PUMPLOGIC

User Guide

Automated Pump Controller for Arduino Nano ESP32-S3

Temperature-triggered | Schedule-based | Voltage-protected

Web-based control panel accessible via WiFi Access Point at 192.168.4.1

Version 1.0

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Introduction

PumpLogic is an automated pump controller built on the Arduino Nano ESP32-S3. It is designed for solar-powered or battery-powered installations where a pump must run on a schedule while protecting the battery from over-discharge.

PumpLogic controls a pump relay based on **three conditions** that must all be met simultaneously:

Condition	What It Checks
Temperature	Current reading is at or above the configured trigger threshold
Schedule	Current time falls within the configured operating window
Voltage	Battery voltage is at or above the low voltage cutoff

When all three conditions are satisfied, PumpLogic energizes the relay for a configurable ON duration, de-energizes for a configurable OFF duration, and repeats. If any condition fails, the pump will not start a new cycle.

Key capabilities:

- Separate weekday and weekend operating schedules
- Optional blackout window to block pump operation during specific hours
- Low voltage lockout with sustained charge recovery
- Daily min/max temperature and voltage tracking
- Daily and lifetime pump runtime counters
- Battery percentage estimation for Lead-Acid and LiFePO4 batteries
- 24-hour battery charge/discharge graph with 15-minute intervals
- Voltage trend indicator (rising, falling, stable)
- Event log with up to 100 entries
- Hardware watchdog timer for unattended reliability
- Web-based control panel accessible from any device with a browser

PumpLogic hosts its own WiFi network (Access Point mode) and serves a complete control panel from the device itself — no internet connection or external server required.

Quick Start

1. Power on the PumpLogic controller

2. Connect to WiFi — On your phone or computer, join the network named **PumpLogic** (no password by default)

3. Open a browser — Navigate to **http://192.168.4.1** or **http://pumplogic.local**

4. Review the Status card — Confirm temperature, voltage, and relay state are displaying

5. Configure settings — Expand the Settings card, adjust values for your installation, and press **Save Settings**

6. Verify operation — Use the Manual Control card to test Force ON and confirm the relay clicks

PumpLogic begins automatic operation immediately. The pump will cycle ON and OFF whenever all three conditions (temperature, schedule, voltage) are met.

Connecting to PumpLogic

WiFi Connection

1. On your phone, tablet, or computer, open **WiFi settings**

2. Look for the network named **PumpLogic** (this is the default; the name may differ if changed in settings)

3. Connect to the network (no password by default; a password can be set in settings)

4. Open a web browser and navigate to:

• **http://192.168.4.1** (always works), or

• **http://pumplogic.local** (mDNS — works on iPhones, Macs, and most computers)

The PumpLogic control panel will load in your browser.

Important Notes

• PumpLogic creates its **own WiFi network** (Access Point mode). It does not join your home or office WiFi.

• Only devices connected to PumpLogic's WiFi network can access the control panel.

• **You will not have internet access** while connected to PumpLogic's network.

• The IP address is always **192.168.4.1**.

• **mDNS support:** iPhones, iPads, Macs, Windows, and most Linux computers support **http://pumplogic.local**. Android devices may have limited mDNS support — use the IP address instead.

• **Range:** The ESP32-S3 Access Point typically covers 10–30 meters indoors. Move closer if you have trouble connecting.

Understanding the Web Interface

Interface Layout and Navigation

The web interface is organized into **seven cards** stacked vertically. Each card serves a distinct purpose:

Card	Purpose	Collapsible?	Default State
Status	Real-time monitoring dashboard	No	Always visible
Charge Recovery	Charge progress during lockout	No	Hidden (appears only during lockout)
Manual Control	Direct relay and system controls	Yes	Collapsed
Network	WiFi, mDNS, uptime, and clock info	Yes	Collapsed
Battery Charge/Discharge	24-hour battery percentage graph	Yes	Collapsed
Settings	All configurable parameters	Yes	Collapsed
Event Log	History of pump runs and events	Yes	Collapsed

Expanding and collapsing cards: Click the **arrow button** in the upper-right corner of any collapsible card header to toggle it open or closed.

Expand/Close All: Inside the Settings card, a button next to Save Settings lets you expand or collapse all collapsible cards at once.

Refreshing data: The Status card includes a **Refresh button** that fetches the latest sensor readings from the device on demand. The Status card also auto-refreshes every 30 seconds.
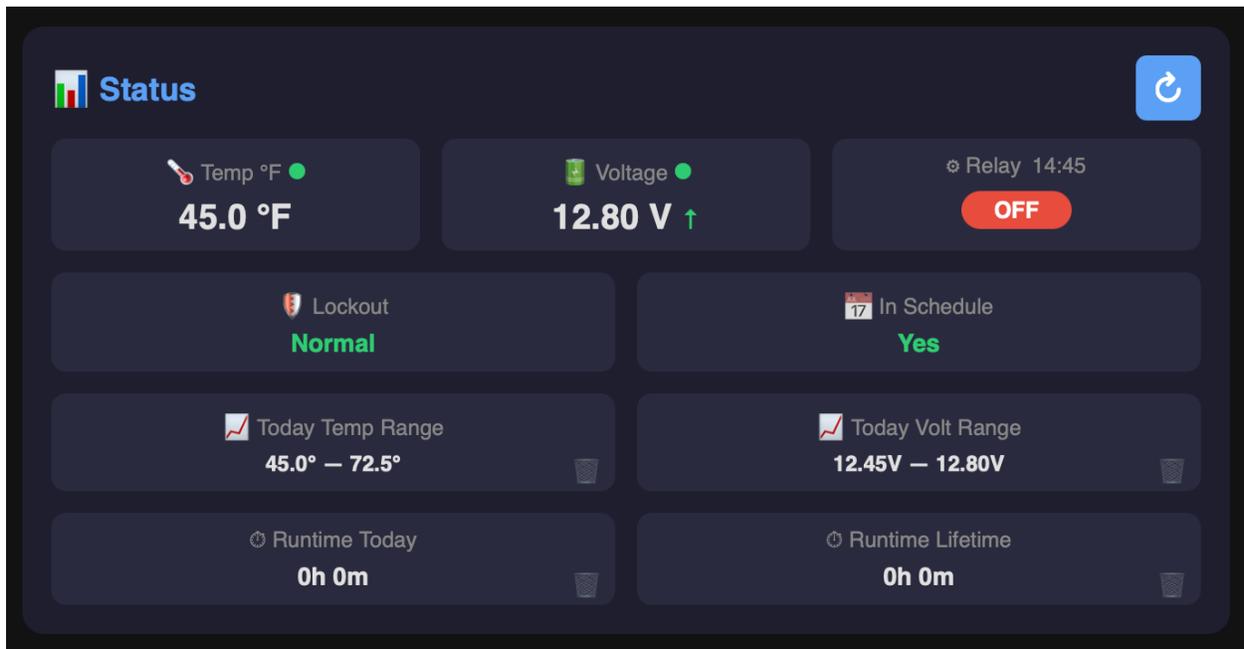
Status Card — The Main Dashboard

