AUTONOMOUS POWER SUPPLY SYSTEMS OPTIMIZATION FOR ENERGY EFFICIENCY INCREASING

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***Abstract* — The paper focuses on the calculation of electricity power generated by solar panel for an autonomous house. It was drawn a block diagram based on the research. The advantage of this automatic system is the elimination of moving elements. It allows the decreasing of the risk of various mechanisms failure and increasing the stability of the system.**

***Keywords*—solar panel, energy consumption, energy saving microcontroller, control system**

I. INTRODUCTION

In modern conditions the use of electronic and electrical devices has increased. This increasing of electronics and electrical appliances use and consumption has negatively impacted on unprecedented energy consumption. Due to the gap between the supply and demand, the price paid by the end-user subsequently increases annually.

As a result, there is a need to optimize and develop more energy efficient technologies and electrical systems. Because of this fact, the development of new fundamental and applied research in the field of energy efficiency and saving began. Among these research areas leading to significant changes in energy consumption are the development of integrated, improved monitoring and control mechanisms with the ability to monitor and control energy consumption effectively so that users can easily measure the energy consumption of electronic devices and optimize their use to improve energy efficiency. [1]

In this research, we have chosen a solar panel as the energy source for our automatic system. Solar energy has undergone significant changes in recent years and has also taken the lead in development in comparision to other alternative energy sources. Solar energy simply uses sunlight as energy. This does not require large generators that take up a lot of space. Another advantage of this automatic system is the absence of moving elements, which eliminates the risk of failure of various mechanisms in this system.[2]

The total energy outflowing from the sun is more than we consume at all, which means that this energy source is theoretical one of the best sources for the future. The challenge is to use and save this energy in a cost effective way in practice [3].

II. DEVELOPMENT OF A STRUCTURAL DIAGRAM OF THE FACILIT IES POWER SUPPLY

In order to calculate the required power for our solar panel, it is necessary to know electricity consumption per month. It is possible to determine the required consumed electricity volume in kilowatts per hours by looking at an electric meter (Table 1).

Table 1.Electricity consumption by devices (approximate).

№	Electrical devices	Power con-sumption, kW	kWh	kW / m
1	Refrigerator	0,04	24	30
2	TV set	0,166	3	15
3	Electric stove	1,3	1,5	58,5
4	Oven	1,8	1 (per week 3 days)	21,6
5	Washer	1	2 (per week 3 days)	24
6	Computer	0,22	2	13,2
7	Teapot	1	0,5	15
8	Dishwasher	0,47	1	14,1
9	Vacuum cleaner	0,5	1 (per week 3 days)	6
10	Iron	0,5	0,3 3(per week 3 days)	2
11	Microwave	1	0,05	4,5
12	Multicooker	0,166	1	5
13	Bulb (10pcs) 100w	0.1	3	9
14	Heater	2	1	60
15	Energy saving lamp (10pcs) 20 W	0,02	5	3

After finding out how many kW of electricity can be consumed in one day, it is possible to find out how much energy the solar panel needs to produce. We need the solstice and solar panel power for calculation. For example:

the time of the sun from dawn to dusk (Trz) is multiplied by the power of the panel (P): Trz * P = 542 * 2 = 1084W (Table 2) (Figure 1).

Table 2. The generated annual power of one solar panel.

