IoT Home Energy Monitor with Appliance-Level Tracking

An ESP32-based home energy monitor using non-invasive CT clamps to track per-appliance power, energy and cost on a live cloud dashboard.

Title

IoT Home Energy Monitor with Appliance-Level Tracking — per-circuit power metering with ESP32.

Introduction / Background

An electricity bill is a single aggregate number: it never tells you which appliance costs what. Commercial sub-metering is expensive and needs an electrician to break into wiring. Split-core CT (current transformer) clamps change the economics — they clip around a live wire without cutting it, making per-appliance metering a safe student build. Combined with an ESP32, a mains voltage sensor and a cloud dashboard, this becomes a full IoT energy monitor: live watts per appliance, daily kWh, and rupee cost estimates.

The project is also a compact course in AC power measurement — RMS sampling, burden resistors, calibration against a known load — packaged as something every household understands.

Problem Statement

Households cannot manage what they cannot measure: the geyser, the old refrigerator, the room heater all hide inside one bill. A useful monitor must measure each appliance separately and non-invasively, convert power to energy and cost, show it live on a phone dashboard, and stay safe around mains — all at a student-project budget.

Objectives

- Measure per-appliance current with three non-invasive SCT-013 CT clamps plus mains voltage via a ZMPT101B sensor.
- Compute live power (W), accumulate energy (kWh) and estimate cost at a configurable tariff.
- Show readings locally on an OLED and remotely on a Blynk cloud dashboard.
- Install without cutting any wire — fully non-invasive sensing.
- Provide a buyer-run calibration procedure against a known resistive load.

Proposed Methodology

Each CT clamp feeds a burden resistor producing a small AC voltage proportional to line current; the ESP32 samples all channels plus the voltage sensor at a few kHz, computing true RMS current and voltage per mains cycle. Real power follows from Vrms × Irms (with an assumed or measured power factor noted in the docs); energy is integrated over time into per-appliance kWh registers. Readings publish over WiFi to Blynk virtual pins every few seconds; the OLED cycles through the same values locally. Calibration: a known load (e.g. a 100 W bulb) sets the per-channel scale factor, documented as a procedure the buyer runs.

System Architecture / Working

Sensing: 3× SCT-013 clamps (one per appliance cord) + ZMPT101B mains voltage module. Controller: ESP32 sampling ADCs, running the RMS/power/energy math, driving the OLED. Cloud: Blynk dashboard with per-appliance gauges, daily kWh charts and tariff-based cost widgets. Power: 5 V USB adapter; sensing side fully isolated by the CTs and transformer.

Hardware / Software Requirements

- Hardware: ESP32 dev board, 3× SCT-013 CT clamps, ZMPT101B AC voltage sensor module, 0.96" OLED display, 5 V supply, burden resistors, enclosure.
- Software: Arduino IDE, Blynk IoT app/account; no paid services.

Expected Outcomes

A working 3-channel monitor with per-appliance live watts, daily kWh and cost on both OLED and phone dashboard, at a design-target ±3% of a reference meter after the buyer-run calibration (component datasheets: SCT-013 ±1% linearity, ZMPT101B ±1%). A calibration procedure, wiring diagram and dashboard template ship with the build; no measured accuracy is claimed before the build.

Applications

- Home energy audits — finding which appliance drives the bill.
- Hostel/PG shared-bill splitting by appliance.
- Lab demonstration of AC power measurement.
- Energy-saving campaigns with before/after data.

Future Scope

- Single-clamp NILM disaggregation of whole-house load.
- Three-phase version for shops and small industry.
- Tariff-slab billing with ToD rates.
- Relay integration to switch heavy loads from the same dashboard.