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Mains Power for Permanent Installations

Mains Power for Permanent Installations

Where mains (AC grid) power is available, it is convenient and low-maintenance for routine operation: it provides essentially unlimited energy day-to-day, avoids battery-cycling wear, and simplifies the build. **But for emergency communications, this framing has a critical caveat: in a disaster the grid is usually the first thing to fail.** A node that depends solely on mains power will go dark in exactly the incidents the mesh exists to serve. For any node that must survive a grid-down event, treat mains as *primary-with-battery-backup at best*, and prefer solar + battery for nodes whose whole purpose is grid-down resilience. Mains is "reliable" only for normal-day uptime, not for disasters.

Safety: Any work on the 120/240 V AC side - adding a circuit, an outdoor outlet, or hard-wiring a supply - can be lethal and almost always requires a licensed electrician. Permit requirements vary by jurisdiction; check your local code. AC branch-circuit conductors must be sized per NEC (14 AWG for a 15 A circuit, 12 AWG for a 20 A circuit) regardless of the small load the node draws - never use thin wire on a branch circuit. The low-voltage DC guidance below applies only downstream of a listed AC adapter or power supply.

When to Use Mains Power

- Rooftop or building-mounted nodes where a power run is feasible
- Nodes at locations with existing power (communications towers, buildings, facilities)
- High-power nodes like the Station G2 (requires 15V PD - impractical with solar)
- Room Server nodes that are expected to be always-on for message storage

For any of the above that has an emergency-communications role, pair mains with battery backup sized for the expected outage (see Battery Backup, below) - a node's value during a disaster is exactly when grid power is most likely gone.

Power Supply Requirements by Device

Input requirements below follow each board's published documentation (Meshtastic hardware docs and the respective vendor datasheets, as of 2026-06-08). The current figures are minimums for a single node; confirm against your specific board revision.

Device	Input	Power Supply Needed
Heltec V3, V4	5V USB-C	Any 5V USB-C charger, minimum 1A
LilyGo T-Beam, T-Deck	5V USB-C or Micro USB	Any 5V USB charger, minimum 1A
RAK WisBlock (RAK19007)	5V USB or battery	5V USB-A charger or 5V regulated supply
Station G2	15V USB-C PD	USB-C PD charger supporting 15V, ≥20W output (e.g. 15V/2A)
Any node with LiPo	Battery + charger	Power the charger circuit; see device documentation

Station G2 Power Requirements

The Station G2 requires 15V USB-C Power Delivery. This is a specific PD negotiation - the charger must support 15V PD output, not just 5V. The manufacturer specifies a USB-C PD adapter that supports the 15V PD protocol with a maximum output power of 20W or more (i.e. ≥20W, e.g. 15V/2A). Compatible chargers include:

- Most 65W+ USB-C laptop chargers (verify 15V output in spec sheet)
- Anker 65W or 90W USB-C GaN chargers
- Any charger explicitly listing "15V/2A" or "15V/3A" in its PD output specs

A 5V USB charger plugged into the Station G2 will not provide enough power. The device may appear to power on but will behave erratically or fail to transmit at full power.

Battery Backup for Mains Installations

For mission-critical nodes on mains power, a battery backup (UPS function) maintains operation during power outages. **Match the backup capacity to the outage you actually need to survive:** small UPS modules give only a few hours, which covers brief utility blips but NOT disaster-length outages, which routinely run days to weeks after major storms, wildfires, or earthquakes. For genuine grid-down resilience, size battery backup in *days*, or use solar + battery so the node self-recharges. Options:

