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A Real-Time Energy Consumption and Monitoring for Domestic Houses by using Internet of Things Approach

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Abstract: Nowadays, mitigating domestic energy demand is a crucial concern for consumers. In the same way that one technology evolves into a more advanced one, it also happened in the electrical energy meter. If at first, one traditional energy meter could evolve into a smart energy meter. This study addresses the smart energy meter could be integrated into a portable device where the same concept of the Internet of Things (IoT) platform as a medium of clouding data is applied for conventional use for customers. The use of a microcontroller that is integrated with a serial WIFI module act as the backbone of the system prototype to operate as a medium to upload data that encompassed of sensing scheme and mathematical approaches to obtain the electricity consumption of one consumer. This paper aims to discover instances where consumers might cut power consumption by monitoring overall energy consumption using the SCT013 current clamp transformer as the sensor component. To achieve this goal, a monitoring device-based on real-time data collection must be developed using the IoT medium of the ThingSpeak platform, where the data may be viewed on a PC, laptop, smartphone, etc. Based on the current results, the electricity usage statistics could be displayed graphically or numerically as well as users could observe the maximum and minimum peak consumption at one time period. With this effort, users can manage and control their overuse of energy by lively monitoring real-time electricity consumption.

Keywords: Energy Meter, SCT013, Internet Of Things, Real Time Electricity Consumption

1. Introduction

In this era of modernization, new innovations of technology were introduced to the world, opening society's eyes to the next version of technology, which is more advanced in many ways. Including household technology, the old and convenient energy meter was innovated with a new smart energy meter that brings many benefits, such as time and cost savings. Smart electricity meters end the cost estimation of electric billing consumption done by conventional energy meters.

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This paper adapts the complexity of smart energy meters into a device compatible with any current electricity meter to display real-time energy consumption data. The developed device seems to be a digital utility meter that records home energy usage and shows the cost of electric bill consumption on the registered user's phone. This advanced metering infrastructure saves users time by putting data at their fingertips. [1] Moreover, a special feature of the system is built by getting used the non-invasive alternating current (AC) current sensor split core type clamp meter sensor named SCT-013 that can be used to measure AC up to 100 amperes. This sensor operates like a clamp-on ammeter. Emphasizing their operation, these two devices will get used to the magnetic field surrounding the single current-carrying wire. In this case, the system will contain not only the amount of electric energy consumed but also the amount of money spent in ringgit (RM), which the clamp-on meter couldn't offer.

In a nutshell, monitoring electrical power consumption is an efficient means of managing energy efficiency and savings. Because of the availability of mobile phone connectivity and WIFI coverage, the precise information regarding one's electric bill will be kept essentially up to date at all times. Registered users will receive the latest data to independently monitor their energy bill use. [2] Self-monitoring of nearly real-time information promises a better ability to regulate and manage the bill and inspect current data to spot significant electricity bill losses [3]. Existing power meters lack real-time monitoring, making them impractical. Consumers must monitor their electricity use to be energy conscious. Real-time power information can inspire consumers to save without waiting for their monthly bills. Fortunately, the development of Information and Communication Technology (ICT) has accelerated quickly during the past decade. Wireless communication allows people to access information from anywhere [4]. Consequently, this paper will leverage the development of wireless communication technology by building a real-time monitoring system for electrical power usage in order to address this issue. Overall, this paper presents “A Real-Time Energy Consumption and Monitoring for Domestic Houses by Using IoT Approach” by specifically using the SCT013 clamp sensor for the purpose of lively monitoring the data of current, power, energy consumption and as well as money spend in ringgit.

The prime purpose of this paper is to focus on monitoring the real-time data on energy consumption. Therefore, in order to achieve the following aim, the project is required to develop a handy version device of the real-time monitor by specifically using the SCT013 current transformer clamp sensor with integration between ThingSpeak application software.

2. Materials and Methods

Further discussions regarding the prototype and so the system development of real-time energy consumption and monitoring using the IoT approach will be explained in this section.

