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Fault Diagnosis and Redundant Technique for 24 Hours Clock Design Using VHDL

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Abstract: ***In digital systems, precise timekeeping and fault tolerance are essential, especially in mission-critical applications. This project presents the design and implementation of a 24-hour digital clock using VHDL (VHSIC Hardware Description Language) with integrated fault diagnosis and redundancy techniques. The primary objective is to ensure the accurate display of time and the continuous operation of the clock even in the presence of faults. A redundant architecture is employed to provide backup operations in case of component failure, and diagnostic logic is incorporated to detect and isolate faults in real-time. Keywords: Test Vector Generator, Carry-out, Work mode, Repair mode, Test mode.***

I. INTRODUCTION

Digital clocks are widely used in modern electronic systems for precise timekeeping and control. Among these, the 24-hour format clock is preferred in applications such as transportation, military, automation systems, and industrial control, where accurate and uninterrupted time tracking is essential. However, digital systems are prone to faults due to hardware failures, signal disturbances, or environmental factors, which can compromise the reliability of time-sensitive applications. To address this issue, fault-tolerant design techniques are increasingly being integrated into digital systems. Redundancy and fault diagnosis mechanisms play a critical role in enhancing system reliability by detecting, isolating, and correcting faults without interrupting system functionality. This project aims to design a 24-hour clock using VHDL, a powerful hardware description language suited for modeling digital systems. The design incorporates a fault diagnosis mechanism to monitor the clock's operation and identify anomalies. Additionally, a redundant architecture is implemented to ensure continuous functionality even if a fault occurs. The use of VHDL allows for precise hardware-level simulation, synthesis, and real-time implementation on programmable logic devices such as FPGAs, making the system suitable for real-world deployment. Digital clocks are timekeeping devices that display the time using digits, typically based on a 24-hour or 12-hour format. Unlike analog clocks, which use hands to represent hours, minutes, and seconds, digital clocks present time in a straightforward numerical form, making it easier and quicker to read.

II. LITERATURE REVIEW

In the modern world, time management has become a critical aspect of daily life, and digital clocks serve as an efficient and reliable means of keeping time. Unlike analog clocks, digital clocks offer several advantages that make them indispensable in various environments. They provide precise and easily readable time displays, which are especially useful in situations where quick and accurate time referencing is essential. The need for digital clocks arises from the demand for automation, synchronization, and integration in systems like communication networks, transportation systems, industrial machinery, and home appliances. Their ability to interface with digital electronics and microcontrollers makes them ideal for embedded systems. Additionally, digital clocks can be programmed to include features like alarms, timers, and time zone adjustments, further enhancing their utility. As technology advances, the integration of digital clocks in smart devices and IoT applications continues to grow, reinforcing their role in ensuring efficiency, productivity, and convenience in everyday life. The existing system operates in two main modes: working mode and test mode. The existing system uses various modules, such as counters, bus multiplexers, test vector generator, comparator and a BCD seven segment display. The counter modules in the system are essential for accurately tracking and displaying time. There are four counters, each plays a specific role based on their module such as two Mod-10, Mod-6 and Mod-3 counters [1-5].In working mode, these counters are connected in series. First Mod-10 counter keeps track of minutes (0-9), the Mod-6 counter counts ten minutes (0-5), second Mod-10 counter counts hours (0-9), and the Mod-3 counter increments to ten-hours. (0-2). This series configuration allows the system to keep and show time in a standard 24-hour format.

In test mode, the counters are reconfigured in parallel mode enables the counters to be tested individually for faults by applying test vectors to the comparator, the outputs of test vector generator and comparator differs then fault is identified and it can be corrected.

The control signal is applied to the bus multiplexer selects the counter, then counter output compares both outputs of bus

multiplexer output and test vector generator results to correct the fault in the system and displayed with the help of BCD seven segment display. It converts binary coding to decimal format for BCD seven segment display and checks for discrepancies. If any issues are detected, the comparator helps in fault identification and diagnosis by the problem counter and generating diagnostic output. This testing process ensures the system's long-term reliability by providing information for diagnosing and fixing any issues.

III. PROPOSED SYSTEM ARCHITECTURE MODEL

The proposed system is a fault-tolerant digital clock design that integrates a diagnostic and repair mechanism to ensure continuous and accurate timekeeping. It operates using a combination of working and repairable clock signals, supported by various testable modules configured in modes such as Mode 3, Mode 6, and Mode 10. These testable repairable modules are capable of operating under both normal and testing conditions, allowing for internal fault checks. A central control unit, along with repairable control logic, governs the operation of these modules and determines which mode or unit should be activated based on operational status and detected faults. The outputs from these modules are passed to a bus multiplexer, which selects the correct signal path based on control signals from the control logic. To ensure reliability, a test vector generator produces predefined test patterns that are fed into the system.

