

IOT APPLICATION FOR CONVEYOR MOTOR LOAD CURRENT AND TEMPERATURE MONITORING DEVICE FOR FACTORY ACCEPTANCE TEST IN INDUSTRIAL APPLICATION

Ali Rospawan¹⁾, Joni Welman Simatupang^{*2)}, Irwan Purnama^{3,4)}

¹⁾Department of Electrical Engineering, National Chung Hsing University, Taichung, Taiwan

²⁾Study Program of Electrical Engineering, Faculty of Engineering, President University, Cikarang, Indonesia

³⁾Technical Implementation Unit for Instrumentation Development (UPT BPI), LIPI-BRIN, Bandung, Indonesia

⁴⁾Department of Electrical Engineering, Telkom University, Bandung, Indonesia

e-mail: alirospawan34@gmail.com, joniwsmtpt@president.ac.id, irwa002@gmail.com

Received: September 24, 2021 – Revised: January 2, 2022 – Accepted: January 3, 2022

ABSTRACT

In industrial application on machine manufacturer multinational company, especially on the conveyor manufacturing company, before delivering the conveyor to overseas customer, there are some regulations need to be complied to ensure the product quality is always good. The system to ensure the product quality before delivery is named by Factory Acceptance Test (FAT). The purpose of doing this is to gain the trust and satisfaction of the buyer company by ensuring the quality before delivery. To ensure the product quality, this device was designed following the customer check sheet and requirement by giving them reliable data of the load current on each line of the motor and the motor temperature. This device is consisting of WEMOS D1 mini as the main controller and an IoT device, thermocouple type K as a temperature sensor, MAX6675 as the driver of the thermocouple, SCT-013-005 as a split-core current sensor, Arduino Nano as the second controller, and LCD 2004 as a real-time display. The IoT Application for Conveyor Motor Load Current and Temperature Monitoring Device is successfully created with the output is a table of data and the line chart which consists of Load current on each phase (U1, V1, W1), the motor temperature, and the limitation of each data so the user is easier to determine the commissioning result of the Factory Acceptance Test.

Keywords: Arduino, Current Monitoring, Factory Acceptance Test, Industrial IoT Application, Temperature Monitoring, WEMOS D1 Mini.

ABSTRAK

Dalam aplikasi pembuatan mesin industri pada perusahaan multinasional, khususnya pada perusahaan pembuat konveyor, sebelum mengirimkan konveyor ke pelanggan yang berada di luar negeri, terdapat beberapa peraturan yang harus dipenuhi untuk memastikan kualitas produk selalu dalam keadaan baik. Sistem untuk memastikan kualitas produk sebelum pengiriman disebut dengan Pengujian Penerimaan Pabrik (FAT). Tujuan melakukan hal ini adalah untuk mendapatkan kepercayaan dan kepuasan pelanggan dengan memastikan kualitas sebelum pengiriman. Untuk memastikan kualitas produk, perangkat ini dirancang mengikuti lembar pemeriksaan dan kebutuhan pelanggan dengan memberikan data berupa arus beban listrik pada masing-masing jalur kabel motor serta suhu dari motor. Perangkat ini terdiri dari WEMOS D1 mini sebagai controller utama dan perangkat IoT-nya, termokopel tipe K sebagai sensor suhu, MAX6675 sebagai pengontrol dari termokopel, SCT-013-005 sebagai sensor arus dengan inti terpisah, Arduino nano sebagai controller kedua dan LCD 2004 sebagai tampilan dalam waktu nyata. Aplikasi IoT untuk Perangkat Pemantauan Arus dan Suhu Beban Motor Konveyor berhasil dibuat dengan output berupa data tabel dan diagram garis yang terdiri dari arus beban pada masing-masing fasa kabel (U1, V1, W1), suhu motor dan batasan maksimum pada setiap data, sehingga pengguna lebih mudah untuk menentukan hasil dari Pengujian Penerimaan Pabrik.

Kata Kunci: Aplikasi IoT di industri, Arduino, Pengujian penerimaan pabrik, Pemantauan arus, Pemantauan suhu, WEMOS D1 mini.

I. INTRODUCTION

IN industrial application on machine manufacturer multinational company, especially on the conveyor manufacturing company, before delivering the conveyor to overseas customer, there are some regulations need to be complied to ensure the product quality is always good. The system to ensure the product quality before delivery is named by Factory Acceptance Test (FAT) [1], [2]. Following its name, this system is done in the house of the manufacturer company. For the overseas customer, it is rare for them to do factory visits before delivery for the various reason for example because of cost-saving, low budget, or due to the border closed of the origin country of the manufacturer company that prevents all foreigners from entering the country, etc.

