SMART ENERGY NEIGHBORHOOD

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What We Achieved

This Design Project was our first opportunity to work under the able guidance of Dr. Gaurav Trivedi, who pushed us to better ourselves at every turn. So, instead of settling for the norm, we strived to achieve something greater.

We designed a model of a 'Smart Neighbourhood'. To achieve this, we used Home Automation and various electronic requisites pertinent to our objective.

We used an Internet-of-Things Energy Meter, connected to a current sensor to relay data regarding the power consumption in our circuit, which in turn was connected to a Wi-Fi module to upload the information to a server for monitoring power usage. Apposite measures were also undertaken to safeguard against common malpractices, like Power Theft.

Our aim was to design a model of a neighbourhood simulating the one we reside in, to as close a degree as possible with our limited expertise. And we believe we were successful in doing that.

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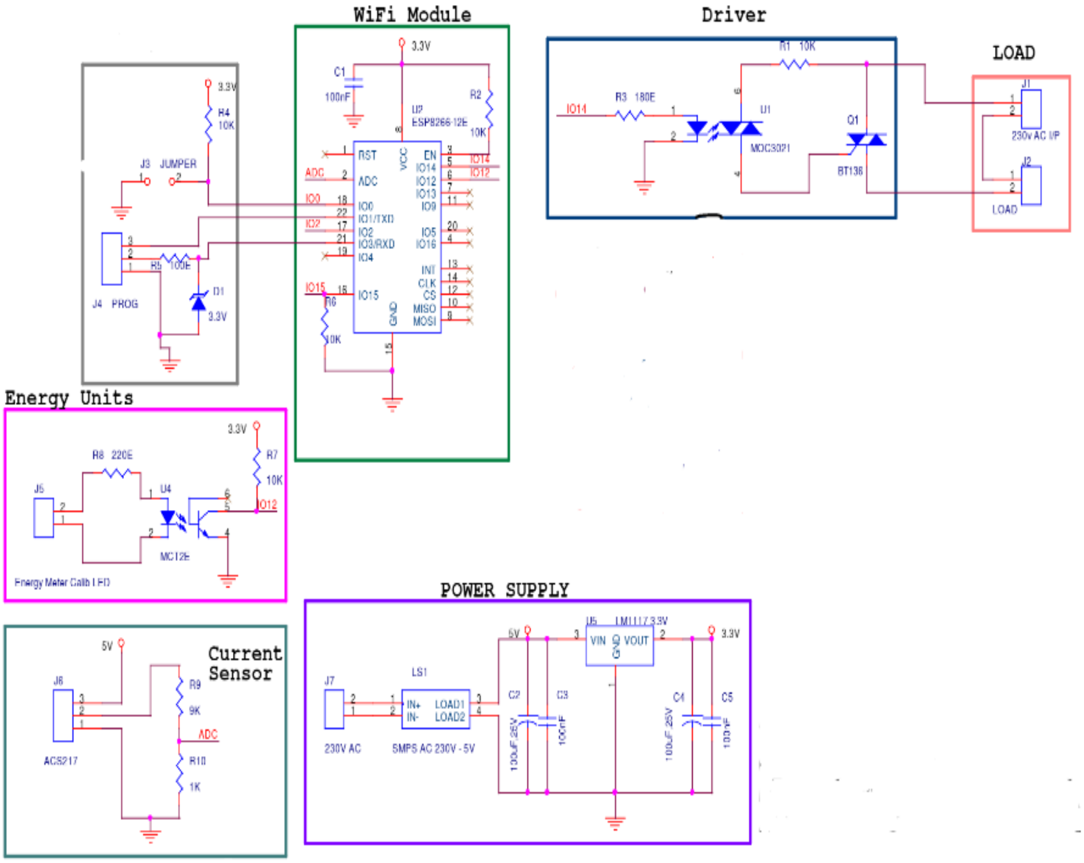
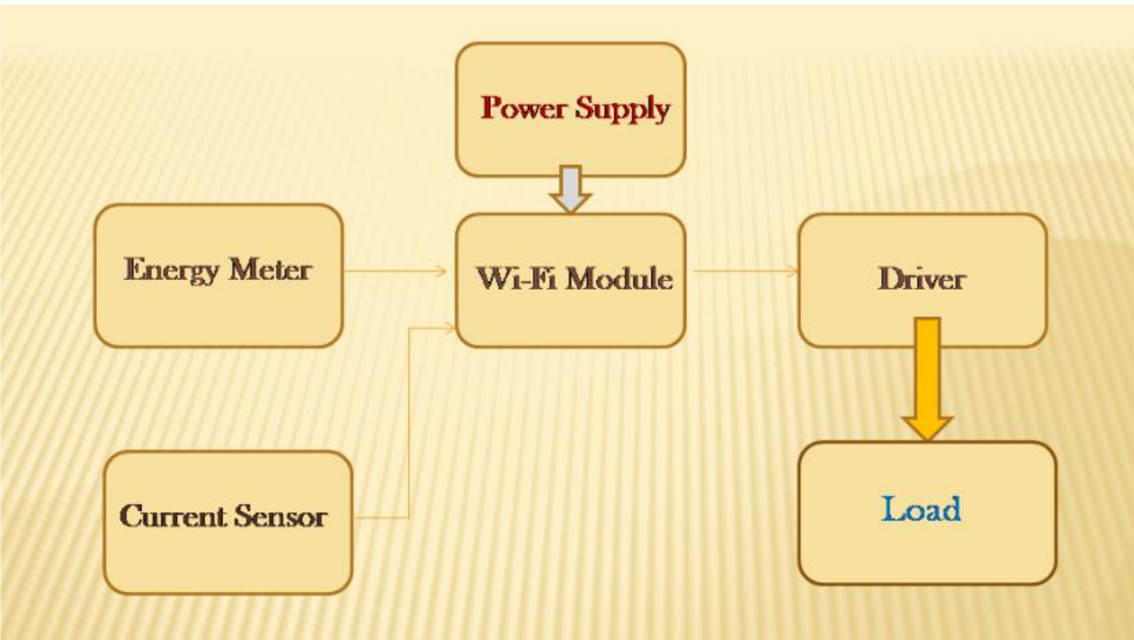
Schematic of Complete Circuit