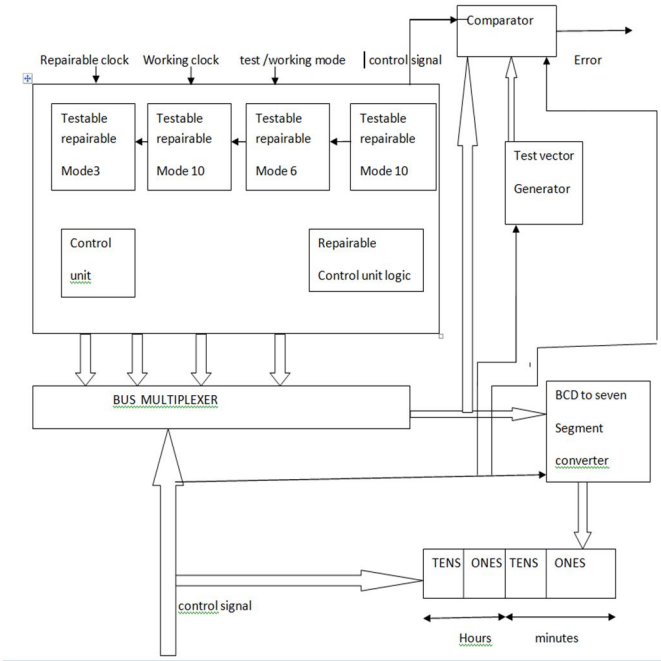


Fig 1. Block diagram of testable and repairable 24 hours clock

The resulting outputs are compared by a comparator, which checks for mismatches against the expected results. If discrepancies are found, an error signal is triggered, prompting the control logic to switch to a backup (repairable) mode. Once a valid output is confirmed, the signal is sent to a BCD (Binary-Coded Decimal) to seven-segment converter, which transforms the digital output into a format suitable for visual display. The final stage of the system is the digital display, which shows time in a 24-hour format using seven-segment displays arranged to represent tens and ones of both hours and minutes. Through this robust design, the system ensures fault detection, self-repair, and uninterrupted clock operation, making it suitable for applications that require high reliability and precision.

This design includes

1) When an error occurred in any module at a certain/particular time. The real-time clock should not be corrupted, and the real-time clock will show the actual time after the repair.
2) Implementation of two modular redundancy circuits for repairable capability.
3) Design of switching circuit which witching all counters from ripple mode to synchronous mode when it switches from work mode to repair mode
4) Test vector generator for test fault in test module to identify where and which type of error is in it.

IV. INDIVIDUAL MODULES AND THEIR SIMULATIONS

1) *Testable and Repairable 60 Minute counter*: It is a two-digit BCD (Binary-Coded Decimal) counter for a 00 to 59 minutes counter is a digital circuit that counts from 00 to 59 in decimal format, representing minutes in a digital clock or timer. This counter is constructed using two cascaded counters: a MOD-10 counter and a MOD-6 counter, which together represent the units and tens place of a 2-digit decimal number.

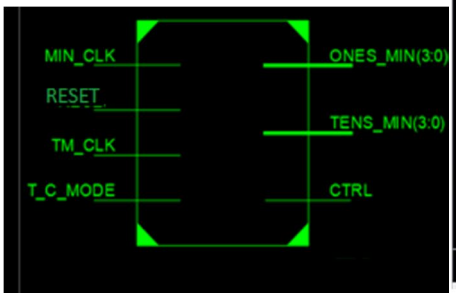


Fig 2. Entity of 00 TO 59 minutes counter



Fig 3. Simulation waveform of Mod 00 TO 59 counter

The above fig 2. Shows the entity of testable minutes counter. It have not only a working mode but also testable capability of where the error is in that module if error occurs. fig 3. Shows the simulated waveform of the two-digit BCD counter (00 to 59) using cascaded MOD-10 and MOD-6 counters shows the correct counting sequence for minutes. The MOD-10 counter (units digit) increments with each clock pulse from 0 to 9, then resets to 0 and generates a **carry-out** signal. This carry-out triggers the MOD-6 counter (tens digit) to increment by 1, counting from 0 to 5. When the tens digit reaches 5 and the units digit reaches 9 (i.e., 59), the next clock pulse resets both counters to 00, starting the cycle again. This waveform confirms the accurate operation of a 60-count minute timer, where the units count drives the tens through cascading, forming a BCD-based minute counter from 00 to 59.

