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Systematic Analysis of Sequential Circuits in Digital Clock and It Display Mode Comparison

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Abstract: The design idea of the seven-segment digital tube electronic clock and its potential applications against a contemporary backdrop are the main topics of this study. The seven-segment digital clock's low cost and straightforward design make it popular, especially for gadgets with tight budgets. Accurate time reading, adjustment, countdown, and warning functions are achieved through the study and design of a range of digital circuits, demonstrating the broad application potential of digital logic in time control. The circuit's synchronization, stability, and operability are checked using the Multisim simulation tool, guaranteeing the design's dependability in real-world applications. The findings of the study demonstrate the seven-segment digital clock's long-term utility in particular situations, particularly in settings where affordability and durability are crucial. However, the seven-segment digital clock is also under pressure from competitors due to the growing popularity of new display technologies like OLED and smart technology. According to the research, it can continue to be used in particular industries in the future by merging intelligent characteristics to broaden its range of applications.

Keywords: Seven-segment Digital Clock, Digital Circuit, Time Control, Multisim Simulation

1. Introduction

The increasing need for time management in human civilization, which reflects the complexity of economic activity, the level of science and technology, and the ongoing advancement of social progress, led to the creation and development of the clock. The clock serves not only as a precondition and instrument for managing daily time, initially characteristic of European industrial societies and subsequently of industrial societies at large, but also as a symbol of the European modernization process [1].

One type of LED diode used to display decimal numbers is called a seven-section show (SSD). In digital meters, digital clocks, simple calculators, and other electronic gadgets that display numerical data. The seven-segment module, which has 10 pins—two for the GND connection, one for the dot connection, and the remaining seven for the number of SSDs—is used to show the number of persons who registered [2]. In addition to altering how time is shown in everyday life, it has accelerated the switch from mechanical to digital, electronic displays. The seven-segment digital clock's fundamental component is the digital logic sequence circuit, whose output is dependent on both the current input and the previous state in order to complete an exact time measurement while being synchronously controlled by the clock signal. Each clock module, including carry, borrow, and base conversion logic

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operations, is designed and simulated in this study using Multisim software. Ultimately, time reading, adjustment, countdown, alarm, and other applications are realized. This design demonstrates the seven-segment digital tube clock's broad range of potential uses in contemporary digital electronic technology.

2. Seven-digit tube design

Digital storage oscilloscopes emerged approximately twenty-five years ago. At that point, their performance was constrained, failing to match that of contemporary analog (cathode ray tube) storage oscilloscopes in most aspects, particularly bandwidth. Nonetheless, they included certain features absent in previous analog storage oscilloscopes, primarily pre-trigger storage, enabling the user to capture a portion of a waveform that occurred before a trigger event [3]. The seven-digit digital clock design is an electronic clock that uses seven segments of digital tubes to display the time. The seven-segment digital tube is an electronic component used to display Arabic numerals, which can display the numbers 0 to 9 by controlling the lighting of different segments. Therefore, designing a clock using a seven-bit digitizer is a classic electronic circuit design project that can often be used to demonstrate the application of digital circuits and microcontrollers.

2.1. Design principle

A clock signal was applied as the CLK for the unit of seconds. The most important part was the CLR and it was necessary to ensure that when the unit bit is 9, a low level to the CLR will be the input, and when the unit bit is other numbers, a high level to the CLR should be guaranteed since CLR is low level effective. That's why firstly pins 12 and 14 were connected to NOT gates, and then connected together with pins 11 and 13 to NAND gates as inputs for CLR as shown in the figure 1 for basic clock circuit and different bases.

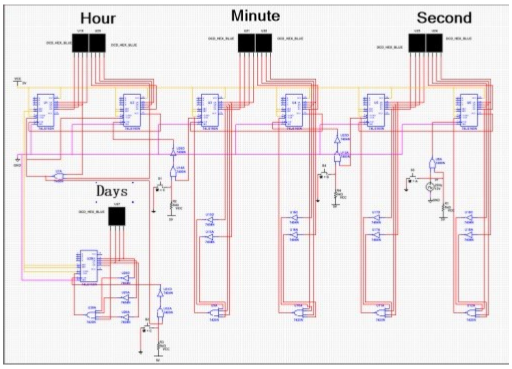

Figure 1: Basic clock circuit

The logic of the tens of seconds is similar to what was previously mentioned. The difference is that its CLK was connected to the RCO of the bits (green line in the figure), and it needs to be set to zero at 6. Same method of using NOT gates and NAND gates mentioned above was applied again, but the connection of NOT gates was needed to be changed by connecting pins 11 and 14 to NOT gates. It also needed to be noted that the zero terminal of this part was connected to the CLK of the unit of the minute part, which meant that the second enters the minute at 60 (black line in the figure).