Energy Meter

Energy meter or watt-hour meter is an electrical instrument that measures the amount of electrical energy used by the consumers.

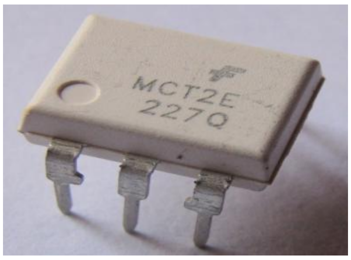
An Energy meter measures the rapid voltage and currents, calculate their product and give instantaneous power. This power is integrated over a time interval, which gives the energy utilized over that time period.

Generation of Electric Pulses:

We extract pulses, indicating electric power supplied from the Cal-LED port of the Energy Meter, to supply to the next stage of the circuit i.e. the opto-coupler.

❖ In our project, we have used the MCT2E opto-coupler.

The MCT2E series of opto-coupler devices are packaged in a 6-pin DIP package.



Pin 1: Anode.

Pin 2: Cathode.

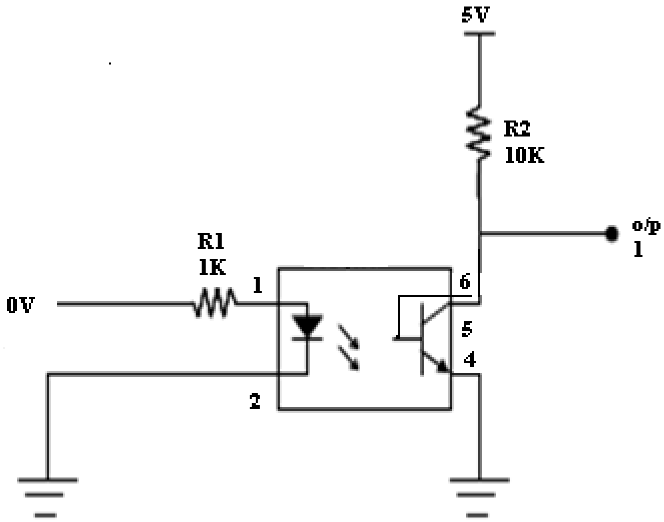
Pin 3: No connection.

