International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-9, July 2020

Near-Field Wireless Power and Data Transmission Through two-wire Power Carrier

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Abstract*: These days wireless power transfer is the widely used technology to transmit power and information simultaneously. In this paper, the magnetic induction principle is used to transfer power and information simultaneously through a single winding arrangement. It is shown that a 7W LED lamp can be illuminated between a distance of about 5mm. Magnetic induction principle can be applied to a short-range power and information transfer only. This paper discusses the underwater LED light luminaire transmitter and receiver design components, along with it shows the mode switching of LED. The power transfer efficiency is about 65% when the transmitter and receiver are placed in-line and power efficiency decreases with the displacement of the lamp to either side.

Keywords: Data transfer, Near Field Communication (NFC), Power coupling, Wireless Power Transfer (WPT), Light emitting diode (LED), MOSFET (Metal oxide semiconductor field effect transistor), Power Amplifier.

I. INTRODUCTION

Wireless power transfer is the transfer of electrical energy from a power source to an electrical load without the use of physical connection and with the help of mutual induction principle. The main purpose of the WPT is allowing devices to be continuously getting charged without the need of wires. Hence, this is an efficient way of transmitting signals from one point to another in a vacuum, underwater or any atmosphere where the use of wires or cables is not convenient. The applications of WPT include charging devices such as mobile phones, electric toothbrushes, implantable medical devices, and underwater lights. In this paper, wireless power transfer eliminates the need to store power using bulky batteries [4]. Furthermore, the areas like underwater where human access is very limited luminaires that involve an eventual repair of drivers are inappropriate to be used. Because of this limitation, remotely-powered luminaires are being used.

Revised Manuscript Received on July 30, 2020.

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Near-field wireless power transmission converts electrical energy into electromagnetic fields, and then receives electromagnetic fields into electrical energy through a receiving device [5]. In the process, other information contained in the power transmission mostly ignored.

Existing two-wire power transmission systems, in the eyes of professionals, include other information in addition to transmitting power, such as AC and DC information, voltage amplitude information, and frequency information [7]. Changing these information parameters can transmit some signals without affecting the power transmission. For example, we can transmit the power in 60Hz or 120Hz. Or the signal can be coupled on the power transmission line to realize the power carrier.

Combining the above two points, to realize simple digital processing of the information contained in power transmission at low cost, and to simply modulate the near-field wireless power transmission electromagnetic field to realize the near-field wireless power transmission through the low-frequency two-line power carrier for special occasions [3].

For example, Mohamed Zied and Rashid Rahimi have demonstrated that how a LED lamp of 20W can be illuminated using a table thickness of 50mm. The efficiency stated is 100% at the distance of 5cm with an exactly aligned position of transmitter and receiver unit [1]. Yong-Ho Son, Byung-Jun Jang [2] presented a design in which maximum 5W class E power amplifier with the suggested ASK transmitter was designed using a low cost IRF510 power MOSFET at the frequency of 6.78MHz.

Below Fig. 1., categorize the wireless power transfer into two basic types: Near-field WPT and Far-field WPT.

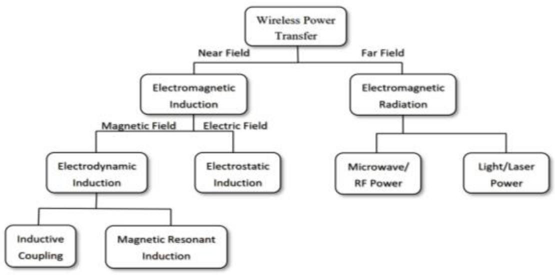

Fig. 1. Types of Wireless Power Transfer

A. Near-field WPT

It includes an electromagnetic induction principle which is further divided between magnetic induction and electric induction [5].

a. In magnetic induction, a substance, such as iron or steel, becomes magnetized by a magnetic field. The induced magnetism is produced by the force of the field radiating from the poles of a magnet.

b. Mutual Induction Principle

Using this principle, a magnetizing force and a static magnetic field develop around the coil when DC current pass through the conducting wire as shown in Fig. 2. Two devices are said to be mutually coupled or magnetically coupled when any change of current in one coil induces a voltage around the end of the second coil through electromagnetic induction [5][11]. The amount of current flowing through the coils winding determines how intense magnetic flux developed around the coil. The developed magnetic field around the coil is proportional to the amount of current flowing through the windings. Again, the amount of current produced in the secondary coil depends upon the spacing between the coils. The short distance between the primary and secondary winding can produce strong magnetic flux rather than a larger distance. Hence, the voltage produced at the secondary is more. The static magnetic field can also be increased if an extra wire to be wounded upon the same coil.

