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RPM MEASUREMENT COMPARISON USING A THERMOMETER AND LM393 MICROCONTROLLER

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Abstract

RPM measurement is a crucial measurement tool for assessing a machine's rotation quality and ensuring that it meets the DC motor manufacturer's specifications. The quality of rotation of electric motors and combustion motors can both be observed through RPM measurements. The precision with which the LM393 sensor measures the rotation of a DC motor engine is the problem formulation in this study. Thus, the purpose of this study is to evaluate the rotation measurement accuracy of the LM393 Microcontroller sensor and compare it to a traditional tachometer. In order to conduct rotational variations on the DC motor, the following voltages will be applied: 0.93V, 2.83V, 4.25V, 7.05V, and 9.07V. Next, a tachometer and an LM393 microcontroller are used to measure the DC motor rotation. The gathered data will be made available for verification. Based on the measurement results, the corresponding data differences are -5.560 RPM, -1.577 RPM, -2.182 RPM, -3 RPM, and 0.334 RPM. Therefore, measurement validation was done based on the disparity in readings, yielding results of 0.252%, -1.45%, 0.12%, 0.038%, and 0.0725%. Based on validation results showing a presentation of no more than 10%, the LM393 measuring tool for DC motor RPM measurement is deemed valid and suitable for use.

***Keywords**: LM393, Microcontroller, RPM Measurement, Tachometer.*

1. INTRODUCTION

The process of measuring rotation is intended to determine the amount of rotation of a piece of machinery, both internal combustion engines and electric motor engines. The results of measuring engine rotation have an impact on determining the quality of the results of the initial or final rotation of a piece of machinery. If the measuring instrument shows that the rotation of a machine is starting to decrease then the quality of the engine must be improved, thus a measuring instrument for measuring engine rotation is needed to determine the quality of the engine. The rotation measuring instrument is generally called a Tachometer. A tachometer is often called an RPM measuring tool which functions to measure engine rotation. However, over time, many RPM measuring instruments have been developed. In this research, the measuring instrument for developing engine rotation measurements uses a microcontroller-based LM393 sensor. So the quality of the measurement results needs to be tested with a Tachometer measuring instrument that is sold commercially. The use of the LM393 measuring tool is generally used in automatic control processes to stabilize machine rotation automatically. With this use, accurate data is needed to read the LM393 motor rotation. From the background of these measurements, the problem formulation in this research is how accurate the LM393 sensor is in measuring DC motor engine rotation. So the aim of this research is to analyze how accurate the LM393 Microcontroller sensor is in

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measuring rotation and compare it with a conventional Tachometer measuring instrument. This study is based on Michal Vidlak's [1] research, which describes the comparative calculation of rotation measurement results using the engineering model of DC motor method based on the ripple component of DC motor current. The method compares rotation measurements caused by electric current using a rotation sensor and a potentiometer. This research has been updated to compare the results of the LM393 sensor RPM measurements against the Tachometer. A DC motor machine is used as a measurement object in this study. DC motors are electric motors that convert energy from electricity into mechanical form and produce rotation [2][3][4]. Using the following equation, the rotation produced by a DC motor produces a unit in the measurement process, namely RPM (Revolution Per Minute).

$$RPM = (F \times 120)/P \quad (1)$$

RPM is the rotation per minute (RPM), F is the frequency (Hz), and P is the pole or number of poles [5][6][7]. So, in the microcontroller system, equation 1 of the RPM measurement is changed to produce a rotation value reading. Microcontrollers are software and hardware that are used to easily and quickly control electronic projection systems [8][9]. The data processing results will be entered into the microcontroller and displayed on the LCD display; the appearance of the microcontroller measurement results can be displayed on a computer LCD, IOT, or assembled LCD [10]. Figure 1 shows an example of a measurement display.

Figure 1. RPM measurement display [10]

With the rotation monitoring display, you can see and observe how much rotation is produced in a DC motor machine with a certain voltage and current. Monitoring the rotation of a motor can be controlled using a PWM mechanism, namely, pulse width modulation in another sense, namely pulse width modulation which regulates the strength of the incoming signal to the DC motor so as to produce changes in rotation [11][12]. The use of the rotation of a DC motor is not only used solely as a rotation to move places but can be a static rotation, namely as an energy generator, but the static rotation must also be taken into account because to find out how much rotation is produced to obtain electrical energy from rotational energy [13][14][15].

