

# From Zero to 48V

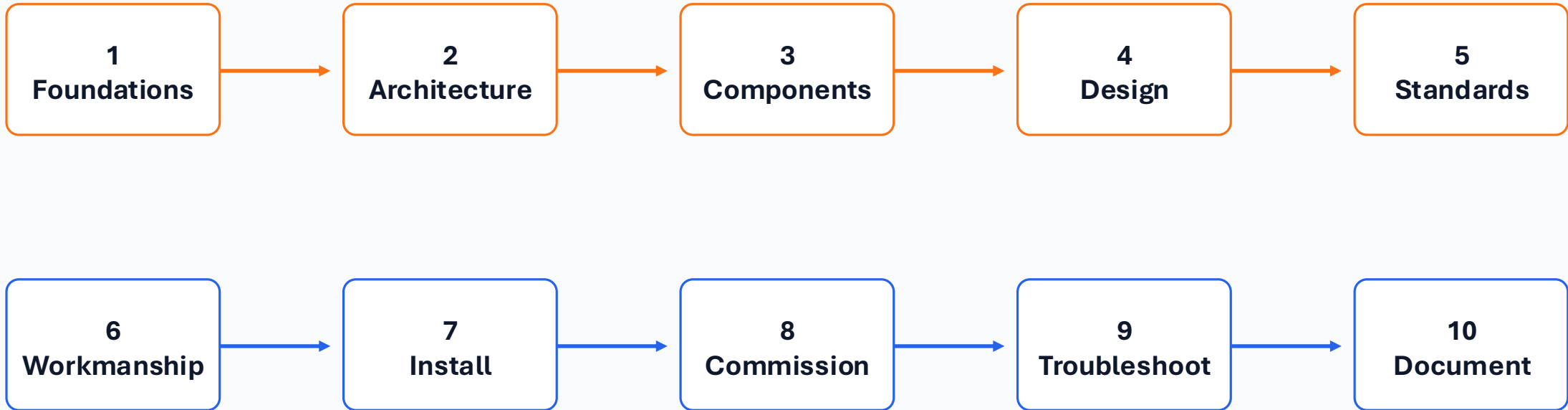
A mixed-media training deck for understanding, designing, installing, and documenting a modern camper van electrical system

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Built around a 48V Transit house system, dual Ford 12V alternators, Sterling BB1248120 charging, solar, shore power, and professional documentation discipline.

# How this course is built

A practical pathway from layperson math to owner-builder competence.

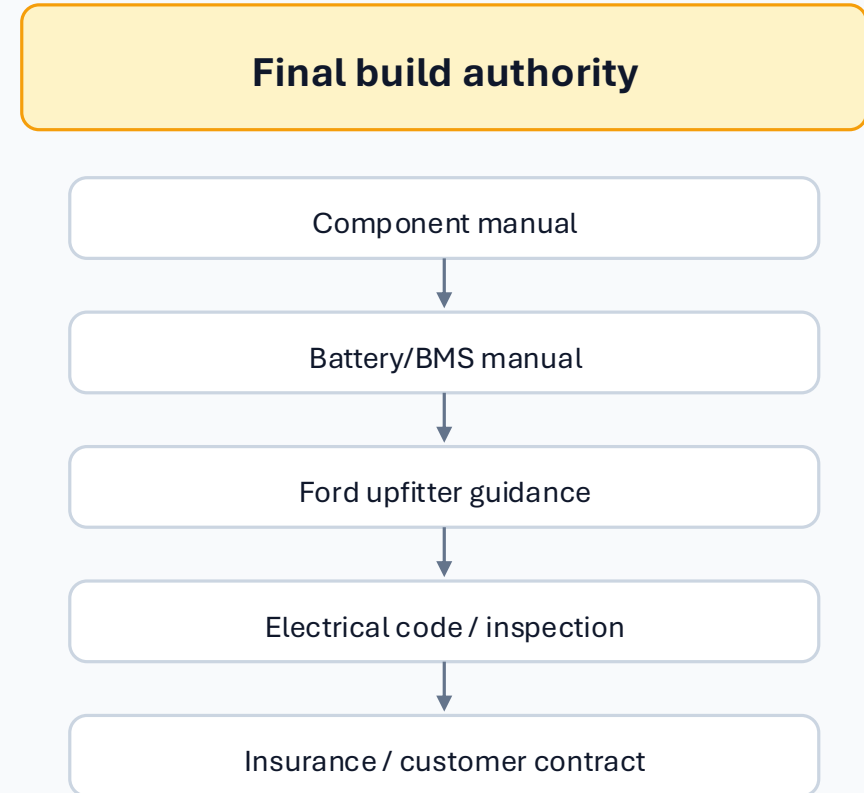


Every module produces an artifact: worksheet, checklist, diagram, log, or binder section.

# Safety & authority hierarchy

The course teaches judgement; manuals and codes govern final work.

- Manufacturer manuals override course examples
- Battery/BMS requirements control charger settings and protection
- Ford upfitter guidance controls chassis-side connections
- Canadian/provincial/insurer requirements must be resolved before customer builds
- 120V AC shore power requires code-aware professional review



LEVEL 1

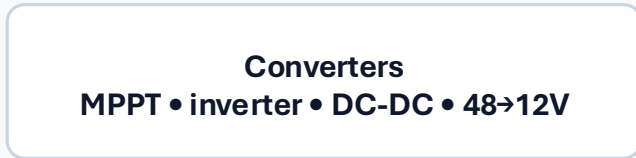
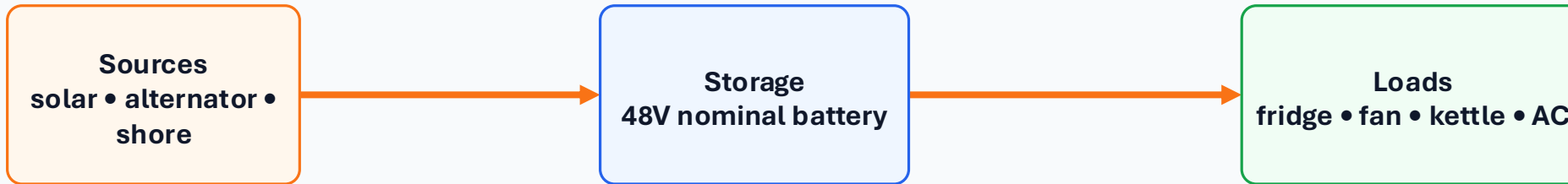
# Electrical Foundations

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Read labels. Calculate energy. Understand what loads do to a battery.



