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Design of Remote Temperature Monitoring System Tool Using VHF Waves Based on VFC LM331

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Abstract

A remote temperature monitoring system has been designed and manufactured using VHF waves based on VFC LM331. This remote temperature monitoring system uses the IC LM35 temperature sensor. The technique used for sending data uses radio waves on VHF lines with an OOK (On-Off Keying) modulation system. So that the analogue voltage signal from the sensor can be modulated and transmitted by the transmitter, the voltage must be converted to frequency using a VFC LM331. From the results of measuring the accuracy of the design tool, it was found that the design tool worked well at a temperature of 0 ºC up to 99% compared to a reference device. The range of the system that has been designed is much influenced by the frequency of the transmitter used, the more users on that frequency, the shorter the range. The farthest distance that can be reached is around 120 meters at a frequency of 80 MHz while at a frequency of 89 – 106.3 MHz it can only reach around 48 meters.

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1 Introduction

The development of wireless technology is currently increasing rapidly along with human needs in everyday life. The use of remote systems is not only for household appliances but also for electronic data transmission. Data transmission can be done using wired or wireless media (Qingbai & Yongzhi, 2004; Doppiu et al., 2007). The problem that arises is how data collection can be carried out over long distances without endangering our safety, for example sending weather data to a critical place around a volcano, a beach with big waves or engine temperature in a factory with high voltage. To overcome the above problems, the right way is to use wireless technology (Hogenboom, 1988; Coughlin et al., 1992). There are many ways to send information remotely without using cables, including using infrared light systems, laser light, ultrasonic waves and radio waves (Supardi et al., 2022). In this study, a radio wave system was chosen that uses the VHF frequency because it is more resistant to interference from other frequencies. This remote temperature monitoring tool is made using an LM35 temperature sensor based on VFC LM331 which functions to convert the LM35 sensor output voltage to a frequency so that this data can be sent via VHF waves (Pathmanathan, 2012; Arief, 1984).

2 Materials and Methods

The VFC LM331-based remote temperature monitoring system created in this study consists of two unit block diagrams as Figure 1.

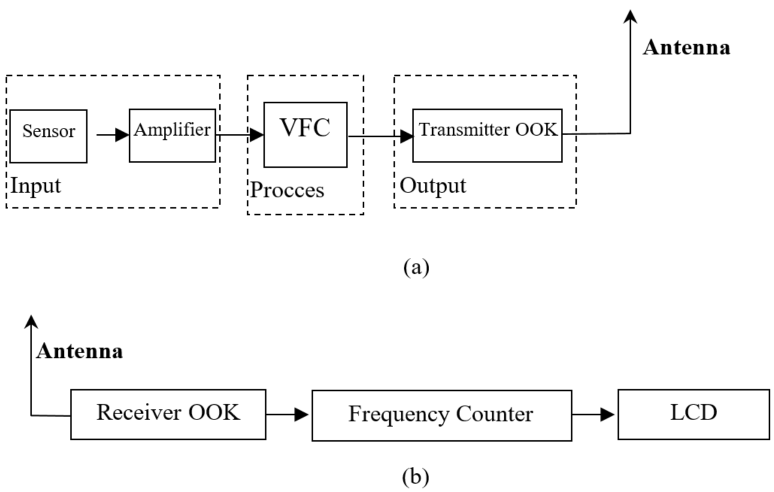

Figure 1. Research Block Diagram. (a) Network Transmitters, (b) Receiver Network

Tests on this sensor circuit are carried out to ensure that the sensor is truly linear and produces an output voltage on the amplifier of 100 mV/oC, then entered in a table and graphed the relationship between temperature and voltage (Koerner & Koerner, 2006). This test uses a standard laboratory thermometer. The observation of the VFC output frequency was carried out to compare the sensor output voltage with the VFC output frequency (Astuti et al., 2007; Benny et al., 2015).

3 Results and Discussions

Figure 2. Designed tool

To determine the level of accuracy of the design tool, a calibration process is carried out. Calibration is carried out to compare the measurement results of the design tool with a reference tool (Kuzubasoglu & Bahadir, 2020; Mahadeva et al., 2011). The results of the calibration of the design device's temperature readings with reference devices are shown in Table 1.

