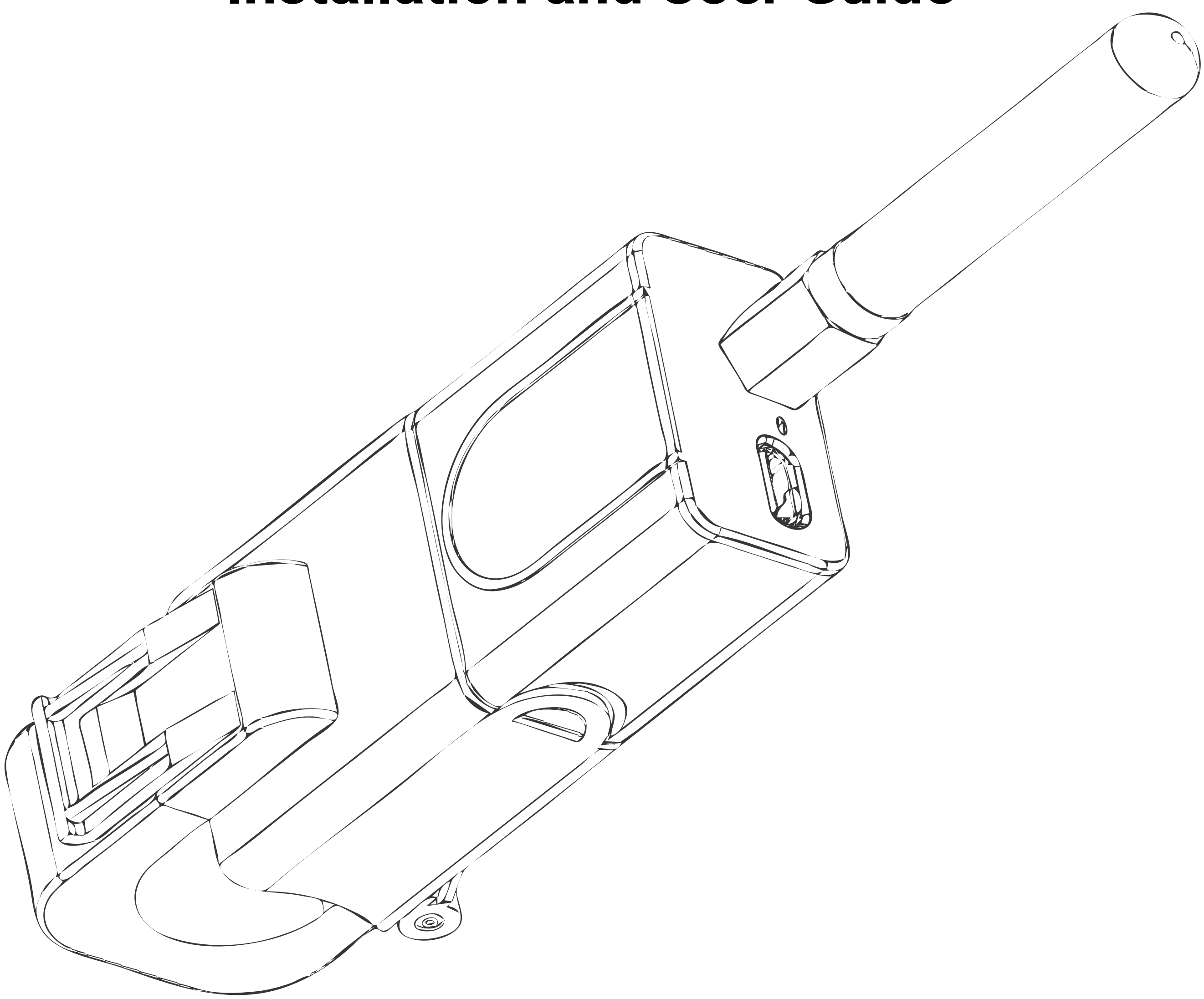
HotDrop™ Non-Contact Current Monitor Installation and User Guide



Version A.02 - Beta

June 12, 2025

Contents

IMPORTANT SAFETY INSTRUCTIONS

This manual and device labels provide important safety warnings. **Do not use the device in an unspecified manner. Misuse of the device may impair the user's protection.**

⚠ DANGER

Indicates a hazardous situation which may cause serious injury or death.

⚠ WARNING

Indicates a hazardous situation which may cause injury, damage to the device, or improper operation.

⚠ DANGER

- **This device should only be installed and serviced by a licensed electrician.**
- Use appropriate personal protective equipment (PPE) rated for the electrical source.
- Risk of electric shock: Do not exceed maximum voltage ratings when installed on uninsulated conductors.
- Risk of fire or explosion: Device is not rated for use in explosive or flammable atmospheres.

⚠ WARNING

- Do not exceed device temperature ratings.
- Do not exceed maximum current ratings for extended periods of time. Damage to HotDrop may occur.
- Device is not rated for use in wet or condensing humidity environments.
- Do not open or disassemble. The device contains no user serviceable components.

National Electrical Code (NEC) requires a **Disconnecting Means/Overcurrent Protection** to be installed on all electrical systems. It is the customer's responsibility to meet applicable electrical regulations. HotDrop is intended to be installed downstream from **Disconnecting Means/Overcurrent Protection** on monitored circuits.

1 Introduction

This document provides operating, maintenance, and installation instructions for the HotDrop non-contact alternating current (AC) monitor.

HotDrop is a wireless and self-powered electrical current monitoring device. It is capable of reporting average, peak, and minimum RMS Amperes and tracking accumulated Amp-Hours. The device parasitically harvests energy from the monitored conductor, negating the need for routine maintenance to replace or charge batteries.

With six current ranges varying from 300A to 4000A, the HotDrop is prepared to accommodate systems and conductors of nearly any size. See section 3: Use-Case Scoping for applicable system and conductor sizing to HotDrop models.

Simple non-contact clip-around design enables easy installation on live circuits, often requiring no facility downtime.

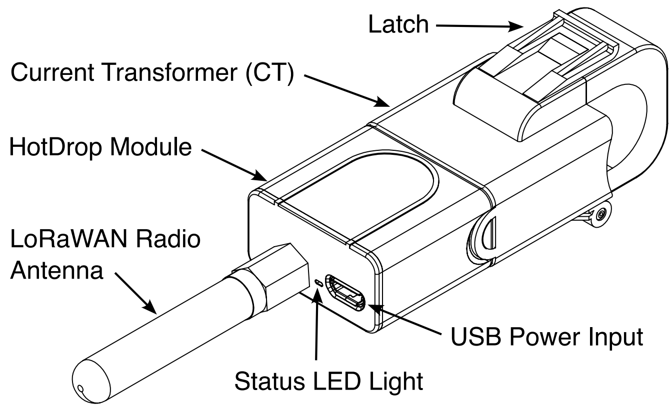
HotDrop uses sub-gigahertz LoRaWAN for long range wireless communications. This IoT interface can be deployed as a private network, or used with an available public one. The use of short data messages increases reliability of transmission in suboptimal environments such as metal electrical panels.

WARNING

HotDrop is intended for indoor applications only and should be installed in an electrical panel conforming to applicable electrical codes for the monitored circuit.

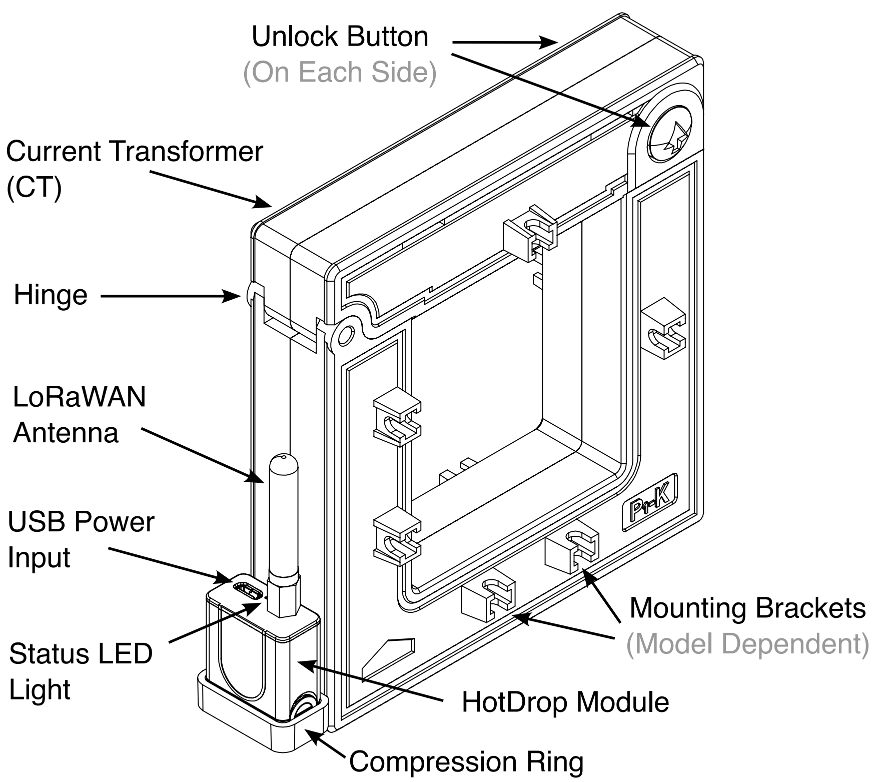
1.1 300A HotDrop

The 300A is the smallest and most-integrated model. Consisting of a small current transformer with a 15mm window and an attached communications module, this device is designed to directly hang off conductors.



1.2 400A, 1000A, 1500A, 4000A HotDrops

For larger systems, the HotDrop is available in a selection of rectangular current transformers up to 4000A. Sizes 1500A and 4000A have brackets (1500A shown in image below) to aid in mounting.



2 Specifications

2.1 Metering Characteristics

Accuracy	IEC Class 2 Meter (±2%)
Accuracy Range	1% to 120% of nameplate current.
Sampling Rate / Duration	3.3kHz / 50ms (per interval)
Sampling Interval	1 second (configurable)
Data Aggregation	Mean/Averaged
Reporting Interval	1 Minute (minimum, configurable)

2.2 Operational Characteristics

	Min	Typical	Max	Unit
Voltage (300A)	85	–	480	VAC
Voltage (400-4000A)	85	–	600	VAC
Power Consumption (300A)	–	–	0.7 [1, 2]	W
Power Consumption (400-4000A)	–	–	0.6 [1, 3]	W
Frequency	47	–	63	Hz
Temperature Range	-25	–	70	°C
Humidity	–	< 60	80	%RH

[1] Maximum power consumption at full rated current of transformer.
[2] Primary Voltage Drop: 2.33mV, Equivalent Resistance: 8µΩ.
[3] Primary Voltage Drop: <1.25mV, Equivalent Resistance: <3µΩ.

