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Design & Implementation of LED Driver for Illumination and Visual Light Positioning

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Abstract: In this paper design of LED driver is proposed which can be used for both Illumination and Visual Light Positioning (VLP). The LED current is modulated to transmit a unique code devised in the driver circuit through free optical space and is received using photodiode based receiver circuit. The detailed modelling and simulation of proposed LED Driver is presented in this paper. The transmission and receiving of the signal is experimentally evaluated and presented in this paper.
Keywords: Visual Light Positioning, Light Emitting Diode, On-Off Keying, Variable pulse position modulation.

I. INTRODUCTION

High Brightness white Light Emitting Diode (LED) are used extensively as a source of illumination in commercial and industrial environments. The use of LED lighting can also serve the purpose of smart lighting and especially indoor positioning system. There are other techniques of achieving indoor positioning such as Bluetooth, Wi-Fi, Radio Frequency identification (RFID) and camera based positioning system which may give higher accuracy but at higher cost due to installation of additional sensors and infrastructure.

HB LED can be switched on and off at a very fast rate. Human eyes cannot detect flicker above 50Hz due to stroboscopic effect therefore a frequency above 200Hz is considered safe and can be used for Pulse width modulation (PWM) Dimming to control illumination [1] therefore HB LED can be used for data communication in free space propagation of optical waves called as Visual Light Communication (VLC) [2]. In VLC based positioning system the LED luminaries' are usually the transmitter which transmits a unique code or ID which contains information about its location in an indoor facility this signal is received by the mobile receiver usually a Photodiode or image sensor. This received signal is then decoded by the receiver and can be processed with a preloaded database which contains location information of luminaries'. Fig. 1 shows how the luminaries' are assigned unique ID and transmitted through optics and then the receiver detects the transmitted ID or code

Visual light positioning finds its application in wide variety of fields such as to locate a person in a refinery or in a large industrial area, Automatic pallet truck, and indoor navigation to identify a location like in a food store to identify a food item and many others. PWM Dimming is carried out in LED drivers to vary the intensity of light output and is often a customer requirement.

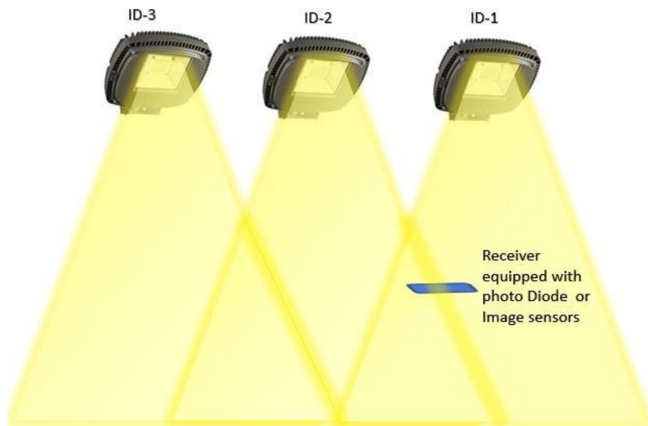

Fig. 1 A model of Visual Light Positioning system

Therefore, to support this requirement the data is modulated with variable pulse position modulation (VPPM). IEEE 802.15.7 standard [3] supports various modulation schemes for the VLC. The VPPM modulation scheme in IEEE 802.15.7 supports both, illumination and PWM dimming. The amount of information required for positioning system is very modest and hence the bandwidth efficiency can be sacrificed if it results in a simpler system. Example: signals can be transmitted at frequent intervals.

