Original Research Paper

Volume-8 | Issue-9 | September-2018 | PRINT ISSN No 2249-555X

Engineering

INEXPENSIVE MASS-PRODUCIBLE NIGHTLIGHT SYSTEM

C. He-Chuan Department of Electrical & Computer Engineering, Michigan State University, East Lansing, MI 48824, USA

A. Alforidi* Department of Electrical & Computer Engineering, Michigan State University, East Lansing, MI 48824, USA *Corresponding Author

D. M. Aslam Department of Electrical & Computer Engineering, Michigan State University, East Lansing, MI 48824, USA

ABSTRACT With an ultimate goal of fully integrated inexpensive nightlight system, the current work reports the study of technologies needed for inexpensive system integration. All the required structures of the system are designed by SolidWorks and 3-D inkjet printed. Different circuits and configurations are tested in the study.

KEYWORDS : Night light system, light dependent resistor (LDR), microcontroller, 3-D inkjet printer, Solar tracking system, stepper motors.

I. INTRODUCTION

A low cost commercial solar nightlight system, with lowest price of $1, consists of a light sensor, a control circuit on a printed circuit board (PCB), rechargeable AAA battery, solar panel, control circuit and mechanical packaging. The major cost of such a system is due to the solar panel, rechargeable battery and mechanical structure (3-D printed material).

This paper focuses on system packaging technology using 3-D inkjet printing while the other needed components used in the system integration are off-the-shelf. Unique features of this research are a) the development of a hybrid breadboard/PCB (HBP) system that reduces the cost by first making a 3- D printed custom breadboard that, through minor design changes, can be developed into a PCB and b)incorporation of metallization using a 3-D printed shadow mask. The hybrid design allows vertical integration of 3-D printed structures that are susceptible to miniaturization. By studying the design, fabrication and testing of HBP is applicable to the package of a) IC and MEMS chips and b) other small systems for a number of applications including smart home devices.

As shown in Figure 1, for the first time, a large scale integration of Si, GaAs, thin film battery and 3-D inkjet printing technologies [1] can be used to produce a nightlight and other similar systems under $0.15 or less.

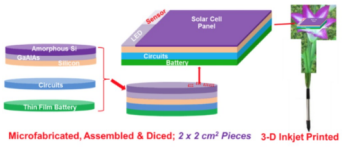

Fig. 1. Concept diagram of inexpensive integrated nightlight that is mass- producible.

II. EXPERIMENTAL RESULTS

A. Night Light System using NPN transistor

In the first design, shown in Figure 2 [2], the use of Schottky diode inhibits the battery discharge in the absence of solar energy. It also used due to its very low forward-voltage drop and very fast switching speed. The bipolar junction transistor (BJT) circuit acts as a switch turning the LED on at night and charging the battery or the super-capacitor in the daytime.

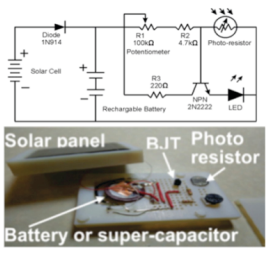

Fig. 2. Circuits diagram and packaging of nightlight system using NPN transistor.

Figure 2 shows a circuit diagram for a night light system using NPN transistor. As the resistance of LDR is much greater than R1 during the night, NPN transistor is turned on switching on the LED. During day time, the LDR has a very low resistance and almost all current flows through R1 to the LDR. The amount of current goes to the base is not enough to switch on the transistor. That will cause the LED to switch off. The sensitivity of the circuit can be controlled by increasing or decreasing the resistance of R1.

The major goal of the prototype shown in Figure 2 was to study the design, fabrication and testing of HBP. The system was successfully tested using inexpensive components and 3- D printed PCB. However, there are two limitations of this system; Bipolar Junction Transistor (BJT) consumes more power and the PCBs made by 3-D printing do not provide metal interconnect lines.

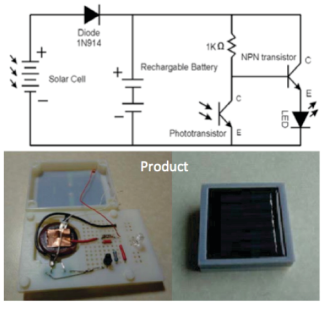

Fig. 3. Night light using photo-transistor.

