A HANDS-ON GUIDE

# Your First Servo Cabinet

Wiring a Leadshine EL8-EC1000F drive and ELM1H-1000MA80E motor, from the wall socket to the first move

Jasper van Leuven · Swivel project · 16 November 2026

# Contents


| | |
|---|---|
| Preface | How to use this book |
| Chapter 1 | The big picture |
| Chapter 2 | Electricity in five words |
| Chapter 3 | How to read an electrical diagram |
| Chapter 4 | Every part on your bench |
| Chapter 5 | The drive and the motor |
| Chapter 6 | The DIN rail and terminal rows |
| Chapter 7 | The 230 V circuit |
| Chapter 8 | The 24 V circuit |
| Chapter 9 | The emergency stop and STO |
| Chapter 10 | The holding brake |
| Chapter 11 | The motor and encoder cables |
| Chapter 12 | Building it, step by step |
| Chapter 13 | When something does not work |
| Appendix A | Shopping list |
| Appendix B | Glossary |
| Appendix C | Sources |

PREFACE

# How to use this book

This book takes you from “I have a box with a servo drive and a motor” to a working, safely wired axis that you understand. It is written for a first build and assumes no electrical background.

It is a hands-on guide rather than a manual. Every chapter explains one idea, shows it on a drawing, and tells you what to do with your hands. Where Leadshine’s documentation is unclear, the book says so once, plainly, and tells you how to check it yourself.

## What you are building

A small control cabinet that powers and protects one **Leadshine EL8-EC1000F** servo drive and one **ELM1H-1000MA80E** 1 kW servo motor with a holding brake. You will add an emergency stop wired to the drive’s Safe Torque Off input, a 24 V power supply, a breaker that doubles as the main switch, and a tidy row of DIN-rail terminals. A computer running LinuxCNC talks to the drive over EtherCAT.

We deliberately leave out two parts you may see in vendor drawings: the **line filter** and the **main contactor**. Many small machines run without them, including the build in the Marco Reps video you used as a reference, and the manual itself only suggests a filter “in environments with strong interference”. Appendix A explains when you would add them later.

## How the book is organised

- **Part I, Foundations**: the five electrical words you need, and how to read an electrical diagram.
- **Part II, The parts**: every component on your bench, what it does and why it is there.
- **Part III, The circuits**: the 230 V circuit, the 24 V circuit, the emergency stop, the brake and the motor cables, each with its own drawing.
- **Part IV, Building it**: the build sequence, and the first power-up with the tests that prove it works.
- **Appendices**: shopping list, glossary and sources.

## Conventions used in this book

> **TIP**
> A practical shortcut or a habit that saves you time.

> **NOTE**
> Background that helps you understand, but which you can skip on a first read.

> **WARNING**
>
> Something that can hurt you or break hardware. Read these every time.

Wire colours in the drawings match the wire you will buy: **brown** live, **blue** neutral, **green/yellow** earth, **red** +24 V and **dark blue** 0 V.

CHAPTER 1

# The big picture

Before any detail, hold the whole system in your head. There are only two kinds of electricity in your cabinet, and one rule tying them together.

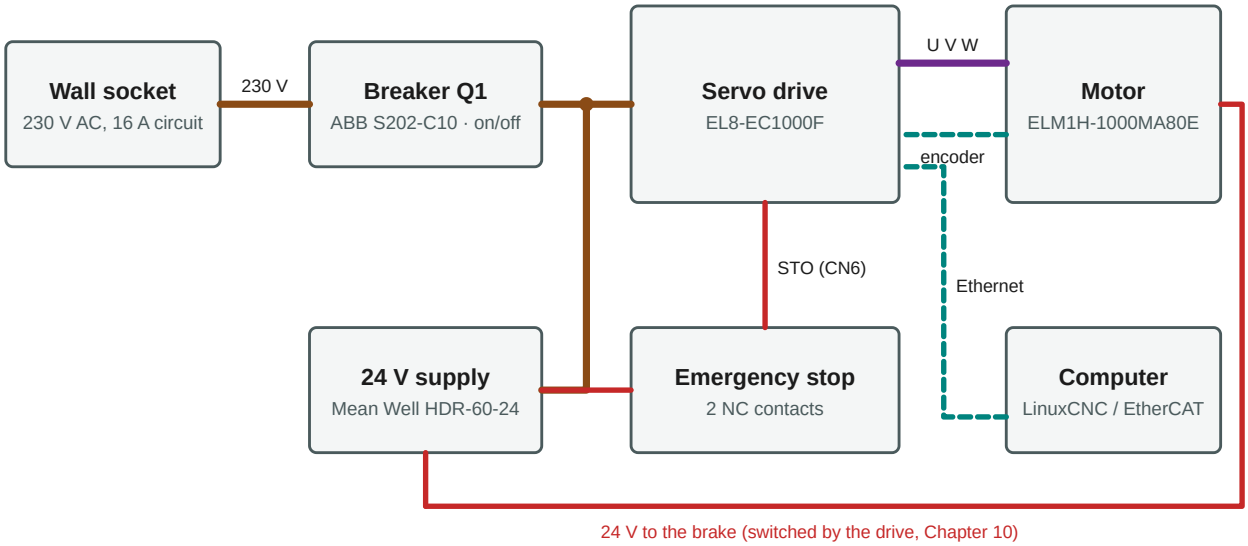



**Figure 1.** The whole system on one page. Thick brown lines carry 230 V, red lines carry 24 V DC, dashed teal lines carry data. Every block is a part you will hold in your hand.

## Two kinds of electricity

**230 V AC from the wall** feeds the drive and the 24 V power supply. This is the dangerous side: it can kill. Everything on this side is switched and protected by the breaker Q1 and connected only while the plug is out.

**24 V DC from the Mean Well supply** feeds the things that only need a small, safe voltage: the motor's holding brake and the emergency-stop circuit. Later it will feed sensors, relays and EtherCAT I/O too. You can touch 24 V without harm, which is exactly why machine builders use it for everything a person interacts with.

## One rule

**The wall powers the drive; the drive powers the motor.** Mains never goes to the motor directly. The drive takes 230 V AC in, turns it into a precisely controlled three-phase current on U, V and W, and reads back the motor's exact position from the encoder thousands of times a second. That feedback loop is what makes it a *servo*.

## What each block does, in one line

| Block | Its job |
|---|---|
| Wall socket | Supplies 230 V AC. Your house breaker protects the socket circuit. |
| Breaker Q1 | Your main on/off lever, and protection if a wire in the cabinet shorts. |
| Servo drive | Turns mains into precisely controlled motor current; talks EtherCAT; watches the encoder. |
| Motor | Turns current into torque. Contains the encoder (position) and the holding brake. |
| 24 V supply | Makes safe 24 V DC for the brake, the emergency stop and future I/O. |
| Emergency stop | A big red button that removes the drive’s ability to make torque, through STO. |
| Computer | Tells the drive where to go. Not a safety device: it can crash. |

> **NOTE**
> Professional cabinets add more blocks: a line filter, a contactor, a safety relay. They are improvements, not prerequisites. You can add them later without redoing this wiring, because each one slots into a line you will already have.

CHAPTER 2

# Electricity in five words

You need exactly five ideas to follow every circuit in this book. Water in a pipe is a good enough picture for all of them.

## Voltage (V): the push

Voltage is the pressure difference between two points. It is always measured *between* two things: “230 V between L and N”, “24 V between +V and −V”. A single wire does not “have” a voltage on its own. Higher voltage pushes harder, which is why 230 V can drive current through your body and 24 V cannot.

## Current (A): the flow

Current is how much electricity actually flows. A load takes the current it needs: the 11.5 W brake at 24 V draws 11.5 ÷ 24 ≈ **0.48 A**, even though the supply could deliver 2.5 A. A supply’s rating is its capacity, not what it forces out.

## Power (W): the work

Power = voltage × current. It tells you how much a supply must deliver and how hot things get. Your 60 W supply has plenty of room: brake 11.5 W, STO inputs a fraction of a watt.

