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Quality Test of Flexible Flat Cable (FFC) With Short Open Test Using Law Ohm Approach through Embedded Fuzzy Logic Based On Open Source Arduino Data Logger

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Abstract. A technological development, especially in the field of electronics is very fast. One of the developments in the electronics hardware device is Flexible Flat Cable (FFC), which serves as a media liaison between the main boards with other hardware parts. The production of Flexible Flat Cable (FFC) will go through the process of testing and measuring of the quality Flexible Flat Cable (FFC). Currently, the testing and measurement is still done manually by observing the Light Emitting Diode (LED) by the operator, so there were many problems. This study will be made of test quality Flexible Flat Cable (FFC) computationally utilize Open Source Embedded System. The method used is the measurement with Short Open Test method using Ohm's Law approach to 4-wire (Kelvin) and fuzzy logic as a decision maker measurement results based on Open Source Arduino Data Logger. This system uses a sensor current INA219 as a sensor to read the voltage value thus obtained resistance value Flexible Flat Cable (FFC). To get a good system we will do the Black-box testing as well as testing the accuracy and precision with the standard deviation method. In testing the system using three models samples were obtained the test results in the form of standard deviation for the first model of 1.921 second model of 4.567 and 6.300 for the third model. While the value of the Standard Error of Mean (SEM) for the first model of the model 0.304 second at 0.736 and 0.996 of the third model. In testing this system, we will also obtain the average value of the measurement tolerance resistance values for the first model of - 3.50% 4.45% second model and the third model of 5.18% with the standard measurement of prisoners and improve productivity becomes 118.33%. From the results of the testing system is expected to improve the quality and productivity in the process of testing Flexible Flat Cable (FFC).

1. Introduction

Technological developments will affect all the changes in all fields, one of which is the development of hardware electronic device that would change very quickly and significantly, one of which is the media interface cable that connects the main board Printed Circuit Board (PCB) with the other parts of the device the electronics. Interface is now widely used in electronic devices is a Flexible Flat Cable (FFC) which has a very thin design and size so they can follow the shape of the mechanical groove design an electronic device in which case it requires a wide space for the placement of the cable in the design of electronic devices proficiency level. The manufacturing process of Flexible Flat Cable (FFC) will go through the testing process before it is sent to the company that booked Flexible Flat Cable (FFC). Testing Flexible Flat Cable (FFC) one of which is to identify whether Flexible Flat Cable (FFC) in conditions PASS (Good) or FAIL (No Good) by providing a flow of DC voltage and output indicator lamp in the form of Light Emitting Diode (LED).

The testing process is separated into two stages: the first stage is to test the condition of the Open (disconnected) for each leg of the Flexible Flat Cable (FFC) and the second stage is to test the condition Short (connected) between the legs on a Flexible Flat Cable (FFC) do manually by the operator and the determination of Flexible Flat Cable (FFC) to observe the condition of the lights light Emitting Diode[1]. This study will be made of quality test system Flexible Flat Cable (FFC) with Short Open Test using Ohm's Law through the Embedded Fuzzy Logic approach based on Open Source Arduino Data Logger. With the research and manufacture of these systems, we can get the precision measurement according to Ohm's law and gain level measurement speed and better accuracy in determining the condition of Flexible Flat Cable (FFC) PASS (Good) or Fail (No Good), in addition to the system created can be obtained reports on the results of each measurement will be stored in memory and Data Logger which can be used as a report on the production of Flexible Flat Cable (FFC).

Identification problems research is:

1. The system is used in determining the results of tests and measurements using indicators Light Emitting Diode (LED), so if there is a difference in resistance value of each foot Flexible Flat Cable (FFC) will be difficult to distinguish because there is no value measurement and display only the light intensity of Light Emitting Diode (LED).
2. The process of testing and measurement requires the operation by the operator consists of two stages: test and measurement Short (connected) and Open (disconnected).
3. There is no report in real time the results of the testing process and measurement Flexible Flat Cable (FFC).
4. Decision-making test results Flexible Flat Cable (FFC) is determined by the operator that runs the system by observing the condition of the lights Light Emitting Diode (LED).

Based on the identification of the problem, the problem is limited as follows:

1. Flexible Flat Cable (FFC) used testing has eight legs with UL Style No. 2896.
2. The method used in this research is the method of Short Open Test, Ohm's Law approach to measuring 4-wire (Kelvin) and Fuzzy Logic.
3. Embedded System that was designed and built an Arduino-based system minimum and Flow Sensor INA219.
4. In the store the measurement data using Data Logger Shield Arduino.

Based on the identification and restriction problems that have been described, it can be formulated how the test of the quality Flexible Flat Cable (FFC) can be done by an embedded system based open source arduino with the application of methods Short Open Test is using a legal approach Ohm 4-wire (Kelvin) as a process measure value detainee a Flat Flexible Cable (FFC) and fuzzy logic as decision makers the results of measurements and data logger as a data storage processing of the measurement results.

2. Related Research

In this study [2] do Arduino as an LCR meter designs using the AD5933 impedance converter for measuring reactance. The system incorporates an on board frequency generator with 12-bit, 1 MSPS and Analog to Digital Converter (ADC). Impedance response signal sample from Analog to Digital Converter (ADC) and signal Discrete Fourier Transform (DFT) is processed by on-board DSP engine. The results of processing that can be read from the I2C serial interface. Arduino controls the AD5933 via a serial interface I2C protocol. Measurements for high value capacitance and inductance values lower in impedance in the range of 1 Ω - 10 Ω by using additional circuit reference resistors are added to the reactive component of the unknown and make corrections to the measured impedance value.

