14th Annual International Conference on Industrial Engineering and Operations Management
Dubai, United Arab Emirates (UAE), February 12-14, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/AN14.20240180
Published: February 12, 2024

Illuminating Efficiency: A Deep Dive into the Performance and Characteristics of 9W LED Illuminator

Fakir Sheik Zihad
Manager (Product Development), Super Star Group
Engineer, Master's in Industrial Engineering
Lamar University
Beaumont, Texas, USA
zihadsheik@gmail.com

Asif Mohammad Mithu
Graduate Research Assistant at Biomedical Signals, Systems and Analysis Laboratory
Ph.D. in Electrical Engineering
Villanova University
Villanova, Pennsylvania, USA.
asif.mithu@gmail.com

Mehrab Masayeed Habib
Engineer, Master's in Electrical Engineering
Lamar University
Beaumont, Texas, USA
mehrabh@gmail.com

Mrinmoy Sen
Manager (Product Development), Super Star Group
Engineer, BSc. In Mechanical Engineering
Rajshahi University of Engineering & Technology
Rajshahi, Bangladesh
mrinmoyxyz@gmail.com

Md. Yasin Arafat
Engineer, Master's in Industrial Engineering
Lamar University
Beaumont, Texas, USA
arafatmdyasin123@gmail.com

Abstract

This paper elucidates the multifaceted capabilities of the 9-Watt LED illuminator, a paradigm of technological sophistication in the lighting industry. Combining advanced LED technology, precision engineering, and eco-conscious design, these compact yet powerful luminaries offer luminous efficacy that surpasses their incandescent and CFL counterparts. The 9W LED illuminator not only exhibits a marked reduction in energy consumption but also boasts a longevity exceeding 25,000 hours, thus contributing to a smaller carbon footprint and a sustainable future. Additionally, these LED lights exhibit versatility, adaptable to various settings, and offering a range of light tones for tailored ambiances. The paper further explores their driver circuit performance, chromaticity characteristics, safety aspects, and heat management. Ultimately, the 9W LED bulb is presented as more than just a product of advanced technology; it is a symbol of our collective dedication to sustainability and a beacon of progress in the lighting industry.

Keywords
Photometric Characteristics, Sustainable Lighting Solution, Residential Lighting, Illuminator, LED Driver CKT

1. Introduction
In the world of illumination, where brightness meets energy efficiency, 9-Watt LED bulbs stand as a remarkable embodiment of technology's ability to deliver practical, sustainable solutions. As we traverse through the journey of enlightenment, these luminous wonders radiate far more than just light; they illuminate the path towards a greener, more sustainable future.

The 9W LED bulb has carved its own niche in the lighting industry, setting new benchmarks for performance and characteristics that extend well beyond its humble size. As a testament to innovation, it masterfully combines precision engineering, advanced LED technology, and environmentally-conscious design principles. This trifecta of elements enables the 9W LED bulb to provide exceptional luminosity, extended lifespan, and energy efficiency that outperforms traditional incandescent and CFL counterparts. Capable of delivering lumens comparable to a 60-Watt incandescent bulb, a 9W LED bulb, quite impressively, operates on a fraction of the energy, demonstrating how size isn't necessarily synonymous with power. From its compact form factor emerges a luminous efficacy that paints every corner of a room in high-quality, comfortable light, without the excess energy consumption or heat output traditionally associated with incandescent bulbs. [McAuliffe, M., 2016] Moreover, the 9W LED bulb's superior lifespan, often exceeding 25,000 hours, positions it as a beacon of sustainability. This longevity not only reduces frequent bulb replacements but also minimizes waste, thereby contributing to a smaller carbon footprint. [Voet E, 1999 & Kumar S., Gupta S., Auddy A., Bose A., Chakraborty A, Ganguly R., 2016] Characterized by versatility, the 9W LED bulb fits in various settings - from homes and offices to commercial establishments, casting an adaptable light that caters to an array of lighting needs. Additionally, with options ranging from warm to cool white light, it provides tailored ambiances that suit every mood, task, or setting.

1.1 Objectives
This research aims to convey the superior performance and environmental benefits of the 9W LED illuminator. They discuss its energy efficiency, longevity, and low carbon footprint, comparing it favorably with incandescent and CFL bulbs. The paper also delves into specific aspects like driver circuit performance, chromaticity characteristics, safety, and heat management, highlighting the LED's versatility and adaptability. The overarching theme is the LED's role in sustainable lighting solutions, emphasizing its technological advancement and contribution to a greener future.