## AC and DC

**AC** (alternating current) reverses direction 50 times a second; that is what the wall delivers. Polarity does not matter for AC, which is why a Schuko plug fits either way round. **DC** (direct current) always flows the same way and has a fixed + and −. Polarity matters for DC: swap +24 V and 0 V on the wrong device and it will not work, or it will break.

## A circuit: there and back again

Current only flows in a closed loop: out on one wire, back on another. A switch works by breaking the loop. This is the single most useful idea in this book: **whenever you look at a drawing, trace the loop**. For the brake: +24 V → brake switch → brake coil → 0 V → back to the supply. If any link in that chain is open, nothing happens.

## And one safety word: earth (PE)

Protective earth is the green/yellow wire. In normal operation it carries **no current**. It connects every touchable metal part back to the earth pin of the plug, so that if a live wire ever touches a metal case, a large current flows straight to earth and the breaker or the house RCD trips in milliseconds, instead of the metal case sitting at 230 V waiting for your hand.

> **WARNING**
>
> Earth is not a return path. Never use PE in place of N or 0 V, and never leave it off “because it works without”. It always works without, right up to the day it doesn’t.

## Mains wires, named

| Name | Colour | What it does |
|---|---|---|
| L (live, line) | brown | Carries the 230 V push. The dangerous wire. |
| N (neutral) | blue | The return wire for mains. Near 0 V in normal operation, but treat it as live. |
| PE (protective earth) | green/yellow | Safety conductor to every metal part. Never carries normal current. |

> **WHY TWO POLES**
>
> On a Schuko socket, L and N can come out on either pin depending on how the plug is inserted. That is why Q1 is a **two-pole** breaker: it disconnects both wires, so you never have to know which one is live.

CHAPTER 3

# How to read an electrical diagram

A wiring diagram looks intimidating because it is dense, not because it is hard. It uses a small alphabet of symbols and a few rules. Learn both and you can read any drawing in this book, and most drawings in vendor manuals.

## Rule 1: a diagram shows connections, not positions

A schematic is a map of *what connects to what*. It does not show where parts sit in the cabinet, how long wires are, or which way a connector faces. Two terminals drawn side by side may be half a metre apart in reality. For positions you use a **layout drawing** (Figure 5 in Chapter 6 is one).

## Rule 2: contacts are drawn at rest

Every switch, button and relay contact is drawn in its **unpressed, unpowered** state. An NC contact is drawn closed, because at rest it is closed. When you read a circuit, first read it at rest, then ask "what changes when this button is pressed, or this coil gets power?"

## Rule 3: power flows from top or left, to bottom or right

By convention the supply sits at the top or left, and the loads hang below or to the right. Long horizontal or vertical lines that run across the whole drawing are **rails** (also called buses): every dot on them is the same electrical point.

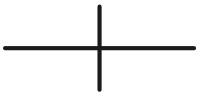
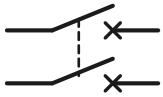
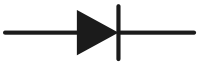
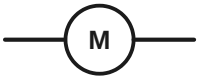
## Rule 4: dots join, crossings do not

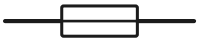
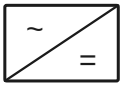
A filled dot means wires are connected. Two lines crossing without a dot pass over each other. This is the most common beginner mistake, so check every crossing.

## Rule 5: labels tell you where to put the wire

Text next to a terminal is its name, printed on the real part: `L1C` on the drive, `11` on an emergency-stop contact block, `X10:4` on your fourth terminal in row X10. The convention **X10:4** means "terminal row X10, position 4". Device names follow a letter code: **Q** for breakers and switches, **S** for buttons, **K** for relays, **X** for terminals and connectors, **M** for motors.

## The symbol alphabet

| Name | Symbol | What it means |
|---|---|---|
| **Wire (conductor)** |  | A path for current. Length and angle on paper mean nothing; only what it connects matters. |
| **Connection** |  | A **filled dot** where wires meet means they are joined. |
| **Crossing, no connection** |  | Lines that cross **without a dot** are not connected: they just pass each other on paper. |
| **Terminal** |  | An open circle is a place where you clamp a wire: a screw, a spring clamp, a connector pin. |
| **NO contact** |  | **Normally open**: open (no current) while nobody touches it. Pressing or energising closes it. |
| **NC contact** |  | **Normally closed**: closed (current flows) at rest. Pressing or energising opens it. |
| **Emergency-stop button** |  | An NC contact operated by a red mushroom head. It latches when pressed; you twist to release. |
| **Circuit breaker** |  | A switch with a built-in trip (the ×). It opens by itself on overload or short circuit. |
| **Linked poles** |  | A **dashed line** between two contacts: they are one device and move together. |
| **Coil** |  | The electromagnet of a relay, contactor or brake. Current through it moves something. |
| **Diode** |  | Lets current pass only in the direction of the arrow. Across coils it absorbs the switch-off spike. |
| **Motor** |  | A circle with M. Your servo motor has three winding wires (U, V, W) and an earth. |

| Name | Symbol | What it means |
|---|---|---|
| **Protective earth** |  | PE: the green/yellow safety conductor. It carries current only when something has gone wrong. |
| **Fuse** |  | A one-time version of a breaker: a wire that melts on overcurrent. |
| **DC supply** |  | A box with ~ (AC in) and = (DC out): a converter like your Mean Well. |

## Worked example: reading the vendor drawing

Here is the drawing from page 27 of the Leadshine manual. It shows a more complete installation than yours: line filter, contactor, Start/Stop buttons, an alarm relay and a brake relay. Reading it is good practice, and you will see exactly which parts we are leaving out.