Table 1
Data from the temperature calibration of the design tool with reference

No	Reference (ºC)	Design (ºC)
1	0	0,1
2	5	5,0
3	10	10,4
4	15	15,5
5	20	20,5
6	25	25,2
7	30	30,2
8	35	35,8
9	40	40,3
10	45	45,0
11	50	50,8
12	55	55,7
13	60	60,8
14	65	65,4
15	70	70,7
16	75	75,6
17	80	80,8
18	85	85,6
19	90	91,4
20	95	96,3
21	99	99,8

From Table 1. Then a graph of the relationship between the design tool and the reference tool is made. Figure 1. Shows a graph of the measurement results between the design tool and the reference tool. The graph shows that the level of accuracy of measurement results between the design tool and the reference tool is very good, this is shown in the equation y = 0.9912x -0.1232, where the coefficient of termination (R^2) shows the number 0.9999 which means the accuracy between the design tool and the reference tool reaches 99%.

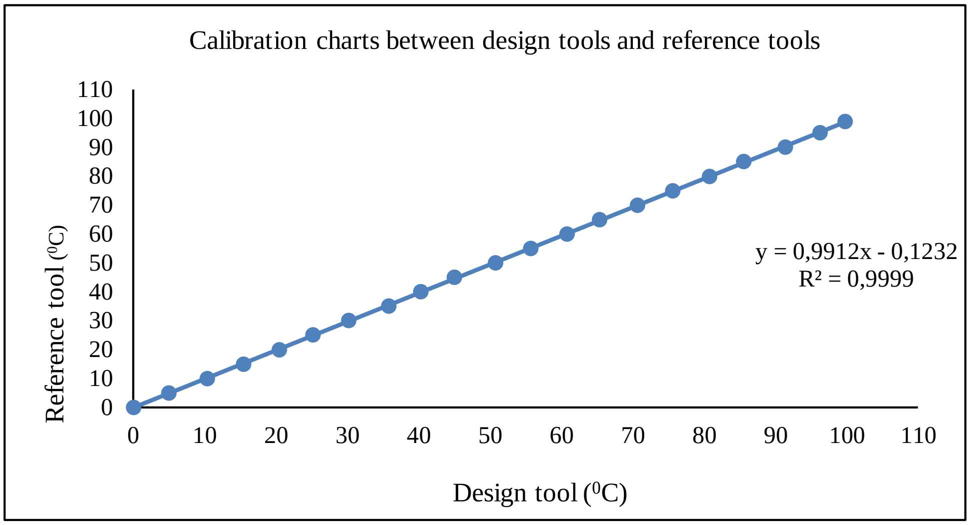

Figure 3. Calibration graph between the design tool and reference tool

To determine the accuracy of the performance of the LM35 on the design tool, measurements are also carried out by comparing it with a reference thermometer (León-Luis et al., 2011). Data from research on a reference thermometer with an LM35 thermometer with different transmitter frequencies ranging from 80 MHz to 108 MHz. In this observation, for every change in transmitter frequency, the receiver unit must also be calibrated so that the frequency of reception is correct (Kirana & Suryono, 2016; Yunus, 2003). Table 2 shows the results of temperature measurements between the design tool and the reference. Then a graph is made of the relationship between the temperature of the design tool and the reference device for each transmitter frequency. Figure 3 shows a graph of the results of temperature measurements between the designed thermometer and the reference thermometer at a transmitter frequency of 80 MHz. The graph shows that the level of accuracy of measurement results between the design tool and the reference tool is very good, this is shown in the equation y = 0.9906x -0.104, where the coefficient of termination (R^2) shows the number 0.9999 which means the accuracy between the design tool and the reference tool reaches 99%.