In our comparisons between various lighting technologies, we have found an interesting correlation in power usage and output. A 9-watt LED bulb, for instance, has demonstrated an equivalent light output to that of a 15-watt Compact Fluorescent Lamp (CFL) and a 75-watt General Lighting Service (GLS) incandescent bulb. This comparison illuminates the remarkable energy efficiency of LED technology. Despite consuming less power, the 9W LED bulb generates a level of brightness comparable to its higher wattage counterparts. In other words, it is capable of producing the same amount of light as a 15W CFL bulb and a 75W GLS bulb, while consuming substantially less energy. Compared to Compact Fluorescent Lamps (CFLs), LEDs cut energy consumption by approximately 50%. This translates to halving the energy bill for lighting when switching from CFLs to LEDs, making LEDs the smart choice for those mindful of both their budgets and environmental footprints.

The efficiency of LEDs extends beyond the bulb itself. The driver circuit, an essential component that regulates the power supply to the LED, boasts an impressive efficiency of over 90%. On the other hand, the driver circuit efficiency for CFLs lags behind, clocking in at around 80%. The superior efficiency of the LED driver circuit ensures that most of the energy is utilized to produce light, rather than being wasted as heat. The use of LED provides a 41-50% reduction in mercury emissions, mainly due to a reduction in electricity consumption [Principi P. and Fioretti R,2014].

In terms of lifespan, LEDs continue to outshine CFLs. On average, an LED bulb can last for about 30,000 hours. In contrast, the lifespan of a CFL is only around 10,000 hours. This extended life of LEDs means fewer bulb replacements, resulting in additional cost savings and reduced environmental impact over time (Figure 1).

- LED :

Efficacy : 100105Lm/W

Savings: ≡ 50% than CFL
≡ 89% than GLS

- **CFL :**

Efficacy: 60-65Lm/W

- **GLS:**

Efficacy:10-13Lm/W

Figure 1. LED

The 9W LED illuminator is widely used in various settings due to its versatile nature, energy efficiency, and superior performance characteristics. Here are the key areas of application:

Residential Lighting: In homes, the 9W LED illuminator is ideal for general lighting purposes due to its ability to produce a high-quality, comfortable light. Its range from warm to cool white light allows it to suit different moods and settings within a household.

Office Spaces: The illuminator's capability to provide clear, bright light makes it suitable for office environments where good illumination is essential for productivity.

Commercial Establishments: In commercial settings such as retail stores, restaurants, and hotels, the 9W LED illuminator's adaptability and energy efficiency make it a popular choice. It can create various ambiances while minimizing energy consumption and heat output.

Public Spaces and Outdoor Areas: The long lifespan and durability of the 9W LED illuminator make it suitable for lighting in public areas and outdoor environments, contributing to safety and visibility.

Industrial Applications: In industrial settings, the 9W LED illuminator's reliability and efficiency are valuable for consistent and cost-effective lighting solutions.

Finally, LED bulbs offer significant environmental advantages over CFLs. Specifically, LED bulbs do not contain mercury, a harmful substance present in CFLs. Mercury can be toxic to both humans and wildlife, and it poses disposal challenges. The absence of mercury in LEDs eliminates this risk, making them a safer choice for your home and the environment (Figure 2).

Figure 2. Driver circuit, LED chip and Bulb body

All things considered, the choice of LEDs over CFLs is clear. With superior energy efficiency, longer lifespan, and environmental safety, LED bulbs are not just the future of lighting – they are the present. Make the switch to LEDs and experience the difference for yourself. This LED lighting creates a safe environment and requires very less operational maintenance too [Prasad R.,2020].

Choosing Proper Led Chips

The choice of LED chip voltage can greatly influence both the performance and the complexity of LED light systems. Among the different available options, the 9V LED chip holds a distinctive position, offering several unique benefits compared to its 6V and 3V counterparts.
Firstly, a standout advantage of 9V LED chips is their suitability for series connections. The higher voltage inherent in these chips means fewer are needed to achieve a particular voltage level, thereby streamlining the circuit's design. It offers a more straightforward approach to achieve the desired illumination.

