SEISMIC SENSE

TinyML Earthquake Guard: Real-time P-Wave Detection on Raspberry Pi Pico

Early Earthquake Warning System

RP2350 | SM-24 | Edge Impulse

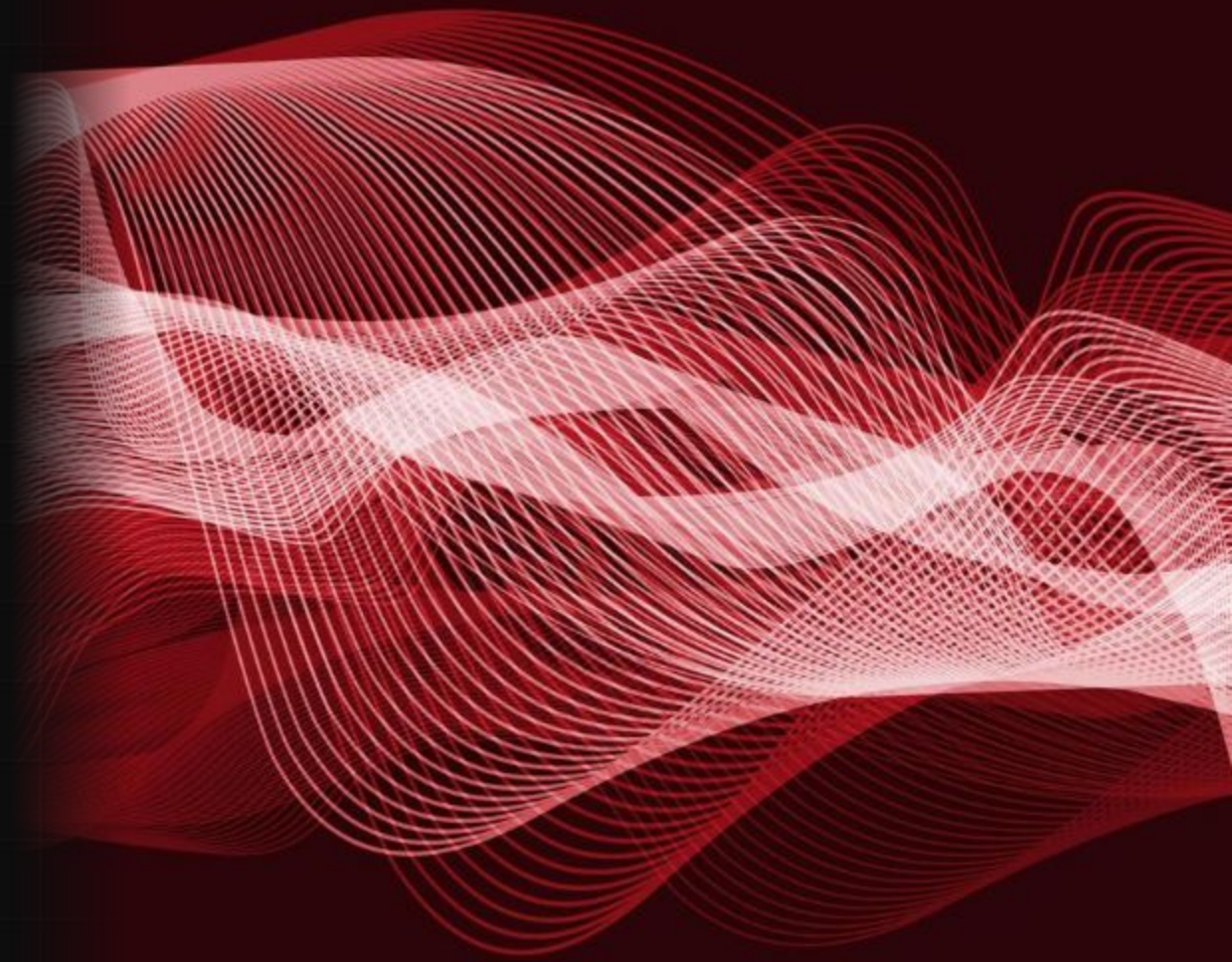
THE "LAST-MILE" GAP

COST & CONNECTIVITY

Traditional seismographs cost **$1000+** and rely on fragile internet infrastructure. In a disaster, the cloud is often the first thing to fail.