Figure: Status card showing sensor readings and system state

!Status Card

The Status card is the primary monitoring view. It is always visible and organized into four rows.

Row 1 — Sensor Readings and Relay State

Three equally spaced indicators across the full width:

Temperature (Temp °F)

Element	What It Means
Number (e.g., "45.0 °F")	The current reading from the DS18B20 temperature sensor
Green dot	Temperature is **at or above** the trigger threshold — condition met
Red dot	Temperature is **below** the trigger threshold — condition not met
"Error"	The sensor is disconnected or unresponsive

Voltage

Element	What It Means
Number (e.g., "12.80 V")	The current battery voltage reading
Green dot	Voltage is **above** the low voltage cutoff — condition met

Element	What It Means
Red dot	Voltage is **at or below** the cutoff — lockout may trigger
Trend arrow ↑ (green)	Voltage is **rising** (increased by more than 0.1V since the last reading)
Trend arrow ↓ (red)	Voltage is **falling** (decreased by more than 0.1V since the last reading)
Trend arrow → (gray)	Voltage is **stable** (within ±0.1V of the last reading)

Relay

Element	What It Means
Green **ON** badge	Relay is energized — the pump is running
Red **OFF** badge	Relay is de-energized — the pump is stopped
Countdown timer (e.g., "8:32")	Time remaining in the current ON or OFF cycle

When the countdown reaches zero, the status card automatically refreshes to show the new cycle state.

Row 2 — Lockout and Schedule Status

Two equally spaced indicators:

Lockout

Display	Meaning
Green **"Normal"**	System is operating normally — no voltage issues
Red **"LOW VOLTAGE LOCKOUT"**	Pump is disabled due to low battery voltage. The Charge Recovery card will appear.

In Schedule

Display	Meaning
Green **"Yes"**	Current time is within the active operating schedule
Red **"No"**	Current time is outside the operating schedule
Yellow **"Blackout"**	Current time is within the blackout window — pump blocked

The system automatically uses the weekend schedule on Saturdays and Sundays.

Row 3 — Daily Min/Max Tracking

Indicator	Description
Today Temp Range	The lowest and highest temperature readings recorded today (e.g., "28.5° — 47.2°")
Today Volt Range	The lowest and highest voltage readings recorded today (e.g., "11.92V — 13.45V")

Both ranges reset automatically at midnight. A small reset button (trash icon) in the bottom-right corner of each stat lets you manually reset the range.

Row 4 — Runtime Counters

Indicator	Description
Runtime Today	Total pump-on time today, displayed as hours and minutes (e.g., "2h 15m"). Resets at midnight.
Runtime Lifetime	Total cumulative pump-on time since first use (e.g., "148h 32m"). Persists across reboots. Stored in non-volatile memory.

Each counter has a small reset button (trash icon) in the bottom-right corner for manual reset.

Status Card During Lockout

When a low-voltage lockout is active, the Status card layout changes:

• **Row 1** expands to five columns: Temp, Voltage, Relay, Lockout, and In Schedule — showing all critical indicators at a glance

