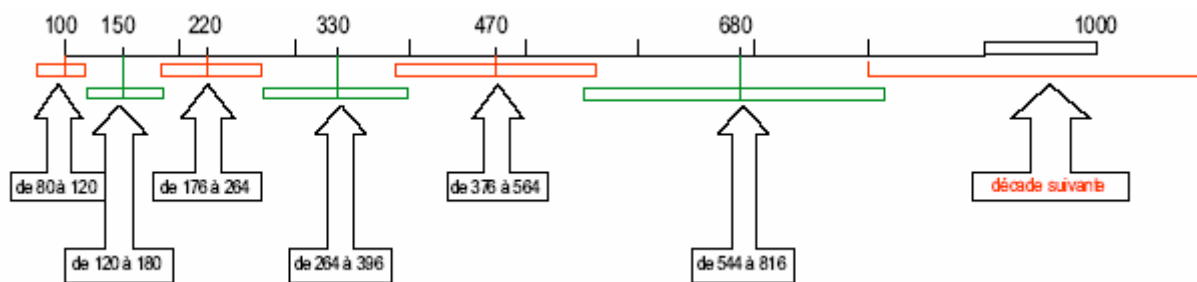


Figure 47: Example of resistance values for the E6 series

In the example given above, the E6 series only includes 6 resistance values (see table below). Therefore, for a "shelf" value of 150 k Ω , with E6 type resistances having a tolerance of 20%, the "actual" value will be between 120 and 180 k Ω .

9.1.5.4. Marking values

The standardised value and the tolerance are marked on the resistance using colour rings (tolerance up to 1% and power up to 1 watt). From 2 watts and a tolerance of 0.5%, values are marked as figures.



Figure 48: 4 ring colour code

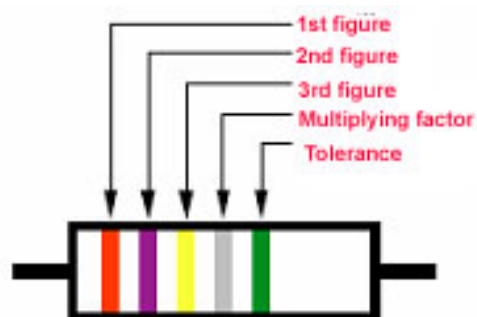


Figure 49: 5 ring colour code

Each colour is assigned a meaning.

Hold the resistance the right way round (gold/silver line to your right).

Reminder of coefficients									
atto	fento	pico	nano	micro	milli	kilo	mega	giga	tera
a	f	p	n	μ	m	k	M	G	T
10^{-18}	10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^3	10^6	10^9	10^{12}

Table 59: Coefficients

Colour	Significant figures	Coefficient	Tolerance	Memory aid 1	Memory aid 2
Silver			$\pm 10\%$		
Gold		0,1	$\pm 5\%$		
Black	0	1		Black	Better
Brown	1	10	$\pm 1\%$	Beetles	Be
Red	2	100	$\pm 2\%$	Running	Right
Orange	3	10^3		On	Or
Yellow	4	10^4		Your	Your
Green	5	10^5		Garden	Great
Blue	6	10^6		Brings	Big
Violet	7	10^7		Very	Venture
Grey	8	10^8		Good	Goes
White	9	10^9		Weather	Wrong

Table 60: Resistance colour code

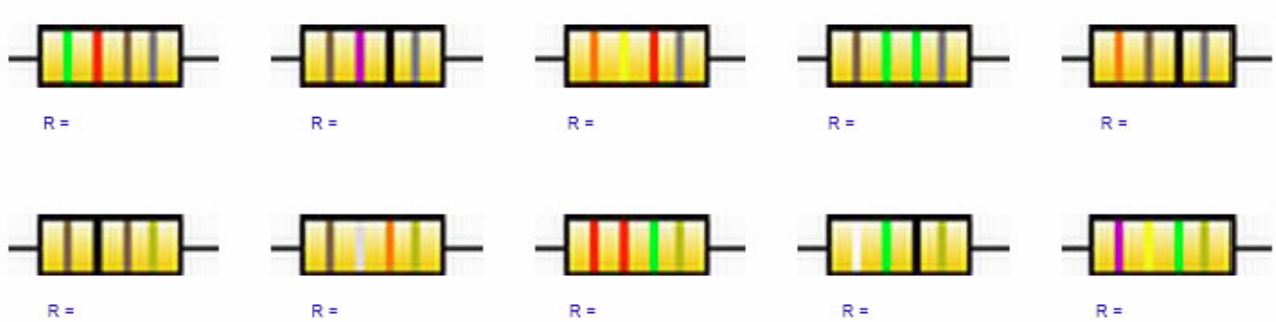
The following table indicates resistance values for the five series, E6 - E96.
With this table, you will avoid looking for inexistent resistances!

E6 ± 20%	E12 ± 10%	E24 ± 5%	E48 ± 2%	E96 ± 1%	E6 ± 20%	E12 ± 10%	E24 ± 5%	E48 ± 2%	E96 ± 1%
100	100	100	100	100				316	316
				102					324
			105	105	330	330	330	332	332
				107					340
		110	110	110				348	348
				113					357
			115	115			360	365	365
				118					374
	120	120	121	121				383	383
				124		390	390		392
			127	127				402	402
		130		130					412
			133	133				422	422
				137			430		432
			140	140				442	442
				143					453
			147	147				464	464
150	150	150		150	470	470	470		475
			154	154				487	487
				158					499
		160	162	162			510	511	511
				165					523
			169	169				536	536
				174					549
	180	180	180	178		560	560	562	562
				182					576
			187	187				590	590
				191					604
			196	196			620	619	619
		200		200					634
			205	205				649	649
				210					665
			215	215	680	680	680	681	681
220	220	220		221					698
			226	226				715	715
				232					732
		240	237	237			750	750	750
				243					768
			249	249				787	787
				255					806
			261	261		820	820	825	825
	270	270		267					845
			274	274				866	866
				280					887
			287	287			910	909	909
				294					931
		300	301	301				953	953
				309					976

Table 61: Standardised values for resistances in the series E6 - E96

9.1.5.5. Exercise on resistance values

16. Describe the ohmic value and tolerance for each of these resistances



9.1.6. Capacitor colour code

This looks like as the resistance colour code. However, you must be careful when decoding, the order must be read differently depending on the type of capacitor. The first figure is located opposite the "feet".