# Electricity in the van: source → storage → load



Every useful circuit has a controlled path out and back.

# Four numbers the learner must own

**Volts**

electrical pressure

12V chassis • 48V house •  
120V AC

**Amps**

electrical flow

how much current is moving

**Watts**

power right now

volts × amps

**Watt-hours**

energy over time

watts × hours

$$\text{Watts} = \text{Volts} \times \text{Amps}$$

$$\text{Wh} = \text{Watts} \times \text{Hours}$$

**A 2000W kettle is not 2000Wh unless it runs for one full hour.**

# Worked example: kettle energy use

From appliance label to kWh.

- 1 Find wattage** 2000W
- 2 Convert time** 3 min ÷ 60 = 0.05 h
- 3 Multiply** 2000W × 0.05h = 100Wh
- 4 Convert** 100Wh ÷ 1000 = 0.1kWh

$$\text{kWh} = (\text{Watts} \times \text{Hours}) \div 1000$$

Two boils/day ≈ 200Wh AC  
Through a 90% inverter ≈ 222Wh from battery

**Lab: time one cup, half-full, and full kettle. Fill in Wh and kWh.**

# Fridge duty cycle: small watts, long time

Daily energy depends on average power, not just rated running watts.

**Running watts × duty cycle = average watts**



**Hot weather can push a 40% duty-cycle estimate much higher. Fridge ventilation matters.**

# Battery capacity: amp-hours need voltage

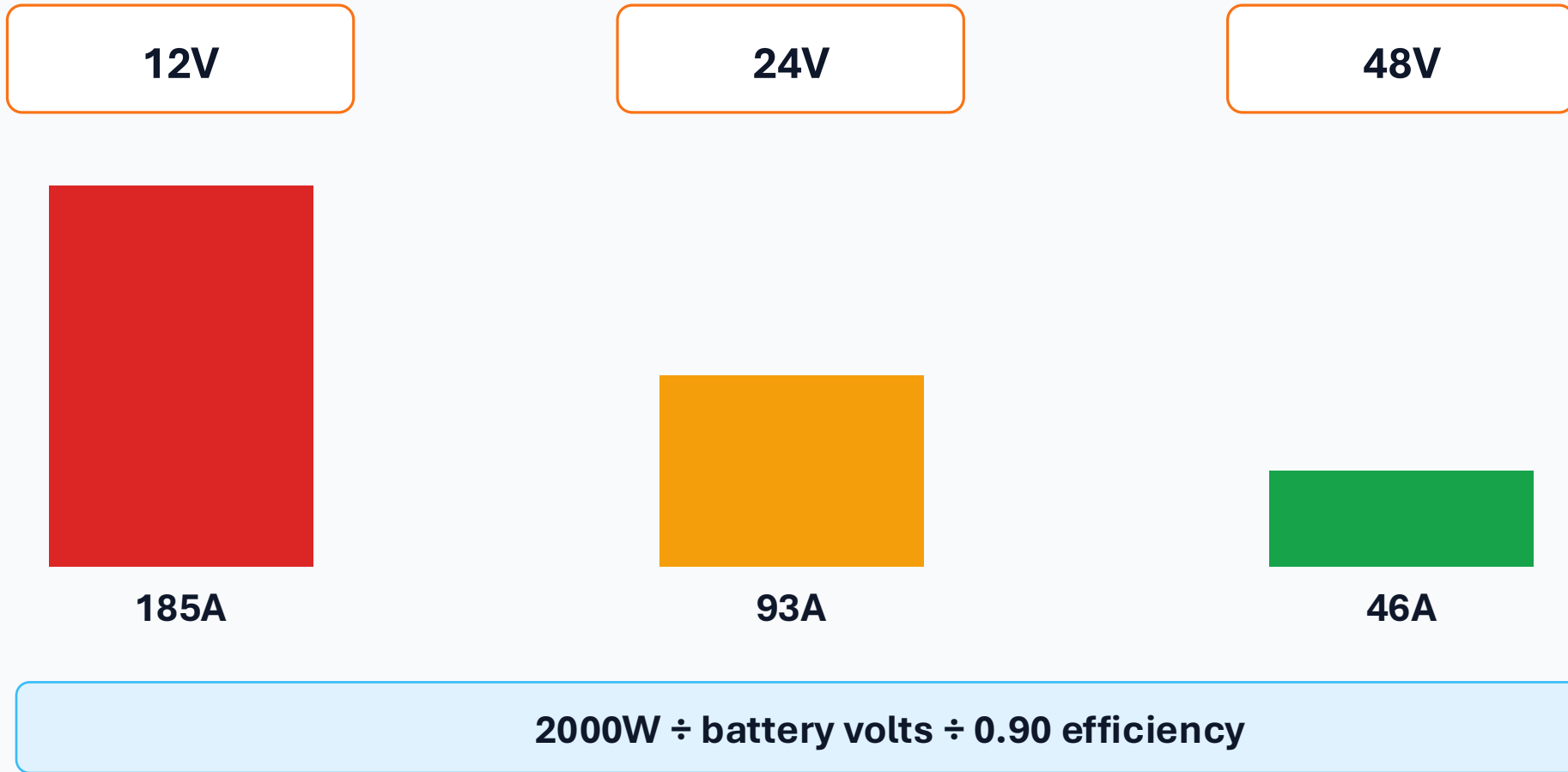
Battery	Simple math	Energy
12V 100Ah	$12 \times 100$	1.2kWh
48V nominal 100Ah	$48 \times 100$	4.8kWh
48V nominal 200Ah	$48 \times 200$	9.6kWh

**Battery Wh = Volts × Amp-hours**

**“600Ah” is incomplete without system voltage. Use kWh for whole-van planning.**

48V nominal is a teaching label. Final design uses the battery’s actual voltage range, charger profile, and BMS limits.