In this research [4] is to create a weather station to monitor the characteristics of lightning. Data Logger will be SD Card Shield is used to store data read distance of a lightning strike, the frequency as well as the movement of the lightning from the sensor lightning and GPS data from this study has the advantage of which consumes low power, small size, greater portability and lower cost.

In this research [4] is to create a tool to be used to test the functionality of a Cable Insulation Displacement (IDC) whether there is an error or malfunction. This tool uses Microcontroller ARM7 LPC and 74HC574 octal D-latch with a test gives a value of 1 and 0 binary data and compared with the logic of Ex-OR, output using the LCD 24 * 2 as an indicator to display error messages Short or Open, the testing has been done several scenario combination of methods Short Circuit and Open Circuit.

In this research [5] is to design a measuring instrument for voltage, current and frequency of the alternating current electric single phase-based personal computer where there are two, namely microcontroller and computer hardware for implementation by generating an error average of 0.45% voltage measurement, current measurement by 2 % and a measurement frequency of 0.09%.

3. Research Methodology

3.1. Research Method

The method used in this research is the method of Short Open Test using Ohm's law approaches to measurement with 4-wire (Kelvin). Short Open Test is the method used to determine the condition of a circuit no current flow or not. In Short Open Test method, a circuit will be given voltage so the current will flow. Circuit condition is said to be "Short" if the current flowing is huge because of the resistance value close to 0 Ω (Ohm) and the circuit is said to be "open" if the current does not flow or a current value of 0 Ampere because the resistance value is very large or infinite. Ohm's Law approach method 4-wire (Kelvin) is used to measure a resistance value which is smaller than a conductor material with the aim of getting more value detainees measurement precision. The next method is fuzzy logic is implemented in an Arduino-based Embedded System Data Logger. Fuzzy logic is used to determine whether the measurement results in a condition Pass (Good) or Fail (No Good) on a Flexible Flat Cable (FFC). The resulting value is the measurement process that has been done is stored in a data logger that will be used as a place to store measurement results and used as a production report.

System development method used in this study is the waterfall method, and for testing the system using the Black-box testing other than that the system is built to be compared with the results of measurements from other instruments and compared with the results of the calculation of an equation of the resistance value of a conductor and using standard deviation and tolerance to get the value of the accuracy of the measurement.

3.2. Sampling Selection Method

The sample selection based on quota sampling method for samples taken based on the needs of researchers and predetermined criteria or condition. Samples are Flexible Flat Cable (FFC) that have been determined by the number of feet 8 specification which has a length of each is 210 mm, 420 mm and 630 mm. Samples Flexible Flat Cable (FFC) in good condition and will be prepared several scenarios for testing a system that meets the measurement function Short Open Test conductor resistivity values.

3.3. Data Collection Method

To get the data in this study used multiple methods of data collection that the method of data collection by direct observation of the test system Flexible Flat Cable (FFC) which is running at the moment, but it uses the way literature by studying various references such as document / file, datasheet, scientific papers / journals and collect data relating to Flexible Flat Cable (FFC) and study the measurement method to obtain the resistance value of a conductor.
In this study used two groups of data, data about the group's first standard specification Flexible Flat Cable (FFC) in accordance with UL2896 and eungsung-ind is used as reference for the calculation of the resistance value of a conductor. With this data we can get the value of resistance Flexible Flat Cable (FFC) on each leg by performing calculations with equations $R = \frac{\rho \cdot l}{A}$. Group second data is a group of data relating to Current Sensor INA219, Minimum System Embedded Arduino Data Logger as a test system Flexible Flat Cable (FFC) which serves to determine the resistance value of each foot on a Flexible Flat Cable (FFC) with the process of measuring the flow and voltage.

3.4. Framework Concepts

Proposed a system of quality testing Flexible Flat Cable (FFC) with Short Open Test Using Ohm's Law through the Embedded Fuzzy Logic approach is based on Open Source Arduino Data Logger. The purpose of the proposal is to change the tests and measurements manually before becoming computationally and utilize measurement data as a report of production so that it can be used as feedback to improve the quality. By way of computing all the testing, measurement and determination of the results of measurements performed by a program embedded on a board that is based on Arduino, thus avoiding errors in the determination of the quality Flexible Flat Cable (FFC).