More complex tables exist, accounting for temperature coefficients.

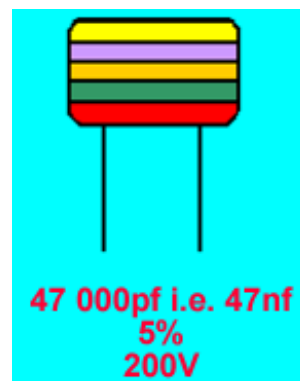
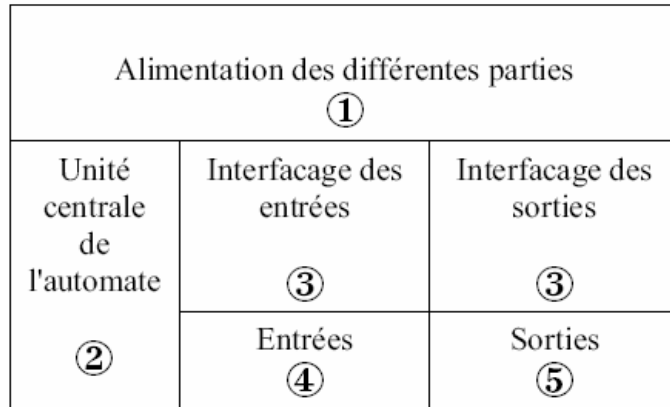


Figure 50: Example of a capacity or colour code (see table below)

	FIGURE 1	FIGURE 2	MULTIPLIER in pf	TOLERANCE	VOLTAGE
Black		0	1	20%	
Brown	1	1	10	1%	100
Red	2	2	100	2%	200
Orange	3	3	1 000 (or 1 nF)		300
Yellow	4	4	10 000		400
Green	5	5	100 000	5%	500
Blue	6	6	1000 000 (or x 1µF)		600
Purple	7	7	10 000 000		700
Grey	8	8	0,01		800
White	9	9	0,1	10%	900
Gold				5%	1000

Table 62: Capacitor colour code

9.2. AUTOMATED CONTROL SYSTEM SYMBOLS (PLC)



An automated control system is more or less a box in which things happen, to which input and output components are connected.

This box also needs energy, and therefore supply systems.

Figure 51: Basic architecture of a control system

1 Supply of the different components:

This supply must provide the energy required for the correct functioning of the entire control system. Supply will depend on the consumption of the different components.

2 Control system CPU:

This component processes data. It stores the program in its memory and prepares commands.

Its core consists of a micro-controller supplied with very low voltage (5 volts).

3 Interfacing of input and output:

These are circuits which adapt the signals between the CPU and input-output in terms of voltage and current.

They also isolate input-output and the CPU.

4 Input:

These are specialised circuits able to receive signals from sensors in a safe manner for the control system. They may be logical (T.O.R.), analog, or digital.

5 Output:

These are specialised circuits able to issue commands to external circuits in a safe manner for the control system. They may be logical (T.O.R.), analog, or digital.

With regard symbols and diagrams, they generally resemble the above example for **“hard” cabling**, and manufacturers can also create new representations...

E.g. Automatic inversion of the direction of rotation by the sensor (S2 and S3), with Cycle start (S4), automatic and manual operation (S1), emergency stop (S0), and final course stop (S5 and S6).