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The System Architecture of proposed LED Driver for VLP is shown in Fig. 2

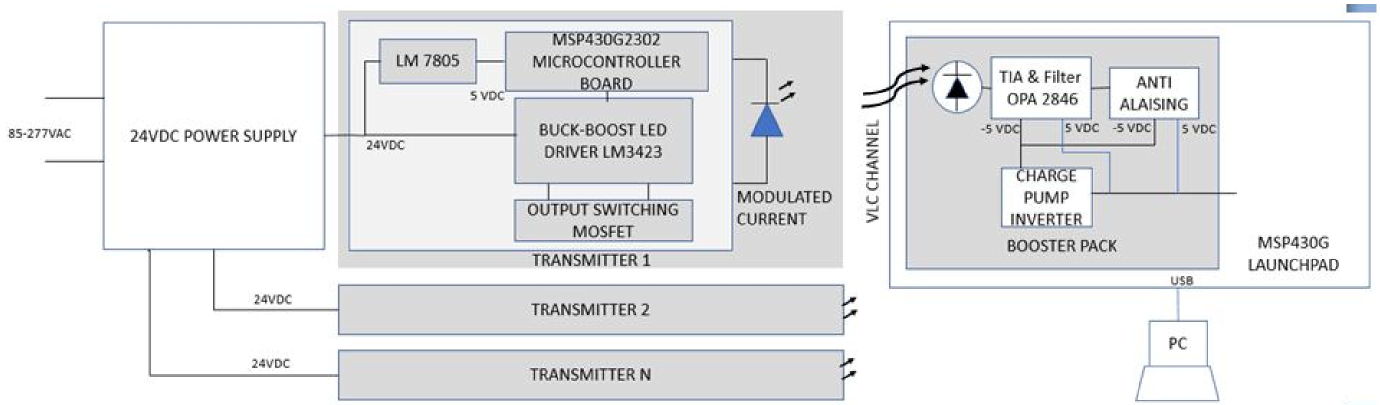

Fig. 2 VLP System Architecture

This Driver outputs constant current by using a floating buck-boost converter. The modulation of LED current is achieved by using a switch in series with the LED’s. The data to be transmitted is modulated with a Binary code . This modulation is called variable pulse position modulation (VPPM). Using VPPM, transmitter supports communication under different brightness level by changing the duty cycle (DC). The receiver has a photodiode which receives the transmitted signal and outputs a current signal. A transimpedance amplifier converts this current signal to voltage. A filter circuit filters the ambient light and after signal conditioning it is given to the microcontroller which decodes the signal and sends it to computer for showing the position of the receiver.

II. TRANSMITTER

A. LED Driver

The LED driver provides a constant current of 700 mA with VPPM-modulated data to the LED. This requires a constant current controller; The Topology used was a Floating Buck-Boost DC to DC Converter For PCB Texas Instruments LM3423 Evaluation Board was used and modifications were made to accommodate the desired parameters

A study of LED driver controllers led to the LM3423 as optimal device. This IC can drive the selected LED at 700 mA, 32.5V. An output voltage up to 72 V assures proper operation, even when the forward LED voltage increases due to degradation.