To make it clear and meet the customer requirement also that there are no lies between the manufacturer company and the customer, this online conveyor load current and temperature monitoring for factory acceptance test on industrial application device were made [1]–[4]. This device is designed to be able to monitor the motor load current on each phase (commonly 3 phase (U1, V1, W1)) and the motor temperature continuously and in real-time. After that, the monitored data is sent directly to online Google Sheets through WEMOS D1 mini and stored there to make the customer can see it.

To make the data is easier to view, the online and real-time line chart is attached. Inside the chart has the real-time value from the device received at one-minute intervals. Besides the motor loads current and the motor temperature, the limitation or maximum value for the loads current and temperature line is also attached to the chart. The limitation data of the load current is calculated carefully and comparing the calculated data with the maximum load current which is shown on the motor datasheet. This limitation is having a big contribution because it is used to determine the conveyor factory acceptance test is passed or not by only viewing the value on the chart, is exceeding the limit or not. If the limit of the load current and temperature achieved the maximum line, the customer can give an order to the manufacturer company to re-check the conveyor, push the motor moving going well without abnormality, and make the motor specification calculated perfectly, etc. until the Factory Acceptance Test passed.

The rest of the paper is given as follows. Chapter II describes the design specification and design method and implementation. Chapter IV shows the experimental results and analysis. And lastly, Chapter V is the conclusion.

II. RESEARCH METHOD

A. Design Specification

IoT application for conveyor load current and temperature monitoring device for factory acceptance test on industrial application is a device specifically designed to read the load current from the motor conveyor (commonly 3 phase) and the motor temperature of a single unit conveyor then display it online on google sheets so the customer who has granted to access the data can view it from anywhere.

The main part of this device is consisting of WEMOS D1 Mini as the main controller and an IoT device, thermocouple type K as a temperature sensor, MAX6675 as the driver of the thermocouple, SCT-013-005 as a split-core current sensor, Arduino Nano as the second controller and LCD 2004 as a real-time display.

In this device, to display the real-time value of loads current and temperature of the motor on the conveyor over the online google sheets, the WEMOS D1 Mini is required (See Figure 1). WEMOS D1 Mini is an IoT device which able to connect to the internet using WIFI communications [5], [6].

WEMOS D1 mini programmed using an Arduino IDE which is convenient and easier to use, also its library is accessible online for free [5], [6].

The real-time temperature monitoring system is consisting of thermocouple type K (Silicone Wire) with continuous performance temperature capabilities 180°C from Deange Industry Corporation, a Taiwanese company product as a temperature sensor [7]. The thermocouple type K used on this system is shown in Figure 2.

The output voltage from the thermocouple is too small for Arduino Nano to read the value directly using the analog pins, the average sensitivity of the type K thermocouple in the temperature range 0 °C to 100 °C is 40 $\mu\text{V}/^\circ\text{C}$, so an operational amplifier is required [8].

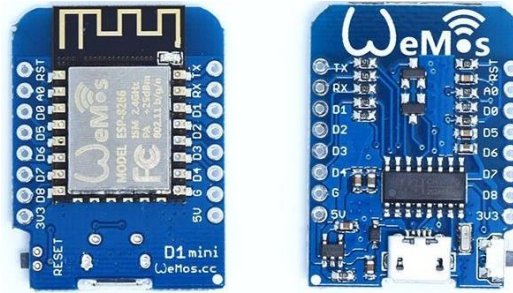


Figure 1. WEMOS D1 mini [5]



Figure 2. Thermocouple type K [7]

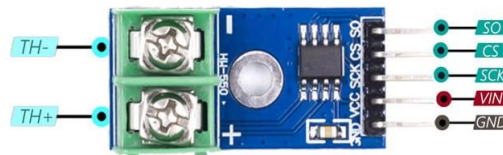


Figure 3. MAX6675 configuration [9]



Figure 4. Split core current sensor (SCT-013-005) [10]

MAX6675 is a thermocouple amplifier IC that is specifically designed to read the thermocouple type K analog data and convert it to digital data [9]. The MAX6675 module which is used on this system is shown in Figure 3.

The MAX6675 converts the temperature with 0.25°C accuracy and maximum reading allowance is +1024°C to digital data. The data is outputted in a 12-bits resolution using SPI communication. Based on Figure 3 above, the left side pins are connected to the thermocouple type K sensor and the right side is connected to the Arduino nano pins [9].

Real-time load current monitoring is a system to read the load current of the motor (commonly 3 phases (U1, V1, W1)) on each phase of the cable on the motor conveyor continuously with one-minute intervals. SCT-013-005 is a split-core current sensor from Beijing Yaohuadechang Electronic (YHDC), China. This sensor has a sensing allowance from 0 to 5 Ampere and $\pm 3\%$ of accuracy. Its core is splittable, so it is easier to insert the load wire without disconnecting the wire phases on the motor [10].

