Design and Implementation of Automotive Sunlight Curtain for Cars Using Digital Electronic Circuit

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Abstract: In this paper, a novel technique of an automotive electromechanical sunlight curtain for the cars is designed and implemented. It depends on applying the sunlight rays on a photodiode at an angle fitted to that of the sunlight rays falling on the eyes of the car driver and the person beside him and make them uncomfortable. The proposed system is composed from four main parts: The photodiode and related comparator, a control circuit, 12 Volt DC motor with gearbox, and sunlight curtain plate with some mechanical parts. When the sunlight rays fall onto the photodiode with an desired angle, the control circuit will instruct the DC motor to rotate in clockwise direction, the motor will rotate the curtain plate to the downside location, where the curtain plate will prevent the sunlight rays to fall on eyes of the car driver or the person beside him. The proposed system has been tested practically in different environment conditions and different seasons, and it has exhibited stimulant results.

Keywords: Comparators, Flip-flop, One-shot-to, Photodiode, Sunlight Curtain.

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1. Introduction

One of the important and essential inventions today is the car, as it known, it is a high speed instrument utilized for transporting the humans and goods from a location to another with high speed and facility, although it suffers from the continuous maintenance and fuel consuming. Continuously, the cars subject to improvements to their essential parts and accessories for making them approach to the perfect model [1][2].

One of main parts of the cars is the sunlight curtain, which is located at inner forehead of the cars. Usually, there are two sunlight curtain in each car, one for the car driver and the other for the person beside the driver. The role of this part of the car is preventing the falling of the sunlight rays onto the eye of the car driver when the rays starts to fall onto the eyes of the car driver directly, then this is considered as a disturbance source for the car driver [3][4].

The traditional sunlight curtain is manually moved to multi-locations by the car driver or its adjacent person according to the upsetting effect of the sunlight rays falling onto their eyes. This manually movement is also considered as a disturbance source to the car driver [5].

The proposed system differs from the other previous traditional systems. The traditional system depends on moving the sunlight curtain manually, while the proposed system is an automotive sunlight curtain [1], i.e. the sunlight curtain moves automatically without human intermediation. The proposed system mainly depends on falling of the sunlight rays onto a photodiode that is located above the forehead of the car driver. The face of this photodiode is connected to a plastic light director. This director can specify the angle of the falling light ray. When the sunlight rays fall onto the photodiode with an angle fitted to that of the rays falling onto the car driver eye, an activation signal will be generated at the input of the control circuit. Then the circuit will present an instruction signal to the 12 Volt DC motor to move the curtain plate rotationally to downside location to prevent the sunlight rays from falling onto the car driver eyes. In this case the curtain plate acts as a wall between the sunlight rays and car driver eyes, which protects the eyes of the car driver. In the other hand, when the sunlight rays fall onto the photodiode with an angle differs from the angle of the rays falling onto the car driver eyes that make him uncomfortable, a deactivating signal will be generated into the input of the control circuit.

This circuit will instruct the DC motor to move rotationally to upside location.

2. Related Works

In 2014, D. Tutunea *et al*. [6] has presented several designed techniques of sunlight visor, these techniques depends on traditional model of sunlight visor that is used today in the cars. The sunlight visors of the traditional techniques consist of a thin plate that is moved by the car driver manually depending on falling the sunlight ray on eye of the car driver that make him uncomfortable, the sunlight visor plate of traditional sunlight visor is connected on a shaft the fixed in front of the car driver and person beside him, and in same time above the front glass of the car, where it is fixed by two points in that location. The proposed techniques in this work consist of only mechanical movable plate, it based on fixing the sunlight visor plate in a single fixed movable slide point in front the car driver and person beside the driver and above the front glass of the car. The proposed sunlight visors in this work can be manually moved by the car driver and the person beside him depending on falling the sunlight ray on eye of them.

In 2016, L. Engstrom *et al*. [7] have proposed a design and implementation of an electronic sunlight visor. It consists of two main parts, the polarized screen and the electronic circuit. Four polarized screens is located above the front and front side glasses, two for the car driver and the other two screens are for the person beside the car driver. The electronic circuit consists of two main parts, the photocell and the control circuit. When the sunlight ray fall on the photocell with an angle equals to that of falling these ray on the eye of the car driver or the person beside that make them uncomfortable, the control circuit presents an activating signal to polarize the screen of the sunlight visor and make it dark to prevent the sunlight ray from falling on the eye of the car driver and the person beside him. The proposed system of this work has not included any moving mechanical part such as relays or motors.