Table 2
Data on temperature measurement results between reference thermometers and design tool thermometers for different transmitter frequencies

No	Thermometer Reference (^{0}C)	Thermometer LM35 (ºC)				
		80 MHz	89,1 MHz	94,3 MHz	106,3 MHz	107,9 MHz
1	0	0,1	0,2	0,1	0,2	0,3
2	5	5,0	4,9	5,2	4,8	5,3
3	10	10,4	10,2	10,8	10,5	10,1
4	15	15,5	15,1	15,3	15,0	15,2
5	20	20,5	20,0	20,2	20,1	20,4
6	25	25,2	25,1	25,0	25,1	25,1
7	30	30,2	30,0	30,0	30,1	29,9
8	35	35,8	35,2	35,2	35,5	35,4
9	40	40,3	40,0	40,1	40,3	40,4
10	45	45,0	45,0	45,0	45,0	45,0
11	50	50,8	50,0	50,5	50,7	50,0
12	55	55,7	55,5	55,5	55,2	55,4
13	60	60,8	60,5	60,0	60,8	60,3
14	65	65,4	65,0	65,5	65,3	65,1

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No	Thermometer Reference (^{0}C)	Thermometer LM35 (ºC)				
		80 MHz	89,1 MHz	94,3 MHz	106,3 MHz	107,9 MHz
15	70	70,7	70,3	70,5	70,3	70,6
16	75	75,6	75,4	75,1	75,4	75,6
17	80	80,8	80,9	80,5	80,0	80,4
18	85	85,6	85,0	85,8	85,7	85,6
19	90	91,4	90,2	90,8	89,9	90,5
20	95	96,3	95,2	96,1	94,5	94,8

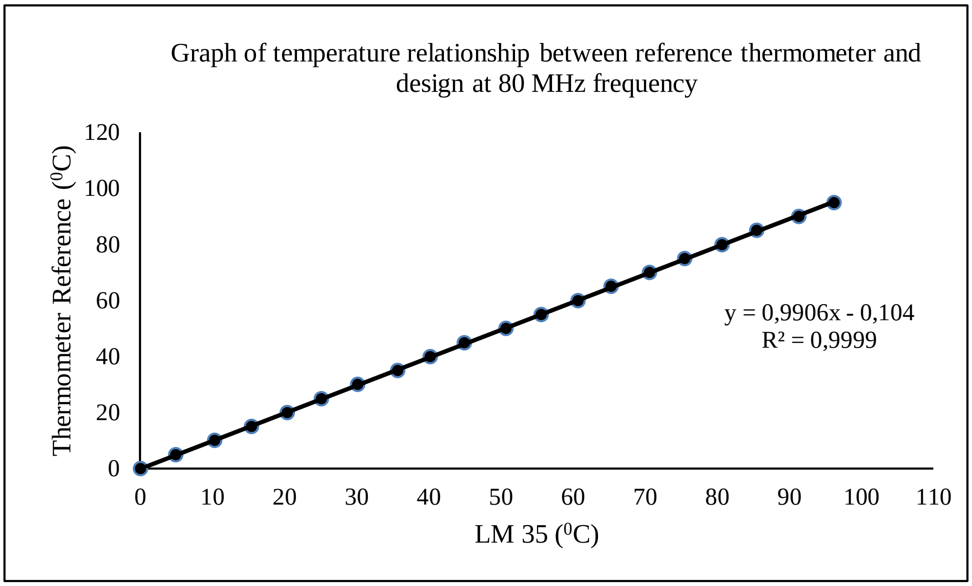

Figure 4. Graph of temperature relationship between reference thermometer and design at 80 MHz frequency