2.2. Use of Multisim

NI Multisim is a free web-based platform developed by National Instruments that aims to provide significant simulation tools to revolutionize the way people study circuits [4]. In Multisim,

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components including switches, 7-segment and clock signals can be found in the library, added into the circuit and modified. Once the wires are connected, press the button "run" in the "simulation" column then the simulated result can be seen on the display elements.
Clock comparison of different display devices

2.3. Detailed design

The key to build this circuit lies in how to set up base-60 and base-24. An example of the design of Second part will be explained and the Minute is similar.as shown in the figure 2.

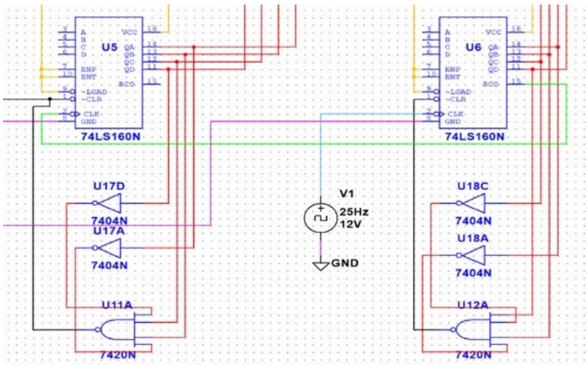

Figure 2: Realization of Second

The minute was basically the same as the second, so it is no longer repeated. Here is how to implement the 24-hour decimal system for hours. As shown in the figure 3, to achieve the zero-setting function for the hour section, the 12 pin of the hour bits were connected and the 13 pin of the hour bits to the NAND gate, and use the output of the NAND gate as the input of the CLR. (2 is 0010 and 4 is 0100 in binary).

The day of the week part is the simplest since the only one thing needed to ensure that it is set to zero at 7, and the idea was still to use NOT gates and NAND gates.

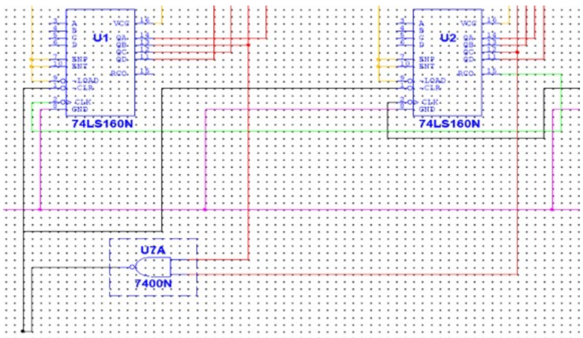

Figure 3: Realization of Hours

3. Digital clock different display mode comparison

3.1. LCD clock

The LCD clock use liquid crystal display technology to illuminate the panel by backlight or reflected light sources, capable of presenting extensive information in digital or textual format. The technical idea is based on the configuration of liquid crystal molecules, which show characters or images by regulating light transmission, supplemented by backlighting to improve display quality and visibility. The primary advantage of LCD is its capability to exhibit a variety of content, including numbers, graphics, symbols, and full text, to accommodate diverse informational display requirements [5]. Simultaneously, LCD power consumption is remarkably little, particularly in the absence of backlighting (as seen in ebook-style reflecting LCDs), rendering it especially appropriate for portable devices.