2) *Testable and Repairable 24 Hours counter*: In working mode, the 24-hour clock counter system utilizes two main counters: a Mod-10 counter and a Mod-3 counter as shown in fig 4. The Mod-10 counter is responsible for counting the hours from 0 to 9, and it works together with the Mod-3 counter, which counts the tens of hours. The system's inputs include HR_CLK (hour clock), RESET, TMOD_CLK (test mode clock), and TE_CT_MOD (test/control mode signal). The outputs are ONE_HR (representing the current hour) and TENS_HRS. (representing the tens of hours) as shown in figure 5. When the RESET input is set to 0, the system initializes and begins counting. With HR_CLK set to 1, the Mod-10 counter increases its count from 0 to 9 hours. Each time the Mod-10 counter completes a full cycle from 0 to 9, it triggers the Mod-3 counter to increase by 1. This increase in the Mod-23counter effectively adds 10 hours to the total count. The Mod-2 counter continues this process, counting from 0 to 2, effectively managing the tens place in the 24-hour format. As the Mod-3 counter moves from 0 to 2, the Mod-10 counter keeps counting hours from 0 to 9. When the Mod-3 counter reaches its maximum value (2), it signifies that 20 hours have been counted.

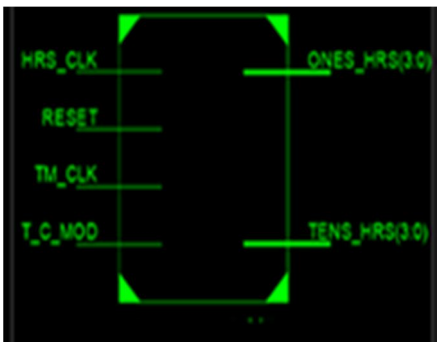


Fig 4. Entity of testable 24 Hours module

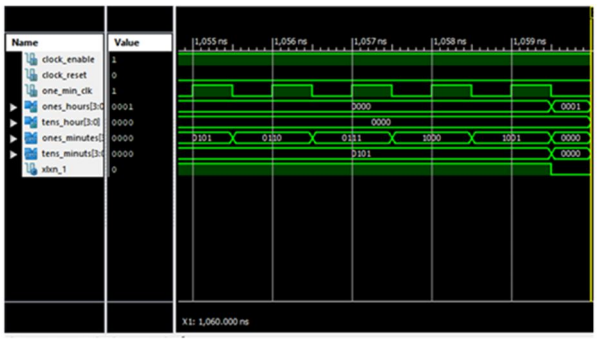


Fig 5. Simulation of testable 24 Hours Module

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A Repairable 24 hours Counter is a digital counter that counts from 0 to 23 and resets back to 0 after reaching 23. It is designed with fault detection and correction mechanisms to maintain functionality even when errors occur in 24 hours module Means it cycles through 24 states (0–23).as shown in below fig:6. Repairable Includes logic to detect faults like stuck bits or illegal values and automatically correct or switch to a backup. It uses components like comparators, redundant counters, multiplexers, and error detection logic. Commonly used in digital clocks to count hours in 24-hour format. Ensures continuous, reliable operation even if a part of the counter malfunctions. This enhances system reliability, especially in critical time-based digital systems. Fig 7. Shows simulated wave form of repairable 24 hours module



Fig 6: Entity of repairable 24 hours module

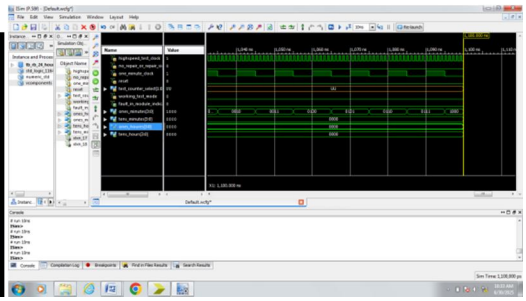


Fig 7. Simulation of repairable 24 hours module

3) *Faulty chip fault identification and repair:* When any fault during manufacture and working that can be detected and repaired my test mode signal and repair signal in that module. The repair mode of the testable and repairable digital clock is activated through a dedicated test mode signal, which enables fault detection across all modules of the clock system. During this mode, each functional block is tested for possible faults using built-in self-test (BIST) or scan techniques, and any detected error is flagged. Once a fault is identified, a repair signal is triggered, which enables a redundant or spare module through modular redundancy to take over the operation of the faulty component. After successful rectification, the system resumes error-free and reliable operation, ensuring continuous and accurate clock functioning even in the presence of faults. Fig 8 shows faulty chip simulation and identification of running error.