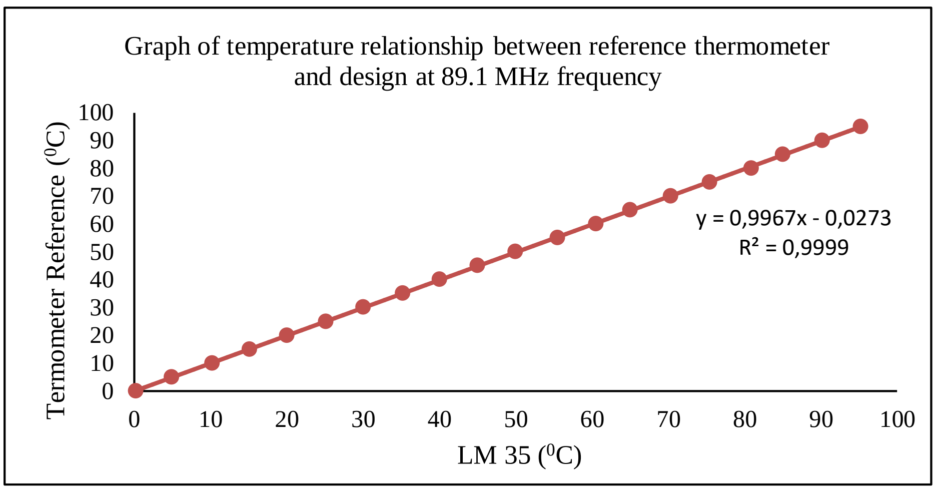

Figure 5. Graph of the temperature relationship between the reference thermometer and the design at 89.1 MHz frequency

Figure 5 shows a graph of the results of temperature measurements between the designed tool thermometer and the reference thermometer at a transmitter frequency of 89.1 MHz. The graph shows that the level of accuracy of measurement results between the design tool and the reference tool is very good, this is shown in the equation y = 0.9967x - 0.0273, where the coefficient of termination (R^2) shows the number 0.9999 which means the accuracy between the design tool and the reference tool reaches 99%.

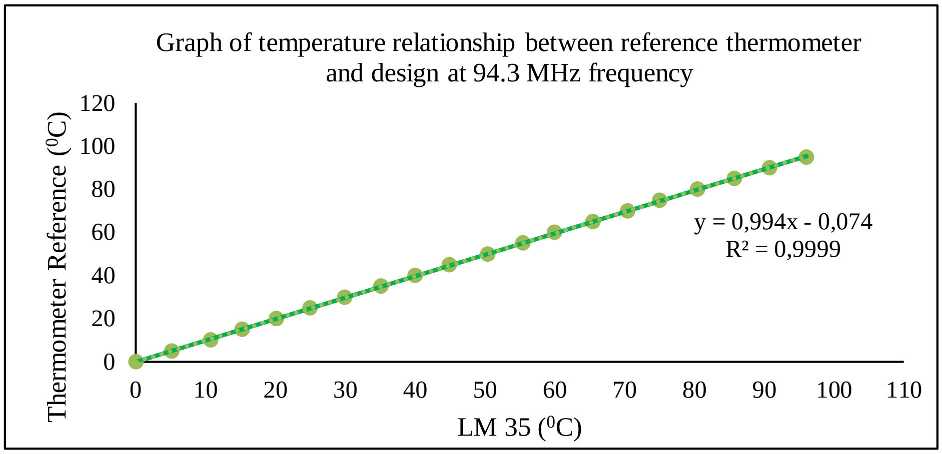

Figure 6. Graph of the temperature relationship between the reference thermometer and the design at 94.3 MHz frequency

Figure 6 shows a graph of the results of temperature measurements between the designed tool thermometer and the reference thermometer at a transmitter frequency of 94.3 MHz. The graph shows that the level of accuracy of measurement results between the design tool and the reference tool is very good, this is shown in the equation y = 0.994x - 0.074, where the coefficient of termination (R^2) shows the number 0.9999 which means the accuracy between the design tool and the reference tool reaches 99%.