2.1 Project Block Diagram

Figure 1 shows the block diagram that consists of three major parts of the system stated as input unit, processing unit and output unit.

i. Input unit

Consists of two main components that act as the sensing scheme of the related observed data. In this case, the SCT-013-00 is used as the current sensor, and thus the data obtained is transmitted into the Arduino Wemos D1 R1 to continue the process.

ii. Processing Unit

Require Arduino Wemos D1 R1 board as the main component of the system, otherwise, the system may malfunction. This Arduino Wemos D1 R1 was operated to receive the information data signal from the recent sensors used. Hence, transmits the data to the IoT cloud data storage which is the ThingSpeak application.

iii. Output Unit

Integration of IoT platform making human works become easier and its application will lead to the Industrial Revolution of IR4.0. The implementation of the ThingSpeak IoT cloud application makes the received data such that easy to monitor through the smartphone device.

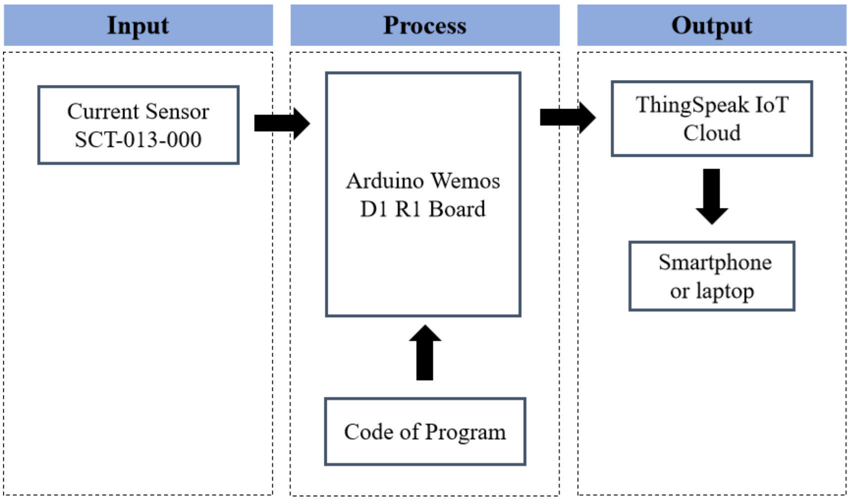

Figure 1: Block diagram of the system

2.1 Circuit Design

Behind all of the overall prototypes, there is a simulated circuit design that is always used to be try and error method before applying it to the real one. Technically, the prototype is similarly developed as what is demonstrated in Figure 2. The transformer over there is represented by the CT sensor of SCT-013-000 as it consists of a transformer build with a turn ratio of 1:1800. And on the other hand, the motor has represented the load while the AC voltage source is adjusted fix at 230V supply.

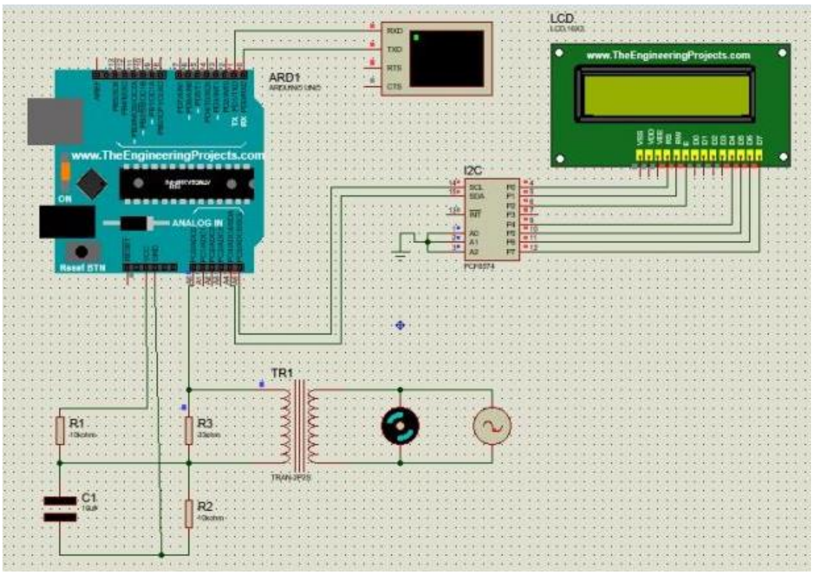

Figure 2: Schematic diagram of the developed prototype.