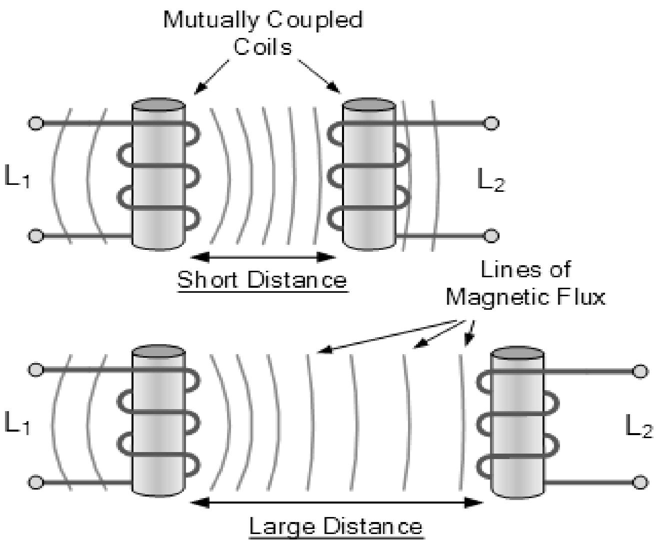

Fig. 2. Mutual inductance between coils

c. Electrostatic induction, when an electrically charged object is brought near to a material, then it generates static electricity and this method is known as Electrostatic induction. Due to this, electrical charges set up in material, causing an excess of a positively charged particles on one side or negatively charged particle. When the objects are conducting materials such as metals, then this phenomenon becomes most effective. The problem associated with this phenomenon is that the conductor loses its charge, once the electrically charged object is removed. The solution to this problem is to temporarily ground the conductor.

B. Far-Field WPT

Far-field WPT includes electromagnetic radiation. Another method radio frequency radiation, which is basically a non-line-of-sight (NLoS) environment the far-field electromagnetic radiation for remote power delivery, which has many promising advantages such as extended power transmission range, smaller receiver/transmitter form factors, easy implementation of power multicasting to a great number of devices simultaneously, etc.

II. WORKING

The wireless light sources have become very familiar in different fields of life. The wirelessly powered lights and wirelessly charged lights inclusive of rechargeable batteries have become much popular among people today. The main reason behind their increasing demand is that these LED lights are movable, hence are convenient to use at wet places [8][9]. Moreover, these products are gaining popularity in swimming pools and SPAs where the installation of LEDs is a cumbersome task. Floating lights are taking the place of traditional wired LED lighting in pools and SPAs, so a race among designers has started to design more attractive lighting products. The following block diagram in Fig. 3. shows the wirelessly powered light components which are required to illuminate RGB LED and mode change information using wireless power and data transfer. In this, we are using only two coils primary(L1) and secondary(L2) which acts as transmitter and receiver coils respectively [13]. Two coils are made to transfer power and data using the mutual inductance principle. The oscillator(U1) is connected with the primary coil through a power amplifier (U2) to provide a modulated signal. In this paper, Amplitude shift keying modulation is used to modulate and demodulate the signal [6]. The wireless power and data transmitter circuit consists of a rectifier, filter, digitizer, control, oscillator, and power amplifier. The control block provides the signal in binary which further controls the frequency generated by the oscillator. The digital pulse from the control module acts as a switch for an oscillator. Traditionally, in some wireless power transmission systems, separate windings are employed for power transfer and information transmission, which generally makes the system complex and cumbersome. The proposed method is more beneficial over traditional one, due to its simple design which eliminates the clock signal required for synchronization and demodulation of data at receiver side.

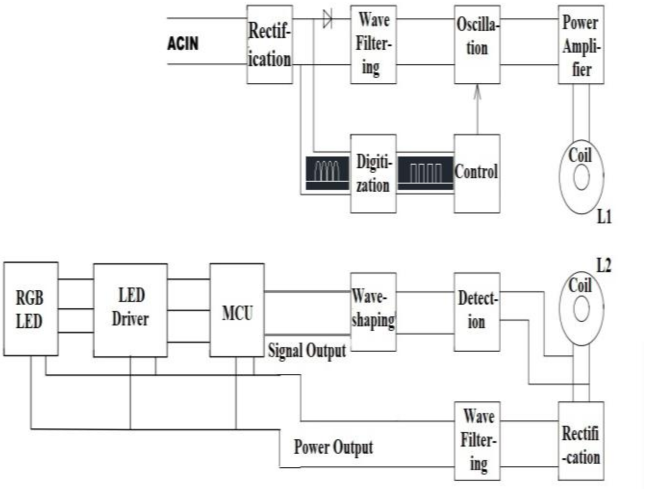

Fig. 3. Block diagram of Wireless power and data transfer using mutual inductance for pool lighting LED