Overvoltage Category	CAT III 600VAC (Non-300A Models)
Pollution Degree	2
Operational Altitude	2000m

2.3 Mechanical Characteristics

Mounting (300-1000A)	Wire-Hang
Mounting (1500-4000A)	Wire-Hang, Mounting Brackets
Ingress Protection	IP51 (indoor/sheltered only)
Flammability	UL 94 V-0/130°C

Size	Weight	Window Dimensions (L×W)	Exterior Dimensions[1] (L×W×D)
300A	2.3oz (65g)	0.6" × 0.6" (16 × 16mm)	3.2" × 1.25"× 0.6" (82 × 32 × 16mm)
400A	8.7oz (247g)	1.25" × 1.25" (32 × 32mm)	3.2" × 3.8" × 1.25" (82 × 98 × 32mm)
1000A	1 lbs. 4.3oz (575g)	2" × 2" (51 × 51mm)	4.4" × 5" × 1.25" (111 × 127 × 32mm)
1500A	2 lbs. 7oz (1.1kg)	3.5" × 3.1" (90 × 80mm)	6.1" × 6.27" × 1.25" (154 × 160 × 32mm)
4000A	5 lbs. 11oz (2.6kg)	6.1" × 4.1" (155 × 105mm)	9.3" × 7.9" × 1.8" (235 × 201 × 45mm)
4000A (Large)	6 lbs. 2oz (2.8kg)	7.0" × 5.1" (180 × 130mm)	10.2" × 8.9" × 1.8" (260 × 226 × 45mm)

[1] External dimensions do not include length of LoRaWAN antenna.

2.4 Communications

Wireless Interface	800-900MHz LoRaWAN
LoRaWAN Specification	1.0.2 RevB
LoRaWAN Device Class	Class A
Transmit Power	+20dBm
Receive Sensitivity	-137dBm

2.5 Certifications

UL/CSA	UL 508, CSA C22.2 #14-18
FCC ID	2APCG-VUHDC1
RoHS	Compliant

2.6 Patents

The HotDrop is protected by the following US and international patents: US 10615641, US 11205927, US 11661776, US 11874361, US 11991490, US 12035086, US D931820, EP 3646040, JP 7300399, KR 10-2526567. Additional patents pending.

2.7 Warranty

One year from date of purchase. Extended warranty negotiable by contract.

Calibration and repair to be performed by manufacturer only. The HotDrop contains no user serviceable parts; disassembly of case voids warranty.

3 Use-Case Scoping

⚠ DANGER

- **This device should only be installed and serviced by a licensed electrician.**
- Use appropriate personal protective equipment (PPE) rated for the electrical source.

3.1 Applicable Circuit Types

Determine the circuit type to identify how many devices are needed. Install one HotDrop per phase; the neutral typically does not carry full load current in multiphase systems and should not be monitored. See section 10: Appendix - Wiring Color Codes for additional details into identifying a circuit's type.

For high-current systems with multiple conductors per phase, a single HotDrop must encompass all conductors in a phase to accurately monitor the current.

Single-phase two-wire with neutral	1 HotDrop Device
Single-phase (split-phase) three-wire	2 HotDrop Devices
Three-phase three-wire (Delta)	3 HotDrop Devices
Three-phase four-wire (Wye)	3 HotDrop Devices

3.2 Load Suitability

HotDrop is a self-powered device that parasitically harvests energy from the monitored circuit to operate. This gives the HotDrop the advantage of requiring no external power supply or regular battery changes. However, harvesting from the source imposes a few requirements on the monitored circuit.

- The HotDrop requires current to be flowing in the monitored circuit in order to harvest energy.
- There is an initial charging time before the HotDrop has enough energy to begin operation.
- The amount of current flow in the monitored circuit determines how long the HotDrop needs to charge before operation and what operational state it can maintain.

The HotDrop has multiple low-power modes to enable circuit monitoring before high-power systems such as the LoRaWAN radio are enabled. These extend the operational range of the device across situations such as low circuit currents or momentary shutoff. For details into HotDrop's low-power modes, see section 6.3: Capacitor Voltage Power States.

⚠ WARNING

HotDrop is not suitable for all loads and circuits. The device will perform poorly under the following conditions:

- Loads with less than 1% of the rated sensor current.
  - Very low currents impact the accuracy of the current transformer, and may not provide sufficient power harvesting for the HotDrop to operate reliably.
- Loads that are active for short periods of time.
  - Due to the initial charging time, the HotDrop may not reach operational state before the load shuts off.
- Periodic loads where high-accuracy amp-hour totalization is required.
  - Current flowing in the circuit while the HotDrop is initially charging is not recorded. Loads with many on/off cycles may not give high-accuracy amp-hour totalization.
  - HotDrop continues operating for some time after the load has shut off. Periodic loads where the off-time is shorter than the HotDrop's power-off discharge will not be impacted by repeated initial charge states.

See section 6.2: Power Harvesting Charge and Discharge for details on how the HotDrop behaves under load power-on/off.

Non-ideal conditions can be mitigated by externally powering the HotDrop with a 5V micro USB power supply. See section 6.4: Externally Powered Behavior for details.

3.3 HotDrop Sizing

The size of HotDrop required is determined by multiple factors.

- Overcurrent protection device rating. (e.g. 400A MCCB)
- Conductor sizing and type. (e.g. 600V THHN 4AWG)
- Number of phase conductors.

Select a HotDrop with a nameplate current larger than the overcurrent protection rating of the circuit. Exceeding the rated current of a HotDrop for extended periods of time may damage the measurement circuitry.

A conductor's outer diameter varies depending on material, construction, voltage rating, environmental ratings, and manufacturer. See section 9: Appendix - Conductor Sizing for details on identifying wire gauge and common THHN/THWN sizing.

Ensure that all conductors belonging to a phase can be brought together in such a way that they will fit within the current transformer window of the selected HotDrop. If necessary, use non-conductive cable banding to colocate conductors for measurement. Do not use the HotDrop current transformer to restrain conductors under high force. Doing so may lead to a broken release latch and poor contact between the split transformer sections.

4 Installation

4.1 Unpacking and Preparation

The HotDrop package should contain the following:

- HotDrop monitoring device
- SMA LoRaWAN antenna

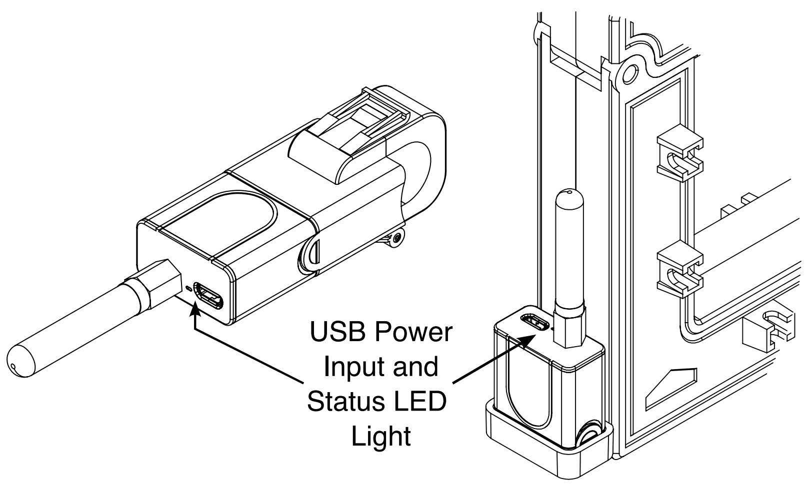
Recommended Tools:

- Clamp-on Ammeter
- Micro USB Cable and Wall Charger

4.2 Pre-Charge and LoRaWAN Connectivity

It is recommended to onboard HotDrops to a LoRaWAN network and pre-charge them via USB before installation. This allows verification of network connectivity and device operation prior to integration into the electrical system.

The HotDrop can operate fully when powered through its micro USB port and should report zero current during testing. When pre-charging, leave the device connected for several minutes to ensure enough energy is stored to prevent immediate shutdown upon disconnection.



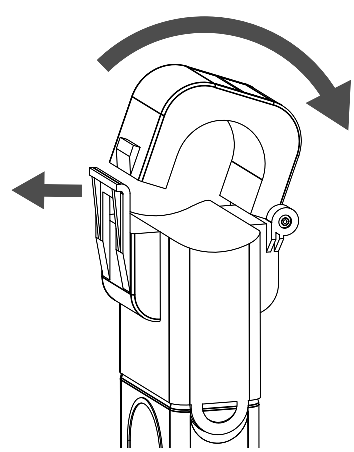
Once the HotDrop is powered, note the red status light on the front face. (See 6.1: Status Flashing Codes)

- On device power-up the status light will flash 20 times at 1Hz.
- The status light may then flash once every 10 seconds while the backup power capacitor charges.
- After a few minutes, the status should be flashing either 2 or 3 times every 5 seconds.
  - Two flashes indicate that the radio has joined a LoRaWAN network and is operating correctly. An initial data packet should be sent within 60 seconds on the device's default configuration.
  - Three flashes indicate that the radio is sending join requests in an attempt to discover and connect to LoRaWAN.
- The process of joining a device to a LoRaWAN Network Server (LNS) varies depending on the software package used.
  - For customers using Vutility.io please see the onboarding documentation at: `https://vutility.com/support/documentation`
  - Contact the vendor for assistance with other LNS providers.

4.3 Current Transformer Latches

All models of the HotDrop use a split-core current transformer to allow easy installation on existing wiring.

4.3.1 300A Model



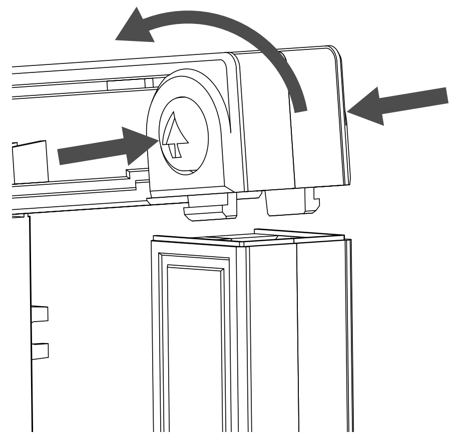
To open the 300A HotDrop, gently pry the front latch outward by a few millimeters and rotate the hinged transformer half upward.

To close the 300A HotDrop, rotate the hinged half downward until the latch clicks into place.

Exercise caution when handling devices exposed long-term to heat and high humidity. These conditions can eventually cause the nylon plastic to become brittle, increasing the risk of latch or hinge breakage if forced.

4.3.2 Rectangular Models

The 400–4000A HotDrop models use a heavy-duty rectangular current transformer with dual side-mounted release buttons. Both buttons must be pressed simultaneously to disengage the latch.



Once released, the internal spring force should open the transformer automatically. Do not apply strong external force, doing so may damage the latch mechanism.

To close the rectangular model transformers, press the hinged portion firmly downward until **both** halves of the latch click into place.

4.4 Phase Identification and Testing

Identify the conductor(s) to install the HotDrop onto. For high-current systems with multiple conductors per phase, a single HotDrop must encompass all conductors to accurately monitor the current. See 10: Appendix - Wiring Color Codes for assistance in identifying common wire colorings.

Once the phase conductors have been identified, it is beneficial to test the circuit current with a clamp-on ammeter. This will indicate if the circuit is passing sufficient current to maintain operation of the HotDrop after install. For details into the HotDrop's behavior at specific currents, refer to section 7: Appendix - Charge Time and Current.

