IDEA

Innovations Deserving
Exploratory Analysis Programs

High-Speed Rail Program

Integrated Quad Gate Crossing Control System

Final Report for HSR-IDEA Project 11

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TRANSPORTATION RESEARCH BOARD • NATIONAL RESEARCH COUNCIL

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Revision History

Revision	Date	Description	By	Checked	Approved
1.0	29 October 1999	Draft Release For Review	MJR (RSE*)		
2.0	17 November 1999	First Release	MJR (RSE*)	JGT	JGT
3.0	18 May, 2000	Second Release	MJR (RSE*)	REL/JGT	JGT
3.1	3 November 2000	Final Release	REL (RSE*)	JGT	JGT

* Rail Safety Engineering (RSE) is a consultant specializing in the design and analysis of safety critical control systems for the rail transportation industry.

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1. EXECUTIVE SUMMARY

Standard warning systems at highway-railroad crossings include one gate on each side of the railroad tracks, but these systems make it easy for cars to simply drive around lowered gate arms. Adding a second pair of crossing gates eliminates this problem. Four-gate crossings require the ability to detect motor vehicles within the crossing boundaries, so that the exit gates may either be raised or delayed in lowering, thus providing an exit path from the crossing. Standard ITS techniques are typically employed at four-gate crossings for detecting motor vehicles, however existing dual gate crossing control systems are expensive to modify for four-gate operation.

This project introduces a prototype quad gate control (QGC) system, developed at RSE, which consists of a design tool, solid state quad gate crossing controller hardware, and software. The controller's operation is scalable to meet the requirements of virtually any at-grade crossing. It is capable of interpreting vehicle detection signals and can operate currently installed entrance gates as well as newly installed exit gates.

The main component of the QGC is a commercially available Programmable Logic Controller (PLC), shown in FIGURE 1-1. The PLC backplane is expandable and accommodates a number of plug-in modules for interfacing to entrance and exit gate mechanisms, obstruction detectors and a user terminal.

FIGURE 1-1 Series 90-30 PLC

The design tools for this non-vital prototype is implemented as a library of crossing logic modules. The crossing logic modules were developed by RSE using a programming environment specifically designed for the GE-Fanuc family of PLCs. The programming environment runs on a host computer connected to the PLC programming port.

The application engineer uses this same environment to access RSE's library of crossing logic modules for configuring the controller. By filling-in specific operational parameters that describe the crossing, and by integrating instances of RSE's logic modules, an application engineer can configure the QGC to meet the exact operational requirements of practically any crossing. Some of the configurable parameters include:

1) Delay between warning system activation and entrance gate lowering.
2) Delay between warning system activation and exit gate lowering.
3) Gate control check period.
4) Number of tracks.
5) Number of inductive loop (primary) vehicle detectors.
6) Number of radar (secondary) vehicle detectors.
7) Maximum "quiet" time before loop check.
8) Maximum "quiet" time before radar.

ITS techniques for vehicle detection are provided via interfaces to standard two-channel traffic loop detectors (LM 632t). The QGC system is also capable of accommodating other ITS standard obstruction detection technologies such as radar, ultrasonic, and video.

A dedicated coprocessor module provides connectivity to millimeter radar based detectors, such as that being developed by Waveband, Inc. The coprocessor module is also responsible for logging the crossing's status and indicators for off-line examination. A user terminal connected to a programming port allows easy configuration to practically any crossing. The entire assembled system is shown in FIGURE 1-2.

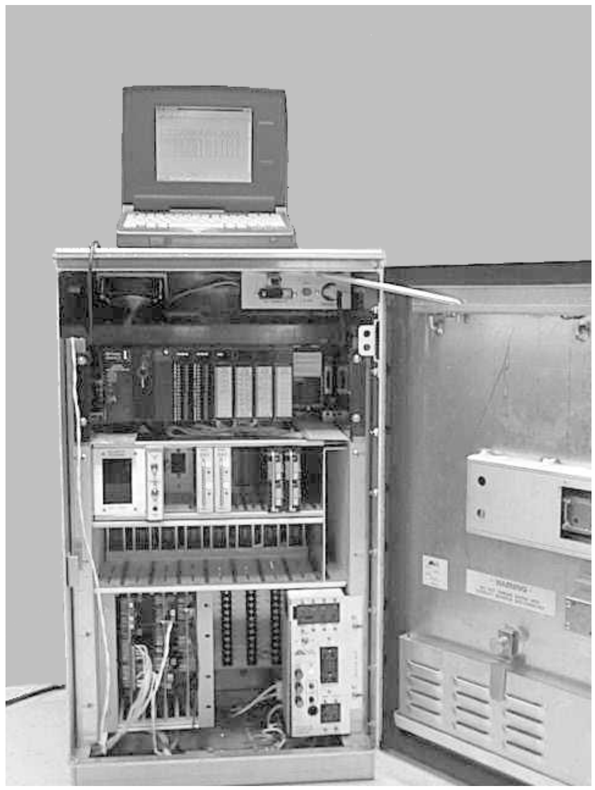


FIGURE 1-2 QGC System

RSE developed and integrated the prototype QGC software and hardware and put the system through a series of lab tests designed to verify its ability to monitor track circuits, control crossing gates, and log event data according to the original system specification.

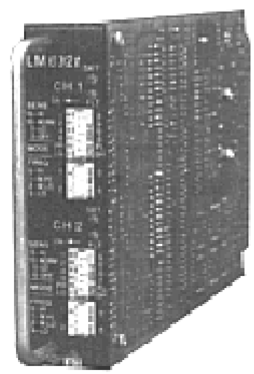
2. IDEA PRODUCT

RSE developed and demonstrated an integrated, design prototype control system for quad and dual gate highway-rail crossings. The open architecture controller is capable of actuating control on all four gates and interfaces to various ITS sensors for intrusion detection, thus improving grade crossing safety. One standard ITS sensing device employed during the design is the LM632t Dual-Channel Loop Detector Module shown in FIGURE 2-1.