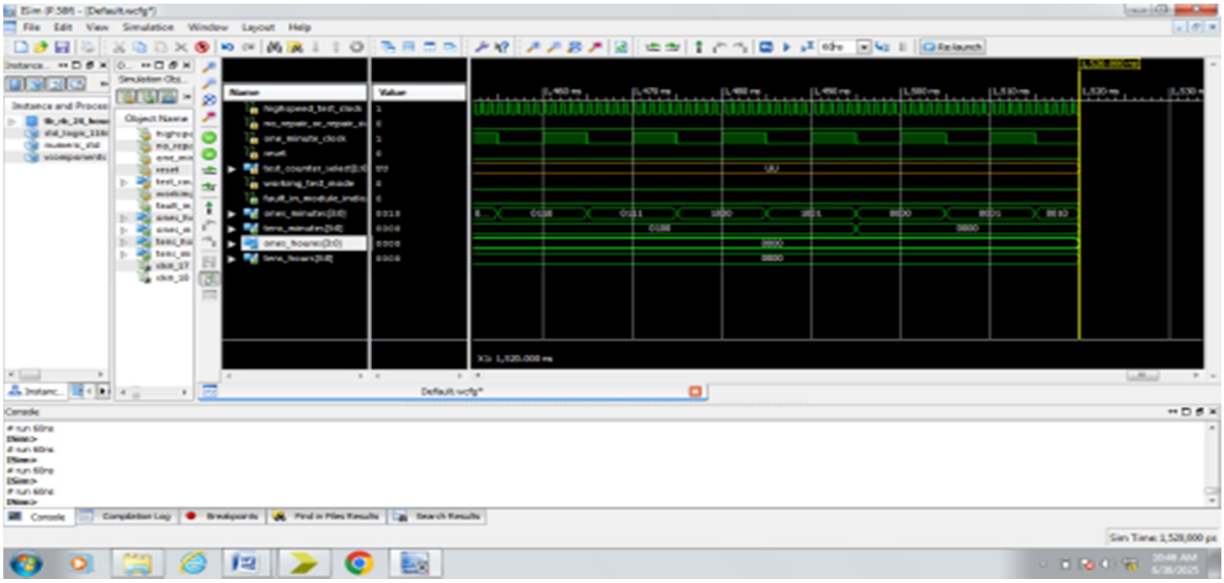


Fig 8. Simulation waveform of faulty clock module

4) Fault testing and repairing: The bellow output waveform shown in fig 9 is for testing mode. that error the module ten minutes is detected by selector module address of " 01" along with test mode signal of high. And that error is detect at the output signal of module error. For repair the error when repair input signal goes high using two modular redundancy technique is added and error module is replaced by good one and error free continuous time is displayed. Bellow fig 10. shows the after repairing error free clock running.

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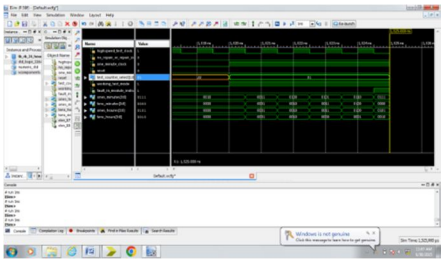


Fig 9. Simulation waveform of faulty testing

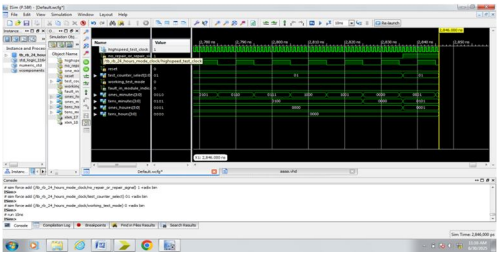


Fig 10. Simulation waveform of fault rectification

V. CONCLUSION

In this project, a fault-tolerant digital clock was successfully designed and implemented using VHDL, integrating key features such as testability and Two Modular Redundancy (TMR). The system was developed to maintain accurate timekeeping functionality while ensuring high reliability and fault resilience in digital hardware environments.