In 2017, S. B. Abdul Kashem *et al*. [8] has presented a design and realization of electromechanical sunlight visor. It consists of two main parts, the mechanical and electronic parts. The mechanical part involves rollers with different sizes and DC motor with a slide plastic paper. The electronic circuit consists of a control circuit, and manual switches for up

and down moving the dark plastic paper. The mechanical part is located above the front glasses and front side glasses of the cat, where they are located inside the car above the car driver and the person beside him. When the uncomfortable sunlight ray falls onto the eye of the car driver or the person beside him, they can push the down manual switch to instruct the electronic circuit to produce an activation signal to the mechanical part to draft down the dark plastic paper by the moving of the rollers until the paper is stopped to prevent the ray of the sunlight to fall on the eye of the car driver or the person set beside him. The DC motor itself moves the rollers in clockwise or anticlockwise depending on the polarity of the power supply feeding that applied across the electric pins of the motor.

3. Mechanical Unit of the Proposed System

The Mechanical unit of the proposed system is responsible on physical or mechanical movements of the proposed system. This unit is shown in Figure 1. As shown from this figure, the mechanical unit consists of the following parts: 12 Volt DC motor, holders, gear box, steel shaft, plastic curtain plate, rotation limiting rheostat, and the fixed bush.

The DC motor is supplied by 12 Volt with a consumed power of 6 Watt, and a speed is 2400 rpm. The task of the holder is holding the motor body at a fixed location. The role of this motor is supplying a rotation movement power for the plastic curtain plate. The role of the gear box is converting the rotation speed from 2400 rpm to 10 rpm with high torque value. The role of the steel shaft is holding the plastic curtain plate in a horizontal manner, where one of its terminals is directly connected to the motor shaft, while the other terminal is fixed to a specific location by using a fixed bush. The task of the rheostat is producing a reference signal levels for rotation limits for the plastic curtain plate. Finally, the job of the fixed bush is holding of terminals of the steel shaft in a fixed location or point.

When the sunlight rays fall onto the surface of the photodiode with an angle similar to that of falling rays onto the car driver eye that make him uncomfortable, an activation signal will be generated in the control unit that instructs the DC motor to rotate the steel shaft in clockwise direction. This rotation moves the plastic curtain plate downside toward the location of the frontal glass of the car.

While when the sunlight rays fall onto the photodiode surface with an angle differs from that mentioned in the previous paragraph, the control unit will present a deactivating signal that instructs the DC motor to rotate in anticlockwise direction. This rotation will move the plastic curtain plate to upside location toward the ceiling of the car.

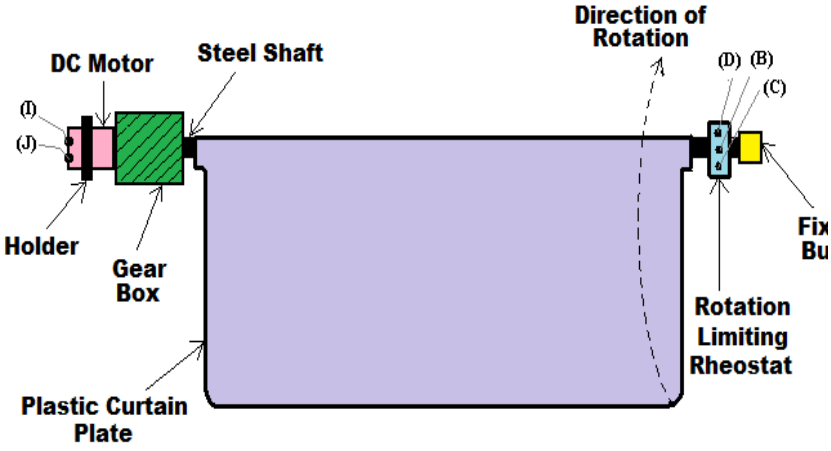

Figure (1): The mechanical unit of the proposed. system.

4. Control Unit of the Proposed System

The control unit receives the activating signal from the photodiode. The photodiode is a device that converts the light energy to electrical signal and this electrical signal is used to control the direction of rotation of the plastic curtain plate of the proposed system. A plastic light director must be connected to the sensing face of the photodiode as shown in Figure 2. The azimuth window (Horizontal Converge) angle of this director should be 130^{o}, and the elevation window (Vertical Converge) angle should be 30^{o}.

