



**ФАН ВА ТЕХНОЛОГИЯЛАР
ТАРАҚҚИЁТИ**
**РАЗВИТИЕ НАУКИ И
ТЕХНОЛОГИЙ**

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РАЗВИТИЕ НАУКИ И ТЕХНОЛОГИЙ

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Ушбу журналда чоп этилган материаллар таҳририятнинг ёзма рухсатисиз тўлиқ ёки қисман чоп этилиши мумкин эмас. Таҳририятнинг фикри муаллифлар фикри билан ҳар доим ҳам мос тушмаслиги мумкин. Журналда ёритилган материалларнинг ҳаққонийлиги учун мақолаларнинг муаллифлари ва реклама берувчилар масъулдирлар.

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THE INFLUENCE OF HARMONICS ON THE LIFESPAN OF LIGHTING DEVICES

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Annotation. This article investigates the significant impact of harmonics on the performance and longevity of lighting devices, with a particular focus on LED-based systems. Although LEDs are widely valued for their high energy efficiency and extended service life, the presence of harmonic distortion in power systems introduces various forms of electrical and thermal stress that degrade key semiconductor components such as diodes and transistors. The study provides a detailed technical analysis of degradation mechanisms induced by Total Harmonic Distortion (THD), including elevated heat generation, current waveform distortion, voltage overstress, and reductions in power factor. Practical circuit implementations, including LM317-based voltage regulation and dimming control schemes, are discussed to highlight both common applications and their vulnerabilities to harmonics. The findings underscore that effective harmonic mitigation strategies can substantially enhance the reliability, efficiency, and operational lifespan of lighting devices, thereby improving overall power quality in modern electrical infrastructure.

Keywords: harmonic, semiconductor, illumination, electrical systems, voltage, frequency, resistors, lifespan, efficiency and temperature.

YORITISH QURILMALARINING ISHLASH MUDDATIGA GARMONIKLARNING TA'SIRI

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Annotatsiya. Ushbu maqolada garmoniklarning yoritish moslamalari, ayniqsa LED asosidagi tizimlar ish faoliyati va xizmat muddati uchun muhim ta'siri o'rganiladi. LEDlar yuqori energiya samaradorligi va uzoq xizmat muddati bilan qadrlansa-da, quvvat tizimidagi garmonik buzilishlar elektr va issiqlik zo'riqishining turli shakllarini keltirib chiqaradi, bu esa diodlar va tranzistorlar kabi asosiy yarimo'tkazgich komponentlarining yemirilishiga olib keladi. Tadqiqot Umumiy Garmonik Buzilish (THD) sabab bo'ladigan yemirilish mexanizmlarining texnik tahlilini taqdim etadi, jumladan ortiqcha issiqlik hosil bo'lishi, tok to'lqin shaklining buzilishi, kuchlanish haddan tashqari oshishi va quvvat omilining kamayishi. Amaliy sxemalar, jumladan LM317 asosidagi kuchlanishni tartibga solish va yorug'likni boshqarish sxemalari muhokama qilinadi, bu orqali keng tarqalgan qo'llanmalar va ularning garmoniklarga nisbatan zaifliklari yoritib beriladi. Tadqiqot natijalari shuni ko'rsatadiki, samarali garmoniklarni kamaytirish strategiyalari yoritish moslamalarining ishonchlilik, samaradorligi va ishlash muddatini sezilarli darajada oshirishi, natijada zamonaviy elektr infratuzilmasida umumiy quvvat sifatini yaxshilashi mumkin.

Kalit so'zlar: garmonik, yarimo'tkazgich, yoritish, elektr tizimlari, kuchlanish, chastota, rezistorlar, ishlash muddati, samaradorlik va harorat.

ВЛИЯНИЕ ГАРМОНИК НА СРОК СЛУЖБЫ ОСВЕТИТЕЛЬНЫХ ПРИБОРОВ

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Аннотация. В данной статье рассматривается значительное влияние гармоник на эффективность и срок службы осветительных приборов, с особым акцентом на системы, основанные на светодиодах (LED). Несмотря на высокую энергоэффективность и длительный срок эксплуатации, светодиоды подвержены различным электрическим и тепловым нагрузкам, возникающим из-за искажений гармоник в энергосистемах, что приводит к деградации ключевых полупроводниковых компонентов, таких как диоды и транзисторы. В исследовании представлен подробный технический анализ механизмов деградации, вызванных суммарным гармоническим искажением (THD), включая повышенное тепловыделение, искажение формы тока, перенапряжение и снижение коэффициента мощности. Рассматриваются практические схемные решения, включая регулировку напряжения на базе LM317 и схемы управления яркостью, что позволяет продемонстрировать как типичные применения, так и их уязвимости к гармоникам. Результаты подчеркивают, что эффективные стратегии подавления гармоник способны значительно повысить надежность, эффективность и срок службы осветительных устройств, тем самым улучшая общее качество электроэнергии в современной электрической инфраструктуре.