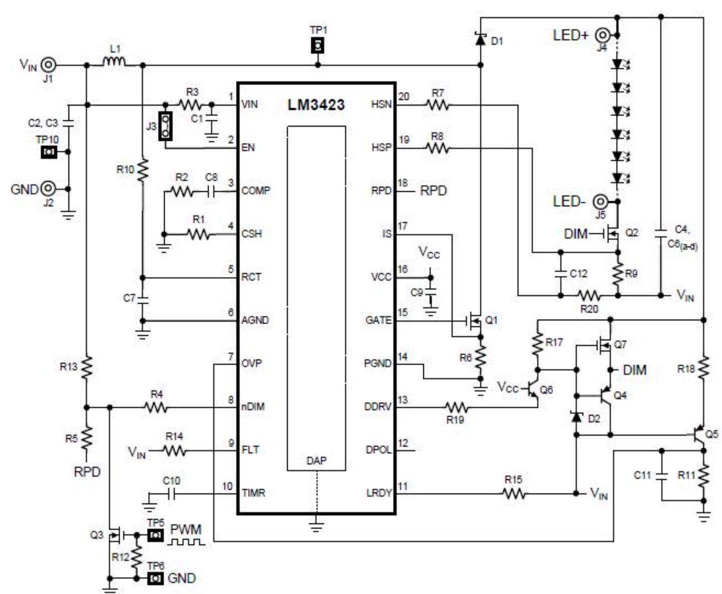

Fig. 3 Circuit Diagram for LED DriverMicrocontroller

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The microcontroller is responsible for the generation of a data signal that is sourced into the PWM input of the LED driver controller. This operation requires little computational power and few IO pins, leading to the MSP430G2x series of microcontrollers. However, accurate timing is important in this application, implying the need for an external crystal. The most basic device that suits these requirements is the MSP430G2302 microcontroller in DIP package, combined with a 32.768 kHz crystal. This configuration is used for the generation of a 0.5 kbps data signal, which is under the 5 kHz PWM limit of the LED driver. This means that the unique 4 chips code can be sent roughly 250 times per second.

The microcontroller requires a voltage of 1.8 V to 7 V. Therefore, a 5 V linear regulator 7805 was selected that regulates the input DC voltage of the LED driver

III. RECIEVER

The receiver converts optical power to an electrical signal. A photodiode is required for this purpose, producing a current proportional to the light falling on the active area. The BPX61 photodiode was selected for its spectral response in the visible light region (400 ... 1100 nm) and active area of 7 mm^2. Despite the large active area, which is important to capture a sufficient amount of light, the photodiode has a bandwidth of17.5 MHz and good noise characteristics.

The output current of the photodiode is transformed into a signal that can be sampled by the ADC. First, the current is converted to a voltage by use of a Trans Impedance Amplifier (TIA) and filtered by an ambient light filter in the feedback loop. Ambient light can originate from surrounding light sources that don't send data and produce a DC current at the photodiode, e.g., the sun. In order to use the maximum dynamic range of the amplifiers, the DC current should be filtered out in the first stage. Fig. 4 shows the schematic for Receiver. The TIA needs a large open loop gain because of the large amplification and a low input bias current due to the small current from the photodiode. Because this is the first stage of our receiver it should also have good noise characteristics because the noise factor of the total receiver will mostly be determined by the first stage. The OPA2846 meets these requirements and was designed for TIA applications. An additional advantage is the second OPAMP in the casing, which can be used to implement the ambient light filter using "General Active Feedback" in the feedback loop of the TIA. The human eye can't observe flickering when the frequency is above 300 Hz, so in VLC systems all signals should be above this threshold. This results in a cut-off frequency of 300 Hz for the ambient light filter.

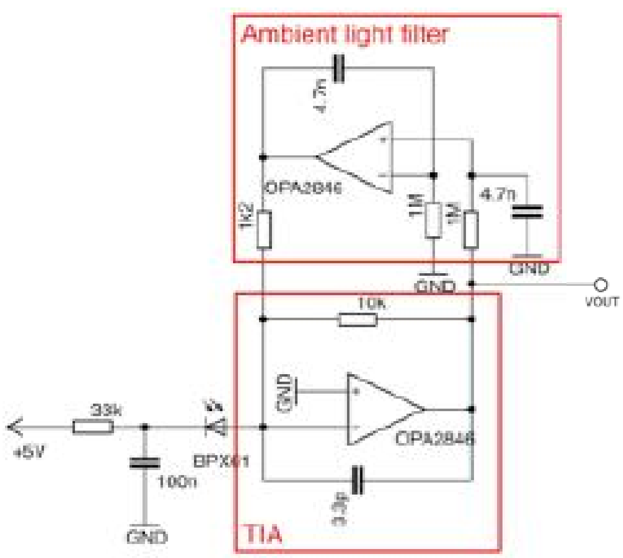

Fig.4 Schematic of Receiver Circuit

IV. TEST AND EXPERIMENTAL RESULTS

A. Lab Prototype

The Lab Prototype was constructed for Experiment. The LED's were placed on a PCB and the PCB was mounted on Heatsink suitable to keep the temperature of the LED's below 70°C. The LED Driver and the Microcontroller PCB were placed on the back side of the Heat sink so that the entire setup can be made suitable to hang from the ceiling **Error! Reference source not found.** Fig. 5 show the picture of the Entire Test Setup.