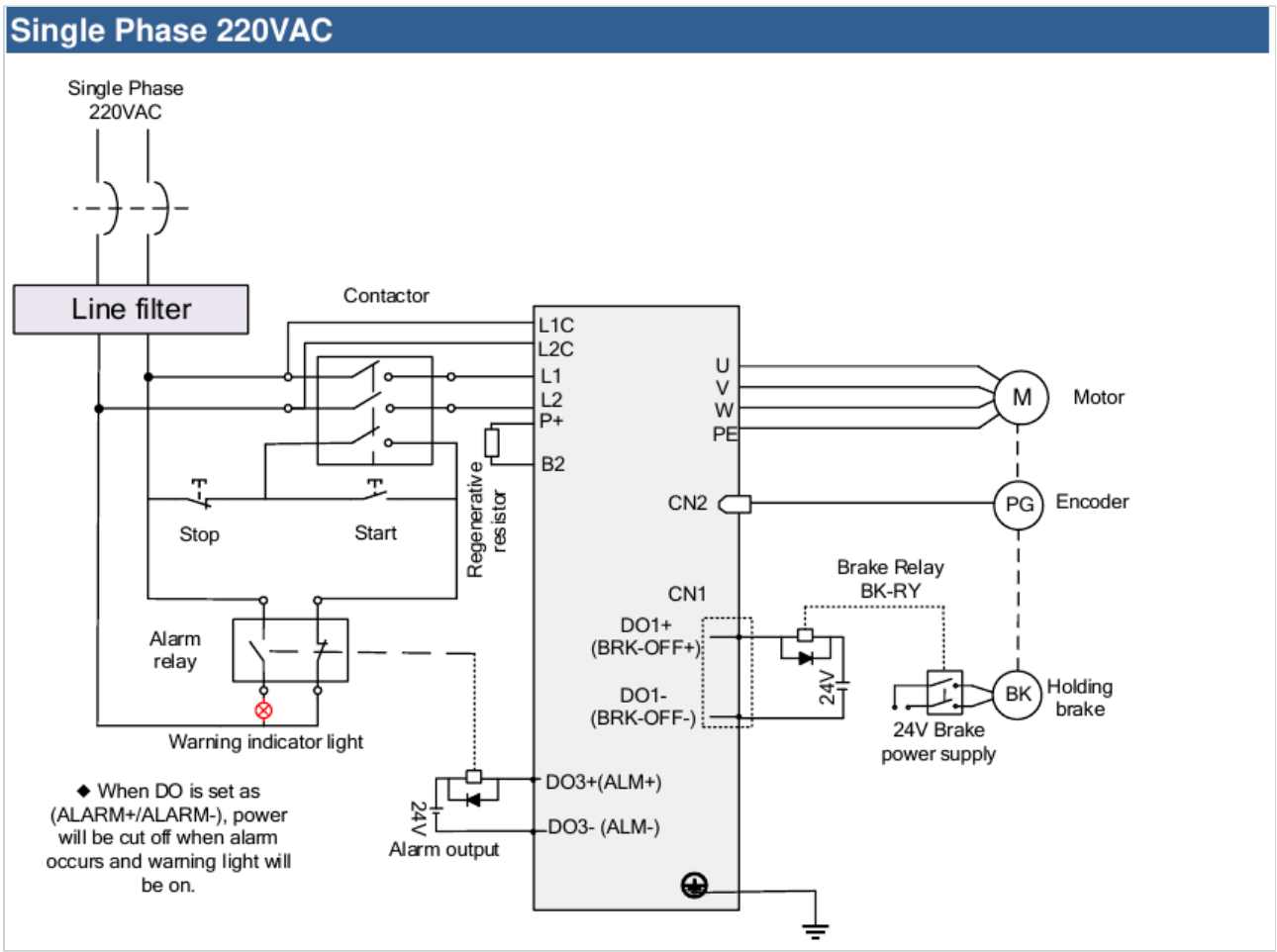



**Figure 2.** Leadshine's single-phase wiring example (manual V2.0.1, p.27). Read it in five passes, as described below.

1. **Find the supply.** Top left: "Single phase 220 VAC". Two wires leave it. Follow them right.

2. **Find the protection.** The two linked contacts with a dashed line between them are a two-pole breaker, the same idea as your Q1.
3. **Find the loads.** The wires reach the drive at L1C/L2C (control) and, through the contactor's main contacts, at L1/L2 (power). In your build the contactor is gone, so L1/L2 connect straight to the rails, the same as L1C/L2C.
4. **Trace each small loop.** The Start button (NO), Stop button (NC) and the contactor coil form one loop: press Start, the coil pulls in, its auxiliary contact holds it on. Press Stop, the loop breaks, the coil drops out. You are not building this loop.
5. **Read the right side.** U, V, W and PE go to the motor M. PG is the encoder. The brake relay BK-RY switches the brake's 24 V. This is one of the two brake options in Chapter 8.

> **TIP**
> When a drawing overwhelms you, take a highlighter and trace one loop at a time from supply to load and back. The same method works on the drawings in this book.

## Reading your own drawings

Every circuit in Part III is drawn with the same alphabet and the same colours as your real wire. Before you wire each one, read it out loud: "brown from Q1 terminal 2 to X10:1; from the L rail a brown wire to the drive's L1C...". If you can say it, you can wire it.

CHAPTER 4

# Every part on your bench

This chapter is a reference you can come back to. For each part: what it is, what it does, and why it is in this build.

| Part | What it does and why you need it |
|---|---|
| Mains lead with Schuko plug, 3×1.5 mm² | Brings 230 V from the socket into the cabinet. 1.5 mm² cores are rated for a 16 A socket circuit. The plug is also your **isolator**: pulled out, the cabinet is dead (after the drive discharges; see Chapter 12). |
| Cable gland | Clamps the mains lead where it enters the enclosure, so a tug on the cable pulls on the gland and not on the terminals. |
| Breaker Q1: ABB S202-C10 | Two-pole miniature circuit breaker, 10 A, curve C. It is your on/off lever and it trips if a cabinet wire shorts or overloads. “C” means it tolerates the short inrush when the drive’s capacitors charge, so it will not trip on switch-on. Leadshine’s manual asks for exactly this kind of device: “use a fuseless circuit breaker to turn on/off power supply to driver”. |
| 24 V supply: Mean Well HDR-60-24 | 230 V AC in, 24 V DC out, up to 2.5 A. Isolated: the 24 V side has no electrical path to the mains. It is double insulated, so its input has only L and N, no earth terminal. |
| DIN rail, 35 × 7.5 mm | The standard steel mounting rail. Breakers, supplies and terminals clip onto it. The steel rail itself is earthed through the green/yellow terminals. |
| WAGO 2002-1201 terminals (grey) | Feed-through terminals: one wire in on top, one out on the bottom, both clamped by push-in springs. Used for L and +24 V. |
| WAGO 2002-1204 terminals (blue) | Identical, blue, used for N and 0 V so you can see the return wires at a glance. |
| WAGO 2002-1207 PE terminals | Green/yellow. They clamp onto the rail and connect each earth wire to it. |
| WAGO 2002-402 / -404 bridges | Push into the centre slot of adjacent terminals to join them into a rail. One wire in feeds several outputs. A row of three bridged grey terminals is your “L rail”. |
| WAGO 2002-1291 end plates | Cover the open side of the last terminal in a group so no metal is exposed. |
| WAGO 249-116 end stops | Clamp onto the rail at both ends of a terminal group so it cannot slide. |
| Emergency-stop button, 2 NC | Red mushroom in a yellow box. Pressing it opens both contacts and latches; twist to release. Its two contacts feed the drive’s two STO channels. |
| 4-core control cable, 0.75 mm² | Connects the emergency-stop box to the cabinet terminals. |

| Part | What it does and why you need it |
|---|---|
| Wire 1.5 mm² brown and blue | Short links inside the cabinet for 230 V: breaker to terminals, terminals to the drive and the 24 V supply. |
| Wire 2.5 mm² green/yellow | Earth links. Leadshine asks for at least 2.1 mm² on PE; 2.5 mm² is the next standard size. |
| Wire 0.75 mm² red and dark blue | All the 24 V wiring: brake, STO, future I/O. |
| Ferrules | Small metal sleeves crimped onto stranded wire ends so the strands cannot splay or break in a terminal. |
| STO cable (in the drive box) | Leadshine supplies a cable for CN6 with flying leads, plus a shorting plug that is fitted at the factory. |
| Encoder battery box | Keeps the motor’s multi-turn position memory alive while the drive is off. Leadshine ships it on the drive or on the encoder cable. |

> **TIP**
> Lay every part out on the table and tick it off against this list before you start. Anything you cannot identify, label “unknown” with tape rather than guessing.

CHAPTER 5

# The drive and the motor

The drive has many connectors, but you only wire six of them. Each one has a single job.