• **Rows 3–4** (min/max tracking and runtime) are hidden to keep the display focused on the lockout situation
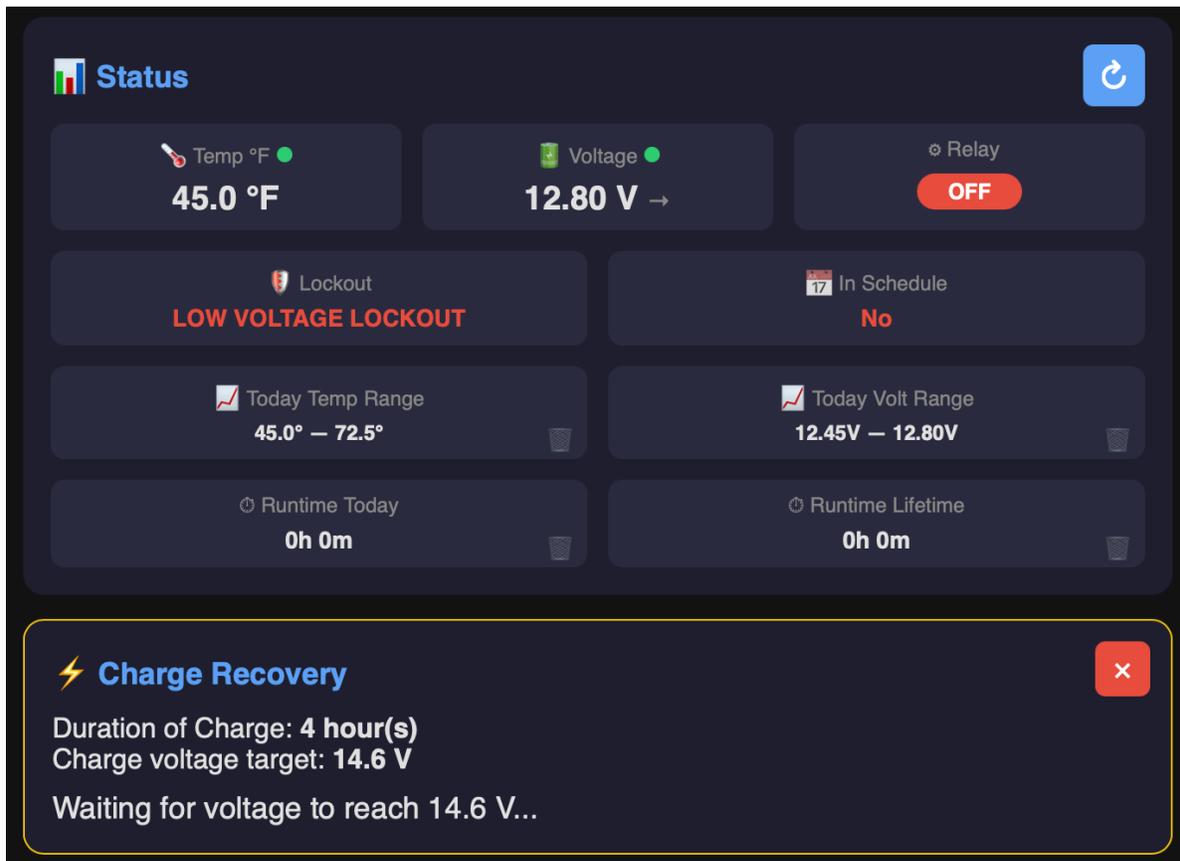
Charge Recovery Card

Figure: Charge Recovery card with lockout progress

!Charge Recovery Card

This card **only appears** when a low-voltage lockout is active. It provides real-time progress of the charge recovery process.

Field	Description
Duration of Charge	Total hours required at or above the charge voltage (e.g., "4 hour(s)")
Charge voltage target	The minimum voltage required to count toward charge recovery (e.g., "14.6 V")
Status	Shows "Waiting for voltage to reach XX.X V..." until voltage meets the target, then shows "Charging..." with a countdown timer
Countdown timer	Displays remaining time in H:MM:SS format. Counts down in real time. Resets if voltage drops below the charge target.

A red **X** button in the upper-right corner cancels the charge recovery and immediately resumes normal operation. See the Charge Recovery section for full details.
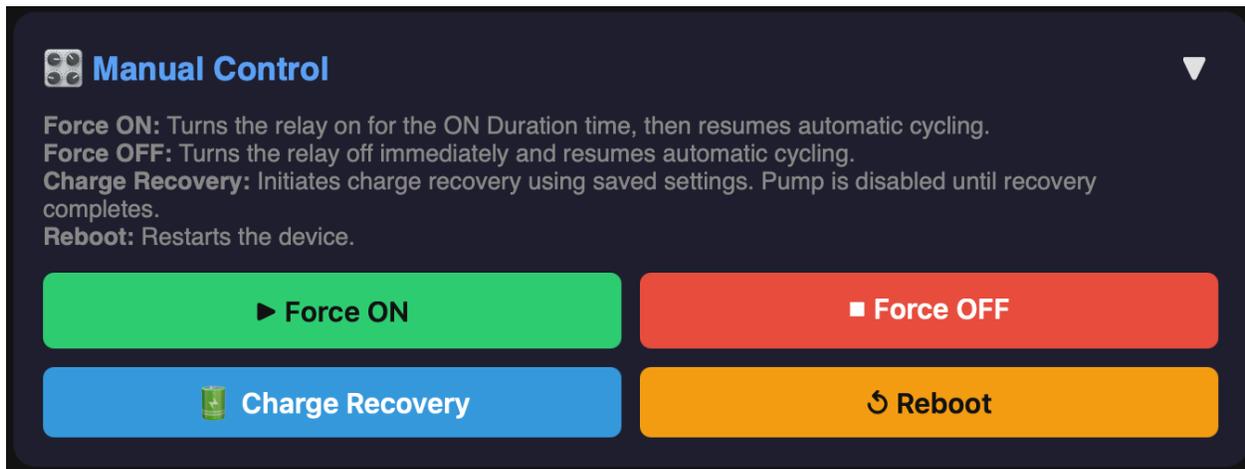
Manual Control Card

Figure: Manual Control buttons

!Manual Control Card

A collapsible card providing direct control over the pump and system. A brief description of each action is displayed at the top, followed by four buttons in a 2x2 grid:

| Button	What It Does
Force ON	Immediately turns the pump ON for the configured ON Duration, regardless of conditions. After the ON duration elapses, PumpLogic logs the run and resumes automatic cycling.
Force OFF	Immediately turns the pump OFF and resumes automatic cycling. The OFF duration timer begins counting down.
Charge Recovery	Manually initiates charge recovery. A confirmation dialog appears first. The pump is disabled until the charge recovery requirements are met. The event is logged.
Reboot	Restarts the device. A confirmation dialog appears first. After rebooting, reconnect to WiFi and reload the page.

