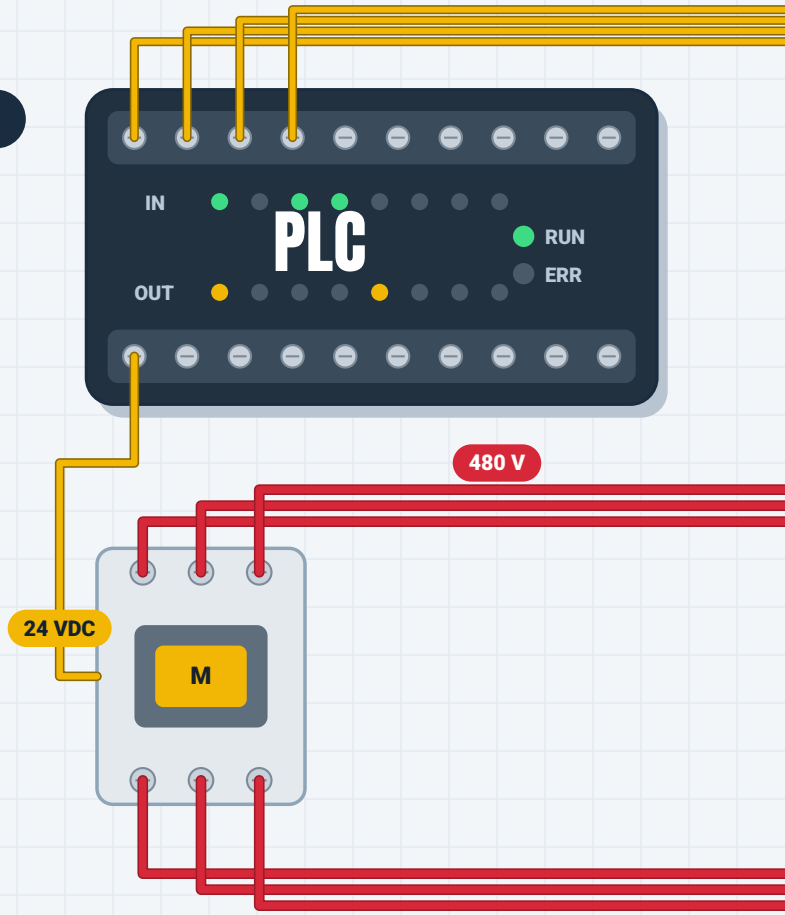
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FREE GUIDE FOR ELECTRICIANS & MAINTENANCE TECHS

YOU KNOW THE CONTACTOR?
NOW READ THE LADDER.



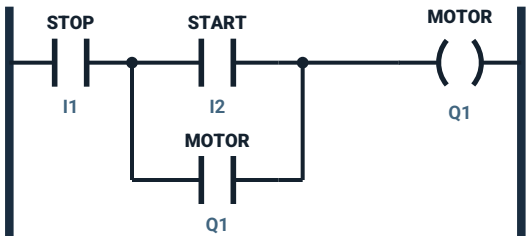
PLC BASICS

FROM CONTACTOR TO LADDER LOGIC

Start/stop, overloads and timers drawn next to their ladder rungs, plus PLC I/O wiring and 10 solved exercises.

- Relay circuits drawn next to ladder
- I/O, 24 VDC, sinking vs sourcing
- XIC, XIO, OTE, OTL/OTU, TON, TOF, CTU
- 10 solved exercises + I/O tables
- Safety tips + EN/ES glossary

THE SEAL-IN RUNG



HOW TO USE + SAFETY FIRST

Each relay idea comes first, then the same idea in ladder. Then you practice with 10 solved exercises.

1 SEE IT SIDE BY SIDE

Pages 3 to 6: relay panel vs PLC, symbols, seal-in and the motor power circuit.

2 LEARN THE PLC

Pages 7 to 13: hardware, I/O, sinking/sourcing, the scan and every instruction.

3 PRACTICE

Pages 14 to 23: 10 exercises with ladder and I/O table. Glossary on page 24.

LOCK OUT, TAG OUT, TEST BEFORE TOUCH

1 ISOLATE

Open the main disconnect, not just the PLC or a control switch. PLC off does not mean the machine is dead.

2 LOCK + TAG

Your own lock and tag on every energy source (OSHA 1910.147). Bleed air, hydraulics and stored energy.

3 TEST

Check the meter on a live source, test phase to phase and to ground, then check the meter again.

4 NFPA 70E

Work de-energized. If live testing is justified, do the shock and arc-flash risk assessment and wear that PPE.

PLC-SPECIFIC RULES

- E-stops and guard doors work through a hardwired or safety-rated circuit, never only a standard PLC input.
- Forcing an input or output can start a machine. Never force with people near moving parts.
- Output cards may be fed from other 120 VAC circuits: test each terminal, even with the PLC off.
- Edit and test offline or on a bench. Online edits in RUN change the machine at once.

WHAT'S INSIDE

3 Relay panel vs PLC
4 Symbols: wired vs ladder
5 Seal-in, side by side
6 Power circuit + overload relay
7 What is inside a PLC
8 Digital and analog I/O
9 Sinking vs sourcing
10 The scan cycle
11 XIC, XIO, OTE, OTL, OTU
12 Timers: TON and TOF
13 Counters + comparisons
14 Ex. 1 · Direct-on-line start
15 Ex. 2 · Forward / reverse
16 Ex. 3 · Tank fill, two floats
17 Ex. 4 · Start-up warning horn
18 Ex. 5 · Wye-delta start
19 Ex. 6 · Fan run-on (TOF)
20 Ex. 7 · Parts counter
21 Ex. 8 · Traffic light
22 Ex. 9 · Alarm with acknowledge
23 Ex. 10 · Analog temperature
24 Glossary EN/ES + sources

RELAY + LADDER
Drawn side by side

10 EXERCISES
Solved, with I/O tables

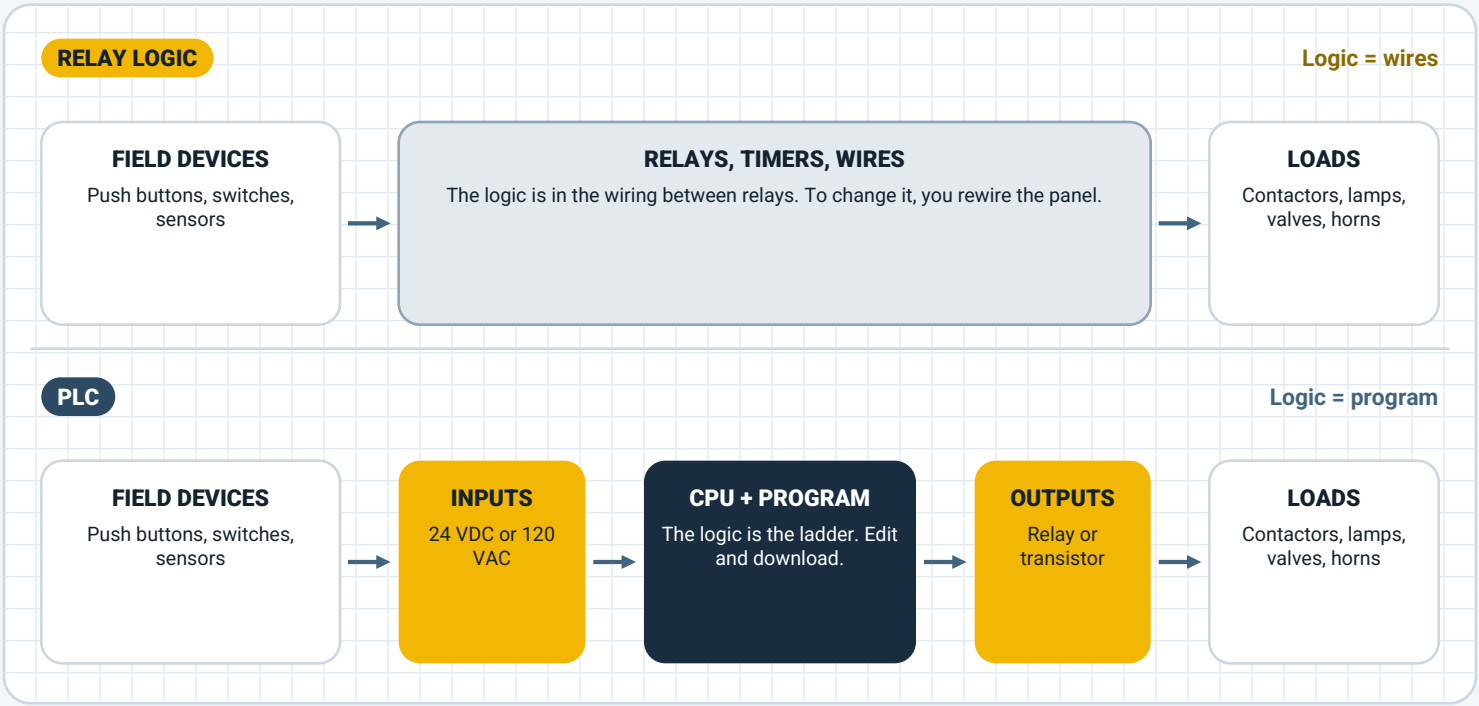
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Generic instructions

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RELAY PANEL VS PLC: SAME JOB, NEW BRAIN

The buttons, sensors, contactors and motors stay. What changes is where the logic lives.



WHAT STAYS THE SAME

The power circuit, contactors, overload relays, motors, push buttons, sensors and the wires out to the machine. You still need a meter and a schematic.

WHAT MOVES INTO THE PROGRAM

Seal-in contacts, interlocks, timer relays, counters and the order of operations. The wires between relays become rungs.

WHY PLANTS USE PLCs

Changes without rewiring, fewer relays to wear out, a status LED on every point, a live view of the logic, analog signals and networks.

WHAT A PLC IS NOT

Not a safety device: E-stops and guard switches go through hardwired or safety-rated circuits. Not a power device: outputs drive coils, not motors.

	RELAY PANEL	PLC
Change the logic	Rewire, add relays	Edit the program and download
Timers and counters	One device for each	As many as the memory allows
Troubleshooting	Meter, follow the wires	Meter + I/O LEDs + live ladder view
Panel size	Grows with every relay	Small; more logic, same size

Ladder logic copied relay drawings on purpose: left rail = power, rungs = circuits, coil on the right. If you can read a control schematic, you can read ladder.

RELAY + LADDER
Drawn side by side

10 EXERCISES
Solved, with I/O tables

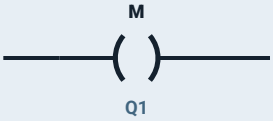
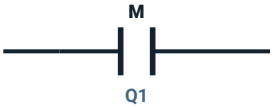
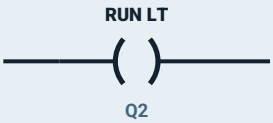
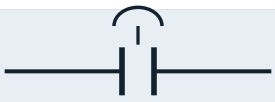
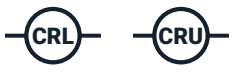
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SYMBOLS: WIRED VS LADDER

Left: the NEMA symbol on a control schematic. Right: what the same part becomes in the PLC program.