THE BLIND ZONE

Centralized warnings often arrive too late for those near the epicenter. We need detection at the edge.



THE SOLUTION: SEISMIC SENSE

STANDALONE AI

Fully offline inference on the Raspberry Pi Pico 2 using a custom TinyML model.

LOW COST

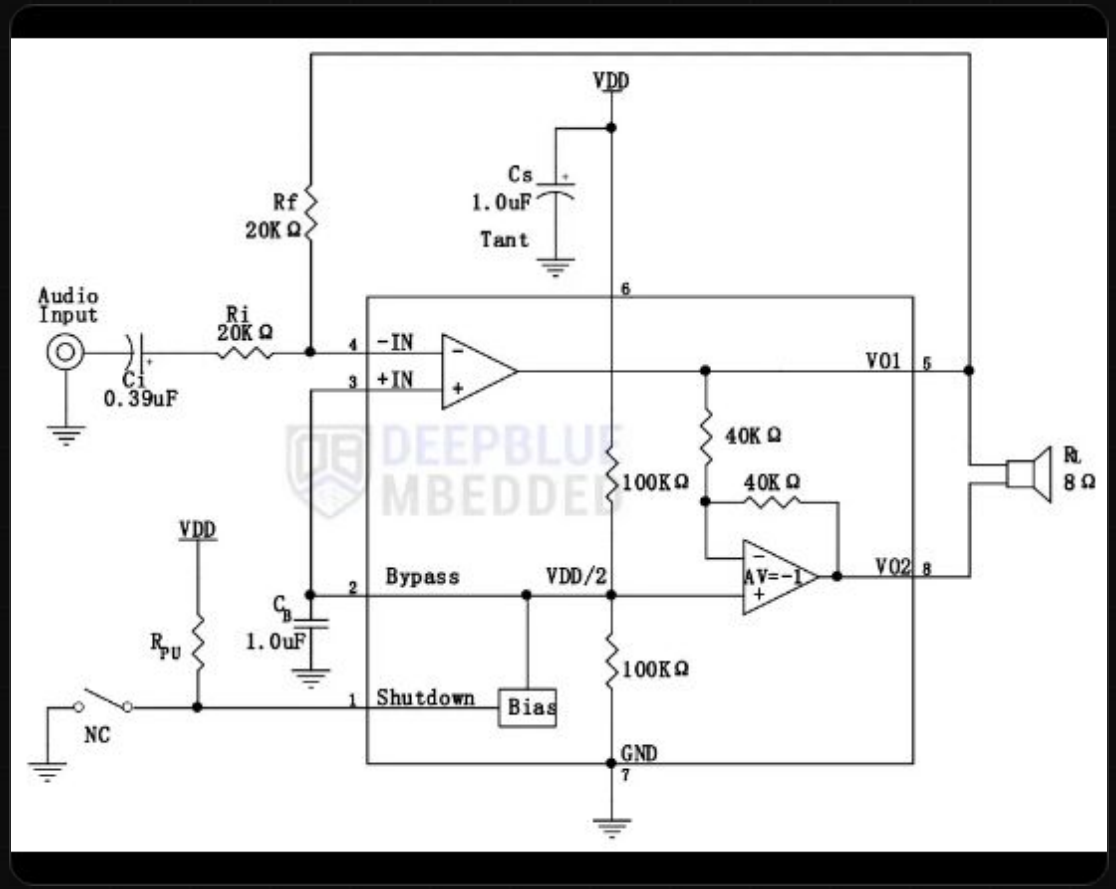
Total Bill of Materials (BOM) under **$50**, democratizing safety.

ULTRA-LOW LATENCY

Detects P-waves in milliseconds, providing crucial seconds of warning.