Network Card
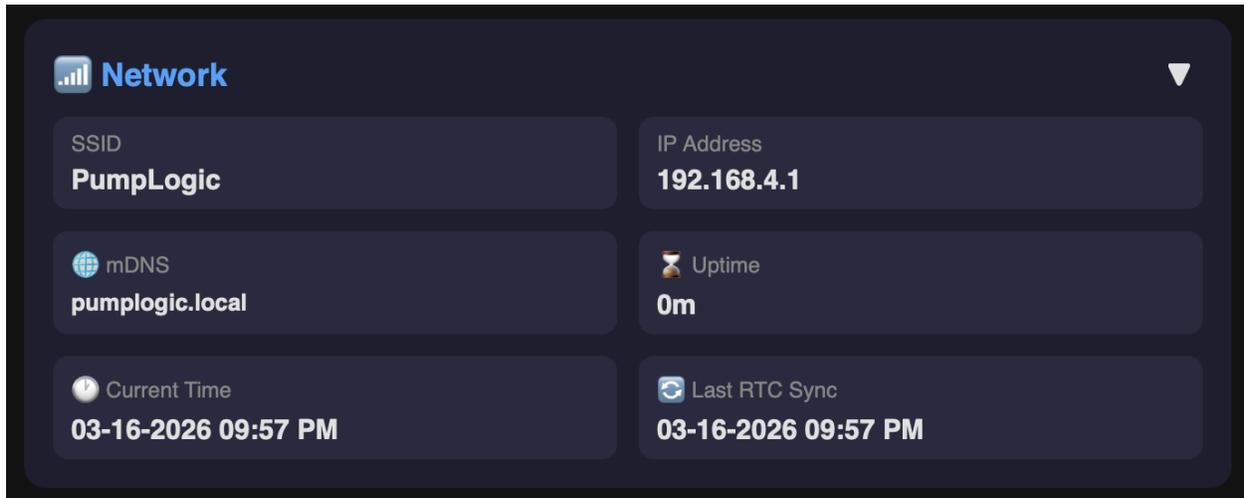
Figure: Network card showing connectivity and time info

!Network Card

A collapsible card displaying connectivity, system, and time information in three rows:

	Fields	
	SSID — the WiFi network name being broadcast	**IP Address** — always 192.168.4.1
	mDNS — the hostname (pumplogic.local)	**Uptime** — time since last reboot (days/hours/
	Current Time — live date and time from the synced clock	**Last RTC Sync** — timestamp of the most rece synchronization

All timestamps are displayed in **MM-DD-YYYY HH:MM AM/PM** format.

Time is synced automatically when you load the page if the device has not been synced yet or if the last sync was more than 24 hours ago. See Time Synchronization for details.
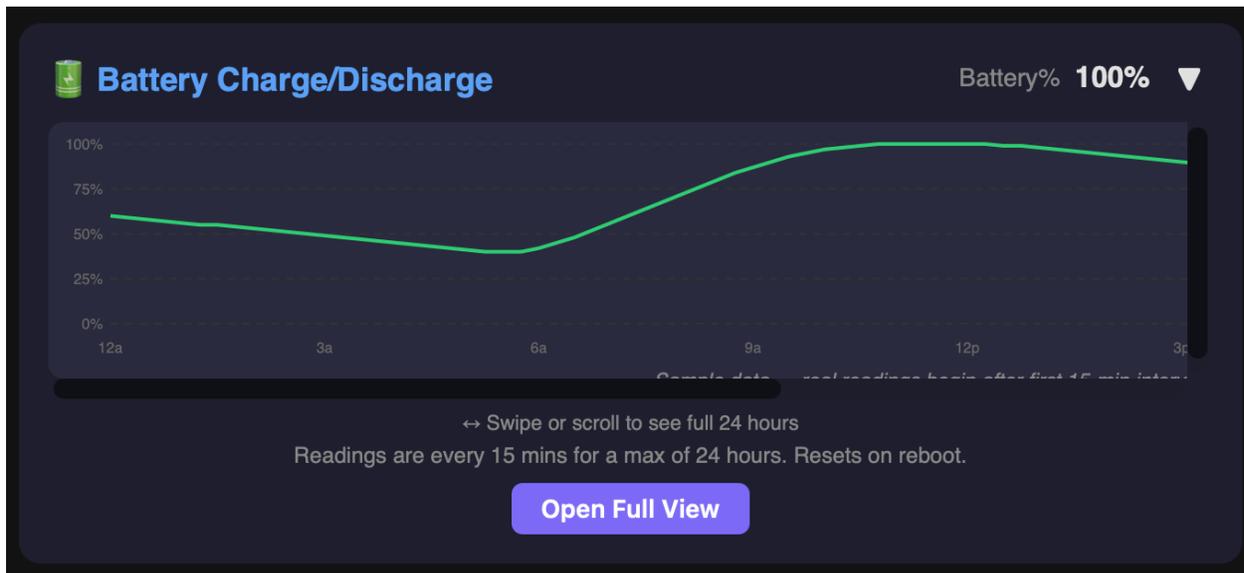
Battery Charge/Discharge Card

Figure: Battery Charge/Discharge card showing 24-hour battery percentage graph

!Battery Charge/Discharge Card

A collapsible card displaying a 24-hour battery percentage line graph. The graph plots battery charge percentage (0–100%) at 15-minute intervals, providing a visual overview of charge and discharge patterns throughout the day.

Element	Description
Battery%	Current battery charge percentage displayed in the card header
Line graph	Green line plotting battery percentage over 24 hours at 15-minute intervals
X-axis labels	Time labels from 12a (midnight) through 12p to 11:45p, shown every 3 hours
Y-axis labels	Percentage scale: 0%, 25%, 50%, 75%, 100%
Current slot dot	Accent-colored dot highlighting the most recent reading on the graph
Sample indicator	Text below graph indicating sample data is displayed (clears after first real reading)
Open Full View	Button that opens the graph in a dedicated full-page view at /battgraph

On initial boot, the graph displays sample data showing a realistic 24-hour charge/discharge cycle. Once the first real battery reading is recorded (after 15 minutes), all sample data is cleared and replaced with actual readings.

The graph is horizontally scrollable within the card — swipe or scroll left/right to see the full 24-hour timeline. Readings are every 15 minutes for a maximum of 24 hours and reset on reboot.