DEVICE	WIRED (NEMA)	PLC LADDER	WHAT TO KNOW
Start push button (NO)			Wired to an input. The bit is 1 while pressed, so the rung uses XIC.
Stop push button (NC)			Wired NC to an input. The bit is 1 at rest, so it is ALSO XIC. Pressing it makes the bit 0.
Contactor coil M			Becomes an output (OTE). The output terminal energizes the real coil.
Auxiliary contact NO			No wire needed: the program reads the output bit Q1 with XIC (seal-in).
Auxiliary contact NC			XIO of the output bit. Used for interlocks.
Overload contact 95-96 (NC)			Wired to an input, programmed XIC. A trip makes the bit 0 and the rung false.
Pilot light			Its own output (OTE), driven by any condition you choose.
Limit switch / float (NO)			Wired to an input, XIC. Check how the device is set: NO or NC.
Timer relay contact (on-delay)			A TON instruction. Its done bit (T1.DN) replaces the timed contact.
Latching relay (set / reset)			OTL sets a bit, OTU clears it. The bit holds even when the rung goes false.

Key idea: XIC and XIO do not tell how the device is wired. They only ask: is this bit 1 or 0? An NC stop button that is not pressed gives 1, so you use XIC.

RELAY + LADDER
Drawn side by side

10 EXERCISES
Solved, with I/O tables

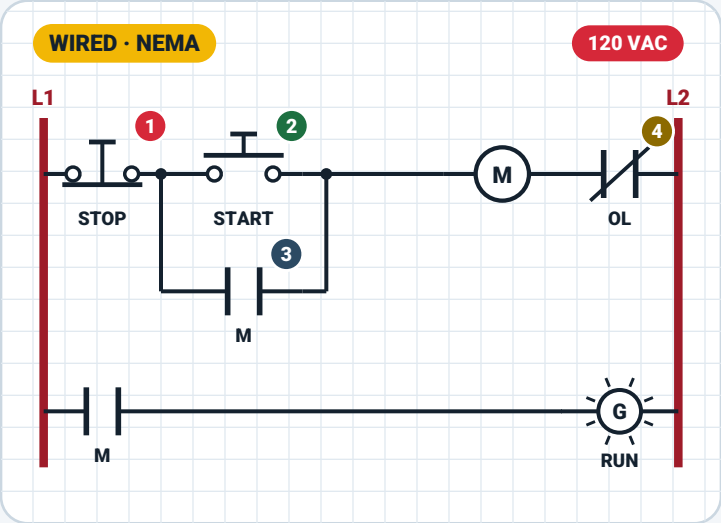
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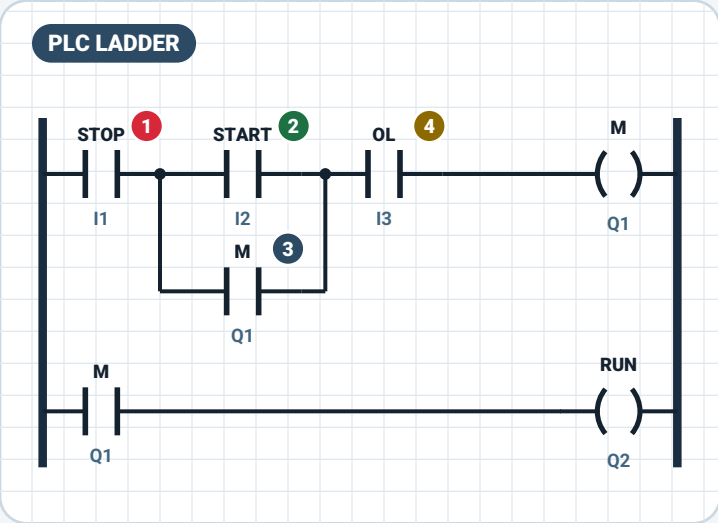
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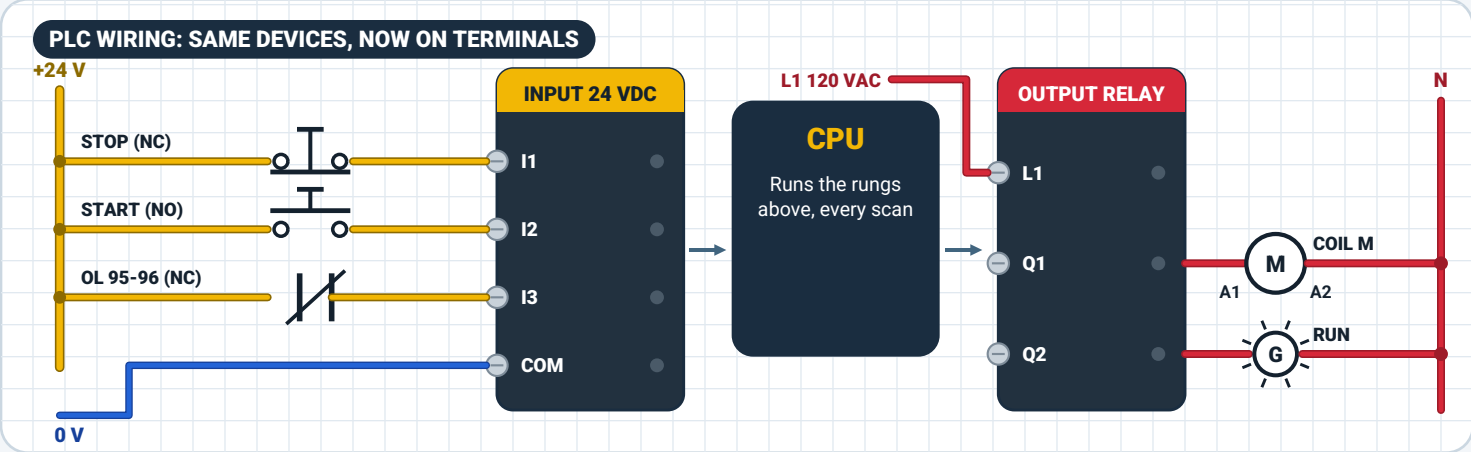
Independent training guide, not affiliated with any PLC maker. Follow the machine drawings, the maker's manuals, NFPA 70E, the NEC and local code.

SEAL-IN: WIRED VS LADDER

The classic 3-wire start/stop circuit and its ladder twin: 1 STOP, 2 START, 3 seal-in contact, 4 overload contact.







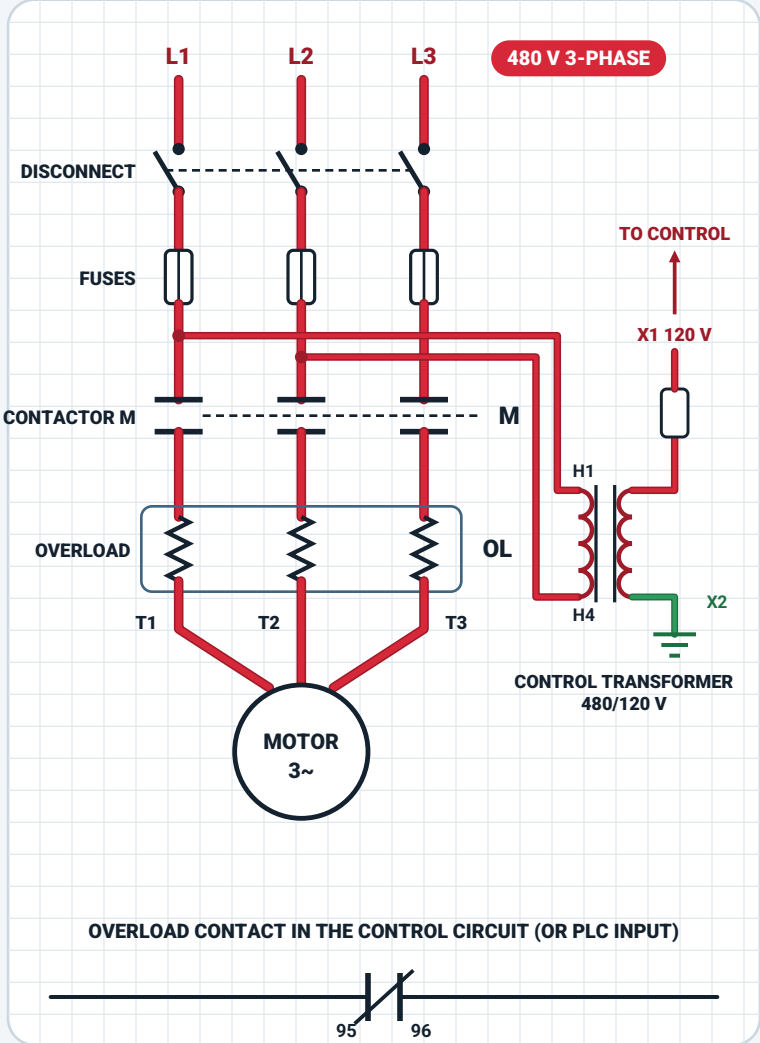
1. Press START: the input bit goes to 1, the rung is true and Q1 energizes contactor M.
2. Release START: the Q1 contact (seal-in) keeps the rung true. The motor keeps running.
3. Press STOP or the overload trips: that input goes to 0, XIC turns false and Q1 drops.
4. Power fails and comes back: Q1 stays off until someone presses START. That is 3-wire control.

Fail-safe rule: STOP and OL are wired NC and programmed XIC. A loose wire or blown fuse stops the motor instead of leaving a stop button that does nothing.

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POWER CIRCUIT + OVERLOAD RELAY

The PLC never carries motor current. This part of the drawing is the same with or without a PLC.



MAIN CONTACTS (M)

Three NO power contacts close when coil M is energized. The coil is fed by the control circuit or by a PLC output.

OVERLOAD RELAY (OL)

Senses the current in all three legs. Too much for too long and it opens 95-96, so the coil drops. Set it per the maker, usually to the motor nameplate FLA.

TRIP CLASS

Class 10 trips within 10 s at 6 times the setting; Class 20 within 20 s. Find the cause before you reset.

CONTROL POWER

A control transformer gives 120 VAC with X2 grounded and a fuse on X1. Many panels add a 24 VDC supply for the PLC and sensors.

480 V can kill and cause arc flash. Only qualified people open this panel energized, after an NFPA 70E risk assessment and with the right PPE. NEC Article 430 sets the motor protection rules.

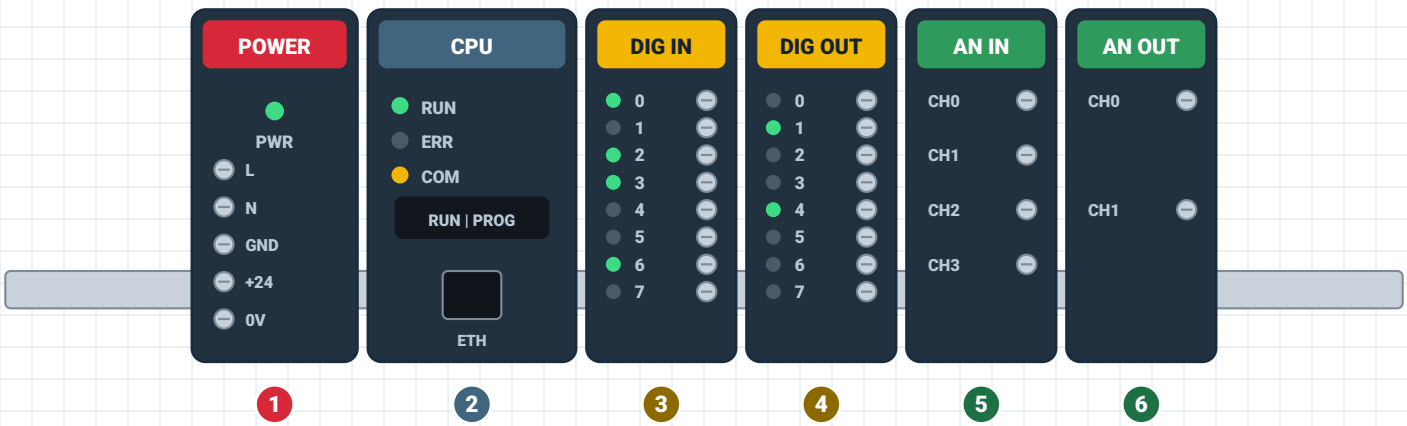
IF THE OVERLOAD KEEPS TRIPPING

- Measure the current in all three legs with a clamp meter and compare it with the nameplate FLA.
- Check the voltage on all three phases: a lost or low phase (single-phasing) overheats the motor.
- Check the dial setting and the trip class against the motor nameplate and the drawing.
- Look at the load: a jammed conveyor, bad bearings, a pump running off its curve.