2. MATERIALS AND METHODS

This study follows Elin Nur Afifah's [16] research methodology and necessitates several additional research methods, such as sensor design, calibration, and comparison trials of microcontroller sensor data and infrared sensors. Figure 2 depicts the differences in research methods.

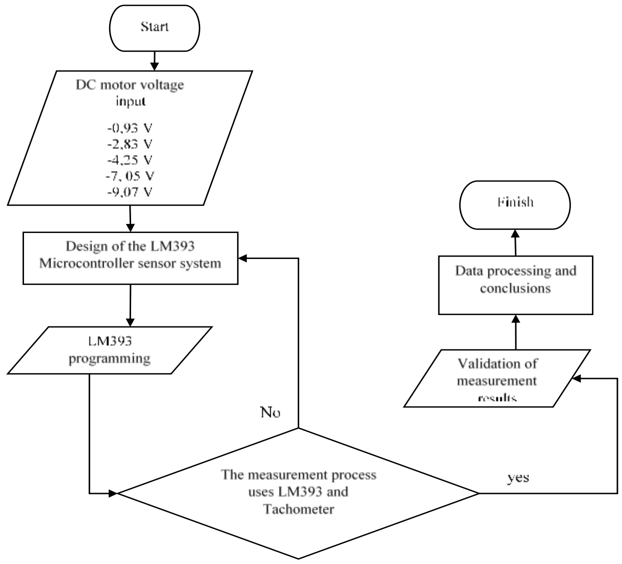


Figure 2. Research methods

The flowchart in Figure 2 begins by determining the input parameters of the DC motor so as to produce rotation variations. The input voltage variations are: 0.93 V, 2.83 V, 4.25 V, 7.05 V, 9.07 V. The specifications of the DC motor used can be seen in Table 1.

Table 1. Specifications of the DC motor used

Indicator	Specification
Voltage	5-9 V DC
Rated-Speed	1300 RPM
Current	0.5 A
Shaft d	5 mm

From Table 1, it can be seen that the specifications of the DC motor used and the rated-speed are used as a reference in validating all data from measuring the RPM sensor rotation. The DC motor type can be seen in Figure 3.

Figure 3. DC motor used

Following the determination of the input parameters for the DC motor voltage, the next step is to design a mechatronic system using a fritzing application [17]. Figure 4 illustrates the design.

2.1. System design

The mechatronic system design of the LM393 system and the design of the DC motor control system can be seen in Figure 4.

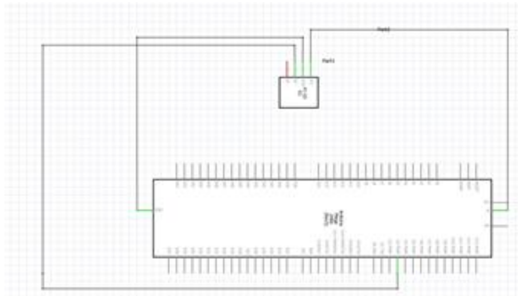
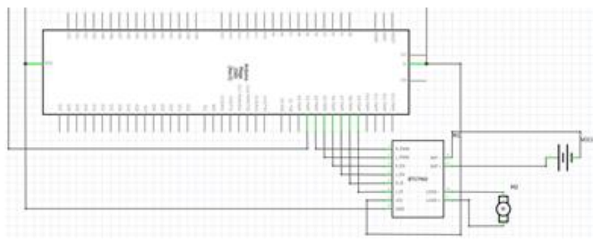


Figure 4. LM393 Microcontroller system design

The design of the microcontroller-based LM393 system uses an input system for the Arduino Mega as the microcontroller system. The microcontroller uses pin D2 for input D0 on the LM393 RPM sensor system with the following input indicators:

« pinMode(2, INPUT); »

After designing the LM393 system, the next step is to design the DC motor rotation system using the IBT2 H-Bridge motor driver, the system circuit can be seen in Figure 5.



Figur 5. DC motor system design

From Figure 5 it can be concluded that the component used to control the rotation of the DC mo-tor is the IBT2 H-Bridge [18][19], with a pin out control output process. Position and rotational speed can be controlled by using output programming on the motor driver. The LM393 sensor assembly and DC motor are shown in Figure 6.