The **Open Full View** button opens the graph in a dedicated full-page view that is optimized for both portrait and landscape viewing on mobile devices.

Settings Card
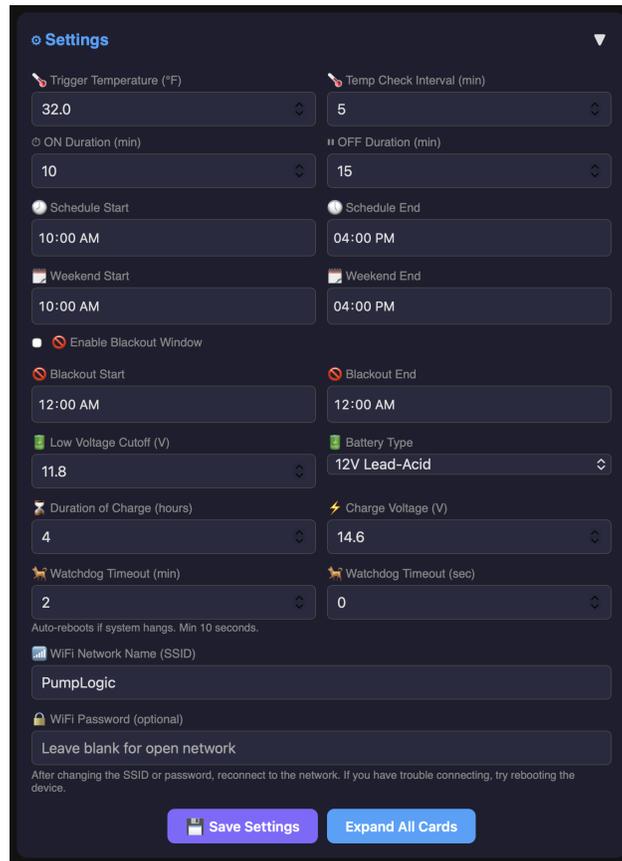
Figure: Settings form with all configurable parameters

!Settings Card

A collapsible card containing all configurable parameters, organized into logical groups. Expand the card, adjust values, and press **Save Settings** to apply changes. Most changes take effect immediately — no reboot required (except for WiFi name/password changes).

The Settings card contains two action buttons at the bottom:

Button	Action
Save Settings	Saves all current values to non-volatile memory. A green toast notification confirms the save.
Expand All Cards / Close All Cards	Toggles all collapsible cards open or closed at once.

See the Settings Reference section for a detailed description of every setting.

Event Log Card

Figure: Event Log showing run history

!Event Log Card

A collapsible card showing a scrollable table of recorded events. Each row includes five columns:

Column	Description
Event	The event type — either "Successful Run" or "Charge Recovery"
Time	When the event occurred (MM-DD-YYYY HH:MM AM/PM)
Temp	Temperature at the time of the event
Voltage	Battery voltage at the time of the event
In Sched	Whether the event occurred within the configured schedule window (Yes/No)

Color coding:

Event Type	Color
Successful Run	All columns displayed in **green** text
Charge Recovery	Event name and voltage in **red** text; remaining columns in white

Storage details:

> • Up to **100 events** are stored using a circular buffer. When full, the oldest entry is overwritten by the newest.
>
> • Entries older than **7 days** are automatically filtered from the display.
>
> • Events are stored in non-volatile memory (14 bytes per entry, 1.4 KB total) and persist across reboots.
>
> • A **Clear All Logs** button at the bottom of the card clears the entire event log.

Toast Notifications

All confirmations and status messages appear as brief, non-blocking toast notifications at the bottom of the screen — not as popup dialogs.

Toast Color	Meaning
Green	Success (e.g., "Settings saved!", "Relay forced ON")
Red	Error (e.g., a failed operation)

Toasts automatically disappear after 3 seconds (10 seconds for reboot messages).

How Automatic Pump Cycling Works

PumpLogic continuously evaluates conditions in its main loop. Here is the decision flow:

Step 1 — Check Manual Override

If a **Force ON** or **Force OFF** is active, automatic logic is skipped:

- **Force ON:** The relay stays on until the ON duration elapses, then normal cycling resumes.
- **Force OFF:** The relay stays off and the OFF duration timer begins.

Step 2 — Periodic Sensor Reads

Sensors are read at configurable intervals. Between reads, the most recent value is cached and used by the decision logic.

Sensor	Interval	Configurable?
Temperature (DS18B20)	Every 5 minutes	Yes — Temp Check Interval
Voltage (ADC)	Every 30 seconds	No — fixed for responsive lockout detection

Step 3 — Low Voltage Lockout Check

If the battery voltage drops below the **Low Voltage Cutoff**:

- The relay is immediately turned OFF
- The event is logged in the Event Log
- The pump cannot run until charge recovery completes (see Charge Recovery)
- All other automatic logic is skipped

Step 4 — ON Cycle Active?

If the relay is currently ON, PumpLogic checks whether the ON duration has elapsed. If yes, it turns the relay OFF, logs the run, and begins the OFF cycle.

Step 5 — OFF Duration Elapsed?

If the relay is OFF, PumpLogic waits for the OFF duration to elapse before evaluating conditions. If the OFF duration has not yet elapsed, no action is taken.

Step 6 — Evaluate Three Conditions

Once the OFF duration has elapsed, all three conditions are evaluated:

Condition	Requirement
Temperature	Sensor reading is valid AND at or above the Trigger Temperature
Schedule	Current time is within the operating window (weekday or weekend, as appropriate) AND not in the blackout window
Voltage	Battery voltage is at or above the Low Voltage Cutoff

- **All three met:** Relay turns ON — a new ON cycle begins.

- **Any condition not met:** Relay stays OFF, the OFF timer resets, and PumpLogic re-evaluates after another OFF duration.