# Why 48V helps: same watts, less current



# First multimeter skills

Begin with voltage, polarity, and continuity — not current measurement.

- Measure DC voltage on known low-voltage sources
- Confirm polarity: a negative reading means reversed leads
- Use continuity only with power off
- Check fuses electrically, not just visually
- Avoid current measurement until trained

## Meter modes to master

V $\equiv$  DC voltage

V $\sim$  AC voltage

$\Omega$  / beep continuity

**A current (advanced/risky)**

**Never use continuity mode on a live circuit.**

# Level 1 capstone: mini load audit

Load	Voltage	Watts	Runtime	Wh/day
Kettle	120V AC	2000	3 min × 2	200
Fridge	12VDC	45 running	40% × 24h	432
Lights	12VDC	24	5h	120
Laptop	USB/AC	90	3h	270
Fan	12VDC	20	6h	120

## Learner must explain

- highest power while running
- highest energy over the day
- short-duration vs long-duration loads
- which loads require inverter
- what assumptions need measurement

**Artifact: first draft daily load audit**

LEVEL 2

# Whole-System Architecture

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Five zones. Two electrical worlds. One controlled bridge.

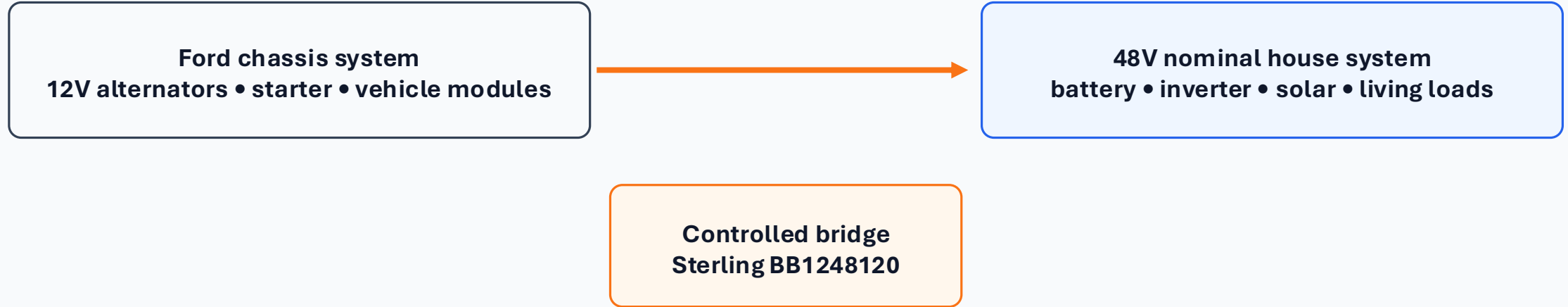


# The five-zone system map



**Use this map as the recurring mental model for the entire course.**

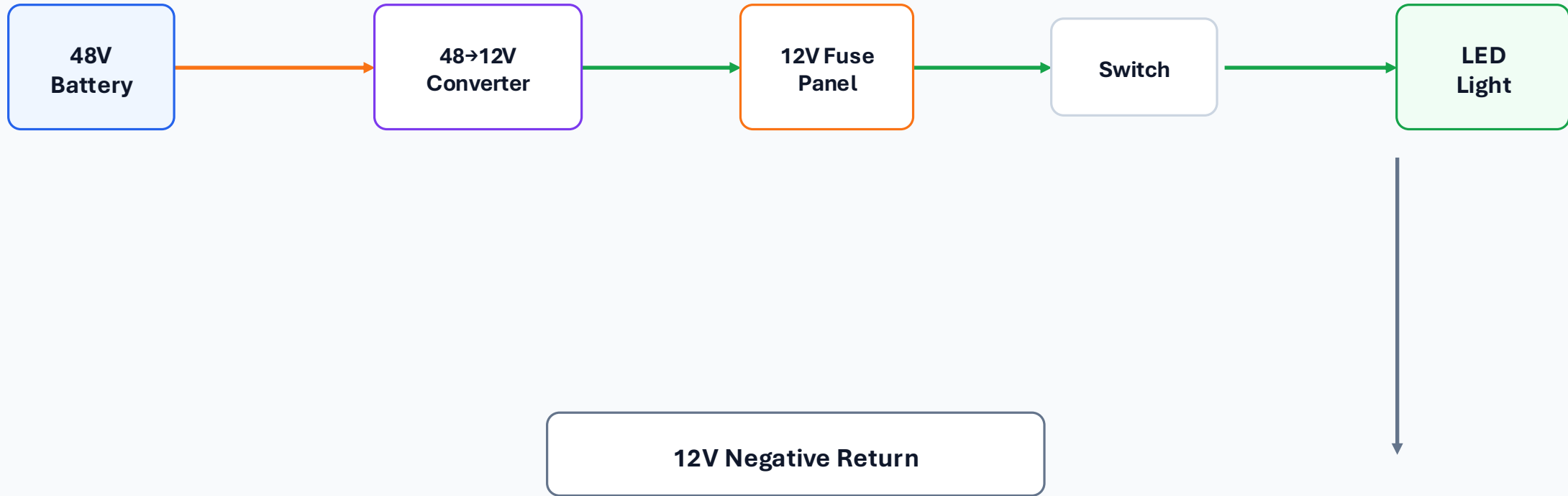
# House system vs. Ford chassis system



**Not a direct alternator-to-house-battery tie.**

**Dual 12V alternators do not equal unlimited upfitter current.**

# Simple schematic: 12V light circuit



Trace the fault in order: source → fuse → switch → load → return.

# Charging sources: what they are good at

Source	Strength	Weakness
Solar	Quiet, automatic background charging	Weather, shade, roof area
Alternator / BB1248120	Strong recovery while driving	Ford limits, heat, smart alternator behavior
Shore power	Reliable full recovery when plugged in	Not always available

**Daily recovery = solar harvest + drive charging + shore time**

**Design for real travel patterns, not best-case charging claims.**

# Schematic vs. physical layout

## Schematic

- How components connect
- Power path and return path
- Fuses and disconnects
- Voltages and functions

## Physical layout

- Where parts are mounted
- Cable routes and pass-throughs
- Ventilation and service access
- Strain relief and labels

**You need both before you start cutting cable.**

LEVEL 3

# Component Literacy

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What each major component does, what it does not do, and what its manual decides.

