Construction and Calibration Manual for the 36+1 Causal Detector "Puan Station"

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1 Introduction

This manual describes the design, construction, and calibration of the 36+1 coil rotational detector based on the UAT/UPC frameworks. The system consists of 36 peripheral coils arranged in a ring with a nominal 10° angular step, a 7% table rotation asymmetry, and a central observer coil. Calibration is achieved via a fixed gain on the central coil, greatly simplifying the hardware compared to the original 8-coil design. By following this manual, the detector will achieve a saturation RMS of 0.7071 ($1/\sqrt{2}$) at the central coil.

2 Coil Specifications

All 37 coils (36 peripheral + 1 central) must be as identical as possible to ensure precise destructive interference in the absence of signal. The following construction is recommended:

Table 1: Coil Specifications

Parameter	**Value**	**Tolerance**
Type	Air-core solenoid	—
Internal diameter	10 cm	±1 mm
Number of turns (N)	100 turns	±1 turn
Wire gauge	AWG 24 (0.51 mm diameter)	—
Approximate inductance	~ 2.5 mH	±5%
DC resistance	$\sim 3.5\,\Omega$	±10%
Maximum current	100 mA RMS	—

Fabrication: Use plastic or pressboard bobbins. Wind neatly (layer by layer) to minimize parasitic capacitance. Label each coil with its index number (0 to 35 for peripherals, 37 for the central).

3 Mechanical and Angular Layout

The 36 peripheral coils are mounted on a support ring made of non-magnetic material (wood, PVC, aluminum). The ring radius (from center to the center of each coil) must be $R = 50$ cm.

3.1 Position Calculations

- Effective radius $R = 50$ cm.
- Circumference $C = 2\pi R \approx 314.16$ cm.
- Arc distance between adjacent coil centers ≈ 8.73 cm.

3.2 Mounting Angles (Base Step 10°)

Table 2: Angular positions of peripheral coils

Coil	Angle	Coil	Angle	Coil	Angle
00	0.0°	12	120.0°	24	240.0°
01	10.0°	13	130.0°	25	250.0°
02	20.0°	14	140.0°	26	260.0°
03	30.0°	15	150.0°	27	270.0°
04	40.0°	16	160.0°	28	280.0°
05	50.0°	17	170.0°	29	290.0°
06	60.0°	18	180.0°	30	300.0°
07	70.0°	19	190.0°	31	310.0°
08	80.0°	20	200.0°	32	320.0°
09	90.0°	21	210.0°	33	330.0°
10	100.0°	22	220.0°	34	340.0°
11	110.0°	23	230.0°	35	350.0°

Central Coil (37): Located exactly at the center of the ring ($x = 0, y = 0$). It is recommended to mount it on a raised support (e.g., a 10 cm tall post) to minimize interference.