January	February	March	April	May	June	July	August	September	October	November	December
1084	1190	1348	1532	1698	1822	1840	1742	1580	1406	1232	1104
1086	1194	1354	1536	1704	1824	1838	1736	1574	1400	1226	1102
1088	1200	1360	1542	1708	1826	1836	1732	1568	1394	1220	1100
1090	1204	1366	1548	1712	1828	1834	1728	1562	1388	1216	1098
1092	1210	1370	1554	1718	1830	1832	1722	1556	1382	1210	1094
1094	1214	1376	1560	1722	1832	1830	1718	1550	1376	1206	1092
1096	1220	1382	1566	1728	1834	1828	1716	1546	1370	1200	1090
1098	1224	1388	1572	1732	1836	1826	1708	1540	1364	1196	1088
1100	1230	1394	1578	1736	1838	1824	1704	1534	1358	1190	1086
1104	1234	1400	1584	1742	1840	1822	1698	1528	1352	1186	1085
1106	1240	1406	1588	1746	1841	1820	1694	1522	1346	1182	1084
1110	1246	1412	1594	1750	1843	1818	1688	1516	1342	1176	1082
1112	1252	1418	1600	1754	1844	1814	1682	1510	1336	1172	1081
1116	1256	1424	1606	1760	1846	1812	1680	1504	1330	1168	1080
1118	1262	1430	1612	1764	1847	1808	1674	1498	1324	1164	1079
1122	1268	1436	1618	1768	1849	1806	1670	1492	1318	1158	1078
1126	1274	1442	1622	1772	1850	1802	1664	1488	1312	1154	1078
1130	1278	1448	1628	1776	1851	1798	1658	1482	1306	1150	1077
1134	1284	1454	1634	1780	1851	1796	1654	1476	1304	1146	1077
1136	1290	1460	1640	1784	1851	1792	1648	1470	1298	1142	1076
1140	1296	1466	1644	1786	1851	1788	1642	1464	1292	1138	1076
1144	1302	1472	1650	1790	1851	1784	1638	1458	1286	1134	1076
1148	1306	1478	1656	1794	1851	1780	1632	1452	1284	1330	1077
1152	1312	1484	1660	1798	1850	1776	1626	1446	1278	1128	1077
1158	1318	1490	1666	1800	1848	1772	1620	1440	1272	1124	1078
1162	1324	1496	1672	1804	1847	1768	1616	1434	1266	1120	1078
1166	1330	1502	1676	1808	1846	1764	1610	1428	1262	1116	1079
1170	1336	1508	1682	1810	1844	1760	1604	1422	1256	1114	1080
1176	1342	1514	1686	1814	1843	1756	1598	1416	1250	1110	1082
1180		1520	1692	1816	1841	1752	1592	1410	1246	1108	1082
1184		1526		1818		1748	1588		1240		1084

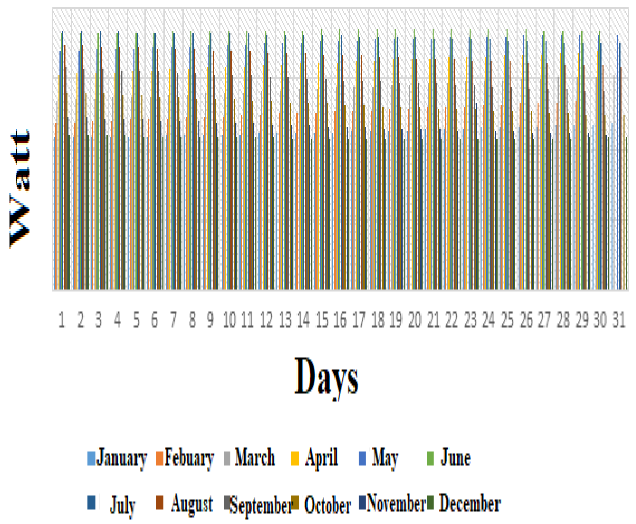


Figure 1. Graph of the generated annual capacity of one solar panel.

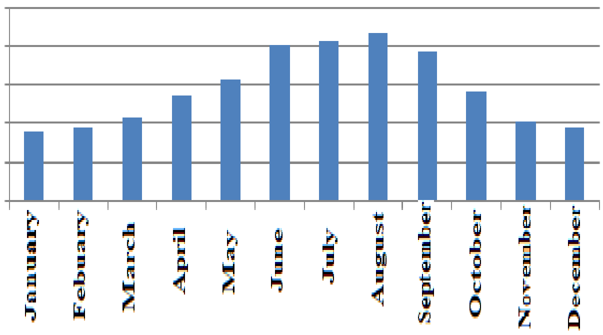


Figure 2 - Accurate energy production in one month (no cloudy days).

Then we calculate the electricity generated by the solar panel per one month. To do this, we need the average value of the generated energy in one day (Pд) and the number of cloudy days in one month (Кпас). We multiply the received data: Pд * Кпас = 1126.5 * 15 = 168975, and we get the lost power. To obtain the exact generated power in one month, it is necessary to subtract the lost power (Pp) from the received power in one month (Pm):

Pm-Pp = 34922 -16897.5 = 18024.5. (Figure 2)

Having calculated in detail the need for electricity and to fully supply the house, we need to purchase 15 solar panels with a capacity of 120W.

According to the study, a block diagram of the facility power supply was drawn up, which is shown on Figure 3. The solar battery is used for a low-voltage LED lighting system and after voltage conversion for the power supply system. [5-6]

The power of solar panels is 5 to 6 V in direct sunlight. The solar panels charge the lithium battery through the TP4056 charger module. This module is responsible for charging the battery and preventing overcharging. The lithium battery provides 4.2V when fully charged.