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WHAT IS INSIDE A PLC

A modular PLC on a DIN rail. A compact PLC packs the same parts into one box.



Modules snap onto the rail and talk over the backplane. Every I/O point has a status LED.

1 POWER SUPPLY

Turns 120/240 VAC into 24 VDC for the CPU and modules. Field sensors are often fed by a separate 24 VDC supply.

2 CPU

Stores and runs the program, scans the I/O and talks to the laptop and the HMI. RUN mode runs; PROGRAM mode stops.

3 DIGITAL INPUTS

On/off signals: buttons, limit switches, sensors. Usually 24 VDC; 120 VAC cards exist. LED on = bit 1.

4 DIGITAL OUTPUTS

Turn on coils, lamps, solenoids and horns. Relay, transistor or triac type (page 8).

5 ANALOG INPUTS

Read a range, not just on/off: 4-20 mA, 0-10 V, RTDs, thermocouples. Pressure, level, temperature.

6 ANALOG OUTPUTS

Send 4-20 mA or 0-10 V: VFD speed reference, valve position, panel meter.

Addresses depend on the brand (I:0/0, %I0.0, X0, I0.0...). This guide uses simple names: I1 = input, Q1 = output, M1 = internal bit, T1 = timer, C1 = counter.

READING THE CPU LEDs

- PWR off: no supply. Check the breaker, the fuse and the 24 VDC.
- RUN off or blinking: the CPU is in PROGRAM mode or stopped by a fault.
- ERR / FAULT on: read the fault code with the software before you cycle power; it may clear the evidence.
- I/O LED on: the PLC sees (input) or drives (output) that point. Confirm at the terminal with a meter.

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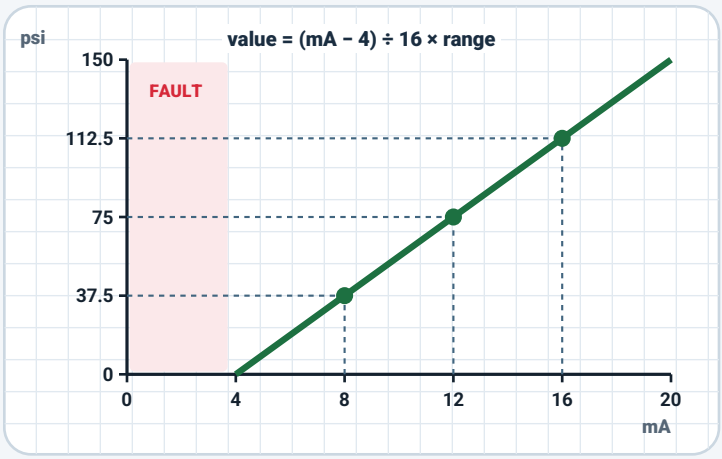
DIGITAL AND ANALOG I/O

Digital is on or off. Analog is a number in a range. Both start as a voltage or a current on a terminal.

DIGITAL INPUTS (24 VDC)

- Typical 24 VDC input: ON above about 15 V, OFF below about 5 V. In between is undefined: check the data sheet.
- Each point draws a few mA through an optocoupler, so the PLC side is isolated from the field.
- LED on but bit 0 in the program? Check the address. 24 V on the terminal but LED off? Check the COM.
- 120 VAC input cards exist too. Never land 120 VAC on a 24 VDC card.
- Dry contacts (buttons, limit switches) take the 24 V from your supply; electronic sensors need 3 wires (page 9).
- Inputs filter a few ms of noise. Very fast pulses need a high-speed counter input.

ANALOG INPUT: 4-20 mA



SIGNAL	PERCENT	0-150 psi SENSOR
4 mA	0 %	0 psi
8 mA	25 %	37.5 psi
12 mA	50 %	75 psi
16 mA	75 %	112.5 psi
20 mA	100 %	150 psi
< 3.6 mA	—	Broken wire or dead sensor

OUTPUT TYPES

TYPE	SWITCHES	WHAT TO KNOW
Relay	AC or DC loads, typically up to about 2 A per point	Slow (about 10 ms) and wears out after millions of cycles. Fine for coils and lamps.
Transistor	DC only, typically about 0.5 A per point	Fast and long-lived. Sourcing (PNP) or sinking (NPN): match the load wiring.
Triac	AC only, typically 0.5 to 1 A per point	No moving parts. Leaks a little current when off, which can keep a small relay buzzing.

Values are typical; always check the module data sheet. For a big load use an interposing relay or a contactor: the PLC output only drives the coil.

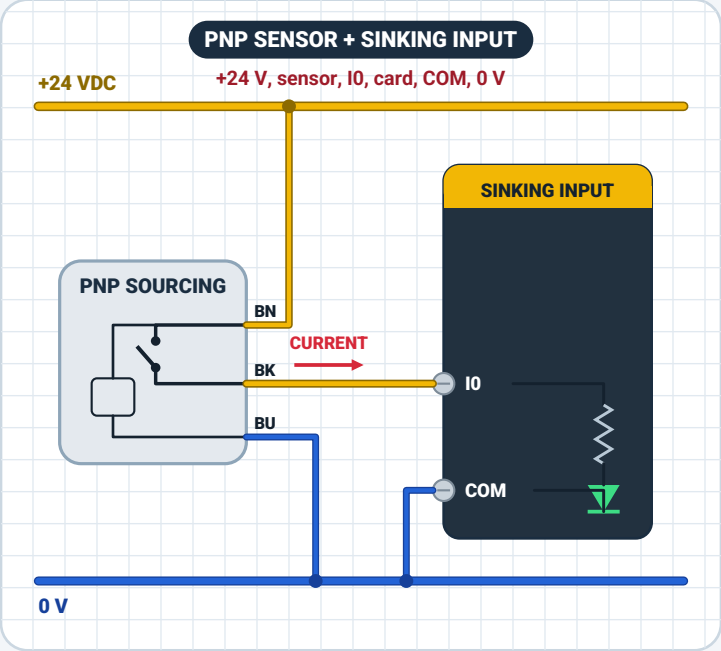
ANALOG WIRING TIPS

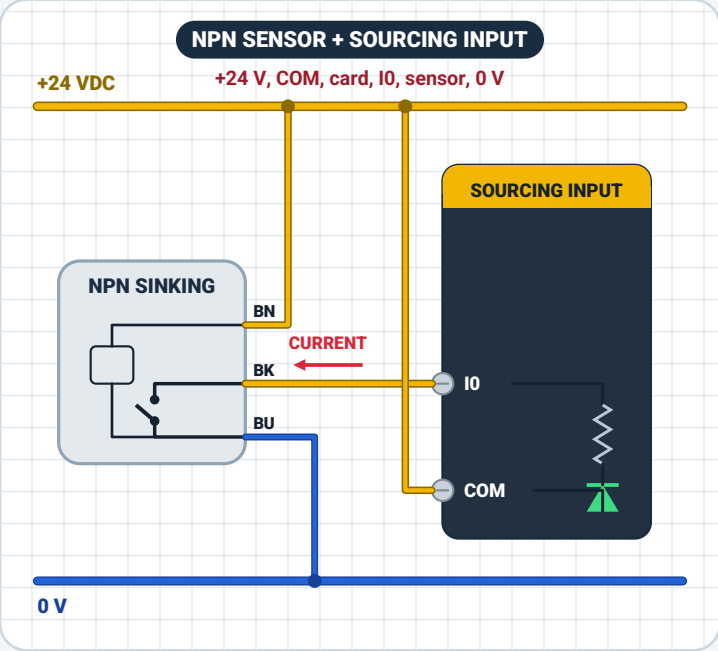
- 0-10 V is simple but picks up noise and cannot tell 0 from a broken wire. 4-20 mA can: 4 mA is the live zero.
- Run analog signals in shielded twisted pair, away from motor leads, with the shield grounded at one end only.

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SINKING VS SOURCING

Current needs a full loop. One side supplies +24 V (sourcing), the other side gives the path to 0 V (sinking).





The rule: a SOURCING device goes on a SINKING input, and a SINKING device goes on a SOURCING input. Many input cards are sink/source: the COM wiring decides.

SENSOR	SWITCHES WHICH SIDE	BLACK WIRE WHEN ON	PAIRS WITH
PNP (sourcing)	Between +24 V and the signal	About +24 V	Sinking input: COM to 0 V
NPN (sinking)	Between the signal and 0 V	About 0 V (pulled low)	Sourcing input: COM to +24 V

TROUBLESHOOTING TIPS

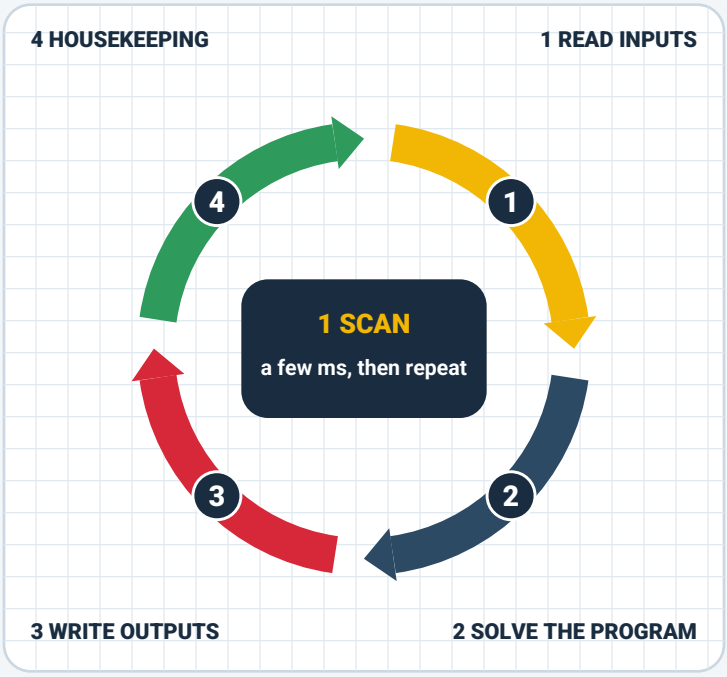
- 3-wire sensor colors (IEC 60947-5-2): brown = +24 V, blue = 0 V, black = signal.
- PNP sensor ON: meter from black to blue reads about 24 V. OFF: about 0 V.
- NPN sensor ON: meter from brown to black reads about 24 V (black pulled to 0 V).
- Sensor LED on but PLC LED off: wrong pairing, open COM or a broken signal wire.

Outputs follow the same rule: a sourcing (PNP) output sends +24 V to the load, whose other end goes to 0 V. A sinking (NPN) output gives the load its path to 0 V, and the other end of the load goes to +24 V.