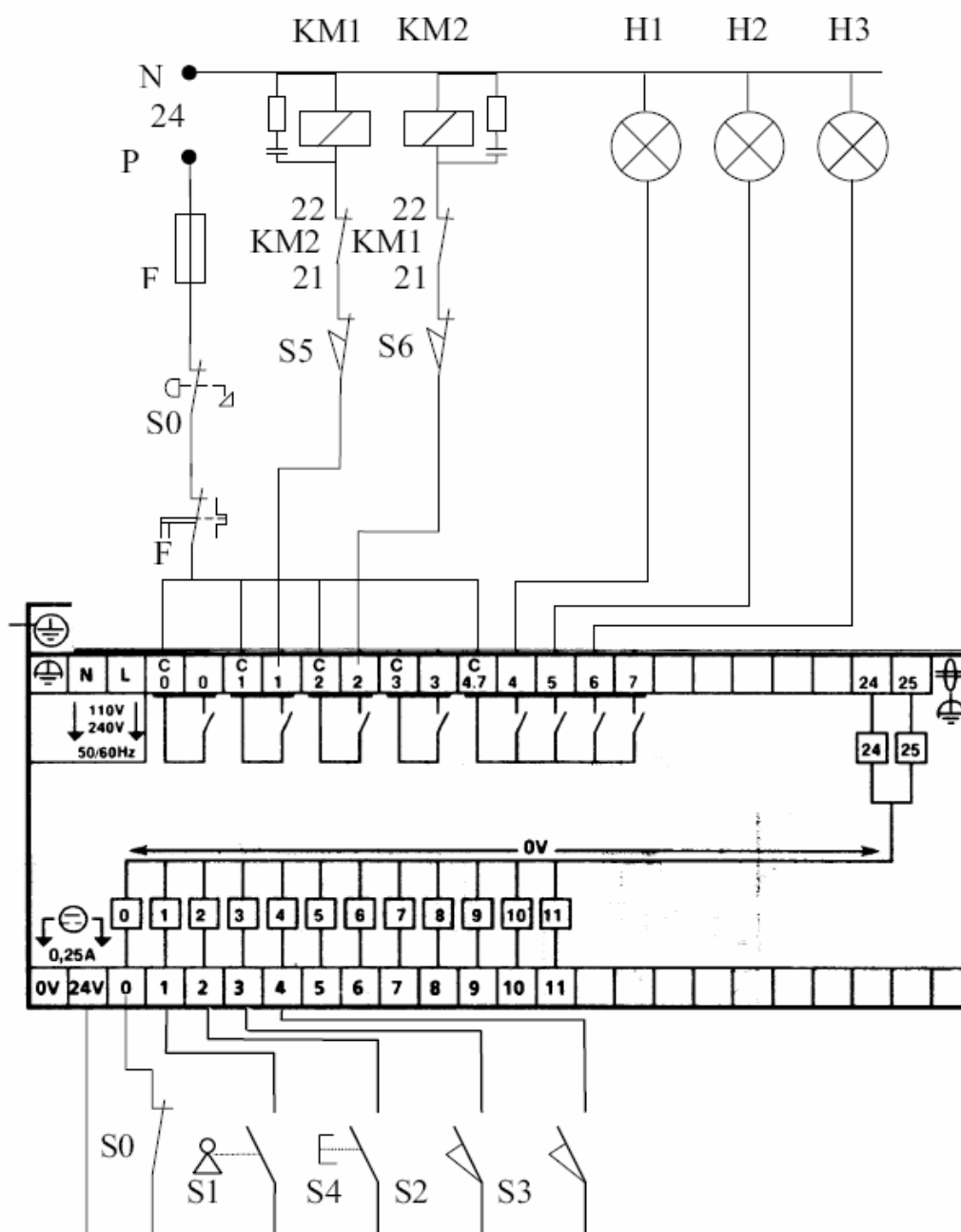


Figure 52: Example of input/output cabling for a control system

We considered symbols (external contacts and devices) earlier, so nothing new there.

As for the "LADDER", you will consider this element in the course on automated control systems

This is a graphic language. This language directly translates an equation or a logic into an electric diagram using specific symbols

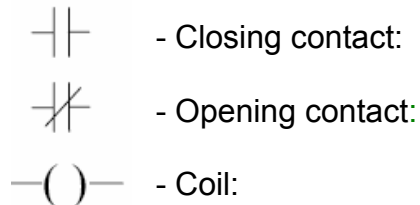


Figure 53: Basic PLC symbols

Other symbols depend on the manufacturer and can be resumed as a block (box or function) explaining the role (timing, clock, algebraic function, etc.)

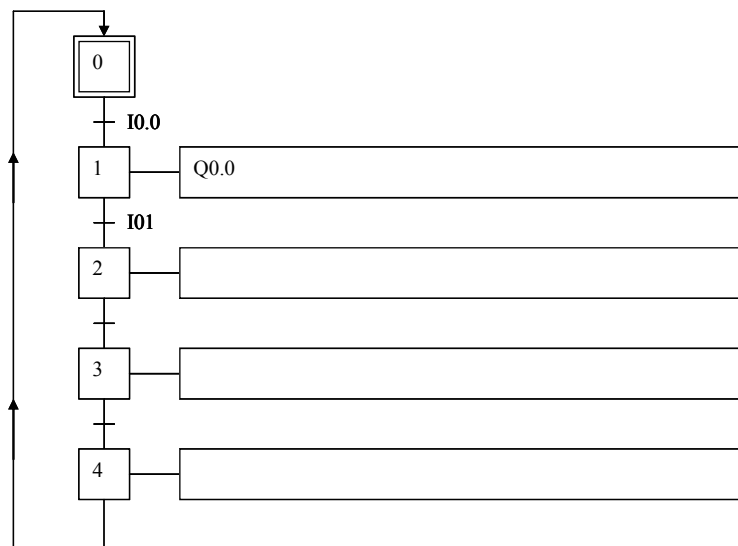
More details will be given in the course on APIs/PLCs.

9.3. GRAFCET SYMBOLS

The grafcet is a “method” rather than a combination of symbols.

A chapter on GRAFCETS is included in the course on ‘electric plans and diagrams’.

Figure 54: Basic representation of a grafcet



10. EXERCISES – APPLICATIONS

Let us consider 3 examples of what we can do with symbols: electric diagrams, the focus of the next course.