There are four photodiodes must be used for four proposed circuits in the car, each one is connected to its specialized proposed circuit, the first two proposed circuits are used to protect the car driver from front and left side locations, while the other two circuits are used to protect the person beside the car driver from front and right locations. The four photodiode must be located above and outside the car as shown in Figure 3.

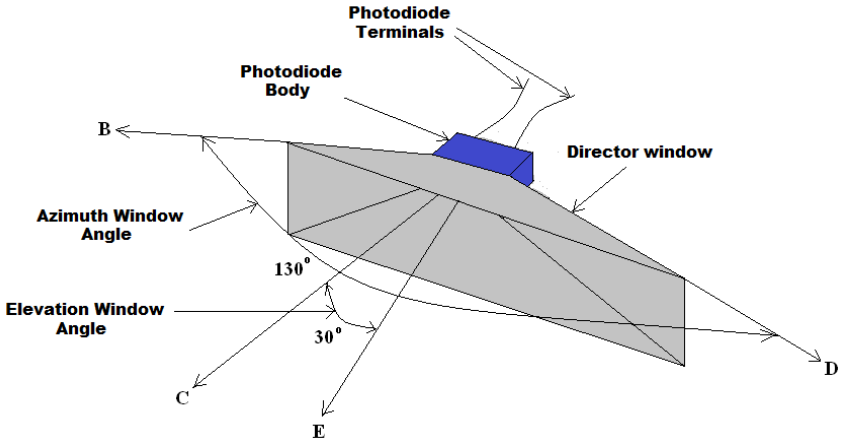

Figure (2): The photodiode and its light director of the proposed system

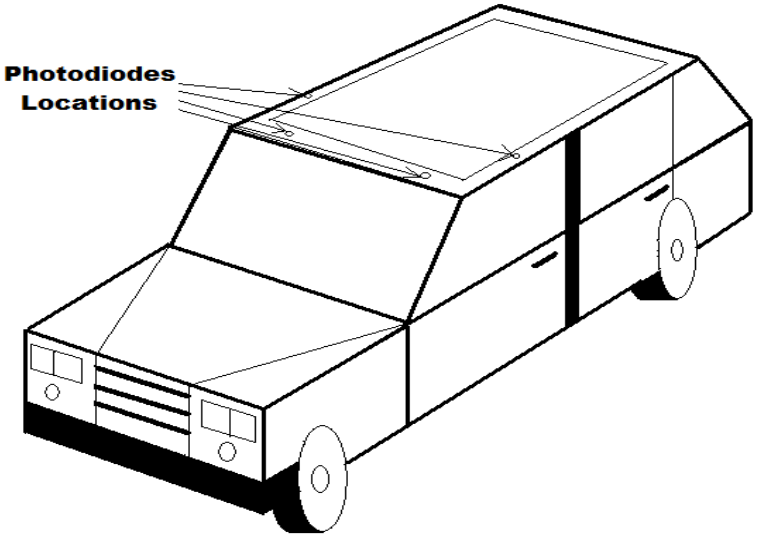

Figure (3): Illustration of four photodiodes location on the car.

The circuit diagram of the proposed system is illustrated in Figure 4. As shown in this figure, the electrical terminals of photodiode D1 (TIL 100 type) had been connected to the analog comparator IC (integrated circuit)

U1 (LM393 type) [9]. The role of this IC is translating the output analog signal of the photodiode to digital signal. When a sunlight ray is applied onto the surface of the photodiode D1, the comparator IC U1 presents a HIGH level signal at its output, and when this ray is disappeared, the output of the IC U1 will be LOW level. The output of the IC U1 should be connected to the input of One-shot-to circuit that is composed from an Inverter IC U2 (SN74LS04 type) [10], capacitor C1, and the AND gate IC U3 (SN74LS08 type) [10]. The role of this one-shot-to circuit is presenting a narrow positive pulse when the output of the comparator IC U1 is changed from LOW to HIGH level. This narrow pulse shall feed the clock input of the D-type flip-flop IC U14 (SN74LS74 type) [11]. The role of this IC U14 is presenting a HIGH level output, whenever, this IC is ignited by the narrow pulse of the one-shot-to circuit (U2, U3, and C1). The D input of the flip-flop U14 should be supplied by a HIGH level signal (or +5 Volt). The output of the IC U14 should be connected to one of the inputs of the OR gate IC U15 (SN74LS32 type) [10]. While the other input of this IC is connected to a control switch S1, which is responsible on the selection of manual or automatic movement of plastic curtain plate of the proposed system. The output of the OR gate IC U15 is connected to the base of the transistor Tr1 (BFY51 type) [12] through the resistor R8. Tr1 is a switching transistor which is utilized for switching the Relay Re2 ON-OFF. When the output of the OR gate U15 is at HIGH state, then the transistor Tr1 is switched ON, which switches the Re2 ON and this Relay will supply the DC motor by forward DC voltage that forces the motor to rotate in clockwise direction. This clockwise rotation will move the plastic curtain plate rotationally to the downside location.