Software configurability allows the controller to handle gates as either fail-up or fail-down and interface directly to the particular vehicle detection scheme used at a given crossing. Software configurability and the capacity to control all four gates in new installations, significantly reduce the cost of implementing such systems. The use of Windows-based software tools, as shown in FIGURE 2-2, greatly increase the portability of the application environment.

A vital version of the controller, specifically designed to meet the application requirements of quad and dual gate crossing control, would make systems that use ITS detection techniques for maximizing crossing safety more cost effective to implement.

FIGURE 2-1 Model LM 632t Detector Module



LM 632t

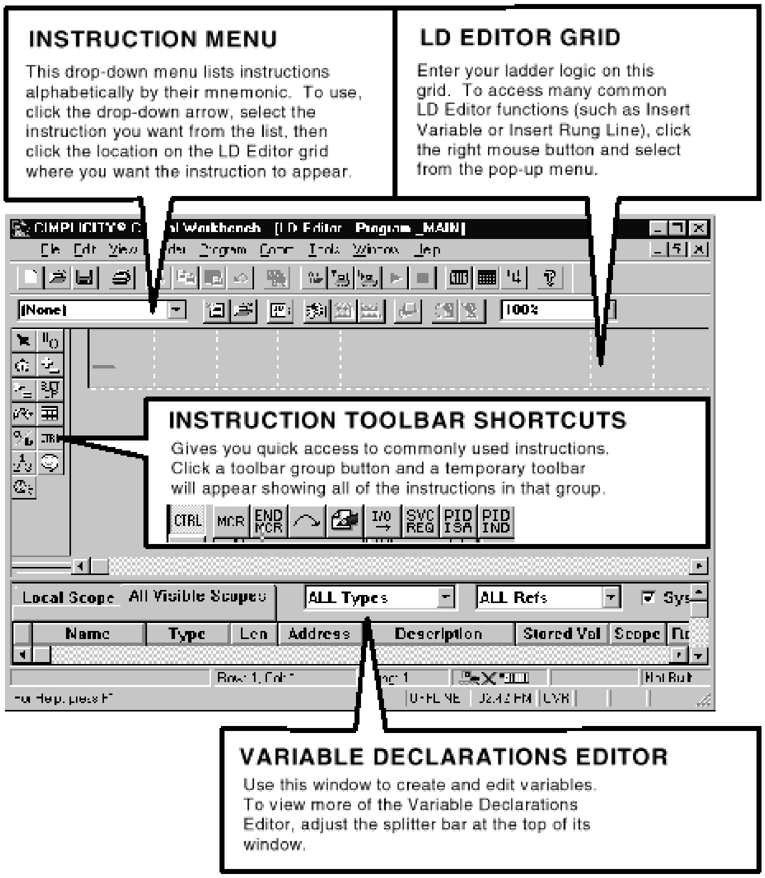


FIGURE 2-2 Programming Environment Screen

3. CONCEPT AND INNOVATION

Current implementations of quad gate crossing systems are individually adapted to meet the specific requirements of each individual crossing. While these quad gate systems have been feasible, the highly customized and application specific nature prevents their design and installation from being cost effective. The crossing controller developed for this project introduces the benefits of software configurability, open architecture and modular design to quad gate crossing control applications.

The control system developed for this project supports existing ITS techniques for on-crossing vehicle detection and approaching train detection to assure that vehicles will be given sufficient train warning and cannot be trapped within at-grade track crossings. Integral data logging allows traffic engineers and accident investigators to observe crossing controls and indicators by feeding logged data into an analysis tool to view crossing traffic patterns or events leading to a crossing incident.

A commercialized version of the prototype system developed for this project would greatly simplify and streamline the design process for safe quad or dual gate crossing system, as well as reduce the life cycle cost of such systems.

4. INVESTIGATION

4.1 REQUIREMENTS SOLICITATION

With Safetran Systems as a commercial partner during the proposal phase of this project, we had already identified the high-level requirements for the quad-gate control system. Configuration flexibility, integral data logging, and elimination of the need for a separate relay-based controller for vital operations were among the requirements identified. A *Functional Requirements Specification* document was subsequently drafted, that outlined each of the high-level functional requirements. The document defines the QGC requirements for capability, external interfaces, and environment. It was used in finalizing a design concept and during later phases of the design process. This document is included as Section 9 for completeness.

4.2 HIGH LEVEL DESIGN CONCEPT

We originally envisioned using a standard 2070 traffic controller as the main component of the QGC. However, slow acceptance of the 2070 in the traffic industry as well as time constraints on equipment procurement led us to choose a COTS PLC by GE-Fanuc as an alternative. We found that the PLC's plug-in modules could interface easily to track circuits, entrance and exit gate mechanisms, and obstruction detectors, including ITS standard vehicle detectors (even though not a typical arrangement). The PLC coprocessor module provides the connection to a user terminal, and is responsible for logging crossing status and indicators for real-time or off-line examination. With custom software and custom vital I/O, the PLC would be able to monitor the crossing, control the crossing gates, and log event data as prescribed in the Functional Requirements Specification.