Ключевые слова: гармоника, полупроводник, освещение, электрические системы, напряжение, частота, резисторы, срок службы, эффективность и температура.

Introduction. We know that today lighting devices are a significant amount of electricity consumers. The reason for this is that today's lighting devices named LEDs, provide high illumination with low power consumption. And these indicators are available to users of lighting devices. Although today's lighting devices are much more efficient than their predecessors, they still have their drawbacks. As an example, we can cite below the factors that affect the life of lighting devices.

The problem to be solved and the statement of the issue. These are: the level of quality of devices used in lighting devices, the effect of higher harmonics, the certification of lighting devices, the rate of switching on and off, the level of user experience and the environment. Among the factors that affect the life of the above-mentioned lighting devices, the most important factor is harmonics. Harmonics in electrical systems refer to signals whose frequencies are integer multiples of the fundamental frequency. These unwanted distorted waveforms have frequencies higher than the fundamental frequency. Since electrical equipment is typically rated for either 50 Hz or 60 Hz (depending on the region), the presence of higher-frequency harmonics can degrade system performance. Harmonics can lead to increased system temperature, elevated neutral voltage, and reduced efficiency [1, 2].

Fig.1 illustrates a general understanding of higher harmonics. Here, the first, second and third harmonics are described. We can see that one period means one frequency. The third harmonic has 3 complete oscillations in one normal period.

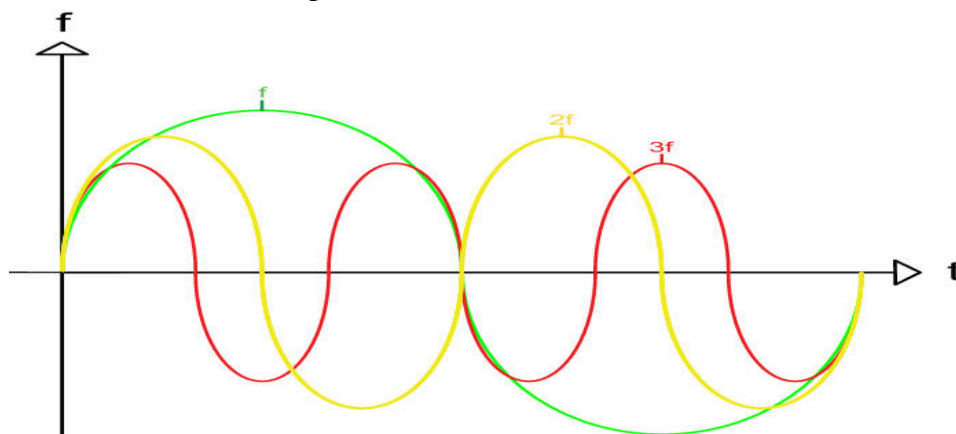


Fig1. Total harmonic distortion

Experiment and analysis of the results obtained. In order to know the effect of harmonics on lighting devices named LED, we need to have an understanding of the scheme of the LED, which is a lighting device, and the information about the electronic devices used in it. As an example, in Figure 2 we can see a scheme that allows you to control the light.

An LED Dimmer is a circuit designed to adjust the brightness of a light fixture. It achieves this by modifying the voltage waveform applied to the lamp or LED, which reduces the intensity of the light output. While variable-voltage devices serve many purposes, dimmers are specifically designed for controlling light output across various types of lighting, including resistive incandescent, halogen, compact fluorescent lights (CFLs), and light-emitting diodes (LEDs).