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-9, July 2020

A. Transmitter Section

The input to the Transmitter module is 60Hz 12v AC signal as shown in Fig. 4. This input is fed into the rectifier, which provides +15V to the designed circuitry. The rectifier is an electrical device that converts a.c signal into the d.c signal. This is known as the rectification process. This device uses a full-wave bridge rectifier circuit that provides a pulsating signal.The pulsating signal is changed to a square wave pulse of +5V after digitization. This digitized signal is passed through a control that changes this voltage to vary between +7V to + 8V to obtain oscillations. The received input square wave is then applied to an oscillator which creates a signal waveform of around 75KHz. This waveform further drives the power amplifier, which induces a current through the coil, denoted as a primary coil(L1). This coil is aligned with a second coil, labeled as a secondary coil(L2). The primary and secondary coils are so matched that they can transfer the power [12]. All of the energy in the magnetic field to be captured by the secondary coil, resulting in a perfect transmission of voltage and current between primary and secondary coils.

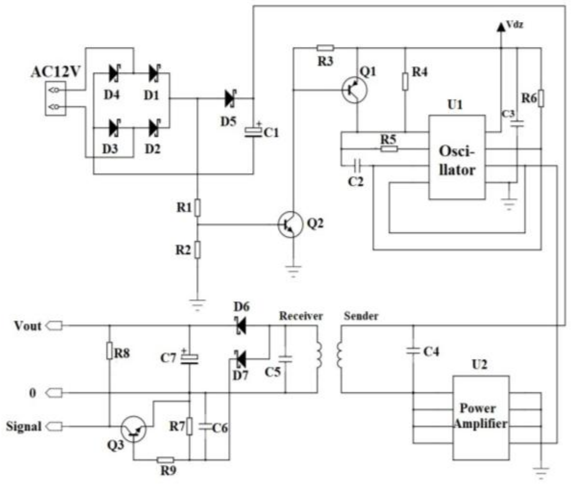

Fig. 4. Schematic diagram of wireless power and data transmission based on mutual inductance principle

a. Digitizer

A square wave signal is required to control the operation of an oscillator as shown in fig. 5. To obtain a square wave signal with 50% duty cycle, a digitizer is connected. When the digital signal is high then high-frequency signal pass to the power amplifier. When digital signal is low, the high-frequency signal suppressed by the oscillator.

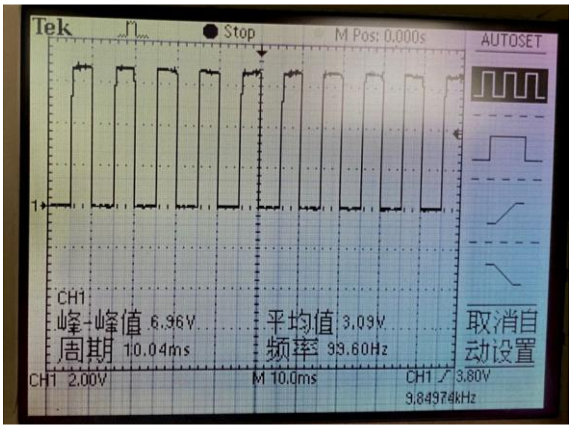

Fig. 5. Digitizer output

b. Oscillator

U1 shown in fig. 4. is the oscillating chip. An oscillator is a circuit that generates a cyclic (periodically separating) signal. Classic examples of oscillator signal patterns include a signal (one that goes smoothly back and forth between two extremes, as a pendulum does in the physical world) or a square wave (one that switches instantaneously back and forth between two extremes, like an on-off switch). Through the peripheral (U1) network components R6, C2, R4 & R5 controls the oscillation frequency and amplitude. This oscillator IC outputs the square waveform, where C2 and R5 mainly control the oscillation frequency. By adjusting the parameters, it can control the oscillation frequency to a preset value, whereas R4, R6, C2 divide the voltage to control the triangular amplitude. After the internal shaping of U1, the preset value square frequency wave is output, and the adjustment parameters control the triangular amplitude. It can control the duty cycle by reshaping the rear wave and finally it is amplified and sent to the power transmission coil by U1. The control output signal acts like a switch to oscillator. When it is ON, signal is present at the output, otherwise output is zero. The duty cycle of the square wave is 50%.

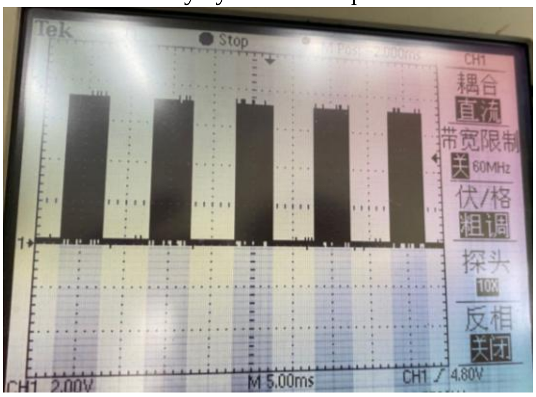

Fig. 6. Set up showing the oscillator output

c. Power Amplifier

Power amplifier (U2) is an electronic device used to amplify the power level of the signal. The reason to increase the power level is to drive the loads e.g., speakers, headphones, RF transmitters, etc. A power amplifier is also used to drive the loads directly and is used as a final block in an amplifier chain [10].