Furthermore, due to the capability of LCD screens to be produced in ultra-thin configurations, they are significant in the domain of mobile devices, including smartwatches, portable displays, and mobile phones. Nonetheless, LCDs possess several limitations, including narrower viewing angles and a potential need for enhanced backlighting in brightly lit settings to maintain clarity. Simultaneously, its luminosity is inferior than that of LED, and it cannot function adequately in exceedingly dim settings without backlighting. Consequently, LCDs are frequently employed in low-power gadgets and items necessitating prolonged display durations, including digital watches, electronic clocks, mobile phones, calculators, and monitors. The minimal power consumption of the LCD clock not only prolongs the device's battery life but also guarantees reliable operation of the portable device under constrained energy conditions, highlighting its significance and prospective applications in portable technology.

3.2. LED clock

LED clocks utilize dot-matrix or light-strip light-emitting diodes (LEDs) to exhibit time, providing big, luminous digital displays and the capability to showcase basic graphics. The theory is based on the electroluminescence effect of light-emitting diodes, which emit light upon being activated. The high brightness feature of the LED clock renders it particularly ideal for both indoor and outdoor applications, ensuring a clear display even in bright light or at considerable distances. In comparison to alternative display technologies, LED clocks offer diverse color display effects and exhibit rapid responsiveness to dynamic information and basic animations [6]. The LED clock is extensively utilized for information transmission and time display in public venues, including stadiums, airports, and train stations.

Nonetheless, the elevated luminosity and substantial dimensions of LED displays result in increased energy consumption issues, particularly in comparison to LCD and seven-segment nixie technologies. In applications requiring substantial size and high luminosity, the energy consumption of LEDs escalates markedly, particularly for all-weather displays. Moreover, the production process of LEDs is more intricate, particularly for full-color displays, resulting in elevated manufacturing costs. The LED clock, because to its vibrant color display and dynamic capabilities, is appropriate for short-term events necessitating high brightness; however, its energy consumption requires optimization to fit various application scenarios.

3.3. VR clock

The VR clock, functioning as a time display apparatus, employs virtual reality technology to render the clock as a three-dimensional model or virtual interface, allowing users to see the time within a virtual environment via VR headsets (such as VR glasses). This design transcends a mere time display, prioritizing an immersive experience. By integrating the clock within the virtual scene, users may access time information at any moment within their preferred location. Due to the distinctive attributes of virtual reality, VR clocks can be tailored into diverse configurations, such as a prominent 3D clock positioned centrally in the virtual conference room, or a diminutive clock icon located in the periphery of the user's visual field, thereby enhancing the flexibility and convenience of time information retrieval [7]. The immersive and adaptable nature of the VR clock facilitates its seamless integration into the virtual environment, resulting in a more personalized and inventive representation of time.

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Virtual reality clocks also advantage from their highly adjustable design and versatility. Beyond only indicating time, the VR clock can exhibit intricate data and incorporate many interactive features, transforming it from a simple "clock" into a comprehensive information hub within the virtual realm. For instance, VR clocks can exhibit timetables, task reminders, and seamlessly interface with other applications to furnish users with an all-encompassing time and task management experience. Nonetheless, the disadvantage of VR clocks is their dependence on VR gear, which presently has low market adoption [8]. Moreover, the elevated resolution and minimal latency demands of virtual reality devices result in significant power consumption for VR clocks, necessitating robust computational and power support. In straightforward time display activities, the utilization of a VR clock may appear overly intricate for effective resource allocation.

The VR clock is primarily designed for virtual gaming, virtual meetings, and virtual workplaces. In these virtual settings, the immersive time display fulfills users' fundamental requirements while also facilitating task management and time reminders within VR scenarios. Notwithstanding the substantial power consumption of the VR clock, its immersive experience, adaptable design, and interactive functionalities have established a novel approach to time management within the virtual realm, transcending the confines of conventional two-dimensional displays.

3.4. Compare and Analyze

Then, this paper makes a simple comparison of the display complexity, visual effect, energy consumption, application scenario, cost and interactivity of the seven-segment digital tube clock, the LCD clock, the leader clock and the virtual reality clock, which can be more intuitive and convenient to compare. Canonical contrast is shown in Table 1.