In situations where the available power supply is rated at 9V, choosing a 9V LED chip is a perfect match. This compatibility eliminates the need for conversion circuitry, reducing complexity and potential points of failure in your lighting system.

Moreover, the 9V LED chips shine when it comes to energy efficiency. When embedded in systems designed to cater to their higher voltage, these chips often need fewer power conversions. This is critical as each conversion step can introduce inefficiencies, leading to energy losses.

Heat management is another domain where 9V LED chips have an edge. By virtue of Ohm's Law, which states that power equals voltage times current, these chips, with their higher voltage, require less current for a given power level. This reduction in current can lead to decreased heat generation, which in turn might extend the chip's lifespan.

Lastly, in terms of protection, 9V LED chips can demonstrate more robustness. Lower voltage chips may require additional safeguarding against voltage spikes, while a 9V chip inherently resists minor voltage surges, offering a degree of self-protection.

In our recent findings, we examined a unique LED chip that presents compelling characteristics, showing potential for a variety of applications. Our investigations revolved around the chip's physical parameters and operational limitations.

The power dissipation of the chip is rated at 500 mW, which reflects the amount of power the chip can handle without overheating or experiencing detrimental effects. This value is especially significant given the correlation between LED performance and heat management. Our chip also demonstrated a forward current (IF) of 60 mA, the electrical current passing through the LED during regular operation. Remarkably, its peak forward current (IFP), which is the highest amount of current the chip can withstand in short bursts, was measured at 150 mA. The operating temperature range for this chip spans from -20 to +85 degrees Celsius, a broad range which ensures its functionality under varying environmental conditions. Its storage temperature range is even more extensive, from -40 to +100 degrees Celsius, indicating robustness in fluctuating storage conditions. The chip can withstand soldering temperatures up to 260±5 degrees Celsius, which provides versatility during the manufacturing process and allows for application in different electronic systems. Moreover, the junction temperature, the maximum temperature the semiconductor in the LED chip can handle, stands at 115 degrees Celsius. Our findings also shed light on the chip's thermal resistance, with a measurement of 20 degrees Celsius per Watt. This value reflects how efficiently the chip can dissipate heat into its surroundings. Reverse voltage, the maximum voltage the chip can endure in the opposite direction to standard current flow, was found to be 15V. This information is critical for safeguarding the chip against voltage surges and spikes.
Finally, our chip has proven robust against electrostatic discharge (ESD), surviving up to 1000V under the Human Body Model (HBM). This trait is vital for any electronic component, as ESD can pose a significant risk to performance and lifespan.

2. Methods

First and foremost, abiding by these standards ensures that your LED lamps meet the global criteria for safety and performance. This provides a level playing field in the international market, where your products will be competing with others that also comply with these standards. By ensuring your LEDs meet these criteria, you signal to your customers that your products are trustworthy and high-quality.

The IEC 62612:2015 standard sets out the performance requirements for LED lamps, including metrics such as luminous flux, power consumption, lifetime, and color properties. It is an essential benchmark for the efficiency and longevity of LED lamps, and compliance with it ensures that your products deliver on their promises.

Similarly, the IEC 62560:2015 standard specifies the safety specifications for LED lamps for general lighting services. Compliance with this standard ensures that your LED lamps are safe for consumer use, thus reducing the risk of product liability issues and bolstering your brand's reputation.
Moreover, following these standards could potentially lead to lower product returns and increased customer satisfaction. If a product consistently meets or exceeds its advertised specifications, customers are more likely to be satisfied with their purchase, leading to positive reviews and word-of-mouth recommendations.

Lastly, adhering to these standards may also be a requirement for certain certifications or for selling your products in certain markets. In this case, compliance is not just a good idea – it's a necessity for your business.

3. Driver CKT Performance

The data set provided represents a set of measurements taken from five samples of a power device or system. The extensive analysis of the 9W LED Bulb across various parameters including Driver Circuit Characteristics, Photometric Characteristics, Total Harmonics Distortion, and other physical findings has presented a comprehensive view of its performance and compliance.

Driver Circuit Characteristics: The investigation into the input and output characteristics, efficiency, and operating voltage confirmed the samples' compliance with the required values. Each attribute, including current, power factor (PF), power, voltage, forward and total current, and efficiency, met or exceeded the specified parameters, demonstrating a consistent performance across all samples.