Another one-shot-to circuit is utilized in this proposed system, which is composed from ICs U5, U6, and the capacitor C2. This one-shot-to circuit is utilized for presenting a positive narrow pulse when the output of the comparator U1 is suddenly changed from HIGH to LOW level. This state occurs when the sunlight is removed from the surface of the photodiode D1. The output of the one-shot-to circuit U5, U6, and C2 is connected to the clock input of the D-type flip-flop U8, i.e. the output of this flip-flop goes to HIGH level when it is ignited by a narrow pulse from the one-shot-to circuit (U5, U6, and C2). The output of the IC U8 should be connected to one of the three inputs of the OR gate IC9, while the second input of this IC is connected to a control switch S2, which is responsible on the

selection of manual or automatic movement of plastic curtain plate of the proposed system and the third input of the OR gate U9 is connected to the output of the AND gate U11 (SN74LS08 type) which is responsible on automatic rotation of the curtain plate to the upside location when the switch S3 is switched OFF. The output of the OR gate IC U9 is connected to the base of the transistor Tr2 through the resistor R7, Tr2 is a switching transistor which is utilized for switching the relay Re1 ON-OFF. When the output of the OR gate U9 is at HIGH state, then the transistor Tr2 is switched ON, which switches the Re1 ON and this Relay will supply the DC motor by reverse DC voltage that make the motor to rotate in anticlockwise direction. This anticlockwise rotation will move the plastic curtain plate rotationally to the upside location.

The integrated circuits U7 and U12 (type LM393) [10] are in charge of rotation limiting process. U7 is an analog comparator IC which is responsible on limiting process of anticlockwise rotation of the curtain plate toward the upside location, while U12 is also an analog comparator IC which is responsible on limiting the process of clockwise rotation of the curtain plate toward the downside location. As mentioned in the last section, a variable resistor which is called rotation limiting rheostat in the mechanical unit of the proposed system is the main mechanical element of the rotation limiting part. The middle electrical terminal of this rheostat is connected to the non-inverting inputs of the Comparator ICs U7 and U12.

The output of the comparator IC U12 is connected to the CLEAR input of the flip-flop IC U14 via an inverter gate IC U13. When the output of the comparator U12 is activated or in HIGH state, the inverter U13 will change this state to LOW state. That clears the flip-flop U14 and then it generates LOW state output, which will deactivate the transistor Tr1 and then will deactivate the Relay Re2. The output of the comparator IC U7 is connected to the CLEAR input of the flip-flop IC U8 directly. When the output of the comparator U7 is deactivated or in LOW state, this state clears the flip-flop U8 and then it generates LOW state output. This action deactivates the transistor Tr2 and then will deactivate the relay Re1.