Cycle Example

With default settings (10 min ON, 15 min OFF, 32°F trigger, 10:00–16:00 schedule):

```
10:00 AM — Temperature 35°F, voltage 12.5V → all conditions met → Relay ON
10:10 AM — ON duration elapses → Relay OFF, run logged, OFF cycle begins
10:25 AM — OFF duration elapses → Conditions re-evaluated
           If all three still met → Relay ON for another 10-minute cycle
           ...repeats until 4:00 PM (schedule end), or until temperature
           drops below 32°F, or voltage drops below cutoff
```

Settings Reference

All settings are accessible from the Settings card. Changes are saved to non-volatile memory and persist across reboots.

Temperature Settings

Setting	Default	Description
Trigger Temperature (°F)	32.0	The minimum temperature required to allow pump operation. The pump will not run if the reading is below this value. Set this to your desired operating threshold (e.g., freezing point for freeze protection).
Temp Check Interval (min)	5	How often the temperature sensor is read, in minutes. Lower values provide more responsive monitoring but increase sensor activity.

Pump Cycle Timing

Setting	Default	Description
ON Duration (min)	10	How long the pump runs during each ON cycle. After this time, the relay turns off and the OFF cycle begins.
OFF Duration (min)	15	How long the pump rests between ON cycles. After this time, PumpLogic evaluates conditions to decide whether to start a new ON cycle.

Schedule Settings

All times use **24-hour format** (e.g., 16:00 = 4:00 PM).

Setting	Default	Description
Schedule Start	10:00	Beginning of the weekday (Mon–Fri) operating window. The pump will not run before this time.

Setting	Default	Description
Schedule End	16:00	End of the weekday operating window. The pump will not start a new ON cycle at or after this time.
Weekend Start	10:00	Beginning of the weekend (Sat–Sun) operating window.
Weekend End	16:00	End of the weekend operating window.

Blackout Window Settings

Setting	Default	Description
Enable Blackout Window	Off	When enabled, defines a time range during which the pump is blocked from running, regardless of the normal schedule.
Blackout Start	00:00	Beginning of the blackout window (24-hour format).
Blackout End	00:00	End of the blackout window (24-hour format).

The blackout window supports **midnight wrapping** — for example, setting Start to 22:00 and End to 06:00 blocks from 10 PM to 6 AM.

Voltage and Battery Settings

Setting	Default	Description
Low Voltage Cutoff (V)	11.8	If voltage drops below this value, PumpLogic enters low-voltage lockout and the pump is disabled until charge recovery completes.
Battery Type	12V Lead-Acid	Configures the voltage-to-percentage curve. Options: **12V Lead-Acid** (10.5V–12.8V = 0%–100%) or **12V LiFePO4** (10.0V–13.4V = 0%–100%).

Charge Recovery Settings

Setting	Default	Description
Duration of Charge (hours)	4	How many hours the battery must remain continuously at or above the Charge Voltage before the lockout is cleared. A real-time countdown timer tracks the remaining charge time. If voltage drops below the target, the timer resets.
Charge Voltage (V)	14.6	The minimum voltage a reading must reach to count toward charge recovery. Typically set to the voltage indicating active charging.

System Settings

Setting	Default	Description
Watchdog Timeout	2:00 (120s)	Hardware watchdog timer that automatically reboots the device if the main loop hangs. Set in minutes and seconds. Minimum 10 seconds. Under normal operation, the watchdog is never triggered.
WiFi Network Name (SSID)	PumpLogic	The name of the WiFi network broadcast by the device. Maximum 32 characters. Changing this requires reconnecting to the new network name.
WiFi Password	*(empty/open)*	Optional WPA2 password. Leave blank for an open network. Maximum 63 characters. Changing this requires reconnecting with the new password.

Saving Settings

Press **Save Settings** to save all changes. A green toast notification confirms the save.

- **Most settings** take effect immediately — no reboot required.
- **WiFi name/password changes** cause the WiFi network to restart. You will need to disconnect and reconnect to the new network name or with the new password.
- All settings are stored in **non-volatile memory** and persist across reboots.

Manual Controls

The Manual Control card provides four actions for direct control. Expand the card by clicking its header arrow.

Force ON

Press **Force ON** to immediately energize the relay and run the pump, regardless of whether the three conditions are met.

- A toast notification confirms: "Relay forced ON (manual mode active)"
- The countdown timer shows the remaining ON time
- When the ON duration elapses, the run is logged and automatic cycling resumes
- Press **Force OFF** at any time to stop a Force ON cycle early

Force OFF

Press **Force OFF** to immediately de-energize the relay and stop the pump.

- A toast notification confirms: "Relay turned OFF, automatic mode resumed"
- The OFF duration timer begins counting down
- After the OFF duration elapses, PumpLogic will start a new ON cycle if all conditions are met

Charge Recovery (Manual)

Press **Charge Recovery** to proactively initiate a charge recovery cycle before the voltage drops below the automatic cutoff.

- A confirmation dialog appears before proceeding
- The relay is immediately turned OFF
- The system enters lockout mode and the event is logged
- The pump cannot run until charge recovery requirements are met (see Charge Recovery)

Reboot

Press **Reboot** to restart the device. A confirmation dialog appears first. After rebooting:

- All saved settings are preserved
- The relay starts in the OFF state
- Temperature and voltage sensors are re-read
- Time will re-sync from your browser when you reload the page
- Wait approximately 10 seconds, then reconnect to WiFi and reload the page

Low Voltage Protection

PumpLogic monitors battery voltage to protect against over-discharge. This is especially important for solar-powered or battery-powered installations where the battery is the sole power source.