Photometric Characteristics: The study showcased a high level of compliance in aspects such as current, power, lumen, efficacy, color rendering (Ra), spatial chromaticity deviation (SDCM), and beam angle. The consistency across these elements confirms the quality of the 9W LED Bulb in delivering precise luminance and color reproduction.

Total Harmonics Distortion: The PF and VTHD (Voltage Total Harmonics Distortion) exhibited full compliance with the required values. However, the ITHD (Current Total Harmonics Distortion) recorded values slightly above the required limit, indicating an area that may require further optimization or investigation.

Physical and Thermal Characteristics: Additional examinations regarding LED chip specifications, dimensions, materials, and thermal performance reaffirmed the product's compliance, substantiating its robust design and material quality.

3.1 Electrical Test

From the table 1, we have seen two input and output section are divided, where the first parameter, Input Current, appears to be within the required range of 70-86 mA for all five samples, with an average value of 70.4 mA, indicating that the device consistently draws a similar level of current.

The Power Factor (PF), a unitless ratio, is also consistent across all five samples, showing an average value of 0.542. This is above the requirement of ≥0.5, indicating the device successfully converts a considerable portion of the input power into useful output power.

Table 1. Driver CKT Test Results

	Parameters	Unit	Required Value	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Remarks
Input	Current	mA	70-86	70	71	71	70	70	70.4	Comply
	PF	-	≥ 0.5	0.542	0.545	0.542	0.541	0.542	0.542	Comply
	Power	Watt	9 ± 10%	8.83	9.04	9.00	8,85	8.92	8.92	Comply
Output	Voltage	Volt	≤ 99	95.6	95.6	95	95.7	95.5	95.5	Comply
	Total Current	mA	≥ 74	83	85	86	84	84.2	84.2	Comply
	Power	Watt	≥ 7.29	8.02	8.22	8.2	8.06	8.11	8.11	Comply
	Efficiency	%	≥ 90	91%	91%	91%	91%	91%	91%	Comply

The Input Power across all five samples falls within the specified range of 9 ± 10% Watts, with an average value of 8.92 Watts. This suggests that the device operates as intended and remains within the desired power consumption limits.

In table 1, all the output parameters are categorized into a total of four sections voltage, total current, output power, and efficiency respectively. In terms of output parameters, the Voltage is below the maximum threshold of 99 Volts in all samples, averaging at 95.5 Volts. This is well within the safety limits set.

The Total Output Current meets the requirement of being ≥ 74 mA, with all samples exceeding this figure and averaging at 84.2 mA. This indicates that the device can provide the necessary current for its expected output performance.

The Output Power also meets the requirement, with the values of all samples ≥ 7.29 Watts, averaging at 8.11 Watts. This shows that the device is capable of delivering the necessary power output.

The Efficiency of the device is excellent, with all samples showing 91% efficiency. This greatly exceeds the requirement of ≥90%, meaning that the device is highly efficient in converting input power to output power.

Lastly, the Operating Voltage range for the device is 90V to 300V, which allows for flexible operation under various electrical conditions.

3.2 Photometric Characteristics Test

Table 2. Photometric Characteristics of a 9W LED Illuminator Performance Data

Parameters	Unit	Required Value	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Avg.	Remarks
Current	mA	70 - 86	71	73	73	71	71	72	Comply
Power	Watt	9 ± 10%	9.05	9.24	9.37	8.95	9.00	9.12	Comply
Lumen	Lm	900 ± 10%	936.3	935.4	955.2	908	921.7	931.32	Comply
Efficacy	Lm/W	≥ 100	103.5	101.3	102.0	101.5	102.4	102.1	Comply
Ra	%	≥ 80	83.3	82.8	82.8	83.5	83.0	83.1	Comply
SDCM	-	≤ 5	1.70	2.20	3	1.4	2.4	2.14	Comply
Beam Angle	°	200 ± 25%	183.70	184.00	181.9	180.0	180.8	182.08	Comply

As seen in table 2, the data set we have here illustrated the photometric characteristics of a 9W LED bulb according to IEC Standard 62612:2015 & IEC 62560:2015. These parameters include Current, Power, Lumen, Efficacy, Ra (Color Rendering Index), SDCM (Standard Deviation of Color Matching), and Beam Angle.

Initially, the Current parameter for all five samples falls within the desired range of 70-86 mA, with an average value of 72 mA. This demonstrates a consistent electrical performance, validating the bulb's compliance with its designated specifications.