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THE SCAN CYCLE

A PLC does not run every rung at the same time. It repeats the same 4 steps, usually in a few milliseconds.



1 READ INPUTS

Copies every input terminal into memory (the input image). The program sees this snapshot, not the live wire.

2 SOLVE THE PROGRAM

Rung 0 to the last rung, left to right. A bit written on one rung is already new for the rungs below it.

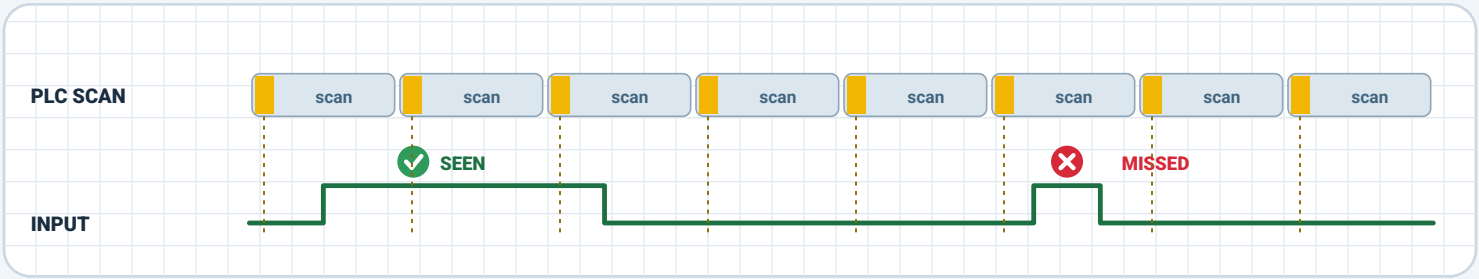
3 WRITE OUTPUTS

Sends the output image to the output terminals, all at once, after the program ends.

4 HOUSEKEEPING

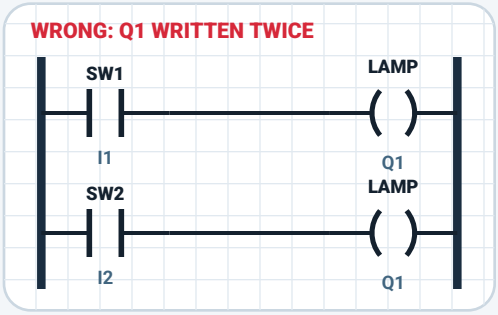
Talks to the laptop and the HMI, runs self-tests and the watchdog. If a scan takes too long, the CPU faults.

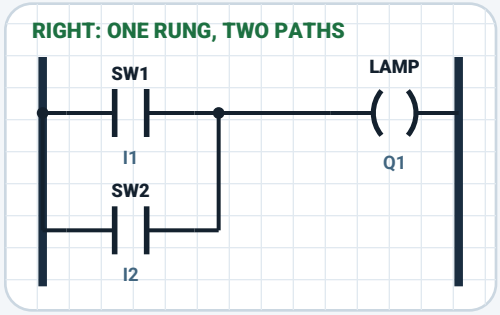
A PULSE SHORTER THAN ONE SCAN CAN BE MISSED



Two rules from the scan: never write the same output (OTE) on two rungs, because the last rung wins; and use a high-speed counter input for pulses faster than the scan.

WHY THE LAST RUNG WINS (DOUBLE COIL)





With SW1 on and SW2 off, rung 0 writes Q1 = 1 and rung 1 writes Q1 = 0 in the same scan. Only the last value reaches the terminal, so the lamp never lights from SW1. Put both conditions in parallel on one rung.

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BIT INSTRUCTIONS: XIC, XIO, OTE, OTL, OTU

Names change by brand, the idea does not. IEC 61131-3 draws the same thing as -| |-, -|/|-, -( )-, -(S)- and -(R)-.



XIC Examine If Closed

True when the bit is 1. Think: is it ON? Used for START, for NC stop buttons at rest and for seal-in contacts.



XIO Examine If Open

True when the bit is 0. Think: is it OFF? Used for interlocks and to react when a signal is missing.



OTE Output Energize

Writes the rung result into the bit every scan: 1 while the rung is true, 0 as soon as it is false.



OTL Output Latch

When the rung is true, sets the bit to 1 and leaves it there, even after the rung goes false.



OTU Output Unlatch

When the rung is true, clears a latched bit to 0. Pair every OTL with an OTU.

WHAT THE PROGRAM SEES

DEVICE WIRED TO THE INPUT	STATE	INPUT BIT	XIC IS	XIO IS
START button (NO)	Not pressed	0	FALSE	TRUE
START button (NO)	Pressed	1	TRUE	FALSE
STOP button (NC)	Not pressed	1	TRUE	FALSE
STOP button (NC)	Pressed	0	FALSE	TRUE

Troubleshooting trick: compare the input LED with the bit in the software online. If they agree, the problem is in the logic or on the output side, not in that wire.

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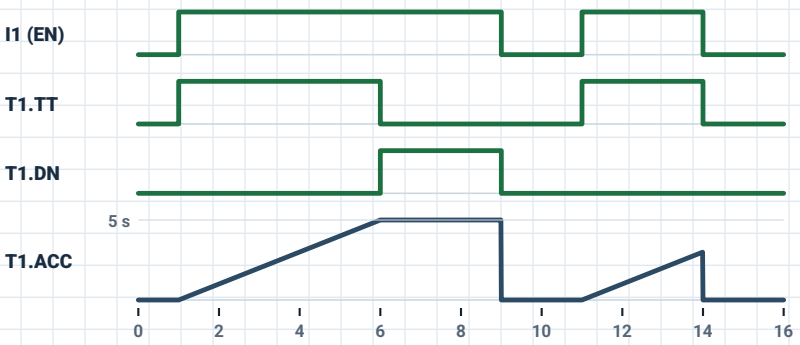
TIMERS: TON AND TOF

The waveforms come from a scan simulation of the rung on the left. ACC counts the time; DN is the time-is-up bit.

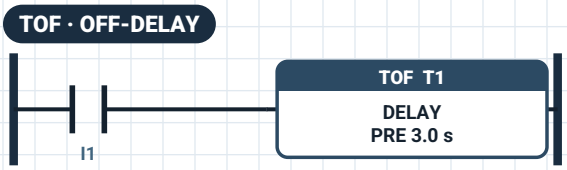
TON · ON-DELAY



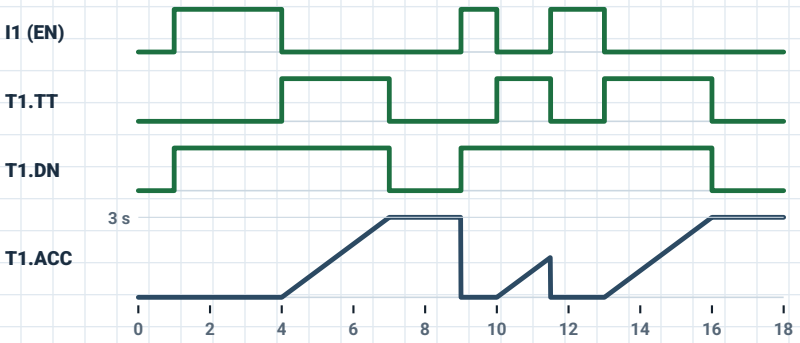
Rung true: ACC counts up. At the preset (5 s) DN turns on. Rung false: ACC and DN reset to 0. A 3 s pulse never reaches DN.



TOF · OFF-DELAY



Rung true: DN turns on at once. Rung false: ACC counts and at the preset (3 s) DN turns off. True again before that: ACC resets.



COMMON NAME	IEC 61131-3 NAME	MEANING	EXAMPLE
EN (enable)	IN	Rung condition into the timer	Start request
PRE (preset)	PT	Time to reach	5 s (or 5000 ms)
ACC (accumulated)	ET	Time counted so far	2.4 s
DN (done)	Q	Time is up (TON) / still holding (TOF)	Start the motor
TT (timing)	—	Timer is counting right now	Horn during the delay

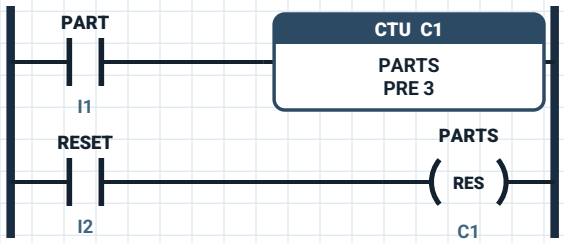
An RTO (retentive timer) keeps ACC when the rung goes false, so it adds up run time; only a RES clears it. Check the time base: many PLCs use 1 ms, so 5 s = 5000.

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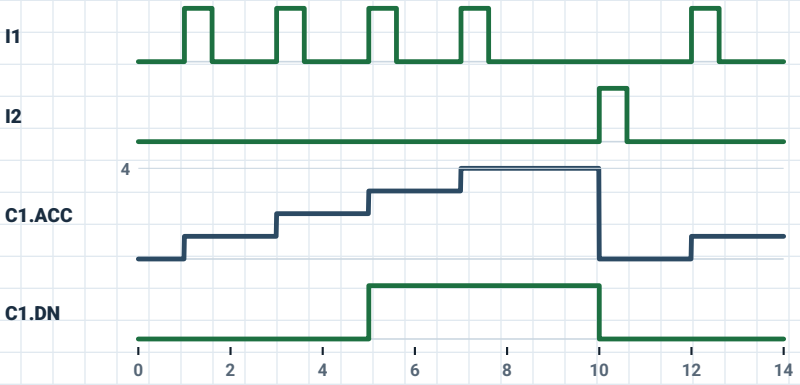
COUNTERS + COMPARISONS

A counter adds 1 on each false-to-true change of its rung. A comparison turns a number into a true/false condition.

CTU · COUNT UP



Preset 3: the 3rd part turns DN on. ACC keeps counting past the preset (4). RES clears ACC and DN. CTD counts down the same way.



COMPARISON INSTRUCTIONS

NAME	SIGN	TRUE WHEN	TYPICAL USE
EQU	=	A equals B	Recipe step = 3
NEQ	≠	A is not equal to B	Mode is not 0
LES	<	A is less than B	Temperature < 55 °C: heat
LEQ	≤	A is less than or equal to B	Level ≤ 20 %: start the pump
GRT	>	A is greater than B	Pressure > 120 psi: alarm
GEQ	≥	A is greater than or equal to B	Timer ACC ≥ 25 s: yellow
LIM	≤ A ≤	Low ≤ A ≤ High	Speed inside its window

Do not use EQU on a timer ACC or an analog value: the exact number can be skipped between scans. Use ranges with GEQ and LES instead.

CTD · COUNT DOWN

Subtracts 1 on each false-to-true edge. Pair it with a CTU on the same counter to track parts in a buffer: in minus out.

RES · RESET

Clears ACC and DN of a counter or a retentive timer. Give it its own rung with the reset condition.