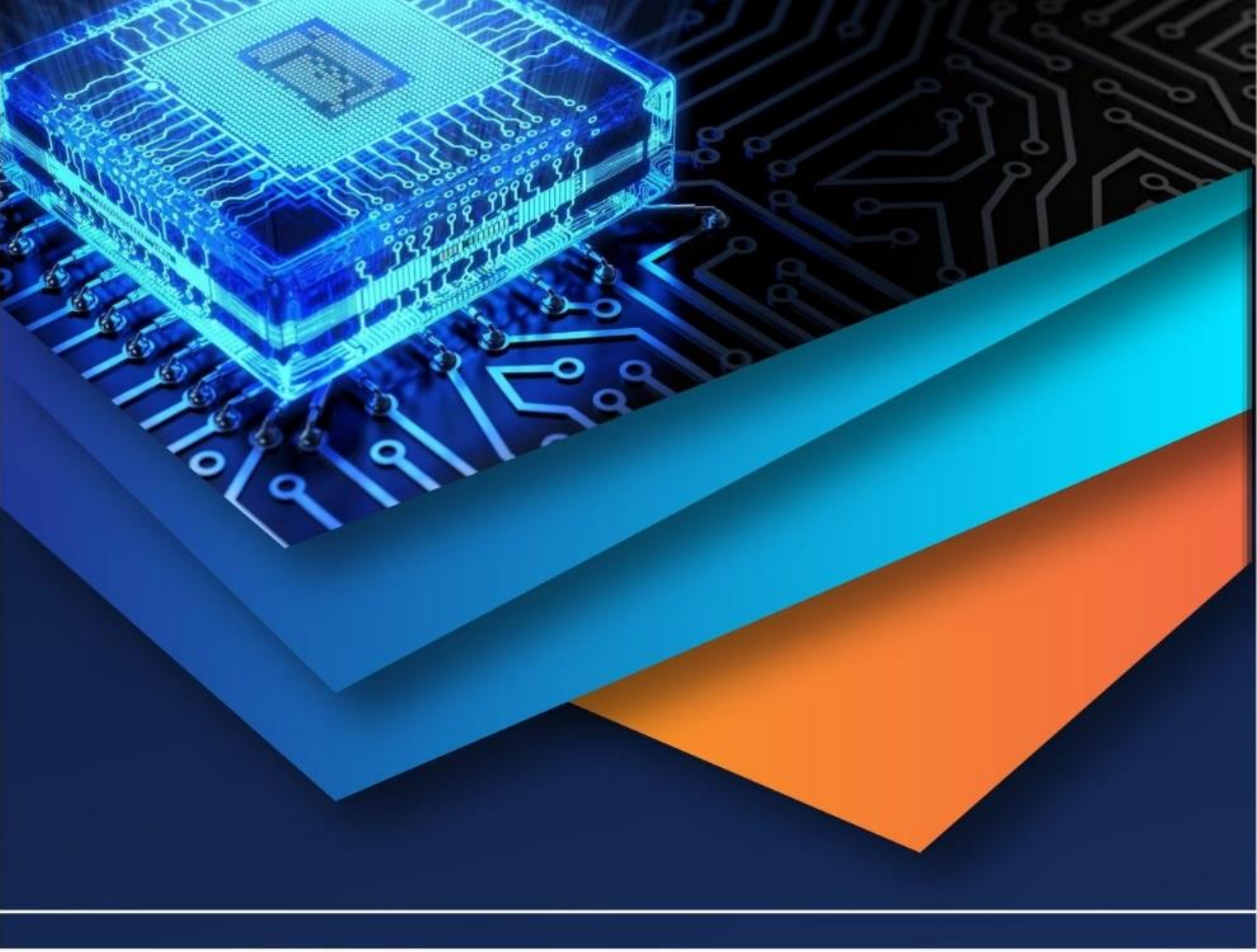
The incorporation of TMR allowed the system to continue operating correctly even in the presence of single-module failures, thereby enhancing its robustness. The use of majority voting logic ensured that any faulty output from one of the redundant modules did not affect the final result, demonstrating the effectiveness of redundancy in fault masking.

Furthermore, testability features such as self-checking mechanisms and internal signal monitoring were embedded into the design, enabling the detection and isolation of faults during both simulation and synthesis stages. These features significantly improve the maintainability and diagnostics of the clock system.

Overall, the project showcases how digital systems can be made reliable and maintainable through thoughtful architectural design using VHDL. This design approach can be extended to other mission-critical digital systems where fault tolerance and testability are paramount.

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