2.2 Internal Project System

Figure 3 illustrates the internal prototype of the project. The internal prototype clearly consists of a processing unit of Arduino Wemos D1 R1, a printed circuit board (PCB) design as the body of the project system, and also an LCD display that interfacing with an I2C component that is attached to the side of the project box. With the current clamp sensor connected with an analog pin of A0 of Arduino

Wemos D1 R1, the AC current could be read and sensed by the current clamp sensor when once there is a current flow through it after the clamping procedures were taken.

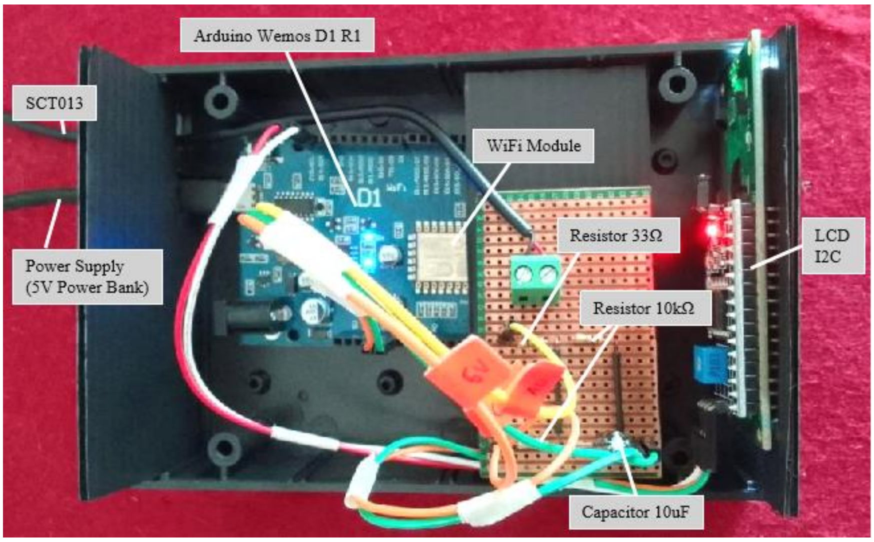

Figure 3: Internal prototype of project.

2.3 External Project Prototype

The plan view of the external project of the electrical energy monitoring device is shown in Figure 4. A black project box with dimensions of 150mm x 100mm x 50mm is used as the casing to cover and as well give protection to the internal project prototype. This prototype is supplied by the 5V source of the power bank as the input, if lower than that the system will not function well as the LCD interfacing with I2C requires 5V to stay active. This is why the chosen board of processing unit needs to be emphasized so that it has a 5V pin feature in this case of this project, the Arduino Wemos D1 R1 board is used as a processor for the project.

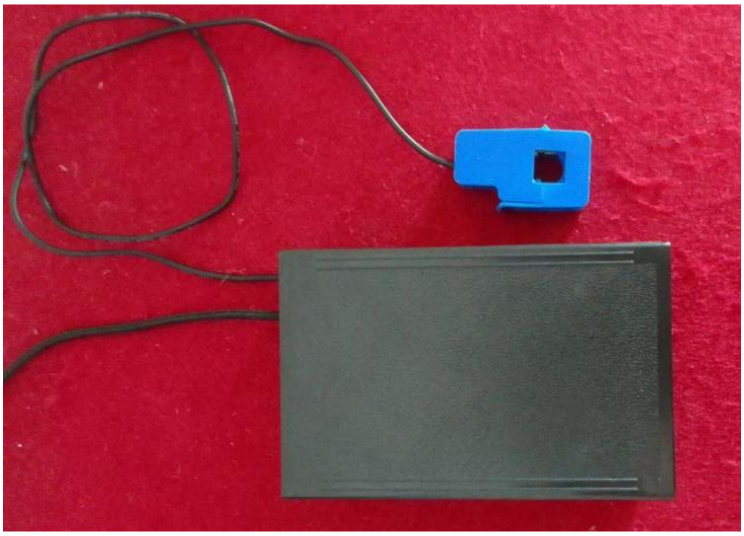

Figure 4: Prototype of the project with complete enclosure.