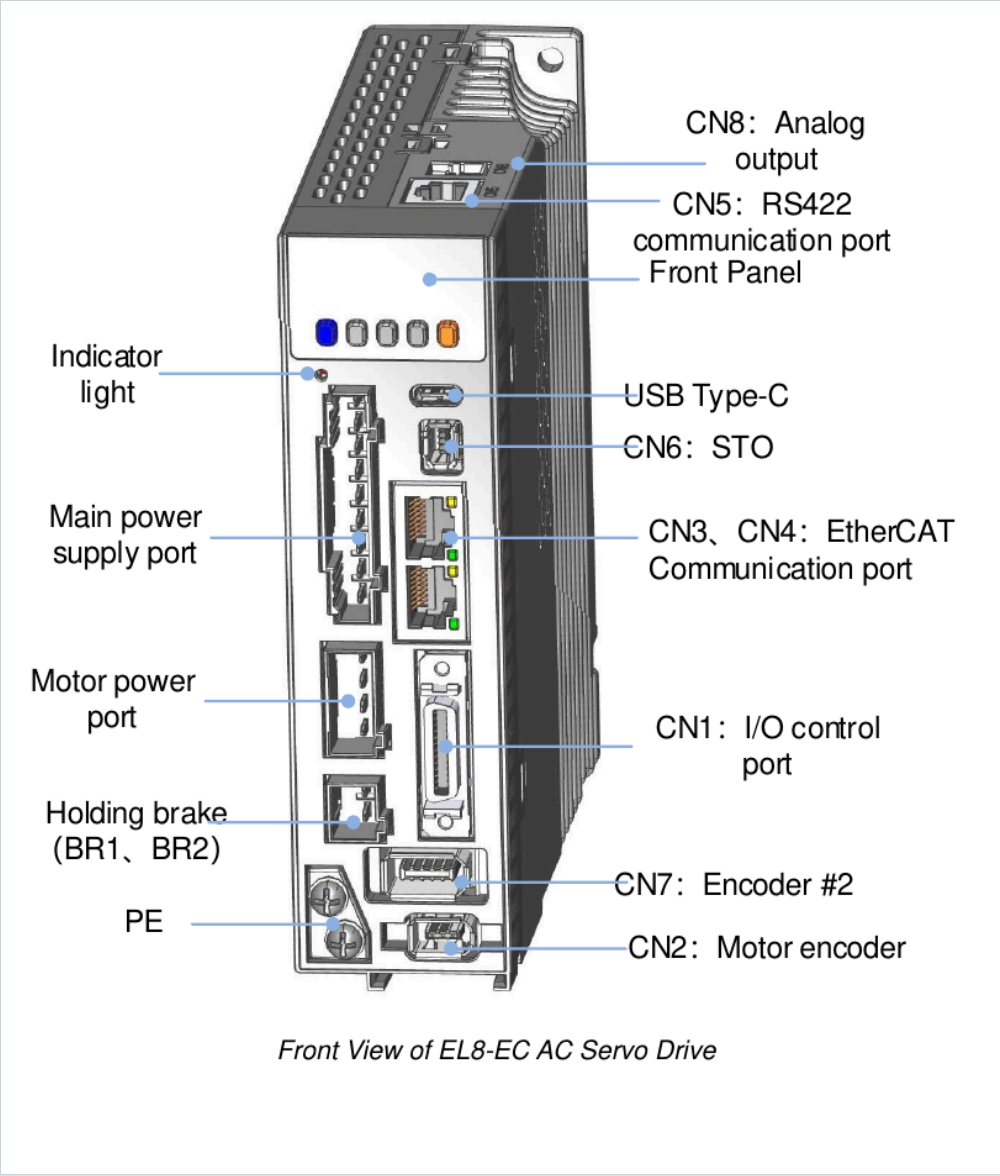



**Figure 3.** The EL8-EC drive's connectors (manual p.16). The large green plug connectors at the bottom carry power; the small ones at the top carry signals.

## The connectors you use

| Connector | Name | What goes there |
|---|---|---|
| **X1** | Mains input | `L1C`, `L2C`: 230 V for the control electronics (display, CPU, EtherCAT). `L1`, `L2`: 230 V for the power stage that drives the motor. `L3`: only for three-phase supply, leave empty. |
| **X1** (other pins) | DC bus, regen resistor | `P+`, `B1`, `B2`: B1 and B2 are bridged at the factory to use the internal braking resistor. Leave them. `N`: the internal DC bus negative. **Never connect anything here.** |
| **X2** | Motor output | `U`, `V`, `W`, `PE` from the motor power cable. Never mains. |
| **X3** | Brake output | `BR+`, `BR-`: the drive's built-in switch for the motor brake. See Chapter 10. |
| **CN2** | Encoder | The motor's encoder cable, including the battery box lines. |
| **CN3 / CN4** | EtherCAT in / out | Ethernet cable from the computer into CN3. CN4 goes on to the next drive if you add one. |
| **CN6** | STO | The emergency stop. Chapter 7. |
| USB | Service port | For the Leadshine setup software. Already working on your desk. |

> **THE TRAP ON X1**
> The letter N on X1 is not mains neutral. It is the minus side of the drive's internal 300 V DC bus. Putting a mains wire on it will destroy the drive and can injure you. Mains neutral goes to `L2` and `L2C`.

## Why two pairs of mains inputs?

L1C/L2C keep the brain alive; L1/L2 feed the muscle. Professional machines use this to cut the muscle with a contactor while the brain stays on and keeps reporting errors and position. You have no contactor, so both pairs are fed from the same rails and switch on together with Q1. That is a normal, supported arrangement: the manual simply requires both to be connected.

## The motor

Your ELM1H-1000MA80E contains three things in one housing:

- **Windings** (U, V, W): three coils the drive energises in sequence to make torque. 1 kW rated, 3000 rpm.
- **Encoder**: the `M` in the part number means a 23-bit magnetic **multi-turn absolute** encoder. It knows the shaft angle to one part in 8 million, and counts whole turns.
- **Holding brake**: a spring-applied brake that clamps the shaft when it has *no* power. 24 V DC ±10 %, 11.5 W, at least 3.2 N·m holding torque. Give it 24 V and it releases.

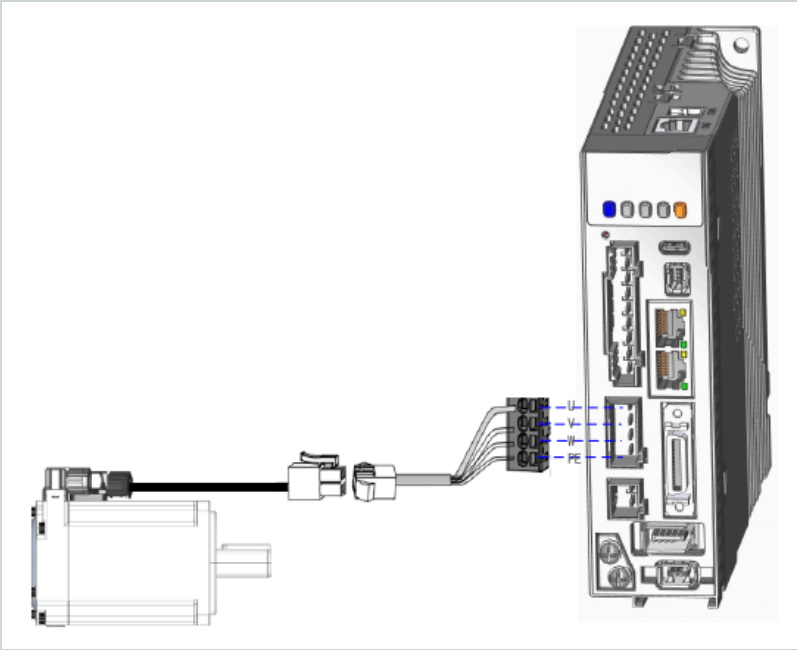



**Figure 4.** Motor power cable pinout (manual p.28). On your braked cable, the brake wires are A = 0 V (black) and B = 24 V (red). Match by printed labels, not by colour alone.

## The encoder battery

An absolute encoder must remember how many turns the shaft made while the drive was off. A small battery does that. Leadshine ships the battery box either on the drive or as a small module on the encoder cable, which is very likely the small white tail on your cable. You do not need to buy one.

When you first power up in multi-turn mode the drive may show `Er153` (multi-turn data lost). That is expected: set parameter `P00.15` to clear it (manual §6.16.4). If the battery later drops below 3.0 V, the drive warns with `ArA03`; change the battery with the drive powered on and the axis disabled so the position is kept.

CHAPTER 6

# The DIN rail and terminal rows

Terminals turn a tangle into a tidy, labelled, testable system. Every wire in the cabinet starts or ends on one.

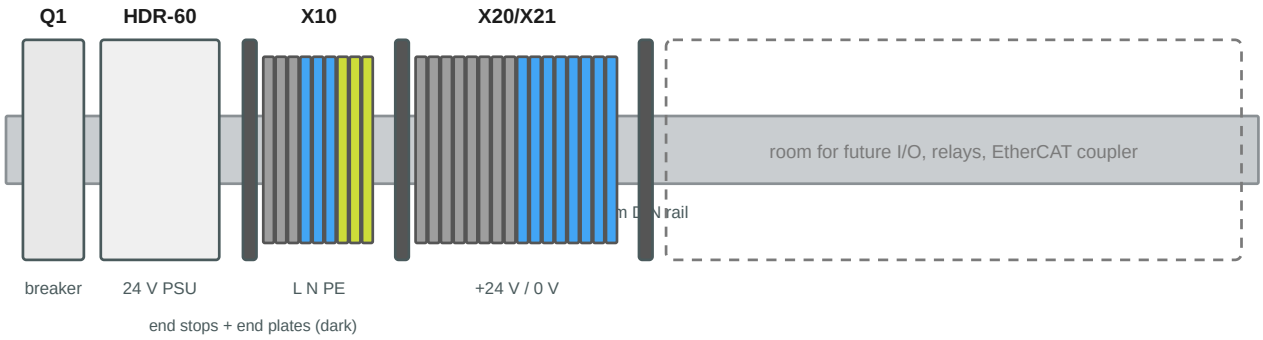



**Figure 5.** One way to arrange the DIN rail, seen from the front. 230 V on the left, 24 V in the middle, spare space on the right. Grey terminals carry L or +24 V, blue carry N or 0 V, green/yellow carry earth.