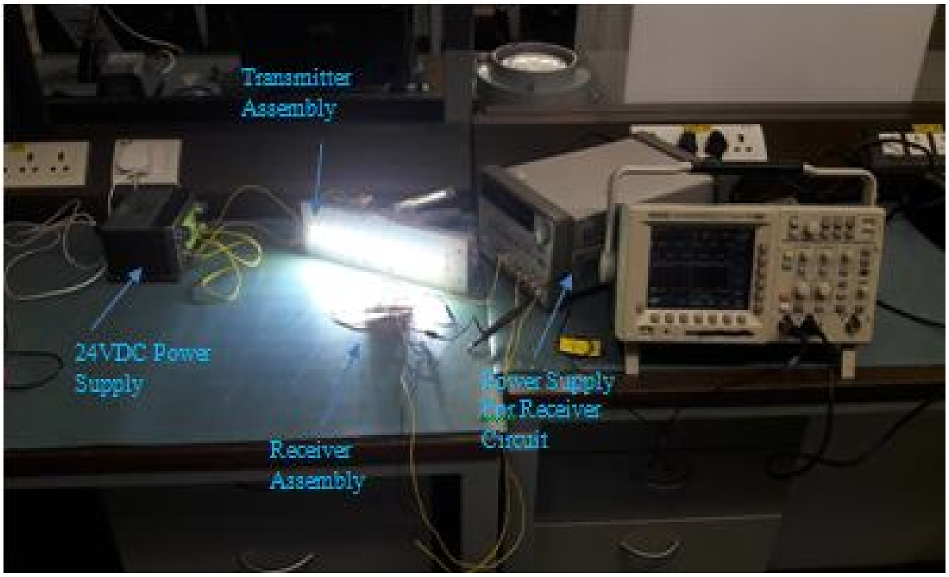

Fig.5 Experimental Test Setup

B. Results

The Transmitter was programmed to transmit a code of 1010 repeatedly with duty cycle 50% that is Dimming of 50% at 1KHz Frequency. Thus, the device transmits a unique code of 4 chips at 0.5 kbps, as depicted in **Error! Reference source not found.**, representing the data signal and LED current. The frequency can be increased upto 11 KHz after which the LED current amplitude starts to distorts.

The Duty cycle of 98% can be achieved with these codes, an average duty, resulting in a nearly maximum light output.

Performance of the LED driver was investigated, revealing efficiency of 83.3% @ Vin=24.7 V. Delivered output power was 19.23 W. The designed power supplies were tested at 234 VAC, 0.94 A to the LED driver. This means that 23 W of input power results in a luminous flux of 2000 lm (taking LED temperature into account), enough for lighting a workplace of 10 m^2. This brings total transmitter efficacy at 87 lm/W, exceeding performance of many commercially available LED lights without VLC capabilities, further improvement can be achieved by merging the LED driver and power supply in single circuit.