HARDWARE IMPLEMENTATION

- **Sensor:** SM-24 Geophone (10Hz resonance) for professional-grade sensitivity.
- **Amplifier:** TI INA333 Instrumentation Amp for differential noise rejection and 1.65V DC biasing.
- **Compute:** Raspberry Pi Pico 2 (Cortex-M33) handling ADC sampling and DSP.



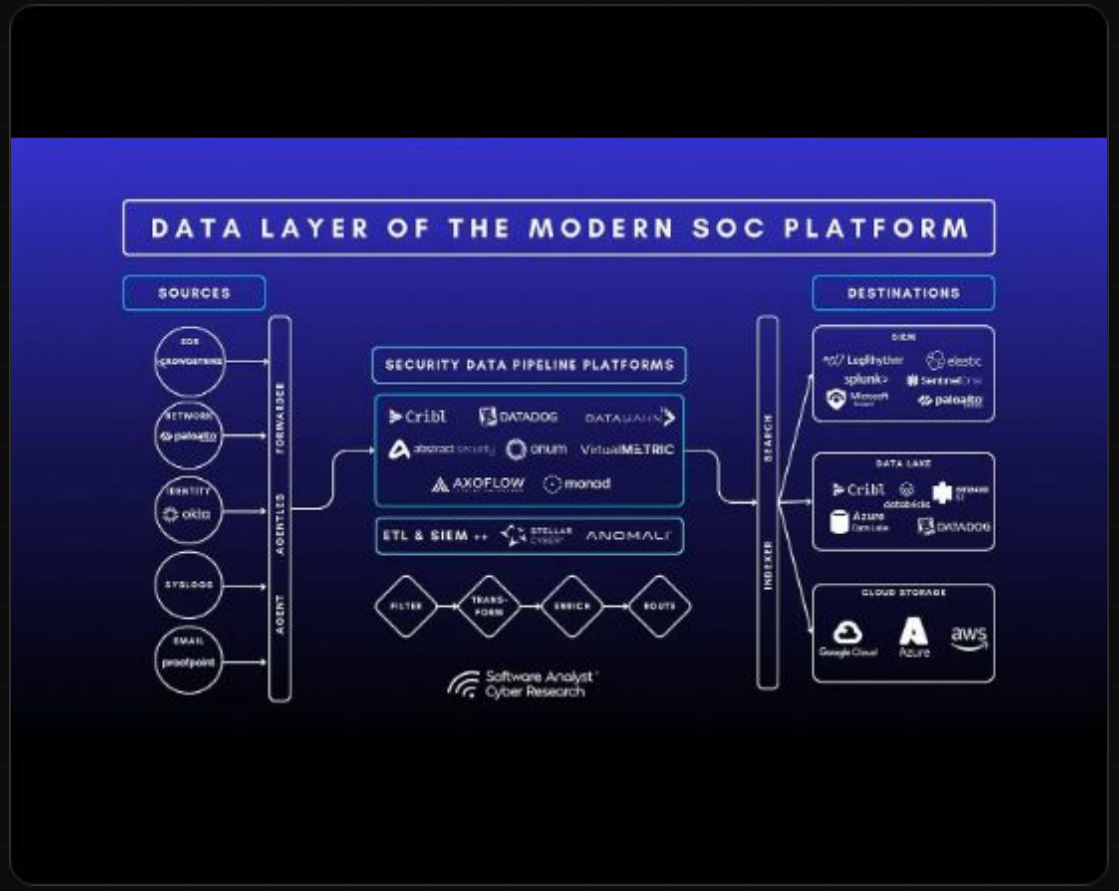
DATA STRATEGY: FROM BIG DATA TO TINYML

THE STEAD DATASET

We leveraged the Stanford EArthquake Dataset, converting terabytes of HDF5 waveforms into a lightweight training set.