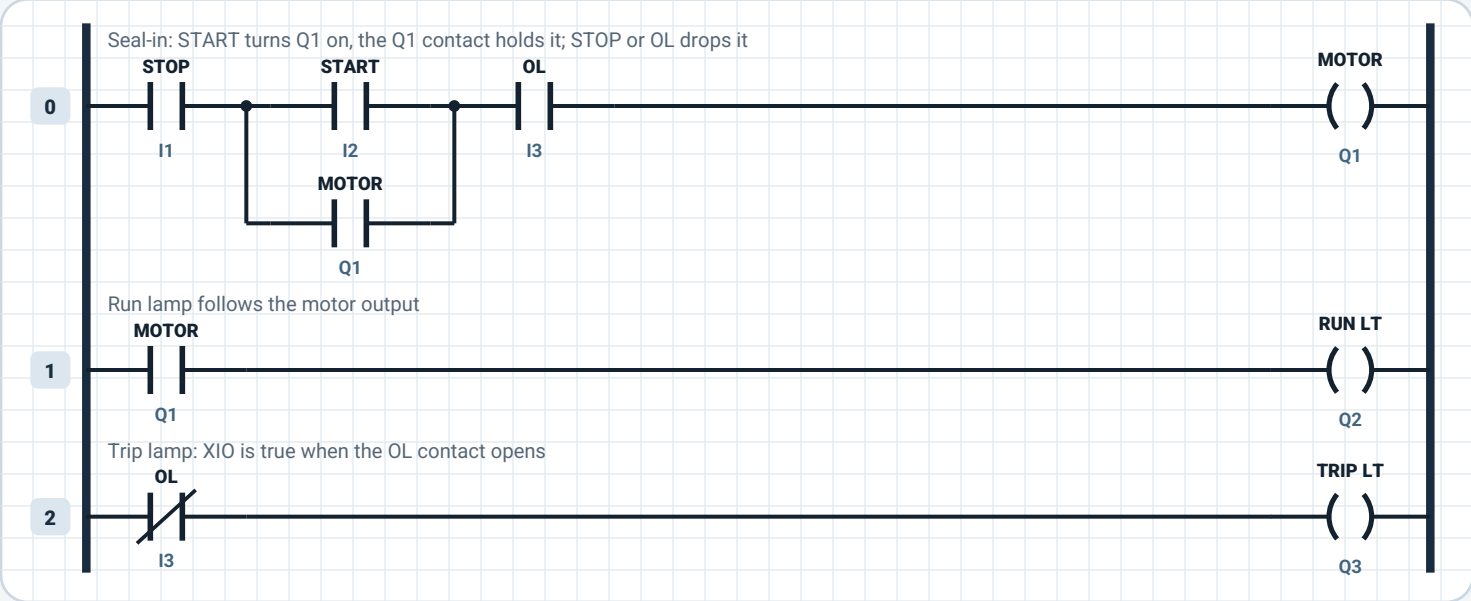
ONE-SHOT · EDGE

Makes a rung true for one scan on a false-to-true edge (IEC 61131-3: R_TRIG). A held button then counts only once.

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EX. 1 · DIRECT-ON-LINE START / STOP

START and STOP buttons run a motor through contactor M. The overload trips it. A green lamp shows RUN, an amber lamp shows TRIP.



INPUT	NAME	DEVICE / WIRING
I1	STOP	Stop push button, NC
I2	START	Start push button, NO
I3	OL	Overload contact 95-96, NC

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	MOTOR	Contactor M coil
Q2	RUN LT	Green pilot light
Q3	TRIP LT	Amber pilot light

STOP and OL are wired NC and programmed XIC: a broken wire stops the motor instead of hiding a fault. After a trip the motor does not restart by itself (checked in simulation).

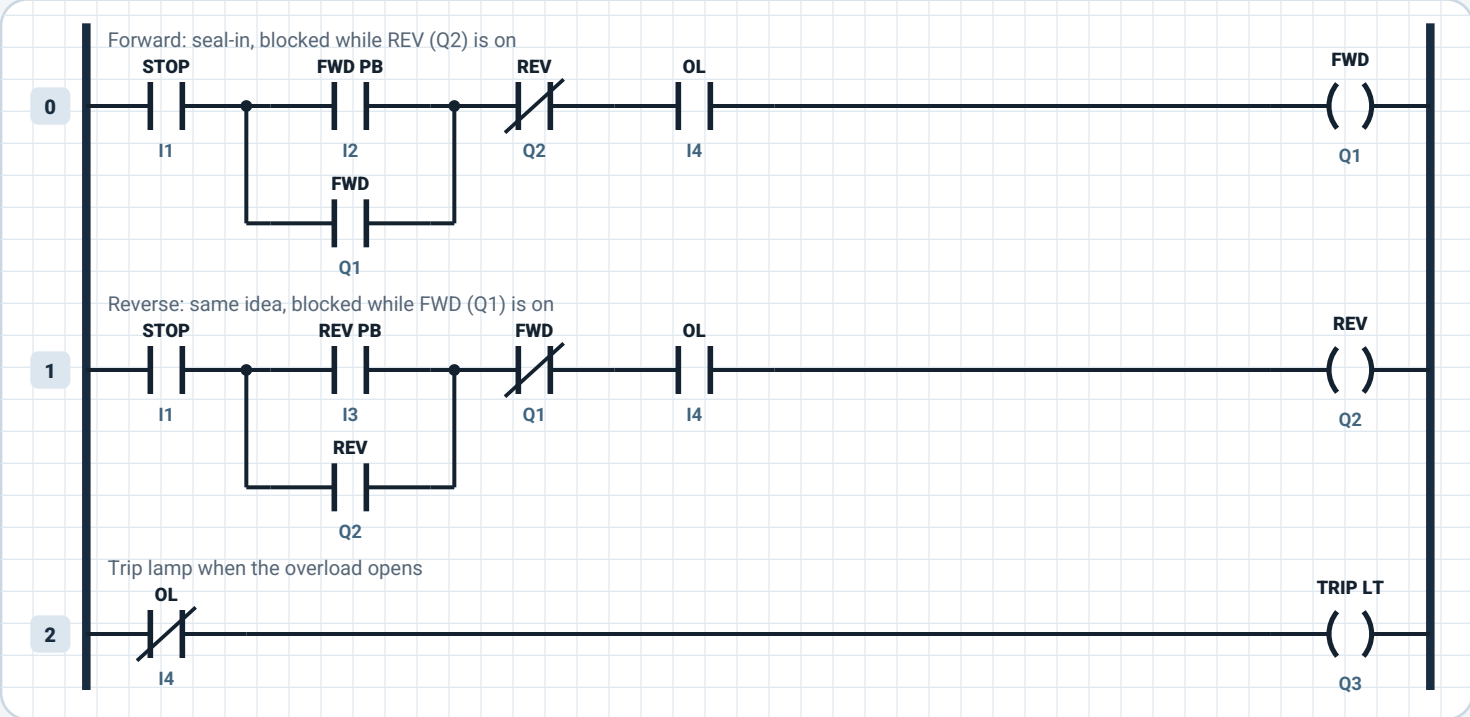
TEST IT ON THE BENCH

1. Press START: Q1 MOTOR and Q2 RUN LT turn on and stay on after you release it.
2. Press STOP: everything drops. Press START again: it runs.
3. Open the OL contact: Q1 drops and Q3 TRIP LT turns on. Close it: the motor stays off until START.

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EX. 2 · FORWARD / REVERSE WITH INTERLOCK

Two contactors swap two phases. FWD and REV can never be on together, and the operator must press STOP before changing direction.



INPUT	NAME	DEVICE / WIRING
I1	STOP	Stop push button, NC
I2	FWD PB	Forward push button, NO
I3	REV PB	Reverse push button, NO
I4	OL	Overload contact 95-96, NC

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	FWD	Forward contactor KF
Q2	REV	Reverse contactor KR
Q3	TRIP LT	Amber pilot light

Keep the hardwired interlock too: an NC auxiliary contact of each contactor in series with the other coil, plus a mechanical interlock. The PLC cannot see a welded contact.

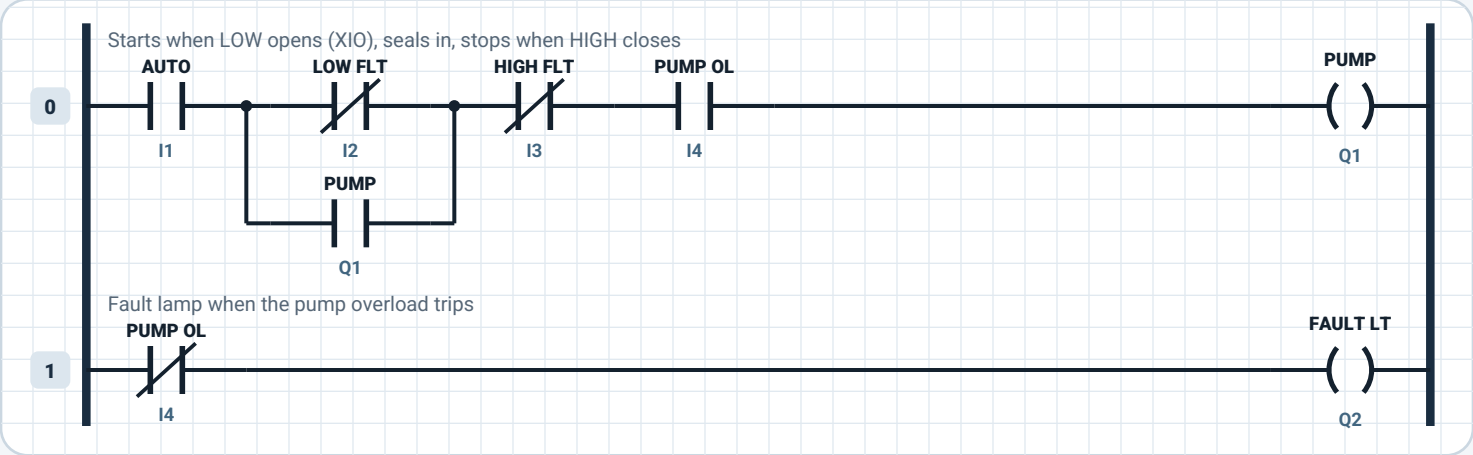
TEST IT ON THE BENCH

1. Press FWD: Q1 runs. Press REV now: nothing changes (interlock).
2. Press STOP, then REV: Q2 runs.
3. Press FWD and REV together: only the rung solved first (FWD) wins; never both.

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EX. 3 - TANK FILL WITH TWO FLOATS

A pump fills the tank when the water drops below the LOW float and stops at the HIGH float. In between it keeps its last state (hysteresis).



INPUT	NAME	DEVICE / WIRING
I1	AUTO	Selector switch, NO
I2	LOW FLT	Low float, closed = water above it
I3	HIGH FLT	High float, closed = water above it
I4	PUMP OL	Pump overload, NC

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	PUMP	Pump contactor
Q2	FAULT LT	Pump fault lamp

Checked in simulation: with the tank losing 1 %/s and the pump adding 2 %/s, the level swings between 20 % and 80 %, 60 s filling and 60 s draining. Add a hardwired high-high float against overflow.