The Power usage of the bulb is around 9 Watts for all samples, varying within the allowed ± 10% tolerance range, and averaging at 9.12 Watts. This indicates a consistent power consumption rate across all bulbs, adhering to the power usage requirements.

In terms of light output, the Lumen value, a measure of the total amount of visible light emitted by a source, is well within the expected range of 900 ± 10% Lumens, with an average value of 931.32 Lumens. This confirms that the light output of the bulbs is in line with expectations.

The Efficacy of the bulb, measured in Lumens per Watt, is greater than the required value of 100 Lm/W for all samples, with an average of 102.1 Lm/W. This excellent efficacy denotes a high efficiency of light production per unit of power consumed.
The bulbs also comply with the Ra (Color Rendering Index) requirements, with all samples displaying values greater than the specified 80%, and an average value of 83.1%. This means that the bulbs are capable of reproducing colors faithfully compared to a natural light source.

In terms of color consistency, the Standard Deviation of Color Matching (SDCM) is less than or equal to 5 for all samples, with an average of 2.14. This means that color differences between the different bulb samples are minimal, and within the acceptable limit.

Finally, the Beam Angle, which indicates the spread of light from the light source, is within the acceptable range of 200 ±25%, averaging at 182.08 degrees across all samples. This suggests that the light is well-distributed and falls within the expected area.

In conclusion, the data clearly shows that the 9W LED bulb meets or exceeds all the specified requirements, demonstrating high performance, efficacy, color accuracy, and consistency in light distribution.

3.3 Chromaticity Performance

Table 3. Chromaticity Performance of 9W LED Illuminator

Sl No.	Parameters	Standard	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Avg.	Remarks
1	CCT	6500±500k	6356	6302	6444	6476	6307	6377	Comply
2	X-Axis Coordinates	0.3-0.32	0.314	0.315	0.312	0.312	0.314	0.314	Comply
3	Y-Axis Coordinates	0.33-0.35	0.340	0.341	0.341	0.338	0.340	0.340	Comply

Table 3 illustrates, chromaticity tolerance test for a light-emitting source, likely an LED bulb. The parameters analyzed are CCT (Correlated Color Temperature), and X & Y Axis Coordinates, which represent the chromaticity coordinates of the light source in the CIE 1931 color space.

The row of the table revealed a Correlated Color Temperature (CCT), which refers to the color appearance of the light emitted by the bulb, is within the desired range of 6500 ± 500K for all samples, with an average CCT of 6377K. This suggests that the light source produces a color temperature close to daylight conditions, meeting the requirements.

Following the first row, the X-Axis Coordinates, which together with the Y-Axis Coordinates help in defining the color of the light source, fall within the given range of 0.3 - 0.32. The average across the samples is 0.314, indicating consistency in the color representation along the X-axis.

Similarly, third row, in the Y-Axis Coordinates, another aspect of color representation, are within the expected range of 0.33 - 0.35. The average of the Y-coordinates across all samples is 0.340, further reinforcing the consistency of color representation in the tested light source.

It is crucial to note that X and Y coordinates represent a point in the chromaticity diagram (a 2D representation of color) and can be used to describe the color of the light source. When the X and Y coordinates consistently fall within the specified range, as in this case, it signifies that the chromaticity or quality of color of the light source is in line with the specified requirements (Figure 3).

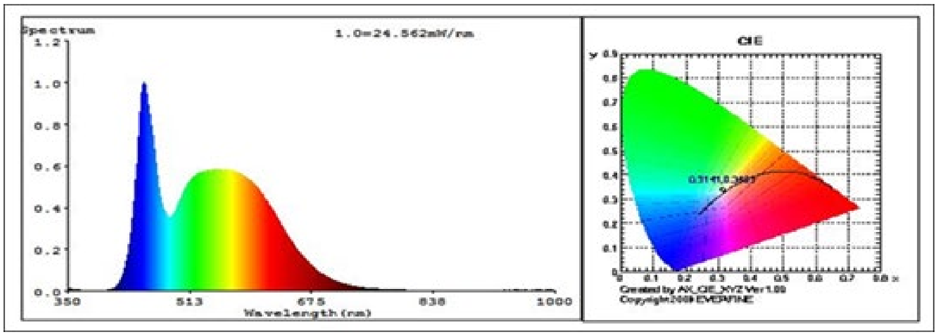

Figure 3. Chromaticity performance in Graph

3.4 Total Harmonics Distortion (THD) test:

Table 4. THD Performance

Sl No.	Parameters	Unit	Required Value	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	Remarks
1	PF	-	≥ 0.5	0.550	0.550	0.550	0.545	0.547	0.549	Comply
2	VTHD	%	< 3	0.3	0.3	0.3	0.3	0.3	0.3	Comply
3	ITHD	%	≤ 135	145.9	145.0	143.1	148.2	146.2	145.68	Not Comply