- **Small UPS:** A compact DC UPS module (available from AliExpress for $10 - $20, price as of 2026-06-08) passes through 5V USB power and switches to battery automatically on

outage. Battery runtime of a few hours is typical for small units - adequate for short utility interruptions only, not for a multi-day disaster.
- **Battery + charge controller:** Some boards with a battery connector and an onboard charge/power-path IC can charge a LiPo or 18650 from USB and run from battery when USB power is removed, giving automatic failover. **This is not universal:** many cheap boards cannot safely charge while running or may overcharge, so check your specific board's documentation before relying on it for UPS failover. Also note that on-board USB chargers (TP4056-class) have no temperature sensing - in a cold or hot outdoor enclosure they will happily charge a lithium cell below 0 °C or at high temperature, which causes lithium plating and a hidden fire risk. For an outdoor backup battery exposed to sub-freezing or high temperatures, use a charger or BMS with a low-temperature charge cutoff, put an inline fuse on the battery lead, and prefer LiFePO4 with a low-temp-cutoff BMS over a bare LiPo.
- **Full UPS:** For the Station G2 and other high-power nodes, a proper UPS with 15V PD output is required. These are less common but available from server hardware suppliers.

Weatherproofing Mains-Powered Outdoor Nodes

If the node is outdoors on mains power, weatherproofing requirements are the same as for solar nodes:

- Use an IP65+ enclosure
- Route mains wiring through appropriate weatherproof conduit (AC wiring and connections should be installed by a licensed electrician per local code)
- Use a weatherproof outdoor power outlet or a sealed junction box for the power entry
- Keep the power supply (transformer/adapter) inside the weatherproof enclosure or in a separately housed waterproof enclosure. **Watch enclosure heat:** an AC adapter dissipates heat, and a sealed box traps it - co-locating a hot adapter against a lithium battery can drive internal temperatures into the cell's charge-derating range (typically above ~45 °C) or damage the cells. Separate the power supply from the battery, provide thermal mass or ventilation, and monitor enclosure temperature; do not press a hot adapter against a lithium pack.
- If using a standard USB charger adapter, note that most USB chargers are not rated for outdoor use - enclose them in an additional weatherproof housing or use an industrial-rated outdoor power supply

Cable Run Considerations

For nodes mounted at height (rooftop, tower, pole), the cable run from power to the node may be significant. At 5V, voltage drop over long cables is a real concern. The voltage-drop figures below assume a modest node load of about 500 mA; drop scales with current, so a higher-draw node (e.g.

~1A during Wi-Fi/transmit) sees roughly double these values:

Cable Run	Cable Gauge	Voltage Drop at ~500mA	Action
<5m	24 AWG USB cable	Negligible (at ~0.5–1A)	Standard USB cable fine
5 - 15m	22 AWG or better	0.3 - 0.9V (at ~0.5–1A)	Use thicker cable or boost supply voltage
>15m	18 AWG or higher, or 12V supply	Significant with 5V	Run 12V and use a 12V→5V DC-DC converter at the node

For long cable runs, running 12V DC (lower current for same power, less voltage drop) and using a small buck converter at the node end is more efficient than running 5V USB over a long distance. (This 12V/24V/18V guidance is for low-voltage DC runs only - not AC mains branch circuits, which must follow NEC conductor sizing.)

Lightning Protection for Mains-Powered Sites

Mains-powered outdoor nodes are vulnerable to both direct lightning strikes and power line surges. Protect with:

- A quality surge protector or transient voltage suppressor (TVS) on the mains input
- A DC-grounded lightning arrestor on the antenna feedline
- Ground the enclosure and mast to an earth ground rod
- Consider a whole-circuit surge protector at the breaker panel for critical sites (installed by a licensed electrician)

AC Mains Power for Permanent Node Installations

For fixed infrastructure nodes at permanent sites with grid power access, AC mains power is the lowest-maintenance power solution for routine uptime, eliminating battery replacement cycles and enabling higher-power configurations. It is **not** the most reliable option in an emergency, however — the grid is commonly the first thing to fail in a disaster. Pair any mission-critical mains node with battery (and ideally solar) backup sized for the outage length you must survive.