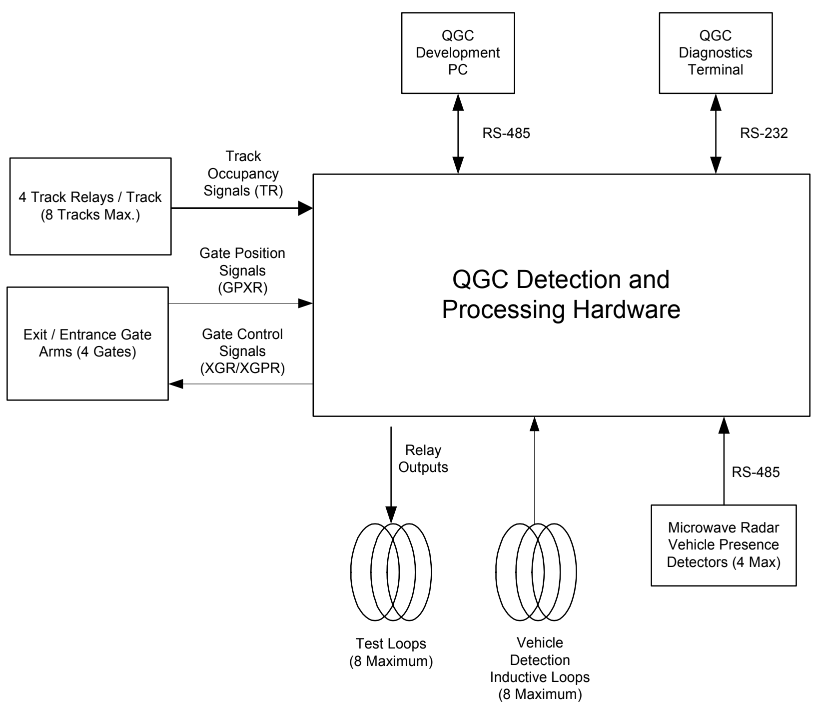


FIGURE 4-1 QGC High-Level System Diagram

FIGURE 4-1 shows the high-level architecture concept for the prototype QGC system. The *QGC Detection and Processing Hardware* block consists of the PLC, Coprocessor, Plug-in interface modules and vehicle detectors, all of which connect to ancillary devices.

The Development PC would communicate with the PLC over an RS-485 serial interface. This PC runs the COTS-based design environment and contains all of the development tools needed for this project. This PC is not connected to the rest of the QGC during regular operation.

The user interface is realized through the connection of a diagnostics terminal to the coprocessor module. This could be a laptop PC running *HyperTerminal* or any other VT100 terminal emulator program. With the diagnostics terminal connected, the user could start or stop data logging and capture the states of crossing controls and indicators for observation in real-time or off-line. This diagnostics terminal could theoretically remain connected at all times.

A maximum of 8 test loops and 8 vehicle detection loops can be connected to the prototype QGC. One test loop is dedicated to each detection loop.

24-volt DC signals are provided to actuate the entrance and exit gate relays (XGR/XGPR). Actual gate position indications (GPXR) are fed back to the QGC for verification. The prototype QGC is accepts occupancy inputs for up to eight tracks, each possessing two approaches, one island, and an optional industry track circuit.

4.3 PEER REVIEW

On June 15, 1999 we convened a regional panel of experts to discuss issues on operational acceptance of the proposed QGC system capabilities and evaluate the project plan. The chief outcomes of that meeting addressed the minimum size of obstacles that the QGC should to be able to detect and different field testing scenarios.

We suggested the possibility of conducting the field test in a "parking lot" scenario, citing the cost and logistics of preparation involved from the user's perspective for a non-vital system. However, given the perceived limited value in this type of test, we agreed to attempt to locate a suitable "live" demonstration site. As requested by the panel, RSE drafted a list of test crossing requirements on 30-Jun-99 to help identify appropriate sites. The site requirements [2] addressed issues relating to track circuit, gate/crossing control, loop detector connectivity and power sources.

4.4 SYSTEM LEVEL DESIGN

RSE devised a QGC system level design that satisfies all of the high-level system requirements [1]. The QGC system design establishes the criteria needed for performance, design, development, analysis, implementation, and testing of the QGC system. Major components for an operational non-vital QGC system are defined and system design decisions are allocated to each component.

The QGC is described by breaking it down into functional components and their related interfaces as shown in FIGURE 4-2.

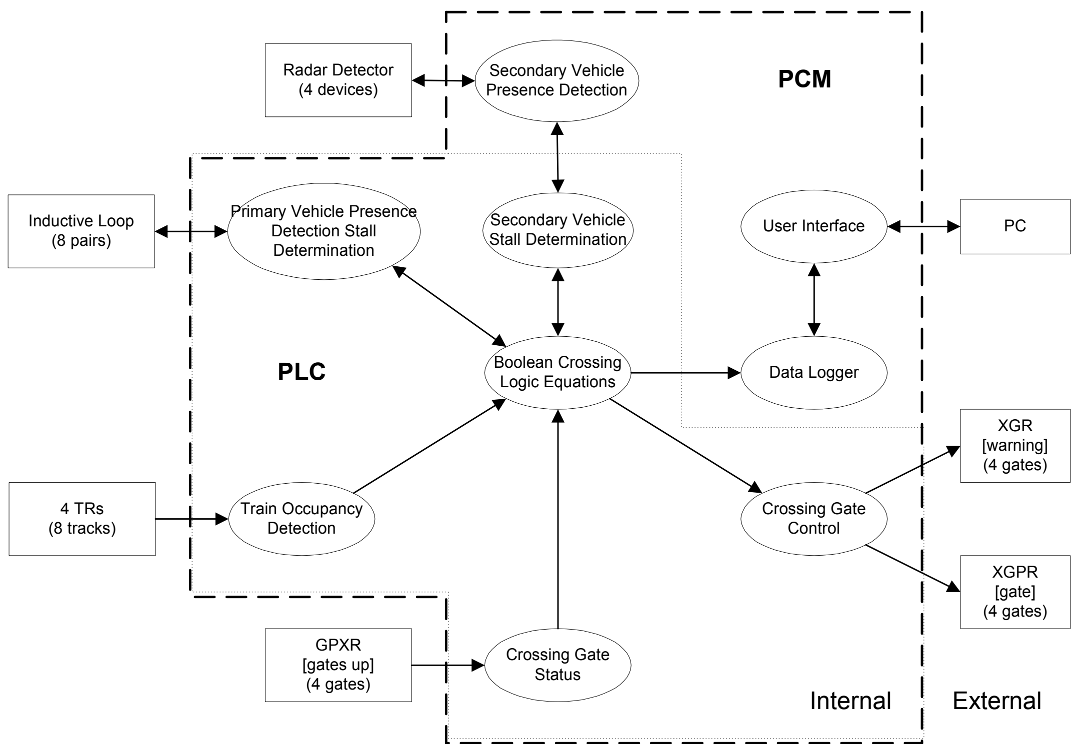


FIGURE 4-2 QGC Architecture

The QGC Function assignment is shared between a dedicated Programmable Coprocessor Module (PCM) and the actual PLC module. The PLC performs most of the crossing logic and interfacing while the PCM is dedicated to serial communications.