Figure 5 depicts the LCD displaying data after the prototype execution. As in Figure 5, it is just intended to prove that the device is well functioned and used for monitoring the usage of electricity consumption, regardless of the load applied within the system. It is expected that once the CT sensor clamp of SCT-013-000 is clipped at the single conductor cable, it will sense or detect the flow of the current through the wire. Hence, immediately transmits the required data into the processing unit, so that later then it will be read on the cloud IoT platform

Figure 5: LCD displaying data after the prototype execution.

3. Results and Discussion

As a result of the prototype system, data uploaded to the ThingSpeak IoT cloud platform could be exported directly in Microsoft Excel table list format. Each transmitted data takes 15 minutes for ThingSpeak to process, after which consumers can access and monitor the data. From the data tabulated in Table 1 in Appendix A, the results of data are expected to fall under a range of various load consumption, which in this case, the load implemented onto the system is such 45W fan and 120W laptop charger, with both being used continuously. With assumption in terms of single phase residential household application, the domestic supply is assumed as 230Vrms with unity power factor. By that, the total current of the respective load mentioned previously is 0.7A. The value of the current consumption could be varied in many aspects, this is explained why there's distinguish between the measured and experimental values. Those aspects are because of the factor of V_{rms} which in actuality, the parameter will be varied and inconsistent, and then the power factor of the household could be affected the output of the system since technically 1.0 power factor which is a unity condition is nearly impossible to be obtained.

From Table 1, a clear observation can be made where the peak or maximum power consumed is at exactly 200W while the minimum is at an equivalent of 128W. It can be seen that varied the parameter of current and power consumed over a period of time affects the increment of the electricity consumption and money spent. Therefore, it is literally proved that all of the parameters are related to each other by the relation of direct proportionality. Taking an example, as power usage increases, energy consumption also will be increased over a period of time intervals. Looking at the current measurement, as the current readings vary within the range of load consumed, it is possible to conclude that the measurement is accurate. In this instance, the difference between the readings is due to the implementation of a high rating of the current transformer clamp sensor, which reduces its accuracy by up to 2% of the current reading's output. To ensure for accurate readings, it is essential to confirm that the core has been properly closed because even a small air gap can cause a 10% deviation.

The consumer lives data display could be viewed using the website or via the mobile smartphone application of ThingSpeak. As portrayed in Figures 6 - 9, the ThingView application's interface, represents the parameter of current (A), power (W), energy consumption (kWh), and also in ringgit unit of Malaysia (RM) with respect to the time duration when the device is still online and connected to the same WIFI as ThingSpeak IoT platform was used. This graphical view of the related parameters was taken and recorded over a real-time application, and in addition, the displays of them are obtained by using a landscape view screenshot of each graph through the mobile phone application.

i. Current measurement

All of the particular data of current, power, electricity consumption in kWh, and as well ringgit unit of money spend is corresponding to the duration of time taken by the users. This electrical parameter will be displayed once after clamping the CT sensor to one live current carrying conductor of a plug extension with running load conditions. In this case, the time taken recorded is adjusted to be around up to 20 minutes. From the graph observation, it could be seen such that the current waveform quite vary against time period. Based on the graph of I_{rms} versus time, the peak of the current can be viewed obviously throughout 20 minutes running load which is equivalent to 0.87A as shown in Figure 6.