Safety warning — AC mains can be lethal. Working on 120/240 V AC mains and breaker panels can kill you, and mistakes are unforgiving. AC mains and branch-circuit work should almost always be done by, or under the supervision of, a licensed electrician. Ensure proper equipment grounding/bonding of the enclosure and mast (NEC 250.x). This page describes the hardware involved, but it is not a substitute for a qualified electrician.

Power Supply Selection

Most ESP32/nRF52 LoRa mesh nodes regulate to 3.3V internally and accept 5V via USB or 3.7V from a single lithium cell. For AC-powered installations, you need a reliable AC/DC converter:

USB Wall Adapters

The simplest option for indoor nodes:

- **5V/3A USB-C adapter** - A basic 5V/3A USB-C adapter (full PD negotiation is not required) powers any USB-C node (Heltec V3, T-Beam Supreme). Roughly $10-20 for quality Anker or Baseus adapters (prices as of 2026-06-08).
- **Quality matters** - Cheap switching adapters can emit RF noise. Use a reputable brand with proper EMI filtering. Choose adapters that comply with FCC Part 15 Subpart B (Class B) emission limits (see 47 CFR 15.107/15.109).
- **UPS integration** - A small USB UPS (Anker PowerCore Fusion, Cyberpower CP685AVR with USB output) adds battery backup to any USB-powered node.

DIN Rail Power Supplies

For professional installations in electrical enclosures or server racks:

- **Meanwell HDR-15-5** - 5V/2.4A (12W) DIN rail supply, ~$15-20 (as of 2026-06-08). Widely used in industrial automation, proven reliable.
- **Meanwell HDR-30-12** - 12V/2A DIN rail supply for nodes that accept 12V input (most PoE-powered nodes, some T-Beams with barrel jack).
- DIN rail supplies mount in standard electrical enclosures alongside circuit breakers and terminal blocks.

PoE (Power over Ethernet)

For nodes at locations with Ethernet infrastructure (commercial buildings, outdoor fixtures with Cat5e runs):

- A PoE splitter converts standardized PoE (nominal 48V, range 44-57V) to 5V/12V for powering a node. Note that passive PoE may run at 24V or other voltages — match standard 802.3af/at gear to standard gear to avoid mismatch or damage.
- Enables remote power cycling via managed PoE switch (reboot a node from the office)
- Single cable for both data (if using an Ethernet-capable node or Pi-based room server) and power
- Requires Ethernet infrastructure - not practical for standalone outdoor nodes without network connectivity

UPS Integration for Grid-Powered Nodes

Even grid-powered nodes benefit from battery backup:

- **Mini UPS modules** - IP UPS boards (Waveshare UPS HAT, PiJuice) that sit between the power supply and the Pi or node. Runtime depends on load and battery capacity (commonly 1-4 h for low-power loads).
- **Standard UPS** - A small APC BE425M (~$40, as of 2026-06-08) protects against power line surges and provides battery backup for a low-power node; runtime is load-dependent (commonly 30+ minutes for a sub-watt node). Verify the specific model's USB output before relying on it.
- **Lead-acid battery bank** - For extended outage protection (24+ hours), a 12V 7Ah SLA battery (84Wh) on a float charger provides long runtime — roughly 24-40 h at a 1-2W

node load. SLA tolerates continuous float charging well (unlike lithium), though chronic overvoltage causes gassing/drying and shortens life. Self-discharge (~5%/month at room temperature) is comparable to or slightly higher than LiPo.