The heart of the System is the *Boolean Crossing Logic Equations* (BCL) software component. It is responsible for performing all grade-level crossing control logic. The BCL accepts 1) Train occupancy data from the *Train Occupancy Detection* component, 2) Gate status data from the *Crossing Gate Status* (CGS) component, and 3) Vehicle stall data stall data from the *Primary* and *Secondary Stall Determination* components. The BCL processes this data to produce the correct control signals for each pair of crossing gates.

Other outputs from the BCL functional component include test-loop outputs for periodically testing the integrity of the inductive loops, and messages sent to the PCM for data logging purposes.

The PCM's *Data Logger* software component accepts and parses data messages from the BCL. The Data Logger formats that data for recording and sends it to the *User Interface* component.

The User Interface component handles the serial communication to the user terminal. It displays selected crossing controls and indicator status to the user, and accepts user commands to affect certain non-critical operations of the QGC.

The *Secondary Vehicle Presence Detection* (SVP) is designed to handle serial communications between an auxiliary type of vehicle detector that possesses a serial interface, such as the microwave radar system developed by Waveband, Inc. The SVP component delivers occupancy state data to the *Secondary Vehicle Stall Determination* (SVS) component running on the PLC.

4.5 REQUIREMENTS SPECIFICATIONS

RSE identified and documented subsystem requirements with regard to the QGC system design. The *Software Requirements Specification* (SRS) [3] document draws upon the SDD to define the required elements for the software. The SRS was written to uniquely identify requirements allocated to the particular components of the system architecture so as to assure the testing phase would cover all requirements identified at the functional level. The requirements allocated are traced back to functional requirements in a table to support Verification and Validation of the project.

The interfaces between the QGC and peripheral hardware were defined and documented in the *External Interface Requirements Specification* document [4]. This document includes requirements pertaining to both non-vital and vital interfaces, primarily the interface to the WaveBand microwave radar vehicle presence detector. This interface's serial message format is designed to be compatible with the ATCS protocol. The intent of this document is to provide a sufficient list of required elements for each interface. This will allow the design of the components at either end of the interface to be complete and accurate. The interface document identifies the physical requirements of each interface, the data transferred across each interface and the handshaking required to control each interface.

4.6 SOFTWARE DETAILED DESIGN

All of the QGC functional modules that comprise the design tools and their interfaces are implemented by one or more *Computer Software Components* (CSCs). RSE created detailed designs for all of the QGC's embedded CSCs, to address each requirement set forth in the SRS. These designs were documented in the *Software Detailed Design Document* (SDDD) [5], which identifies and fully describes the design of the software components. The level of detail for each component is sufficient to allow the coding and unit testing to be completed.

The QGC system CSCs, their relationships and interfaces are illustrated in FIGURE 4-3 and FIGURE 4-4. The remainder of the SDDD further decomposes the requirements identified in the SRS and allocates them to each component.