The split-core current sensor SCT-013-005 device used on this system is shown in Figure 4. The SCT-013-005 comes with standard male three-core plug or three-pin audio jacks on its end. Because of that, we need a female connector to make it easier when connecting and disconnecting the current sensor to



Figure 5. Three pins audio jack [10]



Figure 6. Arduino nano [11]



Figure 7. LCD 2004 [11]

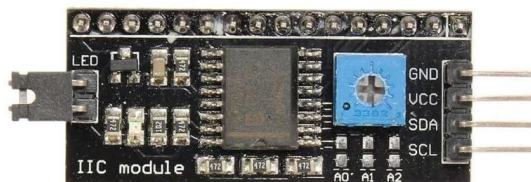


Figure 8. I2C LCD controller device [13]

the main body of the device [10]. The female three-core audio jack connector which is used on this system is shown in Figure 5.

The required analog input for this system is 3 pins for the load current. But the WEMOS D1 MINI only provides one analog pin, so it is impossible to read the three-load current at the same time if still insisting to use only provided pin. For this problem, the writer is using Arduino Nano as the second controller to read the analog data [5], [11]. The partial view of this Arduino nano is shown in Figure 6.

Arduino nano provides 14 digital I/O pins plus 6 can PWM output pins and 8 analog pins, so it is enough to comply with the requirement of this system. The Arduino Nano is also equipped with I2C communication so the MAX6675 is also possible to connect directly to its SDA & SCL pins [11]. Because the analog data is inputted to Arduino Nano, to make it easy for programming, the MAX6675 digital temperature converter is also inputted to Arduino Nano.

For the convenient usage of this device, the load current of each phase (U1, V1, W1) and temperature value are displayed independently on the LCD 2004. The purpose is user does not necessary to open the internet to view the load current and temperature value. The real part views LCD 2004 is shown in Figure 7. This LCD 2004 is a dot-matrix LCD module to show letters, numbers, and characters in 4 lines of 20 characters [12]–[15].

The I/O Pin on the Arduino Nano is not enough for handling the LCD 2004 using data pins on the LCD communications, so the I2C LCD Controller is attached [11]–[13]. The I2C module used on this system is shown in Figure 8.

LCD I2C module is a device used to convert the data from Arduino nano I2C serial data to parallel data for LCD 2004. This device helps maintain the insufficient I/O pins on the microcontroller (Arduino nano) because it only needs 2 pins of the microcontroller (SDA, SCL) to control the LCD2004 [11]–[13]. To maintain the data read by Arduino Nano is readable in the WEMOS D1 Mini, serial communication is used [5], [11], [16].

B. Design Method and Implementation

The concept for the proposed design is an implementation of WEMOS D1 mini, Thermocouple type