From the table 4, we have seen different parameters under THD, where the data set provided refer to a Total Harmonics Distortion (THD) test. The parameters under scrutiny are PF (Power Factor), VTHD (Voltage Total Harmonic Distortion), and ITHD (Current Total Harmonic Distortion).

Starting with the Power Factor (PF) in row one, all five samples meet the requirement of being ≥0.5, with an average value of 0.549. This indicates that the device or system under test is fairly efficient at converting input power into usable output power.

The Voltage Total Harmonic Distortion (VTHD) mentioned in row two, a measure of distortion in the voltage waveform due to harmonics, is less than the requirement of 3% for all samples, with an average value of 0.3%. This low percentage indicates that the voltage waveform is relatively free of harmonic distortion, indicating that the power supply or device under test has a low influence on the distortion of the voltage waveform.

Moreover, we observed at the Current Total Harmonic Distortion (ITHD) in the third row, a measure of distortion in the current waveform, we have seen that all samples do not meet the requirement of being ≤135%. With an average value of 145.68%, this is an indication that the current waveform contains a significant amount of harmonic distortion. The effect of this could range from overheating in conductors to malfunctions in some types of equipment, and it may also indicate a high level of inefficiency in the device under test [Abbas M. H,2000].

To sum up, the data indicates that the device under test meets the requirements for Power Factor and Voltage Total Harmonic Distortion. However, it fails to comply with the Current Total Harmonic Distortion requirement, indicating that there may be a significant amount of distortion in the current waveform. This suggests that there may be an issue that needs to be addressed to improve the efficiency and reliability of the device under test (Figure 4).

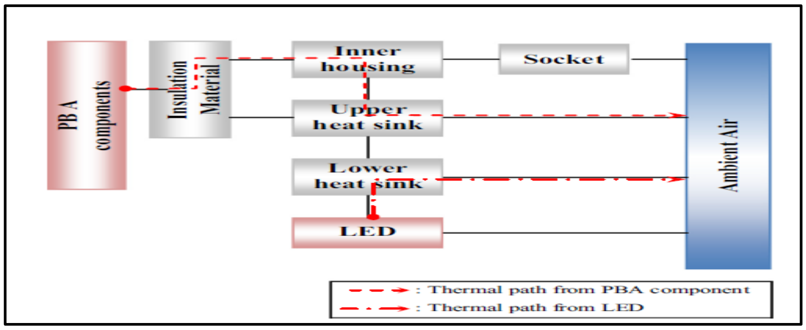

Figure 4. Thermal resistance diagram of LED lamp. [Park D. H., Lee D. B., Seo E. R., and Park Y. J.,2016]

One additional information to add that cellar structures are considered to be very effective in heat transfer augmentation and weight reduction in natural convective applications [Yang K.-S., Chung C-H., Lee M-T., Chiang S-B., Wong C-C. and Wang C-C.,2013].

4. Proposed Improvements / Validation

The provided data for 9W LED Bulb illustrates an impressive alignment with most of the required specifications. Key parameters like current, power, efficiency, and voltage show consistent compliance across all samples. However, a significant observation is the non-compliance in the ITHD parameter under the Total Harmonics Distortion section, which could be an area of concern.

The key aspects they emphasize are:
Energy Efficiency and Sustainability: The 9W LED illuminator is presented as a more energy-efficient alternative, with a significantly longer lifespan than traditional bulbs, contributing to a smaller carbon footprint and promoting sustainability.

Advanced Technology and Performance: The paper underscores the use of advanced LED technology and precision engineering in the 9W LED bulb, which allows it to deliver high luminous efficacy, versatility in various settings, and a range of light tones for different ambiances.