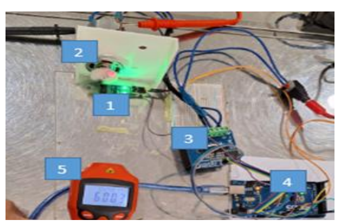


Figure 6. Assembled components

From Figure 6 there is a numbering of components with names which can be seen in Table 2.

Table 2. Component Assembly

No.	Components
1	LM393
2	Motor DC
3	IBT2 H-Bridge
4	Arduino Mega
5	Tachometer

After assembling the LM393 system, the next step is to carry out the LM393 programming process.

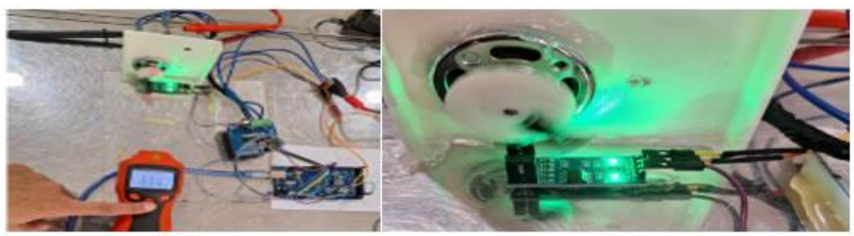
2.2. LM393 programming

The microcontroller used is an Arduino mega type with an Open Source system [20][21] which can be used freely and programmed easily. The application used is the Arduino IDE with the "C" program-ming language. The LM393 programming process has 3 stages, namely: Void Setup, Void Loop and Void Display.

The third programming process produces a notification of round data input, reading processing and monitored data display. After successful programming, the next step is to carry out the RPM measurement process using the LM393 and Tachometer.

2.3. Measurement process

The measurement process is carried out to see the RPM that occurs on the DC motor by turning on the DC motor and the measurement process can be carried out. Figure 7 is the measurement process using the LM393 and Tachometer.



(a) (b)

Figure 7. a. Measurement using a tachometer b. measurements using LM393

The measurement process of the two measuring instruments can be seen on their respective mon-itor displays. Measurements were carried out for thirty seconds each with variable input at varying DC motor voltages. After the measurement process is carried out, data validation is then carried out.

2.4. Validation and data processing

Validate the data to see how accurate the RPM measurement using the LM393 is against the ta-chometer by comparing the maximum rotation on the DC motor according to the specifications in Table 1. If the LM393 sensor and Tachometer obtain values that are close to the DC motor specifications then the LM393 measuring instrument is correct and valid so that the stage Next, rotational variations are carried out and the level of error or difference that occurs in the two RPM measuring instruments is compared.

3. RESULTS

This test refers to predetermined rotations with DC motor voltage input parameters, namely 0.93, 2.83, 4.25, 7.05 and 9.07. The first data can be seen in Table 3.

Table 3. The results of the input voltage measurement are 0.93 V

Time (s)	Voltage (v)	LM393 RPM)	Tachometer (RPM)	E (error)	Time (s)	Voltage (v)	LM393 RPM)	Tachometer (RPM)	E (error)
1	0,93	145	145,23	-0,23	16	0,93	149,52	145,23	4,29
2	0,93	145,5	145,23	0,27	17	0,93	149,52	145,23	4,29
3	0,93	138	145,23	-7,23	18	0,93	149,52	145,23	4,29
4	0,93	140	145,23	-5,23	19	0,93	149,52	145,23	4,29
5	0,93	142	145,23	-3,23	20	0,93	149,52	145,23	4,29
6	0,93	143	145,23	-2,23	21	0,93	149,52	145,23	4,29
7	0,93	140,3	145,23	-4,93	22	0,93	145,65	145,23	0,42
8	0,93	142,3	145,23	-2,93	23	0,93	145,65	145,23	0,42
9	0,93	145	145,23	-0,23	24	0,93	145,65	145,23	0,42
10	0,93	145,3	145,23	0,07	25	0,93	145,65	145,23	0,42
11	0,93	145,5	145,23	0,27	26	0,93	142,3	145,23	-2,93
12	0,93	146,3	145,23	1,07	27	0,93	143,3	145,23	-1,93
13	0,93	142,3	145,23	-2,93	28	0,93	148,9	145,23	3,67
14	0,93	148,3	145,23	3,07	29	0,93	149,3	145,23	4,07
15	0,93	149,3	145,23	4,07	30	0,93	145,3	145,23	0,07
Average						0,93	145,56	145,23	0,334

From Table 3 it can be seen that the average measurement results show that the DC motor rotation measured using the LM393 sensor produces a rotation of 145.56 RPM and the tachometer measuring instrument displays a measurement result of 145.23, so the difference is 0.33. Furthermore, the results of the input voltage measurement are 2.83 V which can be seen in Table 4.

