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DESIGN AND IMPLEMATION OF TRAFFIC LIGHT CONTROL USING D-FLIP FLOP

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Abstract – A VLSI-based traffic light control system designed using D flip-flops as the primary sequential elements. In the proposed design, D flip-flops act as memory units that retain the present state of traffic signals such as red, yellow, and green. Through appropriate logical design and timing control, the system ensures an orderly and efficient transition between traffic light phases. The project further focuses on the design, implementation, and performance evaluation of a 2-bit binary counter realized using D flip-flops. Binary counters are essential components in digital systems and are widely applied in timing circuits, digital clocks, and control units. A 2-bit counter is capable of generating four distinct states, ranging from 00 to 11 in binary form, and automatically resets to the initial state after reaching its maximum count. The design methodology involves configuring two D flip-flops such that the state of each flip-flop is determined by the present output conditions. State transition behavior is derived using a state table, followed by the formulation of corresponding logic equations. The counter operates synchronously with the clock signal, responding to either the rising or falling edge based on the flip-flop characteristics. Performance evaluation includes an analysis of propagation delay, power dissipation, and operating speed. The integration of the 2-bit D flip-flop counter into the traffic light controller enables reliable state storage and precise control of signal transitions. With two input bits representing the current traffic state and two output bits driving the signal lamps, the proposed system demonstrates an effective application of digital logic in traffic management. This work provides a structured foundation for implementing compact, reliable, and efficient traffic control systems using VLSI design principles, ultimately contributing to improved road safety and intersection efficiency.

Key words: D Flip-Flop, VLSI Design, Sequential Logic Circuit, 2-Bit Binary Counter, Finite State Machine (FSM), Digital Traffic Control System, Clock and Timing Control.

1. INTRODUCTION

The application of VLSI technology in traffic light control systems enables the development of compact, high-performance, and energy-efficient solutions for modern traffic management. By utilizing D flip-flops as core sequential elements, the proposed system efficiently regulates traffic signals through well-defined state transitions. Traffic signal systems play a critical role in controlling vehicle and pedestrian movement at road intersections, where accurate timing and reliable sequencing are essential for safety and smooth traffic flow. D flip-flops, as fundamental components of sequential digital circuits, provide the capability to store and update system states in synchronization with a clock signal. Their integration into traffic light controllers enhances operational stability and enables precise control over signal transitions. The use of a 2-bit D flip-flop configuration allows the system to represent multiple traffic states effectively, directly influencing the order and duration of signal phases such as red, yellow, and green. The successful realization of such a system requires meticulous planning during the design and implementation stages. This includes defining functional requirements, selecting suitable flip-flop configurations, and ensuring seamless integration with associated logic circuits. Equally important is rigorous

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testing and validation to confirm the reliability and performance of the system under various operating conditions. This introduction provides a foundation for a detailed examination of the design and implementation of a 2-bit D flip-flop–based traffic light controller, highlighting its role in improving traffic regulation efficiency and enhancing overall road safety.

2. DESIGN

The initial simulation of the proposed system, the required components include D flip-flops, IC 7408 (AND gate), IC 7404 (NOT gate), a function generator, a +5 V power supply, and LEDs for visual output. Two D flip-flops are labeled as D1 and D2. Each flip-flop has its own clock input, named CLK1 and CLK2, along with complementary outputs Q and $\bar{Q}$. The clock input CLK1 of the first flip-flop (D1) is connected to the function generator, which provides a square wave signal to operate the circuit. The D input of D1 is connected to its complementary output ($\bar{Q}1$). The same clock signal is also given to the clock input of the second flip-flop (D2). The D input of D2 is connected to its complementary output ($\bar{Q}2$), allowing proper switching between states.The output Q1 of D1 is connected to the positive terminal of the yellow LED and also connected to the input of a NOT gate in IC 7404. The output of the NOT gate is combined with $\bar{Q}2$ using an AND gate in IC 7408, and the output of this gate drives the red LED. In a similar manner, $\bar{Q}1$ from D1 and Q2 from D2 are connected to another AND gate in IC 7408, and its output is connected to the green LED. All ICs are powered using a +5 V supply, and all ground pins are connected together along with the negative terminals of the LEDs. This arrangement allows the traffic lights to change in a fixed sequence based on the clock signal provided by the function generator.