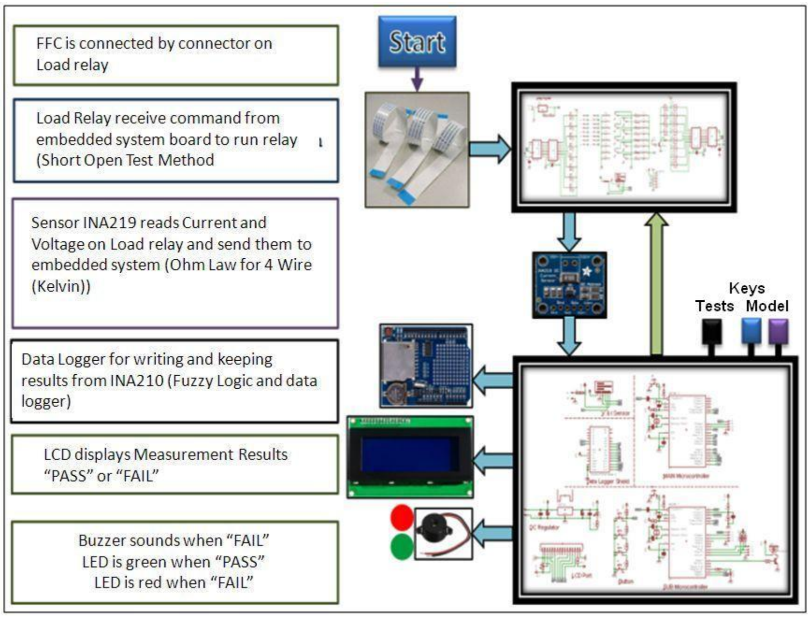

Figure 1. Conceptual framework

Figure 1 shows the overall system design. Following further clarification of the system design:

1. Flexible Flat Cable (FFC) mounted on the connectors available and connected on Load Relay Board.
2. Press the model to choose a model that will run and press the test button, the Embedded System will command Load Relay Board works according to the methods short open test, then the sensor reading INA219 current and voltage according to the instructions of embedded systems.
3. The process of testing and measurement systems performed sequentially from the first leg Flexible Flat Cable (FFC) until the last leg Flexible Flat Cable (FFC).
4. Embedded System to process data of current and voltage measurements with fuzzy logic further determines that the Flexible Flat Cable (FFC) in a test in good condition with the LCD indicator "PASS" Light Emitting Diode (LED) light green or unfavorably with the LCD indicator " FAIL "Light Emitting Diode (LED) lights up red.

4. Result of Research

4.1. Overview

Step-by-step testing process:

1. Prepare the tools used and turn the key in the ON position.
2. Press the switch up to the ON position.
3. Enter a Flat Flexible Cable (FFC) as a target to be checked on a connector that has been prepared.
4. Observe the Light Emitting Diode on the instrument, if there is one or more lights on, the Flexible Flat Cable (FFC) in conditions No Good (NG) Short.

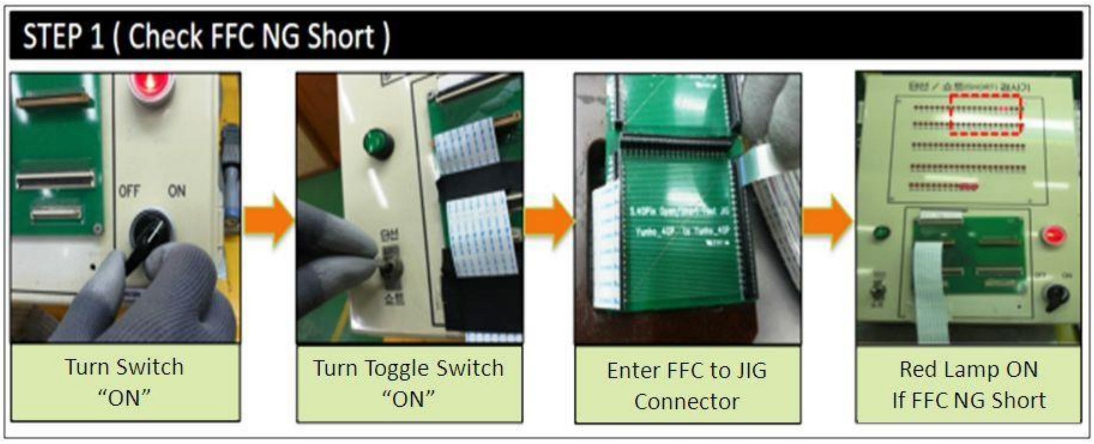

Figure 2. Short-checking process flow

Step-by-step testing process:
1. Prepare the tools used and turn the key in the ON position.
2. Press the switch up to the ON position.
3. Enter a Flat Flexible Cable (FFC) as a target to be checked on a connector that has been prepared.
4. Connect one end of Flexible Flat Cable (FFC) with an iron plate or other materials that can conduct current.
5. Observe the Light Emitting Diode on the instrument, if there is one or more lights there were dead, then Flexible Flat Cable (FFC) in conditions No Good (NG) Open.

