

Build a Better Panel

Control panel tips and tricks from the people who see hundreds of panels a year: how to plan, select, lay out, and wire a panel that is easier to build, easier to service, and passes inspection the first time.

WHAT'S INSIDE

- The five complaints we hear from every panel builder, and what causes them
- A seven-step design sequence that starts with the machine, not the catalog
- A supplier scorecard for choosing best-in-class products by category
- Enclosure sizing, wire duct fill, and voltage separation rules of thumb
- Wiring habits that separate a good panel from a great one

WHO IT'S FOR

- Panel shop leads and wiring technicians
- Controls engineers at OEMs and machine builders
- Anyone who has opened a panel and thought "there has to be a better way"

What we hear from panel builders

The same five themes come up in almost every shop visit. None of them are about a lack of skill. They are about decisions that got made too late, usually after the enclosure was already ordered.

"We need to service and expand this later."

Panels live for decades and get modified by people who never saw the original drawings. Serviceability is a design input, not a finishing touch.

"The wire duct is always too small."

Duct gets sized to the first revision of the drawing. Every change order adds conductors and nobody adds duct.

"Customers want a smaller footprint."

Floor space is expensive, so the enclosure shrinks. The wiring, spacing, and heat inside do not shrink with it.

"Components are spaced too closely."

Creepage, clearance, and thermal derating are real. A tight layout that fits on the drawing may not be legal or cool enough in the box.

"Space for building and servicing is an afterthought."

Nobody drew the technician's hands, the screwdriver, or the ferrule crimper into the layout.

"How do we do this with fewer wires?"

Bridged terminals, plug-in relays, multi-conductor cable, and networked I/O all reduce point-to-point wiring, if they are chosen at design time.

How we approach it

Product selection. The right part in the right package size. Modern components are smaller, cooler, and easier to wire than what many drawings still specify.

Product procurement. Can you actually get it, on the date you need it, in the quantity you need? A great part with a 30-week lead time is not a great part.

Technology and integration. New technology should save hours, not create them. If a product needs a week of setup software to save a day of wiring, it is not helping.

Building an excellent control panel doesn't happen by chance. It is detailed work, and the panel will be in service, and worked on by people from other firms, for decades.

Start with the purpose, then work backwards

The best panels are designed from the process outward. Decide what the machine must do, find the sensors that tell you it is doing it, add the controls that make it happen, and only then size the power. Catalogs come last.

1 Define what the machine must do.

Write down every motion, every process step, every operator interaction. This list is the foundation for the schematic, the layout, and the PLC program.

2 Start with the sensors.

What has to be measured or detected for each function? Sensor choice drives signal type, cable type, and I/O count.

3 Add the controls that act on those signals.

Relays, safety devices, drives, controllers. The simplest control scheme with the fewest components is usually the best one.

4 Now calculate the power.

Sum the loads, add margin, and specify the power circuit: supply voltage, disconnect, protection, transformers, and power supplies.

5 Draw the concept as one line drawing.

Show the relationship of sensor, control, and power for the whole machine before drawing a single terminal.

6 Break it into functions.

Define one control process at a time and give each its own schematic sheet. Functions that are easy to read are easy to build, test, and troubleshoot.

7 Perfect each circuit.

Walk each sheet and confirm it has everything it needs to work properly and safely, including protection, grounding, and the failure mode when power is lost.

One protective device per device. Give the PLC, the signal conditioner, and the transducer their own supplementary protection instead of hanging all three on one breaker. It costs a few dollars. In return you can isolate any single device for testing, troubleshooting, or replacement without taking the machine down.

Draw the home position. Show every actuator in its de-energized state on the concept drawing. It exposes missing home sensors and missing end-of-travel limits before they become field problems.

Separate operator controls from maintenance controls. Over-populated operator interfaces are confusing and, for operators, intimidating. Give maintenance and setup their own place.

Select products with the physical layout in mind. Technology, expansion, wiring, and spacing are all layout questions. A component that is electrically perfect but needs 40 mm of clearance on each side may not be the right part for a panel that has to be 600 mm wide.

Choose products by category, not by catalog

The easiest path is to sole-source everything from one manufacturer because they offer it. The better path is to pick the best-in-class product for each category, from a supplier who has earned it. Here is what to look at.

CRITERION	WHAT TO ASK	WHY IT MATTERS IN A PANEL
Years in the product	How long have they made this specific product line? What is their expertise?	Mature product lines have fewer surprises in certifications and documentation.
Production capability	Are they actually the manufacturer, or a re-labeler?	Affects quality control, traceability, and what happens when something fails.
Certifications	UL, cULus, TÜV, CE, RoHS. Is the certification for the exact part number and the way you intend to use it?	A Listed panel is only as certified as its least certified component.
Customer service	Do they answer the phone? Do they have local application people?	You will need help at 4 p.m. on a Friday before a ship date.
Delivery and commitments	What is their track record on promised dates?	A panel waits for its slowest component.
Reliability	Do they have references in your industry?	Field failures cost more than any component price difference.
Global supply chain	Can you get it anywhere? Do they have distributors?	Your customer's plant in another state or country will need spares.
Culture and ethics	How willing are they to work with you? Do they follow the rules?	Social compliance and ethical behavior are part of your customer's supplier audits now, too.