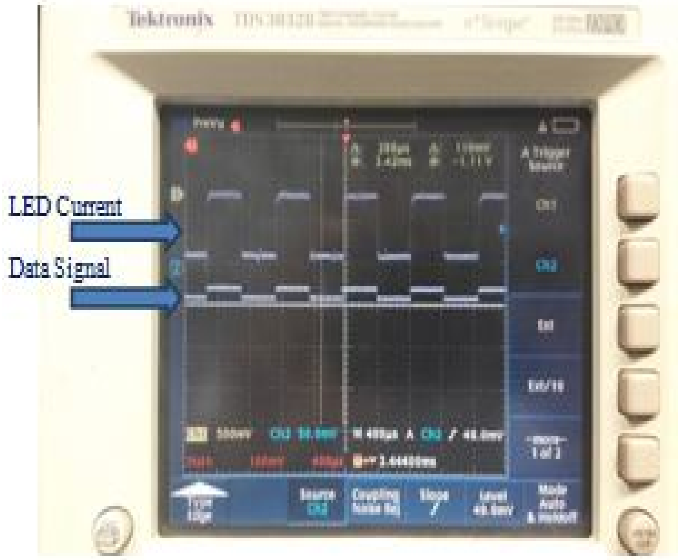

Fig.6 Waveforms of Transmitted Signal and Receiver Output Signal

The Distance between the receiver was varied from the lighting fixture and the amplitude voltage of the data signal was observed while keeping the duty cycle at 50% and current at 670mA and frequency of 1 KHz

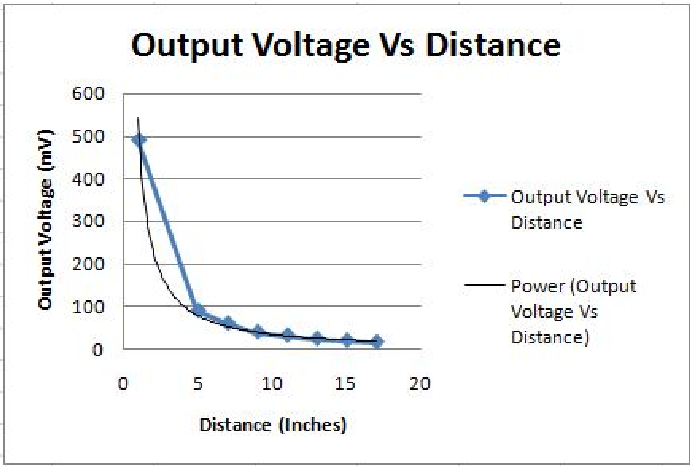

Fig.7 graph of Distance between transmitter and receiver versus output voltage of receiver

It is observed that the output voltage of the receiver decreases with the increase in distance between the transmitter and receiver. The received output voltage is directly proportional to the intensity of light falling on the photodiode. The maximum achievable distance between the transmitter and receiver is 17 inch after that the received signal is not properly recovered back at the receiver side. Fig. 7 shows the graph of vertical distance between the transmitter and receiver and the output voltage.

V. CONCLUSIONS

In this project, an LED Driver suitable for both illumination and Visual Light positioning system was designed. In this system, a Buck Boost LED Driver was designed providing a constant LED current with 0.5 kbps VPPM CDMA Data Modulation. The Unique ID for each Transmitter is provided by a Microcontroller. A Receiver was also designed to receive the modulated light signals. The receiver design has a Tran impedance amplifier properly tuned to give output. An Ambient light filter was designed to filter the modulated light from the Ambient light noise

A Prototype of the system was developed and the experimental verification of the prototype was done. The result is easy to install VLP system with 87 lm/W system Efficiency. The modulated signal can work with Dimming control

The Location information of the fixture is obtained from the receiver in analog form and maximum distance being 17 inch . The microcontroller can be programmed to change the Unique ID that are assigned to the system. The designed output switcher using MOSFET in series with LED Array works well up to 11 KHz and can be employed in VLP systems.

Future work lies in evaluating the system with multiple transmitters so that each transmitter will transmit unique codes. The receiver should be able to decode the signals and identify the locations based on the positioning system

The receiver can also be designed as a Booster Pack which can be stacked on a microcontroller board. The microcontroller board can then be interfaced with PC wirelessly. The distance between the transmitter and the receiver can be increased by employing lens or increasing the photodiode sensing area to suit more practical condition in industry.