⚠ WARNING

- Note the HotDrop can only monitor a **single** AC phase. Combining phases within a current transformer will result in inaccurate readings due to phase offset.
- Failing to encompass all conductors in a phase will result in inaccurate readings.
- Generally the neutral conductor does not carry full load current in multiphase systems and should not be monitored.

4.5 Install Location

HotDrops below 1500A are designed to hang from the monitored conductors. If installation on a vertical conductor is necessary, non-conductive cable ties or similar are recommended to hold the HotDrop in place. Larger models of HotDrop include molded mounting brackets on the current transformer.

For maximum wireless reception the LoRaWAN antenna should be angled away from metal sidewalls as much as possible while not being perpendicular[1] to the antennas on the LoRaWAN gateway.

It is recommended that a minimum of 1" (25mm) of clearance is maintained between current transformer devices such as the HotDrop. Placing multiple current transformers adjacent to each other will impact their accuracy.

[1] Omnidirectional stick antennas, like those used on the HotDrop, have weaker signal strength directly above and below the antenna — along the tip and base. Mounting two antennas at right angles to each other can lead to poor alignment and reduced signal strength.

5 LoRaWAN Data Format

5.1 Introduction

LoRaWAN (Long Range Wide Area Network) is a low-power, wide-area networking protocol designed for wireless communication between devices and centralized gateways. It operates on unlicensed radio frequencies (typically in the 868 MHz or 915 MHz ISM bands, depending on region) and is optimized for long-range, low-bandwidth applications such as remote sensing, monitoring, and control.

LoRaWAN is built on top of LoRa® modulation, which enables robust and energy-efficient data transmission over long range or under challenging radio environments such as electrical panels. The protocol defines secure communication, adaptive data rate (ADR), and network scalability, supporting a high device count per gateway.

LoRaWAN networks are typically structured such that devices communicate directly with one or more gateways. These gateways forward data to a LoRaWAN network server (LNS), which handles message deduplication, device authentication, and routing to customer applications.

5.1.1 Data Length Restrictions

LoRaWAN adaptive data rate (ADR) and variable modulation spreading enables tradeoffs between range/noise immunity and data throughput. Devices with good signal strength to the gateway will use efficient data rates and spreading factors to reduce the amount of airtime required to send data. Devices with poor signal will use settings that improve reception at the cost of longer airtime and lower throughput.

LoRaWAN regional specifications limit maximum airtime for devices. This ensures fair access for all systems in highly contested radio frequencies. Because the HotDrop reports data at a high rate compared to typical LoRaWAN devices, it is required that the data packets have limited size to keep the airtime under the regulatory limits in worst-case conditions.

Note that public LoRaWAN networks may throttle devices that violate their terms of use and often impose additional restrictions on airtime and uplink count.

5.1.2 HotDrop Open-Source Codec

Verified open-source JavaScript codecs (data decoders) are available for a variety of major LoRaWAN network servers (LNS). When deploying the HotDrop it is highly recommended that these be utilized over developing custom implementations when possible.

The codec's are freely available on GitHub:
`https://github.com/the-real-vutility/payload-codecs`

5.1.3 HotDrop LoRaWAN Port Field

LoRaWAN frames contain a "FPort" field which accompanies data payloads. An FPort value of 0, which is reserved by specification, indicates that the payload contains a LoRaWAN protocol control command. FPort values 1 to 223 are application specific and may be defined by users.

HotDrop sends and receives user-facing data on FPort 3. Data received on other ports will be discarded.

5.2 Uplink Packet Definitions

Uplinks are data packets sent from devices to the LoRaWAN network server (LNS). The HotDrop defines only a single uplink that contains all of the metrics it reports.

The interval between sent uplinks can be configured. See section 5.3.3: Transmit Interval for details on building the configuration LoRaWAN downlink.

5.2.1 Packet 50 - Comprehensive

Byte Index	Field	Type	Description
0	Packet ID	uint8	This value is equal to 50.
1-4	Amp-Hour Accumulation	uint32	An unsigned integer in network byte order (MSB) reported in deci-ampere-hours (dAh).
5-6	Average Current	uint16	An unsigned integer in network byte order (MSB) reported in deci-amperes (dA). This value is the rolling average of the RMS current since the last transmission.
7	Max Offset	uint8	An unsigned integer representing the percent offset above the Average amps value. The peak amperage can be calculated by the following equation: $$Amps_{Max}[dA] = Amps_{Avg}[dA] \times \frac{100.0 + MaxOffset}{100.0}$$
8	Min Offset	uint8	An unsigned integer representing the percent offset below the Average amps value. The minimum amperage can be calculated by the following equation: $$Amps_{Min}[dA] = Amps_{Avg} \times \frac{100.0 - MinOffset}{100.0}$$

Packet 38 - Comprehensive (Continued)

Byte Index	Field	Type	Description
9	Capacitor Voltage Scalar	uint8	An unsigned integer representing the capacitor voltage. The capacitor voltage can be calculated by the following equation: $CapacitorVoltage[V] = \frac{5.0}{255.0} \times (CapacitorVoltageScalar)$
10	Temperature Scalar[1]	uint8	An unsigned integer representing the device internal temperature. The temperature in degrees Celcius can be calculated by the following equation: $Temperature[^{\circ}C] = \frac{120.0}{255.0} \times (TemperatureScalar) - 40.0$

[1] Internal temperature sensor accuracy is $\pm 5^{\circ}$C and is intended for informational use only.

Example Packet 50 - Comprehensive

Note: Values are randomized and provided for decoder verification only.

Base64 Encoding		MgAAW74DQCEsrog=	
Raw Packet (Hexadecimal Bytes)		[32, 00, 00, 5B, BE, 03, 40, 21, 2C, AE, 88]	
Decoded Values			
Amp-Hours	2348.6 Ah	Average Current	83.2A
Maximum Current	110.66A	Minimum Current	46.59A
Capacitor Voltage	3.41V	Temperature	24°C

5.3 Downlink Configuration Definitions

Downlinks are data packets sent from the LoRaWAN network server (LNS) to the device. The HotDrop is configurable via several downlinks described in this section. The following downlinks must be padded to a length of 10 bytes, and values are encoded as IEEE-754 32-bit floating-point (i.e. "float") with network-byte order (MSB). Due to the complexity of this format, it is recommended to use the provided options to prevent invalid or unexpected device operation. Downlinks should be sent to FPort 3.

Note: Depending on the LNS used, the downlink may need to be encoded as Base64 to be sent. Upper and lower case in Base64 is part of the encoding; do not modify capitalization.

5.3.1 Device Reboot (Soft Reset)

This will initiate a software reset, causing the device to rejoin the LoRaWAN network.

Raw Packet (Hexadecimal Bytes)	Base64 Encoding
[5A, 00, 00, 00, 00, 00, 00, 00, 00, 00]	WgAAAAAAAAAAAA==

5.3.2 Factory Reset

This will initiate a factory reset. Accumulated amp-hours and configuration will be set to initial values and the device will reboot.

Raw Packet (Hexadecimal Bytes)	Base64 Encoding
[46, 00, 00, 00, 00, 00, 00, 00, 00, 00]	RgAAAAAAAAAAAA==

5.3.3 Transmit Interval

The interval between data packets can be configured to reduce the frequency of updates.

Reducing the interval increases power requirements and the minimum circuit current necessary to maintain full power state on the HotDrop. Increasing the transmit interval results in a longer rolling window for averaged current values.

Transmit Interval	Raw Packet (Hexadecimal Bytes)	Base64 Encoding
1 minute (Default)	[54, 00, 00, 00, 70, 42, 00, 00, 00, 00]	VAAAAHBCAAAAAA==
2 minutes	[54, 00, 00, 00, F0, 42, 00, 00, 00, 00]	VAAAAPBCAAAAAA==
5 minutes	[54, 00, 00, 00, 96, 43, 00, 00, 00, 00]	VAAAAJZDAAAAAA==
15 minutes	[54, 00, 00, 00, 61, 44, 00, 00, 00, 00]	VAAAAGFEAAAAAA==
30 minutes	[54, 00, 00, 00, E1, 44, 00, 00, 00, 00]	VAAAAOFEAAAAAA==

5.3.4 Measurement Interval

The HotDrop spends the majority of its time harvesting power and transitions to high-resolution measurement on a periodic interval.

Higher resolution data can be achieved by reducing the measurement interval at the cost of greater power requirements and an increased minimum circuit current to maintain full power state on the HotDrop.

It is **highly** recommended to leave this value at the default configuration.

Interval (msec)	Raw Packet (Hexadecimal Bytes)	Base64 Encoding
200	[4D, 00, 00, 00, 48, 43, 00, 00, 00, 00]	TQAAAEhDAAAAAA==
500	[4D, 00, 00, 00, FA, 43, 00, 00, 00, 00]	TQAAAPpDAAAAAA==
1000 (Default)	[4D, 00, 00, 00, 7A, 44, 00, 00, 00, 00]	TQAAAHpEAAAAAA==
2000	[4D, 00, 00, 00, FA, 44, 00, 00, 00, 00]	TQAAAPpEAAAAAA==
10000	[4D, 00, 00, 40, 1C, 46, 00, 00, 00, 00]	TQAAQBxGAAAAAA==

5.3.5 Low Power Threshold

The low power threshold determines when a HotDrop transitions to increased measurement and transmit intervals to conserve power. This extends the operating region of the device.

Decreasing the low power threshold causes the device to remain in full operation longer, but will result in a rapid shutoff once circuit current falls below the minimum required to sustain full operation.

It is **highly** recommended to leave this value at the default configuration.

Threshold (Volt)	Raw Packet (Hexadecimal Bytes)	Base64 Encoding
3.9	[50, 00, 9A, 99, 79, 40, 00, 00, 00, 00]	UACamXlAAAAAAA==
3.4 (Default)	[50, 00, 9A, 99, 59, 40, 00, 00, 00, 00]	UACamVlAAAAAAA==
2.1	[50, 00, 66, 66, 06, 40, 00, 00, 00, 00]	UABmZgZAAAAAAA==

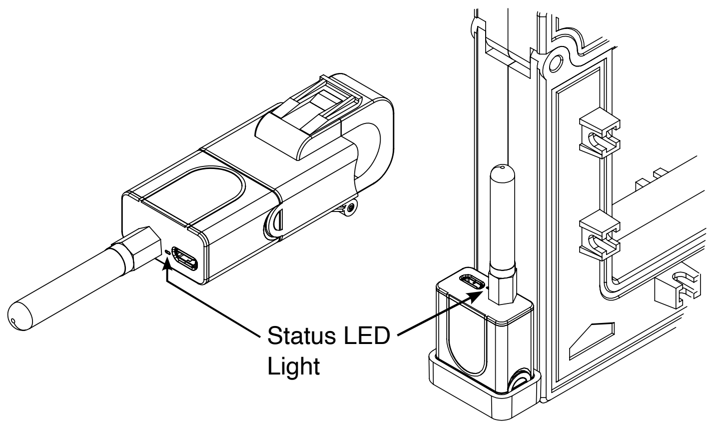
6 Troubleshooting

Because HotDrop is a parasitically powered device that harvests energy off the monitored circuit, most common issues are related to current flow and device sizing. The HotDrop changes its transmit and measurement behaviors depending on the amount of stored energy in its capacitor. The device sizing changes the harvesting capabilities and minimum current requirements. For details about minimum current and charging time see section 7: Appendix - Charge Time and Current.

