# Turbulent Flow-Based Temperature Monitoring System

## 1. Physical Inspiration: Turbulent Flow and Reynolds Decomposition

From turbulence theory:

u(x,t) = u_bar(x) + u_prime(x,t)

We analogously define for temperature:

T(t) = T_bar(t) + T_prime(t)

Where:

- T_bar(t): Stable rolling mean over time window -- base state.
- T_prime(t): Fluctuating component -- anomalies, faults, or sensor issues.

## 2. Feature Definitions

Rolling Mean (T_bar): Mean temperature in a 1-hour window.
Delta Upper/Lower (DeltaUpper, DeltaLower): Spread from mean -> measures turbulence.
1st Derivative (DeltaT): Rate of temperature change.
2nd Derivative (Delta2T): Acceleration -- flags sudden spikes.

## 3. System State Mapping

A. Window Classification:

- Delta < 1.5C -> Normal
- Delta in [1.5, 3.0] -> Warning
- Delta > 3.0 -> Critical

B. Derivative Thresholds:

- |DeltaT| > 0.5 -> Temperature drift
- |Delta2T| > 0.75 -> Spikes or quick shifts

## 4. Decision Tree Logic

1. Update 1-hour rolling window: Mean, Max, Min, DeltaUpper, DeltaLower
2. Compute DeltaT, Delta2T
3. If T is NaN or 0 -> Invalid
4. If Delta2T > 0.75 and DeltaT > 0.5 -> Spike Alert
5. If DeltaT > 0.5 and DeltaUpper > 3 -> Critical
6. If DeltaUpper or DeltaLower in [1.5, 3] -> Warning

7. Else -> Normal
8. Every 6 hrs: Adapt thresholds

## 5. Algorithm Flowchart

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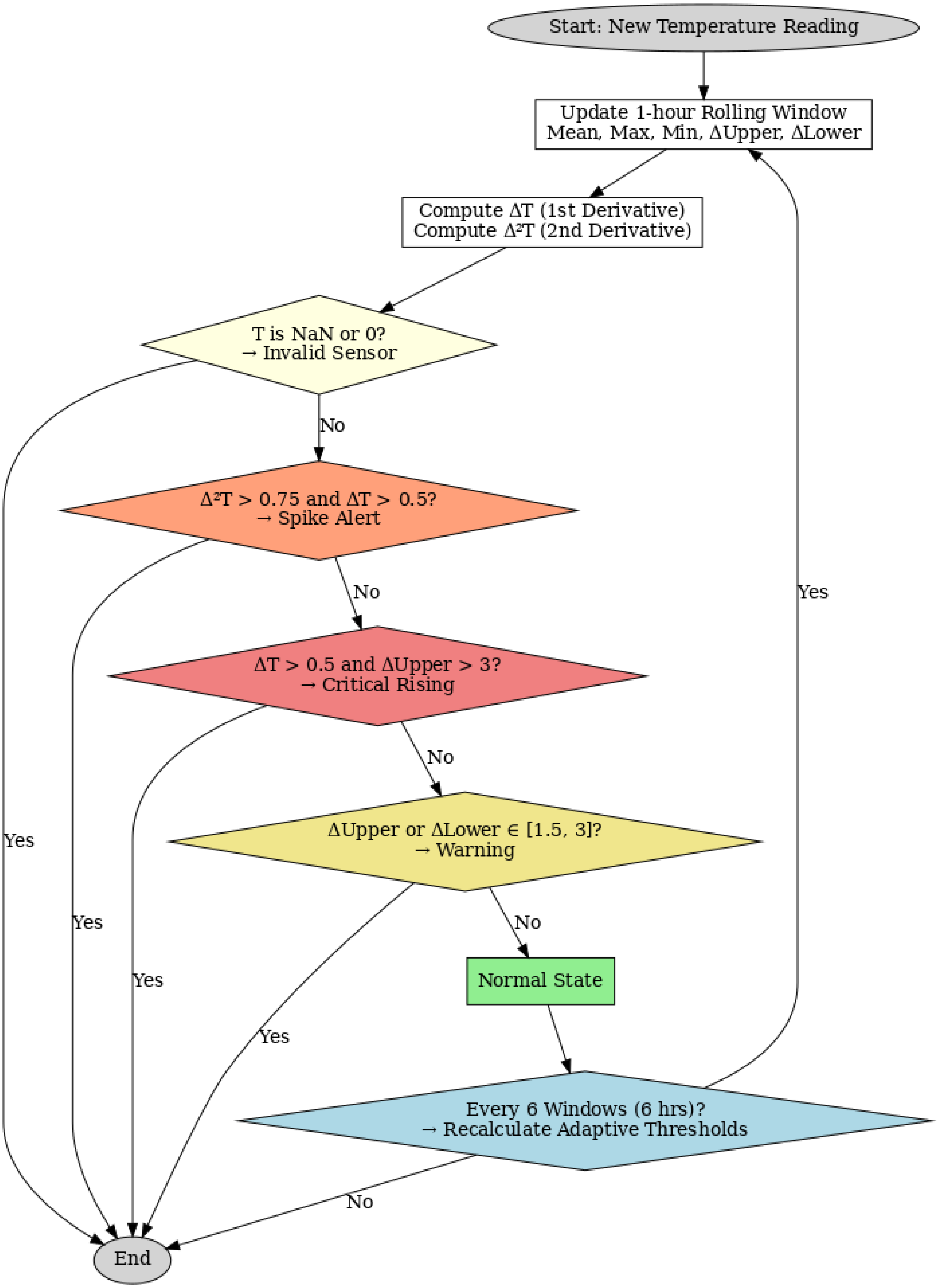

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## Plot: Temperature vs Rolling Stats

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## Plot: Temperature Gradient (1st Derivative)

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## Plot: Rate of Rate of Change (2nd Derivative)

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## Plot: Deviation from Rolling Mean

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## Plot: System Health Timeline