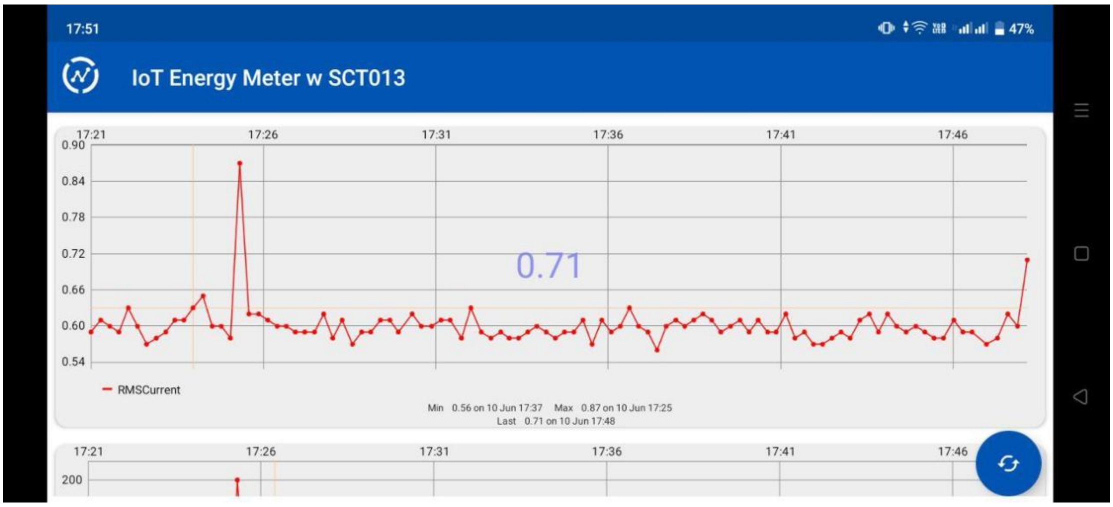

Figure 6: Graph of I_{rms} versus time via ThingSpeak IoT platform.

ii. Power measurement

As previously mentioned, the voltage used in this project is assumed to be constant at exactly equivalent to 230V. Therefore, the power relationship with respect to current must be proportional to each other, where the increasing value in current results in an increasing value of power indeed. As shown in Figure 7, it could be observed from the graph of power versus 20 minutes of time taken, the power usage at its peak is equivalent to 200W while the minimum is 128W

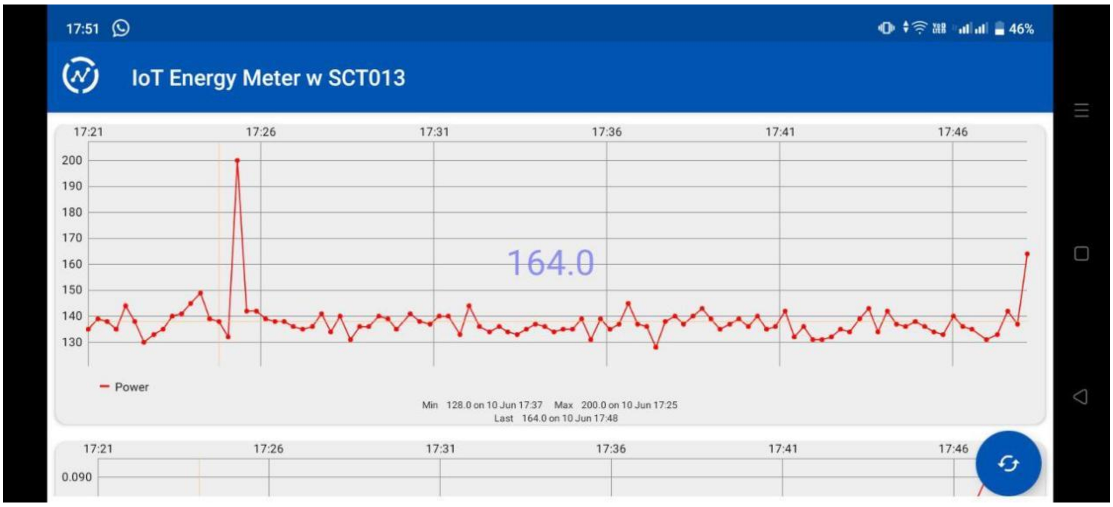

Figure 7: Graph of power versus time via ThingSpeak IoT platform.

iii. kWh measurement

On the other hand, looking at the perspective of electrical energy consumption as represented in Figure 8, the waveform of the energy consumption is in a form of an increasing stair shape from some time interval to another. However, the graph trend of linear increase could be seen if the decimal point of electricity consumed in kWh is extended further. From the electricity consumption in kilowatt-hour (kWh) versus time, the most recent electricity consumed is about 0.09kWh for over 20 minutes with the continuous running load.