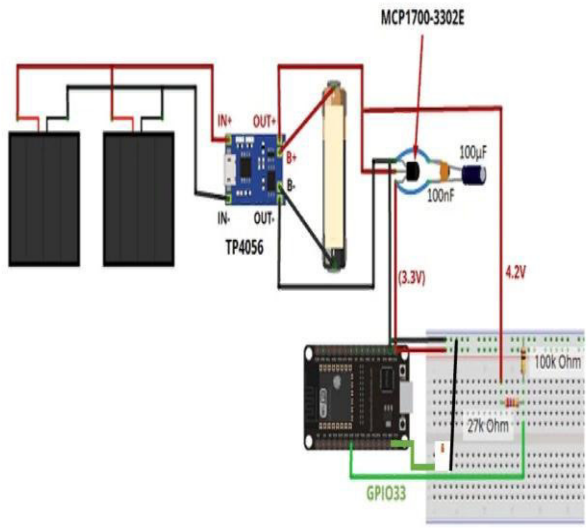


Figure-3. General diagram of the power supply monitoring and control system

Figure-4. Solar panels

We need to use a low dropout regulator circuit (MCP1700-3302E) to get 3.3V from the battery output. The voltage regulator output will power the ESP32 through the 3.3V pin.

The solar panels we use have an output voltage of 5 to 6 V. If we want our battery to charge faster, we can use multiple solar panels in parallel. In this example, we are using two mini solar panels as shown in the Figure 5.

To connect solar panels in parallel, solder the (+) terminal of one solar panel to the (+) terminal of the other solar panel. Let's do the same for the terminals (-). It might look like this.

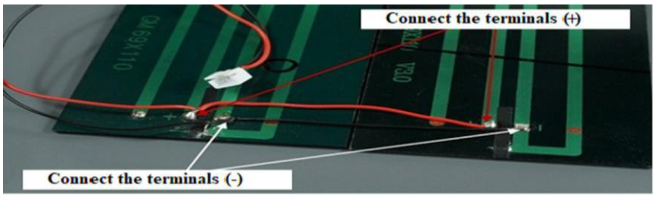


Figure-5. Parallel connection of solar panels

When solar panels are connected in parallel, we will get the same output voltage and double the current (for identical solar panels). In the following figure, solar panels are delivering approximately 6 V.

Figure-6. Measurement of solar panels with a multimeter

The TP4056 Lithium Battery Charger Module comes with circuit protection and prevents battery over-voltage and reverse polarity.

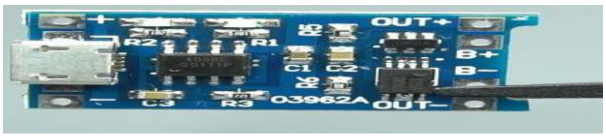


Figure-7. Charging module TP4056

TP4056 module turns on red LED when it is charging the battery and turns on blue LED when the battery is fully charged. Connect the solar panels to the TP4056 lithium battery charger module as shown in the circuit diagram below. Connect the positive terminals to the terminal marked IN + and the negative terminals to the terminal marked IN-.

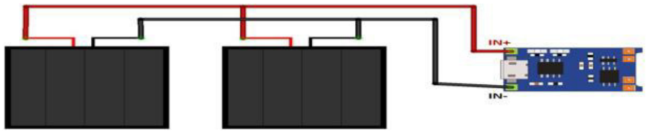


Figure-8. Connecting solar panels to the TP4056 charging module

Then connect the positive terminal of the battery holder to B + and the negative terminal of the battery holder to B-.

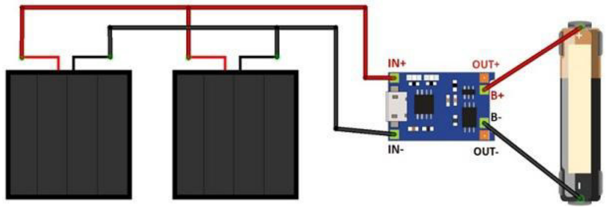


Figure-9. Connecting the battery terminals to the contacts of the TP4056 charging module

OUT + and OUT- are battery outputs. These rechargeable lithium batteries deliver up to 4.2V when fully charged (although the label says 3.7V).

Figure-10. Measurement of lithium batteries with a multimeter

We need a voltage regulator circuit to get 3.3V from the battery output to power the ESP32 through its 3.3V pin. Using a regular linear voltage regulator to reset the voltage from 4.2V to 3.3V is not a good idea, because when the battery is discharged to, for example, 3.7V, our voltage regulator will stop working because it has a high cutoff voltage. It is better use a low dropout regulator to effectively lower the voltage, or LDO for short, that can regulate the output voltage.