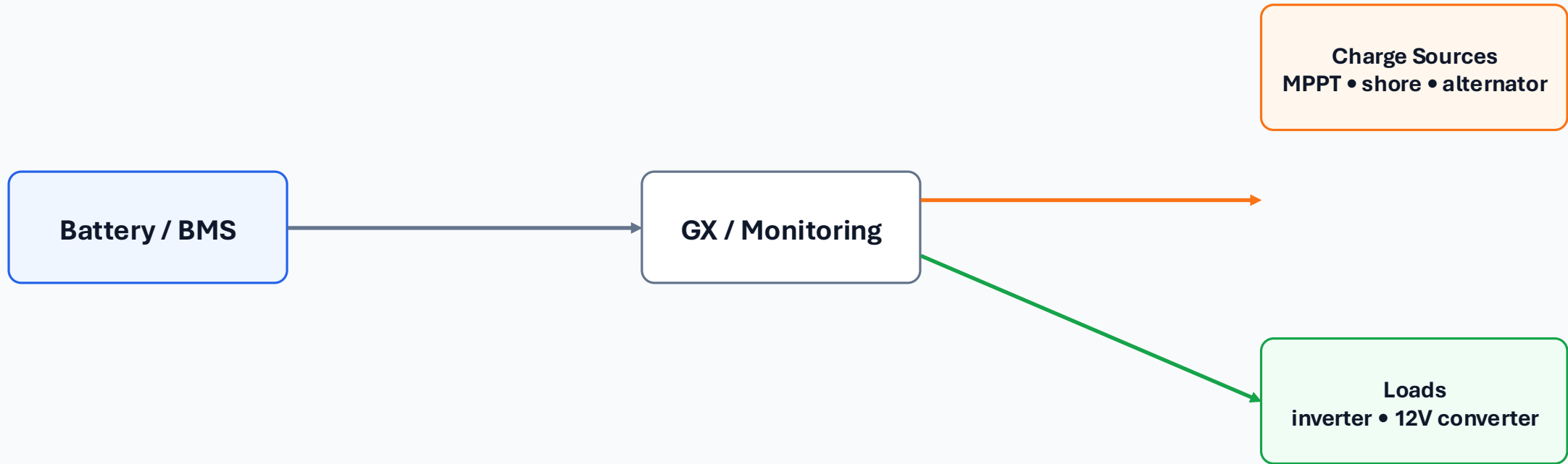


# Battery choice is an architecture decision

Category	Why choose it?	Risk to check
Server/rack 16S LiFePO <sub>4</sub>	Strong \$/kWh, clean package	Mobile warranty, CAN/comms
Drop-in integrated BMS	Simpler mental model	Coordination and charge control
Victron managed lithium	Deep ecosystem integration	BMS architecture and cost
DIY cell bank	Maximum custom control	Highest liability and design burden

**Decision lens**  
**Can I support it repeatedly,  
document it clearly, warranty it  
responsibly, and teach a  
customer?**

# BMS communication changes the system



**Managed systems can limit or stop charging when full, cold, hot, or faulted.**

## Cold battery ≠ charge-ready battery

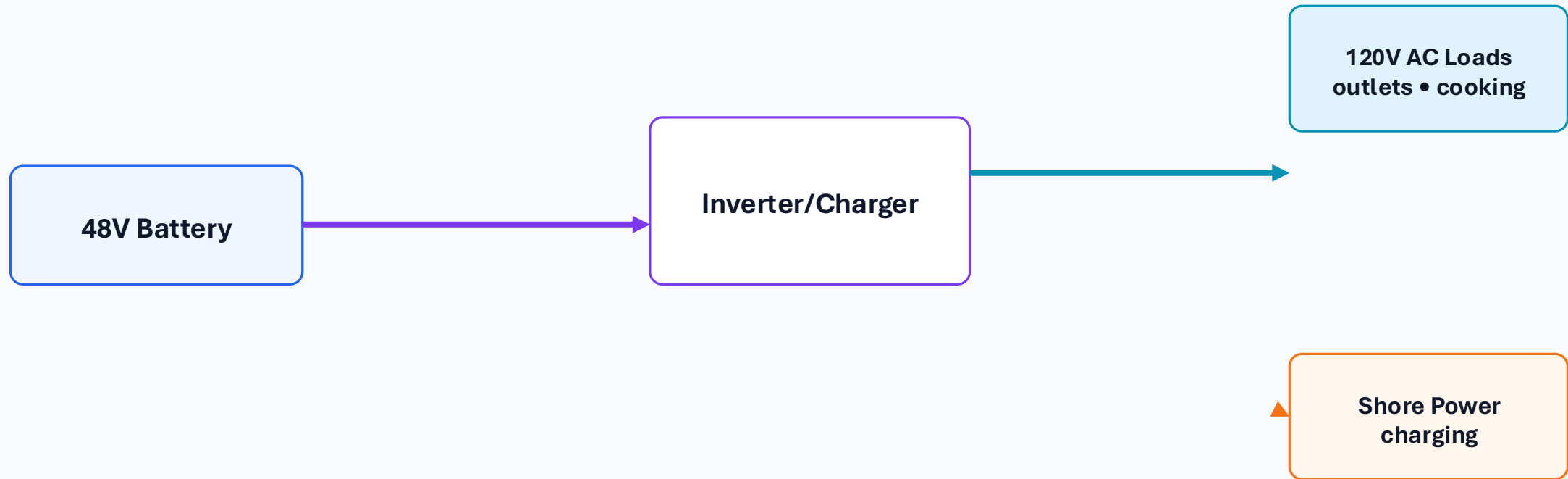
- LiFePO<sub>4</sub> may discharge in cold but block charging below a set temperature
- Internal heaters or heated compartments must be planned as loads
- Battery temperature should be visible in monitoring where possible
- Solar/alternator/shore charging may be delayed until battery temperature is safe

### Winter design question

**If the van sits unplugged at -30°C, what warms the battery enough to accept charge?**

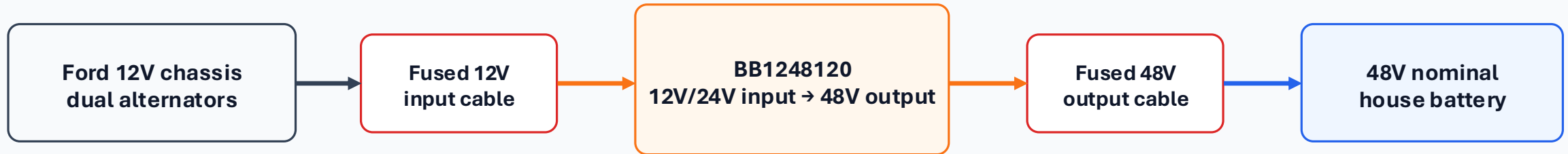
**120W heater × 8h = 960Wh**

# Inverter/charger: 48V DC ↔ 120V AC



AC design and installation review includes shore inlet, breakers, GFCI, transfer behavior, and neutral-ground bonding.