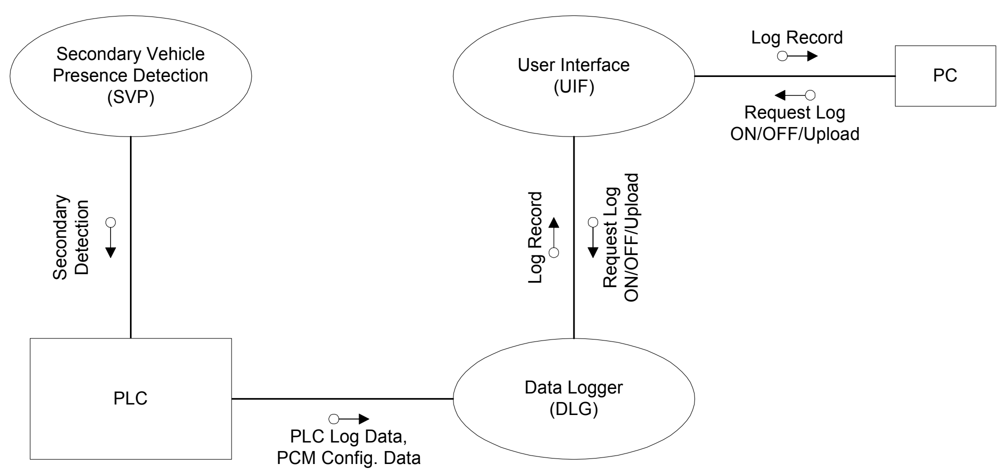


FIGURE 4-3 QGC Coprocessor Module CSCs

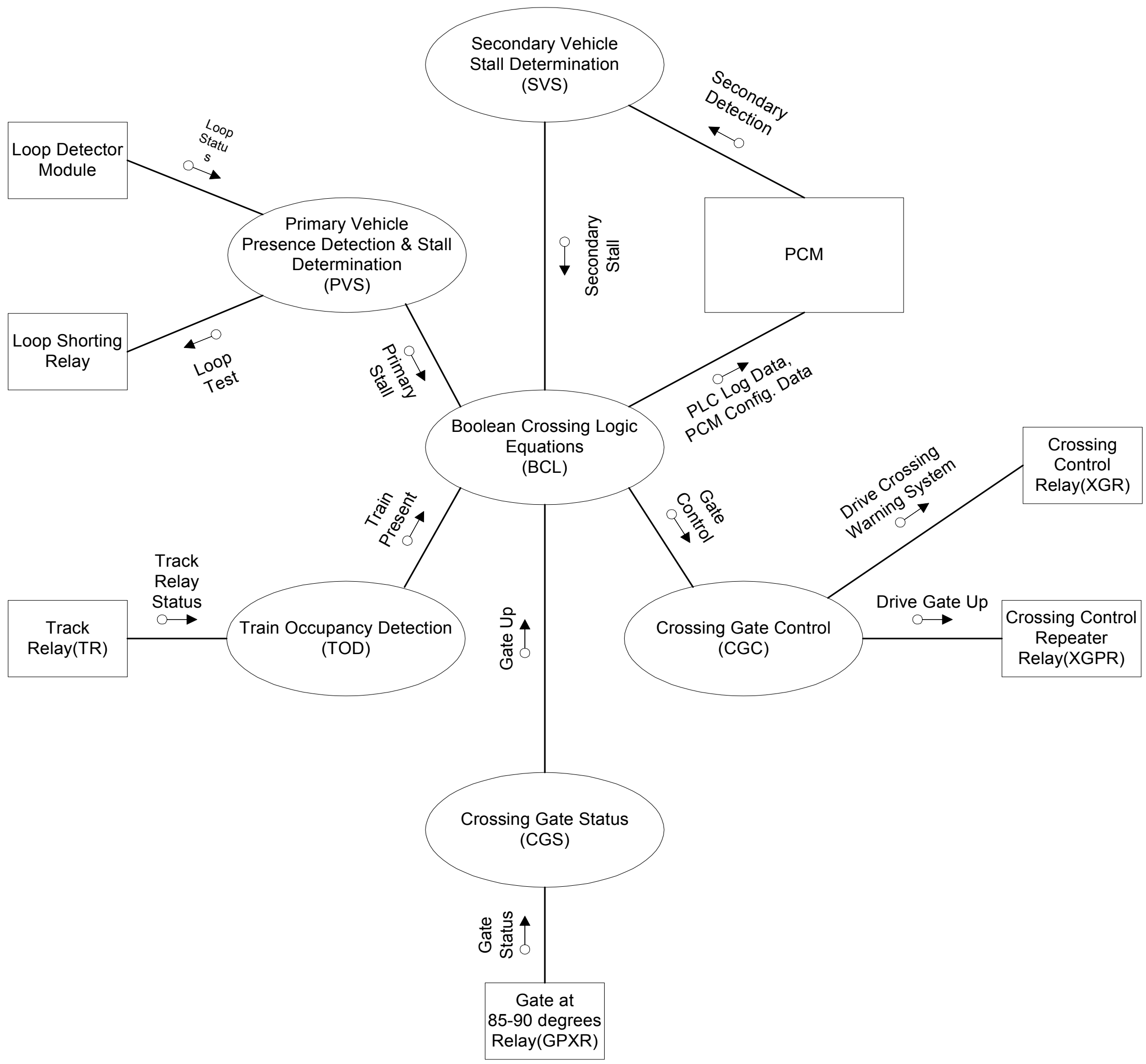


FIGURE 4-4 QGC PLC CSCs

4.7 USER'S MANUAL

RSE generated a QGC User's Manual [9] to provide an overview of installation, set-up, configuration and maintenance of the QGC system for purposes of the IDEA demonstration. The manual was written to be used by the installers and end users of the QGC demonstration system as well as test engineers responsible for independent testing of the QGC system and its components.

4.8 SOFTWARE DEVELOPMENT AND INTEGRATION

The SDDD [5] was used as a detailed blueprint for the prototype software development and integration activities. Initial lab tests proved the QGC system capable of sequencing the gate arms and providing the crossing functionality exactly as cited in the Functional Requirements Specification. The software components were later refined and made ready for formal lab-testing and subsequent field demonstration.

4.9 SYSTEM TESTING

A *Lab Functional Test Procedure* [6] was drafted that presents the detailed test procedural steps for validating the QGC functionality. The test procedures are derived from and based on requirements specified within the QGC Functional Requirements Specification.

RSE successfully lab-tested the prototype QGC System on November 8, 1999 and verified its ability to monitor track circuits, control crossing gates, log event data. The sample log data captured during lab testing shown below depicts the exit gate operation with an obstructed crossing.

mm/dd/yy	hh:mm:ss	West Aprch	Islnd Aprch	East Aprch	Stall Detect	Warning System	Exit Gates	NW GPXR	SW GPXR	SE GPXR	NE GPXR
11/08/99	17:23:14	Clear	Clear	Clear	No	Idle	Up	Up	Up	Up	Up
11/08/99	17:23:25	Clear	Clear	Clear	Yes	Idle	Up	Up	Up	Up	Up
11/08/99	17:23:41	Ocpd	Clear	Clear	Yes	Active	Up	Up	Up	Up	Up
11/08/99	17:24:49	Ocpd	Clear	Clear	No	Active	Up	Up	Up	Up	Up
11/08/99	17:24:54	Ocpd	Clear	Clear	No	Active	Down	Up	Up	Up	Up

Note that the four gate position (GPXR) indications do not apply since the tests were conducted in a laboratory environment without actual crossing gates

17:23:14 - Crossing is clear, No train is approaching, and Warning system is not activated.

17:23:25 - Stalled vehicle detected within crossing boundaries.

17:23:41 - Train approaches from the West, Warning system is activated. Exit gates not commanded to drop since a stalled vehicle is still detected.

17:23:49 - Stalled vehicle is removed.

17:23:49 - Exit gates commanded to drop.

Lab testing was completed according to the Lab Functional Test Procedure without any significant deviations noted.

Field testing of the QGC system and the subsequent peer review panel discussion were originally scheduled to take place in September 1999. However, obtaining the use of a suitable test site proved difficult. Ultimately, live field-testing was not possible due a number of logistical issues with the use of the intended site.

5. PLANS FOR IMPLEMENTATION

RSE is planning to solicit a commercial partner to work with in obtaining a follow-on IDEA grant for the Commercialization phase. The commercial controller would include both vital software and hardware for direct connection to existing vital crossing systems.

6. CONCLUSIONS

The QGC Project (IDEA ITS-67) was completed on 17-Nov-1999. We determined that safe, configurable control of a quad gate crossing system could be realized by implementing standard, commercially available equipment based on a GE-Fanuc 90-30 Series PLC with support software.

The QGC project effort was documented, starting with the initial steps of requirements solicitation through to final lab testing. These documents describe the entire system design, implementation, use and testing and are listed in Section 8.2. All deliverables were submitted as outlined in the Program Plan, with the exception of those directly related to the field test.

Results shown in the Lab Test Report verified that the PLC-based crossing controller meets all of the requirements cited in the Functional Requirements Specification. The results proved that the QGC is able to interface to inductive traffic loops and sequence crossing gate arms in a manner that prevents motor vehicles from becoming trapped within the crossing boundaries.