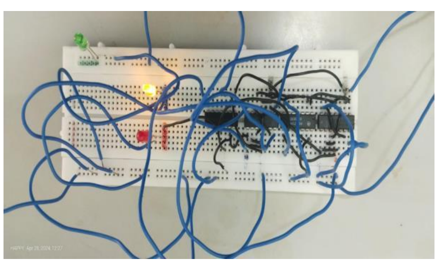

Fig. 1: Hardware implementation

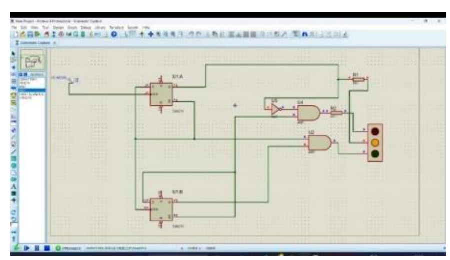

Fig 2: Proteus simulation

Table 1: Components required

Sl. No.	COMPONENTS	QUANTITY
01.	D FLIOP-FLOP	01
02.	IC7404	01
03.	IC7408	01
04.	LED	01
05.	FUNCTION GENARATOR	10

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3. SPECIFICATION OF COMPONENT

D flip-flop is a core element in digital electronics, widely used in sequential logic systems for data storage and timing control. It is designed to hold a single bit of information and plays a crucial role in preserving the state of digital circuits. The term "D" represents "data," as the device operates with one primary data input and provides two complementary outputs. The data input (D) determines the value that will be stored in the flip-flop. This value is captured and transferred to the output only when a triggering event occurs at the clock input. The clock (CLK) serves as a synchronization signal that governs the exact moment when the flip-flop updates its stored data. Depending on the design, the state change occurs at either the rising or falling edge of the clock pulse. The outputs of the D flip-flop consist of Q and its inverse $\bar{Q}$. The Q output reflects the currently stored logic state, while $\bar{Q}$ always maintains the opposite logic level. When the output Q is at a high logic level, $\bar{Q}$ remains low, and when Q is low, $\bar{Q}$ becomes high. This predictable behavior makes the D flip-flop an essential component in counters, registers, and control circuits.

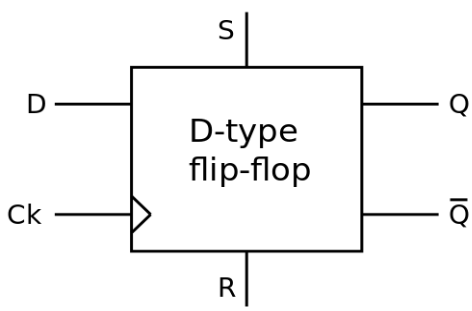

Fig. 3. Block diagram of D flip-flop

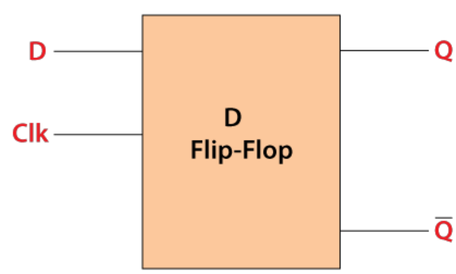

Fig. 4. Block diagram of D flip-flop

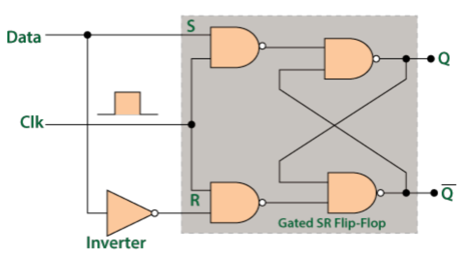

Fig. 5. Circuit diagram of D flip-flop

Truth Table for the D-type Flip Flop

Clock	D	Q	Q'	Description
↓ » 0	X	Q	Q'	Memory no change
↑ » 1	0	0	1	Reset Q » 0
↑ » 1	1	1	0	Set Q » 1