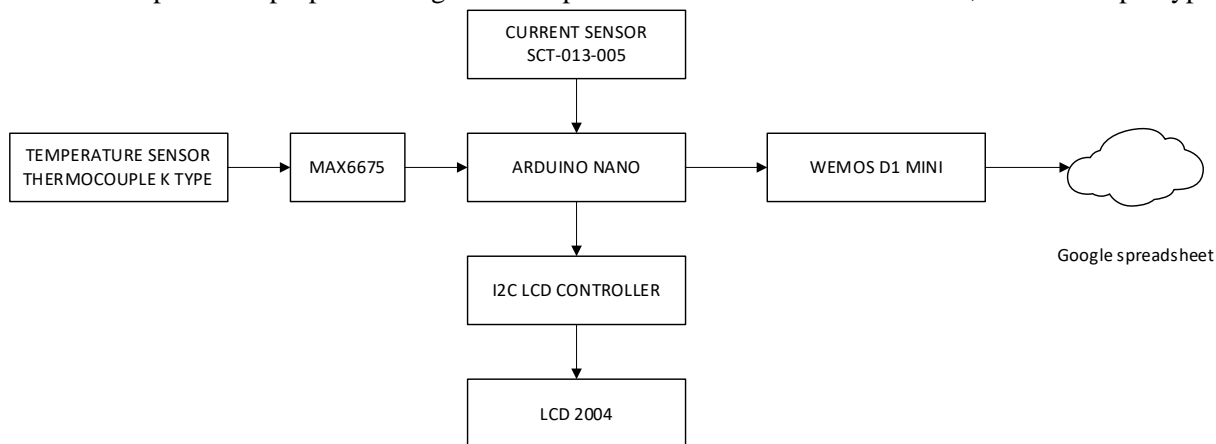


Figure 1. Block diagram of the proposed system

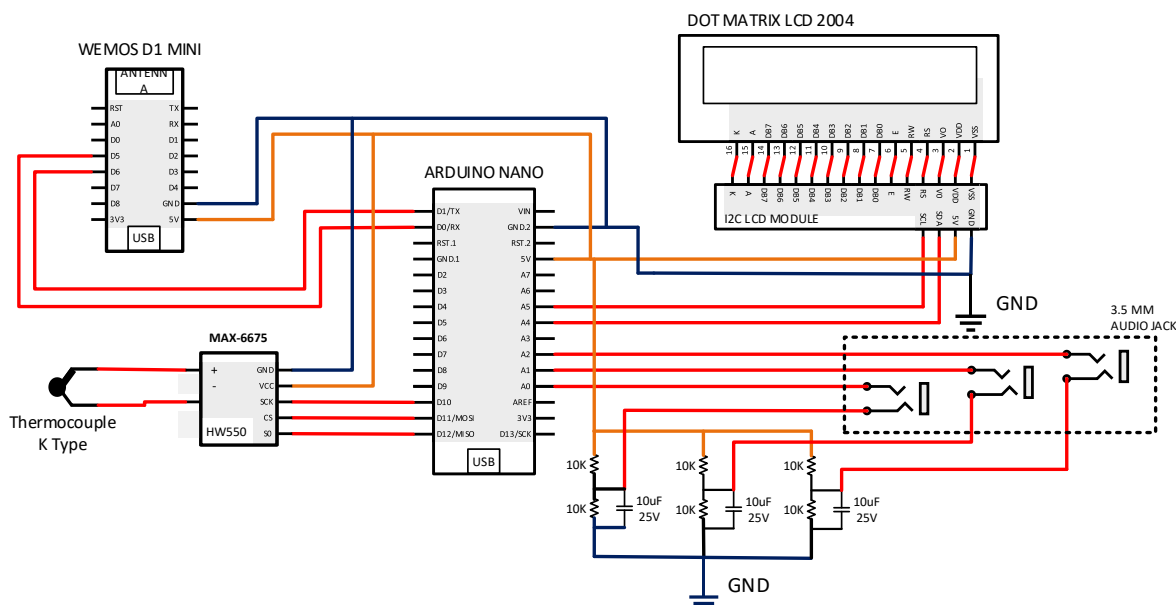


Figure 2. Hardware Diagram Circuit

K, MX6675 as the thermocouple driver, SCT-013-005 split-core current sensor, Arduino nano, LCD 2004 devices, and the I2C LCD controller. The configuration of this system is shown in Figure 9.

As shown in Figure 9, block diagram of the proposed system, the output of this monitoring system is shown in two ways, first is on LCD 2004 as a direct display system and secondly is on google spreadsheet as an online display and data storing system. The schematic diagram for all connected components is shown in Figure 10.

As shown in Figure 10, all load current sensors of the U1, V1, W1, the temperature sensor, and the LCD are connected to Arduino Nano. The output of current sensor analog data read by Arduino nano is processed first before sending directly to WEMOS D1 mini using serial communication in one-minute intervals. The data received by WEMOS D1 Mini is sent to the internet through WIFI [5], [16].