ETL PIPELINE:

1. Filter: dist < 20km
2. Format: .npz Serialization
3. Upload: Edge Impulse SDK

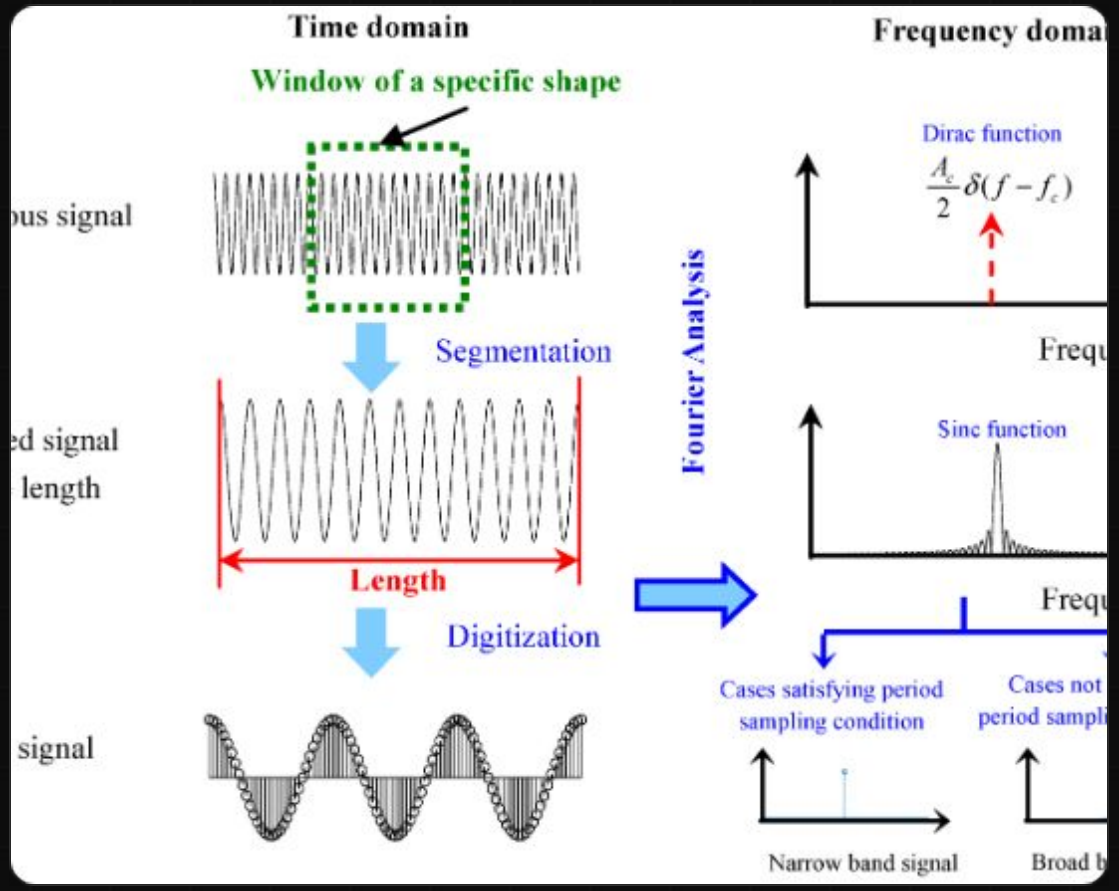


SPECTRAL PREPROCESSING

WHY FREQUENCY DOMAIN?

Raw waveforms are messy. Earthquakes hide in specific low-frequency bands (< 20Hz) that correspond to deep P-waves.

We use **FFT (Fast Fourier Transform)** to create a spectral "fingerprint" of the vibration, making the model robust to amplitude changes and background noise.