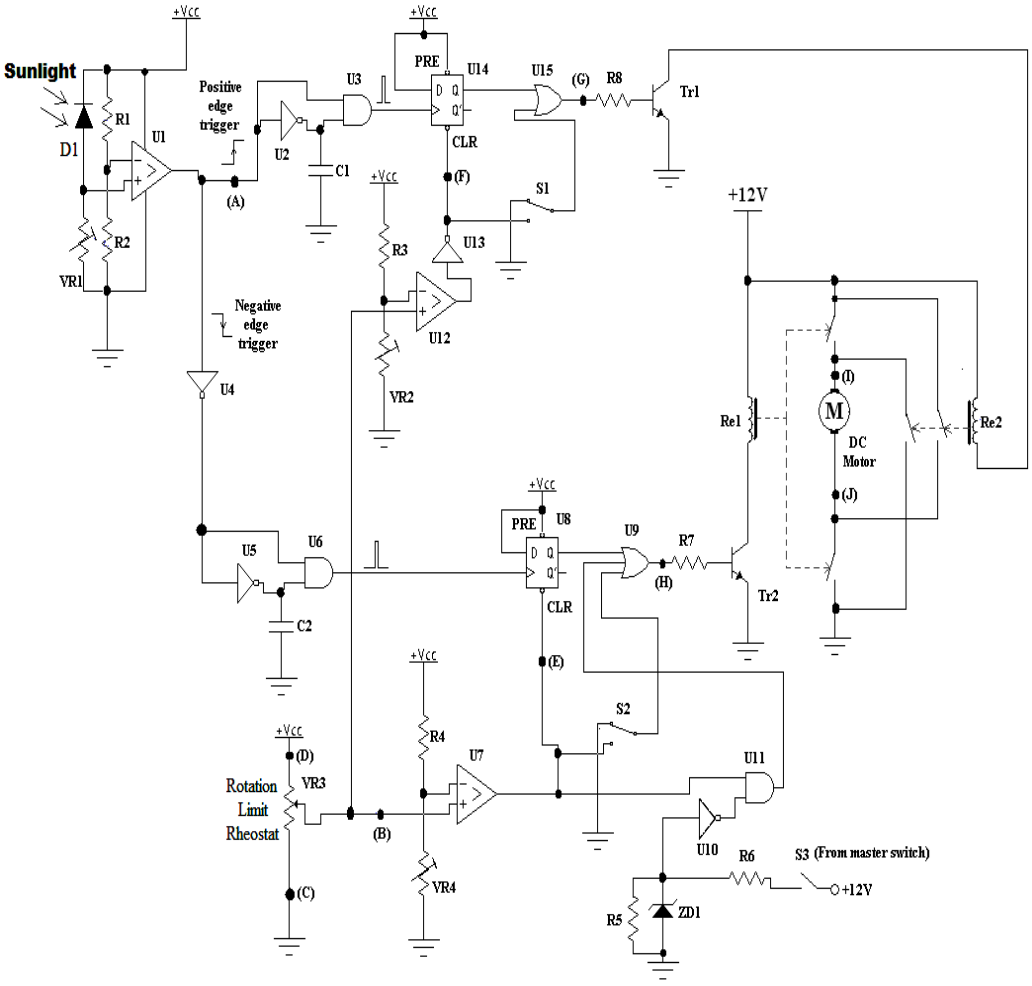

Figure (4): The complete circuit diagram of the proposed system.

ZD1 is a 5.1 Volt Zener diode which is connected in series with the resistor R6 to produce a HIGH level to the input of the inverter IC U10 when the car is switched ON, and to produce LOW level when the car is switched OFF. The curtain plate can be in the downside location when the car is switched ON and the curtain plate will move to the upside location when the car is switched OFF. The implementation of the proposed system is illustrated in Figure 5.

Figure (5): The implementation of the proposed system.

5. Principle of Operation

When the sunlight rays fall on the photodiode surface at an angle similar to the angle of sunlight rays falling on the eyes of the car driver that cause a disturbance to him, the internal resistance of this photodiode will decrease and then the comparator IC U1 will present HIGH level at its output.

The transient of the output level of IC U1 from LOW to HIGH will stimulate the one-shot-to circuit (U2, U3, and C1) to generate a narrow positive pulse at its output. This generated pulse will be applied to the clock input of the D-type Flip-flop IC U14. The output of this Flip-flop will change from LOW to HIGH level and then this HIGH level will activate the OR gate IC U15 to produce HIGH level at its output.

The last HIGH level will activate (through the resistor R8) the transistor Tr1 and then it supplies ON to a bias voltage to the terminals of the coil of the Relay Re2. The Relay Re2 will supply the DC motor with a forward bias voltage to force its shaft to rotate in clockwise direction at speed 2400

rpm. The gear box will reduce this speed to 10 rpm with high torque value. The clockwise rotation of the gear box shaft will move the plastic curtain plate rotationally from upside to downside location.