Pin 4: Emitter.

Pin 5: Collector.

Pin 6: Base.

Application of MCT2E:



- When logic zero is given as input, the light doesn't fall on transistor so it doesn't conduct which gives logic one as output.

- When logic I is given as input, light falls on transistor so that it conducts, that makes transistor switched ON and it forms short circuit this makes the output is logic zero as collector of transistor is connected to ground.

Conversion of pulses to power consumed:

We have used a 3200 imp/kwh energy meter and a 60 W bulb. For one minute, we will get no. of pulses equal to:

$$\frac{(\text{Pulse Rate x Rating of Bulb x Time})}{1000 \text{ x } 3600}$$

$$\Rightarrow \frac{3200 \text{ x } 60 \text{ x } 60}{1000 \text{ x } 3600} \Rightarrow \boxed{3.2 \text{ pulses} \sim 3 \text{ pulses}}$$

Our results obtained experimentally matched this value.

Now, we need to calculate Power factor of a single pulse, means how much electricity will be consumed in one pulse:

Power Factor = Rating of bulb/(Hour x Pulse)

⇨ PF = 60/(60 x 3.2)

⇨ PF = 0.3125 watt in a single pulse

Units consumed = (PF x Total pulse)/1000

Total pulses in an hour = 3.2 x 60 ~ 192 pulses

⇨ Units = (0.3125 x 192) / 1000

= 0.06 per hour.

- If a 60W bulb is lighting for a day then it will consume 1.44 units (0.06 x 24).

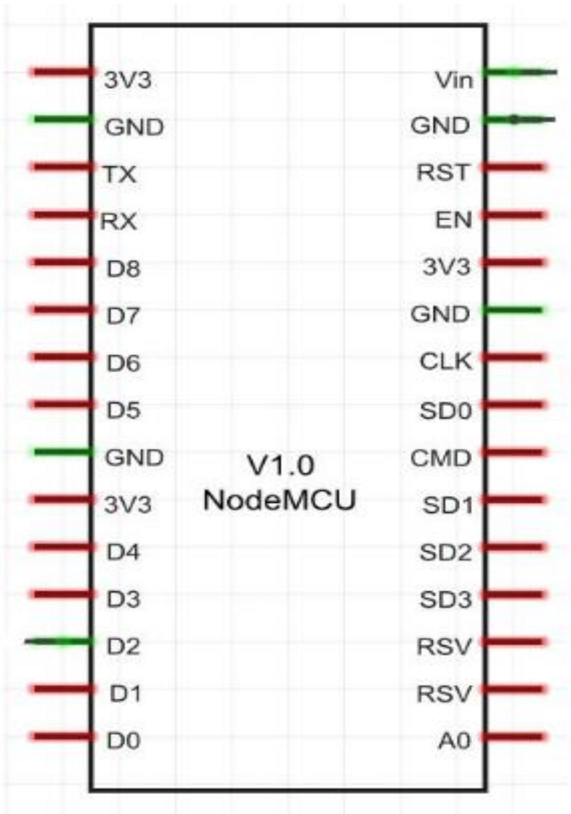
Wi-Fi Module

We have used NodeMCU for Wi-Fi Connectivity. It is an open-source software and hardware development environment that is built around a System-on-a-Chip (SoC) called the ESP8266.

ESP8266 is used as an embedded controller chip, which relays data between the client and server. We have also used it as an Arduino board, to decrease the complexity of the circuit.

We had to solder wires, with the appropriate analog voltage, to its PINs to use it for tasks such as powering it on or sending a keystroke back to the chip.