Table 4, The results of the input voltage measurement are 2,83 V

Time (s)	Voltage (v)	LM393 (RPM)	Tachometer (RPM)	E (error)	Time (s)	Voltage (v)	LM393 (RPM)	Tachometer (RPM)	E (error)
1	2,83	345,2	347,8	-2,6	16	2,83	343	347,8	-4,8
2	2,83	315	347,8	-32,79	17	2,83	355	347,8	7,2
3	2,83	320,42	347,8	-27,38	18	2,83	342	347,8	-5,8
4	2,83	322	347,8	-25,8	19	2,83	348,5	347,8	0,7
5	2,83	346	347,8	-1,8	20	2,83	352,7	347,8	4,9
6	2,83	342	347,8	-5,8	21	2,83	345	347,8	-2,8
7	2,83	348	347,8	0,2	22	2,83	348	347,8	0,2

8	2,83	322	347,8	-25,8	23	2,83	342,85	347,8	-4,95
9	2,83	345	347,8	-2,8	24	2,83	345	347,8	-2,8
10	2,83	348	347,8	0,2	25	2,83	348,52	347,8	0,72
11	2,83	358	347,8	10,2	26	2,83	346,82	347,8	-0,98
12	2,83	320	347,8	-27,8	27	2,83	362,2	347,8	14,4
13	2,83	302,52	347,8	-45,28	28	2,83	354	347,8	6,2
14	2,83	352	347,8	4,2	29	2,83	350	347,8	2,2
15	2,83	345,23	347,8	-2,57	30	2,83	352,22	347,8	4,42
Average						2,83	342,24	347,8	-5,560

From Table 4 it can be seen that the average measurement results show that the DC motor rotation measured using the LM393 sensor produces a rotation of 342.24 RPM and the tachometer measuring instrument displays a measurement result of 347.8, so the difference is -5.56. Furthermore, the results of measuring the input voltage of 4,25 V can be seen in Table 5.

Table 5. The results of the input voltage measurement are 4,25 V

Time (s)	Voltage (v)	LM393 RPM)	Tachometer (RPM)	E (error)	Time (s)	Voltage (v)	LM393 RPM)	Tachometer (RPM)	E (error)
1	4,25	575,23	575	0,23	16	4,25	570,5	575	-4,5
2	4,25	568	575	-7	17	4,25	567	575	-8
3	4,25	570	575	-5	18	4,25	578	575	3
4	4,25	577	575	2	19	4,25	578	575	3
5	4,25	562	575	-13	20	4,25	577	575	2
6	4,25	562	575	-13	21	4,25	578	575	3
7	4,25	566	575	-9	22	4,25	578,5	575	3,5
8	4,25	563	575	-12	23	4,25	577	575	2
9	4,25	578	575	3	24	4,25	577,5	575	2,5
10	4,25	572,25	575	-2,75	25	4,25	578	575	3
11	4,25	575,3	575	0,3	26	4,25	578,5	575	3,5
12	4,25	567,8	575	-7,2	27	4,25	578	575	3
13	4,25	569,2	575	-5,8	28	4,25	578,8	575	3,8
14	4,25	577,5	575	2,5	29	4,25	578	575	3
15	4,25	568,4	575	-6,6	30	4,25	578,2	575	3,2
Average						4,25	573,42	575	-1,577

From Table 5 it can be seen that the average measurement results show that the DC motor rotation measured using the LM393 sensor produces a rotation of 573.42 RPM and the tachometer measuring instrument displays a measurement result of 575, so the difference is -1.57. Furthermore, the results of measuring the input voltage of 7.05 V can be seen in Table 6.