# Sterling BB1248120: controlled chassis-to-house bridge



**Mandatory pre-commissioning: confirm lithium profile, input/output fusing, enable behavior, ventilation, and Ford-approved connection.**

## BB1248120 current: why the numbers feel odd

$$1500W \div 48V \approx 31A \quad | \quad 1500W \div 51.2V \approx 29A$$

Sterling documentation may publish ~26A output at a specific operating point. Do not “correct” the manual by guessing.

Input voltage	1600W input current
12.0V	133A
13.8V	116A
14.4V	111A

**Fuse, cable, and thermal design must follow the current Sterling manual.**

# Smart/ECO alternator behavior must be tested

- Modern Transits can vary chassis voltage based on operating conditions
- The BB1248120 has settings for smart alternator environments
- Poor enable/sense configuration may cause cycling or no charging
- Test cold idle, warm idle, city, highway, hot weather, low chassis voltage

## Test log

Condition	Record
Idle cold	V / A / temp
Warm idle	V / A / temp
City	V / A / temp
Highway	V / A / temp
Hot day	V / A / temp

**Do not add Phase 2 charging until Phase 1 is measured.**

# Solar + MPPT: cold-weather voltage check

$$\text{Voc\_cold} = \text{Voc\_STC} \times [1 + (\text{tempco} \times \Delta T)]$$

1. Panel Voc: 40V

2. Tempco: 0.29%/°C

3. Cold case: -40°C

4.  $\Delta T = 25 - (-40) = 65^\circ\text{C}$

5. Increase = 18.85%

6. Cold Voc = 47.5V per panel

7. 3 in series = 142.5V

**MPPT max PV input voltage must exceed cold string Voc with margin.**

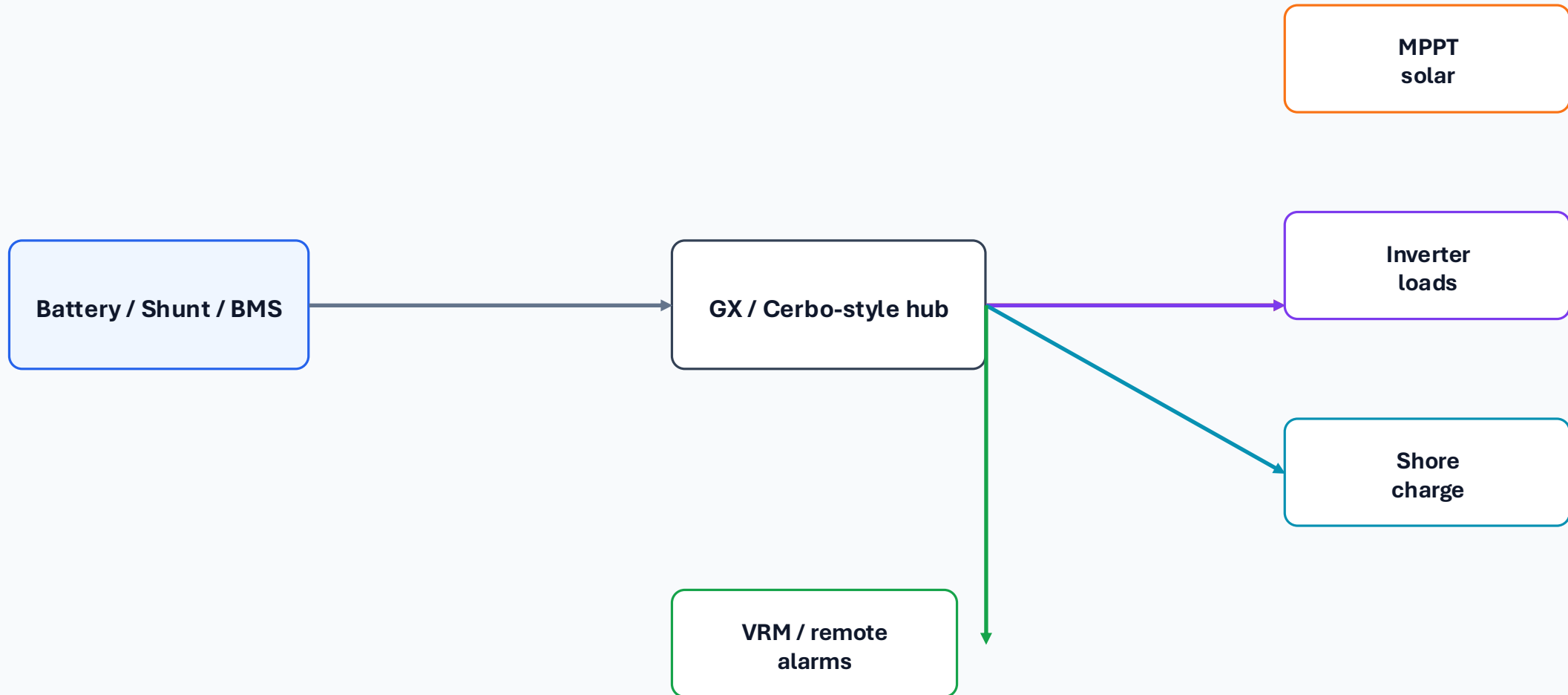
## 48V → 12V converter: keep van loads clean



$$12V \times 30A = 360W \rightarrow 360W \div 48V \div 0.90 \approx 8.3A \text{ input}$$

House 12V loads should not casually drain the Ford starting system.