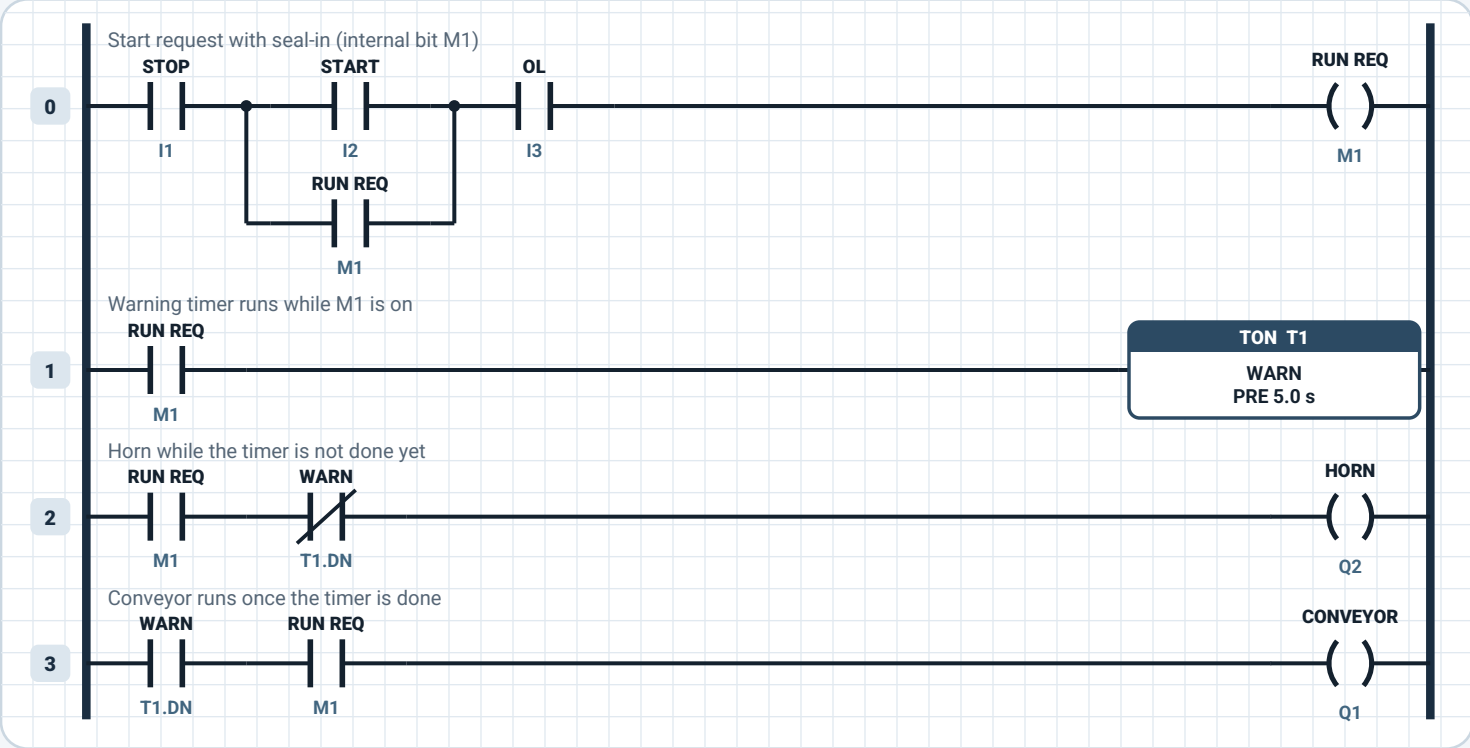
TEST IT ON THE BENCH

1. Level above LOW and below HIGH with the pump off: it stays off.
2. Level falls under LOW: Q1 PUMP starts and keeps running above LOW (seal-in).
3. Level reaches HIGH: the pump stops. Turn AUTO off: it stops at once.

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EX. 4 - CONVEYOR WITH START-UP WARNING

START sounds a horn for 5 s so people can step away. Only then does the conveyor start. STOP or the overload cancels everything.



INPUT	NAME	DEVICE / WIRING
I1	STOP	Stop push button, NC
I2	START	Start push button, NO
I3	OL	Overload contact 95-96, NC

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	CONVEYOR	Conveyor contactor
Q2	HORN	Warning horn and beacon
M1	RUN REQ	Internal bit: start request
T1	WARN	TON 5.0 s warning time

Checked in simulation: START at 1 s, horn from 1 s to 6 s, conveyor from 6 s until STOP. If STOP comes during the warning, the conveyor never starts.

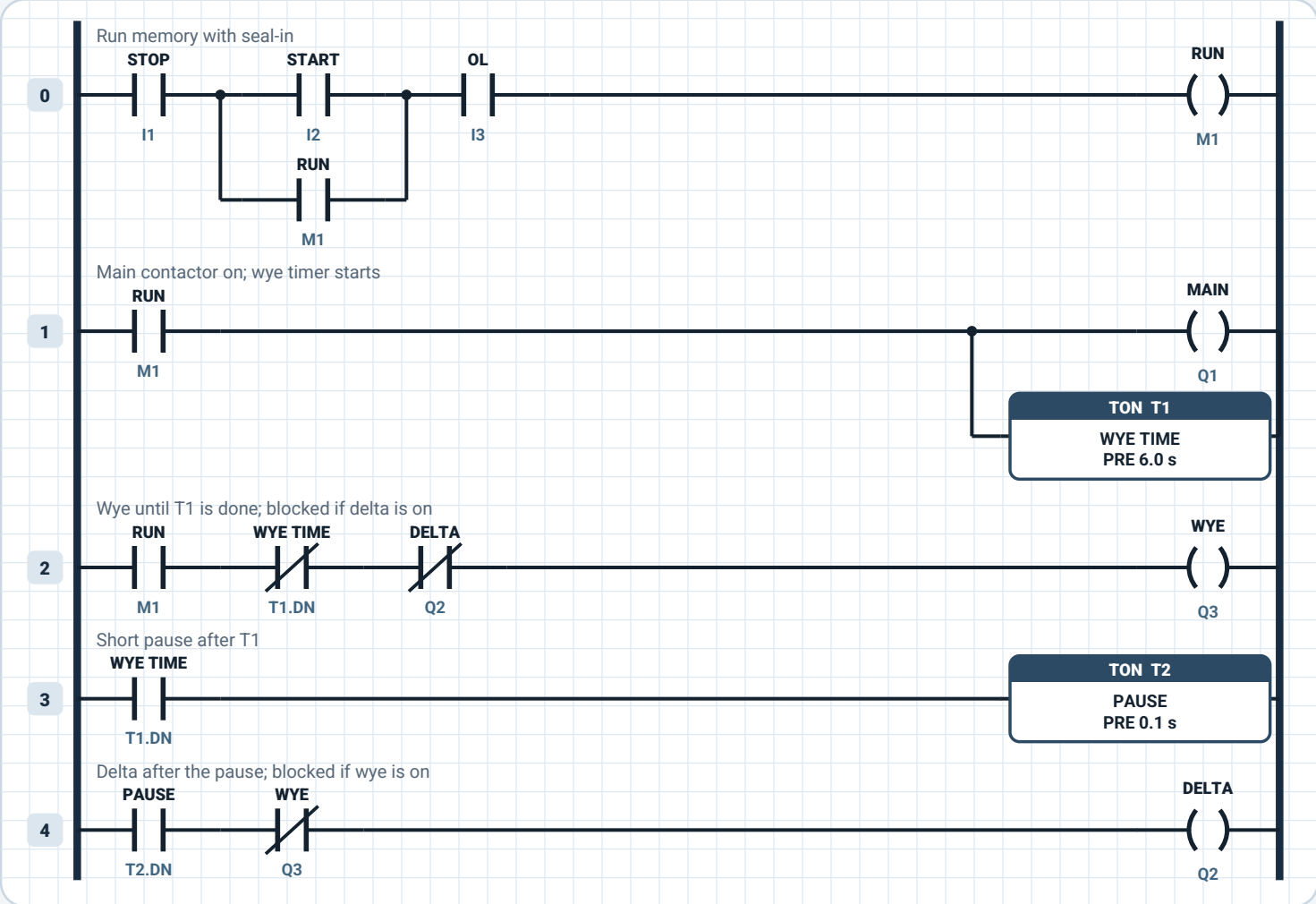
TEST IT ON THE BENCH

1. Press START: Q2 HORN sounds and Q1 stays off.
2. After 5 s: the horn stops and Q1 CONVEYOR starts.
3. Press STOP during the horn: M1 drops, T1 resets, the conveyor never starts.

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EX. 5 · WYE-DELTA START WITH TIMERS

The motor starts in wye (lower inrush) and moves to delta after 6 s, with a 0.1 s pause so the two contactors never overlap.



INPUT	NAME	DEVICE / WIRING
I1	STOP	Stop push button, NC
I2	START	Start push button, NO
I3	OL	Overload contact 95-96, NC

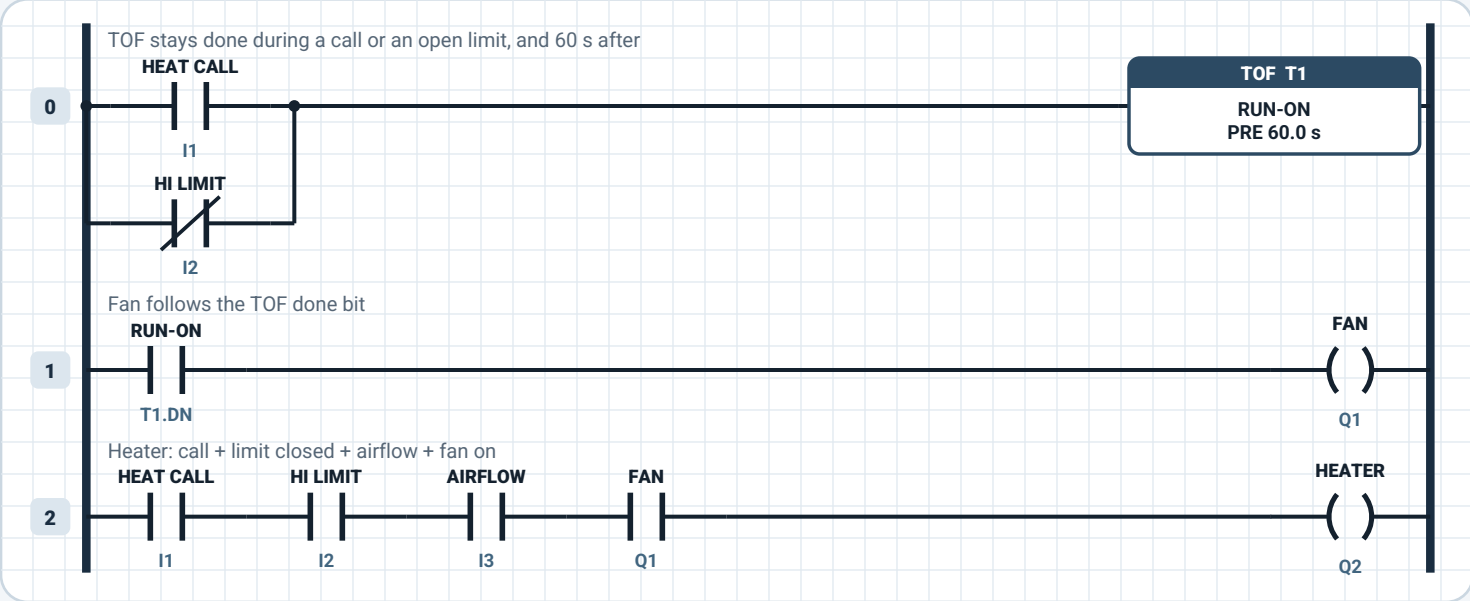
OUTPUT / BIT	NAME	WHAT IT DOES
Q1	MAIN	Main contactor KM1
Q2	DELTA	Delta contactor KM2
Q3	WYE	Wye contactor KM3
M1	RUN	Internal bit: run memory
T1	WYE TIME	TON 6.0 s in wye
T2	PAUSE	TON 0.1 s transition

Checked in simulation: wye from 1.0 s to 7.0 s, delta from 7.1 s, never both. Wye time depends on the load (often 5-15 s). Keep a hardwired interlock between KM2 and KM3.