Fig. 6. Truth table of D flip-flop

IC7404 is a digital logic device that contains six independent NOT gates, also known as hex inverters, integrated within a single package. Each inverter performs a logical inversion operation, where the output state is the opposite of the input logic level. When a logic high signal is applied at the input, the corresponding output produces a logic low signal, and conversely, a logic low

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input results in a logic high output. All six inverters operate independently, allowing the IC to perform multiple inversion operations simultaneously within a digital circuit. The IC functions reliably with a standard supply voltage of 5 V, where a high-level input voltage is typically recognized at 2 V and above, while a low-level input voltage is detected at approximately 0.8 V or below.

The IC integrates six separate NOT gates within a single 14-pin DIP package. It can be directly connected with CMOS, NMOS, and TTL logic families, which allows it to be used in a wide range of digital applications. The device operates over a broad voltage range and delivers consistent and dependable performance under various operating conditions.

Specifications	
Device Type	Bipolar DIP
Supply Voltage Range	4.75 V to 5.25 V
Maximum Output Current	16 mA
Operating Temperature Range	0°C to 70°C
Pin Count	14
Mounting Type	Through-hole

Fig. 7. IC7404

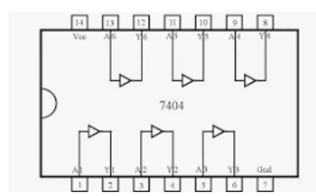

Fig. 8. Pin diagram of IC7404

IC7408 is a digital logic integrated circuit that incorporates four independent two-input AND gates within a single 14-pin package. Each AND gate produces a high output only when both of its inputs are at a logic high level, making the device suitable for various combinational logic applications. The IC features push-pull output stages that ensure reliable signal driving capability. This device is designed to operate over a wide supply voltage range, typically from 2.0 V to 6.0 V, and is implemented using advanced silicon-gate CMOS technology. As a result, it offers switching speeds comparable to LS-TTL logic while maintaining low power consumption characteristic of CMOS circuits. The buffered outputs provide enhanced noise immunity and allow

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the IC to drive multiple LS-TTL loads effectively. The IC 7408 belongs to the 74HC logic family, which is both functionally and pin-compatible with the standard 74LS series. Additionally, all input pins are protected against electrostatic discharge through internal diode clamping to the power supply and ground, improving the device's reliability in practical applications. The IC integrates four separate two-input AND gates within a single 14-pin DIP package. It is designed to connect easily with CMOS, NMOS, and TTL logic families, allowing its use in many digital circuit applications. The device functions over a wide range of supply voltages and ensures consistent and dependable operation under various working conditions.

Specifications	
Device Type	Bipolar DIP
Supply Voltage Range	2.0 V to 6.0 V
Operating Temperature Range	0°C to 70°C
Pin Count	14
Mounting Type	Through-hole

Fig. 9. IC7408

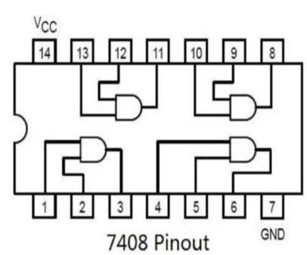

Fig. 10. Pin diagram of IC7408

A light-emitting diode (LED) is a solid-state electronic component that produces visible light when an electric current passes through it. The light generation process occurs due to the recombination of charge carriers—electrons and holes—within the semiconductor material, resulting in the emission of energy in the form of photons. The wavelength, and hence the color, of the emitted light depends on the band gap energy of the semiconductor used in the device. Different semiconductor materials require varying energy levels for electrons to move across the band gap, which directly determines the color of light produced by the LED. Due to their efficiency,

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reliability, and low power consumption, LEDs are widely used as visual indicators and lighting elements in electronic systems.