Note: In the event that a previously connected HotDrop is disconnected from the LoRaWAN network, it will eventually reset after two failed successive LoRaWAN link check attempts. These are sent hourly, and as such, a disconnected HotDrop may continue to indicate connected status for up to two hours.

6.1 Status Flashing Codes

The HotDrop contains a red LED light. Status is communicated via patterns of flashes described by the following table.



Flash Pattern	Condition	Device State
1 Flash every 10 seconds (or no light)	HotDrop is in measurement-only mode or unpowered	The capacitor voltage is low and the device may soon cease operation. Check that the module is seated securely in its socket on the current transformer and that sufficient current is flowing in the monitored circuit. Depending on the current flow, low-power operation may be expected for some time after initial power-on.
1 Flash every 5 seconds	Low power operation	The device is functioning properly but the capacitor voltage has dropped below the full operation point. The rates of transmission and measurement have been decreased to conserve power.

Status Flashing Codes (Continued)

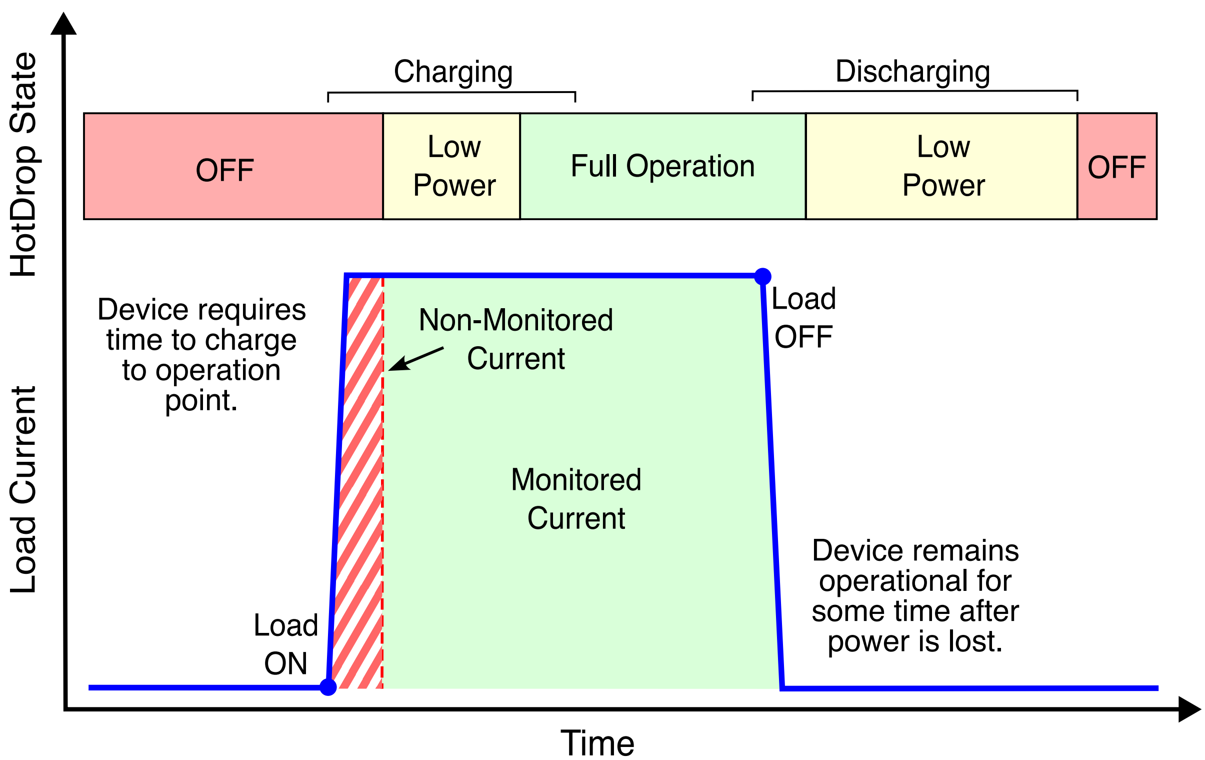
Flash Pattern	Condition	Device State
2 Flashes every 5 seconds	Normal operation	The device is functioning properly and is joined to a LoRaWAN network.
3 Flashes every 5 seconds	LoRaWAN joining in progress	The device is functioning properly and attempting to join a LoRaWAN network.
20 Flashes at 1Hz	HotDrop initialization	The device is initializing after reset. Expected at power-on, occurrences during operation indicate reset due to error conditions.

6.2 Power Harvesting Charge and Discharge

6.2.1 Typical Charge and Discharge

The HotDrop begins charging its internal capacitor-based energy storage whenever current flows through the monitored circuit. Because the device's processor, radio, and measurement circuitry require a minimum operating voltage, there is a brief period after energization during which the capacitor has not yet charged sufficiently for the device to function. During this time, the HotDrop does not collect measurements or record current in its amp-hour totalization.

The length of this initial charge period depends directly on the amount of current in the circuit. Higher currents allow the capacitor to charge more quickly. For detailed behavior by model, refer to Section 7: Appendix - Charge Time and Current.

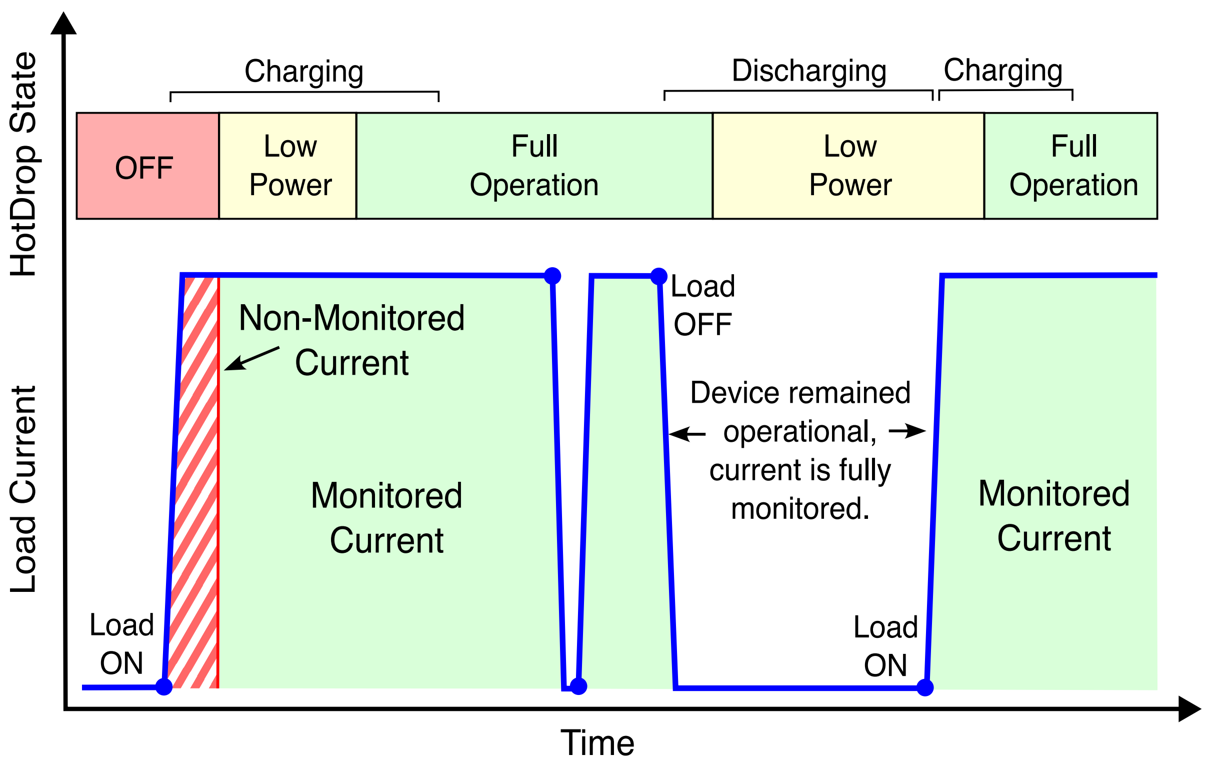


6.2.2 Short Load Interruptions

If circuit current is lost, the HotDrop continues operating from the energy stored in its capacitor. As this energy is depleted, the device transitions through low-power modes to preserve operation. The amount of time a HotDrop can function during an outage depends on how much excess energy it stored prior to the loss of current. In many cases, short outages will not affect the device's ability to operate or measure current.

If the outage is brief and the capacitor does not fully discharge, the HotDrop resumes normal operation without delay once current returns; there is no reinitialization or unmonitored period.

See section 8: Appendix - Discharge Time for information on the holdover time of the HotDrop.

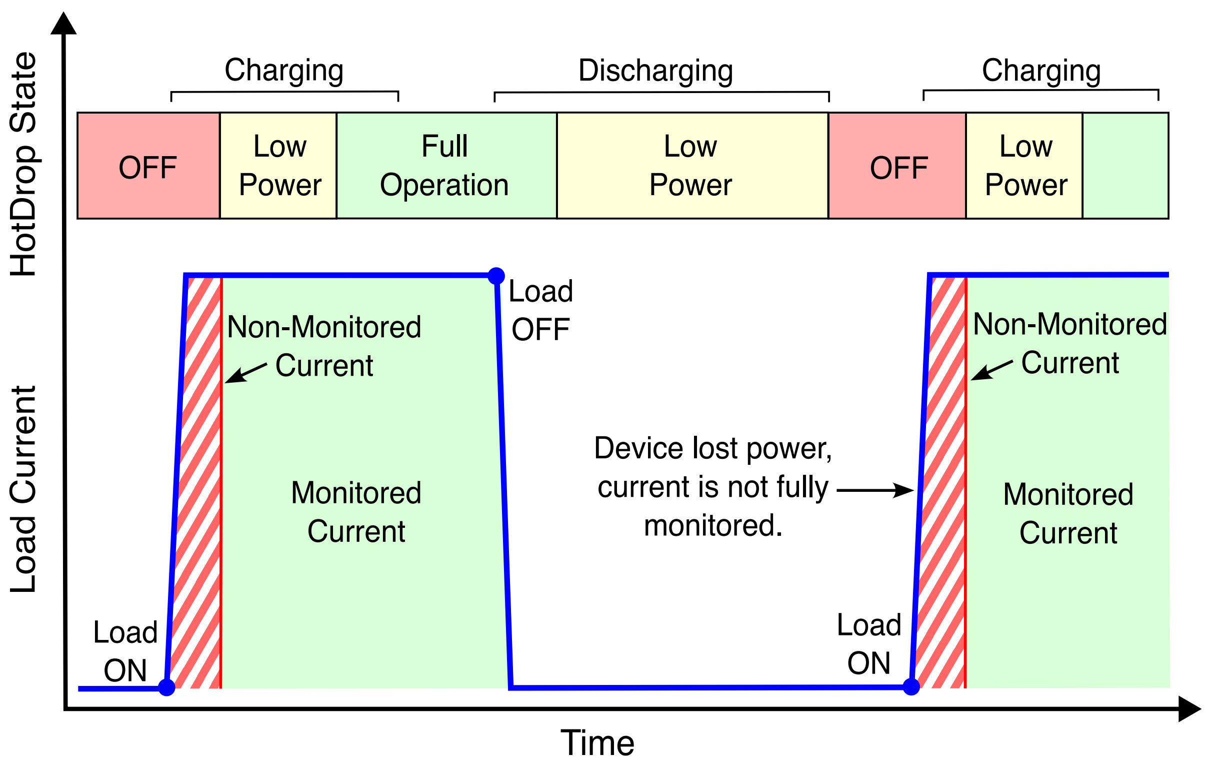


6.2.3 Long Load Interruptions

The HotDrop will shut down completely if an outage is long enough that the capacitor becomes fully discharged. When current is restored, the device must undergo the initial charge period again before it can resume normal operation. During this time, circuit current is not monitored until the capacitor reaches the minimum operating threshold.