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EX. 6 · HEATER FAN RUN-ON (TOF)

The fan must keep running 60 s after the heat call ends, to cool the element. The heater runs only with airflow proven and the high limit closed.



INPUT	NAME	DEVICE / WIRING
I1	HEAT CALL	Thermostat contact, NO
I2	HI LIMIT	High-limit switch, NC (opens hot)
I3	AIRFLOW	Air switch, NO (closed = airflow)

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	FAN	Fan contactor
Q2	HEATER	Heater contactor
T1	RUN-ON	TOF 60 s fan run-on

Checked in simulation: the call ends at 20 s and the fan stops at 80 s. If the limit opens, the heater drops at once and the fan keeps running. The limit must also cut the heater in hardwire.

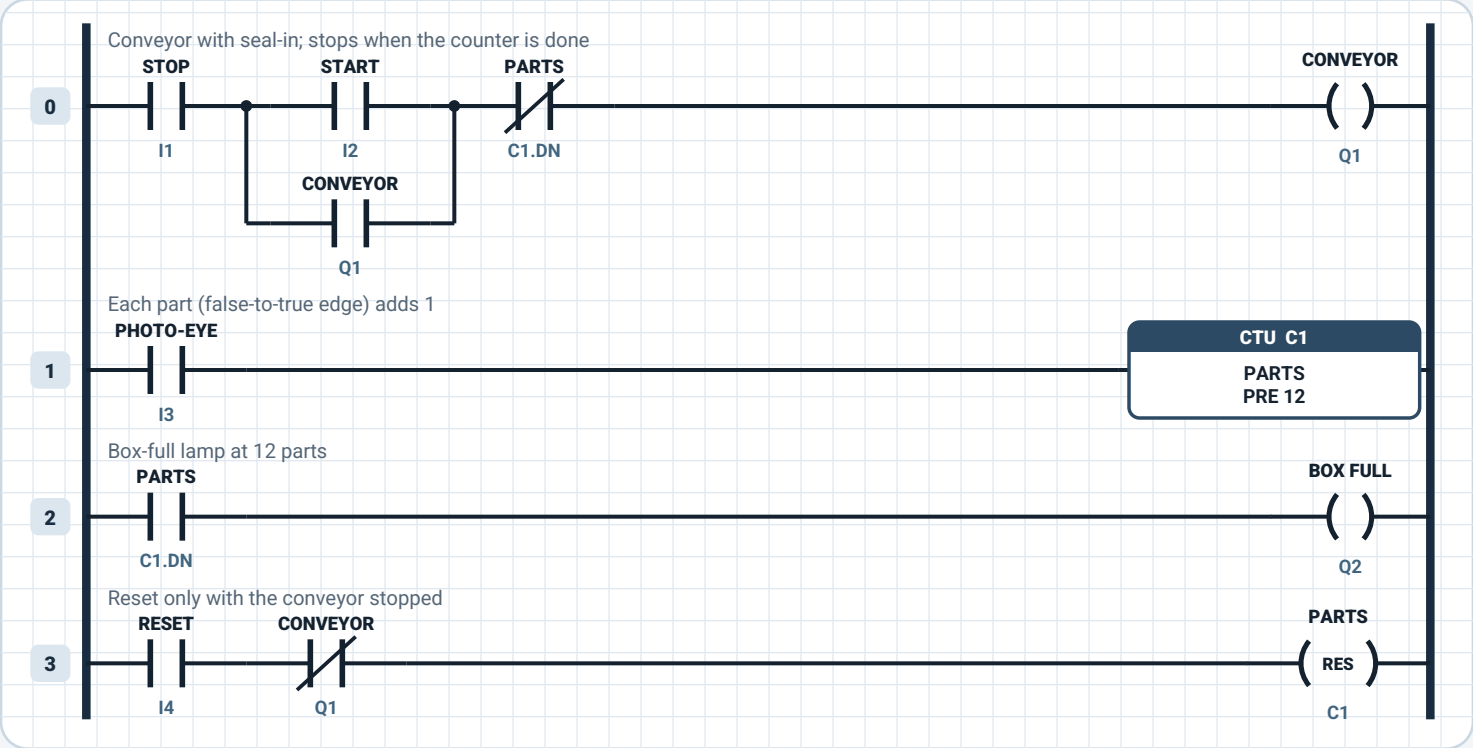
TEST IT ON THE BENCH

1. Close HEAT CALL: the FAN starts; with AIRFLOW proven the HEATER starts.
2. Open HEAT CALL: the HEATER stops at once, the FAN runs 60 s more.
3. Open HI LIMIT during a call: the HEATER drops, the FAN keeps running.

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EX. 7 · PARTS COUNTER: BOX OF 12

A photo-eye counts parts on a conveyor. At 12 parts the conveyor stops and a lamp asks for a new box. RESET, with the conveyor stopped, clears the count.



INPUT	NAME	DEVICE / WIRING
I1	STOP	Stop push button, NC
I2	START	Start push button, NO
I3	PHOTO-EYE	Part sensor, PNP, NO
I4	RESET	Reset push button, NO

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	CONVEYOR	Conveyor contactor
Q2	BOX FULL	Box-full lamp
C1	PARTS	CTU, preset 12

Checked in simulation: 12 parts stop the conveyor, RESET clears C1 to 0 and START runs it again. The part signal must last longer than one scan (page 10).

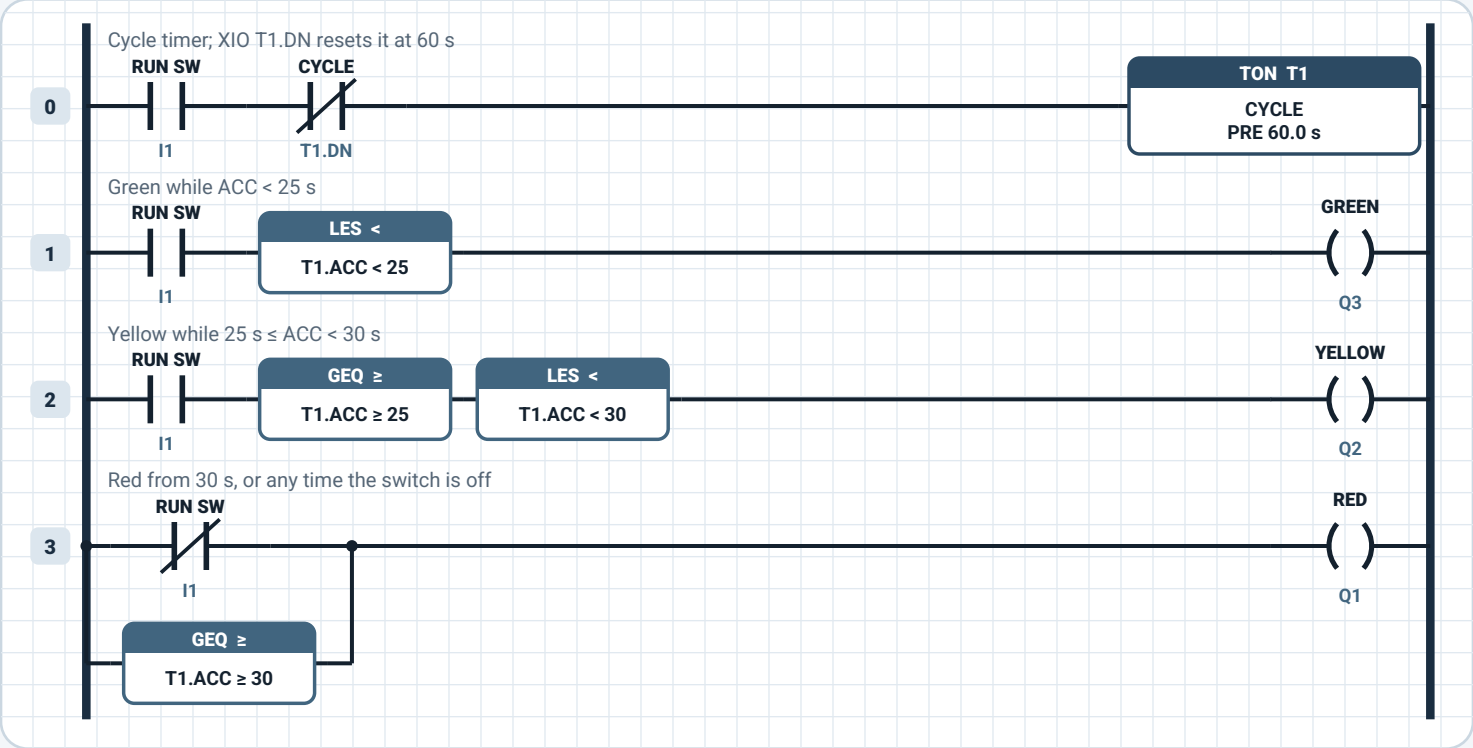
TEST IT ON THE BENCH

1. Press START: the conveyor runs and every part adds 1 to C1.
2. At the 12th part: Q1 stops and Q2 BOX FULL turns on.
3. Press RESET (conveyor stopped): C1 = 0 and the lamp goes off. START for the next box.

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EX. 8 - TRAFFIC LIGHT WITH ONE TIMER

One 60 s timer runs in a loop. Comparisons on its ACC pick the lamp: green 0-25 s, yellow 25-30 s, red 30-60 s. Switch off = red.



INPUT	NAME	DEVICE / WIRING
I1	RUN SW	Run selector switch, NO

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	RED	Red lamp
Q2	YELLOW	Yellow lamp
Q3	GREEN	Green lamp
T1	CYCLE	TON 60 s, resets itself

Checked in simulation: green 25 s, yellow 5 s, red 30 s, always exactly one lamp on. Many PLCs count ACC in milliseconds: then compare with 25000 and 30000.