Outdoor AC Power Runs

Running power to an outdoor enclosure requires weatherproof wiring:

- **Wire gauge:** AC branch-circuit conductors must be 14 AWG (15A) / 12 AWG (20A) per NEC 240.4(D), regardless of how little the node draws — a downstream fault must be cleared by the breaker before the wire overheats. **Do not run 18 AWG on a 15/20A AC circuit** — it cannot survive a 15A fault and is a fire hazard. 18 AWG belongs only on the low-voltage DC side, never as AC branch-circuit wiring.
- **Weatherproof conduit:** Schedule 40 PVC conduit is a common method for outdoor AC runs (NEC Article 352); other approved raceways include RMC and LFNC. Seal entry points with weatherproof conduit fittings.
- **GFCI protection:** The NEC requires GFCI protection for all outdoor outlets (NEC 210.8). Use a GFCI breaker or GFCI outlet at the first outlet in the outdoor circuit.
- **Permit requirements:** New AC circuit runs usually require an electrical permit, depending on your local jurisdiction (AHJ). Check local code — this is especially important for community networks working on public property — and have a licensed electrician perform the work.

Related Pages

This topic overlaps with the "Mains Power for Permanent Installations" page, which focuses more on mains-install practices and USB failover via JST battery. Treat this page as the AC supply-hardware reference; consult that page for installation practices, and follow whichever gives the more conservative safety guidance.

Power-over-Ethernet for Outdoor Node Deployments

Power over Ethernet (PoE) is an excellent choice for outdoor nodes at sites with structured cabling infrastructure. It combines power delivery and network connectivity in a single cable, simplifying installation and enabling remote management.

PoE Standards

Standard	Max Power (at PSE)	Typical Use	Common in
IEEE 802.3af (PoE)	15.4W	IP cameras, VoIP phones	Most infrastructure
IEEE 802.3at (PoE+)	30W	PTZ cameras, APs	Modern switches
IEEE 802.3bt (PoE++)	Type 3 = 60W; Type 4 = 90W (≈71W delivered at the powered device)	Laptops, high-power APs	Newer switches
Passive PoE (non-standard)	Varies	Low-cost IP cameras, some APs	Ubiquiti older hardware

The 802.3bt maximum is 90 W at the power-sourcing equipment (Type 4), not 100 W — "100 W PoE" is a marketing rounding, not the IEEE spec figure.

For mesh nodes, IEEE 802.3af is more than sufficient. Most nodes consume 1-5W.

Active vs. passive PoE — not interchangeable. Standard (802.3af/at/bt) PoE negotiates voltage between the switch and the device (roughly 44 - 57 V) and is safe for compliant gear. Passive PoE simply puts a fixed voltage (often 24 V or 48 V) on the cable with no negotiation, and can damage equipment if mismatched. Match injector, splitter, and node carefully — a passive 24 V injector paired with a splitter that expects active 48 V may deliver no power or fry the node.

Maximum Cable Run Distance

PoE follows the Ethernet 100m (328 ft) cable run limit. Choose by distance:

- **Single run ≤100m:** a standard PoE run works directly.

- **~100 - 200m:** use a PoE extender (repeater) at the 100m mark to extend another ~100m.
- **Beyond ~200m:** use a fiber optic run with a media converter.
- Use cellular or WiFi for power-independent remote nodes.

Note: independent of distance, a fiber optic break between the building and the node is also the strongest *lightning* isolation option (see below) because fiber is dielectric — consider it on any outdoor run in a high-lightning area, not only for long runs.

Lightning Protection for PoE Runs

An Ethernet cable run to an outdoor node creates a lightning risk - the cable can couple surge energy into your equipment:

- **Ethernet surge protector:** Install a PoE-compatible Ethernet surge protector (e.g. Ubiquiti ETH-SP-G2, ~$15 as of 2026-06-08 — confirm current price on the Ubiquiti store) at both the building entry and the outdoor node enclosure. This is essential for any outdoor Ethernet run.
- **Fiber optic break:** Insert a fiber optic run between the building and the outdoor node. Fiber is dielectric - it cannot carry surge current. Best protection option.
- **Grounding:** Properly ground your outdoor enclosure and the surge protectors. The surge protector's ground and the enclosure ground must be bonded to the **same grounding electrode system as the building's AC ground** (per NEC 250.94) — bonding to a separate, isolated ground rod creates dangerous ground-potential differences during a strike. Tie all ground connections into that single building grounding electrode system.