Zener diode vs rectifier diode: The comparison of Gaussian probability distribution charts from full-wave rectifier circuits

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Abstract. The aim of this research is to get an explanation why the use of zener diode in full-wave rectifier circuit is not suitable. The diode used in this research is IN4728 zener diode and IN4002 rectifier diode, which is connected to 1,200 ohm resistor. The circuit is supplied with 5-volt AC power supply with frequency of 50 Hz. The output voltage data of the diode is clipped by using LoggerPro voltage sensor. The data is processed by fitting the data according to the Gaussian probability distribution. The results showed that the Gaussian probability distribution chart of the circuit using IN4728 zener diode has an asymmetric shape, unlike the Gaussian probability distribution chart of the circuit using an IN4002 rectifier diode that has a symmetrical shape. The IN4728 zener diode has breakdown voltage of 3.3 V. When reversed bias is occur and the source voltage exceeds the breakdown voltage of the zener diode, the voltage still pass through the zener diode at 3.3 V. This causes the charts of its Gaussian probability distribution has an asymmetric shape. So it can be concluded that the use of IN4728 zener diode for rectifier circuit is not suitable.

1. Introduction

Many types of probability distributions used in the analysis of experimental data, three of them have a fundamental role: binomial, Poisson, and Gaussian probability distributions [1]. From these three distribution types, the Gaussian probability distribution is the most important in statistical data analysis [1]. Practically, Gaussian probability distribution is particularly useful because it is able to show the distribution of random observations in many experiments, and also capable of showing the obtained distribution when trying to estimate the parameters of other probability distributions [1]. The statistical function of the normal Gaussian distribution can be used to determine the quality of the full wave rectifier circuit [2]. The experimental data that is processed here is the output voltage of the circuit within a certain time interval. If the standard deviation generated from a wave rectifier circuit is smaller then the quality of the full-wave rectifier circuit will be better [2-3]. LoggerPro device is used to obtain the output voltage data from the circuit.

As we have known that diode is an active component of two semiconductor (cathode and anode), so by its nature the diode not only allows electric current to flow in one direction, but also inhibits the current from the opposite direction [4-5]. Diodes can be made from Germanium (Ge) and Silicon or Silsilum (Si) [6]. This active component has functions as: rectifier, voltage regulator, modulator, frequency controller, and switch [7].

Based on their function, diode are divided into many types, two of them are zener diode and rectifier diode [8]. Zener diodes commonly used on voltage divider and serve as voltage stabilizers or voltage regulators, the characteristic of this diode is that it has a stable reversed voltage [9-10].

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In a rectifier circuit, the correct type of diode used is rectifier diode [5, 11-12]. But what will happen if rectifier diode in the rectifier circuit is replaced by zener diode? Based on this simple question, the researcher is interested to compare the charts of the Gaussian probability distribution of a full-wave rectifier circuit using between rectifier diode and zener diode, and trying to provide the explanation why the use of zener diode in a rectifier circuit is not suitable based on the Gaussian probability distribution theory.

2. Experiment
The form of this research is experiment as shown in Figure 1. AC voltage source is set to 5 volts AC 50 Hz frequency. LoggerPro interface is connected in parallel with $R_L$ to get the data and display the output waveform on the laptop. The data taken is a large output voltage recorded by LoggerPro device. By using different types of diodes, these experiment steps are executed again. The diodes used in this experiment are IN4728 zener diode and IN4002 rectifier diode, which is connected in series with a 1,200 ohm resistor. From the data obtained, the average value and its standard deviation are calculated. Furthermore, from each type of diode, the Gaussian probability distribution is determined.

**Figure 1.** Circuit of experiment.

**Figure 2.** Research instrument design.
The equations used are as follows:

\[ \mu = \frac{1}{N} \sum x_i \]

\[ \sigma = \left( \frac{1}{N} \sum (x_i - \mu)^2 \right)^{1/2} \]

\[ P_G(x; \mu, \sigma) = \frac{1}{\sigma (2\pi)^{1/2}} \exp \left[ -\frac{1}{2} \left( \frac{x_i - \mu}{\sigma} \right)^2 \right] \]

where:
- \( \mu \) : mean value of data
- \( N \) : number of data
- \( x \) : distribution of data
- \( \sigma \) : standard deviation
- \( P_G \) : Gaussian probability distribution

3. Result and Discussion

From the experiment using IN4728 zener diode, the average output voltage of 0.89 volts with standard deviation of 0.39 were obtained and the chart of its Gaussian probability distribution is shown in Figure 4.

![Figure 3](image1.png)

Figure 3. Output voltage chart of full-wave rectifier circuit using IN4728 zener diode.

![Figure 4](image2.png)

Figure 4. Gaussian probability distribution chart of full-wave rectifier circuit using IN4728 zener diode.
From the experiment using IN4002 rectifier diode, the average output voltage of 0.16 volts with standard deviation of 0.06 were obtained and the chart of its Gaussian probability distribution is shown in Figure 6.