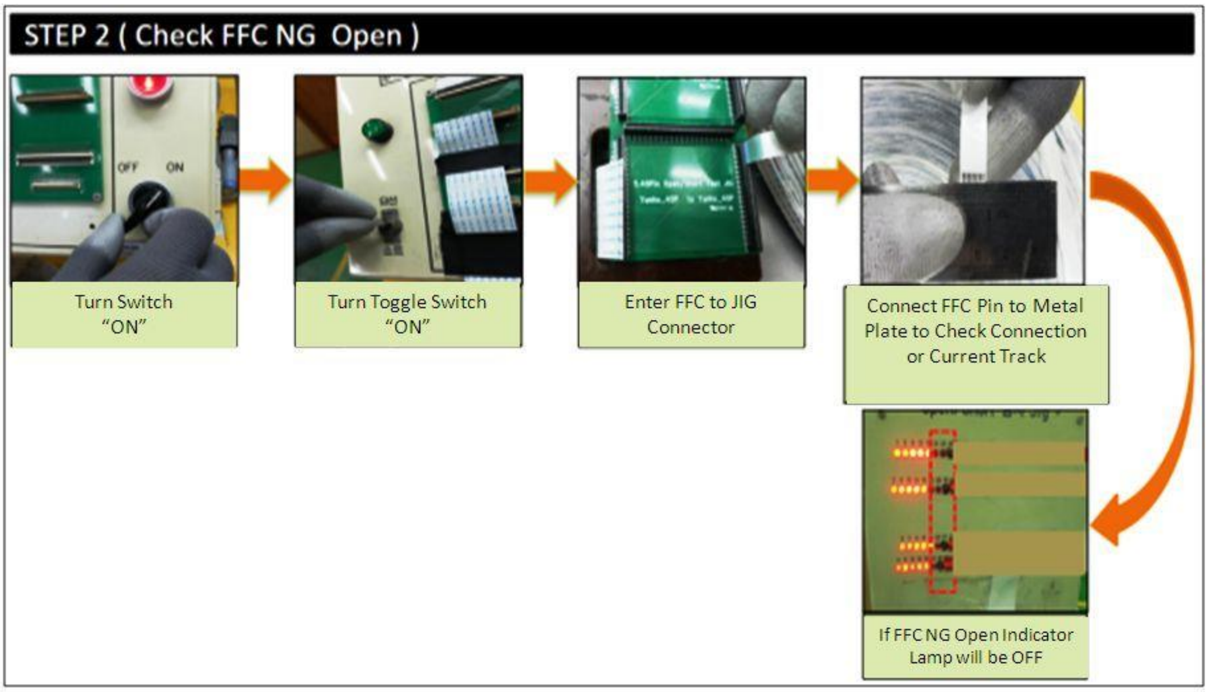

Figure 3. Open-checking process flow

4.2. Implementation System

In the implementation of the system in this study consists of two parts, namely the implementation of the hardware and software implementation on the part. Implementation of this research jointly establishes a system that works in computing. Before implementing the system must understand and process flow to load the system so that the implementation can be done in accordance design. This is a process flow system from the beginning to the end of the process to produce the output of the system.

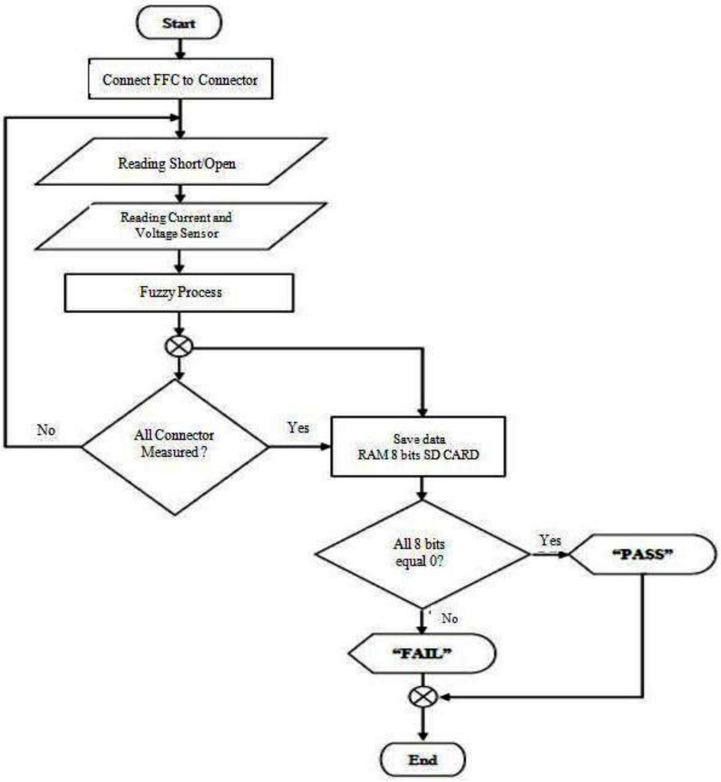

Figure 4. Process Flow System

4.2.1. Hardware

Hardware Implementation of the system in the study includes the design Schematics, PCB layout design and PCB Assembly. On the hardware is made separately into two parts which will cooperate with each other, namely the Load Relay Board and the Main Control Board Arduino. On Load Relay Board has the function of running the command from the main control that implements the method of short open reading test for voltage and current values, while the hardware implementation can be seen in Figure 5.

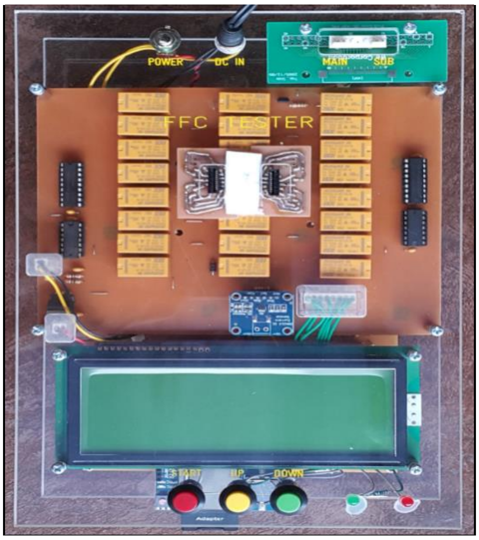

Figure 5. Hardware Implementation

4.2.2. Software

In this study determined that the current value will be streamed at 88.51 mA. In this study, designed the fuzzy logic process using Sugeno Model and Method Height defuzzification method.