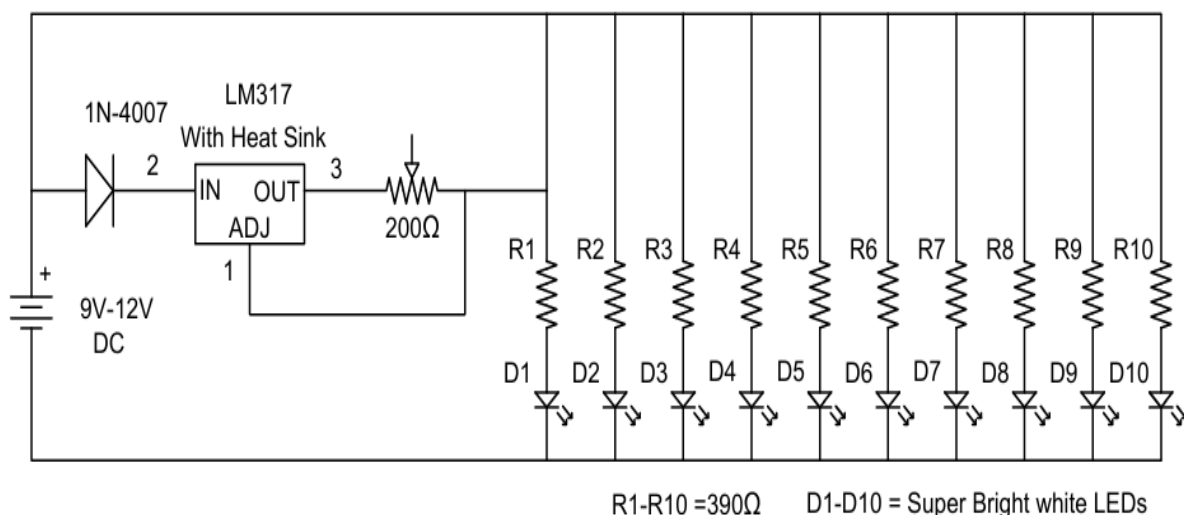


Figure 2. A scheme to control the light.

In scheme given above LM317T Regulator IC is used for making simple LED dimmer circuit. In this case, the LM317 is a three-terminal voltage regulator IC capable of delivering a high output current of up to 1.5A. It offers several key features, including current limiting, thermal protection, and safe operating area protection, ensuring reliable performance under various conditions. Additionally, it supports a floating operation for high-voltage applications. Even if the adjustable terminal is disconnected, the LM317 can still provide overload protection, making it a versatile and robust component for voltage regulation [3, 4].

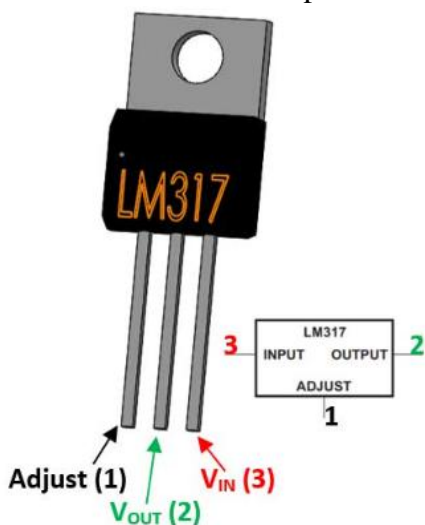


Fig 3. LM317 PINOUT

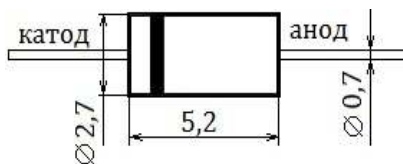


Fig 4. IN4007 diode.

In figure1 Pin1, Pin2and Pin3 as follows: Pin 1 - ADJUST: This pin is used to set or adjust the regulator's output voltage by connecting external resistors in the circuit.

The circuit uses the LM317 voltage regulator IC configured as a current regulator to control the brightness of LEDs. Since LEDs are current-driven devices, their brightness is adjusted by limiting the current passing through them. In this setup, the brightness of 10 super-bright white LEDs is adjusted using a 200 Ω potentiometer, which controls the current supplied to the LEDs. While the circuit supports 10 LEDs, more can be added if needed. To protect the LEDs from the maximum 1.5A output current of the LM317, each LED is paired with a separate current-limiting resistor. These resistors ensure that the LEDs operate safely without being overdriven, thereby extending their lifespan [5,6]

A widely used silicon rectifier diode, commonly found in power supplies of imported household appliances, is known for its versatility and reliability. Beyond rectification, this diode exhibits the ability to vary its capacitance with applied voltage, making it a suitable substitute for a varicap in radio equipment.

Application of the results obtained. Total Harmonic Distortion (THD) affects LEDs by introducing unwanted harmonic frequencies in the electrical supply, which leads to additional stress on the semiconductor diodes inside the LED lighting system. Here's a breakdown of how THD impacts the diode: First one is Increased heat generation. Total Harmonic Distortion (THD) leads to fluctuations in the current passing through the diode, causing irregular power delivery. These fluctuations result in excess heat being generated within the LED. The increased thermal stress on the diode accelerates material degradation, reducing the efficiency and lifespan of the LED.