Your best suppliers are proactive. They keep improving product quality and service without being asked, and they tell you about changes before the change hits your BOM.

Your local rep is part of the team. A good rep sees hundreds of panels a year and knows the latest packaging, total cost of ownership, and which products actually save time. Use that.

Where new technology pays off fastest

Push-in and bridged terminals
Faster terminations, fewer loose screws, and factory-made jumpers instead of hand-formed bridges.

Compact power and protection
Narrow power supplies, electronic circuit protection, and combination motor controllers free up rail and reduce heat.

Networked I/O and connectors
Distributed I/O and pre-made cordsets take point-to-point wiring out of the enclosure entirely.

Enclosure and layout: bigger is better, properly sized is best

Most layout problems trace back to an enclosure chosen before the layout existed. Size the box to the wiring and the service access, not just to the components.

Sizing the enclosure

- ☐ Leave enough space around each DIN rail that mounted components keep their creepage and clearance distances and the manufacturer's thermal spacing.
- ☐ Reserve room to separate field wiring from internal wiring, so the installer never has to route through your work.
- ☐ Reserve room to separate power wiring from control wiring.
- ☐ Leave spare rail and spare duct capacity for future expansion. The customer will ask for it; the enclosure will not get bigger.
- ☐ Estimate the heat load early. Drives, power supplies, and transformers set the internal temperature, and every component has a maximum ambient.

Wire duct

- ☐ Size duct to the cable bending diameters, shapes, and quantities you will actually pull. Cables do not lay flat.
- ☐ Keep conductor fill in the 30% to 50% range. Fill is a heat question as much as a space question: current-carrying conductors bundled tightly need their ampacity adjusted.
- ☐ Conductors between a motor and its starter used only for starting duty, and signal conductors, are not counted as current-carrying for that adjustment.
- ☐ For cable tray, the NEC caps control and signal cables at 50% of the tray's cross-section; treat that as the ceiling for duct, too.

Penetrations and zones

- ☐ Decide where power cables enter and leave the enclosure before the layout is frozen.
- ☐ Keep separation between penetrations so power, control, and signal cables do not enter at the same point.
- ☐ Lay the panel out in voltage sections. Power on one side or at the bottom, control in the middle, signal and network away from both.

Voltage separation

KEEP APART	WHY
Different AC voltage levels	Insulation ratings and spacing rules change with voltage
AC from DC	Prevents induced noise on DC control and signal circuits
Power from 24 VDC control	Protects Class 2 circuits and keeps duct fill sane
Signal from Ethernet	Analog signals and network cabling both suffer from crosstalk

Component spacing is not optional. Electrical components carry creepage distances and thermal properties that require spacing or partitioning between devices and terminals. Read the datasheet; the "mounting" page is where the clearance lives.

Know the standards before the layout, not after. Applying UL 508A and the NEC correctly during layout saves a failed inspection and the redesign that follows it.

Wiring best practices for safety and function

Once the products are selected and the BOM exists, identify the wiring: voltage potential sets the wire type and rating, and device pin-outs set the number of conductors and where they go. Then build it like this.

Respect the bending radius

Every conductor and cable has a minimum bend radius. Duct corners, terminal approaches, and door loops all need to honor it.

Rate for the highest voltage in the duct

Wires sharing a duct or crossing each other must all be insulated for the highest voltage present. Otherwise, separate them.

Cross at 90 degrees

Where high- and low-voltage wiring must cross, cross at a right angle to minimize inductive coupling.

Label so it can be read

Wire labels face up and read left-to-right or top-to-bottom. Label the device and the rail, not the duct lid, because lids get swapped.

Use jumpers and bridges

Factory jumper bars and bridges for terminals make wiring faster, neater, and more reliable than daisy-chained conductors.

Ferrule every stranded conductor

Ferrules prevent fraying and stray strands, and eliminate the accidental bridge between adjacent terminals.

Tap and screw, don't self-tap

Tapped holes and machine screws for duct and rail give a better connection, come apart cleanly for changes, and last the life of the panel.

Ground everything, properly

Panel, back plate, door, and devices. Remove paint at bonding points, use serrated hardware, and give the ground bar room to land field conductors.

A few UL 508A technicalities that bite

- ☐ **Interrupting capacity and SCCR.** Protective devices need interrupting ratings for the available fault current, and the panel needs a short-circuit current rating on the nameplate.
- ☐ **UL Listed or UL Recognized components only.** Recognized components must be used within their Conditions of Acceptability.
- ☐ **Current NEC guidelines.** Finger-safe terminals and guarded contact points where operators can reach.
- ☐ **Label the relevant hardware.** UL expects power supplies, circuit breakers, fuseholders, and field terminals to be identified.

Product awareness and design technique are the whole game

The goal in machine building is the most function in the best form factor at the lowest overall cost. Your local rep sees the latest technology every week and knows the total cost of ownership behind it. Put that to work on your next panel.

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[Ask an application question](#)

Prepared by Dynamic Measurement & Control Solutions, LLC. For the section-by-section version, see the companion download **UL 508A Control Panel Compliance Checklist**. Guidance is general; confirm requirements against UL 508A, NFPA 79, the NEC, and component datasheets.