Figure 8: Graph of kWh energy versus time via ThingSpeak IoT platform.

iv. RM measurement

The money spends on ringgit (RM) is similar to the electricity consumption graph trend. As can be observed based on the money spent versus the time graph, the money spent is depending on the electrical energy consumed in that of 20 minutes time taken. Hypothetically, as the increment of electricity usage results in an increase in money spent in one period, therefore their relationship of them could be described as directly proportional to each other. Analytically, referring to the graph in Figure 9, the most money spend is equivalent to RM0.02 so far within 20 minutes of the time recorded.

Figure 9: Graph of RM versus time via ThingSpeak IoT platform.

4. Conclusion

In conclusion, this paper proposed the development of electrical energy consumption monitoring by the application of the Internet of Things (IoT) that complied with the Industrial Revolution of 4.0, which emphasizes the internet revolution that conceptualizes rapid change in technology, industry, and social patterns and processes in the 21st century due to growing interconnections and smart automation. With IoT technology, it's possible to monitor an appliance's or a household's electric consumption, and the data will be displayed on a smartphone. It measures current, voltage, and power using sensors and an Arduino microcontroller. Overall, the IoT implementation is accomplished by the interconnection between Arduino Wemos D1 R1 as a processing unit and the ThingSpeak IoT cloud platform through the utilization of WIFI network capability. The monitoring concept system is achievable in this project since the data result of the current measurement and subsequently, its pricing could be displayed whenever the prototype is inactivated and online.

Acknowledgement

This research was made possible by the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support and guidance throughout the accomplishment of this thesis.

Appendix A

Table 1: Exported data from ThingSpeak platform.

No	Time (s) in 15s interval	I (A)	P (W)	Energy Consumed (kWh)	Money Spend (RM)	
1	0:00:00	0.59	136	0.03	0.01	
2	0:00:15	0.61	140	0.03	0.01	
3	0:00:30	0.60	138	0.03	0.01	
4	0:00:45	0.59	136	0.03	0.01	
5	0:01:00	0.63	145	0.03	0.01	
6	0:01:15	0.60	138	0.03	0.01	
7	0:01:30	0.57	131	0.03	0.01	
8	0:01:45	0.58	133	0.03	0.01	
9	0:02:00	0.59	136	0.03	0.01	
10	0:02:15	0.61	140	0.03	0.01	
11	0:02:30	0.61	140	0.03	0.01	
12	0:02:45	0.63	145	0.03	0.01	
13	0:03:00	0.65	150	0.03	0.01	
14	0:03:15	0.60	138	0.03	0.01	
15	0:03:30	0.60	138	0.03	0.01	
16	0:03:45	0.58	133	0.03	0.01	
17	0:04:00	0.87	200	0.03	0.01	max
18	0:04:15	0.62	143	0.04	0.01	
19	0:04:30	0.62	143	0.04	0.01	
20	0:04:45	0.61	140	0.04	0.01	
21	0:05:00	0.60	138	0.04	0.01	
22	0:05:15	0.60	138	0.04	0.01	
23	0:05:30	0.59	136	0.04	0.01	
24	0:05:45	0.59	136	0.04	0.01	
25	0:06:00	0.59	136	0.04	0.01	
26	0:06:15	0.62	143	0.04	0.01	
27	0:06:30	0.58	133	0.04	0.01	
28	0:06:45	0.61	140	0.04	0.01	
29	0:07:00	0.57	131	0.04	0.01	
30	0:07:15	0.59	136	0.04	0.01	
31	0:07:30	0.59	136	0.04	0.01	
32	0:07:45	0.61	140	0.04	0.01	
33	0:08:00	0.61	140	0.05	0.01	
34	0:08:15	0.59	136	0.05	0.01	
35	0:08:30	0.62	143	0.05	0.01	