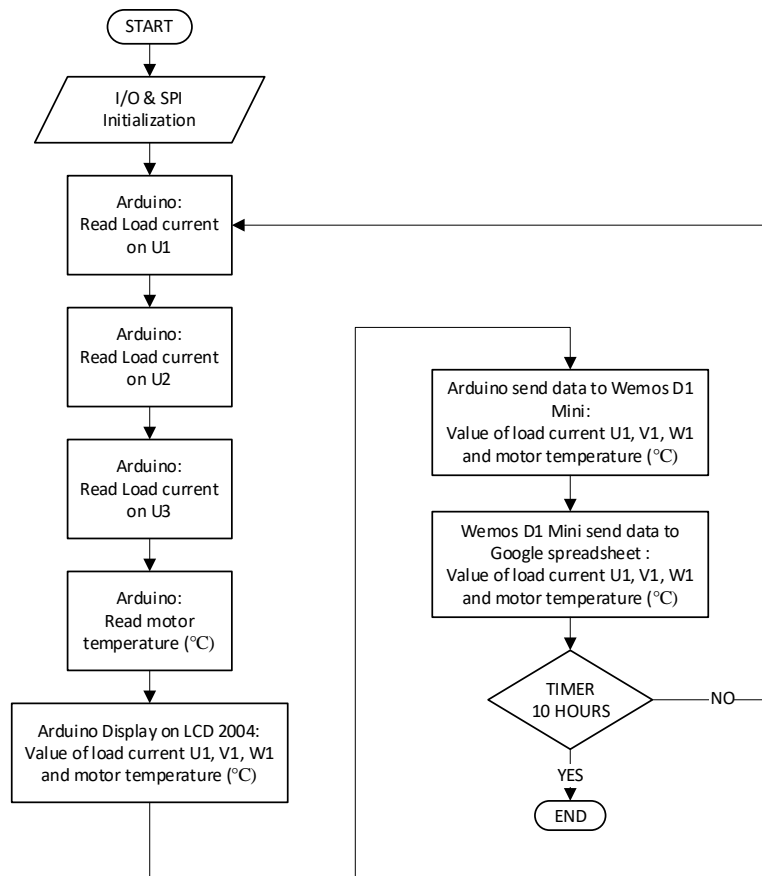


Figure 3. Program Flow Chart



Figure 4. Direct measuring of the load current

The designed program flow for this system is following Figure 11. During the Factory Acceptance Test, as mentioned on the program flow chart in Figure 11, the load current on each line and the temperature sensor are read systematically following the chart, because all the sensors are sense on 10-second sampling rate before sent. The motor should run for 10 hours to achieve its maximum endurance test. In the assumption that if the 10 hours continuous test passes, when the conveyor is installed on the customer company place there should be no problem.

During the data logging process, in an interval of 1-hour, the specified personnel is ordered to take the actual load current and temperature data using a digital AC clamp meter. Direct measuring of the load current is shown in Figure 12.

From Figure 12, the direct current measurement using a digital AC clamp meter is done directly to the cable near the induction motor. As requested, the data from this measurement is shown to the customer using a photo for the actual value.

TABLE 1
MOTOR MAXIMUM LOAD CURRENT DATASHEET [18].

Motor Capacity		Frame Size	Rated RPM	Full Load (A) Current							Starting Torque % of FL	Break-down Torque % of FL	Nominal Efficiency %	Power Factor %	NEMA Code Letter
HP	KW			Torque		Full Load		No Load	Starting						
				In-Lbs	N-m	220V	380V	% of FL	% of FL						
1/8	0.1	V-63S	1400	6.03	0.682	0.6	0.35	78.3	371	230	226	63.3	69.1	H	
1/4	0.2	V-63M	1390	12.2	1.37	1.05	0.61	71.5	361	206	206	67.6	73.7	F	
1/3	0.25	V-63M	1360	15.5	1.75	1.22	0.71	61.4	338	195	181	69.1	77.8	E	
1/2	0.4	V-71M	1410	24.0	2.71	2.06	1.19	68.3	353	201	204	69.7	73.5	F	
3/4	0.55	V-805	1400	33.2	3.75	2.45	1.42	58.5	373	206	196	73.4	80.2	E	

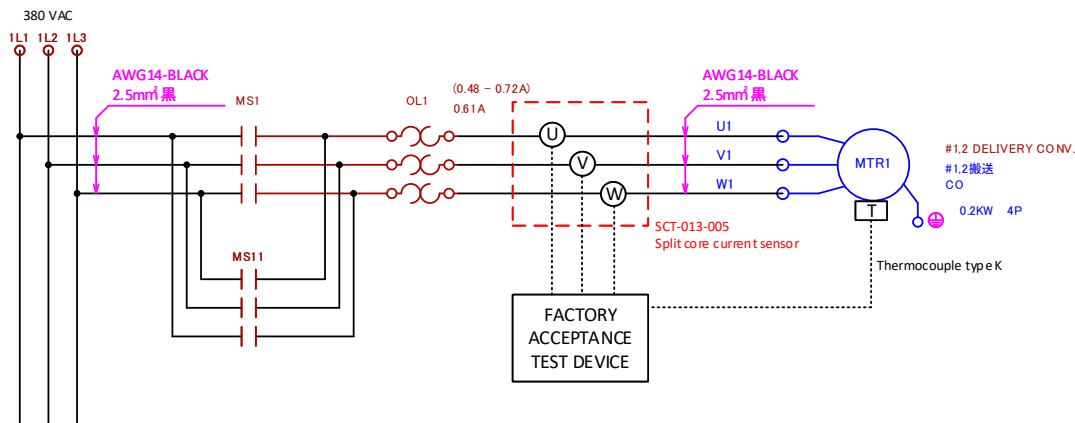


Figure 5. Run Configuration (Drawing)



Figure 6. Motor nameplate



Figure 7. Hardware Actual Implementation

The device configuration for sensor placement for trial is shown in Figure 13. From Figure 13, there are current sensors put on each phase line of the motor and 2 magnet switches for forward and reverse operation, although the reverse operation is only used during the maintenance. Besides the magnet switch, the thermal overload protection device is attached, this device is used for motor protection from overcurrent during the operation. The overload setting value is not calculated directly by motor power (200 Watt) divided by the input voltage (380 Volts), but this overload value is from the datasheet of the motor [17], [18]. The thermal overload setting value from the datasheet is shown in Table 1.