# Monitoring is part of commissioning



Data to verify: SOC, battery current, solar watts, inverter load, alternator charging, temperature, alarms.

LEVEL 4

## Design & Planning

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Turn understanding into a build package: loads, battery, inverter, charging, wire, fuse, layout.



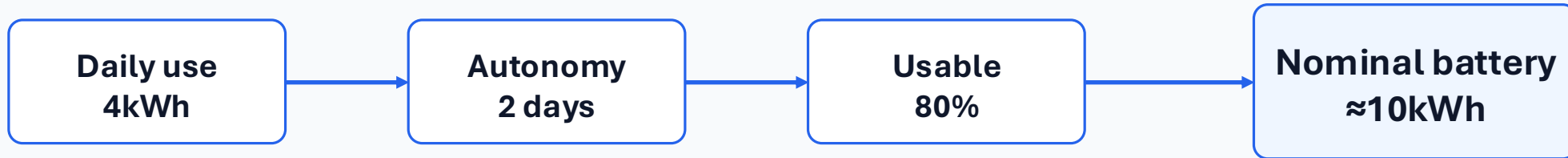
# Full load audit: three scenarios

Scenario	Why it matters	Main added loads
Mild day	baseline energy use	fridge • lights • fan • cooking
Winter day	low solar + heat support	hydronic controls • battery heat • more lights
Hot night	AC dominates design	48V AC • ventilation • fridge duty

**Battery sizing from one “average day” is not enough for a four-season van.**

# Battery sizing from daily kWh

**Required nominal kWh = (Daily kWh × days of autonomy) ÷ planned usable fraction**



**Capacity changes fault current, space, weight, cost, and service strategy.**

# Inverter sizing: behavior is part of design

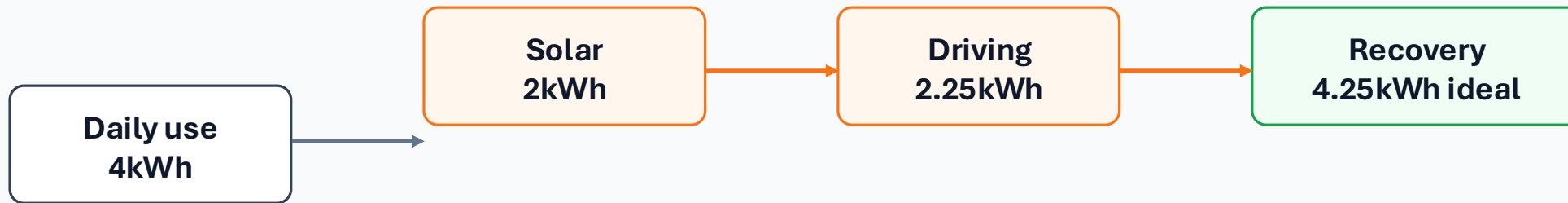
Load combination	Watts	Rule
Induction + coffee + chargers	≈ 2950W	near 3000W limit
Air fryer + kettle	≈ 3500W+	avoid unless sized for it
AC + cooking	variable	define expectations
Coffee + lights + laptop	≈ 1100W	normal

**A larger inverter increases DC-side current, fuse size, cable size, cost, heat, and idle draw.**

**Artifact: load management rules**

# Charging strategy: recovery math

Daily recovery = solar harvest + alternator charging + shore charging



Real-world reductions: shade, charge taper, heat derating, smart alternator behavior, low battery temperature.

# Wire sizing: current + length + voltage drop

$$\text{Voltage drop} = (\text{Current} \times \text{resistance}/1000\text{ft} \times \text{total circuit length}) \div 1000$$

Example	Value
Current	5A
One-way distance	12 ft
Total DC length	24 ft
Wire resistance	2.5 $\Omega$ / 1000 ft
Voltage drop	0.30V
Drop on 12V	2.5%

**Total DC length means positive conductor plus negative return conductor.**

**Wire choice must also satisfy ampacity, fuse size, insulation temperature, routing, bundling, terminals, and manuals.**

# Fuse selection: amp rating is not enough

**Amp rating**  
“When should it open?”

**Voltage rating**  
“Can it handle system  
voltage?”

**Interrupt rating**  
“Can it stop the fault?”

**Lithium banks can deliver very high short-circuit current. BMS ≠ main fuse.**

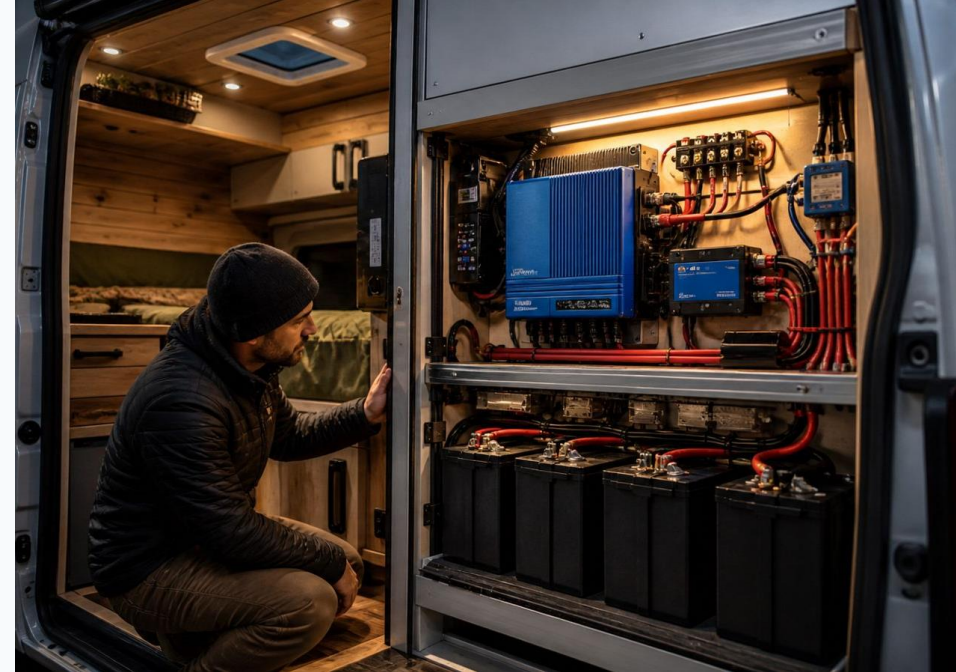
# Fuse types: teaching map, not final authority