How It Works

1. Voltage is checked automatically every **30 seconds** for responsive lockout detection

2. If the voltage drops below the **Low Voltage Cutoff** (default: 11.8V):

• The relay is **immediately turned OFF**

• The system enters **LOW VOLTAGE LOCKOUT** mode

• The event is logged in the Event Log

• The pump **cannot run** until charge recovery is complete

• The **Charge Recovery card** appears on the webpage

What Triggers a Lockout

A single voltage reading below the cutoff threshold triggers lockout immediately. This is intentionally aggressive to protect the battery from deep discharge.

Charge Recovery

When a low-voltage lockout occurs, PumpLogic requires the battery to sustain a charge level before allowing the pump to run again. This prevents rapid cycling between lockout and operation when the battery is marginal.

How It Works

1. The **Charge Recovery card** appears showing status and a countdown timer

2. Voltage is checked every **30 seconds**

3. When voltage reaches or exceeds the **Charge Voltage** (default: 14.6V), the charge countdown timer starts

4. The countdown timer displays the remaining time in **H:MM:SS** format and counts down in real time

5. If the voltage **drops below** the Charge Voltage at any point, the countdown timer **resets** — charging must be sustained continuously

6. When the countdown reaches zero (voltage has been sustained for the full **Duration of Charge**), the lockout clears and normal operation resumes

Charge Recovery Example

With defaults (4 hours, 14.6V charge voltage):

1. Low voltage detected → Lockout activates, card shows "Waiting for voltage to reach 14.6 V..."

2. Charger connected, voltage rises to 14.6V → Countdown starts: **4:00:00**

3. Timer counts down in real time: 3:59:59, 3:59:58, ...

4. If voltage dips below 14.6V at any check → Timer resets, shows "Waiting for voltage..." again

5. Timer reaches 0:00:00 → Lockout clears, normal operation resumes

Cancelling Charge Recovery

If you know the battery is sufficiently charged (e.g., you connected a different power source), press the red **X** button on the Charge Recovery card:

1. A confirmation dialog appears

2. If confirmed, the lockout is immediately cleared

3. The Charge Recovery card disappears

4. Normal automatic cycling resumes (subject to the three conditions)

5. If a subsequent voltage reading falls below the Low Voltage Cutoff, lockout will re-engage

Scheduling

Weekday and Weekend Schedules

PumpLogic supports separate operating windows for weekdays and weekends:

Days	Schedule Used
Monday – Friday	Schedule Start / Schedule End
Saturday – Sunday	Weekend Start / Weekend End

Both schedules work identically: the pump will only start a new ON cycle if the current time falls within the active window. This lets you set different hours for weekdays vs. weekends — for example, a later start on weekends when solar panels begin generating power later in the morning.

Blackout Window

The blackout window is an optional feature that **explicitly blocks** pump operation during a specific time range, regardless of the normal schedule.

Use cases:

- **Quiet hours** — prevent pump noise during sleeping hours
- **Peak demand** — avoid running during times when other devices need the battery
- **Maintenance** — block operation during planned maintenance windows

Behavior when active:

- The "In Schedule" status shows **"Blackout"** in yellow
- The pump will not start new ON cycles
- If the pump is currently running, it will complete its current ON cycle but will not start a new one

Midnight wrapping: The blackout window supports overnight ranges. For example, setting Blackout Start to 22:00 and Blackout End to 06:00 blocks operation from 10 PM through 6 AM.

To enable: Check the **Enable Blackout Window** checkbox in Settings and set the start and end times.

Battery Monitoring

Voltage Trend Indicator

The Status card shows a **trend arrow** next to the voltage reading that indicates whether the battery is charging, discharging, or holding steady:

Arrow	Color	Meaning	Threshold
↑	Green	Voltage is rising	Increased by more than 0.1V since last reading
↓	Red	Voltage is falling	Decreased by more than 0.1V since last reading
→	Gray	Voltage is stable	Within ±0.1V of last reading

Battery Percentage Estimation

Below the voltage reading, PumpLogic displays an estimated battery charge percentage based on the configured **Battery Type**:

Battery Type	0%	20%	40%	60%	80%	100%	Shows "Charging"
12V Lead-Acid	≤10.5V	11.8V	12.0V	12.2V	12.6V	12.8V	≥14.8V
12V LiFePO4	≤10.0V	—	—	—	—	13.4V	≥14.6V

The percentage is calculated using linear interpolation between these reference points. When voltage exceeds the charging threshold, the display shows **"Charging"** instead of a percentage.

Note: Battery percentage estimates from voltage alone are approximate. Factors such as load, temperature, and battery age affect the actual state of charge. Use the percentage as a general guide, not a precise measurement.

Battery Charge/Discharge Graph

The Battery Charge/Discharge card provides a visual timeline of battery charge levels over 24 hours. This helps identify charging patterns, discharge rates, and whether solar panels are adequately replenishing the battery.

How it works:

- Every 15 minutes, PumpLogic records the current battery percentage to an internal buffer of 96 slots (24 hours x 4 readings per hour)

- The line graph plots these readings with time on the X-axis (midnight to midnight) and battery percentage on the Y-axis (0–100%)
- A green accent dot marks the most recent reading on the graph
- The graph is horizontally scrollable within the card for viewing the full 24 hours on mobile devices
- Data resets on reboot — readings are stored in RAM, not non-volatile memory

Sample data on boot: When PumpLogic first boots, the graph displays sample data showing a realistic 24-hour charge/discharge cycle. This demonstrates the graph's appearance before real data is available. Once the first real battery reading is recorded (at the next 15-minute boundary after boot), all sample data is cleared and only actual readings are displayed.

Full-page view: Press the **Open Full View** button to open the graph in a dedicated full-page view at /battgraph. This view displays PumpLogic branding, renders the graph at full viewport width, automatically adapts to portrait and landscape orientations on mobile devices, and auto-refreshes every 30 seconds.