36	0:08:45	0.60	138	0.05	0.01	
37	0:09:00	0.60	138	0.05	0.01	
38	0:09:15	0.61	140	0.05	0.01	
39	0:09:30	0.61	140	0.05	0.01	
40	0:09:45	0.58	133	0.05	0.01	
41	0:10:00	0.63	145	0.05	0.01	
42	0:10:15	0.59	136	0.05	0.01	
43	0:10:30	0.58	133	0.05	0.01	
44	0:10:45	0.59	136	0.05	0.01	
45	0:11:00	0.58	133	0.05	0.01	
46	0:11:15	0.58	133	0.05	0.01	
47	0:11:30	0.59	136	0.06	0.01	
48	0:11:45	0.60	138	0.06	0.01	
49	0:12:00	0.59	136	0.06	0.01	
50	0:12:15	0.58	133	0.06	0.01	
51	0:12:30	0.59	136	0.06	0.01	
52	0:12:45	0.59	136	0.06	0.01	
53	0:13:00	0.61	140	0.06	0.01	
54	0:13:15	0.57	131	0.06	0.01	
55	0:13:30	0.61	140	0.06	0.01	
56	0:13:45	0.59	136	0.06	0.01	
57	0:14:00	0.60	138	0.06	0.01	
58	0:14:15	0.63	145	0.06	0.01	
59	0:14:30	0.60	138	0.06	0.01	
60	0:14:45	0.59	136	0.06	0.01	
61	0:15:00	0.56	128	0.06	0.01	min
62	0:15:15	0.60	138	0.06	0.01	
63	0:15:30	0.61	140	0.07	0.01	
64	0:15:45	0.60	138	0.07	0.01	
65	0:16:00	0.61	140	0.07	0.01	
66	0:16:15	0.62	143	0.07	0.01	
67	0:16:30	0.61	140	0.07	0.01	
68	0:16:45	0.59	136	0.07	0.01	
69	0:17:00	0.60	138	0.07	0.01	
70	0:17:15	0.61	140	0.07	0.01	
71	0:17:30	0.59	136	0.07	0.02	
72	0:17:45	0.61	140	0.07	0.02	
73	0:18:00	0.59	136	0.07	0.02	
74	0:18:15	0.59	136	0.07	0.02	
75	0:18:30	0.62	143	0.07	0.02	
76	0:18:45	0.58	133	0.07	0.02	
77	0:19:00	0.59	136	0.07	0.02	
78	0:19:15	0.57	131	0.07	0.02	
79	0:19:30	0.57	131	0.07	0.02	
80	0:19:45	0.58	133	0.08	0.02	

81	0:20:00	0.59	136	0.08	0.02	
82	0:20:15	0.58	133	0.08	0.02	
83	0:20:30	0.61	140	0.08	0.02	
84	0:20:45	0.62	143	0.08	0.02	
85	0:21:00	0.59	136	0.08	0.02	
86	0:21:15	0.62	143	0.08	0.02	
87	0:21:30	0.60	138	0.08	0.02	
88	0:21:45	0.59	136	0.08	0.02	
89	0:22:00	0.60	138	0.08	0.02	
90	0:22:15	0.59	136	0.08	0.02	
91	0:22:30	0.58	133	0.08	0.02	
92	0:22:45	0.58	133	0.08	0.02	
93	0:23:00	0.61	140	0.08	0.02	
94	0:23:15	0.59	136	0.08	0.02	
95	0:23:30	0.59	136	0.08	0.02	
96	0:23:45	0.57	131	0.09	0.02	
97	0:24:00	0.58	133	0.09	0.02	
98	0:24:15	0.62	143	0.09	0.02	
99	0:24:30	0.60	138	0.09	0.02	
100	0:24:45	0.71	164	0.09	0.02	

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