## Why terminals instead of wire to wire?

- **One wire per clamp.** The drive's connector and the power supply accept one wire per terminal. Terminals with bridges let one incoming wire feed three loads.
- **Testable.** Every terminal is a test point for your multimeter.
- **Changeable.** Adding a contactor or filter later means moving one wire, not rebuilding.

## The rows in this build

| Row | Terminals | Carries |
|---|---|---|
| **X10** | 3 grey (L), 3 blue (N), 3 PE | 230 V distribution after Q1. Bridge the three grey ones with a 2002-402 + one more bridge (or a 2002-404), and the same for the blue ones. |
| **X20** | 4–8 grey, bridged | +24 V distribution |
| **X21** | 4–8 blue, bridged | 0 V distribution |
| **X22** | 3 grey, not bridged | Signals: SF1, SF2, spare |

## How a push-in terminal works

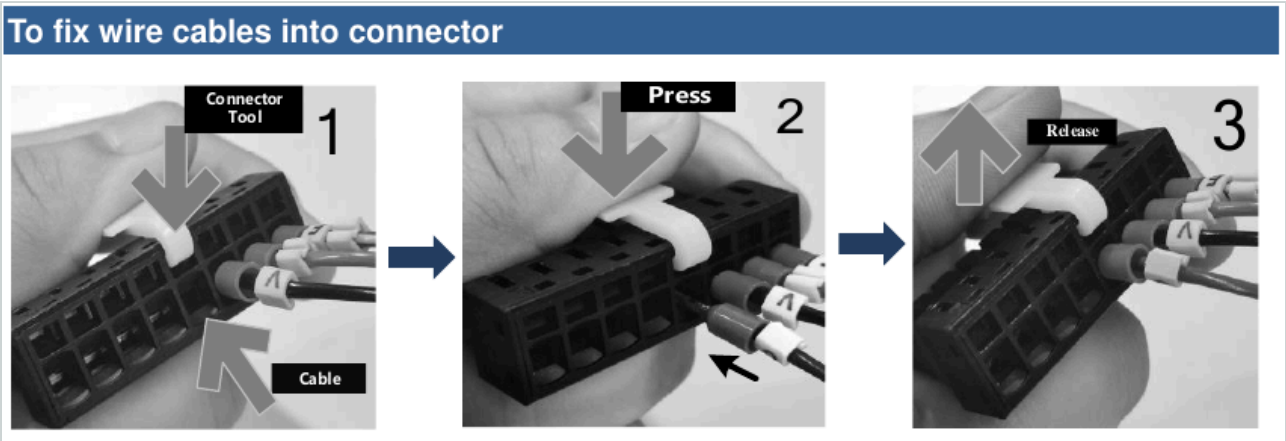



**Figure 6.** Leadshine's connectors use the same principle (manual p.26): press the release, insert the ferruled wire fully, let go, tug to check.

1. Strip the wire to the length printed on the terminal (WAGO 2002: 10–12 mm).
2. Crimp a ferrule of the matching size. The ferrule should cover all the copper.
3. Push the wire straight in. With a ferrule, 1.5 mm² and thicker usually goes in without opening the clamp; for thin wire, press the orange release with a small flat screwdriver first.
4. Tug firmly. A wire that comes out was not clamped.

> **TIP**
> Label both ends of every wire with the terminal it goes to, before you install it. "X10:1 → Q1:2" on one end, the reverse on the other. Your cable labels and the Edding are for exactly this.

CHAPTER 7

# The 230 V circuit

This is the whole mains side. Plug, breaker, two rails, three loads, and an earth to everything metal.

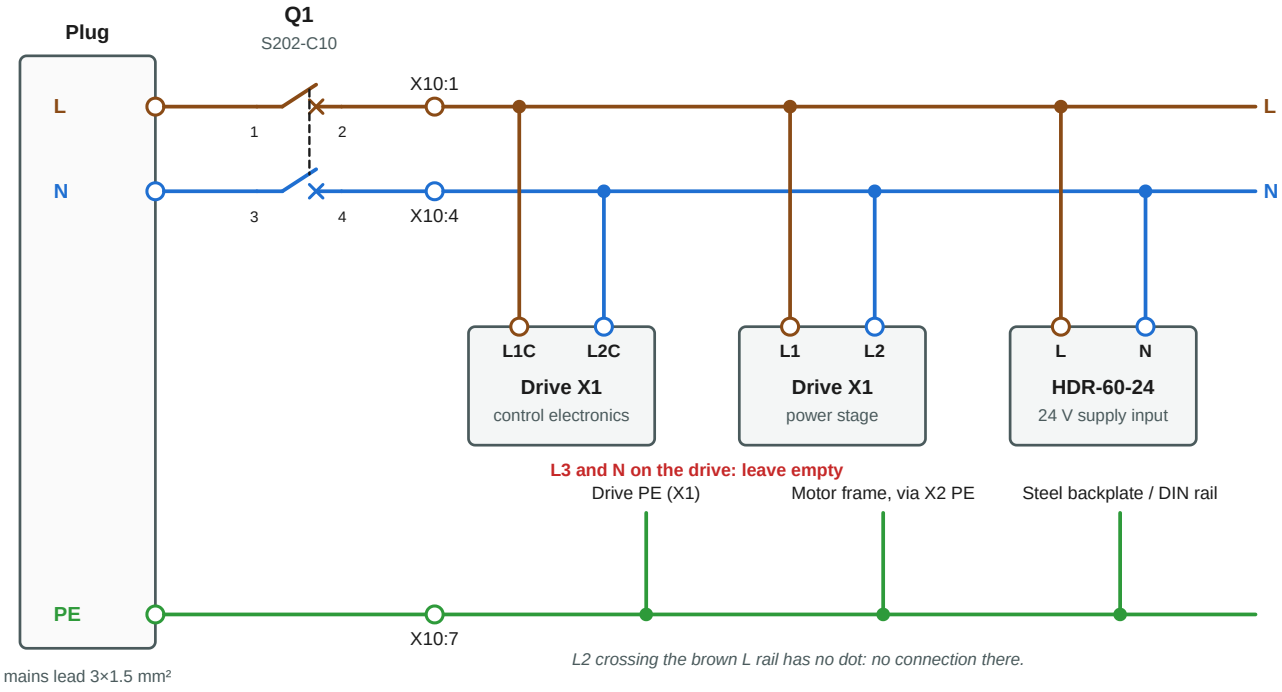



**Figure 7.** The complete 230 V circuit. Read it left to right: the plug, the two-pole breaker Q1, the terminal row X10, then three loads that all hang between the brown L rail and the blue N rail. Earth (green) runs separately along the bottom to every metal part.

## Read it out loud

1. The mains lead's **brown** core goes to Q1 terminal 1, the **blue** core to Q1 terminal 3. The **green/yellow** core goes straight to the PE terminal X10:7. Earth never passes through the breaker.
2. From Q1 terminal 2, a brown 1.5 mm² wire to X10:1. From Q1 terminal 4, a blue wire to X10:4.
3. X10:1–3 are bridged: that is the **L rail**. X10:4–6 are bridged: the **N rail**.
4. From the L rail: one brown wire each to drive `L1C`, drive `L1`, and the supply's `L`.
5. From the N rail: one blue wire each to drive `L2C`, drive `L2`, and the supply's `N`.
6. From the PE terminals: a 2.5 mm² green/yellow wire to the drive's PE screw. The motor frame is earthed through the motor cable's PE core into X2. The rail is earthed by the PE terminals clamping onto it.

## Why this is safe enough for a first build

Q1 protects every wire after it: the 1.5 mm² wires are rated well above 10 A. Your house circuit breaker and RCD protect the mains lead and give fault protection. The drive's nameplate input current is 8.8 A at full load; a single 1 kW axis on a bench draws far less, so a 10 A curve C breaker will not nuisance-trip.