Fuse type	Typical use	Warning
ATC/ATO	small 12V branch	not main lithium protection
MIDI/AMI	medium DC feeds	check DC ratings
MEGA	branch distribution	not automatically main battery
ANL	legacy/high DC	interrupt rating varies
Class-T	main lithium protection	use proper holder/module

**Final schedule must include  
fuse type • amp rating • voltage  
rating • interrupt rating • holder  
rating • protected wire • source  
• location**

## Physical layout: serviceability is safety

- Batteries secure and accessible
- High-current cables short and protected
- Fuses and disconnects visible
- Inverter has ventilation clearance
- AC and DC separated as appropriate
- Labels visible after cabinets are installed
- Room reserved for Phase 2 only if justified



**A beautiful hidden electrical system that cannot be inspected is a bad system.**

LEVEL 5

# Standards & Safety Discipline

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A working system is not automatically compliant, insurable, or professionally defensible.



# Codes, standards, and classification questions

- Manufacturer manuals are binding design inputs
- Canadian/provincial inspection and insurance requirements must be resolved
- RVIA/ANSI and ABYC-style references may be useful but not automatically governing
- Converted van classification may affect registration, insurance, and inspection
- Customer builds need written scope, standards, and handoff documents

## Before first customer build

- Ask insurer what they require
- Clarify provincial classification
- Document AC review path
- Define warranty boundaries
- Keep manuals and sign-offs

# Grounding and bonding: do not improvise

**DC negative  
return path**

**Chassis bond  
where approved**

**AC equipment  
ground**

**AC neutral  
not the same thing**

**Ford BEMM controls chassis-side grounding/return points. “Nearest metal” is not a design method.**

**Inverter/charger manual controls neutral-ground bonding behavior.**

# Emergency shutdown is part of the design

- 1 Turn off large AC loads
- 2 Turn off inverter
- 3 Open main battery disconnect
- 4 Unplug shore power
- 5 Open solar disconnect if safe
- 6 Do not replace blown fuses until inspected

**Customer/passenger should be able to follow this without understanding the whole system.**

LEVEL 6

## Tools & Workmanship

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Good electrical design can still fail if the cables, terminals, torque, and routing are poor.



## Tools that prevent amateur failure

- Quality multimeter + DC clamp meter
- Proper cable cutters and strippers
- Hydraulic/professional lug crimper
- Ferrule crimper for small terminals
- Heat gun and adhesive heat shrink
- Torque screwdriver/wrench
- Label maker
- Deburring tools, grommets, loom, conduit



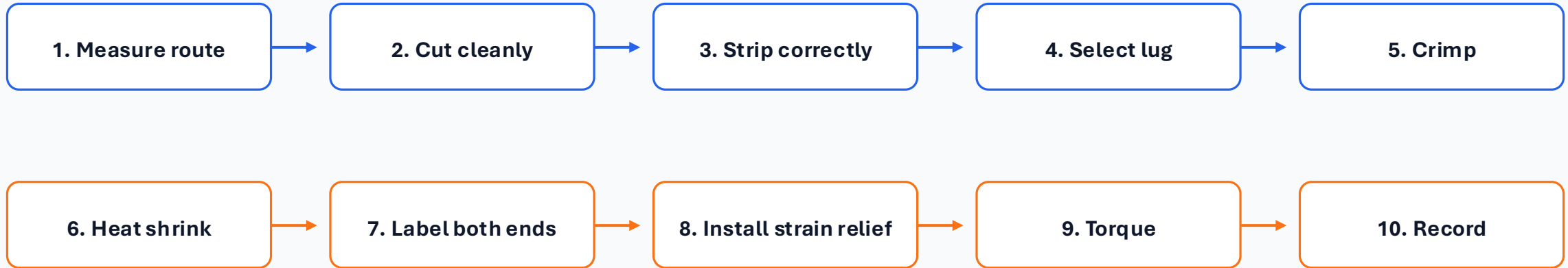
**A premium electrical system is not built with guessed torque and unlabeled wires.**

# Torque: no universal number

Connection type	Torque awareness	Final authority
Small terminal blocks	inch-pound scale	device manual
Fuse holders	varies by model	holder manual
Battery terminals	varies widely	battery manual
Inverter DC terminals	substantial/model-specific	inverter manual
Busbars/Lynx-style	model-specific	manual

**Find the spec. Use the correct tool. Record the value. Do not guess.**

# Cable build workflow



**Do not learn to crimp on the final battery cable. Build practice samples first.**

## Routing: a van moves, vibrates, flexes, and gets wet

- Protect every metal pass-through
- Support cable regularly
- Respect bend radius
- Avoid heat, moving parts, and sharp edges
- Separate AC and DC where appropriate
- Avoid hidden splices
- Photograph before closing walls

**Abrasion can turn a good circuit into a short circuit months later.**

LEVEL 7

# Installation Workflow

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Install in a sequence that makes accidental energizing unlikely.



# Design package before installation

- System overview
- Charging strategy
- Schematic
- Cable schedule
- Manual checklist
- Emergency shutdown
- Load audit
- Component list
- Physical layout
- Fuse schedule
- Commissioning checklist

**Buying parts before design is how expensive rework begins.**

# Safe installation order

1. Mount components — no power
2. Install protection for routes
3. Build negatives
4. Build positives — fuses removed
5. Install monitoring
6. Install 12V distribution
7. Install AC — do not energize
8. Install solar — disconnected/covered
9. Continuity + polarity checks
10. Torque + photos
11. Commission one subsystem at a time

**No fuse goes in “just to see what happens.”**

# Ford upfitter verification: model the process

## Question to ask

“For this exact Transit year/configuration with dual alternators, what approved connection point and grounding/return method supports a 115A-class DC-DC charger input?”