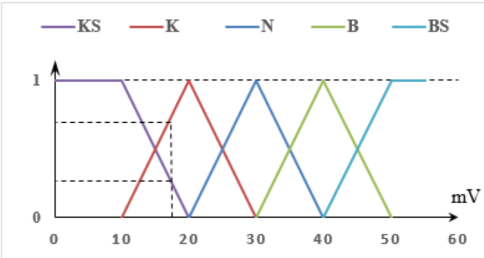

Figure 6. Domain Voltage Membership Function

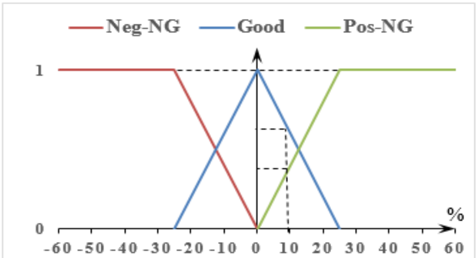

Figure 7. Domain Threshold Membership Function

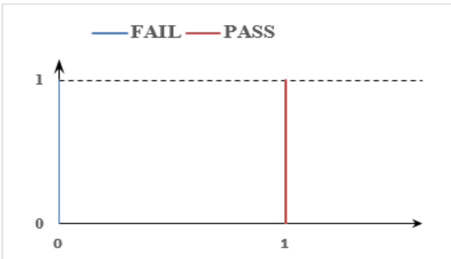

Figure 8. Output Fuzzy Singleton

Table 1. Rule Base Fuzzy Logic

		Voltage (V)				
		Very Small	Small	NORMAL	BIG	Very BIG
Threshold [Th]	Neg-NG	Fail	Fail	Fail	Fail	Fail
	Good	Fail	Pass	Pass	Pass	Fail
	Pos-NG	Fail	Fail	Fail	Fail	Fail

In the process of fuzzy there are two variables that will be used as a variable input voltage shown in Figure 6 and a variable threshold seen in Figure 7. The variable voltage graph that there are 5 3 2 graphics of graphic triangle and trapezoid, Whereas the threshold is 1 and 2 triangular charts trapezoid graph so that it can be made fuzzy rule base as much as 15 as shown in table 1. The following is a fuzzy logic flowchart:

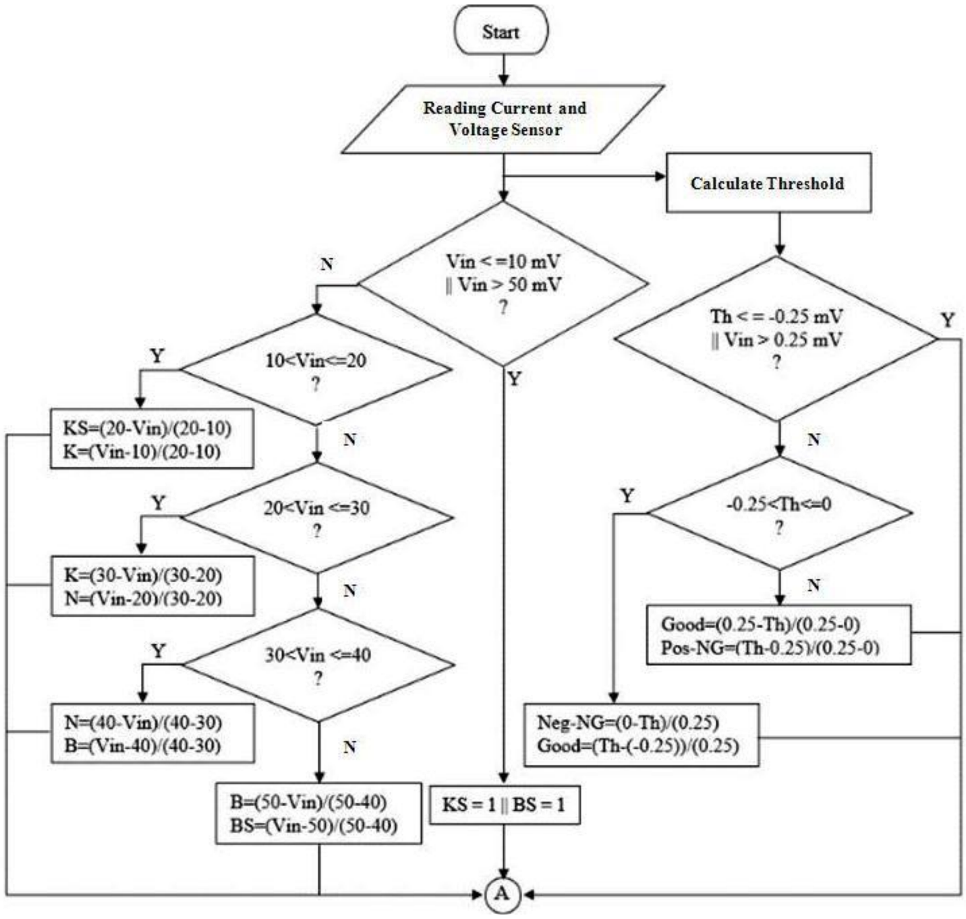

Figure 9. Flowchart Fuzzy

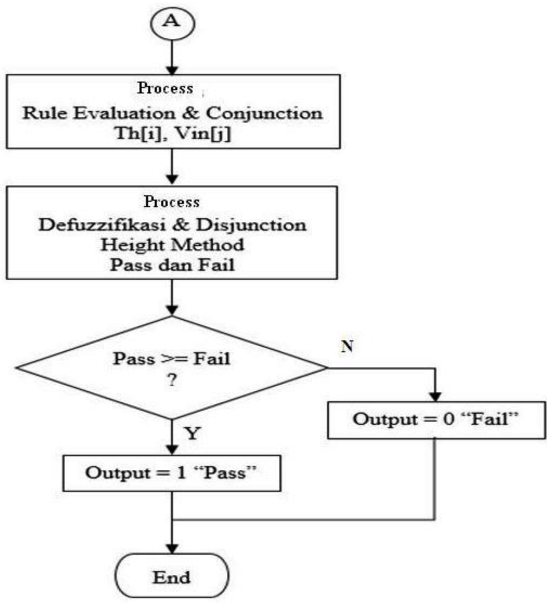

Figure 10. Flowchart Fuzzy next

From Figure 9 and Figure 10 can be seen that the variable voltage and threshold in through using fuzzy logic to output a singleton are pass or fail as shown in Figure 8.

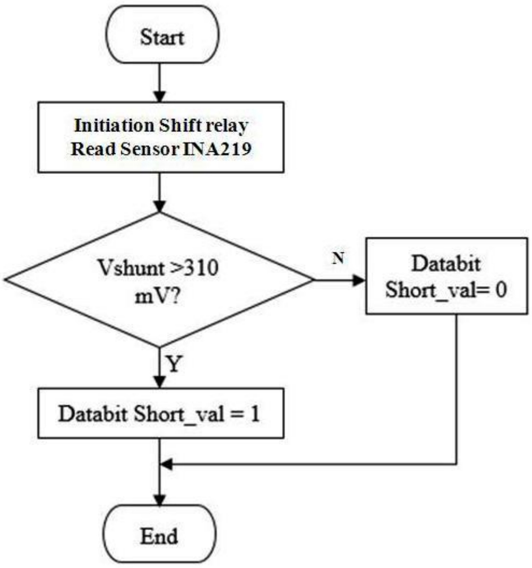

Figure 11. Flowchart Short Open

Figure 11 is a flowchart of the process Short Open test to determine whether the FFC has Short or Open conditions.

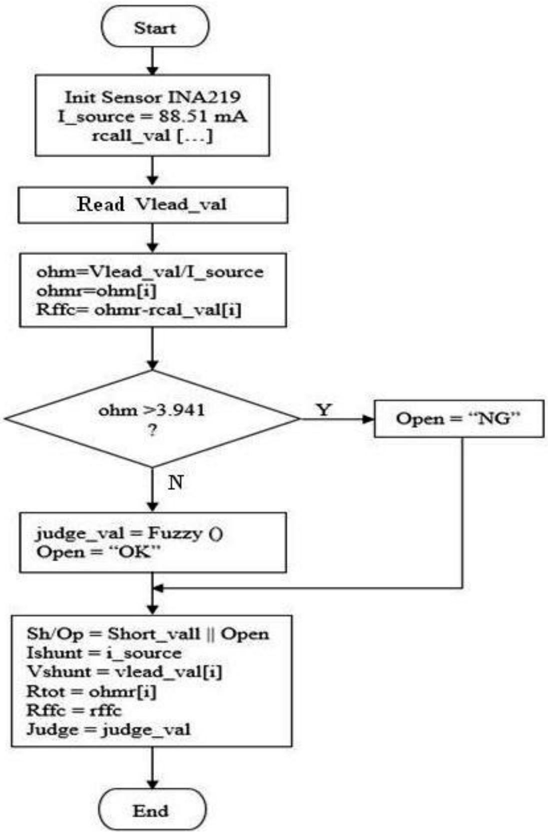

Figure 12. Flowchart Voltage Measure

Whereas Figure 12 describes a process flow measurement and data processing in order to obtain the FFC resistance value and determine whether the measurement value in accordance with the existing specifications.

4.3. Evaluation and Testing

4.3.1. Accuracy, Precision and Tolerance Testing

Testing accuracy, precision and tolerance is focused on the output data from the system functions. The method used is the standard deviation method where precision is determined by the diversity of the variables to be measured against the average, while the value of accuracy depends on the standard deviation and the number of samples and tolerance is an aberration measurements with actual values. In this test uses 40 measurement data on each model or use 5 Flexible Flat Cable (FFC) by the number of feet 8 and the value of the measurement data in units of mΩ. Here is the measurement data that has been done by the system.

Table 2. The Test Data FFC 210 mm

No	Item	K1	K2	K3	K4	K5	K6	K7	K8
1	$FFC_{(1)}$	109	109	105	112	111	106	107	108
2	$FFC_{(2)}$	111	110	105	112	112	106	108	108
3	$FFC_{(3)}$	112	111	109	107	108	106	109	108
4	$FFC_{(4)}$	111	108	109	109	108	109	110	111
5	$FFC_{(5)}$	111	109	110	110	108	109	110	111