We were unfortunately not able to secure a suitable field demonstration site for this non-vital prototype QGC. However we hope to locate a commercial partner to work with us in obtaining a follow-on IDEA grant for Commercialization of a vital controller, to include testing and demonstration at a live crossing or dedicated test bed.

7. INVESTIGATOR PROFILE

RSE, founded in 1993, is a Professional Engineering firm providing technical expertise in the design, specification and evaluation of control systems to the transportation industry.

RSE personnel have been involved in the design and/or evaluation of every type of vital processor-based interlocking controller and ATP carborne equipment developed in the United States, as well as several international systems. Our personnel have an in-depth knowledge of fixed-block, moving block and vital communication-based control systems.

Our executive staff has over 50 years of experience in the design, implementation, analysis, specification and evaluation. We are named on over 200 patents in the field and participated in the design of the first microprocessor-based vital products in the mid-1980's.

8. GLOSSARY AND REFERENCES

8.1 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

COTS	Commercial, Off-The Shelf
GPXR	Gate Position Crossing Relay that repeats the XGR when the gate arms are at 85-90 degrees.
IRS	Interface Requirements Specification
ITS	Intelligent Transportation Systems
PCM	Programmable Coprocessor Module
PLC	Programmable Logic Controller
QGC	Quad Gate Controller
SDD	System Design description
SDDD	Software Detailed Design Document
SRS	Software Requirements Specification
XGPR	Slow Release Crossing Gate Repeater Relay, which repeats the XGR after some time to active the gate arms after the crossing warning system.
XGR	Crossing Gate Relay, which activates the crossing warning system.

8.2 REFERENCES

[1] "Quad Gate Controller System Design Document" (RSE Document 656-201, REV 1.1- 7/30/99).

[2] "Requirements for Grade Crossing Tests" (RSE Memo to TRB, RSE Reference RSE/TRB/IDEA-009).

[3] "Quad Gate Controller Software Requirements Specification" (RSE Document 656-202, REV 1.2- 8/2/99).

[4] "Quad Gate Controller External Interface Requirements Specification" (RSE Document 656-203, REV 1.0- 7/28/99)

[5] "Quad Gate Control System Software Detailed Design Document" (RSE Document 656-302, REV 1.1- 8/30/99)

[6] "Quad Gate Controller Lab Test Procedure/Report" (RSE Document 656-401, REV 1.0- 10/29/99).

[7] "Quad Gate Controller Program Plan" (RSE Document 656-101, REV 1.0- 10/8/98).

[8] "Presence Detector Interface Specification" (RSE Document 656-105, REV 1.0-4/12/99).

[9] "Quad Gate Control System User's Manual" (RSE Document 656-304, REV 1.0- 8/25/99)

[10] Contract with IDEA (ITS-67), 9/30/98

[11] RSE Proposal 656.

9. FUNCTIONAL REQUIREMENTS SPECIFICATION

The following document is the functional requirements specification that identifies the system-level requirements for implementing a quad-gate control system.

The document is identified as 656-102 Revision 2.0, dated 9 July 1999.

1. Introduction

As part of an effort to develop technology for improving highway/rail grade crossing safety, we will apply and demonstrate intelligent control over a pair of entrance/exit gates at a test rail crossing. The Quad Gate Control (QGC) system will be able to detect vehicles stopped within the boundaries of rail crossings equipped with four gates and hence raise the exit gates accordingly. The system described by this document utilizes standard intelligent highway traffic control equipment and application specific software to accomplish intelligent four-quadrant crossing control. The QGC system will be designed to work in conjunction with a crossing's existing track circuit signals and gate control mechanisms.

1.1 Purpose

This document defines the high-level requirements for an operational quad gate control system. It is intended for design personnel and individuals knowledgeable in advanced highway control and grade crossing signal concepts. These requirements will be used in later phases of the design process to finalize a design concept. As the details of the design evolve, more detailed hardware and software requirements may be generated. At the completion of the project, a demonstration of the concept system will be conducted.

1.2 Scope

The goal of the QGC system is to provide a low cost solution to implementing safe control over quad or dual gate crossings. The system will utilize existing ITS techniques for on-crossing vehicle detection and will assure that motor vehicles are given sufficient train warning and cannot be trapped within the crossing boundaries. The QGC will also have the ability to log the states of a crossing's various controls and indications for later review by traffic engineers and accident investigators.

1.3 Definitions, Acronyms, and Abbreviations

1.4 References

The following documents are referenced as background and for more complete information on a particular subject.

Ref#	Document Title
[1]	"Quad Gate Controller Program Plan" (RSE Document 656-101, REV 1.0- 10/8/99).
[2]	"Caltrans/LADOT Transportation Electrical Equipment Specification (TEES)", March 1997.
[3]	"ATCS Communications Systems Architecture Specification 200", V.4.0, ARINC Research Corporation.
[4]	"ATCS Message Formats Specification 250", V.4.0, ARINC Research Corporation.

1.5 Overview of Document

Section 1 (this section) provides an introduction to this document, briefly describes the system requirement, and identifies the source of reference material.

Section 2 describes the general factors that affect the QGC's requirements.

Section 3 defines the requirements that contribute to the design of an operational QGC system.