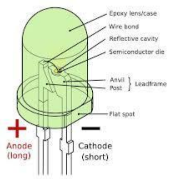

Fig. 11. Diagram of LED

Fig. 12. Symbol of LED

A function generator is an electronic testing instrument, implemented either as hardware equipment or software, that is used to produce a variety of electrical waveforms across a broad frequency range. Commonly generated signals include sine, square, triangular, and sawtooth waveforms. These signals may operate in continuous (repetitive) mode or in single-shot mode, which requires either an internal or external triggering mechanism. Many function generators also offer the capability to superimpose a direct current (DC) offset on the output waveform. Integrated circuits designed specifically for waveform generation are also referred to as function generator ICs.

A general-purpose function generator is capable of producing different types of waveforms such as sine, square, triangular, ramp, and pulse signals. In addition, arbitrary waveform generators can create waveforms of any required shape. These instruments operate over a wide frequency range; for example, the Tektronix FG-502 can generate signals from 0.1 Hz up to 11 MHz.The frequency stability of analog function generators is typically around 0.1% per hour, while digital generators offer higher stability of about 500 parts per million (ppm). For sine wave outputs, analog generators usually have a distortion level of approximately 1%. In comparison, arbitrary waveform generators provide much lower distortion, below −55 dB for frequencies under 50 kHz and below −40 dB for higher frequencies. Some function generators can be synchronized with an external signal source using phase-locking techniques. They may also support modulation methods such as amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM). The output voltage can be adjusted up to 10 V peak-to-peak using calibrated controls. Certain models allow the addition of a DC offset, typically adjustable between −5 V and +5 V. The standard output impedance of a function generator is usually 50 ohms.

Fig. 13. Function Generator

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4. RESULT ANALYSIS

A square wave signal generated by the function generator is applied to the CLK1 input on the breadboard to drive the circuit. The operating frequency of the input signal is varied from 1 Hz to 5 kHz to observe the system's response. At lower frequencies, the LEDs exhibit a visible switching pattern, with each LED remaining illuminated for approximately three seconds. As the input frequency is gradually increased, the duration for which each LED remains ON decreases proportionally. At higher frequencies, the switching becomes too rapid for the human eye to perceive distinctly, causing the individual LED transitions to appear continuous or indistinguishable. This behavior confirms the dependency of the traffic light timing on the applied clock frequency and demonstrates the correct functional operation of the designed circuit.

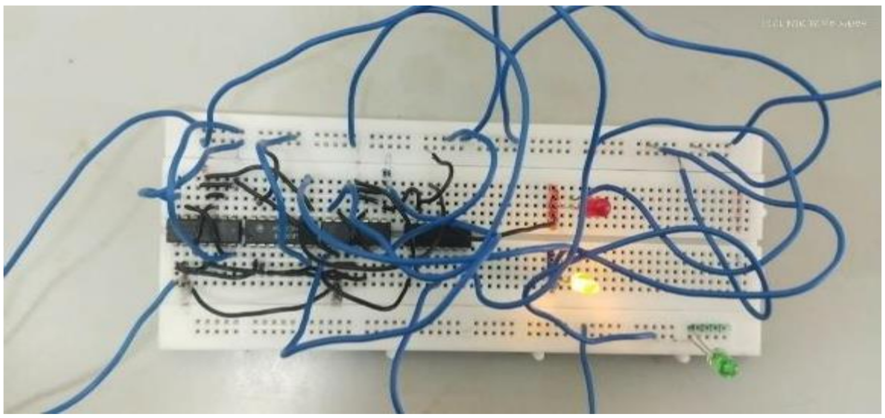

Fig. 14. Implementation of circuit for traffic control

5. CONCLUSION

In the above project, we can conclude that the traffic light which has been design above can be operated from 1Hz to 20Hz safely. For all other frequency from the function generator the time interval of glowing LED is very less.

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