## Where to look

- Ford BEMM/upfitter manual
- Ford Pro/Fleet support
- Commercial dealer/upfitter contact
- Fuse/circuit limits
- Grounding points

## What to record

- question asked
- date/source/person
- guidance received
- documents/pages
- design decision made

**Store the response in the electrical design binder.**

# Solar install workflow: voltage, water, structure

- Finalize roof layout around fan, skylight, AC, deck, antennas
- Check Transit roof load and approved mounting guidance
- Calculate cold-weather Voc before stringing panels
- Protect penetrations and use proper glands
- Connect MPPT per manual sequence
- Commission with polarity and voltage checks

**Roof work is electrical + structural + waterproofing.**

LEVEL 8

## Commissioning & Testing

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Power the system slowly enough to catch mistakes before they become damage.



# Pre-power inspection

- All fuses removed
- Solar disconnected/covered
- Alternator charger disabled
- No unexpected continuity
- Labels installed
- AC reviewed before energizing
- Disconnects open
- Shore unplugged
- Polarity checked
- Torque complete
- Photos taken

**Pre-power inspection is the cheapest time to find mistakes.**

# First power-up: staged commissioning

1. Battery voltage + BMS

2. Monitoring only

3. 48V busbars

4. 48→12V converter

5. 12V circuits one-by-one

6. Inverter no load

7. AC review + test

8. Shore charging

9. Solar charging

10. Alternator charging

11. Thermal inspection

**If something unexpected happens, stop. Do not keep adding fuses or loads.**

# Load testing: prove the design under use

Test	Record	Why
Kettle / induction	volts • amps • temp	high inverter load
BB1248120 charging	chassis V • house A • temp	real alternator behavior
Solar	PV V • watts • battery A	string and MPPT check
AC / fan / fridge	Wh over time	daily load audit validation

**Thermal inspection under sustained load reveals poor crimps, loose terminals, and underrated hardware.**

LEVEL 9

# Troubleshooting & Maintenance

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Diagnose with a method. Maintain before failure.



# Troubleshooting method: do not guess



**Most beginner troubleshooting errors come from replacing parts before checking power and return path.**

# Fault trees: common symptoms

**No 12V power**

converter input • output • fuse panel • return

**Inverter won't start**

battery SOC • BMS • main fuse • settings

**Solar not charging**

shade • disconnect • polarity • MPPT • battery full

**BB1248120 not charging**

enable • chassis V • fuses • profile • thermal • BMS

**GFCI trips**

moisture • appliance • wiring • bond issue

# Maintenance schedule

Interval	Checks
Trip/monthly	visual inspection • alarms • ventilation • loose gear
Seasonal	cable supports • roof penetrations • solar mounts • cold settings
Annual	thermal load test • torque where allowed • spare fuse inventory • documentation update

**Do not re-torque live circuits. Follow manufacturer guidance before re-torquing.**

LEVEL 10

# Documentation & Business Readiness

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A professional system is understandable, repeatable, serviceable, and handoff-ready.



# Owner electrical binder

- Final schematic
- Component list + serials
- Charger/inverter/battery settings
- Fuse schedule
- Photos before walls close
- Load test records
- Physical layout
- Manuals + firmware
- Cable schedule
- Torque record
- Commissioning records
- Emergency shutdown card

**Documentation lets future-you, an inspector, a buyer, or a service tech understand the system without guessing.**

## Customer handoff: teach limits plainly

- Normal operating instructions
- Charging instructions
- Shore power instructions
- Battery cold-weather care
- What not to plug in
- Load management rules
- Emergency shutdown
- Fuse/breaker map
- Warranty and service process

### Business rule

**A customer who does not understand the system can accidentally misuse it. Handoff education reduces risk.**

# Repeatable SOPs for a future van business

Intake form

Component approval checklist

Ford upfitter checklist

Cable build checklist

Commissioning checklist

Warranty/service policy

Load audit worksheet

Manual review checklist

AC review checklist

Torque checklist

Customer handoff checklist

**Custom should mean intentionally designed — not improvised.**

APPENDICES

# High-Impact Design Loads

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Cold-weather battery heat, hydronic loads, 48V air conditioning, and Phase 2 charging decisions.



# Cold-weather electrical loads

Winter load	Why it matters
Battery heater	may be needed before charging
Hydronic pumps/controls	fuel-fired heat still uses electricity
Fan coils / floor loop	long runtimes
Tank/line heat	optional but energy-intensive
Ventilation	moisture control in cold weather

**120W battery heater × 8h = 960Wh**

# Hydronic heat: not electrically free

- Fuel provides heat energy, but controls and pumps use electricity
- Include startup/glow loads separately from running loads
- Fan coils and floor loops can run for long periods
- Winter load audit should include the whole heat system

## Hydronic load worksheet

Component	Start	Run
Controller		
Fuel pump		
Coolant pump		
Fan coil		
Floor loop		

## 48V air conditioning: define the promise

**Average watts × runtime = overnight Wh**

**500W avg × 8h  
= 4.0kWh**

**800W avg × 8h  
= 6.4kWh**

**10kWh usable battery  
AC can dominate the night**

**“Comfortable for sleeping” and “holds house temperature in extreme heat” are different customer promises.**

## Phase 2 alternator expansion: data-driven only

### Decision rule

- Measure daily kWh use
- Measure solar harvest
- Measure real BB1248120 output
- Record charger temperature
- Confirm battery charge acceptance
- Confirm Ford upfitter limits
- Add BB124865-style supplement only if the bottleneck is proven

**More charging is not automatically better. It adds heat, wiring, fusing, complexity, and support burden.**

# Final capstone: complete electrical binder

- System overview + goals
- Full load audit
- Charging strategy
- Alternator plan + Ford notes
- Grounding/bonding review
- Installation sequence
- Troubleshooting guide
- Five-zone diagram
- Battery/BMS selection
- Solar design
- 48V / 12V / AC schematics
- Cable + fuse schedules
- Commissioning + load tests
- Owner/customer handoff

**Pass standard: a reviewer can critique the design instead of reconstructing it.**

# What the learner should become

Not reckless enough to wire anything.  
Informed enough to know what correct looks like, what dangerous looks like, what to document, and when to ask for review.

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**That is the difference between a functioning DIY van and the foundation of a credible camper van conversion company.**