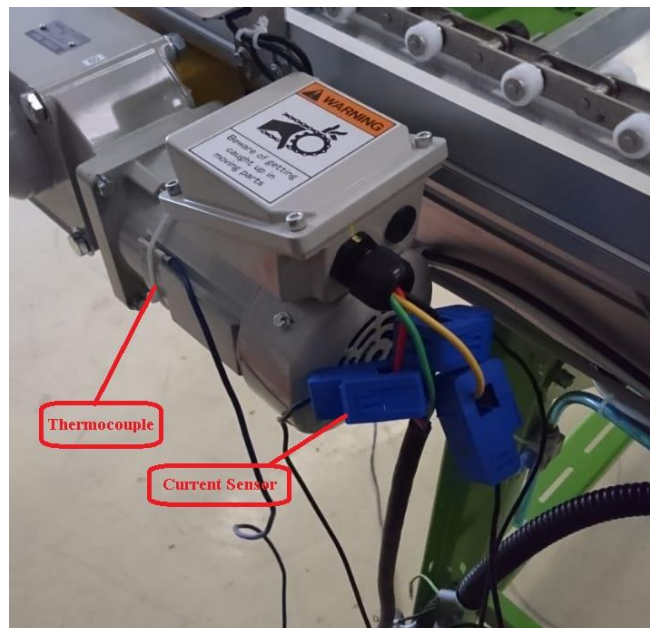


Figure 8. Sensor placement at close look

From Table 1, the full load current for 380V input voltage is 0.61A, so it's safe to set the value on the thermal overload on 0.61 A. For the current condition, the overload value is settled at 0.61 Ampere, so the thermal overload device is selected on its range value, for this condition, the selected thermal overload range is 0.4A – 0.72A [17], [18].

The induction motor parameter shown on the motor nameplate is shown in Figure 14. The motor specification is shown on the motor nameplate in Figure 14 shows that the motor type is Hyponic drive from Sumitomo Heavy Industries, Ltd. Japan. The model used is RNYM02-1320-60 with a gearbox ratio of 1:60, 0.2 KW power, 2.0 safety factor with maximum speed at 1450 Rpm [17], [18]. The actual hardware implementation for this device is shown in Figure 15.

Each phase line of the motor conveyor is attached with one current sensor so in total there are 3 current sensors connected. For the temperature measurement, the thermocouple sensor is-sticked directly to the motor body using cable ties. The detailed closed view of the sensor placement is shown in Figure 16.

III.RESULT AND DISCUSSION

IoT Application for Conveyor Motor Load Current and Temperature Monitoring Device for Factory Acceptance Test in Industrial Application has been built successfully either on the Hardware configuration (WEMOS D1 mini, Thermocouple type K, MX6675 as the thermocouple driver, SCT-013-005 split-core current sensor, Arduino nano, LCD 2004 devices, and the I2C LCD controller), software configuration (Arduino nano program, WEMOS D1 mini program) and the Google Spreadsheet (Table, chart and script editor program).

The result for this device is consists of two types of data. The first data is shown as a table of data and the second data is shown as a line chart data which its value is based on the data on the table. The clip of table data output from this system is shown in Figure 17. Because this table is obtained from the google spreadsheet directly, so we could only make these data in a figure form instead of table form.

As shown in Figure 17, the first column shows the time when the data is received, the second column shows the load current on the U1 line, the third column shows the load current on the V1 line, the fourth column shows the load current on the W1 line, the fifth column shows the motor temperature in Celsius, the sixth column shows the maximum current limitation in milli-Ampere, and the seventh column shows the maximum motor temperature in Celsius.

The second output of this system is divided into the load current chart and temperature chart. The load current chart result is shown in Figure 18. The chart output shown in Figure 18, is a shortage view from