17. Comment on and interpret the "cut-out-free power supply" diagram below

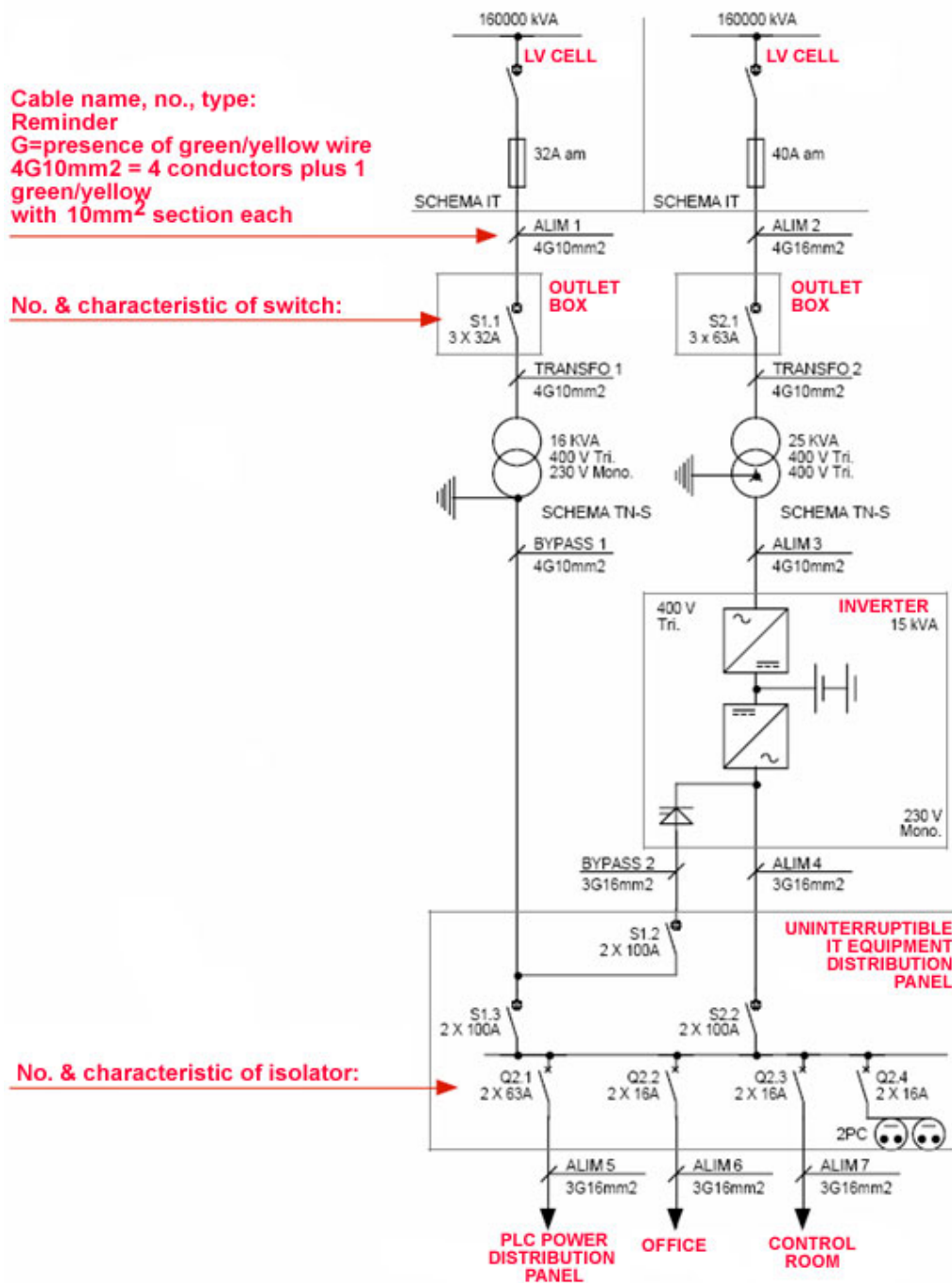


Figure 55: Example of cut-out-free power supply



18. Starter circuit for a squirrel cage three phase asynchronous motor

Block diagram, direct starter, both directions

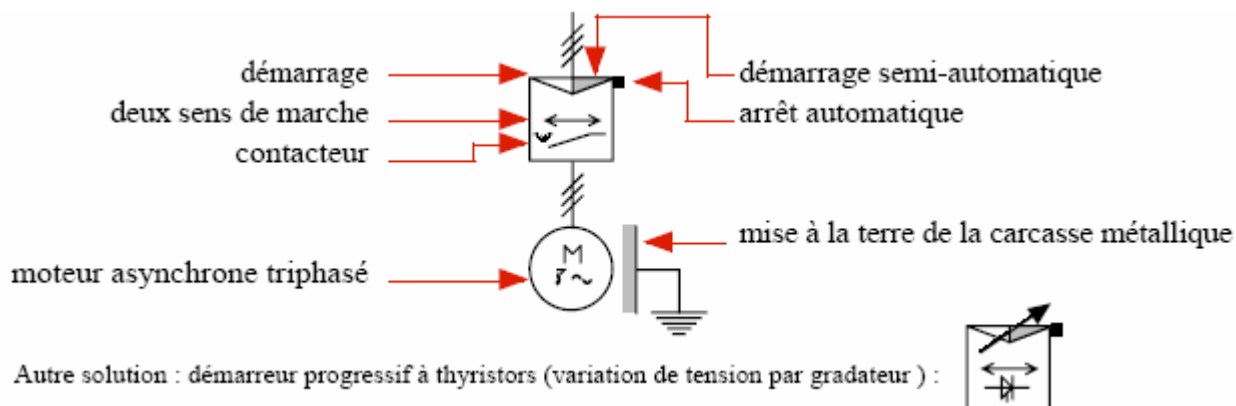


Figure 56: Electric diagram, direct starter, both directions