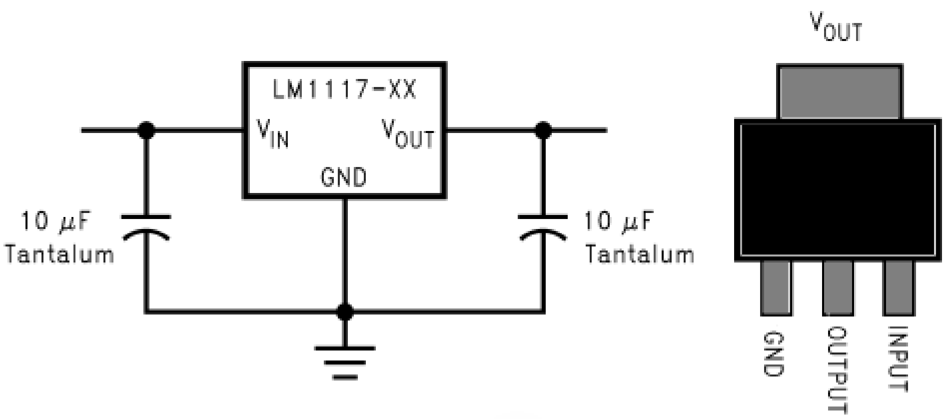
The PIN diagram of ESP 8266 for the connections made in the circuit is:



Power Supply

NodeMCU has a voltage limit of 3.3 V and the current sensor ACS 712 has a voltage limit of 5V. But, the voltage we get from the mains is of 220 V. So, to convert this voltage from 220 V to 5 V we used Switched-Mode Power Supply (SMPS) module in the circuit.

And to further convert it to 3.3 V, we used LM 1117.



Current Sensor

We have used a 30 Amp. ACS 712 as the current sensor.

To calibrate it, we first set the output offset to the desired level. Then with a known current input, we set the output deflection with the gain pot. Sensitivity is then calculated as:

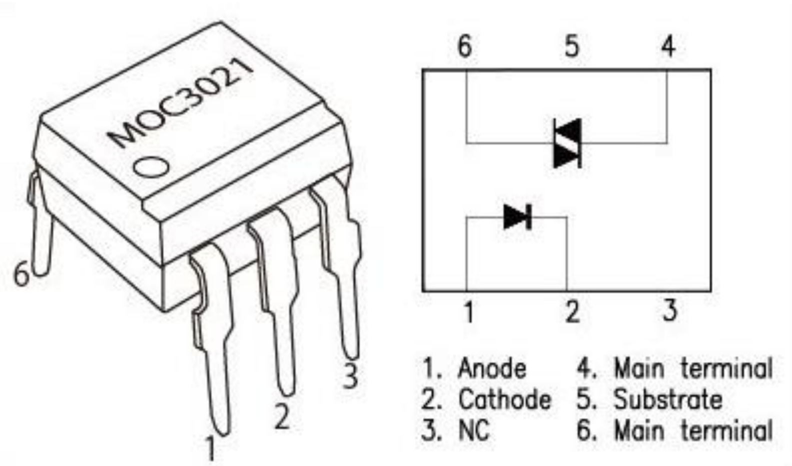
$$\boxed{\frac{V_{ref} - V_{deflect}}{\text{Current Input}}}$$

The current sensor reads the electric pulses and gives an analog voltage as output that varies linearly with sensed current. Thus, we can get the reading for the amount of power consumed.
The current sensor in the main circuit measures the current consumed by the loads which is converted to the number of units.

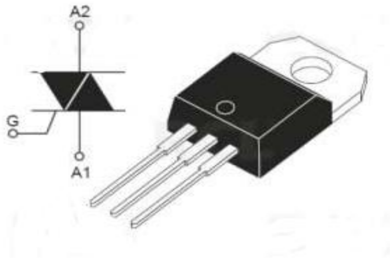
Driver

The driver circuit connects the Wi-Fi module to the Load. It consists of two modules:

i.) MOC3021



ii.) BT136



The driver circuit is the part of the circuit which enables us to prevent malpractices, acting as a failsafe by disconnecting the load soon as there's a hint of power theft.