> **TOUCH PROTECTION**
>
> Every 230 V terminal must be covered when the plug is in: the drive's X1 plug, the breaker and the WAGO terminals are finger-safe on their own, but a bare wire end or a missing end plate is not. Mount everything on a backplate inside an enclosure before the first power-up.

## What a line filter and contactor would add

A **line filter** would sit between X10 and the drive, soaking up the electrical noise the drive creates so it does not upset other equipment on the same circuit. Add one if a nearby device misbehaves when the servo runs. A **contactor** would sit in the L1/L2 wires so a Start/Stop circuit or a safety relay can cut the power stage. Both slot into the wires you already have.

CHAPTER 8

# The 24 V circuit

The low-voltage side. One supply, two rails, and everything a person interacts with.

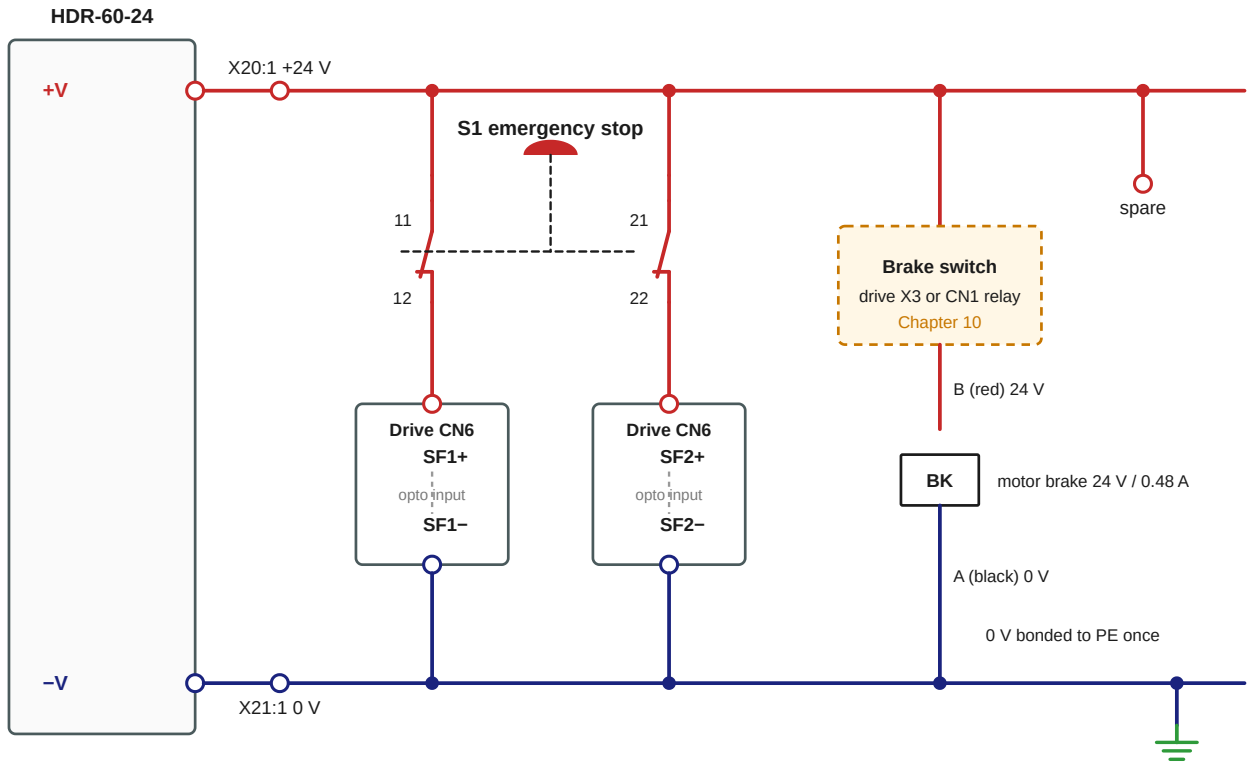



**Figure 8.** The 24 V circuit. Red is +24 V, dark blue is 0 V. The emergency stop S1 has two NC contacts (11–12 and 21–22) that move together; each one carries 24 V to one STO channel. The amber box is the one part whose exact wiring we confirm with Leadshine.

## Read it out loud

1. Supply `+V` to X20:1 with red 0.75 mm². Supply `-V` to X21:1 with dark blue 0.75 mm². Bridge X20 into the **+24 V rail** and X21 into the **0 V rail**.
2. From X21, one green/yellow wire to a PE terminal: this **bonds 0 V to earth at one point**. It means a fault from 230 V into the 24 V wiring trips a breaker instead of leaving the “safe” side live. It is standard practice in machine wiring (EN 60204-1).
3. From the +24 V rail: the emergency-stop feed and the brake feed.
4. From the 0 V rail: the STO channel returns and the brake 0 V.

## Is 60 W enough?

| Load | Current |
|---|---|
| Motor brake | 0.48 A |
| STO inputs (two channels) | about 0.02 A |
| Spare for I/O, relays, a lamp | about 1.5 A |
| **Supply rating** | **2.5 A** |

Plenty. The supply also has a small potentiometer marked `+V ADJ`. Leave it alone, or set it to exactly 24.0 V with your multimeter; the brake needs 24 V ±10 %.

CHAPTER 9

# The emergency stop and STO

STO, Safe Torque Off, is a hardware input on the drive that cuts the motor’s power transistors directly, independent of the drive’s software and of your computer. Your emergency-stop button opens it.

## What STO does, and does not do

- It **does** stop the drive from producing torque, in hardware, within milliseconds.
- It does **not** brake the motor. The shaft coasts to a stop.
- It does **not** disconnect mains. The drive stays powered and the DC bus stays charged. Never work on wiring with the E-stop pressed and the plug in.

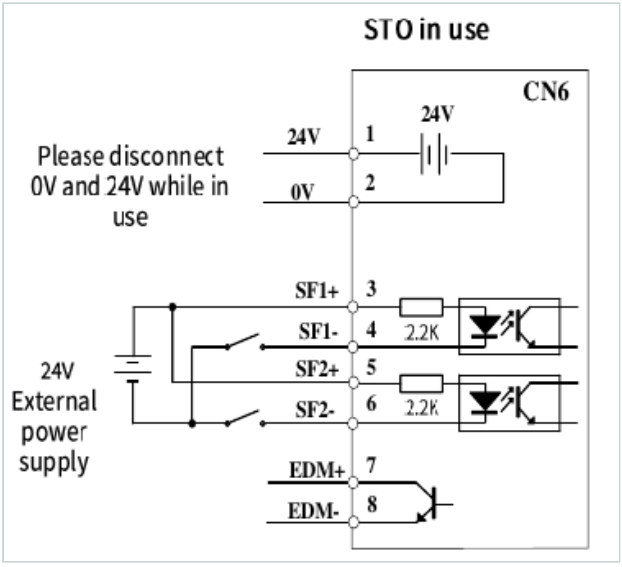



**Figure 9.** Leadshine’s STO wiring when the function is used (manual p.39): the shorting plug is removed, and SF1 and SF2 are fed from an external 24 V supply through the safety contacts.

## How it works

CN6 has two independent input channels, SF1 and SF2. Each is an optocoupler: a small LED that only lights when 24 V is applied in the right direction. Both channels must be powered for the drive to run. The table in the manual (p.38):

| SF1 | SF2 | Drive | Display |
|---|---|---|---|
| 24 V | 24 V | can run | — |
| 24 V | off | torque off | Er 1c2 |

| SF1 | SF2 | Drive | Display |
|---|---|---|---|
| off | 24 V | torque off | Er 1c1 |
| off | off | torque off | Er 1c0 |

From the factory a **shorting plug** sits in CN6. It links the drive's own 24 V (pins 1–2) to both channels, so the drive runs without an emergency stop. You replace that plug with the supplied STO cable.