Factory Acceptance Test Device

Data	current	temperature					
Time	U1 Load Current (mA)	V1 Load Current (mA)	W1 Load Current (mA)	Motor Temperature (C)	Max Current Limit (mA)	Max Temperature (C)	
10:00	0	0	0	36.3	610	70	
10:01	580	588	595	36.4	610	70	
10:02	492	498	516	36.5	610	70	
10:03	489	496	510	37.3	610	70	
10:04	489	496	509	37.5	610	70	
10:05	488	494	508	37.9	610	70	
10:06	488	495	509	38.2	610	70	
10:07	488	494	509	38.5	610	70	
10:08	488	494	509	38.7	610	70	
10:09	488	494	509	38.9	610	70	
10:10	488	494	509	39.2	610	70	
10:11	486	494	509	39.2	610	70	
10:12	488	494	509	39.3	610	70	
10:13	486	494	508	39.3	610	70	
10:14	488	494	509	39.3	610	70	
10:15	488	494	509	39.5	610	70	
10:16	488	494	509	39.5	610	70	
10:17	487	494	509	39.5	610	70	
10:18	488	494	509	39.7	610	70	
10:19	488	494	509	39.8	610	70	
10:20	489	496	510	39.8	610	70	
10:21	488	494	509	40	610	70	
10:22	487	494	509	40.2	610	70	
10:23	488	494	509	40.5	610	70	
10:24	488	494	509	40.7	610	70	
10:25	488	494	509	40.9	610	70	
10:26	488	494	509	41.2	610	70	
10:27	488	494	509	41.3	610	70	
10:28	489	496	510	41.5	610	70	
10:29	488	494	509	41.8	610	70	
10:30	488	494	509	41.8	610	70	

Published by Google Sheets – Report Abuse – Updated automatically every 5 minutes

Figure 9. The results of Google spreadsheet clip data

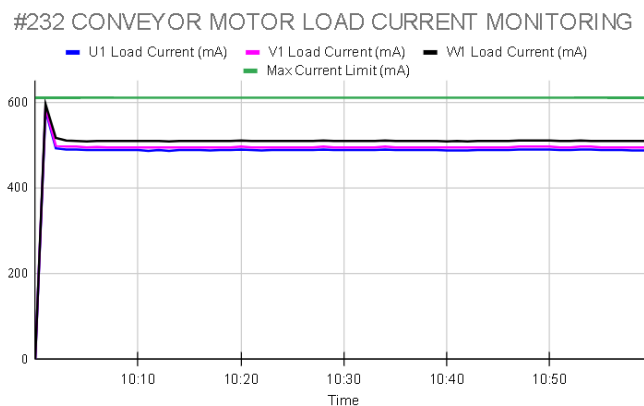


Figure 10. Load current chart with limit line

the table, inside the chart, there are the values of the motor load current on each phase (U1, V1, W1) and its limitation. This limitation data is to help maintain the user for easier to determine the result Good or Not Good, for example when the load current exceeds the limitation, there should be a problem with the conveyor, so the manufacturer company should take a close look and analyze why it happens, maybe the chain is too tense, etc.

The temperature output chart result is shown in Figure 19. The chart output shown in Figure 19 is a shortage view of the motor temperature along with its temperature limitation. As mentioned before this limitation data is to help maintain the user for easier to determine the result Good or Not Good. The temperature limitation is also having the same way of judgment as to the load current limitation. When the temperature exceeds the temperature limitation the manufacturer company should also take an action and analyze the problem.

If the value of the load current and temperature does not exceed the limit value, the buyer or the customer should be happy, because there is no problem with the conveyor and soon will approve the Factory Acceptance Test and be ready to deliver the conveyor to the buyer company place.

The result of measurement using the digital AC clamp meter is shown in Table 2. From the data of direct measurement using the AC clamp meter shown in Table 2 above, the result of this factory

TABLE 2
 DIRECT MEASUREMENT RESULT USING AC CLAMP METER

No	Time	U1 Current (mA)	V1 Current (mA)	W1 Current (mA)	Temperature (°C)
1	11:00 AM	485	482	504	46.9
2	12:00 AM	485	482	506	47.3
3	01:00 PM	486	484	506	47.5
4	02:00 PM	485	484	505	47.8
5	03:00 PM	486	484	504	48.1
6	04:00 PM	485	485	506	48.6
7	05:00 PM	485	485	506	49.2
8	06:00 PM	486	485	506	49.5
9	07:00 PM	485	487	506	49.6
10	08:00 PM	485	487	506	49.9

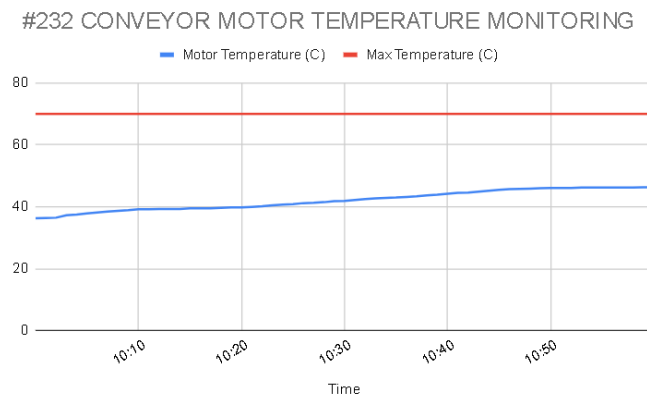


Figure 11. Motor temperature chart with limit line

acceptance test is good. That result can be confirmed with the load current and temperature value never touching the limitation value even after 10 hours of running.