Electric diagram

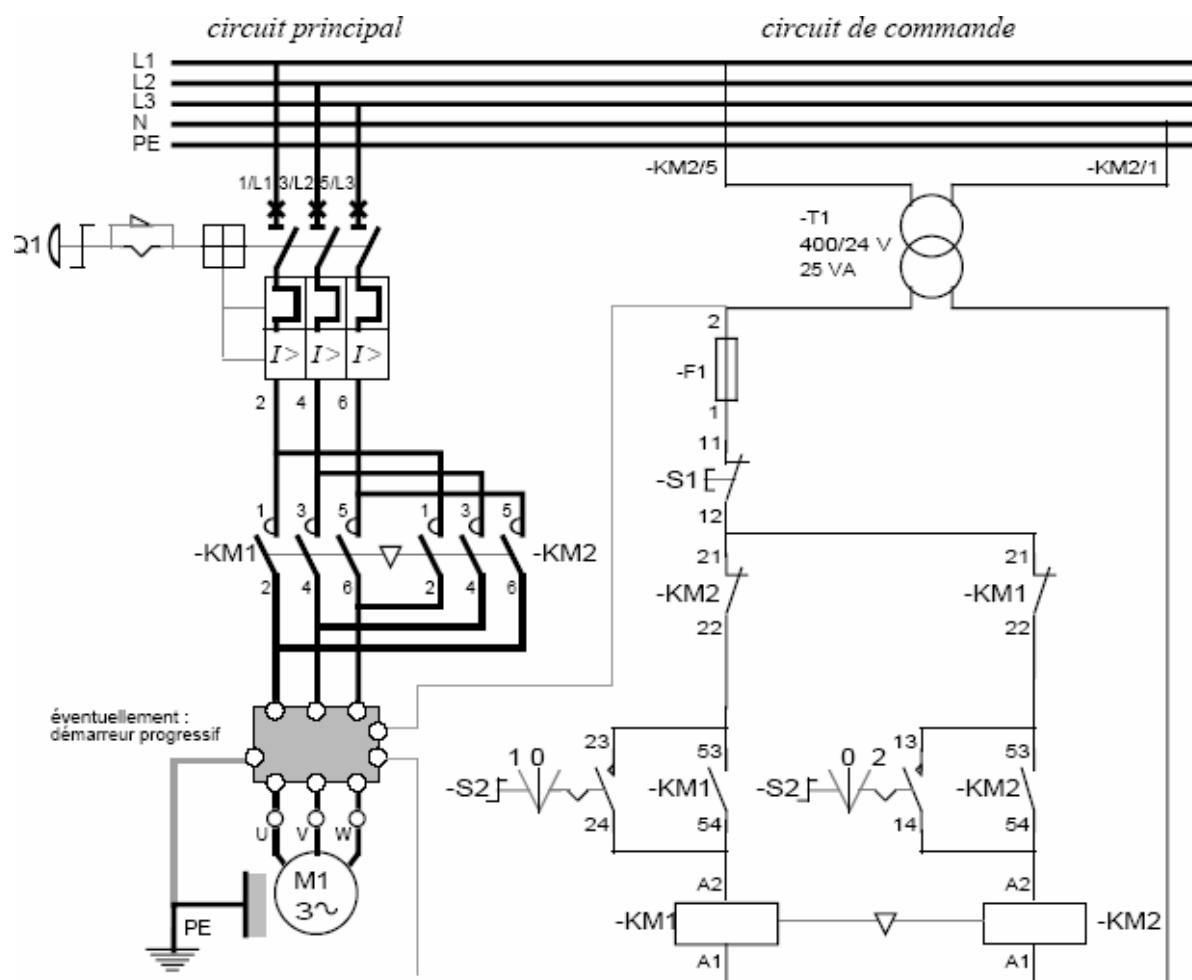


Figure 57: Electric diagram, direct starter, both directions

Question: determine the name and the function of each of the following components:

Q1	
KM1 & KM2	
S1	
S2	
T1	
F1	

19. Cascade regulation (Ω and I) on DC motor - Comment on these 2 versions of the diagrams and the use of the symbols in this document