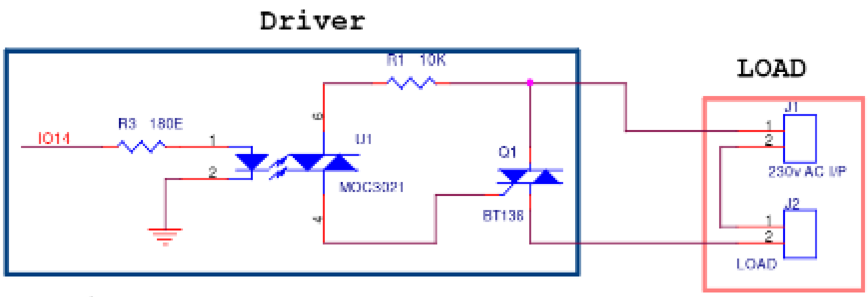
What is Power Theft?

As mentioned earlier in the working of the meter circuit, we take pulses from the Cal-LED giving us the power being consumed from the mains, which is also indicated in the reading of the meter and the current sensor gives the reading of the power being used up by the Load.

In case, all the original connections are intact, the two readings should match.

But, if we bypass the circuit so that, input and output terminals are short circuited, it would prevent the energy consumed to register in the energy meter even though the load is using up power throughout.

To prevent this, we took current readings from both the opto-coupler and from ACS712. Assuming the two don't match, it's an indication of power theft. We used the driver circuit in our model to prevent this as it will disconnect the load instantaneously when this situation arises.



Current Line Circuit for Demonstration

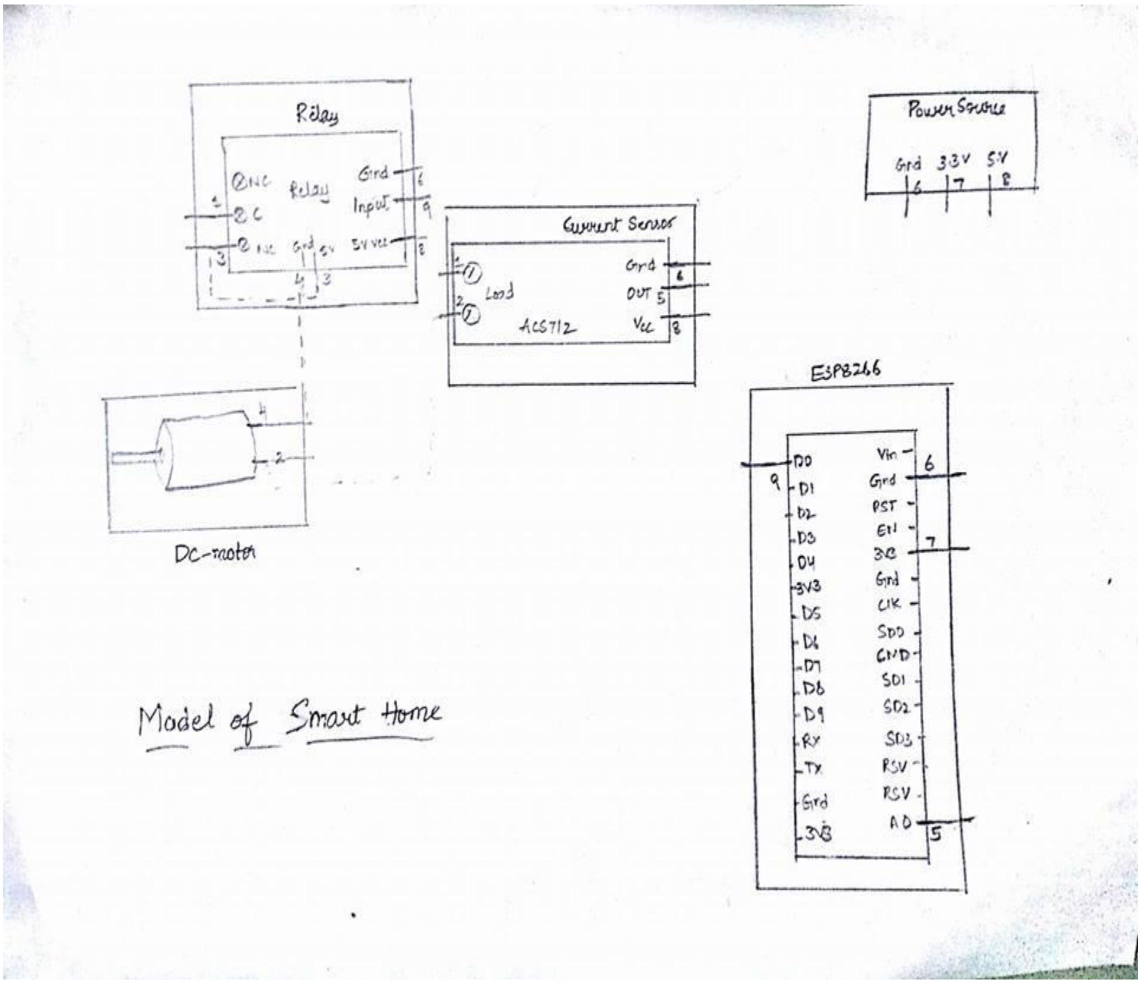
We soldered the entire circuit on a PCB to model a house and connected metallic poles which were in turn connected to other such models using connecting wires. The house model will consist of a DC motor, ESP8266, ACS712, relay and a 9 V battery.