Before the curtain plate starts to rotate, it stays in a position at the upside location and exactly at the ceiling axial location above the head of the car driver. At this position the rotation limiting rheostat produces a threshold voltage of V_{th1} at the non-inverting input of the comparators U7 and U12. In this case the output of the comparator U12 is at LOW level, and the output of the comparator U7 at HIGH level. While the curtain plate continues in its rotation, it will reach to downside position, where the limiting rheostat produces a threshold voltage of V_{th2} at the non-inverting input of the comparators U7 and U12. In this case the output of the comparator U12 at HIGH level, which is changed to LOW level by the inverter IC U13. Then this LOW level will clear the Flip-flop IC U14, i.e. the output of this Flip-flop will be in LOW state. This state will deactivate the transistor Tr1. Then the DC motor will be switched OFF and the motor will be stopped at downside position which is the location in front and above the car driver. In this case the curtain plate will prevent the sunlight from falling onto the eyes of the car driver.

When the sunlight rays fall on the car with an angle different from the angle of the ray that disturb the car driver, the sunlight rays will stop to fall onto the surface of the photodiode due to the existence of the plastic light director. Then the internal resistance of this photodiode will increase and drive the comparator IC U1 to produce LOW level at its output.

The transient of the output level of IC U1 from HIGH to LOW will stimulate the one-shot-to circuit (U5, U6, and C2) to generate a narrow positive pulse at its output. This generated pulse will be applied to the clock input of the D-type Flip-flop IC U8, and then the output of this Flip-flop will change from LOW to HIGH level. Then this HIGH level will force the OR gate IC U9 to produce HIGH level at its output. The last HIGH level will activate (through the resistor R8) the transistor Tr2 to switch ON, which causes to supply a bias voltage on the terminals of the coil of the Relay Re1. Then the Relay Re1 will supply the DC motor with a reverse bias voltage to force its shaft to rotate with anticlockwise direction at speed 2400 rpm. The gear box will reduce this speed to 10 rpm with high torque

value. The anticlockwise rotation of the gear box shaft will move the plastic curtain plate rotationally from downside to upside location.

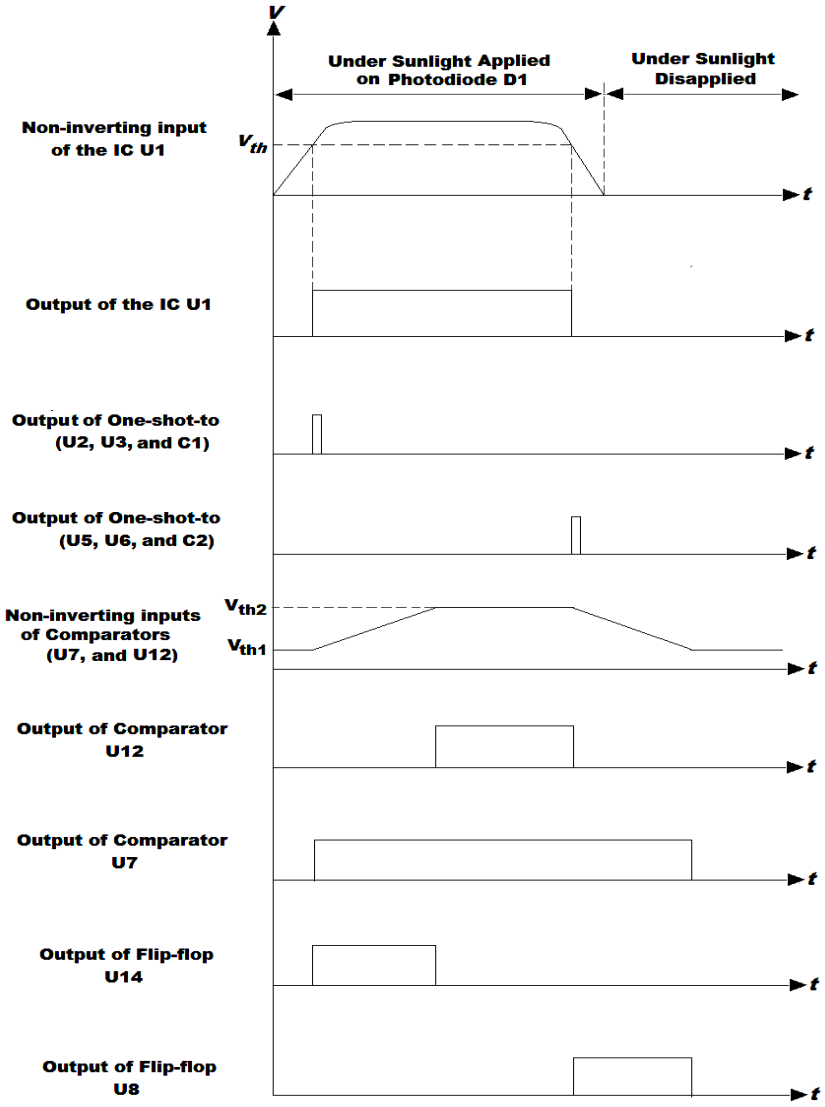

Figure (6): State transition diagram of control unit of the proposed system.