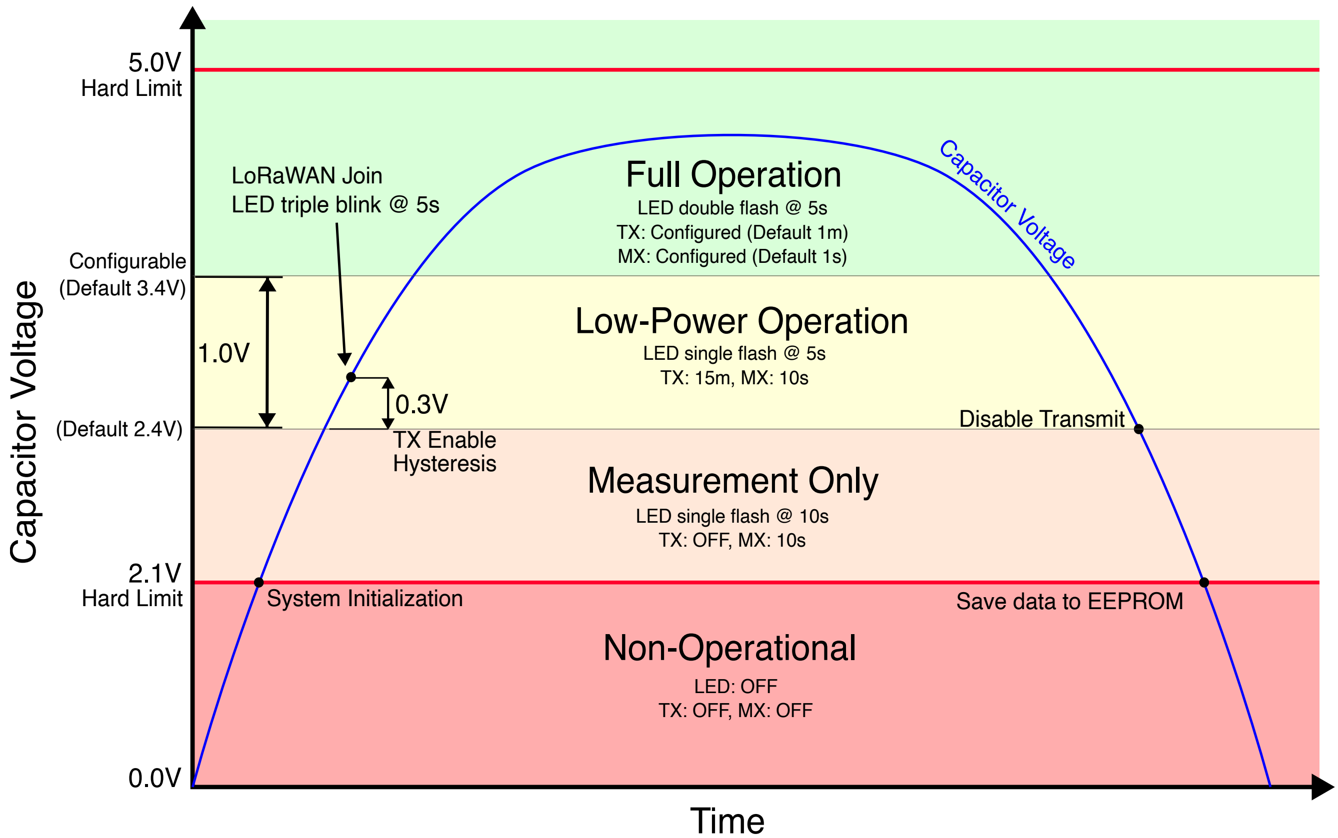
If HotDrop is used to monitor periodic loads where extended outages are common, it is recommended to supply external power via a 5V micro USB connection. This is only necessary when accurate amp-hour totalization is required, as it ensures continuous uninterrupted operation.

See section 8: Appendix - Discharge Time for information on the holdover time of the HotDrop.



6.3 Capacitor Voltage Power States

The rate at which the internal capacitor is charged and discharged depends on the current flowing through the monitored circuit and the configuration of the HotDrop. In order to prevent the device from unexpectedly losing power while operating (causing data loss), the HotDrop uses tiered power modes to regulate consumption of high power systems. These power modes and thresholds are described in the following:



Event	Description
System Initialization	The HotDrop measurement circuitry requires a minimum of 2.1V to operate. Once the capacitor has charged to this value, the device initializes and begins measurement (MX), but does not currently have enough energy to operate the LoRaWAN radio.
Transmit (TX) Enable	The capacitors contain enough energy to power the radio circuits without immediately draining the supply. The device will begin the LoRaWAN joining process and transmit data at a reduced rate to conserve energy.

Capacitor Voltage Power States (Continued)

Event	Description
Full Operation	Enough energy is stored that the device can transmit and measure at full speed. The rates of transmit and measurement are configurable by LoRaWAN downlink.
Low Power Operation	The device is not harvesting enough energy to maintain full operation. To prevent the device from unexpectedly losing power due to high consumption, the rate of transmit and measurements are reduced. This extends the operational limits of the HotDrop.
Transmit Disable	There is no longer sufficient energy to operate the radio without interfering with the measurement circuitry. The HotDrop will continue to monitor and record data, but will no longer transmit updates until increased power is available.
System Shutdown	Below the 2.1V limit, proper operation of the measurement circuitry is no longer guaranteed and the device shuts down. When crossing this limit the device saves measurement values to an EEPROM storage device to prevent data loss.

6.4 Externally Powered Behavior

The HotDrop can be powered by connecting a 5 Volt supply to its micro USB port. When external power is applied, the device's internal capacitors charge rapidly regardless of whether current is flowing through the monitored circuit. This feature is useful for pre-charging the device during installation or for maintaining data reporting in the absence of load current.

During startup, the HotDrop checks for the presence of external power. If detected, it immediately enters full operation, even if the capacitors are not yet fully charged. This check occurs only at power-on. If external power is applied to an already operational HotDrop it will continue to transition through power states based on the capacitor charge level.

If external power is removed before the capacitors have reached sufficient charge, the device may shut off abruptly. To ensure uninterrupted operation after disconnecting external power, it is recommended that the connection be maintained for at least 30-60 seconds to allow the capacitors to charge.

6.5 Common Issues and Resolutions

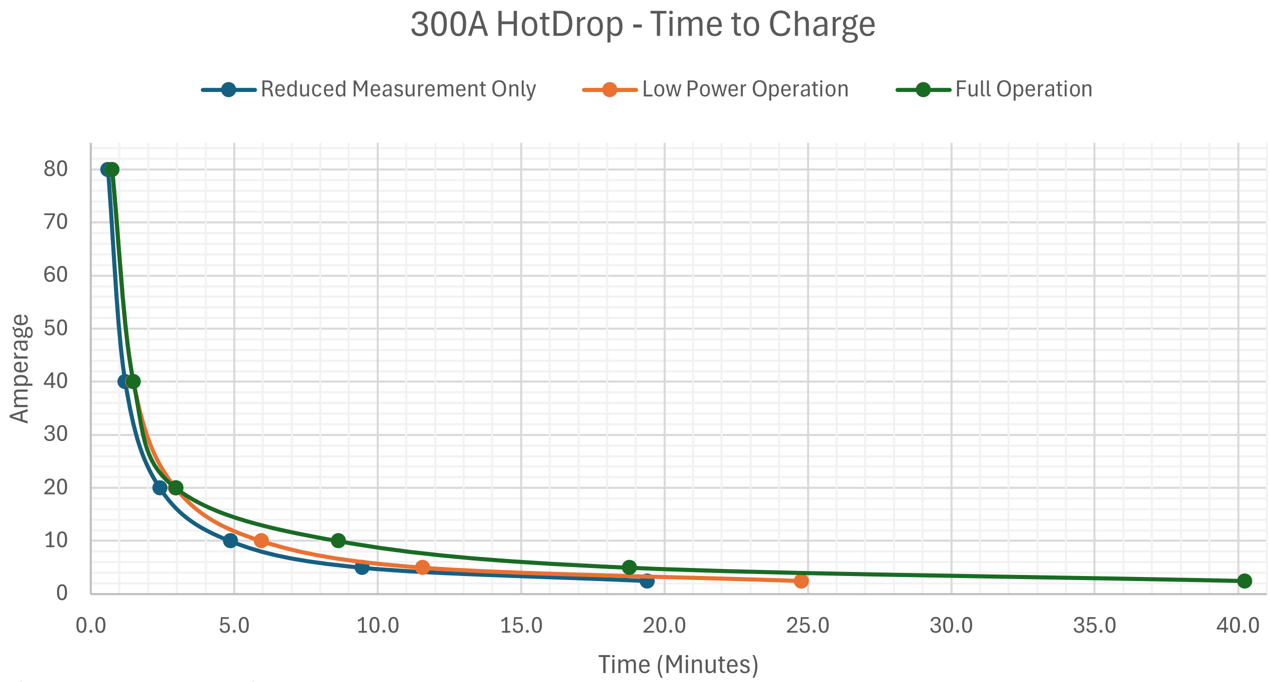
Issue	Cause	Resolution
HotDrop Not Operating	Insufficient circuit current or initial charging period	The HotDrop does not have sufficient power to operate. This may be a temporary state while the capacitor initially charges, or there may be insufficient circuit current to maintain a charged state. Check circuit current and proper CT closure.
Inaccurate Low-Scale Readings	Metered value below 1% of sensor rating	Sensor accuracy decreases in the extreme low-end range. Use an appropriately sized device for the system.
Inaccurate Amp-Hour Totalization	Periodic loads with long inactive time	Each time the HotDrop restarts due to insufficient current, there is an unmonitored initial charging period. These can aggregate into large offsets for loads that cycle routinely. Consider externally powering the HotDrop over USB.
No Data Reported (Three Status Light Flashes)	Device not joined to a LoRaWAN network	Check the device onboarding to the LoRaWAN network server. Ensure that the antenna is screwed on completely. Reposition the HotDrop antenna and/or gateway to increase signal strength.
No Data Reported (Two Status Light Flashes)	LoRaWAN communication unreliable	The device has joined the LoRaWAN network but there is insufficient signal strength for reliable communication, or significant interference from other wireless or electrical systems. Reposition the HotDrop antenna and/or gateway to increase signal strength.
No Data Reported (One Status Light Flash @ 5s)	Device in low-power transmit mode	The device has insufficient power to maintain full rate transmit. Data will be sent once every 15 minutes. Check circuit current and proper CT closure.
No Data Reported (One Status Light Flash @ 10s)	Device in low-power measurement-only mode	The device has insufficient power to transmit and is measuring and recording data only. Check circuit current and proper CT closure.