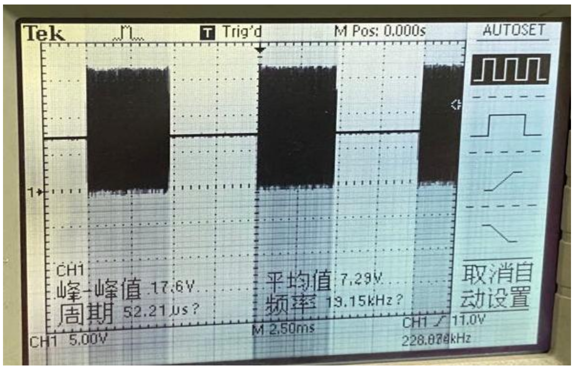

Fig. 7. Set up showing the power amplifier output

Further, in wireless transmission modulated waves are sent over short or long distances via air. The signals to be received depends upon the magnitude of the power level. This supplies voltage around 40V to the primary coil. The secondary coil in turn receives around 42V as shown in fig. 7.

B. Receiver Section

In this wireless power and data transmission, ASK modulated signal is received at the receiver side. The coils are about 5mm apart as shown in fig. 8., and the power is approximately 7W. The receiver circuit consists of a detector circuit which will retrieve the original signal from the modulated signal and pass it to the wave shaping circuit. This modulated wave consists of information according to which lamp change its modes. If the power switch remains off for almost 2s and switched on again, then RGB LED changes the colors in sequence. MCU connected with the driver passes this mode information to it and the driver instructs the lamp accordingly.

III. RESULTS AND DISCUSSION

After completion of circuit connections, the device was tested to check power transmission at the receiver side to illuminate the LED. The first aim of the testing is to check whether the power-driven to the receiver part through wireless transmission is enough to lit up the lamp. After the successful establishment of a connection with lamp, the next goal was to check the distance between the transmitter and receiver unit. In this wireless power and data transmission, ASK modulated signal is received at the receiver side which conveys information about mode control of the LED. The coils are about 5mm apart as shown in fig. 8., and the power is approximately 7W. Fig. 9. shows the experimental set up to illuminate LED using wireless power transfer. It eliminates the digital memory and separate data transmission unit. Instead, we use a pulse stream, which is obtained after converting a signal from AC source by a digitization circuit and control.

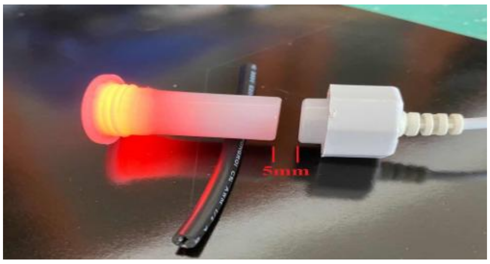

Fig. 8. Distance between transmitter and receiver module

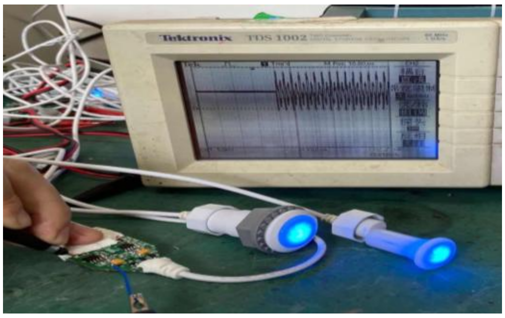

Fig. 9. Set up showing the LED powered by WPT

IV. CONCLUSION

The objective of this paper was to lit up a LED lamp wirelessly and transfer information simultaneously to control modes of LED which can be used in the pool and spa tubs. With this development, it eliminates the need to lower the water level in the pool to replace the burned-out bulb and even get rid of another typical method in which we remove the light housing from the side of the pool, pull the fixture up onto the side of the pool, and change the light bulb there. Here, we have observed that by using magnetic induction principle power can be transferred wirelessly from transmitter to receiver unit which can sufficiently illuminate an LED bulb of around 7W within a distance of about 5mm.

Another aim was to develop various components of the transmitter and receiver units namely digitizer, oscillator and power amplifier.

In the future, work can be done to increase the power, and also to increase the distance between the transmitter and the receiver unit.

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