Before the curtain plate starts to rotate from downside to upside, it stays in downside position at the downside location and exactly in front of and above the head of the car driver. At this position, the rotation limiting rheostat is at downside position, and that produces a threshold voltage of V_{th2} at the non-inverting input of the comparators U7 and U12. In this case the output of the comparator U7 is at HIGH level, and the output of the comparator U12 is at HIGH level.

While the curtain plate continues in its rotation, it will reach to upside position, where the limiting rheostat produces a threshold voltage of V_{th1} at the non-inverting input of the comparators U7 and U12. In this case the output of the comparator U7 is at LOW level. Then this LOW level will clear the Flip-flop IC U8, i.e. the output of this Flip-flop will be in LOW state. This state will deactivate the transistor Tr2 and then relay Re1 will be switched OFF. The DC motor will be switched OFF and stopped at upside position, which is the location at the ceiling and above the car driver. The state transition diagram of the main internal signals of control unit of the proposed system is illustrated in Figure 6.

6. Conclusions

By using proposed design, the consumed current is measured and it is approximately 0.8 Amp. This consumed current is so little if it compared with the current capacity of car battery, and this is considered as first powerful feature of this system. The second powerful feature of the proposed system is the low cost, which is because of using low cost mechanical parts, relays, and electronic component.

Due to the use of high speed analog comparators, switching transistors, TTL logic integrated circuits; the control unit of the proposed system is characterized by high speed of operation, where the frequency response of the control unit is approximately 50 MHz.

In fact, the proposed system makes the car driver so comfortable, because when the sunlight rays fall on the eyes of the car diver, he does not busy with moving of the sunlight curtain plate. In the traditional system, the car driver is busy by moving the curtain plate when the sunlight rays fall on his eyes.

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تصميم و تنفيذ حاجب ضوء الشمس الذاتي الحركة للسيارات باستخدام دوائر إلكترونية رقمية

م. د. أزاد بدر سعيد*

المستخلص: تم في هذا البحث تصميم و تنفيذ تقنية جديدة مبتكرة لحاجب ضوء الشمس الكهروميكانيكي ذاتي التحريك, وتعتمد هذه التقنية على سقوط أشعة ضوء الشمس على ثنائي حساس للضوء بزاوية مطابقة لتلك التي تسقط بها الأشعة على عيني سائق السيارة والشخص الذي يجلس بجانبه فتجعلهم مُنزعجين و غير مرتاحين. إنَّ المنظومة المُقترحة قد بُنيَت من اربعة أجزاء رئيسية و هي:الثنائي الحساس للضوء و المُقارن التابع له, وحدة السيطرة, محرك التيار المستمر 12 فولت مع وحدة التعشيق, ولوحة حاجب الضوء البلاستيكية مع بعض الأجزاء الميكانيكية. عند سقوط أشعة الشمس الضوئية على الثنائي الحساس للضوء بزاوية غير مرغوب بها, سوف يقوم هذا الثنائي بتقديم إشارة تنشيط الى دائرة السيطرة والتي سوف تقوم بدورها بالإيعاز الى المحرك الكهربائي الذي سوف يدور بإتجاه عقرب الساعة و بالتالي سيقوم بتدوير لوحة حاجب ضوء الشمس الى الموقع الاسفل بحيث تقوم هذه اللوحة بمنع سقوط أشعة الشمس الضوئية المزعجة على عيني سائق السيارة والشخص الذي بجانبه. تمَّ فحص المنظومة المقترحة عملياً في مختلف الظروف البيئية و مختلف فصول السنة و قد أظهرت نتائج مؤثرة في النفس.

كلمات المفتاحية: المقارنات، Flip-flop، One-shot-to، الصمام الثنائي ضوئي، ستارة ضوء الشمس.

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