Environmental Considerations: A notable aspect is the environmental safety of LED bulbs, particularly their lack of mercury, which is a toxic component in CFLs. This positions LEDs as a safer and eco-friendlier option.

Driver Circuit Efficiency and Longevity: The efficiency of the LED driver circuit is highlighted, which plays a critical role in energy utilization and heat management, contributing to the overall efficiency and longevity of the bulb .

Compliance and Areas for Improvement: The paper also acknowledges the alignment of the 9W LED illuminator with most industry standards and specifications, while pointing out areas for improvement, such as non-compliance in the ITHD parameter under the Total Harmonics Distortion section. This suggests a potential for further research and development to enhance the efficiency and reliability of the device.

In terms of contributing to academic literature, the research fills a gap by providing a comprehensive analysis of the performance and characteristics of the 9W LED illuminator emphasizing its technological sophistication and environmental benefits. The study also identifies specific areas for improvement, indicating ongoing research opportunities in the field of LED technology to achieve higher standards of efficiency and reliability.

5. Conclusion

The physical findings provide insight into the quality of materials and components used, reflecting good standards in the design. Details related to LED Chip, Driver Circuit, Dimension, Body, Heat Sink, Diffuser Type, and LED Identification appear to be descriptive in nature and meet expected criteria.

Overall, the samples exhibit strong compliance with industry standards.

In conclusion, the 9W LED Bulb has exhibited an exemplary performance across most parameters, aligning with industry standards and requirements. The rigorous testing emphasizes the product's reliability and efficiency, supporting its suitability for various applications. The minor discrepancy observed in the ITHD parameter offers an opportunity for further refinement, ensuring an even higher level of quality and compliance. The collective findings contribute valuable insights to the field of LED technology, illuminating the path towards sustainable and high-performing lighting solutions.

References

Abbas M. H., Total harmonic distortion analysis simulation, PowerCon 2000. 2000 International Conference on Power System Technology. Proceedings (Cat. No.00EX409), Perth, WA, Australia, 04-07 December, 2000, doi:10.1109/icpst.2000.898218

Kumar S., Gupta S., Auddy A., Bose A., Chakraborty A, Ganguly R., Comparative description on the workings of high-power PC leds and its useful life under tropical conditions, *2016 IEEE 7th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON*), Vancouver, BC, Canada, 13-15 October, 2016*,* DOI: 10.1109/IEMCON.2016.7746369

McAuliffe, M., The Perception of Light: Understanding architectural Lighting Design, 1st Edition, Oxford Global Press, 2016

Principi P. and Fioretti R., A comparative life cycle assessment of luminaires for general lighting for the office – compact fluorescent (CFL) vs Light Emitting Diode (LED) – A case study, Journal of Cleaner Production, vol. 83, pp. 96–107, 2014, https://doi.org/10.1016/j.jclepro.2014.07.031

Park D. H., Lee D. B., Seo E. R., and Park Y. J., A parametric study on heat dissipation from a LED-lamp, *Applied Thermal Engineering*, vol. 108, pp. 1261–1267, 2016, https://doi.org/10.1016/j.applthermaleng.2016.08.032

Prasad R., Energy efficient smart street lighting system in Nagpur Smart city using IOT-A case study, 2020 5th International Conference on Fog and Mobile Edge Computing (FMEC), Paris, France, 20-23 April, 2020, doi:10.1109/fmec49853.2020.9144848

Voet E., Books: Our ecological footprint: Reducing human impact on the Earth, *Journal of Industrial Ecology*, vol. 3, no. 2–3, pp. 185–187, 1999, https://doi.org/10.1162/jiec.1999.3.2-3.185

Yang K.-S., Chung C-H., Lee M-T., Chiang S-B., Wong C-C. and Wang C-C., An experimental study on the heat dissipation of LED lighting module using metal/carbon foam, International Communications in Heat and Mass Transfer, vol. 48, pp. 73–79, 2013, https://doi.org/10.1016/j.icheatmasstransfer.2013.08.022