IV. CONCLUSIONS

With the output well displayed on the google spreadsheet, this device is completely built successfully, which means that the current value on each phase line (U1, V1, W1) and the temperature of the motor have been read and displayed on Google Spreadsheet successfully. This matter is in line with the main purpose of this device is to gain customer trust and satisfaction especially during the Factory Acceptance Test (FAT).

The result also shows the limitation, where the user is easy to determine the result of the FAT commissioning: is it good or not good. If the result is not good, the manufacturer company should analyze and fix the problem as soon as possible. When the problem is maintained, the next Factory Acceptance Test should be rescheduled. As mentioned, if the result is good, the customer company and the manufacturer company can arrange the delivery schedule, which means that this project is closed on the manufacturer company site and be ready to install on the buyer company place.

REFERENCES

- [1] Baking Industry Forum, "Factory Acceptance Testing," 2015. <http://www.bema.org/wp-content/uploads/2015/01/BIF-FAT-White-Paper.pdf> (accessed Jan. 23, 2021).
- [2] Johan Hedberg, "Factory Acceptance Testing Guideline," AISTech - Iron and Steel Technology Conference Proceedings, 2007.
- [3] K. Bhadani, G. Asbjörnsson, E. Hulthén, K. Hofling, and M. Evertsson, "Application of optimization method for calibration and maintenance of power-based belt scale," *Minerals*, vol. 11, no. 4, 2021, doi: 10.3390/min11040412.
- [4] J. Szrek, J. Wodecki, R. Błazej, and R. Zimroz, "An inspection robot for belt conveyor maintenance in underground mine-infrared thermography for overheated idlers detection," *Applied Sciences (Switzerland)*, vol. 10, no. 14, 2020, doi: 10.3390/app10144984.
- [5] Wemos, "LOLIN D1 mini — WEMOS documentation." https://www.wemos.cc/en/latest/d1/d1_mini.html (accessed Jan. 23, 2021).
- [6] D. A. Prijambodo, "Purwarupa Sistem Menyalakan dan Mematikan Lampu Ruangan Berbasis An-droid dengan Wemos D1 Mini," *Publikasi Ilmiah*, 2017.
- [7] Deange Industry, "Silicon Wire." <http://www.deange.com.tw/Silicon-Wire.html> (accessed Jan. 23, 2021).
- [8] instrumentation Tools, "Thermocouple Calculations | How to convert thermocouple millivolts?" <https://instrumentationtools.com/thermocouple-calculations/> (accessed Feb. 11, 2021).
- [9] MAXIM, "MAX6675 - Cold junction compensated K-Thermocouple to digital converter," Maxim Dallas, 2002.
- [10] YHDC, "Split core current transformer Model : SCT-013," Yhdc, 2010.
- [11] Arduino, "Arduino Nano - Arduino Official Store," Store.Arduino.Cc/Usa/. 2017.
- [12] Tinsharp Industrial, "TC2004A-01," 2009. [Online]. Available: www.tinsharp.com

- [13] Handson Technology, "User Guide I2C Serial Adapter for LCD Module." [Online]. Available: <https://bitbucket.org/fmalpartida/new-liquidcrystal/downloads>
- [14] A. Rospawan, J. W. Simatupang, and I. Purnama, "A Simple, Cheap and Precise Microcontroller Based DDS Function Generator," *Journal of Electrical and Electronics Engineering*, vol. 3, no. 2, pp. 118–121, 2019, doi: 10.33021/jeee.v3i2.1491.
- [15] L. M. Andrian and J. W. Simatupang, "Design and Implementation of AC Mains Voltage Fluctuation Indicator for Home Appliances," *International Journal of Electronics and Device Physics*, vol. 2, no. 1, Dec. 2018, doi: 10.35840/2631-5041/1704.
- [16] Hackster.io, "Transmit ESP8266 Data to Google Sheets." <https://www.hackster.io/detox/transmit-esp8266-data-to-google-sheets-8fc617> (accessed Jan. 11, 2021).
- [17] Shinmei Industry, "Standardization for the electromagnetic switch and thermal overload selection, SMS SEI2308." 2014.
- [18] Sumitomo Heavy Industries, Hypoid right angle gearmotor and reducer, <https://pdf.directindustry.com/pdf/sumitomo-drive-technologies-america/hyponic-gearmotor-reducer-catalog/15521-26999.html> (Accessed Jan 23, 2021).