## Wiring it

Figure 8 in Chapter 8 shows the circuit: the +24 V rail feeds contact `11` and contact `21` of the button. Contact `12` goes to `SF1+`, contact `22` to `SF2+`. `SF1-` and `SF2-` go to the 0 V rail. Leave pins 1 and 2 (the drive's internal 24 V) unconnected: the manual says "do not use to supply power".

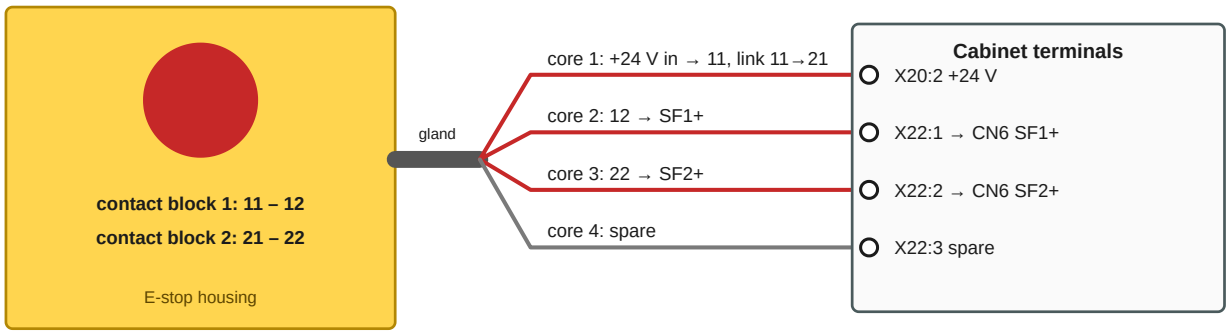



**Figure 10.** The same emergency stop as it looks on your bench: one yellow box, one 4-core cable, four terminals in the cabinet. Core numbers are printed on the cable insulation.

## The one inconsistency, and why it is harmless

The manual's table numbers pin 3 as SF1− and pin 4 as SF1+. Its drawing on p.39 shows them the other way round. You do not need to know which is right, because the inputs **fail safe**: an optocoupler wired backwards simply never lights, so the drive shows `Er 1c0` and refuses to run. Wire it by the labels on the supplied STO cable, then let the test in Chapter 12 tell you whether it is right. If it is backwards, swap the two wires of each channel.

> **TIP**
>
> Why two channels? If one wire breaks or one contact welds shut, the other channel still stops the drive. Keep the two channels on separate contacts all the way to the drive; never join SF1+ and SF2+ together after the button.

> **STO LETS THE SHAFT GO**
>
> If anything on your swivel can move under gravity or spring load, STO alone lets it fall: torque is off, the brake must hold it. Wire the brake (next chapter) before you load the axis.

CHAPTER 10

# The holding brake

The brake holds the shaft whenever the motor is not actively holding it: drive off, drive in alarm, emergency stop pressed. The drive must decide when to release it, so the brake is switched by the drive, not fed from 24 V permanently.

## Two ways the drive can switch the brake

| Option | How | Parts |
|---|---|---|
| **1. X3 direct** (preferred) | The drive has a built-in brake switch on X3 (BR+, BR−). External 24 V goes in, the drive switches it to the brake. | Nothing extra. |
| **2. CN1 output + relay** | A digital output on CN1 (DO1, set to BRK-OFF) drives a small 24 V relay; the relay contact switches 24 V to the brake. | One 24 V relay with a socket and suppression diode. |

The manual (p.30) says the EL8 “supports direct drive holding brake… There is no need for an external relay”. That is option 1. The only open point: the text and drawing do not agree on exactly which X3 terminal takes the external +24 V and which goes to the brake. We will ask Leadshine for the X3 drawing for your exact unit before wiring it. Until then, leave the brake unconnected: it is **applied** when unpowered, so the shaft stays locked and the drive simply refuses to turn it, which is safe.

> **NOTE**
>
> Why not just connect the brake to the 24 V rail? Then it is released whenever the cabinet is on, including during an emergency stop or an alarm. With STO active the motor makes no torque and the brake does not hold: the axis is free. The drive switching the brake closes that gap.

## Brake timing

The brake releases within 40 ms and engages within 60 ms. The drive accounts for that with brake delay parameters; the defaults suit most axes. You will check them during commissioning, not now.

CHAPTER 11

# The motor and encoder cables

These are pre-made cables. You plug them in, but you check them first.

## The motor power cable

One end has the motor plug; the other has four power cores (U, V, W, PE) plus two brake cores (A 0 V black, B 24 V red). The power cores go into the drive's X2 plug by their printed labels: U → U, V → V, W → W, PE → PE. The order matters: a swapped phase makes the motor jerk or run away.

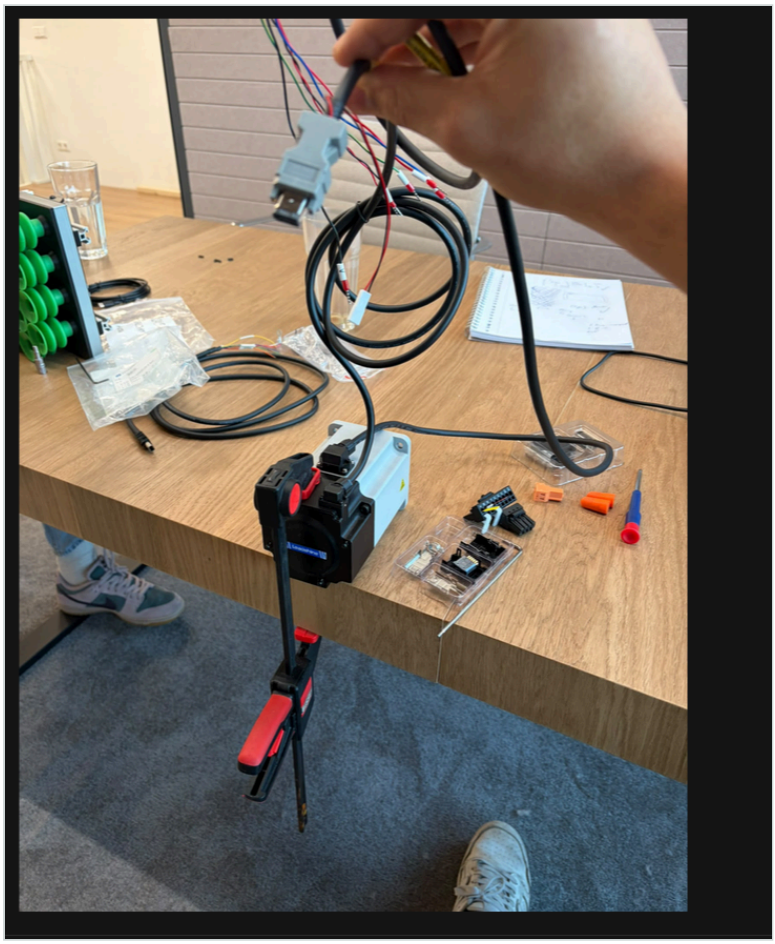


**Figure 11.** Your motor with both cable plugs fitted. Power and brake on one plug, encoder on the other.

## The encoder cable

A plug at each end: one at the motor, one at the drive's CN2. The battery lines (BAT+, BAT−) run through it to the battery box. It carries tiny signals, so route it away from the motor power cable where you can and do not coil the excess tightly around power wires.

## Before you plug in

- Check that every core’s label matches the drive terminal you are putting it in.
- Check that no strands stick out of the X2 connector.
- Fix the motor down. A 1 kW servo’s first move can be violent if a parameter is wrong; a motor lying loose on a table will jump. A clamp is not enough: bolt it to a plate.

CHAPTER 12

# Building it, step by step

Do these in order. Each step ends with a check you can do with your eyes or a multimeter. Nothing is plugged into the wall until step 9.