Biographies

Fakir Sheik Zihad is a impassioned technophile and business strategist, who thrive in organizations that value contribution and innovation. His educational background coupled with two international certifications, Lean Six Sigma & CSPO, and Project Management training ensures a high value-addition to project/product operations. Seasoned Operations professional boasting over 9 years of experience in LED and electronics industries, primarily in the areas of Sourcing, R&D, and Quality Control. Renowned for leading major projects in LED bulb, tube, and panel light production at Energypac Electronics, Walton & Super Star Group, conducting thorough QC audits, and designing standard operating procedures for testing lab machinery. Offer strong acumen in delivering internal employee training and coaching in areas like TQM, 5S, ISO9001:2015, TPM, Time Management, and Team Building, with a proven track record in Walton, SSG & Energypac. Also experienced in international business tours for LED and Switch Sockets' supplier sourcing, PSI, and Mold Inspection. He is also specialized in Lab Management Standards (ISO17025:2017) and Quality Standards (ISO9001:2015), playing key roles in maintaining ISO Audits, overseeing machine installation, maintenance, and calibration, and implementing TQM, KaiZen, and 5S strategies. Further expertise lies in PLC, LED lighting technology, and product knowledge training to boost retail sales market growth.

Asif Mohammad Mithu is a Graduate Research Assistant at Biomedical Signals, Systems and Analysis (Bio-SSA) Laboratory and currently doing a Ph.D. in Electrical Engineering at Villanova University, Villanova, Pennsylvania, USA. Before embarking on his Ph.D. journey, Mr. Asif achieved an MES in Electrical Engineering from Lamar University, Texas, USA, following his B.S. in Electrical and Electronic Engineering from Independent University, Bangladesh. Mr. Asif also pursued a Master's in Development Studies (MDS) from University of Dhaka, Bangladesh. He has shown his research excellency in numerous research projects and wrote few publications Biomedical, Signal Processing, and Biosensor, and EEG signal analysis on human color perceptions. He also completed projects in robotics, PLC, and HMI for industrial automation and Electric Vehicle. His research interests focused on brain imaging for cognitive activity and physiological monitoring using optical methods. He has been using EEG, fNIRS, modalities for his in cognitive neuroscience, signal processing, neural networks. Apart from these domains, he is also interested in social and environmental sustainability, showcasing his holistic approach to both engineering and societal well-being.

Mehrab Masayeed Habib is currently doing MEng in Electrical Engineering at Lamar University, Beaumont, Texas. Previously, he finished his BSc in Electrical and Electronics Engineering at American International University – Bangladesh (AIUB). His research interests include ADAS, Vehicle Safety and Electric Vehicle. He has published two research papers on automated anti-collision systems for automotive. He founded Bangla Automobile Skills in 2013, an eLearning platform that provides online courses on Automotive Engineering and related topics. He also authored a book on Automotive Engineering in the Bangla Language which is supposed to be the first book of its kind published by a private initiative.

Mrinmoy Sen is a distinguished professional in the field of mechanical engineering and product Design, has made significant contributions to the development and manufacturing of innovative products. With a focus on rigorous R&D, he has successfully transformed conceptual designs into tangible manufacturing outputs, backed by thorough feasibility studies. He is also skilled in the installation and support of various heavy-duty machinery, including Injection molding, Power Press, GT Router, High-Pressure Die-casting machines, and CNC machinery. His proficiency extends to ensuring accurate machine installation, developing effective SOPs, TQM, SCM, and conducting selection tests. Internationally, he is engaged in correspondence regarding raw materials, machine tools, accessories, and sourcing of design and mechanical components. His specialization includes project cost optimization, heavy-duty machinery troubleshooting, and operation, as well as expertise in design software such as AutoCAD, SolidWorks, NX, and Solid CAM. His knowledge of plastic materials and metal sheets, along with plastic molds and metal dies, is extensive. His areas of expertise include project planning, execution, schedule management, resource management, team management, cost management, operation management, risk management, product development, change management, and process development and improvement.

Md.Yasin Arafat is currently pursuing a Master of Science degree in Industrial Engineering at Lamar University. He obtained his Bachelor of Science degree in Electrical and Electronic Engineering (EEE) from American International University-Bangladesh (AIUB) in 2017. With several years of experience in the Power and Energy sector and the manufacturing field, Md. Yasin Arafat has developed a strong foundation in these areas. His research interests primarily revolve around cutting-edge technologies such as Industry 4.0, Automation Robotics, Embedded Systems, and Additive Manufacturing. With a keen focus on these emerging fields, he aims to contribute to the advancement and implementation of these technologies in various industries. As a highly motivated individual, Md. Yasin Arafat is committed to conducting research that addresses real-world challenges and enhances productivity and efficiency in industrial processes.