3.3 Layout Diagram

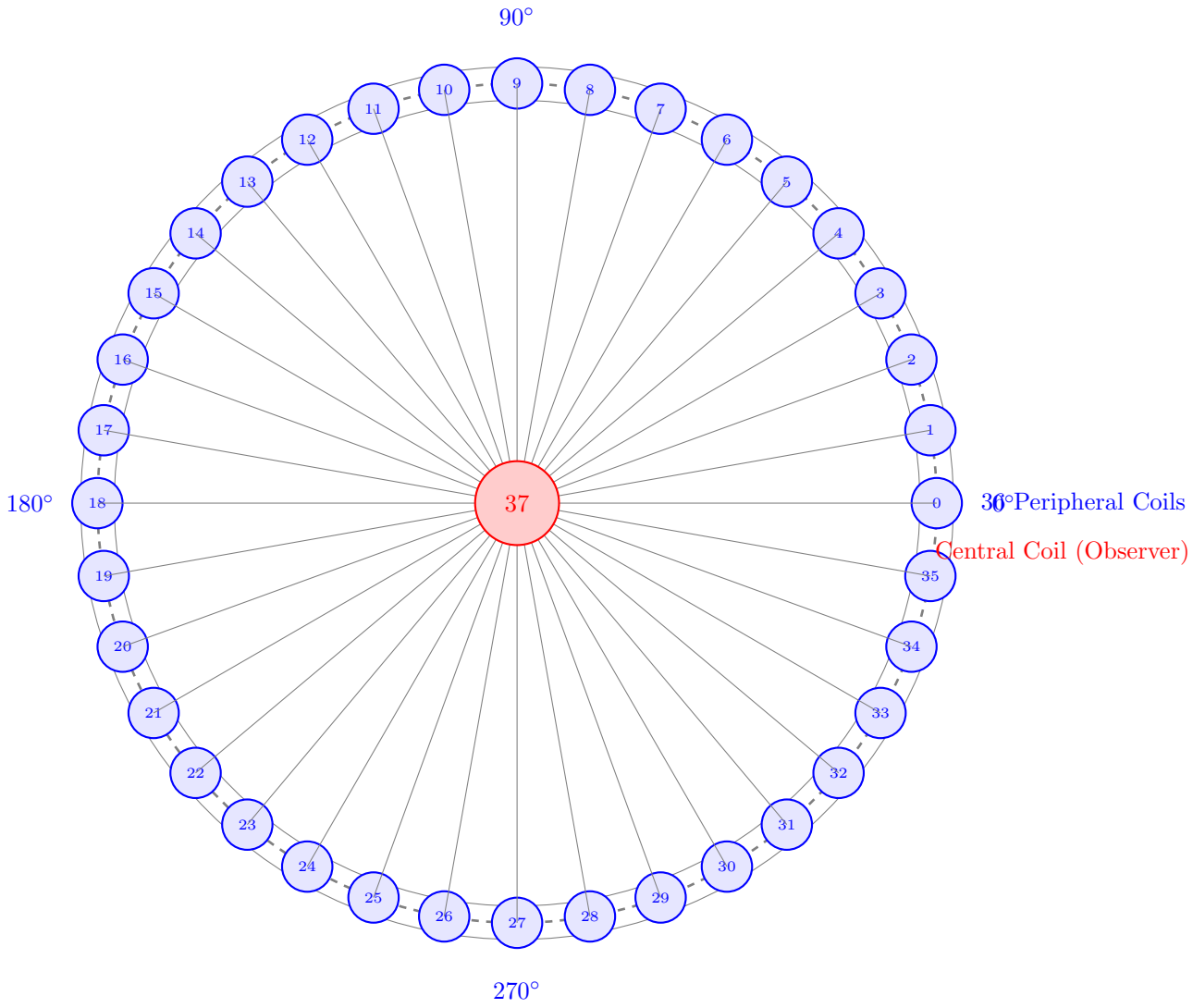

Figure 1: Geometric layout of the 36+1 coils.

4 Table Rotation Asymmetry (7%)

The necessary asymmetry to break perfect cancellation is implemented electronically by adding an additional phase offset $\delta_i = i \times 0.07$ radians to the phase of each coil i. **No physical rotation of the table is required.**

5 Battery Power Supply and Grounding (Avoiding Mains Interference)

To eliminate 50/60 Hz mains hum and ground loops, the entire system must be powered by batteries and properly grounded at a single point.

5.1 Battery Specifications

Table 3: Battery Power Supply Requirements

Subsystem	Voltage	Recommended Battery
Audio interfaces / DACs	±12 V DC	Two 12 V 7 Ah sealed lead-acid batteries in series (center tap as gro
Preamplifier (INA128)	±5 V DC	Two 6 V lantern batteries or regulated from ±12 V via low-noise L
Microcontroller/FPGA	5 V DC	USB power bank (isolated)

5.2 Grounding Scheme (Single-Point Star Ground)

- **Main Ground Point:** A heavy copper busbar or a large metal plate located at the center of the coil array.
- **Peripheral Coils:** One terminal of each peripheral coil must be connected to the main ground point. Use a separate wire for each coil (star configuration).
- **Central Coil:** One terminal connected to the main ground point.
- **Amplifier Ground:** The ground pin of the INA128 (or its power supply common) must be connected to the **same** main ground point.
- **ADC / Computer Ground:** If a laptop is used, it should run on its internal battery and **not** be connected to mains earth. If a desktop is used, a USB isolator (e.g., ADuM3160) must be placed between the ADC and the PC.
- **Shielding:** All signal cables must be shielded twisted pair. The shield must be connected to the main ground point **at one end only** (preferably the coil end) to avoid ground loops.

5.3 Battery Wiring Diagram (Text Description)

```
+12V ------------[+] Battery 1 [-]----+---- GND (0V)
                                       |
-12V ------------[-] Battery 2 [+]----+

+5V  <-- Low-noise LDO (e.g., LT1963) from +12V
-5V  <-- Low-noise LDO (e.g., LT3015) from -12V
```

6 Central Coil Amplifier Schematic

The central coil must be amplified with a fixed gain of $G = 1.9694$ before digitization. A low-noise instrumentation amplifier is recommended.