1. **Inventory.** Lay out every part from Chapter 4. Find the STO cable and the shorting plug in the drive box, and identify the battery box on the encoder cable. *Check:* everything ticked off.
2. **Mount the rail.** Screw the DIN rail to the backplate. Leave room above and below the drive for airflow (the manual asks for clearance around the heatsink). *Check:* rail does not flex.
3. **Clip on the parts** left to right: Q1, the HDR-60, then terminals X10 (3 grey, 3 blue, 3 PE), end plate, end stop, X20 (grey), X21 (blue), X22, end plate, end stop. *Check:* matches Figure 5.
4. **Insert bridges** into X10 L, X10 N, X20 and X21. *Check:* with the multimeter on continuity, every terminal in a bridged group beeps to every other; no beep between groups.
5. **Wire the earth first.** Mains lead PE → X10:7; X10:8 → drive PE screw; 0 V bond X21 → X10:9. *Check:* continuity from the plug's earth pin to the drive's metal case and to the rail.
6. **Wire the 230 V side** as in Chapter 7. *Check:* plug still out. Q1 off: no continuity from plug L or N pins to X10. Q1 on: plug L/N pins each beep through to one rail. No continuity between L and N rails or from either rail to PE.
7. **Wire the 24 V side** as in Chapter 8, including the emergency stop and the STO cable. Brake left disconnected for now. *Check:* no continuity between +24 V and 0 V rails. With the button released, +24 V beeps to SF1+ and SF2+; pressed, no beep.
8. **Connect the motor cables.** Motor bolted down, shaft free and nothing attached to it. *Check:* labels match terminals.
9. **Close up and first power-on.** All covers on. Emergency stop pressed. Plug in, flip Q1 on. *Check:* the drive display lights and shows an STO alarm (Er 1c0). The HDR-60's green LED is on. Measure 24 V between X20 and X21.
10. **Test the emergency stop.** Twist the button to release. *Check:* the STO alarm clears (or can be reset). Press it again: `Er 1c0` returns. If the alarm never clears, swap SF1+/SF1− and SF2+/SF2− (Chapter 9) with the plug out.
11. **Test each channel.** Plug out. Disconnect one core of channel 2 at X22. Plug in, release the button. *Check:* `Er 1c2`. Restore it, repeat with channel 1: `Er 1c1`. This proves both channels work independently.
12. **Brake.** Once Leadshine has confirmed the X3 terminal order, wire it with the plug out. Enable the drive from the software. *Check:* you hear the brake click on enable and again on disable or E-stop.

13. **First move.** In the Leadshine software, jog at low speed. *Check:* smooth rotation in the expected direction; pressing the E-stop stops torque immediately.

> **BEFORE EVERY WIRING CHANGE**
>
> After unplugging, the drive’s DC bus stays charged for several minutes. Wait until the display and the charge LED are completely dark, then wait as long again, before touching X1 or X2.

CHAPTER 13

# When something does not work

| What you see | Most likely cause | What to do |
|---|---|---|
| Q1 trips at switch-on | Short between L and N or to PE | Plug out; repeat the continuity checks in step 6. |
| Drive display dark | L1C/L2C not powered | Measure 230 V across L1C–L2C (qualified person, or check wiring with plug out). |
| `Er 1c0` never clears | STO polarity reversed, or 24 V not reaching CN6 | Check 24 V at SF1+/SF2+ against 0 V; swap + and − if the voltage is there. |
| `Er 1c1` or `Er 1c2` | One STO channel open | Find the loose core or contact on that channel. |
| `Er153` on first power-up | Multi-turn data lost (normal on first install) | Clear with P00.15 (manual §6.16.4). |
| `ArA03` | Encoder battery below 3.0 V | Replace the battery with the drive powered and the axis disabled. |
| Motor will not turn, hums | Brake not released | Check the brake wiring and that 24 V reaches it on enable. |
| Motor jerks or runs away | U/V/W swapped or wrong parameters | E-stop. Plug out. Check X2 labels. |
| HDR-60 LED off | No 230 V at its L/N, or a 24 V short | Disconnect the 24 V loads one at a time. |

APPENDIX A

# Shopping list

## Already in your baskets (16 November 2026, nothing ordered)

| Where | Item | Price |
|---|---|---|
| Amazon | Mean Well HDR-60-24 supply | €26.40 |
| Amazon | ABB S202-C10 two-pole breaker | €19.19 |
| Amazon | Schneider LC1D09BD contactor: **remove**, not needed | (€57.62) |
| Amazon | Tools: Jokari stripper, Knipex ferrule crimper, Wera VDE screwdrivers, Knipex cable cutter | €207.15 |
| Amazon | Safety glasses, cable labels, Edding 400, tape measure | €22.77 |
| Elektramat | WAGO 2002 terminals, bridges, end plates, end stops; two 202 mm DIN rails | €59.48 |

## Still to add

| Item | Why |
|---|---|
| Emergency-stop button, 2 NC, in yellow housing with gland | Chapter 9 |
| 4-core control cable 0.75 mm², about 3 m | E-stop box to cabinet |
| Mains lead with Schuko plug, 3×1.5 mm², open end | Chapter 7 |
| H07V-K 1.5 mm² brown and blue, about 5 m each | Internal 230 V wiring |
| H07V-K 2.5 mm² green/yellow, about 5 m | Earth wiring |
| H05V-K 0.75 mm² red and dark blue, about 10 m each | 24 V wiring |
| Ferrule assortment 0.5–2.5 mm² | Every stranded wire end |
| Enclosure with backplate, and a cable gland for the mains lead | Touch protection; size it after laying out the parts |

## Later, if you need them

| Item | Add it when |
|---|---|
| Line filter | Other equipment glitches when the servo runs, or you add more drives. |
| Contactor + Start/Stop buttons | You want the power stage off while the electronics stay on, or a restart-protected start. |
| Safety relay (e.g. Pilz PNOZ) | You add more axes, guards or a second E-stop, or the machine is used by others. |

| Item | Add it when |
| --- | --- |
| 24 V relay for the brake | Leadshine advises against X3 direct switching for your unit. |

APPENDIX B

# Glossary

| Term | Meaning |
|---|---|
| **Absolute encoder** | Knows the shaft position at power-on without homing. Multi-turn versions need a battery to count turns while off. |
| **Bridge (jumper)** | A comb that joins adjacent terminals into one electrical point. |
| **Breaker (MCB)** | Miniature circuit breaker: a resettable switch that trips on overcurrent. |
| **Contactor** | A heavy-duty relay that switches mains power from a small control signal. |
| **Curve C** | Breaker trip characteristic tolerant of 5–10× short inrush currents. |
| **DC bus** | The drive's internal ~320 V DC store, made from rectified mains. Stays charged after unplugging. |
| **DIN rail** | Standard 35 mm steel mounting rail. DIN is the German standards body. |
| **EDM** | External device monitoring: an STO output that confirms both channels are off. |
| **EtherCAT** | Industrial Ethernet protocol the computer uses to command the drive. |
| **Ferrule** | Metal sleeve crimped onto a stranded wire end. |
| **Isolated supply** | A supply whose output has no electrical connection to its input. |
| **NC / NO** | Normally closed / normally open: the contact state at rest. |
| **Optocoupler** | An LED and a light sensor in one chip, passing a signal without an electrical connection. |
| **PE** | Protective earth. |
| **RCD** | Residual current device (aardlekschakelaar): trips if current leaks to earth. In your house panel. |
| **Regenerative resistor** | Turns energy returned by a braking motor into heat. Internal on your drive. |
| **STO** | Safe Torque Off: hardware input that removes motor torque. |
| **Servo** | A motor controlled in a closed loop using position feedback. |

APPENDIX C

# Sources


- Leadshine EL8-EC***F user manual V2.0.1: X1 p.25, wire sizes p.26, X3 brake pp.30–32, encoder cable p.36, STO pp.38–39, battery §6.16.4. https://www.soprolec.com/web/image/38604?unique=46b2b42148357bbfbe0acc336b3e31c349238101
- Leadshine ELM1H-1000MA80E motor drawing. https://www.leadshine.com/upfiles/downloads/39b9fc0652701ea50d547c48d6c9ae51_1776050402120.pdf
- Mean Well HDR-60 datasheet. https://www.meanwell.com/Upload/PDF/HDR-60/HDR-60-SPEC.PDF
- Marco Reps, “LinuxCNC EtherCAT for reals this time – New Control Cabinet and Leadshine Servos”. youtube.com/watch?v=H1JEY2btwKk
- WAGO 2002 series terminals. wago.com