Common Issues and Resolutions (Continued)

Issue	Cause	Resolution
HotDrop Resets Periodically	Failing LoRaWAN link check (i.e. LinkCheckReq & LinkCheckAns)	The device cannot reliably communicate with the LoRaWAN gateway and is failing consecutive connection checks. This causes a two-hour reset interval. Reposition the HotDrop antenna and/or gateway to increase signal strength.

7 Appendix - Charge Time and Current

7.1 300A



Time to Operation (Minutes)

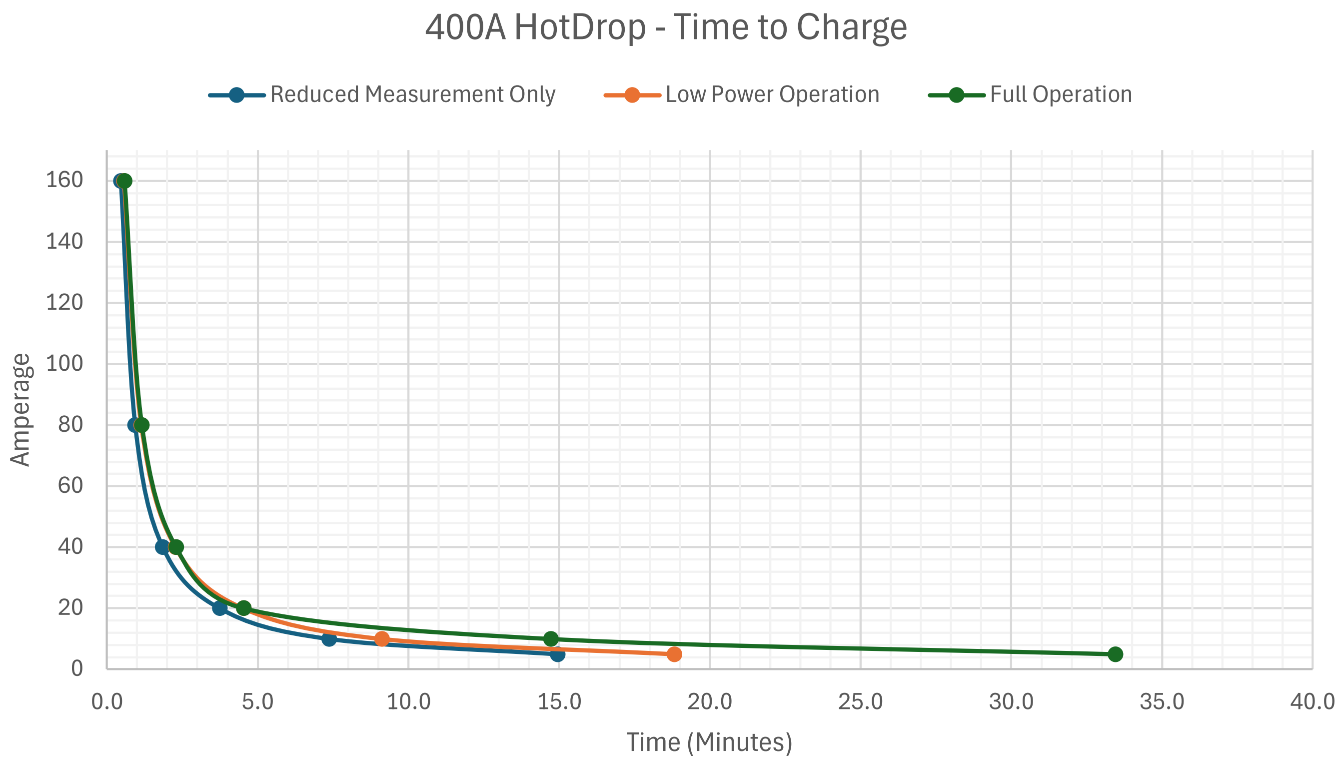
Amperage	Measurement Only	Low Power Operation	Full Operation[1]
80A	0.6	0.7	0.7
40A	1.2	1.5	1.5
20A	2.4	2.9	3.0
10A	4.9	5.9	8.6
5A	9.5	11.6	18.8
2.5A	19.4	24.8	40.2

Electric Charge to Operation (Amp-Hours)

<table>
<tr><th>Amperage</th><th>Measurement Only</th><th>Low Power Operation</th><th>Full Operation[1]</th></tr>
<tr><td>80A</td><td rowspan="6">0.8</td><td rowspan="6">1.0</td><td rowspan="3">1.0</td></tr>
<tr><td>40A</td></tr>
<tr><td>20A</td></tr>
<tr><td>10A</td><td rowspan="3">1.6</td></tr>
<tr><td>5A</td></tr>
<tr><td>2.5A</td></tr>
</table>

[1] At sufficient input current the HotDrop bypasses intermediate capacitor voltage requirements for entering full power operation.

7.2 400A



Time to Operation (Minutes)

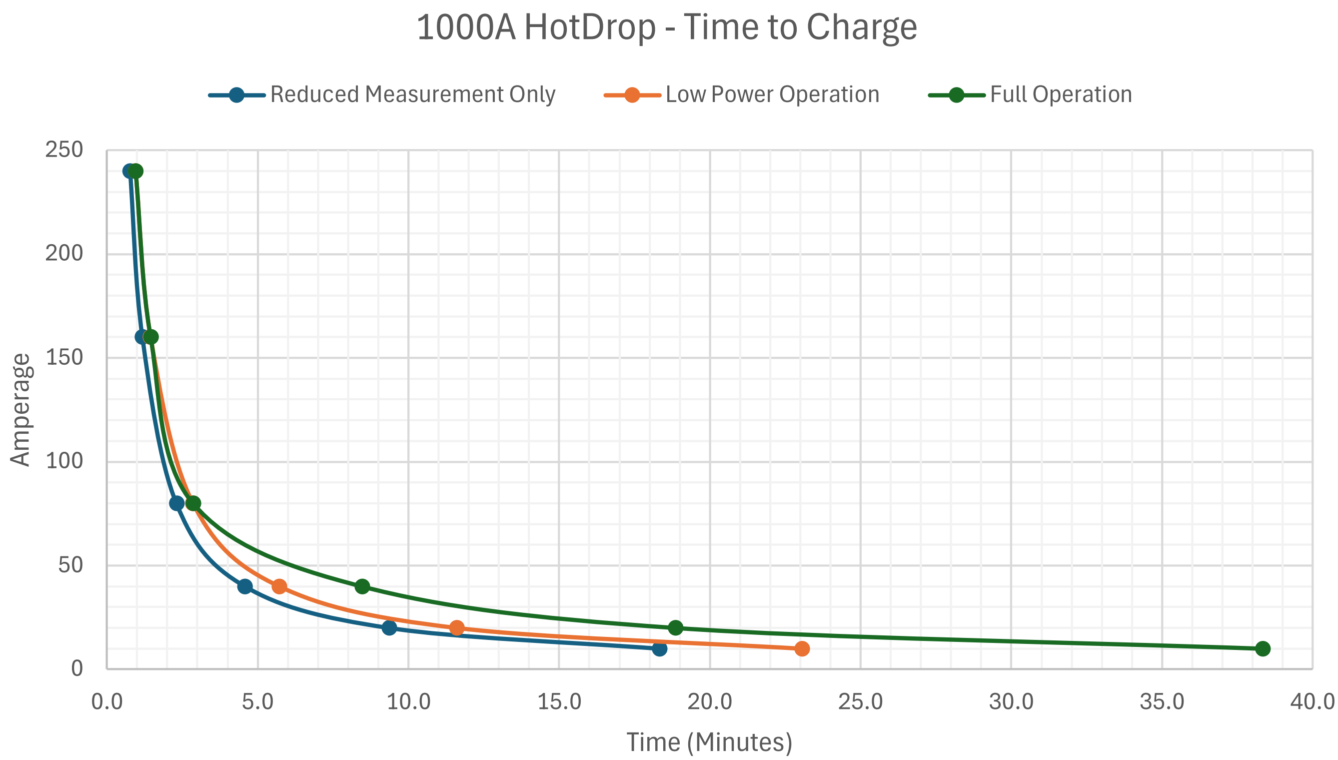
Amperage	Measurement Only	Low Power Operation	Full Operation[1]
160A	0.5	0.6	0.6
80A	0.9	1.1	1.2
40A	1.9	2.3	2.3
20A	3.7	4.5	4.5
10A	7.4	9.1	14.7
5A	15.0	18.8	33.5

Electric Charge to Operation (Amp-Hours)

<table>
<tr><th>Amperage</th><th>Measurement Only</th><th>Low Power Operation</th><th>Full Operation[1]</th></tr>
<tr><td>160A</td><td rowspan="6">1.2</td><td rowspan="6">1.5</td><td rowspan="4">1.5</td></tr>
<tr><td>80A</td></tr>
<tr><td>40A</td></tr>
<tr><td>20A</td></tr>
<tr><td>10A</td><td rowspan="2">2.6</td></tr>
<tr><td>5A</td></tr>
</table>

[1] At sufficient input current the HotDrop bypasses intermediate capacitor voltage requirements for entering full power operation.