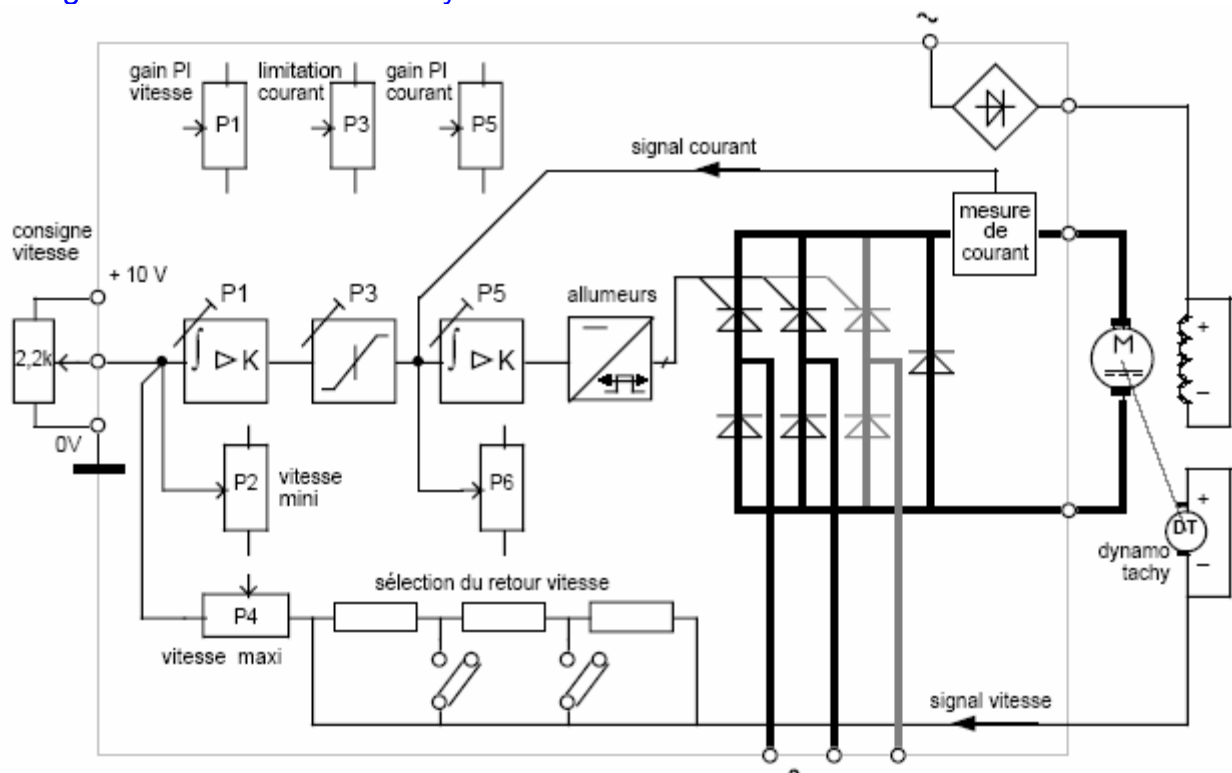


Figure 58: DC motor regulation, a quadrant (non-reversible direction)

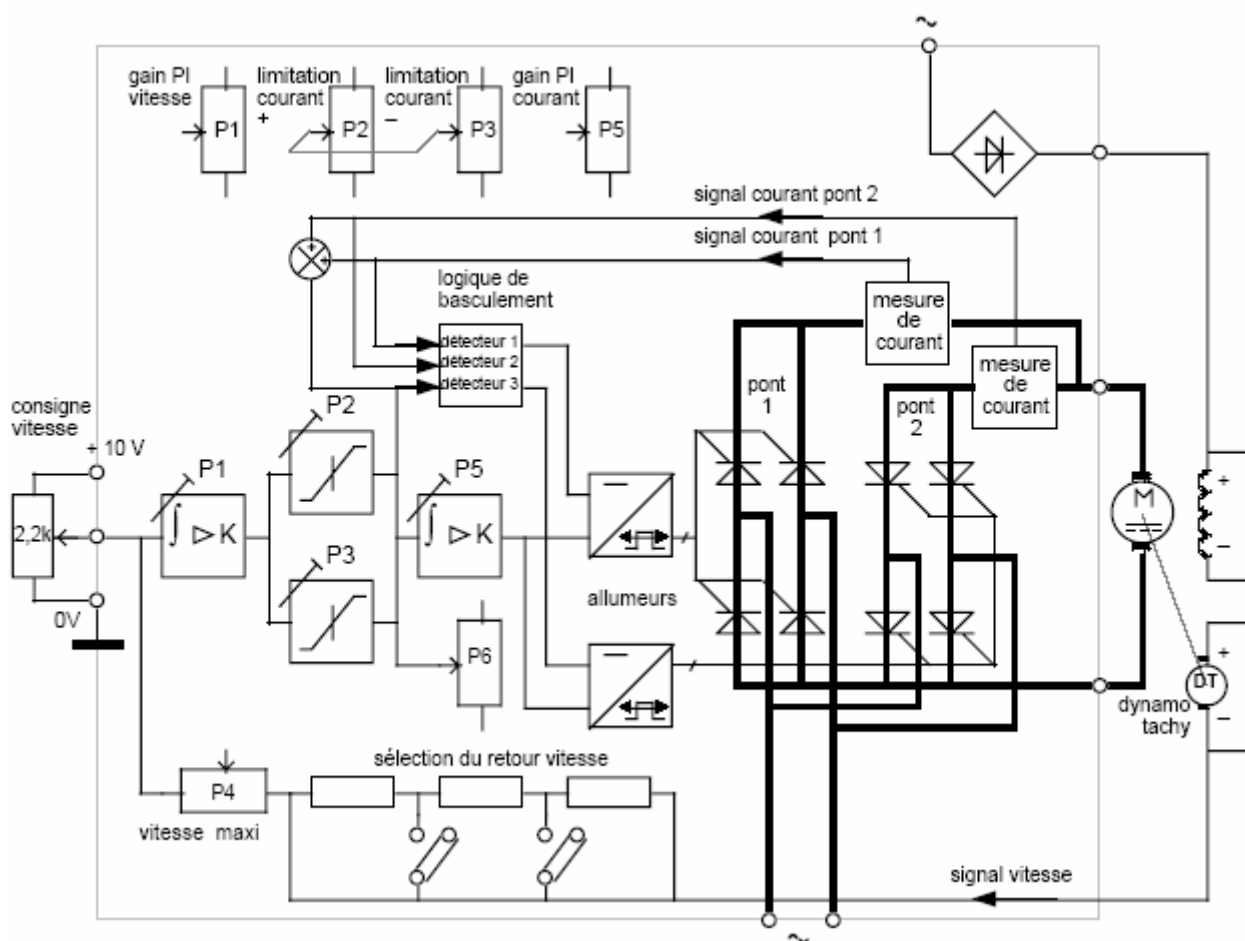


Figure 59: DC motor regulation, four quadrants (reversible direction)

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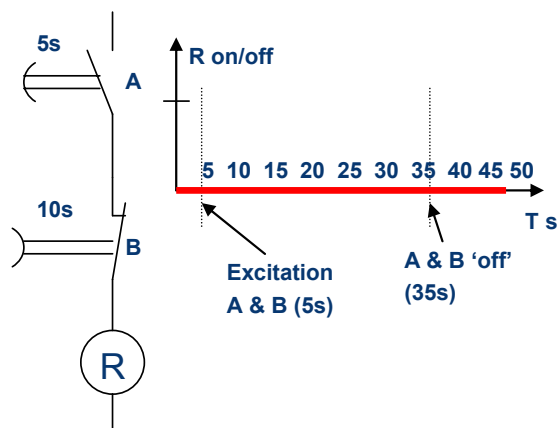
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14. CORRECTION DES EXERCICES

