

Weatherproofing Your Build

IP Ratings Explained

IP (Ingress Protection) ratings are defined by IEC 60529 and describe the degree of protection an enclosure provides against solid particles and liquids. The rating takes the form **IP[X][Y]** where X = dust protection (0 - 6) and Y = water protection (0 - 9K).

Ratings commonly used for outdoor LoRa mesh builds:

- **IP65** - Fully dust-tight. Protected against water jets from any direction. Acceptable only for sheltered or semi-covered outdoor locations (under an eave, soffit, or radiation shield), not for fully exposed installs.
- **IP67** - Fully dust-tight. Protected against temporary immersion in water up to 1 metre depth for 30 minutes. **This is the minimum recommended rating for any fully exposed outdoor fixed install** (rain, condensation, or occasional flooding).
- **IP68** - Fully dust-tight. Protected against continuous immersion at a depth specified by the manufacturer (commonly 1.5 - 3 m). Required for underground or submerged installations.

Recommendation (use this convention consistently across all enclosure and weatherproofing pages): IP65 is acceptable only for sheltered/covered outdoor locations; **IP67 is the minimum for fully exposed fixed installs** (repeaters, solar nodes, rooftop deployments).

Enclosure Types

- **Hammond 1554 Series** - Available in many sizes, widely stocked by electronics distributors (Mouser, Digi-Key, RS). Clear or opaque lids available. **Check the variant:** the **polycarbonate** versions are rated up to IP68 (including IP67), while the **ABS** versions are rated IP66 and are intended for general/lighter-duty use - do not assume the whole series is IP67. (The related "1554N" designation denotes the IP67-class variant; the base 1554 in ABS is IP65/IP66.) Excellent gasket quality. A popular and reliable choice.
- **Bud Industries PN Series** - NEMA 4X rated polycarbonate enclosures. Good availability in North America. Comparable quality to Hammond.
- **Fibox TEMPO Series** - European-origin polycarbonate enclosures with strong IP ratings. Often available with integrated mounting flanges.

- **PVC Electrical Junction Boxes** - Very cheap and widely available at hardware stores. Can be adequate for IP54 - IP65 applications, but gasket quality and seal consistency vary significantly between manufacturers. Avoid for IP67 requirements. Suitable as a low-cost option in sheltered outdoor locations.
- **RAK/Rokland Branded Enclosures** - Purpose-designed for WisBlock and common LoRa boards. Convenient mounting hardware but limited size options and higher cost-per-volume than generic enclosures.
- **Aluminium Die-Cast Boxes** - Excellent rigidity and EMI shielding. Good for installations near sources of interference. Heavier and more expensive than polycarbonate. Ensure the casting seams are properly gasketed. **Note: a metal enclosure also blocks your own node's signal - the antenna must be mounted outside the box via a bulkhead/SMA-or-N bulkhead connector. Never enclose the antenna inside an aluminium die-cast box.**

Cable Glands

Every cable or connector penetrating the enclosure wall is a potential ingress point. Use proper cable glands:

- Select cable glands rated **at least to the enclosure's IP rating**, sized to match the outer diameter (OD) of each cable or pigtail. IP65 glands are fine for IP65/IP67 sheltered use; IP68 glands are required only when the enclosure itself is IP68 or for marine/submersion service (IP68 is a safe default if in doubt). Most glands have a stated clamping range - e.g., "5 - 10 mm OD". Measure your cables before ordering.
- Common types include single-cable compression glands (most common), multi-cable glands, and armoured cable glands. For SMA pigtails, a standard single compression gland is appropriate.
- Apply **PTFE thread-seal tape** to the threaded portion before installing the gland in the enclosure wall (PTFE tape is preferred over thread-sealant compound on gland threads). This prevents water from wicking along the thread over time.
- After routing cables through the gland, tighten the compression nut firmly to form a seal around the cable jacket. Do not over-tighten - this can cut the jacket.
- After final installation, inspect glands annually and re-tighten if they have backed off.

Connector Weatherproofing

RF connectors are a significant vulnerability in outdoor antenna systems:

- **SMA connectors** are not inherently weatherproof and will corrode and degrade if left exposed to moisture. Protect all exposed SMA connections with **self-amalgamating (self-fusing) silicone tape**. Stretch and wrap tightly to form a watertight seal. Unlike

electrical tape, self-amalgamating tape fuses to itself and does not unravel over time.

- **Rubber weather boots** are an alternative to self-amalgamating tape for frequently disconnected connections.
- For permanent or semi-permanent installations, consider upgrading the antenna interface to **N-type connectors**, which are inherently more weatherproof than SMA. **Note: RP-SMA uses the same connector body and thread as SMA - only the centre-contact gender is reversed - so it is NOT meaningfully more weather-resistant than SMA. Both RP-SMA and SMA need the same outdoor sealing** (self-amalgamating tape, or step up to N-type).
- Apply a thin layer of **dielectric grease** to connector threads before assembly to prevent corrosion and galvanic action between dissimilar metals (e.g. brass connector on aluminium mount).