7.3 1000A



Time to Operation (Minutes)

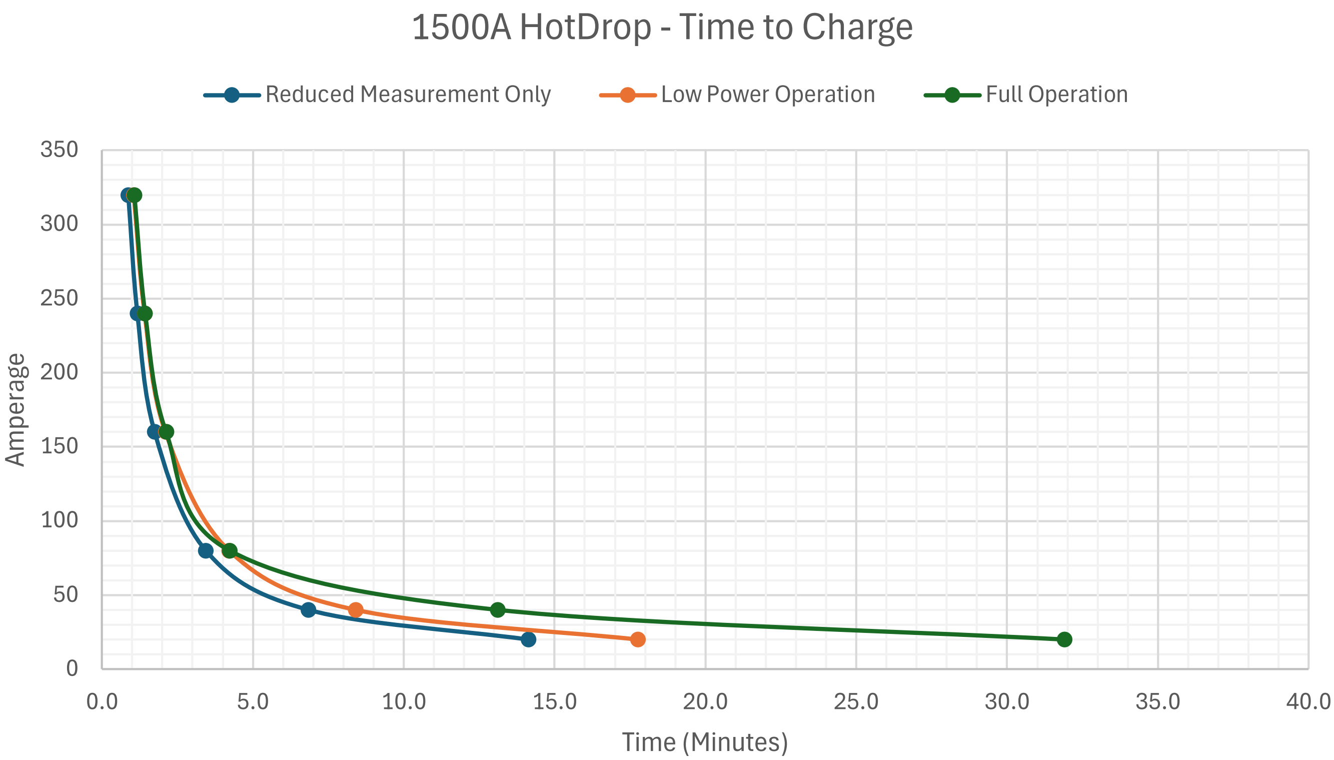
Amperage	Measurement Only	Low Power Operation	Full Operation[1]
240A	0.8	0.9	1.0
160A	1.2	1.4	1.5
80A	2.3	2.8	2.9
40A	4.6	5.7	8.5
20A	9.4	11.6	18.9
10A	18.3	23.1	38.3

Electric Charge to Operation (Amp-Hours)

<table>
<tr><th>Amperage</th><th>Measurement Only</th><th>Low Power Operation</th><th>Full Operation[1]</th></tr>
<tr><td>240A</td><td rowspan="6">3.1</td><td rowspan="6">3.8</td><td rowspan="3">3.8</td></tr>
<tr><td>160A</td></tr>
<tr><td>80A</td></tr>
<tr><td>40A</td><td>5.6</td></tr>
<tr><td>20A</td><td rowspan="2">6.3</td></tr>
<tr><td>10A</td></tr>
</table>

[1] At sufficient input current the HotDrop bypasses intermediate capacitor voltage requirements for entering full power operation.

7.4 1500A



Time to Operation (Minutes)

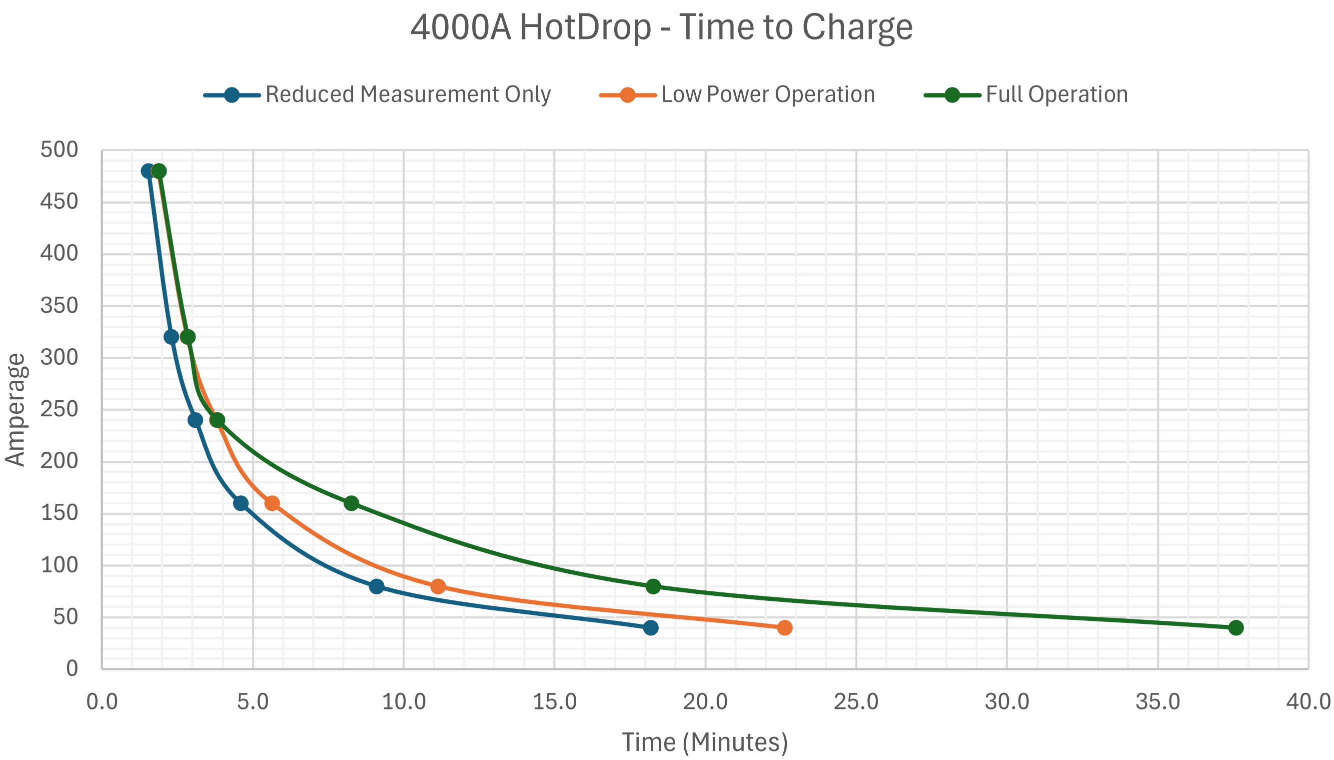
Amperage	Measurement Only	Low Power Operation	Full Operation[1]
320A	0.9	1.1	1.1
240A	1.2	1.4	1.4
160A	1.7	2.1	2.1
80A	3.4	4.2	4.2
40A	6.8	8.4	13.1
20A	14.1	17.8	31.9

Electric Charge to Operation (Amp-Hours)

<table>
<tr><th>Amperage</th><th>Measurement Only</th><th>Low Power Operation</th><th>Full Operation[1]</th></tr>
<tr><td>320A</td><td rowspan="6">4.6</td><td rowspan="6">5.7</td><td rowspan="4">5.7</td></tr>
<tr><td>240A</td></tr>
<tr><td>160A</td></tr>
<tr><td>80A</td></tr>
<tr><td>40A</td><td>8.7</td></tr>
<tr><td>20A</td><td>10.6</td></tr>
</table>

[1] At sufficient input current the HotDrop bypasses intermediate capacitor voltage requirements for entering full power operation.

7.5 4000A



Time to Operation (Minutes)

Amperage	Measurement Only	Low Power Operation	Full Operation[1]
480A	1.5	1.9	1.9
320A	2.3	2.8	2.8
240A	3.1	3.8	3.8
160A	4.6	5.6	8.3
80A	9.1	11.1	18.3
40A	18.2	22.6	37.6

Electric Charge to Operation (Amp-Hours)

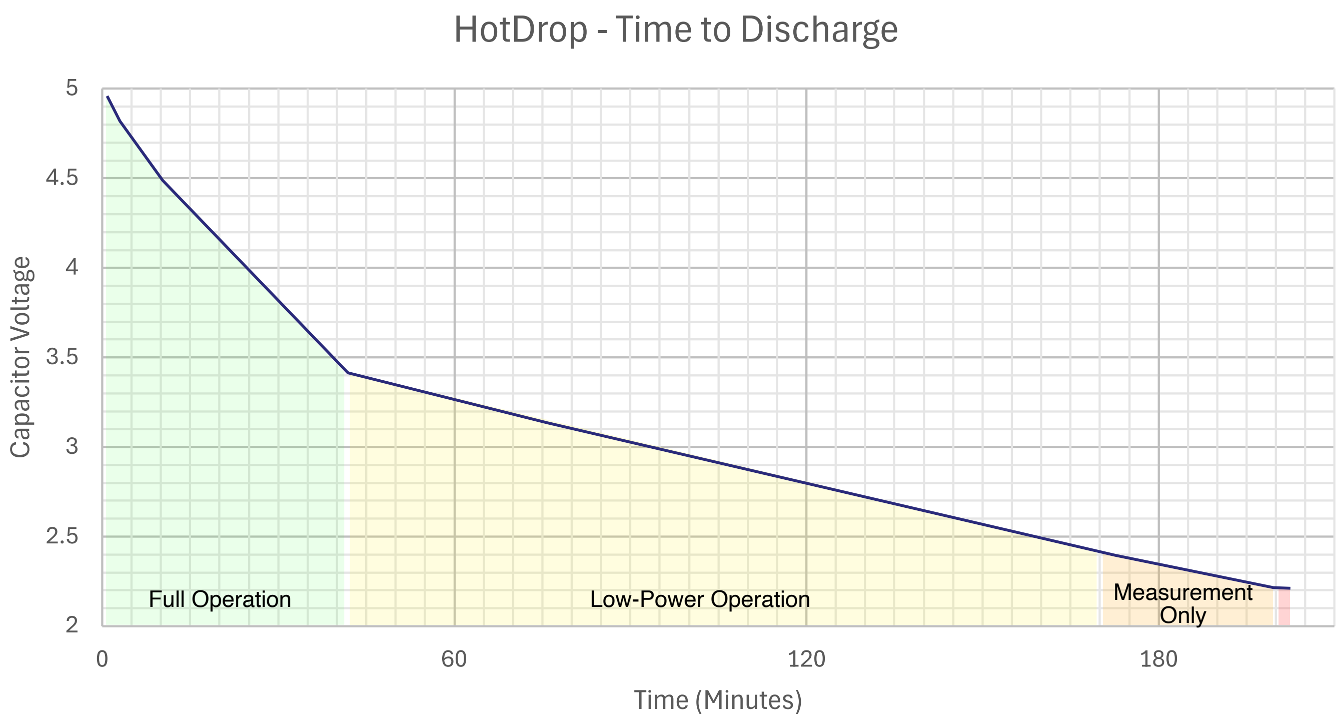
<table>
<tr><th>Amperage</th><th>Measurement Only</th><th>Low Power Operation</th><th>Full Operation[1]</th></tr>
<tr><td>480A</td><td rowspan="6">12.2</td><td rowspan="6">15.0</td><td rowspan="3">15.2</td></tr>
<tr><td>320A</td></tr>
<tr><td>240A</td></tr>
<tr><td>160A</td><td>22.0</td></tr>
<tr><td>80A</td><td>24.4</td></tr>
<tr><td>40A</td><td>25.1</td></tr>
</table>

[1] At sufficient input current the HotDrop bypasses intermediate capacitor voltage requirements for entering full power operation.