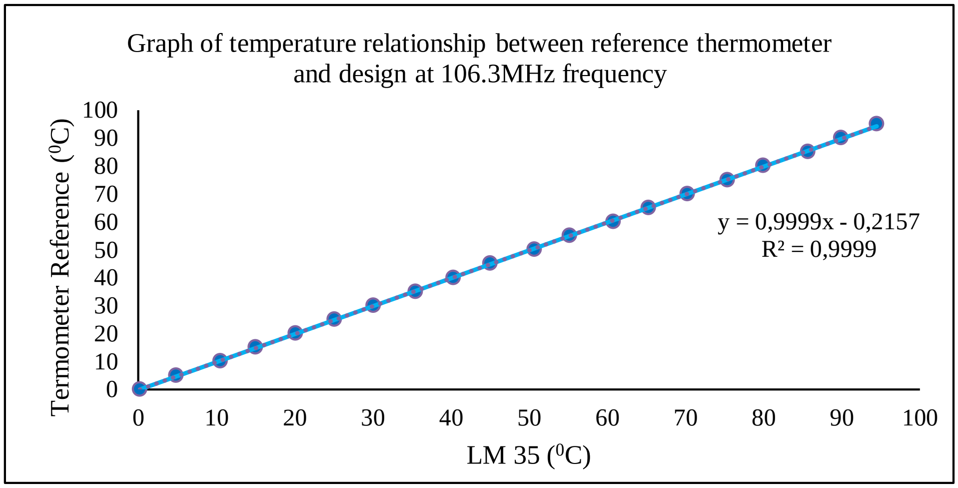

Figure 7. Graph of the temperature relationship between the reference thermometer and the design at 106.3 MHz frequency

Figure 7. Shows a graph of the results of temperature measurements between the designed tool thermometer and the reference thermometer at a transmitter frequency of 80 MHz. The graph shows that the level of accuracy of measurement results between the design tool and the reference tool is very good, this is shown in the equation y = 0.9906x -0.104, where the coefficient of termination (R^2) shows the number 0.9999 which means the accuracy between the design tool and the reference tool reaches 99%.

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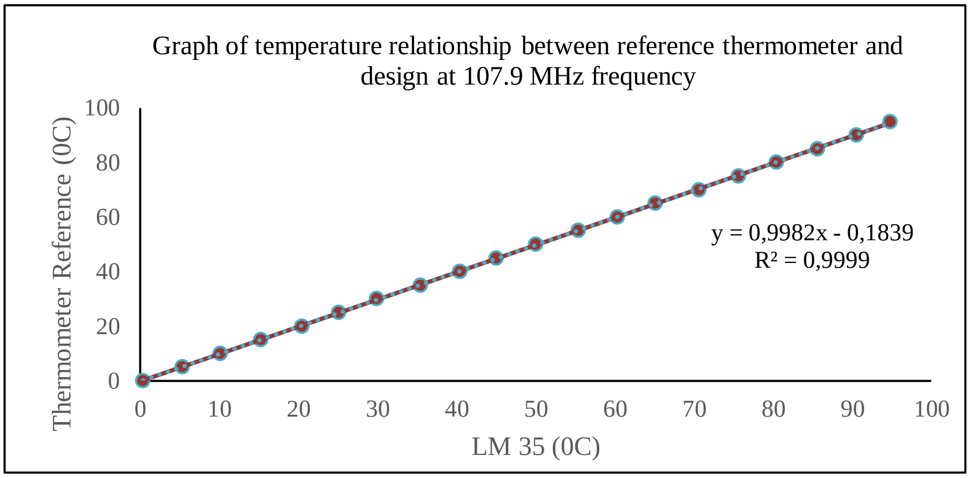

Figure 8. Graph of the temperature relationship between the reference thermometer and the design at 107.9 MHz frequency

Figure 8. Shows a graph of the results of temperature measurements between the designed tool thermometer and the reference thermometer at a transmitter frequency of 107.9 MHz. The graph shows that the level of accuracy of measurement results between the design tool and the reference tool is very good, this is shown in the equation y = 0.9982x -0.1839, where the coefficient of termination (R^2) shows the number 0.9999 which means the accuracy between the design tool and the reference tool reaches 99% (Dorozhovets et al., 2023; Kirianaki et al., 2000).

Observation of the distance that can be reached by transmitters with different transmitting frequencies ranging from 80 MHz to 108 MHz at ambient temperature, around 33.6 ^{0}C. Measurements were carried out 5 times for each different frequency. The measurement results are shown in Table 3.