Prolonged exposure to high THD levels can significantly shorten the diode's operational life and impact overall system performance. Second one is Voltage stress. Harmonics introduce voltage spikes and surges that can exceed the diode's rated voltage. These sudden voltage fluctuations cause electrical overstress on the semiconductor material, particularly at the PN junction of the diode. Repeated exposure to such voltage stress can damage the PN junction, resulting in premature failure, reduced performance, or permanent damage to the diode. This compromises the reliability and lifespan of the LED lighting system.

Third one is current distortion: LEDs rely on a stable current to function efficiently. However, Total Harmonic Distortion (THD) introduces distorted current, causing uneven current distribution through the diode. This irregular current flow can lead to inefficient operation, resulting in flickering, reduced light output, and lower overall performance. Prolonged exposure to distorted current increases the risk of overheating and accelerates wear on the LED, ultimately shortening its lifespan. Fourth one is EMI (Electromagnetic interference).

Higher levels of Total Harmonic Distortion (THD) contribute to increased electromagnetic interference (EMI) within the circuit. This interference can disrupt the stability of the semiconductor diode, causing erratic behavior such as flickering, irregular light output, or malfunction. The constant exposure to EMI can also degrade the diode's performance over time, reducing the reliability and longevity of the LED lighting system. Proper filtering and circuit design are essential to mitigate the effects of EMI and ensure stable LED operation. Fifth one is Reduced power factor. Total Harmonic Distortion (THD) decreases the power factor in the circuit by increasing the proportion of reactive power relative to real power. This forces the LED system to draw more apparent power from the supply. As a result, the diode must handle additional reactive power, leading to inefficient operation and greater electrical stress. The increased current demand also generates more heat, further contributing to reduced performance, higher energy consumption, and a shorter lifespan for the LED lighting system [6,7,8].

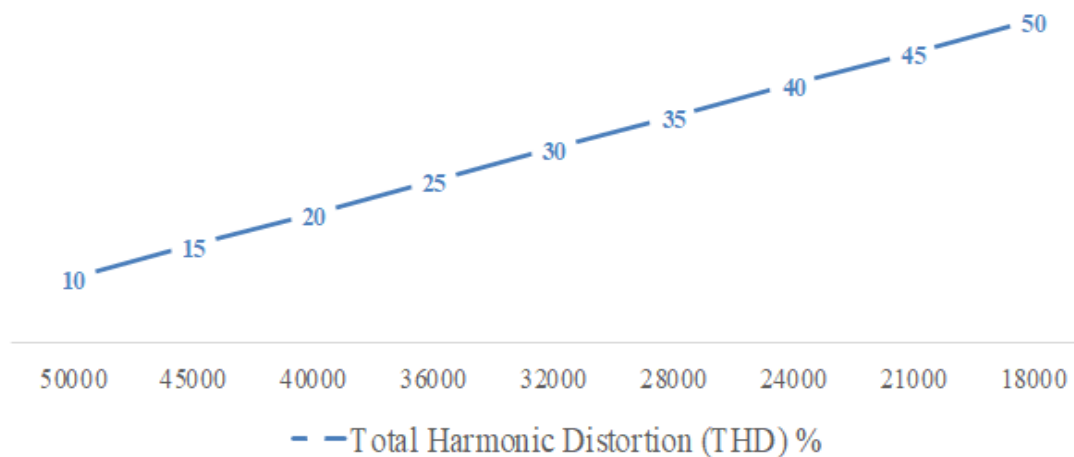


Fig 5. Impact of THD on diode's lifespan.

Fig 5 given above shows how THD impacts on lifespan of a diode for lighting devices while its number of amount changing step by step. In horizontal line lays lifespan of the transistor. As we see in fig 5 as THD's amount increase life span of the transistor decreases respectively.

Total Harmonic Distortion (THD) indirectly affects a transistor's lifespan by influencing operating conditions that may lead to stress or degradation over time. Here are the key mechanisms through which THD can impact the longevity of a transistor. They are thermal stress, overvoltage conditions, increased switching losses, electromagnetic interference (EMI), reduced efficiency, reactive power handling [9,10].

1. Total Harmonic Distortion (THD) introduces fluctuating current and voltage into the circuit, causing irregular power dissipation within the transistor. These fluctuations lead to increased heat generation and thermal cycling, where the temperature of the transistor repeatedly rises and falls. Over time, this thermal stress degrades the transistor's materials, such as its junctions and packaging, ultimately reducing its performance and shortening its lifespan.