8 Appendix - Discharge Time

Discharge testing was conducted on devices with fully charged capacitors (5.0V), default power thresholds, zero circuit current, and a one-minute transmit interval. All HotDrop models exhibit identical discharge behavior under these conditions.

For partially charged devices, discharge time can be estimated by referencing the corresponding capacitor voltage on the discharge curve.



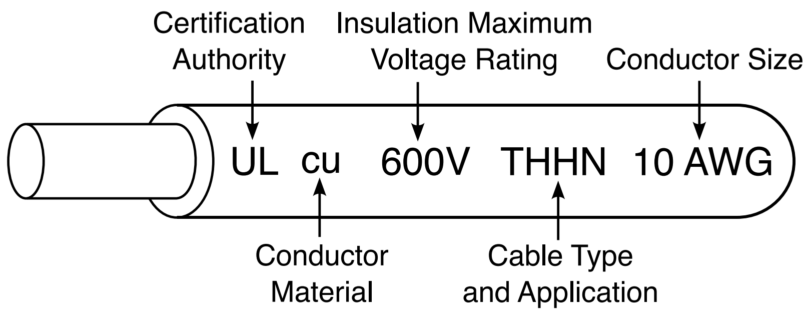
Time to Discharge

State	Duration in State	Transmit Behavior
Full Operation	42 minutes	1 minute (configurable)
Low Power Operation	128 minutes	15 minutes
Measurement Only	30 minutes	None

Total Until Shutdown	200 minutes (3 hours, 20 minutes)

9 Appendix - Conductor Sizing

Electrical wires are labeled with standardized markings that provide critical information about their construction and intended application. These markings typically include the wire type, voltage rating, wire gauge, and the conductor material. This labeling ensures proper selection, code compliance, and safe installation across a wide range of electrical applications.



The outer diameter of an electrical wire is influenced by several key factors, each directly related to the markings and specifications found on the wire:

- Wire Gauge (AWG or kcmil)
  - The larger the wire size, the thicker the cable. For example, a 10 AWG wire has a significantly smaller conductor cross-section than a 4/0 wire or 500 kcmil cable. As the conductor size increases, more material is needed, which directly increases the outer diameter.
- Conductor Material (Copper vs. Aluminum)
  - Aluminum has lower conductivity than copper, so a larger diameter conductor is required to carry the same current. This means aluminum conductors generally result in cables with larger outer diameters than their copper counterparts at the same current rating.
- Insulation Type (e.g., THHN, XHHW, RHW)
  - Different insulation materials have different thickness requirements and thermal properties. For instance, XHHW insulation is typically thicker than THHN, resulting in a larger outer diameter even for the same gauge and conductor material.
- Voltage Rating
  - Higher voltage ratings often require thicker insulation layers to maintain dielectric strength and prevent breakdown. A 1,000V-rated cable will generally have a larger outer diameter than a 600V-rated cable of the same gauge and type.

- Wire Construction (Solid vs. Stranded)
  - Stranded conductors consist of many small wires twisted together and require more space and insulation than a solid conductor. This adds to the cable's overall diameter, especially in flexible or high-strand-count designs.

In situations where a conductor's type, gauge and other ratings cannot be directly determined. It may be nessesary to measure the outer diameter using a non-conductive tool or upsize the HotDrop to ensure proper fit.

9.1 Common Conductor Specifications

The following chart is based off of 600V THHN/THWN PVC insulation with a Nylon outer jacket per UL standard 83. These values are minimums permitted and may not be characteristic of all cable manufacturers. Nylon jacketing is assumed to be 0.005" (5 mils) and included in the insulation thickness.

Ampacity ratings are per the 2023 NEC Table 310.16 with an ambient temperature of 30°C.

Wire Size	**Outer Diameter**		**75°C Ampacity**	
AWG/kcmil	**Copper**	**Aluminum**	**Copper**	**Aluminum**
14	0.111" (2.82mm)	–	15A	–
12	0.130 (3.30mm)	–	20A	–
10	0.164 (4.17mm)	–	30A	–
8	0.185" (4.70mm)	0.200" (5.08mm)	50A	40A
6	0.210" (5.33mm)	0.232" (5.89mm)	65A	50A
4	0.255" (6.48mm)	0.275" (6.99mm)	85A	65A
2	0.305" (7.75mm)	0.335" (8.51mm)	115A	90A
1	0.340" (8.64mm)	0.370" (9.40mm)	130A	100A
1/0	0.380" (9.65mm)	0.420" (10.67mm)	150A	120A

Conductor Sizing (Continued)

Wire Size	**Outer Diameter**		**75°C Ampacity**	
AWG/kcmil	**Copper**	**Aluminum**	**Copper**	**Aluminum**
2/0	0.420" (10.67mm)	0.465" (11.81mm)	175A	135A
3/0	0.470" (11.94mm)	0.515" (13.08mm)	200A	155A
4/0	0.525" (13.34mm)	0.575" (14.61mm)	230A	180A
250	0.590" (14.99mm)	0.640" (16.26mm)	255A	205A
350	0.655" (16.64mm)	0.715" (18.16mm)	310A	250A
500	0.745" (18.92mm)	0.820" (20.83mm)	380A	310A
600	0.805" (20.45mm)	0.885" (22.48mm)	420A	340A
750	0.895" (22.73mm)	0.975" (24.77mm)	475A	385A
1000	1.030" (26.16mm)	1.110" (28.19mm)	545A	445A

10 Appendix - Wiring Color Codes

This appendix contains common wiring codes used across many countries. Note that these colors define convention, and may not represent all systems depending on age, local region, or quality of prior work.

> **WARNING**
>
> It is strongly recommended that the installer manually verify and determine conductor topology prior to installing the HotDrop. The presence of properly colored conductors does not positively indicate that the system is wired per convention.

10.1 US / Canada - NEC

In general, the National Electric Code (NEC) used in the United States agrees with the Canadian Electric Code (CEC) for wiring colors. However, there are a few minor differences, particularly with single-phase systems.

Supply	Conductor	NEC - US / CANADA (120, 208 & 240V)	NEC - US / CANADA (277 & 480 V)
3-PHASE WYE	LINE 1 "L1" LINE 2 "L2" LINE 3 "L3"	Black Red Blue	Brown Orange Yellow
1-PHASE[1]	LINE 1 "L1" LINE 2 "L2" (SPLIT)	Black[1] Red[1]	
COMMON / NEUTRAL "N"		White	Gray
GROUND / EARTH "PG" or "PE"		Green-Yellow	

[1] Canadian Electric Code (CEC) swaps the colors of L1 and L2 for single-phase systems.

10.2 Europe - IEC and legacy UK

Prior to March 2004, the United Kingdom followed its own wiring color code. The legacy UK color code is still used in many countries such as India, Pakistan, UAE, KSA, and South Africa.

Supply	Conductor	IEC Code	Legacy UK Code
3-PHASE WYE	LINE 1 "L1" LINE 2 "L2" LINE 3 "L3"	Brown Black Gray	Red Yellow Blue
1-PHASE	LINE "L"	Brown	Red
COMMON / NEUTRAL "N"		Blue	Black
GROUND / EARTH "PE"		Green-Yellow	

10.3 Australia and New Zealand

Supply	Conductor	AUS & NZ Code
3-PHASE WYE	LINE 1 "L1" LINE 2 "L2" LINE 3 "L3"	Red White Blue
1-PHASE	LINE "L" (Either color valid)	Red Brown
COMMON / NEUTRAL "N" (Either color valid)		Black Light Blue
GROUND / EARTH "PE" (Either color valid)		Green Green-Yellow

10.4 Japan

Note that 3-phase systems in Japan are Delta and do not have a neutral line.

Supply	Conductor	Japan Code (100 & 200V)
3-PHASE DELTA	LINE 1 "L1" LINE 2 "L2" LINE 3 "L3"	Black Red White[1]
1-PHASE	LINE "L" (Either color valid)	Black Red
COMMON / NEUTRAL "N"		White
GROUND / EARTH "PG"		Green

[1] Three-phase Delta systems do not have a neutral line; white in these contexts indicates "L3".

11 Appendix - Glossary of Terms

Active (Real) Energy	The energy consumed by devices to perform useful work, measured in Watt-hours (Wh).
ADR (Adaptive Data Rate)	A LoRaWAN feature that optimizes data rate and energy use.
CAT III	Overvoltage category defining electrical endurance.
Current Transformer (CT)	A rigid sensor for measuring alternating current.
Dialectric	Separation material between a conductor and environment.
EEPROM	A data storage device for persisting information across power loss.
ETL/UL/CSA	Safety certification boards governing electrical equipment in the USA and Canada.
FCC	Certification board approving use of radio devices in the USA
Feeder Cable	A cable that delivers power from the source to the distribution point.
FPort	A field in a LoRaWAN frame that identifies the application port.
Ground (GND)	A reference point in an electrical circuit from which voltages are measured.
Hysteresis	Threshold that changes depending on direction of input. Prevents rapid toggling back and forth across a limit.
Integer	Synonym for a whole (non fractional) number.
Internet of Things (IoT)	A network of physical devices with embedded sensors and connectivity.
IP54	Ingress Protection rating indicating limited dust and minor water spray protection.
Link Check	Process where a LoRaWAN device sends a request to the LNS to determine if it is still connected to a network.
LNS (LoRaWAN Network Server)	Central server that manages LoRaWAN communication and device data.

LoRaWAN	A long-range, low-power wireless communication protocol.
MCCB	Molded case circuit breaker.
Most-Significant-Byte (MSB)	Indicates the order of how large numbers are broken into binary for transmitting.
Nameplate	Listed or specified rating.
Neutral	A return path for current in a circuit.
Phase	A specific stage in a cycle of alternating current (e.g., L1, L2, L3).
RMS (Root Mean Square)	A statistical measure of the magnitude of a varying quantity (voltage or current).
Signed/Unsigned Number	Determines how positive and negative numbers are represented in binary.
SMA	A radio-frequency connector type used by the HotDrop for the LoRaWAN antenna.
THHN	Thermoplastic High Heat-resistant Nylon-coated wire insulation.
THWN	Thermoplastic Heat and Water-resistant Nylon-coated wire insulation.

12 Revision History

Date	Revision	Change Log
2.22.2024		Initial Release
4.29.2025	A.01	Cleaned up formatting and removed unnecessary verbiage.
TBD	A.02	Majority rewrite, removed cloud services sections.