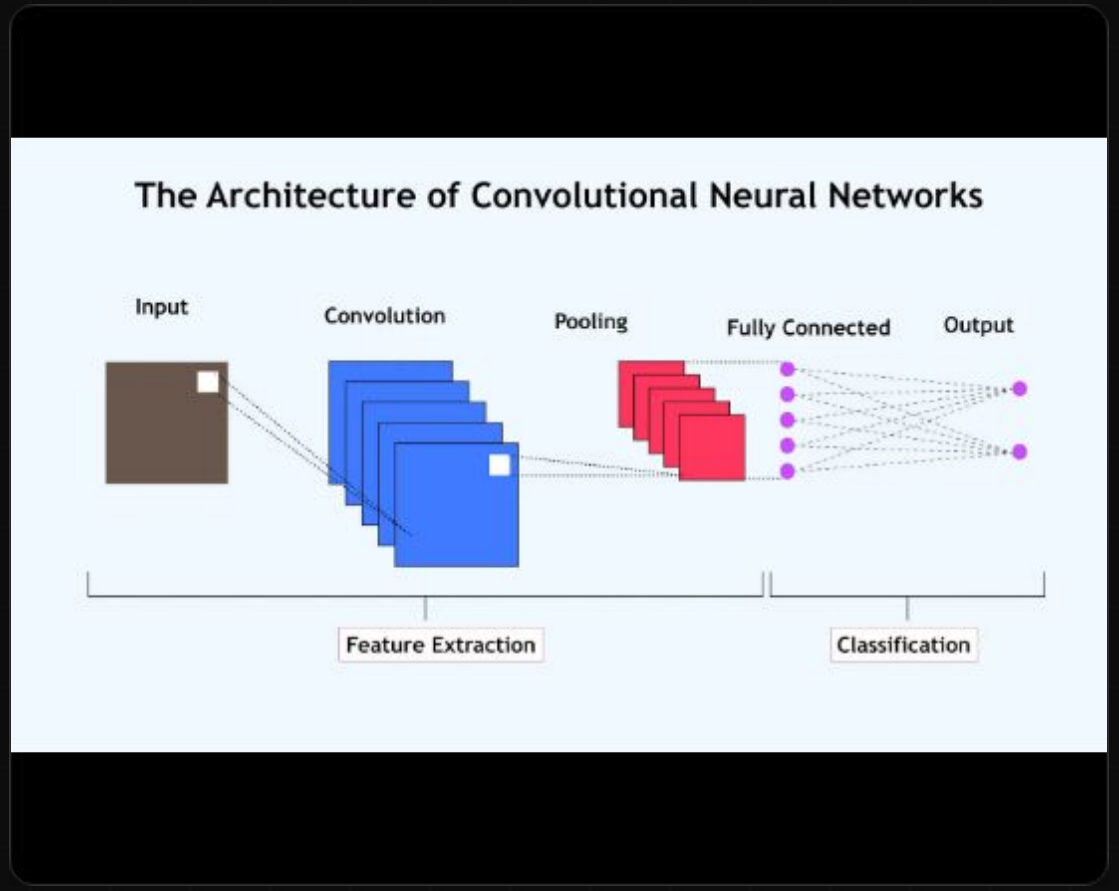


1D CNN ARCHITECTURE

MOBILENET-STYLE BLOCK

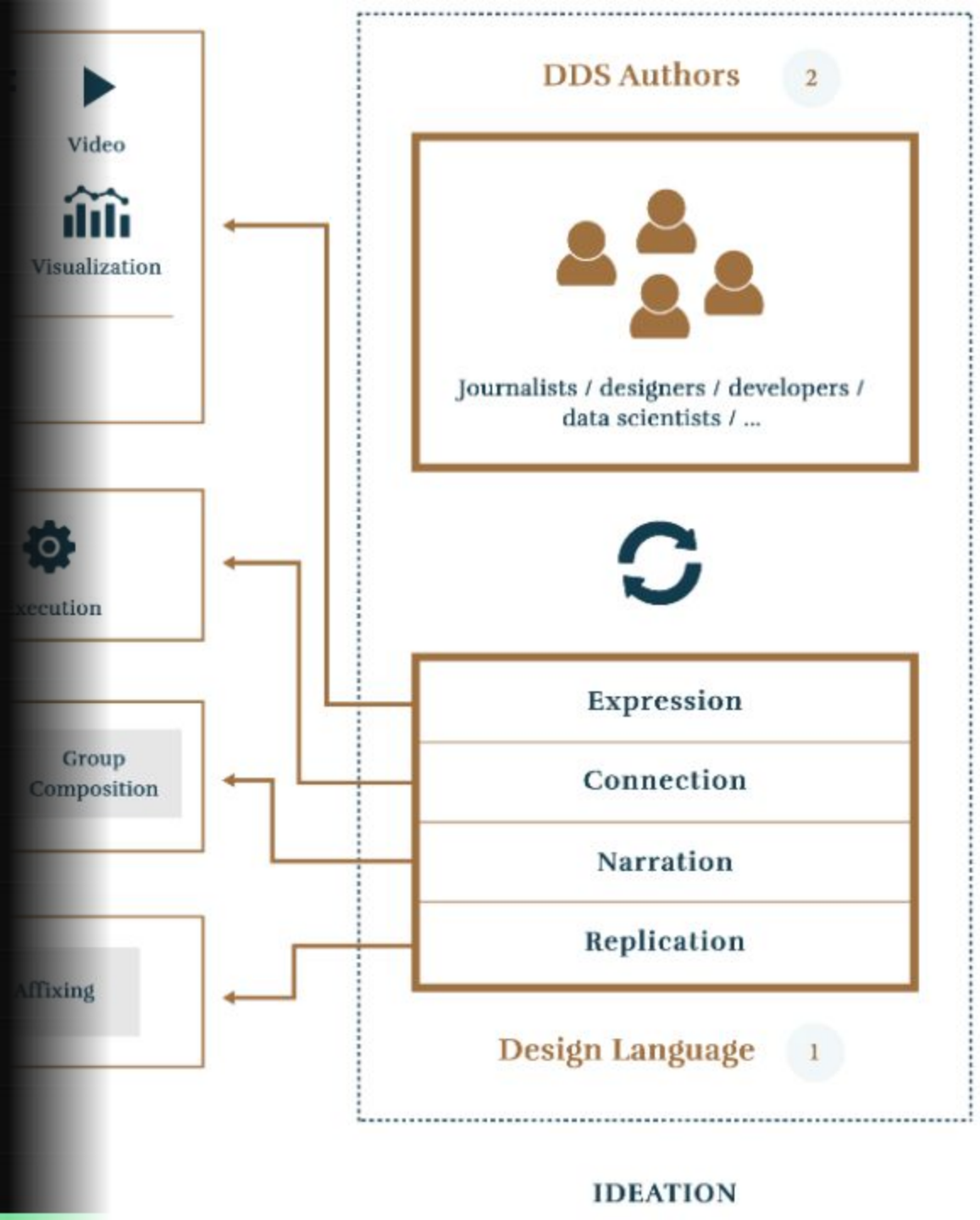
Designed for the Cortex-M33, utilizing **Depthwise Separable Convolutions** to minimize MAC operations.

- Input: 56 Frequency Features
- Conv1D: Feature Extraction
- Global Average Pooling: Reduces RAM
- Output: Earthquake vs Noise



SYSTEM WORKFLOW

1. **Sensing:** SM-24 generates voltage.
2. **Conditioning:** INA333 amplifies signal.
3. **DSP:** Pico runs FFT (2ms).
4. **Inference:** CNN Classifies (7ms).
5. **Action:** Trigger GPIO Alert.



PERFORMANCE METRICS

96%
VALIDATION ACCURACY

9ms
TOTAL LATENCY

<5KB
RAM USAGE

The model successfully distinguishes P-waves from footsteps and traffic noise with minimal computational overhead.

FUTURE ROADMAP

IOT MESH

LoRaWAN integration for city-wide alerts.

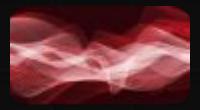
TRIANGULATION

Networked nodes to pinpoint epicenters.

AUTONOMOUS

Solar harvesting for remote deployment.

IMAGE SOURCES



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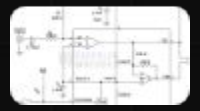

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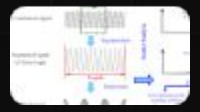

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IMAGE SOURCES

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