Anti-Condensation Measures

Sealed enclosures are subject to condensation from thermal cycling - when the temperature drops rapidly, moisture from humid air inside the enclosure condenses on the coldest surfaces (often the PCB and electronics).

- **Silica gel desiccant packets** - Place one or more packets inside the enclosure to absorb residual moisture. Inspect and replace annually, or when the indicator colour changes. Loose reusable (indicating) silica gel regenerates at $\sim 120^{\circ}\text{C}$ for 2 - 3 hours; do not exceed $\sim 125^{\circ}\text{C}$, which damages the indicating dye. (Do not oven-bake a plug-in/heated mini-dehumidifier unit - those regenerate by plugging into an outlet.)
- **Gore-Tex breather vents** - Small membrane vents (available from Gore and from TE Connectivity) allow slow air and pressure equalisation without admitting liquid water. These dramatically reduce condensation in installations subject to frequent temperature swings. Install per the manufacturer's instructions. Prefer a membrane breather vent over an open hole - see Thermal Management below.
- When sealing an enclosure, try to do so in dry conditions (low humidity). Sealing an enclosure containing humid air guarantees condensation when temperatures drop.

Thermal Management

Sealed enclosures in direct sunlight can reach internal temperatures well above ambient:

- A sealed black polycarbonate box in full summer sun can reach roughly **70 - 80°C internally** even at only 25 - 30°C ambient. (This is an approximate, illustrative figure - actual rise depends on enclosure colour, size, ventilation, and sun angle.) A light/white enclosure reflects most of this heat and is strongly preferred in hot, sunny climates; a darker box can help marginally in extreme-cold climates by absorbing what little sun is

available.

- Most electronics (ESP32, nRF52840, SX1262) are rated to operate up to **85°C**, so they will likely survive. However, **Li-ion and LiPo batteries degrade significantly above 45°C** - expect accelerated capacity loss and reduced cycle life.
- Mitigation options:
 - Use a **light-coloured or white enclosure** to reduce solar heat absorption (best choice for hot/sunny sites).
 - Mount the enclosure in a **shaded location** (north-facing in the Northern Hemisphere, under a roof overhang, etc.) or behind a radiation shield.
 - **Do not drill open vent holes in a rain-exposed enclosure.** Any open vent - even one covered with insect mesh - defeats the IP rating and lets in driven rain and humidity. For a sealed outdoor node, cool it instead with a light colour, shade/radiation shield, and a **Gore-type membrane breather vent** (which equalises pressure and reduces condensation without admitting water). Reserve open screened vents only for rain-protected locations (a node mounted under solid cover where water cannot reach the vent); if you use one, cover it with insect-proof mesh and seal the mesh perimeter with neutral-cure RTV.
 - For battery longevity in hot climates, consider LiFePO₄ chemistry, which tolerates higher temperatures better than Li-ion.

Sealing Cable Entries

1. After routing all cables through their glands and tightening the compression nuts, inspect each entry point from inside and outside the enclosure.
2. Apply a bead of **silicone RTV sealant** around the gland body on the inside of the enclosure wall, filling any gap between the gland and the enclosure surface.
3. Similarly, apply a small bead around the cable jacket immediately inside the gland nut.
4. Allow the RTV to cure for at least **24 hours** before exposing the installation to weather. Acetic-cure RTV (the type that smells like vinegar) releases acetic acid during curing - avoid contact with copper traces or sensitive electronics. Use neutral-cure RTV for electronics-adjacent applications.
5. Inspect all seals annually as part of routine maintenance.

Common Failure Modes

- **Gland nuts backing off** - Vibration (wind, vehicle traffic) can gradually loosen gland compression nuts, breaking the seal. Apply a drop of **medium-strength thread locker** (e.g. Loctite 243) to the nut threads after final tightening to prevent backing off.
- **Gaskets drying out and cracking** - Most enclosure lid gaskets are EPDM or silicone rubber. UV exposure and temperature cycling cause gradual hardening and cracking over 3 - 5 years. Inspect gaskets annually; replace when they show cracks, compression set, or fail to spring back when released.

- **Condensation from thermal cycling** - As described above, even well-sealed enclosures accumulate moisture over time. Include desiccant and inspect annually. A persistent wet interior despite intact seals is a sign the breather vent is absent or blocked.
 - **Corrosion at SMA connections** - Particularly common in coastal or industrial environments with salt or pollutant exposure. Self-amalgamating tape plus dielectric grease prevents this. Inspect and re-tape annually.
 - **UV degradation of polycarbonate** - Clear polycarbonate yellows and becomes brittle after several years of direct UV exposure without UV stabilisation. Use UV-stabilised (UV-resistant) enclosure materials, or apply a UV-protective coating to the outside of standard polycarbonate boxes.
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