Table 1: Canonical contrast

	Seven-segment Digital Tube Clock	LCD Clock	LED Clock	VR Clock
Display Complexity	Low, only numbers can be displayed	Medium Can display numbers, text and images	Medium High brightness, can display simple images	High Can be customized for display in 3D scenes
Visual Effect	Simple intuitive and effective symbol display	Low Brightness, clarity depends on ambient light	High brightness Suitable for long distances or outdoors	Strong sense of immersion, suitable for virtual reality environment
Energy Consumption	Lower	Extremely Low	Higher	High
Application Scenarios	Home clocks and timers	Electronic equipment, watches, monitors	Large display screens, billboards, public places	VR games, virtual offices, meetings, etc.
Cost	Low	Lower	Higher	High, dependent on VR hardware and technology
Interactivity	Low	No interaction	No interaction	High, more interactive elements can be integrated

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Seven-segment digital tube clock: simple, economical and efficient, suitable for ordinary household and industrial equipment. Although relatively backward in technology, it still has strong vitality in terms of low cost, durability and simplicity.

LCD clock: Featuring energy saving and multi-information display, it is the first choice for a large number of portable devices in life. It is used in a wide range of applications, from digital watches to home electronic devices, and is able to balance cost and function well.

LED clock: Because of its high brightness and dynamic display capability, LED clock is widely used in public places where eye-catching display is required. The continuous advancement of LED technology has also made it more energy efficient and diverse in large-scale displays, and may be more combined with intelligent systems in the future.

VR clock: represents the cutting-edge application of time display in the field of virtual reality, although the current practicality is limited, but with the popularity of VR technology, the demand for time management in the virtual world will gradually increase. In the field of virtual office, entertainment or education, VR clock will have a broader application prospect.

4. Challenges and prospects for the future

As a classic electronic display technology, the seven-segment digital tube clock has been widely used in the past decades. However, with the advancement of technology and the change of user needs, the seven-segment digital tube clock faces some challenges, but also has potential development opportunities. The following is an analysis from two aspects: technical challenges and future prospects.

4.1. Challenge

The limitations of the display capability, the seven-segment nixie clock can only display 0-9 numbers, and a very limited number of symbols, cannot display complex information. Aesthetic and design sense is insufficient, the design of the seven-section digital tube is very simple, usually only in a fixed style to display the number, it is difficult to achieve a diversified, personalized appearance design. Energy efficiency issues, in portable devices, low power consumption is a key requirement, seven-segment digital tube compared to LCD clock, in terms of battery life is inferior [9].

With the rise of new display technologies such as OLED and electronic ink (E-ink), seven-segment digital tubes are facing increasingly strong competition. With the popularity of the Internet of Things (IoT) and smart homes, modern clocks often need to have more functions, such as synchronizing with smartphones, displaying weather information, receiving notifications, and so on. The seven-segment nixie clock is difficult to achieve these intelligent requirements due to its limited display capacity.

4.2. Future outlook

Although the seven-segment digital tube clock faces greater challenges in terms of display capability, aesthetics and intelligence, it still has advantages in specific areas. In the future, it is likely to exist more as a low-cost, simple and durable display technology, especially in low-budget equipment, harsh environments and industrial applications [10]. By improving energy efficiency, materials and design, as well as combining with smart technology, the seven-segment tube clock has the potential to find new market opportunities and continue to play a role in specific areas of digital display.

5. Conclusion

In this experiment, the comparison principle of carry, borrow, logic circuit and sequential circuit is fully utilized to realize the clock, countdown, time adjustment and alarm functions mentioned above.

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The core of the project is to build a synchronous system using timer and counter circuits to achieve accurate time display and control. This project will have a wide range of applications, including daily clocks, event timers, and kitchen timers, so it is recommended to repeat and make more improvements on this project. The future prospects of this research entail more functional and technical enhancements to the seven-segment digital tube clock. Future study could explore the implementation of more efficient digital logic circuits to enhance high-precision time control and multifunctional integration, thereby reducing energy consumption and improving stability.

Furthermore, with the advancement of the Internet of Things and smart home technology, the seven-segment digital tube clock can be augmented with intelligent functionalities, enabling it to not only display the time but also receive notifications, present weather information, or interact with other devices. Simultaneously, future exploration may focus on materials or structural designs for display technology that can withstand extreme environments, thereby enhancing their applicability in specialized domains such as industrial settings and medical monitoring. These enhancements will enable the seven-segment nixie clock to maintain its fundamental advantages of affordability and durability while accommodating contemporary requirements.

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