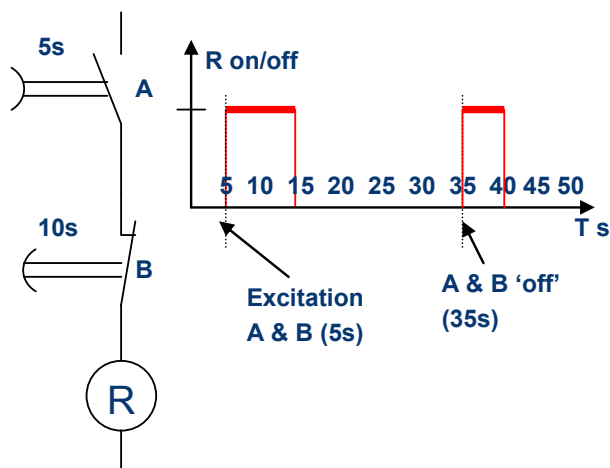
1. A and B are activated simultaneously after 5 seconds and released simultaneously after 35 s. Trace the 'On' excitation of R on the graph.

Nothing happens, 'R' remains non-activated because at $t=5s$, 'B' opens immediately and remains open whereas 'A' closes at $t=10s$. The circuit that powers R remains open; at $t=5s$ 'A' opens immediately and remains open whereas 'B' closes at $t=45s$ on an already open circuit...

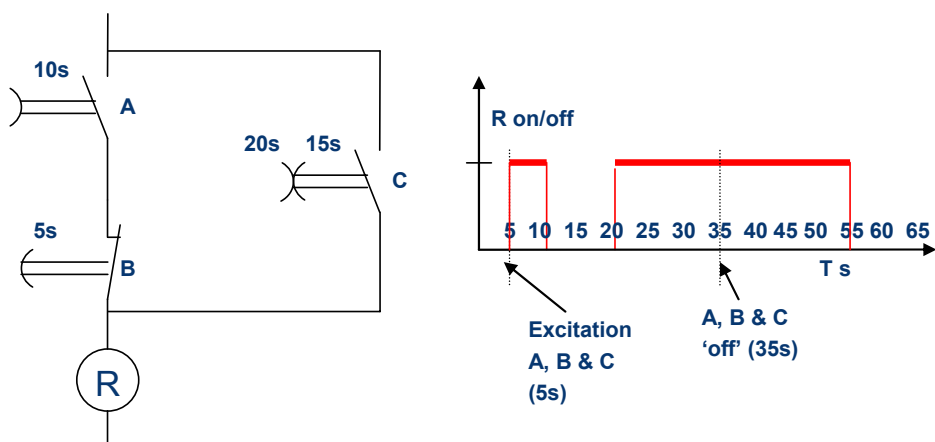


2. Same question as above, trace the excitation of 'R'

At $t=5s$, 'A' closes immediately with 'B' in delayed opening, 'R' is excited.
At $t=15s$, 'B' opens, the circuit is open, 'R' is unexcited
At $t=35s$, 'B' closes immediately and the time delay of 'A' starts, 'R' is re-excited.
At $t=40s$, 'A' opens; the circuit is open.



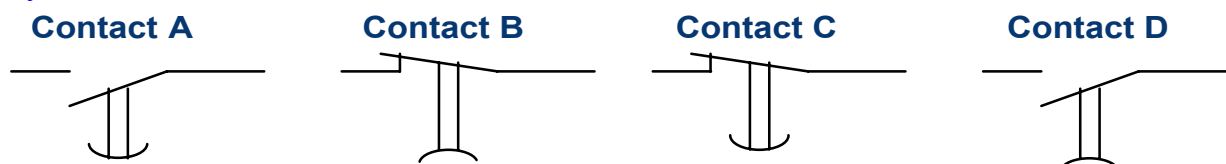
3. Let us add a contact for this exercise as, in practice, this type of assembly is very seldom used. A, B & C are activated simultaneously at $t=5s$ and then released at $t=35s$. How does 'R' behave?



At $t=5s$, 'A' closes immediately and the time delay of 'B' is activated, 'R' is excited; at $t=10s$ 'B' opens, 'R' is un-excited. At $t=20s$, the contact on the parallel 'C' closes, 'R' is

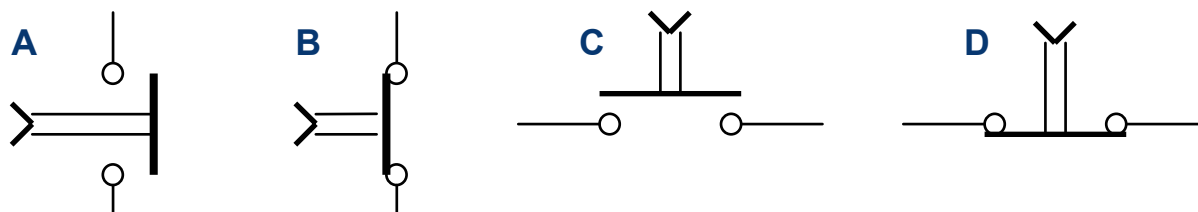
re-excited. At t=35s, 'C' remains closed (two-way time delay), 'B' closes immediately and 'A' remains closed, 'R' is powered by 2 parallel branches. At t=45s, 'A' opens but 'R' remains powered by the 'C' branch. At t=55s, 'C' opens and 'R' is released.