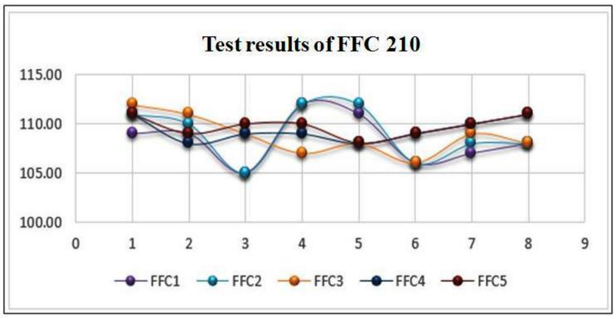

Figure 13. Graph Data Test Result FFC 210

Table 3. The Test Data FFC 420 mm

No	Item	K1	K2	K3	K4	K5	K6	K7	K8
1	$FFC_{(1)}$	236	237	233	236	233	236	239	247
2	$FFC_{(2)}$	236	236	233	236	232	235	239	246
3	$FFC_{(3)}$	231	232	236	229	232	227	232	231
4	$FFC_{(4)}$	233	234	223	233	231	238	232	236
5	$FFC_{(5)}$	232	232	223	231	229	237	231	234

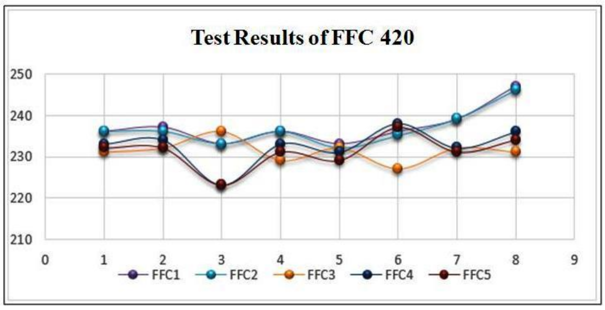

Figure 14. Graph Data Test Result FFC 420

Table 4. The Test Data FFC 630 mm

No	Item	K1	K2	K3	K4	K5	K6	K7	K8
1	$FFC_{(1)}$	369	369	348	354	356	357	363	354
2	$FFC_{(2)}$	356	356	344	355	353	363	353	360
3	$FFC_{(3)}$	358	359	353	372	369	350	352	352
4	$FFC_{(4)}$	355	355	344	354	352	363	353	359
5	$FFC_{(5)}$	355	360	355	351	356	363	360	352

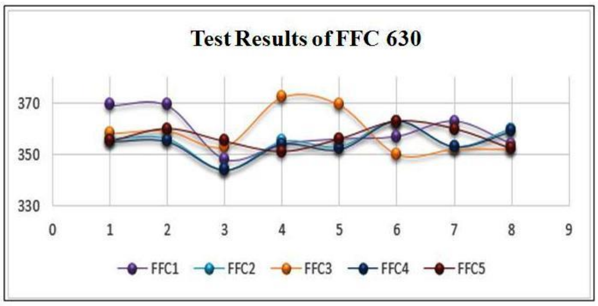

Figure 15. Graph Data Test Result FFC 630

From Table 2, Table 3 and Table 4 can be obtained values are used as the calculation of standard deviation and standard error of the mean by the following equation:

$\boldsymbol{S} = \sqrt{\frac{\sum(\boldsymbol{X}-\overline{\boldsymbol{X}})^2}{\boldsymbol{n}-1}}$ dan $\boldsymbol{SE}_{\overline{\boldsymbol{X}}} = \frac{S}{\sqrt{n}}$ so that the values obtained as follows:

Value mean FFC 210 mm : 4362 mΩ / 40 = 109,05 mΩ

It can be calculated standard deviation is

$$S = \sqrt{\frac{143{,}90}{40-1}} = \sqrt{3{,}690} = 1{,}921$$

While the value of the standard error is $SE_{\overline{X}} = \frac{S}{\sqrt{n}} = \frac{1{,}921}{\sqrt{40}} = \frac{1{,}921}{6{,}325} = 0{,}304$

Value mean FFC 420 mm : 9349 mΩ / 40 = 233,725 mΩ

It can be calculated standard deviation is

$$S = \sqrt{\frac{845{,}975}{40-1}} = \sqrt{21{,}692} = 4{,}567$$

While the value of the standard error is $SE_{\overline{X}} = \frac{S}{\sqrt{n}} = \frac{4{,}567}{\sqrt{40}} = \frac{4{,}657}{6{,}325} = 0{,}736$

Value mean FFC 630 mm : 14262 mΩ / 40 = 356,550 mΩ.

It can be calculated standard deviation is

$$S = \sqrt{\frac{1547{,}900}{40-1}} = \sqrt{39{,}690} = 6{,}300$$

While the value of the standard error is $SE_{\overline{X}} = \frac{S}{\sqrt{n}} = \frac{6{,}300}{\sqrt{40}} = \frac{6{,}300}{6{,}325} = 0{,}996$

In the method of standard deviation is stated that the smaller the standard deviation, the better and the less the value of the standard error of the average value closer to the true value. From the test results can be obtained under the standard deviation and standard error is the smallest is the measurement of Flexible Flat Cable (FFC) with a length of 210 mm with a length of 420 mm next and last is 630 mm.