2. Harmonics in the supply voltage can produce voltage spikes that surpass the transistor's safe operating limits. These overvoltage conditions place excessive electrical stress on the transistor's junctions. Repeated exposure to such spikes can weaken the junctions, leading to insulation breakdown or thermal runaway. Over time, this can cause irreversible damage to the transistor, resulting in failure and reduced reliability of the overall system.

3. Total Harmonic Distortion (THD) introduces high-frequency components into the circuit, which can effectively raise the switching frequency of transistors in systems like inverters or power supplies. This increased switching activity causes higher switching losses as more energy is dissipated during each transition between on and off states. The additional heat generated from these losses intensifies thermal stress on the transistor, accelerating wear and reducing its operational lifespan. Over time, this can degrade the transistor's efficiency and reliability.

4. Harmonics in the electrical system contribute to electromagnetic interference (EMI), which can disrupt the stable operation of transistors. This interference may cause erratic behavior, such as unintended switching or fluctuations in performance, leading to unpredictable electrical stress. Repeated exposure to such conditions can degrade the transistor's reliability, increase wear on its components, and raise the likelihood of premature failure. Proper filtering and shielding are essential to mitigate EMI and protect the transistor from its adverse effects.

5. Distorted current and voltage waveforms from Total Harmonic Distortion (THD) cause inefficiencies in energy conversion within the transistor. As the transistor compensates for the increased losses, it experiences higher electrical and thermal stress. This constant strain accelerates material degradation, leading to premature aging of the transistor. Over time, these effects reduce the component's efficiency, reliability, and operational lifespan, especially in power electronics applications.

6. In systems with significant Total Harmonic Distortion (THD), transistors are often required to handle additional reactive power. This added burden increases the electrical and thermal stress on the device, particularly in power electronics applications. The extra reactive power causes higher current flow and additional switching activity, leading to increased heat generation and accelerated wear of the transistor's components. Over time, this continuous stress reduces the device's efficiency and shortens its operational lifespan [11,12,13].

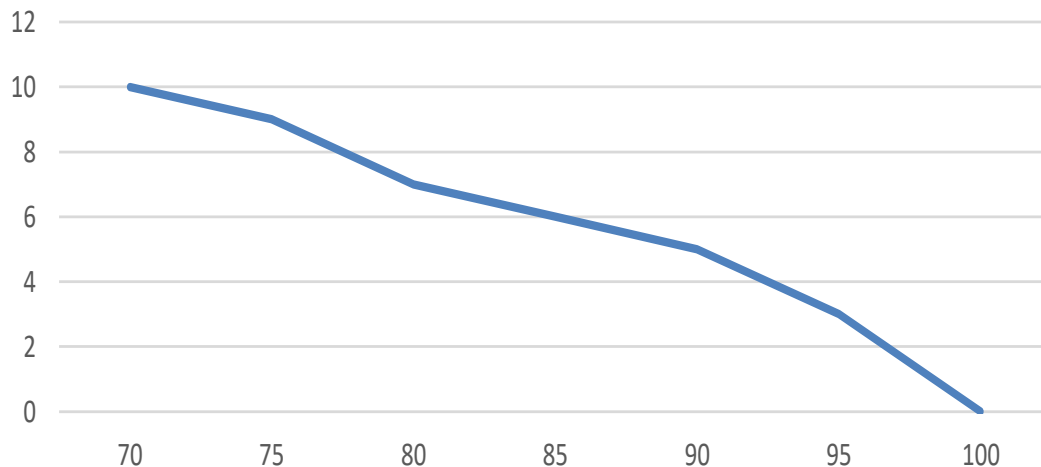


Fig 6. Connection between THD and lifespan of the transistor.

The graph demonstrates a hypothetical inverse relationship between Total Harmonic Distortion (THD) and a transistor's lifespan. As THD levels rise, the lifespan of the transistor steadily declines. To be more clear we can say that the curve likely illustrates a nonlinear relationship, where small increases in THD initially cause a moderate reduction in lifespan, but as THD continues to rise, the impact becomes more pronounced, leading to a steep drop in longevity. This highlights the importance of minimizing THD to preserve the performance and durability of transistors in electrical systems.

Conclusion. The influence of harmonics on parts of lighting devices was considered above. In this, the effect of higher harmonics on transistor and diode was studied. The results showed that as the amount of harmonics increases, the lifetime of lighting devices decreases accordingly. From this we can see that we can indirectly affect the voltage by reducing the effect of harmonics. By doing this, the voltage can be improved. Normal voltage has a positive effect on the life of the lighting device.

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