Although, recently 3-D printers capable of metal inter- connect printing [3] have been reported they are not yet available commercially. Also, as the nightlight became part of a smart home integrated system, it is important to use a micro- controller in the night light system. In the current research, an integration of 3-D printing and metalization technologies was explored.

B. Night Light System using Photo-transistor

The circuit shown in Figure 3 [2] is a night light system using photo-transistor. It is a light-sensitive transistor, also called a photo-BJT which is encased in a transparent pack- aging. During the day time, the photo-transistor is on causing NPN transistor to switch off. In this case the LED will be switched off. In the night time, the photo-transistor is switched off making the base of NPN transistor high. Consequently, the NPN transistor is in the on state turning the LED on.

C. Smart Home Device Integration

In view of smart-home application, the next design uses the TI MSP430G2553 micro-controller as shown in Figure 4. Energia was used to program the micro-controller. A WiFi chip can be integrated with this system and can be programmed to communicate with WiFi router.

D. CMOS Logic

As the CMOS logic combines the advantages of NMOS logic and PMOS logic, it saves the electrical energy and the response speed is faster than the PMOS. In Figure 5, a CMOS logic IC (CMOS 74HC04 IC) and NPN transistor were utilized to build a night light system. R1 and LDR are worked as a voltage divider. During night time, the LDR has a high resistance and the voltage across it is near to 5V. This voltage is logic "1" for the 74HC04 invertor U1:A. After inverting the logic "1" to "0" by U1:A, it fed to the parallel invertors U1:B,C,D. The three parallel invertors were used to increase

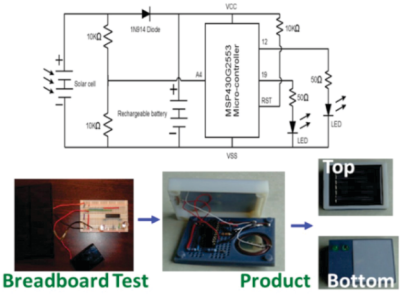

Fig. 4. Nightlight using Micro-controller.

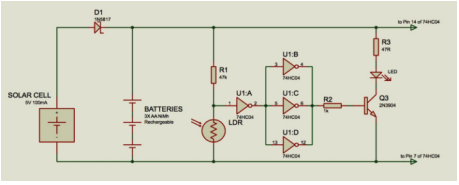

Fig. 5. Night light using CMOS invertors (74HC04 IC).

the output current of the CMOS part of the circuit. The 5V is fed to the base of the NPN transistor and that allows the current to pass from the collector to the emitter and switch on the LED. Same working process during day time in which the LED will be turned off. Figure 6 [5] shows a CMOS NAND gate logic based night light system. As the focus of this work is on the use of 3-D printed HBP, the efficasy of CMOS in saving power was not investigated.

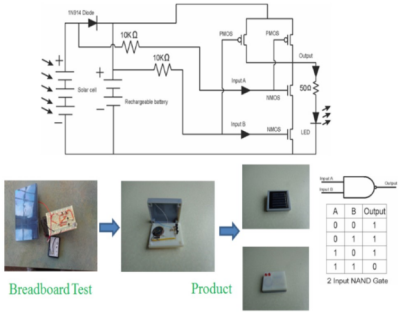

Fig. 6. Nightlight using CMOS NAND logic gate.

III. CONCLUSION

This research has led to the development of a hybrid breadboard/PCB (HBP) system that reduces the cost by first making a 3-D printed custom breadboard that, through minor design changes, can be developed into a PCB. In addition, Different circuit schematic of night light system was proposed in this paper. The hybrid design allows vertical integration of 3-D printed structures that are susceptible to miniaturization.

REFERENCES

[1] D. Aslam, "Inexpensive night light using technology assisted smart-solar system (TASS)," Invention Disclosure, no. TEC2015-0091, 03 2015.
[2] F. Mims, Getting started in electronics (3rd edition), 2003.
[3] 3D System. (2016) Production 3D printers, 3D printing production models. [Online]. Available: http://www.3dsystems.com/3d-printers/ production/overview
[4] A.Alforidi and D. Aslam, "Design, 3d printed packaging, fabrication and testing of a technology assisted smart solar-system (TASS)." under review, 2016.
[5] F. Mims, Electronic sensor and projects. Mster Publishing, 2000.