Table 5. Tolerance Measurement FFC 210 mm

No	Item	FFC Test (mΩ)	$\frac{\rho.l}{A}$ (mΩ)	Difference	Tolerance
1	$FFC_{(1)}$	108,375	113	-4,625	-4,09%
2	$FFC_{(2)}$	109,000	113	-4,000	-3,54%
3	$FFC_{(3)}$	108,750	113	-4,250	-3,76%
4	$FFC_{(4)}$	109,375	113	-3,625	-3,21%
5	$FFC_{(5)}$	109,750	113	-3,250	-2,88%
Average					-3,50%

Table 6. Tolerance Measurement FFC 420 mm

No	Item	FFC Test (mΩ)	$\frac{\rho.l}{A}$ (mΩ)	Difference	Tolerance
1	$FFC_{(1)}$	237,125	226	11,125	4,92%
2	$FFC_{(2)}$	236,625	226	10,625	4,70%
3	$FFC_{(3)}$	231,250	226	5,250	2,32%
4	$FFC_{(4)}$	232,500	226	6,500	2,88%
5	$FFC_{(5)}$	231,125	226	5,125	2,27%
Average					3,42%

Table 7. Tolerance Measurement FFC 630 mm

No	Item	FFC Test (mΩ)	$\frac{\rho.l}{A}$ (mΩ)	Difference	Tolerance
1	$FFC_{(1)}$	358,750	339	19,750	5,83%
2	$FFC_{(2)}$	355,000	339	16,000	4,72%
3	$FFC_{(3)}$	358,125	339	19,125	5,64%
4	$FFC_{(4)}$	354,375	339	15,375	4,54%
5	$FFC_{(5)}$	356,500	339	17,500	5,16%
Average					5,18%

Average tolerance values obtained from tests performed on Flexible Flat Cable (FFC) in accordance with Table 5, Table 6 and Table 7 that with a length of 210 mm is - 3.50%, Flexible Flat Cable (FFC) with a length of 420 mm is 3.42%, Flexible Flat Cable (FFC) with a length of 630 mm was 5.18%. So it can be stated that the measurements made by the system met the standard measurement tolerance prisoners are allowed where the maximum tolerance is ± 25%.

4.3.2. Process Time Testing (Take Time)

At the time of the testing process (take time) this is by comparing the processing time of the system that has been running with the processing time of the system that do the research. The turnaround time on a running system is obtained by looking at the data production targets and production per hour. The following is a comparison of the processing time from a running system with a system that performed the study.

Table 8. Comparison Data Processing Time (Take Time)

Line	Item	Running System			Take Time FFC Tester		
		Target (pcs)	Result (pcs)	Take Time (ms)	Test 1 (ms)	Test 2 (ms)	Estimation Result
1	FFC_210	360	331	10.876	8.471	8.431	426
2	FFC_210	360	329	10.942			
3	FFC_210	360	328	10.976			
4	FFC_420	360	326	11.043	8.491	8.411	426
5	FFC_420	360	327	11.009			
6	FFC_420	360	325	11.077			
7	FFC_630	360	324	11.111	8.451	8.491	425
8	FFC_630	360	326	11.043			
9	FFC_630	360	323	11.146			

From table 8 for systems running data showed that the target every hour testing process Flexible Flat Cable (FFC) for 3 specifications of 360 pcs not met because the production of an average of 91% of its production target, while the processing time (take time) the mean average test every Flexible Flat Cable (FFC) on systems running for FFC_210 is 10.931 ms, for FFC_420 is 11.043 ms and FFC_630 is 11,099 ms. While the system results were obtained when the process (take time) that FFC_210 is 8.451 ms so that the estimated yield is 426 pcs per hour, while the process (take time) on FFC_420 is 8,451ms so estimates of production per hour is 426 pcs and processing time (take time) on FFC_630 is 8.457 ms so that the estimated output per hour is 425 pcs. From the data obtained that the test results using the computing system to increase the productivity of the target of 426 or 360 pcs be increased to 118.33%.

4.3.3. Implications Research
Flexible Flat Cable (FFC) is essential in electronic devices; the quality Flexible Flat Cable (FFC) is very influential on electronic products. Because of the presence of the test system quality Flexible Flat Cable (FFC) is very useful for producing quality Flexible Flat Cable (FFC) is good and improve productivity, where the resistance value on Flexible Flat Cable (FFC) measurement and testing in accordance with the standards that have been determined so that the performance of the Flat Flexible Cable (FFC) used in electronic devices can work optimally.

5. Conclusion

5.1. Conclusion
Based on the discussion of research results Quality Test Flexible Flat Cable (FFC) with Short Open Test using Ohm's Law through the Embedded Fuzzy Logic approach based on Open Source Arduino Data Logger, it can be concluded as follows:
1. Short Open Test Method, Fuzzy Logic and Data Logger can be applied to Embedded System Open Source Arduino-based test system as quality Flexible Flat Cable (FFC).
2. Black box testing results show that the system is free of syntax errors and logic errors and functionally release the results as expected.
3. Results of testing the accuracy and precision of the system with a standard deviation can be obtained results for Flat Flexible Cable (FFC) length of 210 mm is 1.921 to 4.567 lengths is 420 mm and 630 mm length was 6,300. While the value of the Standard Error of Mean (SEM) on a Flat Flexible Cable (FFC) length of 210 mm is 0.304 to 420 mm length is 0.736 and the length of 630 mm is 0.996.
4. The test results can be obtained tolerance on the system tolerance values averaging measurements prisoners on Flexible Flat Cable (FFC) for a length of 210 mm was -3.50%, length 420 mm is 3.42% and the length of 630 mm was 5.18 %.
5. The test results processing time (take time) on the system can increase production to 118.33% or 18.33% above the production target of 360 pcs per hour.

5.2. Suggestion
Based on the results of research by the author, advice to authors give is as follows:
1. The research may be continued by changing the quality of the hardware so that the level of accuracy, precision and tolerance is heading for the better.
2. Research can proceed with implementing the system using other Open Source Embedded systems and integrated with other systems based on object-oriented to support the production process.

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