The ESP8266 in this model is connected to the access point which is the main circuit ESP8266. The access point in itself is connected to the online ThingSpeak server using a mobile hotspot.

The ESP8266 in the house model will be measuring current consumed by DC Motor. This data too is uploaded to the server. Thus, the user can know details of power consumption and the electricity supplier can control the power supply online.

This was done to give the model the appearance of a neighbourhood connected to a centralized transformer (energy meter in our project).

In order to control the loads directly by the electricity supplier we created a webpage. Using JavaScript code and API Write Key of the Thingspeak channel we could change the data present on the server. The ESP8266 present in the house model will take the data from the ThingSpeak server and then control the loads according to it. So, if the consumer does not pay the electricity bill on time, the Electricity supplier can stop power supply without personally coming to each house.



Advantages & Disadvantages of Smart Energy Meter

ADVANTAGES FOR THE ELECTRIC SUPPLIER:

- Eliminates manual meter reading.
- Monitors the electric system more quickly.
- Provides real-time data useful for balancing electric loads and reducing power outages (blackouts).
- Enables dynamic pricing (raising or lowering the cost of electricity based on demand).
- Avoids having the capital expense of building new power plants.
- Helps to optimize income with existing resources.

DISADVANTAGES FOR THE ELECTRIC SUPPLIER:

- Transitioning to new technology and processes is difficult.
- Managing public reaction and customer acceptance of the new meters.
- Managing and storing vast quantities of metering data.
- Ensuring the security of metering data.

ADVANTAGES FOR THE CONSUMER:

- Offers more detailed feedback on energy use.
- Enables them to adjust their habits to lower electric bills.
- Reduces blackouts and system-wide electric failures.

DISADVANTAGES FOR THE CONSUMER:

- Verifying that the new meter is accurate.
- Protecting the privacy of their personal data.
- Paying additional fees for the new meter.

BENEFITS TO THE ENVIRONMENT:

- Prevents the need for new power plants that would produce pollution.
- Curbs greenhouse gas emissions from existing power plants.
- Reduces pollution from vehicles driven by meter readers.

Conclusion

We were successful in designing a compact working model of a neighbourhood, consisting of a smart energy meter and modules to simulate usage of power just like in a regular home, with the added functionality of both the consumer and the supplier being able to monitor power usage online. We also created a circuit to failsafe the energy meter against power theft.

We believe that we have satisfactorily completed all the objectives we undertook and are pleased to have gotten a chance to work on such a project that enhanced our design skills and gave us an invaluable experience of making something technologically significant.

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