Table 6. The results of the input voltage measurement are 7,05 V

Time (s)	Voltage (v)	LM393 (RPM)	Tachometer (RPM)	E (error)	Time (s)	Voltage (v)	LM393 (RPM)	Tachometer (RPM)	E (error)
1	7,05	1102	1120	-18	16	7,05	1119,52	1120	-0,48
2	7,05	1120,5	1120	0,5	17	7,05	1119,82	1120	-0,18
3	7,05	1110,25	1120	-9,75	18	7,05	1119,22	1120	-0,78
4	7,05	1122,05	1120	2,05	19	7,05	1119,52	1120	-0,48
5	7,05	1120,5	1120	0,5	20	7,05	1119,52	1120	-0,48
6	7,05	1132,5	1120	12,5	21	7,05	1119,62	1120	-0,38
7	7,05	1125,5	1120	5,5	22	7,05	1119,42	1120	-0,58
8	7,05	1120,36	1120	0,36	23	7,05	1119,02	1120	-0,98
9	7,05	1102,5	1120	-17,5	24	7,05	1118,45	1120	-1,55
10	7,05	1110,25	1120	-9,75	25	7,05	1119,25	1120	-0,75
11	7,05	1110,58	1120	-9,42	26	7,05	1118,89	1120	-1,11
12	7,05	1108,85	1120	-11,15	27	7,05	1118,52	1120	-1,48
13	7,05	1119,02	1120	-0,98	28	7,05	1119,89	1120	-0,11
14	7,05	1119,52	1120	-0,48	29	7,05	1119,59	1120	-0,41
15	7,05	1119,32	1120	-0,68	30	7,05	1120,58	1120	0,58
Average						7,05	1117,82	1120	-2,182

From Table 6 it can be seen that the average measurement results show that the DC motor rotation measured using the LM393 sensor produces a rotation of 1117.82 RPM and the tachometer measuring instrument displays a measurement result of 1120, so the difference is -2.18. Furthermore, the results of measuring the input voltage are 9,07 V which can be seen in Table 7.

Table 7. The results of the input voltage measurement are 9,07 V

Time (s)	Voltage (v)	LM393 (RPM)	Tachometer (RPM)	E (error)	Time (s)	Voltage (v)	LM393 (RPM)	Tachometer (RPM)	E (error)
1	9,07	1298,6	1320	-21,4	16	9,07	1319	1320	-1,01
2	9,07	1295,5	1320	-24,5	17	9,07	1298,6	1320	-21,4
3	9,07	1315,5	1320	-4,5	18	9,07	1318,9	1320	-1,07
4	9,07	1318,5	1320	-1,48	19	9,07	1318	1320	-2,02
5	9,07	1319,5	1320	-0,5	20	9,07	1319,5	1320	-0,48
6	9,07	1318,2	1320	-1,8	21	9,07	1319,8	1320	-0,18
7	9,07	1318,5	1320	-1,5	22	9,07	1319,8	1320	-0,18
8	9,07	1322,5	1320	2,5	23	9,07	1319,9	1320	-0,11
9	9,07	1318,8	1320	-1,18	24	9,07	1320	1320	-0,02
10	9,07	1318,9	1320	-1,12	25	9,07	1320	1320	-0,02
11	9,07	1318,2	1320	-1,8	26	9,07	1320	1320	-0,02
12	9,07	1318,5	1320	-1,5	27	9,07	1319,8	1320	-0,18
13	9,07	1318,6	1320	-1,42	28	9,07	1319,8	1320	-0,18
14	9,07	1318,5	1320	-1,48	29	9,07	1319,9	1320	-0,08
15	9,07	1318,6	1320	-1,42	30	9,07	1320	1320	-0,01
Average						9,07	1317,00	1320	-3

From Table 7 it can be seen that the average measurement results show that the DC motor rotation measured using the LM393 sensor produces a rotation of 1317.0 RPM and the tachometer measuring instrument displays a measurement result of 1320, so the difference is -3. After knowing the error or difference that occurred, then carry out validation using the following equation:

$$Val(\%) = Error/(Data\ Tachometer) \times 100\% \qquad (2)$$

Data on the difference in measurements between the tachometer and the LM393 measuring instruments can thus be validated using the following equation. The tachometer measurement results are the main reference in validating the LM393 sensor measurement results, so the validation results are shown in Table 8.