Table 3
Data on the results of measuring the distance of the observation range for different frequencies

Measurement	Transmitter Range (m)				
	80 MHz	89,1 MHz	94,3 MHz	106,3 MHz	107,9 MHz
1	120,0	63,0	55,0	48,0	90,0
2	118,0	60,0	50,0	50,0	99,0
3	115,0	61,0	49,0	51,0	100,0
4	109,0	60,0	48,0	52,0	110,0
5	105,0	58,0	48,0	50,0	115,0

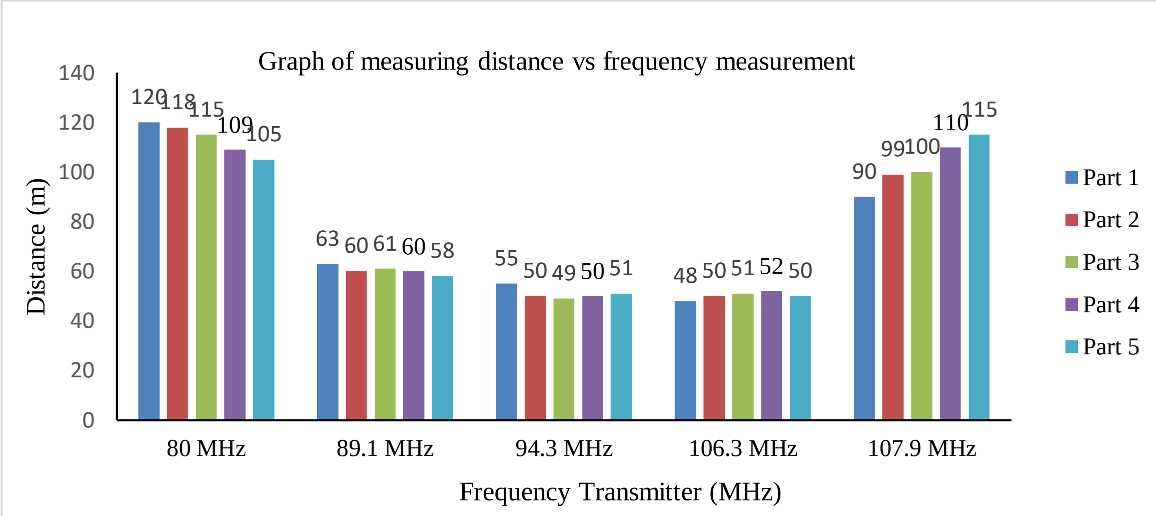

Figure 9. Graph of measuring distance VS frequency measurement

Figure 9 shows a graph of the results of measuring the range of the design tool for various frequencies. The graph shows that the maximum range of the design tool is 120 m at a frequency of 80 MHz, while the lowest range is 48 m at a frequency of 94.3 MHz. At frequencies between 89 MHz to 106.3 MHz, it can only cover about 45 to 60 meters using a standard 9V battery (Amassian & Stewart, 2003; Olsson III et al., 2008). The transmitter range seems to decrease with frequency, this is due to the large number of frequency users on the commercial VHF-FM line operating at the frequency 88 – 106 MHz which has very high power so that the receiver unit receives a lot of interference frequencies (Sulistyanto et al., 2015; Yusuf, 2009). Meanwhile, the range of 80 MHz and 107.9 MHz has increased because there are relatively few users at these frequencies so the receiving unit does not receive much interference from other transmitter frequencies. It can be assumed that the reception range is affected by the number of users on that frequency (Mulyana & Kharisman, 2014; Setiawan et al., 2014; Kumar et al., 2015). The more usage at that frequency, the smaller the range of the tool, conversely the less usage at that frequency, the farther the range of the design tool.

4 Conclusion

Based on the results and discussion of the research it can be concluded:

1) It has been possible to design a tool for designing a remote temperature monitoring system with VHF waves based on VFC LM331
2) The level of the designed device is very good, 99% compared to the reference device with an optimal range of 120 meters at a transmitting frequency of 80 MHz.
3) The range of the device does not affect the transmitter frequency but does affect the number of users at a certain frequency.

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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