The MCP1700-3302E is one of the best solution. There is also a good alternative in the form of HT7333-A.

Figure-11. MCP1700-3302E stabilizer

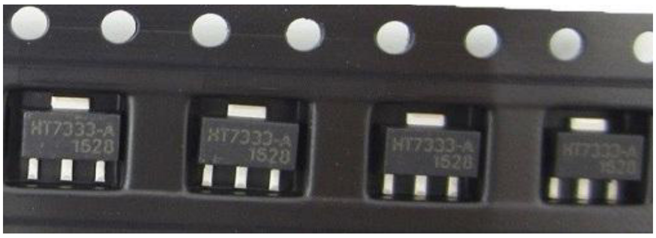
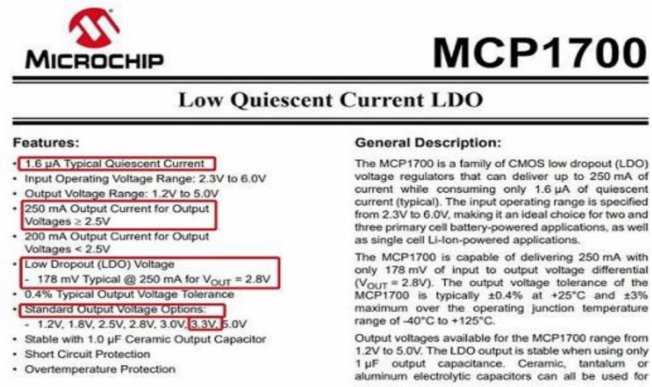


Figure-12. Alternative views of the MCP1700-3302E stabilizer

Any LDO that has similar characteristics to these two is also a good alternative. Our LDO should have similar specifications when it comes to output voltage, quiescent current, output current and low cut-off voltage. This information is at the documentation below.



MICROCHIP

MCP1700

Low Quiescent Current LDO

Features:

- 1.6 µA Typical Quiescent Current
- Input Operating Voltage Range: 2.3V to 6.0V
- Output Voltage Range: 1.2V to 5.0V
- 250 mA Output Current for Output Voltages ≥ 2.5V
- 200 mA Output Current for Output Voltages < 2.5V
- Low Dropout (LDO) Voltage
  - 178 mV Typical @ 250 mA for V_{OUT} = 2.8V
- 0.4% Typical Output Voltage Tolerance
- Standard Output Voltage Options:
  - 1.2V, 1.8V, 2.5V, 2.8V, 3.0V, 3.3V, 5.0V
- Stable with 1.0 µF Ceramic Output Capacitor
- Short Circuit Protection
- Overtemperature Protection

General Description:

The MCP1700 is a family of CMOS low dropout (LDO) voltage regulators that can deliver up to 250 mA of current while consuming only 1.6 µA of quiescent current (typical). The input operating range is specified from 2.3V to 6.0V, making it an ideal choice for two and three primary cell battery-powered applications, as well as single cell Li-Ion-powered applications.

The MCP1700 is capable of delivering 250 mA with only 178 mV of input to output voltage differential (V_{OUT} = 2.8V). The output voltage tolerance of the MCP1700 is typically ±0.4% at +25°C and ±3% maximum over the operating junction temperature range of -40°C to +125°C.

Output voltages available for the MCP1700 range from 1.2V to 5.0V. The LDO output is stable when using only 1 µF output capacitance. Ceramic, tantalum or aluminum electrolytic capacitors can all be used for

Figure-13. MCP1700-3302E documentation

This is the pinout of the MCP1700-3302E: GND, VIN and VOUT pins.

Figure-14. MCP1700-3302E pinout

The LDO must have a ceramic capacitor and an electrolytic capacitor connected in parallel to the GND and Vout to smooth out the voltage peaks. Here we use a 100 UF electrolytic capacitor and a 100 nF ceramic capacitor. Follow the following diagram to add the voltage regulator circuit to the previous diagram. The wire with the white-gray stripe must be connected to the GND.