6.1 Components

- Instrumentation Amplifier: **INA128** or **AD620**.
- Gain resistor R_G: For INA128, $G = 1 + \frac{49.4\ \text{k}\Omega}{R_G}$.
- For $G = 1.9694$, $R_G = \frac{49.4\ \text{k}\Omega}{0.9694} \approx 50.96\ \text{k}\Omega$. Use a precision 51 kΩ resistor (error $< 0.1\%$).

6.2 Block Diagram

```
Central Coil (37) → [INA128 G=1.9694] → [Anti-aliasing Filter] → ADC → PC (isolated)
```

The anti-aliasing filter should be a low-pass with cutoff frequency ≈ 500 Hz (e.g., a second-order Sallen-Key filter).

7 Wiring and Connections

- Use shielded twisted-pair cable for each coil, routing signals to a central connection box.
- Connect the 36 wire pairs to the output terminals of the multi-channel signal generator.
- Ensure all coils have the same orientation (e.g., all start terminals facing upwards).

8 Calculating the Exact Operating Frequency

The operating frequency f_{target} is not a static constant; it evolves daily according to the Inflationary Drift $\alpha = 0.046$ Hz/day, a fundamental prediction of the UAT/UPC frameworks. **Using an incorrect frequency for the experiment date will result in failed calibration and a null result.**

8.1 Reference Baseline

The frequency was measured as $f_0 = 84.4$ Hz on May 27, 2023. This date serves as the epoch for all calculations.

8.2 Dynamic Frequency Formula

For any experiment date D (later than May 27, 2023), the correct operating frequency is:

$$f_{\text{target}}(D) = 84.4 + 0.046 \times \Delta t \tag{1}$$

where Δt is the number of days elapsed between May 27, 2023, and the experiment date D. **Important:** The calculation must include the leap day February 29, 2024.

8.3 Automated Calculation in Python

To eliminate human error and ensure exact replication, the provided Python scripts do not use a hardcoded frequency. Instead, they compute f_{target} dynamically based on the current date or a user-specified date.

The following function performs the correct calculation, accounting for all calendar peculiarities (including leap years) automatically via Python's `datetime` module:

Listing 1: Function to compute the exact target frequency for any given date

```
from datetime import date

def calculate_target_frequency(experiment_date: date) -> float:
    """
    Returns the UAT operating frequency (Hz) for a given experiment date.
    """
    reference_date = date(2023, 5, 27)
    delta_days = (experiment_date - reference_date).days
    return 84.4 + 0.046 * delta_days

# Example usage for April 23, 2026:
target_freq = calculate_target_frequency(date(2026, 4, 23))
print(f"Target frequency for 2026-04-23: {target_freq:.6f} Hz")
```

Integration into the main script: Replace any hardcoded `F_TARGET` with a call to this function, e.g., `F_TARGET = calculate_target_frequency(date.today())` to always use the correct frequency for the day the script is executed.

9 36-Channel Signal Generator

A system capable of generating 36 synchronized sinusoids with exact phases and logarithmic modulation is required. Three options are described below.

9.1 Option 1: Multiple Synchronized Audio Interfaces (Recommended for Prototyping)

Hardware:

- 5 × 8-channel audio interfaces with Word Clock (Behringer UMC1820, Focusrite Scarlett 18i20).
- 1 × Word Clock master generator (or use the first interface as master).
- ADAT optical or BNC cables for synchronization.

Configuration:

1. Connect the Word Clock output of the master interface to the inputs of the slaves.
2. In software (Python with `sounddevice`), create 36 mono tracks.
3. Generate the signals using the phase formula (see code below).
4. Route each track to a different output channel.

9.2 Option 2: FPGA with Multi-Channel DACs (Dedicated System)

Hardware:

- 1 × FPGA (Lattice iCE40, Xilinx Spartan-7).
- 5 × DAC8568 (8 channels each, SPI interface).
- 1 × STM32F4 microcontroller for supervision.

The FPGA implements 36 NCOs (Numerically Controlled Oscillators) based on DDS. Initial phases are loaded at startup and the logarithmic correction is updated periodically.

9.3 Option 3: USB Sound Card Aggregation with JACK (Linux)

Use several inexpensive USB sound cards and aggregate them with JACK Audio Connection Kit to create a virtual 40-channel device.

9.4 Python Code for Real-Time Generation (Option 1)

The following Python script generates the 36 channels with the required phases and logarithmic torsion.