Daily Min/Max Tracking

The Status card tracks the day's highest and lowest temperature and voltage readings. These ranges reset automatically at midnight and are useful for:

- Seeing how cold it got overnight (was freeze protection needed?)
- Tracking battery voltage swings throughout the day (is the solar panel keeping up?)
- Diagnosing issues without being connected to the controller all day

Runtime Counters

Counter	Resets	Stored
Runtime Today	At midnight	In memory (lost on reboot)
Lifetime	Never (manual reset only)	Non-volatile memory (persists across reboots)

These counters are useful for maintenance scheduling and understanding overall pump usage patterns.

Time Synchronization

PumpLogic does not have a dedicated real-time clock (RTC) module. Instead, it syncs its internal clock from your device's browser.

How It Works

1. When you load the PumpLogic webpage, JavaScript in your browser checks if the device needs a time sync

2. A sync is triggered if: the device has **never been synced**, OR the last sync was **more than 24 hours ago**

3. Your browser sends its current date and time to the device

4. The device sets its internal clock and stores the sync timestamp

5. The page reloads to reflect the updated time

Important Notes

• **Time accuracy** depends on your browser's clock being correct — ensure your phone or computer has the correct date and time

• **After a reboot**, time is lost and will re-sync when you next load the webpage

• **Schedule dependency:** If the device reboots and nobody loads the webpage, the schedule will not function until time is re-synced. The pump will not run outside of schedule, but it also cannot determine whether it is within the schedule without accurate time.

• **Sync status** is shown in the Network card under "Last RTC Sync"

• **"Not synced"** appears if time has not been set since the last reboot

Troubleshooting

Temperature Shows "Error"

Possible Cause	Solution
DS18B20 not detected	Verify the DATA wire is connected to pin **D10** and the 4.7kΩ pull-up resistor is between DATA and 3.3V
Loose connection	Check all wiring. CRC errors are logged but do not clear the cached sensor — the next read retries automatically
Reads 185.0°F (85°C)	This is the DS18B20's power-on reset value, indicating a brief power loss. Check wiring connections

Voltage Reads 0.00V

Possible Cause	Solution
Sensor not connected	Verify the voltage sensor module's "S" pin is connected to pin **A0**
No power to sensor	Verify VCC and GND connections to the voltage sensor module
No input voltage	Check that the voltage source is connected to the sensor module's input terminals

Relay Does Not Click

Possible Cause	Solution
Relay not connected	Verify the relay module's IN pin is connected to pin **D4**
No relay power	Confirm the relay module has 5V power (VCC to 5V, GND to GND)
Inverted logic	The relay is active-LOW (LOW = ON). Check the serial monitor for "[Relay] ON/OFF" messages

Cannot Connect to WiFi

Possible Cause	Solution
Wrong network name	Ensure you are searching for the correct SSID (default: "PumpLogic")
Forgotten credentials	If you changed the SSID or password and forgot them, re-flash the firmware or clear NVS storage to restore defaults
Out of range	Move closer to the device — typical range is 10–30 meters indoors

Webpage Does Not Load

Possible Cause	Solution
Not on PumpLogic WiFi	Confirm you are connected to the PumpLogic network, not your home WiFi
Wrong URL	Navigate to **http://192.168.4.1** (not https). Also try **http://pumplogic.local**
Browser cache	Try a different browser or clear your cache
Web server not started	Check the serial monitor for confirmation that the web server started

Time Shows "Not synced"

Possible Cause	Solution
Page not loaded	Load the webpage — time syncs automatically on page load
Incorrect device clock	Ensure your phone or computer's date and time are correct
JavaScript disabled	Enable JavaScript in your browser
Sync failed	Check the status area at the bottom of the page for an error message

Pump Runs Continuously or Won't Stop

Possible Cause	Solution
ON Duration too high	Check and reduce the ON Duration setting
Immediate stop needed	Press **Force OFF** to immediately stop the pump

Possible Cause	Solution
Schedule End incorrect	Verify the Schedule End time is set correctly
Debug needed	Check the serial monitor for "[Logic]" messages showing condition evaluation

Pump Won't Start

Verify all conditions are met by checking the Status card:

1. **Temperature:** Is the colored dot green? (reading ≥ trigger threshold)

2. **Schedule:** Does "In Schedule" show "Yes"? (current time within the schedule window)

3. **Voltage:** Is the colored dot green? (reading ≥ low voltage cutoff)

4. **Lockout:** Does "Lockout" show "Normal"? (not in low-voltage lockout)

5. **OFF Duration:** Has the OFF duration elapsed? (check the countdown timer — if still counting, the system is waiting)

Device Rebooted Unexpectedly

If PumpLogic appears to have restarted (relay OFF, time shows "Not synced"), the hardware **watchdog timer** likely triggered an automatic reboot due to a system hang. This is a safety feature. Check the serial monitor for a `[Boot] Watchdog enabled:` message at startup. The watchdog timeout is configurable in Settings (default: 2 minutes).

Serial Monitor Reference

For advanced diagnostics, connect via USB and open the Arduino IDE Serial Monitor at **115200 baud**. Diagnostic messages are prefixed by source:

Prefix	Source	What It Reports
`[PumpLogic]`	Boot sequence	Startup progress and initialization
`[Relay]`	Relay control	ON/OFF state changes
`[Sensors]`	Temperature sensor	Sensor detection, readings, CRC errors
`[Voltage]`	Voltage sensor	Voltage readings, lockout events
`[Logic]`	Decision engine	Condition evaluation (which conditions pass/fail)
`[Manual]`	Manual control	Force ON/OFF events
`[Time]`	Time sync	Synchronization events and timestamps
`[Web]`	Web server	Settings saved, route registration
`[WiFi]`	Access Point	AP startup, SSID/password changes
`[mDNS]`	mDNS service	Hostname registration
`[Boot]`	Startup	Initial sensor readings, watchdog status

PumpLogic — Automated pump control with battery protection, flexible scheduling, and web-based monitoring.