4. With a 'horizontal' representation, the contact is activated upwards (standard procedure), match the 4 definitions to the 4 symbols



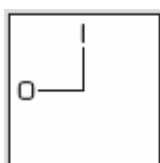
Definition 1: rest time-relay NC = contact B
Definition 2: work time-delay NC = contact C
Definition 3: work time-delay NO = contact A
Definition 4: rest time-delay NO = contact D

5. I found the following representation on an old diagram. Pay attention, the direction of activation does not appear to be indicated: downwards, upwards, to the left, to the right, you have to work it out and identify the 4 possibilities. Delay 'on' = work timing; delay 'off' = rest timing

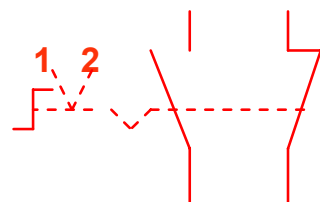


Definition 1: rest time-relay NC = NC delay off = contact D
Definition 2: work time-delay NC = NC delay on = contact B
Definition 3: work time-delay NO = NO delay on = contact A
Definition 4: rest time-delay NO = NO delay off = contact C

6. Identify the next device and draw its symbol (it opens 1 contact and closes another in 2 separate circuits).

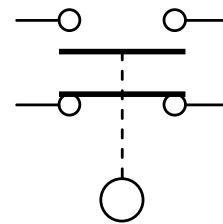


Rotary switch, 2 contacts (NO + NC) at 2 set positions, at 90° and lockable on one position



7. Define this symbol

Level contact, comprising floater with 2 contacts NO + N



8. Define this control device and draw the symbol (with a NO contact)

Palm-button emergency circuit breaker with an indicator light and (theoretically) mechanically locked in "pushed" position



9. For this type of control device (joystick) and the control "signs" shown. How many positions are there? How many contacts (as a minimum) must be "coupled"?

4-way or 4-position switch, 90° between each consecutive command. There must be at least 4 contacts (NO or NC) to ensure that all 4 commands are fully working



10. Technical data for this device states:

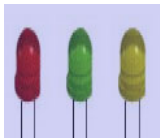
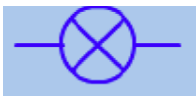
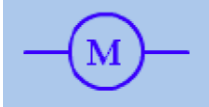


- Setting of relative air humidity
- Inverter contact
- High commutation capacity
- Easy access to terminals

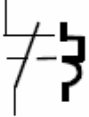
Give an alternative name. Draw the symbol

It is a humidistat (humidity controller)

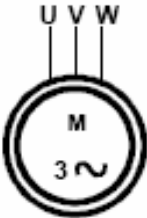
11. Match the 10 images to the 10 symbols and add the corresponding names. You will need to find the names yourself!

D.E.L.			
Fuse			
Closed switch			
Open switch			
Diode			
Motor			
Incandescent lamp			
Resistor			
Electric cell			
Push button			

20. Quiz – only one answer is correct

- 
- ☐ Contact opening due to activation by a magnetic trigger
 - ☐ Contact closing due to activation by a thermomagnetic trigger
 - ☒ Contact opening due to activation by a thermomagnetic trigger
 - ☐ Contact closing due to activation by a magnetic trigger

21. Quiz – only one answer is correct

- 
- ☐ 3-phase induction motor, coil rotor
 - ☒ 3-phase induction motor, squirrel cage
 - ☐ AC motor, general symbol
 - ☐ AC motor with 2 separate windings

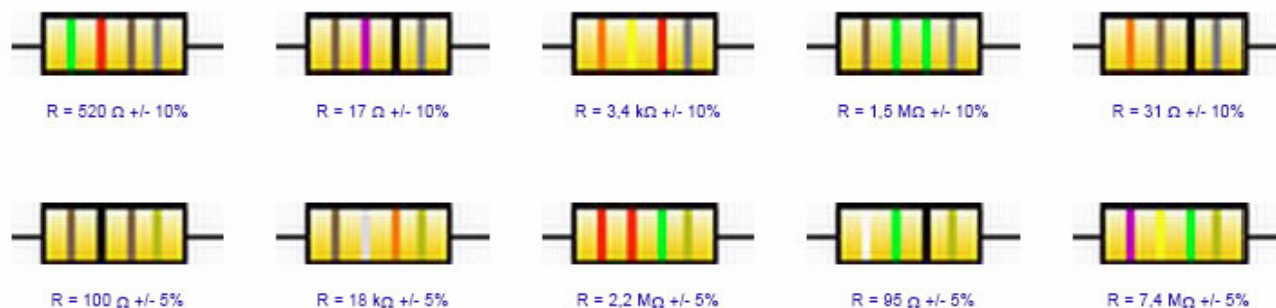
22. Quiz – only one answer is correct

- 
- ☐ Switch, general symbol
 - ☐ NO (normally open) travel-stop contact
 - ☒ Disconnect
 - ☐ Cut-out

12. Quiz – only one answer is correct

- 
- ☒ Load switch with fuse
 - ☐ Disconnect with fuse
 - ☐ Circuit breaker with fuse
 - ☐ Circuit breaker switch with fuse

13. Describe the ohmic value and tolerance for each of these resistances



14. Example of electric power supply without interruption

No correction for this example/exercise

15. determine the name and the function of each of the following components

Q1: Three-pole magneto-thermal circuit breaker. Push button with two stable states: palm button (emergency power off) and rotary (with reset).

KM1 & KM2: 3-pole contactors, mechanical locking between KM1 and KM2

S1: Power off push button

S2: Bouton-tournant "1-2" à positions non maintenues (marche sens 1 & 2) et retour, automatique en position médiane stable. "1-2" rotary button ('on' in directions 1&2) with immediate, automatic return to steady median position.

T1: VLVF Command transformer

F1: gG fuse (protection of transformer's secondary) *main circuit – command circuit*

16. Example of cascade regulation on DC motor

No correction for this example/exercise