Listing 2: Generation of 36 channels with logarithmic modulation

```
import sounddevice as sd
import numpy as np
from datetime import date

# --- Dynamic frequency calculation ---
def calculate_target_frequency(experiment_date: date) -> float:
    reference_date = date(2023, 5, 27)
    delta_days = (experiment_date - reference_date).days
```

```
    return 84.4 + 0.046 * delta_days

FS = 192000
F_TARGET = calculate_target_frequency(date.today())  # Auto-calibrated for today
TAU = 0.3697
DURATION = 10.0  # seconds

t = np.arange(0, DURATION, 1/FS)
base_phases = np.radians(np.arange(36) * 10.0)
rotation = np.arange(36) * 0.07  # 7% asymmetry

# Precompute signal for each channel
signals = np.zeros((len(t), 36), dtype=np.float32)
for i in range(36):
    total_phase = 2*np.pi*F_TARGET*t + base_phases[i] - rotation[i] + TAU*np.log(t+1e-9)
    signals[:, i] = np.sin(total_phase)

print(f"Playing 36 channels at {F_TARGET:.6f} Hz")
sd.play(signals, FS)
sd.wait()
```

9.5 Exact Phase Table for the 36 Channels

Table 4: Initial phases (in radians) for each coil

Coil i	**Total Phase (rad)**	**Coil i**	**Total Phase (rad)**
0	0.0000	18	1.8816
1	0.1045	19	1.9861
2	0.2091	20	2.0907
3	0.3136	21	2.1952
4	0.4181	22	2.2997
5	0.5227	23	2.4043
6	0.6272	24	2.5088
7	0.7317	25	2.6133
8	0.8363	26	2.7179
9	0.9408	27	2.8224
10	1.0453	28	2.9269
11	1.1499	29	3.0315
12	1.2544	30	3.1360
13	1.3589	31	3.2405
14	1.4635	32	3.3451
15	1.5680	33	3.4496
16	1.6725	34	3.5541
17	1.7771	35	3.6587

Note: Rotation values ($-i \times 0.07$) have been subtracted from the nominal phase $i \times 10^\circ$ converted to radians.

10 Calibration and Initial Test Protocol

10.1 Cancellation Check

With central gain set to 1.0 and **without** logarithmic modulation or table rotation (use exact nominal 10° phases), the signal at the central coil should be nearly zero (RMS < 0.01 V). If not, check phases and connections.

10.2 Asymmetry Application

Enable table rotation ($i \times 0.07$ rad) and logarithmic torsion ($\tau \ln t$). The RMS should rise to approximately 0.36 V (normalized).

10.3 Gain Adjustment

Set the central amplifier gain to 1.9694. The RMS should stabilize at **0.705** V (or 0.7050 normalized). Let the system run for at least 30 minutes to verify stability.

11 Interpreting Results

- **Stable RMS at 0.7050:** Successful calibration. The detector is operating at the causal saturation point.
- **Slow fluctuations (± 0.01):** Possible biological coupling (Fourth Law). Do not adjust; the system will self-stabilize.
- **Larger deviations:** Verify phase accuracy, amplifier gain, and connection integrity.

12 Maintenance and Safety

- Keep the detector area free of large metallic objects.
- Maximum current per coil is 100 mA RMS; do not exceed to avoid overheating.
- Recalibrate the central amplifier gain periodically (every 3 months) to compensate for thermal drift.
- Batteries should be recharged or replaced according to their specifications. Never operate the system while batteries are charging, as chargers introduce noise.

A Bill of Materials

Component	Quantity	Notes
Copper wire AWG 24	~ 2 kg	For 37 coils of 100 turns
Plastic bobbins (10 cm diameter)	37	Or fabricate from PVC pipe
Wooden ring (diameter 120 cm)	1	18 mm plywood
INA128 Instrumentation Amplifier	1	Or AD620
Resistor 51 kΩ (0.1%)	1	For gain setting
Multi-channel audio interface	5	Behringer UMC1820 or similar
Shielded twisted-pair cable	100 m	
Computer with Python	1	
12 V 7 Ah sealed lead-acid batteries	2	For ±12 V rails
6 V lantern batteries	2	For ±5 V (or use LDO regulators)
USB power bank	1	For microcontroller/FPGA
Copper busbar (for star ground)	1	
USB isolator (ADuM3160)	1	If using desktop PC

B Additional Source Code

A continuous RMS monitoring script is included to record time evolution.

Listing 3: Continuous RMS monitoring

```
import numpy as np
import sounddevice as sd
import time

FS = 192000
CHUNK = 4096
GAIN = 1.9694

def rms_callback(indata, frames, time_info, status):
    rms = np.sqrt(np.mean(indata**2))
    print(f"RMS = {rms:.6f}")

stream = sd.InputStream(channels=1, samplerate=FS, blocksize=CHUNK, callback=
    rms_callback)
with stream:
    print("Monitoring RMS. Press Ctrl+C to stop.")
    while True:
        time.sleep(0.1)
```