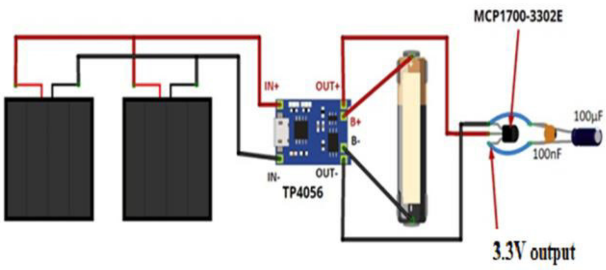


Figure-15. Connecting stabilizers and capacitors to the circuit

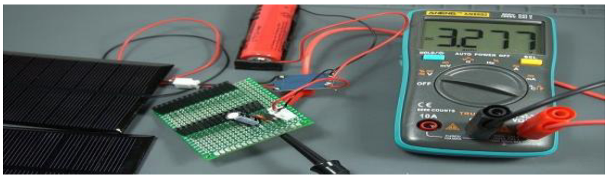


Figure-16. Measuring the voltage regulator with a multimeter

The Vout pin of the voltage regulator should supply 3.3 V. This is the pin that will power the ESP32 or ESP8266.

Finally, after making sure we get the correct voltage at the Vout pin of the voltage regulator, we can connect the ESP32. Connect Vout pin to 3.3V pin of ESP32 and GND to GND.

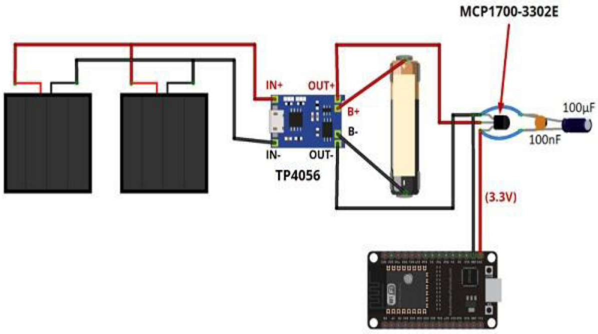


Figure-17. Connecting the voltage regulator contacts to the ESP8266 contacts

If the ESP32 is running on battery power or solar, as is the case, it can be very useful to monitor the battery level. One way to do this is to read the battery output voltage using the ESP32 analog pin. That said, the battery we are using here gives a maximum of 4.2V when fully charged, but the ESP32 GPIO lines run at 3.3V. So we need to add a voltage divider so we can read the voltage from the battery.

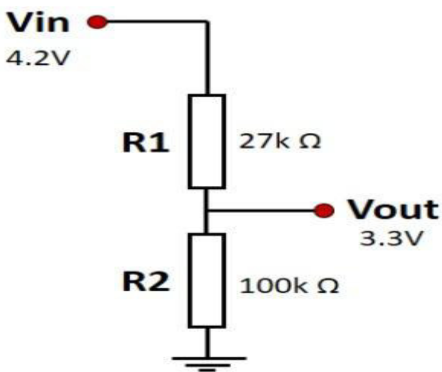


Figure-18. Adding obstacles to the scheme

The voltage divider formula looks like this:

Vout = (Vin * R2) / (R1 + R2).

So if we use R1 = 27 kΩ and R2 = 100 kΩ, we get 3.3 V. So when the battery is fully charged, the Vout output will be 3.3 V, which we can read using the ESP32 GPIO lines. Let's add two resistors to our circuit as shown in the following schematic diagram.

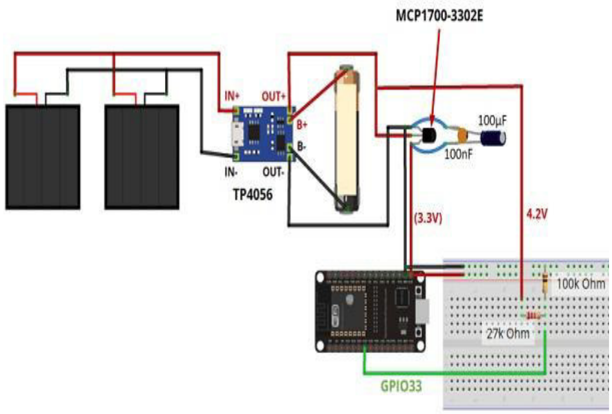


Figure-19. Connecting two resistors to the circuit

In this case, we are monitoring the battery level via GPIO33, but we can use any other suitable GPIO. Finally, to get the battery level, we can simply read the voltage on GPIO33 using the analogRead () function in our code (if we are using the Arduino IDE).

CONCLUSION

It is necessary to use alternative energy in Kazakhstan including solar energy. Based on the analysis, it can be concluded that in order to efficiently generate energy for our automated system in autonomous house.

The use of automated technologies allows an additional energy saving of 30%.

Installing an automated solar power system can have a significant impact on the environment. We can also improve our health and protect the environment by reducing our dependence on fossil fuels and installing an automated solar power system in our home or work.

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