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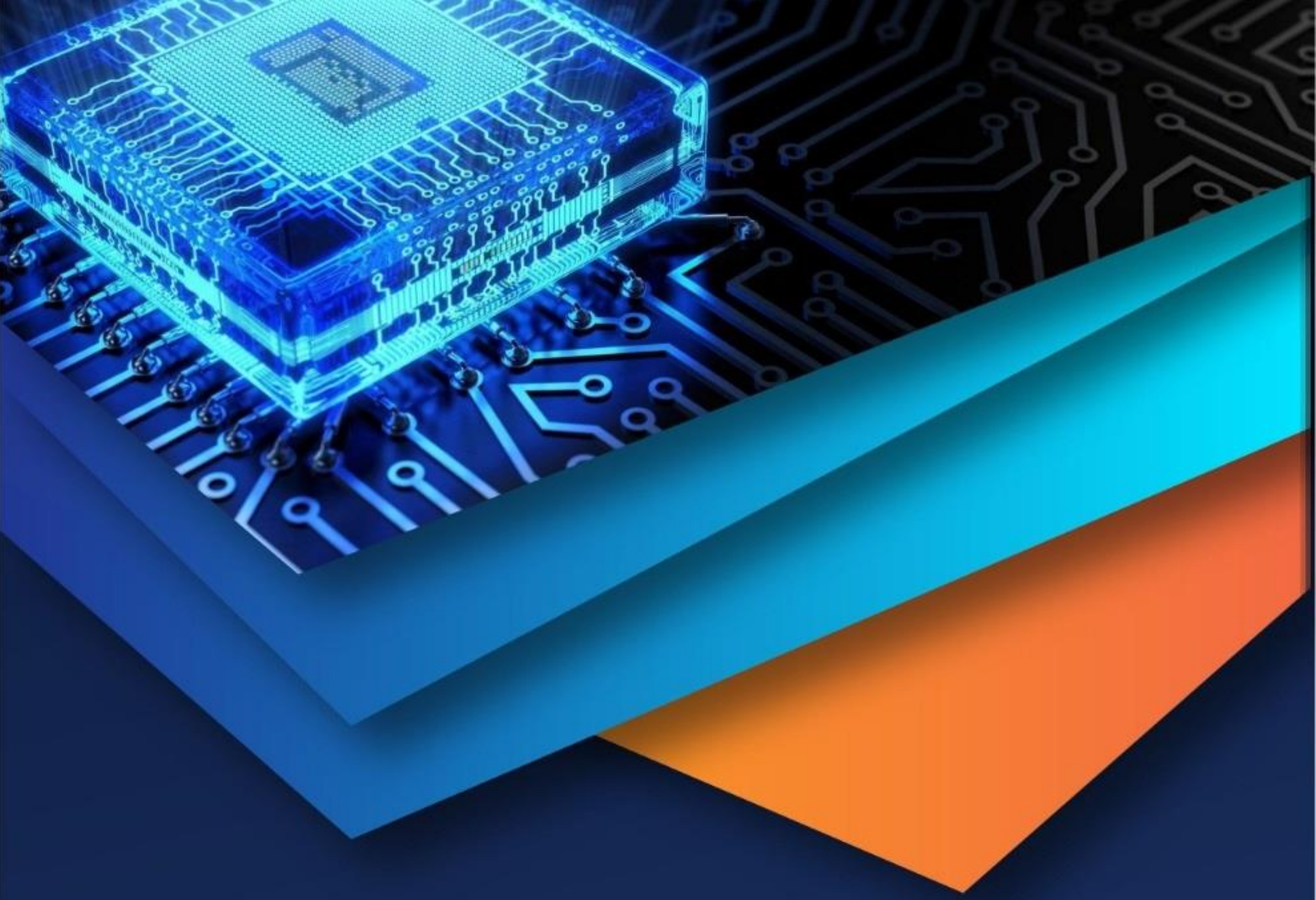

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