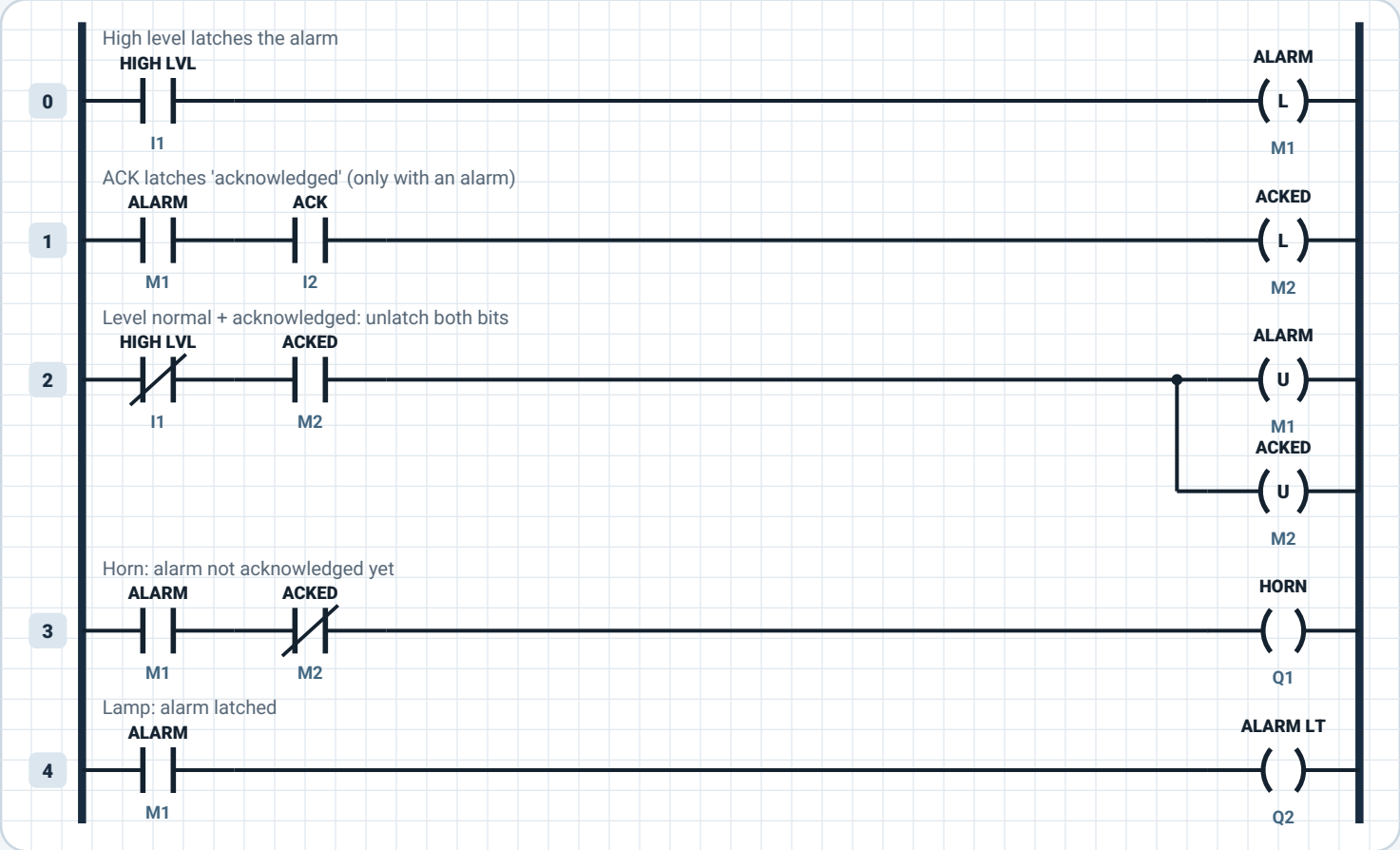
TEST IT ON THE BENCH

1. Turn RUN SW on: GREEN 25 s, YELLOW 5 s, RED 30 s, then repeat.
2. Turn it off at any time: T1 resets and RED stays on.
3. Watch T1.ACC online and each comparison turning true and false.

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EX. 9 · ALARM WITH ACKNOWLEDGE

A high-level switch sounds a horn and lights a lamp. ACK silences the horn. The lamp stays on until the alarm is acknowledged and the level is normal.



INPUT	NAME	DEVICE / WIRING
I1	HIGH LVL	Level switch, NO (closes high)
I2	ACK	Acknowledge push button, NO

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	HORN	Alarm horn
Q2	ALARM LT	Amber alarm lamp
M1	ALARM	Internal bit: alarm latched
M2	ACKED	Internal bit: acknowledged

Checked in simulation: a short high level (30-35 s) still keeps horn and lamp on until ACK at 40 s. Latched bits often survive a power cycle: check how your PLC handles them.

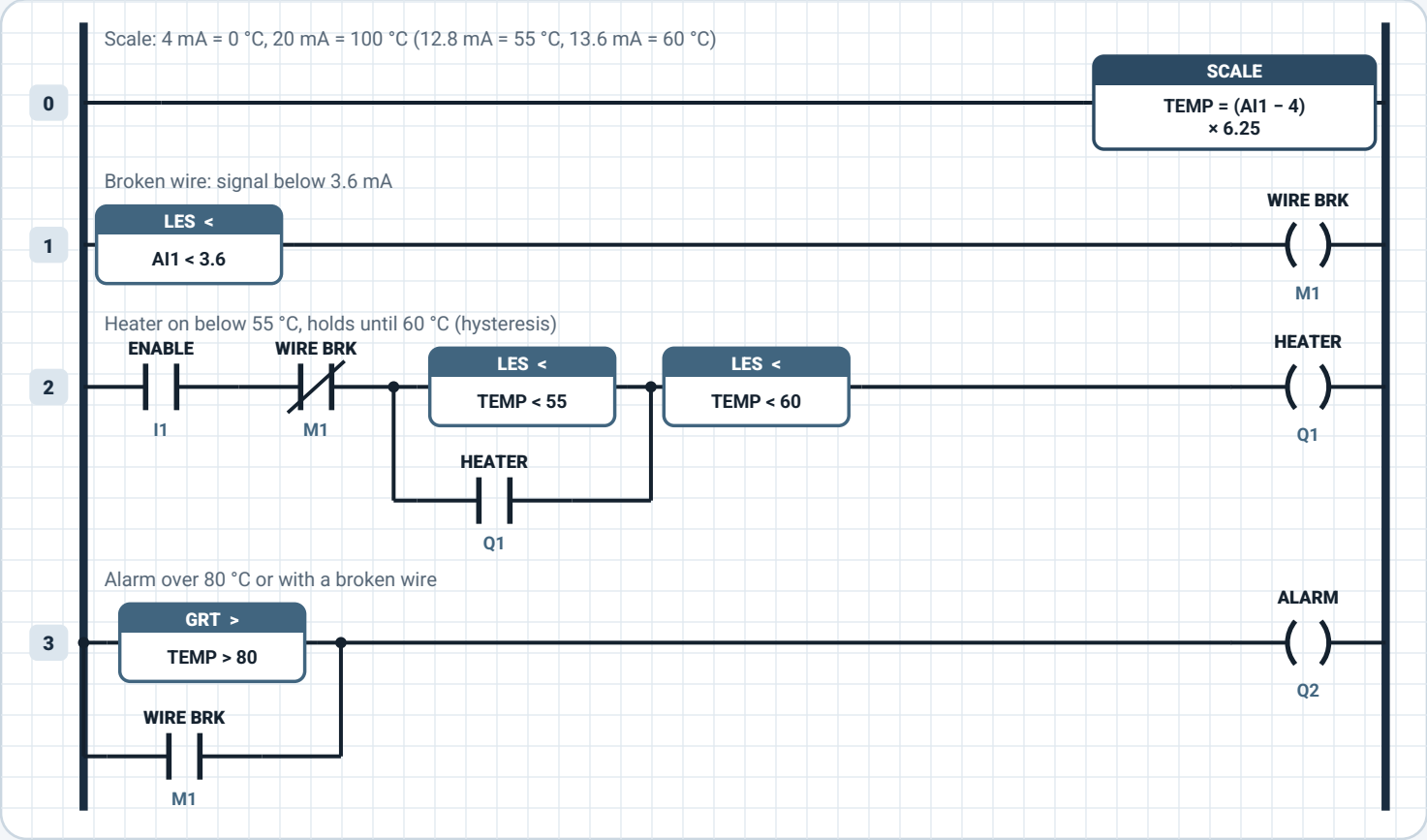
TEST IT ON THE BENCH

1. Close HIGH LVL: HORN and ALARM LT turn on.
2. Press ACK: the HORN stops; the lamp stays on while the level is high.
3. Level back to normal: the lamp goes off. A short alarm still waits for ACK.

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EX. 10 - ANALOG TEMPERATURE CONTROL

A 4-20 mA transmitter (0-100 °C) feeds an analog input. The heater turns on below 55 °C and off at 60 °C. Over 80 °C or a broken wire turns on the alarm.



INPUT	NAME	DEVICE / WIRING
AI1	TEMP TX	Transmitter 4-20 mA = 0-100 °C
I1	ENABLE	Selector switch, NO

OUTPUT / BIT	NAME	WHAT IT DOES
Q1	HEATER	Heater contactor
Q2	ALARM	Alarm lamp
M1	WIRE BRK	Internal bit: signal < 3.6 mA
TEMP	TEMP °C	Internal value: scaled °C

Checked in simulation: the tank holds between 55 and 60 °C; with the wire cut the heater stops and the alarm comes on. Scaling instructions differ by brand; the math is the same.

TEST IT ON THE BENCH

1. Signal below 12.8 mA (55 °C) with ENABLE on: HEATER on.
2. The HEATER stays on until 13.6 mA (60 °C), then turns off.
3. Signal above 16.8 mA (over 80 °C) or below 3.6 mA: ALARM on; with a broken wire the heater stays off.

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GLOSSARY EN / ES + SOURCES

The words you will see on drawings, screens and job sites, in English and Spanish.

ENGLISH	ESPAÑOL	MEANING
PLC	PLC (controlador lógico programable)	Industrial computer: reads inputs, runs a program, drives outputs.
I/O	Entradas y salidas (I/O)	Terminals where field devices connect to the PLC.
Ladder logic	Lógica de escalera (ladder)	Program drawn like a relay schematic: rails and rungs.
Rung	Escalón (rung)	One line of logic, from the left rail to an output.
Contact (XIC / XIO)	Contacto (XIC / XIO)	Checks a bit: is it 1 (XIC) or 0 (XIO)?
Coil (OTE)	Bobina (OTE)	Writes a bit: 1 while its rung is true.
Latch / unlatch	Enclavar / desenclavar	OTL sets a bit and keeps it; OTU clears it.
Seal-in	Sello (auto-retención)	Output contact in parallel with START, so it holds after release.
Interlock	Enclavamiento	Logic that blocks one output while another is on.
Contactor	Contactor	Relay built to switch motor power.
Overload relay	Relevador de sobrecarga (overload)	Senses motor current; opens 95-96 when it runs too hot.
Push button / selector	Botón / selector	Momentary (push) or maintained (selector) operator switch.
Limit switch / float	Interruptor de límite / flotador	Switch moved by a machine part / by the water level.
Prox sensor / photo-eye	Sensor de proximidad / fotoeléctrico	Electronic 3-wire sensor, PNP or NPN.
Sinking / sourcing	Sinking / sourcing	Sinking gives the path to 0 V; sourcing supplies +24 V.
Scan cycle	Ciclo de escaneo (scan)	Read inputs, solve the program, write outputs, repeat.
Timer TON / TOF	Temporizador TON / TOF	On-delay / off-delay timer.
Counter CTU / CTD	Contador CTU / CTD	Counts up / down on each false-to-true edge.
Preset / accumulated	Preset / acumulado	Target value (PRE) / current value (ACC).
Tag / address	Tag / dirección	Name or address of a bit or value (I1, Q1, T1.DN).
Force	Forzar (force)	Overrides an I/O bit from software. Dangerous on a live machine.
Lockout/tagout	Bloqueo y etiquetado (LOTO)	Isolate, lock, tag and test before work.
E-stop	Paro de emergencia	Stops the machine through a hardwired or safety-rated circuit.
Wye-delta	Estrella-triángulo	Reduced-inrush start: wye first, then delta.
4-20 mA	4-20 mA	Analog current loop; 4 mA = zero, so 0 mA means a fault.

SOURCES AND STANDARDS

Standards cited in general terms: IEC 61131-3 (PLC programming languages) and IEC 61131-2 (PLC equipment and I/O); NFPA 70E (electrical safety in the workplace); NFPA 70, National Electrical Code, Article 430 (motors and overloads); NFPA 79 (industrial machinery); OSHA 29 CFR 1910.147 (control of hazardous energy, lockout/tagout); IEC 60947-5-2 (proximity sensors, wire colors); NAMUR NE 43 (4-20 mA failure levels). Every timing, count and scaling value in the 10 exercises was checked by running the ladder in a scan simulator (10 ms scan).

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