![Gaussian probability distribution chart of full-wave rectifier circuit using IN4002 rectifier diode.](image)

**Figure 5.** Output voltage chart of full-wave rectifier circuit using IN4002 rectifier diode.

**Figure 6.** Gaussian probability distribution chart of full-wave rectifier circuit using IN4002 rectifier diode.

By looking at the comparison between figure 4 and figure 6, it is clear that the Gaussian probability distribution charts of the circuit using IN4728 zener diode has an asymmetric shape, unlike the Gaussian probability distribution charts of the circuit using IN4002 rectifier diode has a symmetrical shape. When forward bias is in progress, the function of zener diode is the same as the rectifier diode, which will let the current pass through. But when the reversed bias is occur, unlike the rectifier diode which will not let the current pass through, the zener diode will let the current pass through if the voltage exceeds the breakdown voltage of the zener diode, where the value of the voltage that pass through the zener diode will always fixed depends on the value of the breakdown voltage of the zener diode. IN4728 zener diode has a breakdown voltage of 3.3 V. When reverses bias is occur and the input voltage is maximum AC at 5 Volts, then the value of the voltage across the IN4728 zener diode will remain at 3.3 V. This is the cause why the shape of its Gaussian probability distribution charts is not symmetric, because when reversed bias is occur and the source voltage exceeds the breakdown voltage of the zener diode, the voltage will still pass through the zener diode at the fixed values as the same as its breakdown voltage.
Table 1 is the calculation table of the average output voltage, the standard deviation $\sigma$ and the maximum Gaussian probability distribution of the two types of diodes used in the full wave rectifier circuit.

| Type of diode | Average output voltage (V) | Standard deviation $\sigma$ | PGmax ($x=\mu$) |
|---------------|---------------------------|-----------------------------|-----------------|
| IN4728        | 0.89                      | 0.39                        | 1.02            |
| IN4002        | 0.16                      | 0.06                        | 6.06            |

If the data of IN4728 diode and IN4002 diode in table 1 are compared, it can be seen that the maximum Gaussian probability distribution value of IN4728 diode is smaller than the maximum Gaussian probability distribution value of IN4002 diode. The standard deviation value of IN4728 diode is bigger than standard deviation value of IN4002 diode.

Referring to the shape of the Gaussian probability distribution graph and the maximum value of the Gaussian distribution as well as the standard deviation value of each type of diode, there is a significant difference. Where the graph of the Gaussian probability distribution of the IN4728 diode has an asymmetric shape and has a relatively small maximum Gaussian distribution value and has a relatively large standard deviation value, it can be concluded that the use of IN4728 zener diode for rectifier circuit is not suitable.

4. Conclusion
From the results and discussion, it can be concluded that the use of zener diode in the rectifier circuit is not suitable due to its function as a voltage stabilizer. This can be seen from the charts of its Gaussian probability distribution that is not symmetric.

References
[1] Bevington P R and Robinson D K 2003 *Data Reduction and Error Analysis for the Physical Sciences* (New York: McGraw-Hill Higher Education)
[2] Rosdianto H and Toifur M 2011 Analisis Kualitas Rangkaian Penyearah Gelombang Penuh Melalui Kriteria Nilai Simpangan Baku *Prosiding Seminar Nasional Sains dan Pendidikan* Sains 2 vol 1 no 2 pp 21–26
[3] Rosdianto H and Toifur M 2017 Implementasi Teori Distribusi Probabilitas Gaussian Pada Kualitas Rangkaian Penyearah Gelombang Penuh *Spektra: Jurnal Fisika dan Aplikasinya* vol 2 no 1 pp 83–90
[4] Pyakuryal S and Matin M 2013 Filter Design for AC to DC Converter *International Refereed Journal of Engineering and Science* vol 2 no 2 pp 42–49
[5] Jamjaem T and Burapattanasiri B 2010 High Precision HalfWave Rectifier Circuit In Dual Phase Output Mode *International Journal of Computer Science and Information Security* vol 8 no 3 pp 149–152
[6] Kumngern M and Dejhan K 2007 High Frequency, High Precision CMOS Half-Wave Rectifier *ECTI-CON 2007, The 2007 ECTI International Conference*
[7] Boylestad R and Nashelsky L 2002 *Electronic Devices and Circuit Theory* (New Jersey: Prentice Hall)
[8] Cunţan C D, Baciu I, Panoiu C and Dinis C 2009 Analysis of A Double Wave Accuracy Rectifier’s Operation With Operational Amplifiers *Fascicule* vol 3 pp 371–373
[9] Singh B and Gairola S 2008 An 18-Pulse Full-Wave AC-DC Converter for Power Quality Improvement *Journal of Power Electronics* vol 8 no 2 pp 109–120
[10] Neamen D A 2003 *Semiconductor Physics and Devices: Basic Principles* (New York: McGraw-Hill)
[11] Langhammer L and Jerabek J 2013 Precision Full-Wave Rectifiers with Current Active Elements and Current Biasing *International Journal of Advances in Telecommunications, Electrotechnics, Signals and System* vol 2 no 2 pp 79–83
[12] Pejovic P and Kolar J W 2014 Single-Phase Full-Wave Rectifier as an Effective Example to Teach Normalization, Conduction Modes, and Circuit Analysis Methods *Electronics Journal, Special Issue on: Education in Electronics* vol 17 no 2 pp 123–129