Table 8. validation results, error measurement results

Validation (%)											
Time (s)	Voltage Input (V)					Time (s)	Voltage Input (V)				
	0,93	2,83	4,25	7,05	9,07		0,93	2,83	4,25	7,05	9,07
1	-0,158	-0,748	0,040	-1,607	-1,623	16	2,954	-1,380	-0,783	-0,043	-0,077
2	0,186	-9,430	-1,217	0,045	-1,854	17	2,954	2,070	-1,391	-0,016	-1,623
3	-4,978	-7,872	-0,870	-0,871	-0,341	18	2,954	-1,668	0,522	-0,070	-0,081
4	-3,601	-7,418	0,348	0,183	-0,112	19	2,954	0,201	0,522	-0,043	-0,153
5	-2,224	-0,518	-2,261	0,045	-0,038	20	2,954	1,409	0,348	-0,043	-0,036
6	-1,535	-1,668	-2,261	1,116	-0,136	21	2,954	-0,805	0,522	-0,034	-0,014
7	-3,395	0,058	-1,565	0,491	-0,114	22	0,289	0,058	0,609	-0,052	-0,014
8	-2,017	-7,418	-2,08	0,032	0,189	23	0,289	-1,423	0,348	-0,088	-0,008
9	-0,158	-0,805	0,522	-1,563	-0,089	24	0,289	-0,805	0,435	-0,138	-0,002
10	0,048	0,058	-0,47	-0,871	-0,085	25	0,289	0,207	0,522	-0,067	-0,002
11	0,186	2,933	0,052	-0,841	-0,136	26	-2,017	-0,282	0,609	-0,099	-0,002
12	0,737	-7,993	-1,25	-0,996	-0,114	27	-1,329	4,140	0,522	-0,132	-0,014
13	-2,017	-13,019	-1,00	-0,088	-0,108	28	2,527	1,783	0,661	-0,010	-0,014
14	2,114	1,208	0,435	-0,043	-0,112	29	2,802	0,633	0,522	-0,037	-0,006
15	2,802	-0,739	-1,14	-0,061	-0,108	30	0,048	1,271	0,557	0,052	-0,001
Average							0,2526	-1,453	-0,12	0,0389	0,0725

The average validation in the form of a presentation explains that the difference between the LM393 sensor reading value and the tachometer with an input voltage of 0.93V is 0.252%, an input voltage of 2.83V, namely -1.45%, shows a minus number because the LM393 output value is greater than in the tachometer measurement results, however, the difference in presentation is only slight, a voltage input of 4.25V shows an average validation presentation of -0.12%, a voltage input of 7.05V is 0.038% and a voltage input of 9.07 shows an average presentation of 0 .0725%. Therefore, the results of the validation calculations can be seen in the graph Figure 8.

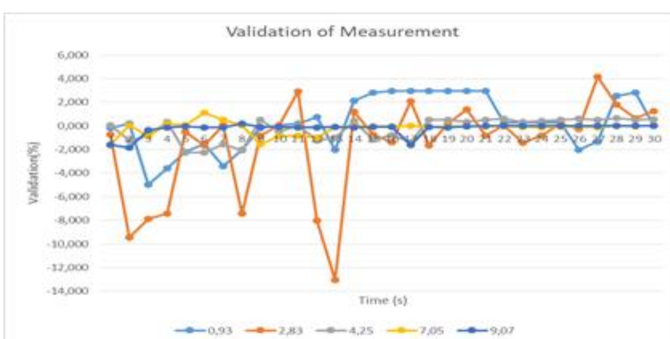


Figure 8. measurement validation chart

From the graph in Figure 8 it can be seen that the highest graph is in the 17th and 28th seconds with a presentation of 5% and the lowest is in the 13th second with a value of -13.019%, but this is not a very significant difference in validation because the average validation those in Table 8 do not touch more than 10% or -10%, in this case the RPM measurement using the microcontroller-based LM393 sensor is valid and appropriate.

4. CONCLUSIONS

The formulation of the problem that arises from the planning of this research is to analyze the differ-ences in RPM measurements using the LM393 and validate it against the conventional Tachometer measuring instrument. The measurement process begins by determining the input voltage of the DC motor with variations, namely, 0.93V, 2.83V, 4.25V, 7.05V and 9.07V. Next, a measurement process was carried out, each of which had a difference in data, namely 0.334 RPM, -5,560 RPM, -1,577 RPM, -2,182 RPM and -3 RPM. So, from the difference in readings, measurement validation was carried out, namely obtaining results of 0.252%, -1.45%, 0.12%, 0.038% and 0.0725%. From the validation results, the average comparison of measurement results shows that the difference between the two measuring instruments is not too far, but does not reach more than 10%, so it can be concluded that the RPM measuring instrument using the LM393 is valid and in accordance with the tachometer measuring in-strument.

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