2. General Description

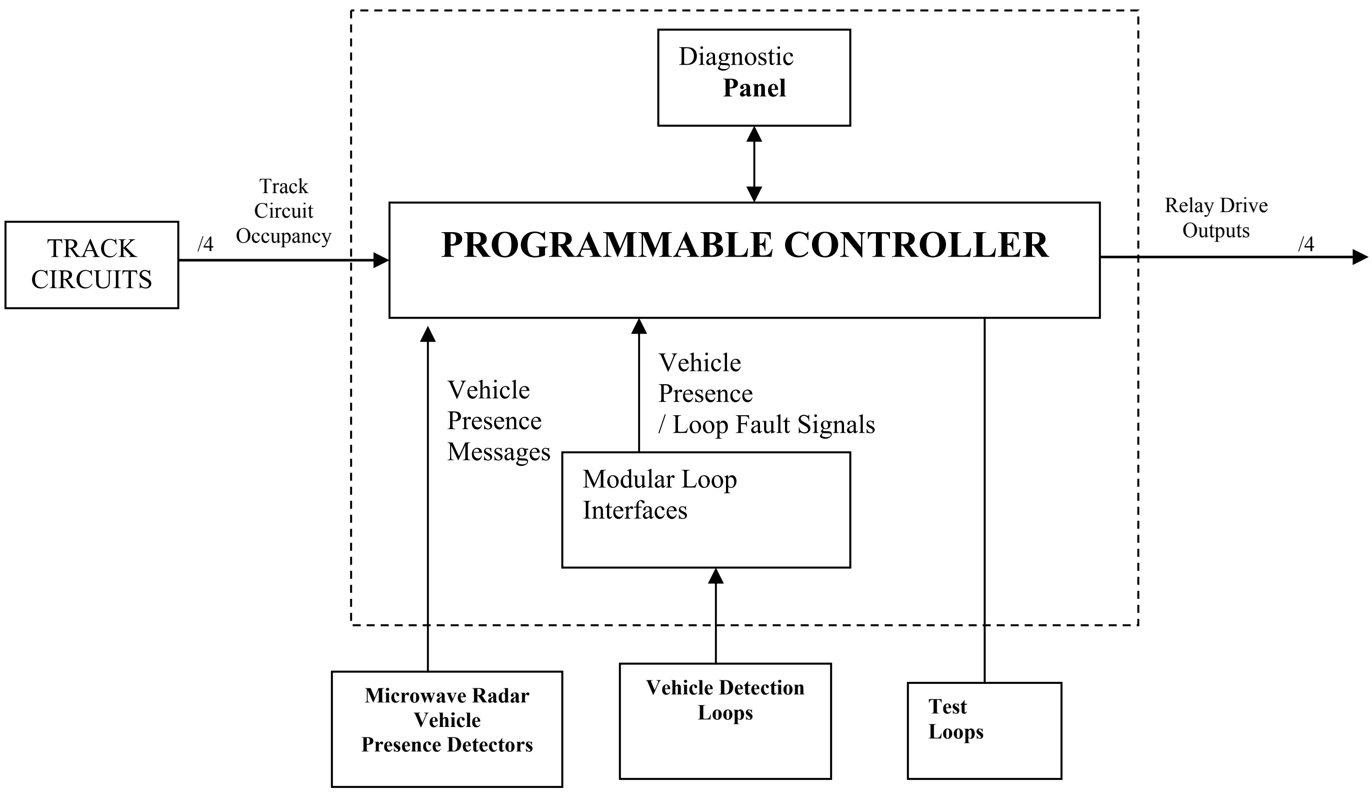
2.1 Product Perspective

The QGC system integrates a commercially available programmable controller, inductive loop and radar-based vehicle presence detectors, modular device interfaces, and external vital software generation to accomplish safe, configurable control over four-quadrant grade crossings. Application specific plug-in modules interface the programmable controller to the track circuit signals, inductive traffic loops, and WaveBand microwave radar detection unit.

The inductive loops are implemented in Detection/Test pairs. A *detection* loop interfaces with the controller to indicate vehicle presence. The *test* loop is placed in close proximity to the detection loop and is used for self-test operations.

The QGC will be configurable by a "software generator" for programming the controller with crossing-specific configurations. The default controller configuration will meet the application needs at most grade crossings that use standard three-circuit logic for each track. If required, the controller may be configured to use a fourth track circuit.

The programmable controller and modular interfaces will all be contained in a weatherproof case along with a built-in power supply and terminal blocks for convenient connection to external signals.



The interface descriptions shown below are the proposed system interfaces. As the details of the QGC system design evolve, more detailed interface requirements may be generated and documented.

Name	Description
Track Circuit Occupancy (4)	24 VDC signals from up to 4 track circuits. The QGC will typically interpret these signals to determine when to raise or lower the crossing gates.
Vehicle Detection Loops	Vehicle presence detector inductive loop connections. The inductive loops are hard-wired to industry standard loop monitor modules, which will provide an indication of motor vehicle presence within the crossing boundaries.
WaveBand Microwave Radar Vehicle Presence Detector	RS-485 serial interface between vehicle detection radar units and the programmable controller. Carries information regarding obstructions that occur within the crossing boundaries, in a format that can easily be adapted to the ATCS protocol [3] [4].
Relay Drive Outputs (4) (Gate Control)	24 VDC signals provided by the QGC typically programmed to control raising and lowering of the crossing gates.

2.2 Product Functions

An intelligent Quad Gate Controller system significantly improves highway/rail grade crossing safety by allowing safe implementation of four gates at a crossing while allowing the exit of any vehicles obstructing the crossing. The QGC monitors the area within the crossing boundaries for stopped motor vehicles and controls the gates accordingly.

The QGC system described here will provide the following functions:

- Accept and process track circuit occupancy signals for up to four track circuits per track.
- Detect Stalled highway vehicles within the grade crossing boundaries.
- Control the entrance and exit crossing gates accordingly to provide trapped motor vehicles an exit route by lifting the exit gate pair.
- Continuously indicate the status of select crossing controls and indicators to a diagnostic display panel.
- Continuously log status of crossing controls and indicators for off-line analysis.
- Perform periodic self-tests to verify stalled vehicle detection ability.

2.3 General Constraints

Inductive loop vehicle detectors must interface to the controller through hardware that is designed especially for ITS systems. Specifically, this means that the controller must be able to accept the industry standard open-collector outputs of such devices, or the open collector outputs must be biased external to the controller.

The controller must also be capable of interfacing to the WaveBand radar unit specifically designed for this application. The WaveBand radar unit uses an RS-485 serial link to transmit and receive data in a format that can be easily adapted to accommodate the ATCS protocol [3] [4].

