DISTRIBUTED RAIL SIGNALING AND TRAFFIC CONTROL SYSTEM

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Keywords:

ARM Cortex M0+, CBTC, Diff_bus_32, Ethernet, FPGA, Multi Core, Programmable Input Output, RTOS, State Machine

Introduction:

The Distributed Rail Signaling and Traffic Control System is is a next generation railway traffic management and control system design as a major improvement of traditional CBTS (Communication Based Train Control System) and ETCS (European Train Control System) With higher standardisation of Electronic Hardware and Software used in Vehicle Management, Signalling, Networking and Communication to reduce operating cost and capital cost with maximum backward compatibility.

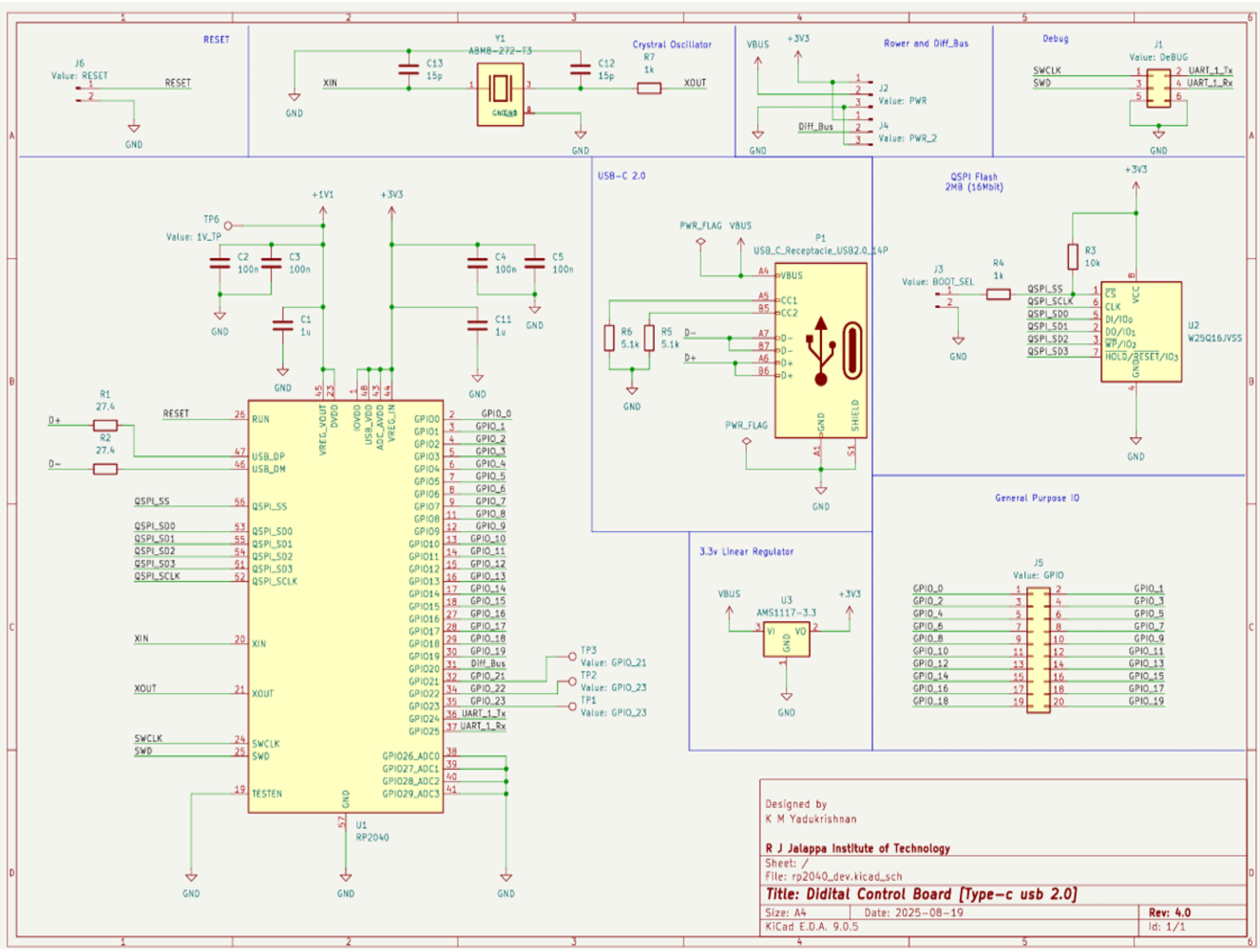

Figure 1: Digital control board Rev1 circuit

1. The Distributed Rail Signaling and Traffic Control System Uses the combination of Fixed Block and Moving Block system. And prioritizes Cybersecurity, Closed Environment and well optimized Linux based Operating System for the enhanced security. It also contains self-diagnostic capabilities (60% of the capabilities are tested). Unlike traditional centralised systems, Distributed Rail Signaling and Traffic Control System utilizes advanced and cross-compatible commutation systems and autonomous sensor networked systems to improve operations.
2. With the distributed, autonomous control mechanism, encrypted communications, and predictive maintenance capabilities, it represents a major leap forward in railway operations. By eliminating centralized vulnerabilities and enhancing real-time decision making, it ensures increased safety, optimized track utilization and improved system efficiency in the modern transit system.

Objectives:

1. **Cross-Compatibility with existing systems**: To achieve seamless cross-compatibility with existing systems, ensuring integration, interoperability, and efficient performance across diverse technological environments like by using existing Fiber networks.
2. **To develop standardised electronic sub-systems:** To design and implement standardized electronic sub-systems with modular architectures, ensuring interoperability, reliability, and compliance with industry protocols, also by using common hardware and designs to simplify training and lifespan cycles.
3. **To reduce operational and total Lifecycle cost:** To reduce operational and total lifecycle costs by optimizing design efficiency, standardizing components, and implementing sustainable maintenance strategies also we only have two main control boards for application in any given task

Methodology:

The methodology of this project is structured to integrate both hardware and software components into a cohesive distributed rail signaling and traffic control framework. At the hardware level, the system employs microcontrollers such as the RP2040 and RP2350, supported by programmable I/O (PIO) modules and crystal oscillators to ensure precise timing and synchronization. These devices are responsible for handling sensor inputs, executing control logic, and maintaining real-time communication across nodes.

The hardware architecture is complemented by block diagrams and state machines that define the flow of operations, including external interrupts and supervisor calls, which enable responsive event handling and fault tolerance. On the software side, the methodology incorporates a layered approach using multiple programming environments. Low-level modules are implemented in C and C++ to guarantee deterministic performance and minimal latency, while Zig and CMake are used to manage modular builds and cross-language integration. Higher-level tasks such as predictive analytics and optimization are executed in Julia, ensuring computational efficiency.

Result and Conclusion

1. The Distributed Rail Signaling and Traffic Control System represents a distributed, intelligent network of autonomous nodes. By decentralizing decision-making to trains, trackside signals, and switching modules, the system eliminates the critical vulnerability of single-point failure inherent in traditional control rooms, enabling rapid, localized responses to safety-critical events. The hybrid signaling approach—integrating fixed block methodology for dense station environments with moving block technology for open mainline sections dynamically optimizes train spacing and track utilization without compromising safety margins
2. The communication infrastructure leverages a closed TCP/IP protocol operating over licensed spectrum bands (850 MHz–2.1 GHz), ensuring encrypted, low-latency data exchange among network nodes. Redundant GSM/GPRS channels provide fallback connectivity, maintaining essential control signals even during primary link degradation. This multi-layered communication strategy substantially improves resilience compared to single-channel dependencies in legacy systems.

References:

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Future Scope:

The future scope of this project includes:

1. Easy development because of modular system
2. Reduced Hardware Designs and complex analog circuits
3. The communications systems can be used in other applications where very high speed is not a high priority compared to reliability.
4. The software APIs can be used in many other places especially Mathematical computing APIs.