2.4 Assumptions and Dependencies

Prior to integrating the radar-based vehicle detection unit into the QGC system, WaveBand must evaluate the radar unit's ability to detect stalled vehicles in standalone tests and generate a summary report. An acceptable performance evaluation is prerequisite to implementing the radar unit as described in this requirements document.

3. Specific Requirements

This section defines the system requirements for the Quad Gate Controller System. The following defines the standard used within this section of the document to identify system design requirements:

"*shall*" indicates a firm requirement and commitment to achieve the stated specification and to validate and verify compliance.

"*will*" indicates that there is project intent to meet the stated specification.

"*may*" indicates a project conceptual idea used to clarify the stated specification

Each requirement identified by a "*shall*" will be uniquely identified with a requirement heading. This requirement heading will be positioned prior to the requirement description and will contain a requirement number and requirement name. The following describes the information contained within each requirement number and the format the requirement number will adhere to:

- Each requirement number will contain a requirement category. All requirements of the QGC are labeled with the QGC designation.
- Each requirement number will contain the section number where the requirement is defined.
- Each requirement number will adhere to the following format:

Format: category-section.number
Example 1: QGC-2.2.1.1
This represents the requirement number for the first "*shall*" within section 2.2.1.

3.1 Capability Requirements

3.1.1 Vehicle Presence Detection (Inductive Loop)

QGC-3.1.1.1 Vehicle Presence Detection (Inductive Loop) - The QGC system *shall* utilize an industry standard inductive loop detection system in order to determine if there is a stalled motor vehicle within the crossing boundaries.

3.1.2 Vehicle Presence Detection (Radar)

QGC-3.1.2.1 Vehicle Presence Detection (Radar) - The QGC system *shall* accept vehicle presence messages transmitted from the WaveBand radar unit over an RS-485 serial interface, and in a format that can be easily adapted to accommodate the ATCS protocol [3] [4].

3.1.3 Crossing Gate Control Requirements

The QGC subsystem *will* support control of the highway/rail grade crossing exit and entrance gates. The requirements for this function are as follows:

QGC-3.1.3.1 Entrance Gate Operation – The QGC *shall* support normal operation of the crossing entrance gates.

QGC-3.1.3.2 Exit Gate Operation – The QGC *shall* support operation of the exit gates in a manner that allows motor vehicles within the crossing to always have an exit route. Lowering the exit gates *shall* not occur until a configurable delay time has elapsed after 1) Lowering of the entrance gates, and 2) Determining that the crossing is clear.

QGC-3.1.3.3 Exit Gate Down Inhibit – The QGC *shall* prohibit/interrupt the lowering of the exit gate pair when either 1) A vehicle is detected in the crossing, or 2) A fault has been detected with the inductive loops, microwave radar, or gate control.

3.1.4 Diagnostics Requirements

QGC-3.1.4.1 Front Panel Configuration– The QGC *shall* be configurable from the diagnostic panel to allow modification of non-crucial operational parameters. These parameters shall include but are not limited to data logging enable/disable and selective display of individual crossing controls and indicators.

QGC-3.1.4.2 Diagnostic Panel Indicators– The QGC diagnostic panel *shall* be able to continuously display the state of crossing controls and indicators including but not limited to:

- States of the track circuit signals.
- Entrance and Exit gate control signal outputs.
- Directional stick status.
- Crossing obstruction status.
- Train Approach Status.
- Vehicle Presence Detection Integrity.
- Gate Control Integrity.

3.1.5 Data Logging Requirements

QGC-3.1.5.1 Local Data Logging – The QGC *shall* log significant events in a 48-hour circular log, stored periodically in local non-volatile memory. The recorded data *will* include the state of crossing controls and indicators including but not limited to:

- States of the track circuit signals.
- Entrance and Exit gate control signal outputs.
- Directional stick status.
- Crossing obstruction status.
- Train Approach Status.

QGC-3.1.5.2 Data Logging Download– The QGC *shall* support downloading of the local data log on demand to a laptop computer for subsequent analysis by traffic engineers and accident investigators.

3.1.6 Verification/Self-Test Requirements

The QGC *will* support the execution of periodic self-tests to ensure system integrity.

QGC-3.1.6.1 Inductive Loop Verification – The QGC *shall* have the ability to self-check the inductive loops' ability to detect vehicle presence within the crossing boundaries.

QGC-3.1.6.2 Radar Verification – The QGC *shall* periodically self-check the WaveBand microwave radar's ability to detect vehicle presence within the crossing boundaries.

3.1.7 Configuration Requirements

QGC-3.1.7.1 Software Generation Tool Support– The QGC *shall* support an application-specific software generation tool, to allow custom controller software generation for site specific applications. The configurable parameters shall include but are not limited to:

- Vehicle detection device types (loops, radar or both).
- Number of inductive loops (16 maximum).
- Frequency of detector loop and radar cycle checking.
- Frequency of exit gate control checking.
- Exit gate lowering delay time.

3.2 External Interface Requirements

QGC-3.2.1 Inductive Loop Vehicle Presence Detectors – Separate inputs *will* be provided for up to 12 individual loops by employing industry standard multi-channel loop monitors. The loop monitors *shall* provide fault outputs for each loop that can be monitored by the application software.

QGC-3.2.2 Microwave Radar Vehicle Presence Detector - The QGC *shall* be required to interface to the WaveBand microwave radar unit over an RS-485 serial interface, using a data format that can be easily adapted to accommodate the ATCS protocol [3] [4].

QGC-3.2.3 Gate Up/Down Requests - The QGC *shall* be able to interface with existing track circuit signals and interpret their state changes.

QGC-3.2.4 Exit / Entrance Gate Control - The QGC *shall* be able to interface with existing gate operation mechanisms.

QGC-3.2.5 Alarm Output Requirement – The QGC *shall* generate a discrete alarm output signal when an internal fault is detected. Such faults shall include but are not limited to self-test failures.

3.3 Environmental Requirements

QGC-3.3.1 System Environmental Requirement - Components of the QGC System *shall* be required to meet the environmental specifications defined in the *Association of American Railroads Signal Manual, Part 11.5.1, Section E. Environmental Parameter Limits*, Class C (Wayside Bungalows & Instrument Cases).