Creating Marine Asset Tracking Systems with MATRIXx

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Product: MATRIXx

Campaign: 2005 Control Design

The Challenge: Designing, simulating, analyzing, and deploying a low-cost, compact inertial-assisted GPS system for shipping container tracking and security.

The Solution: Using the National Instruments MATRIXx software suite to simulate ship movement, analyze power consumption and generation techniques, and test and implement position calculation algorithms based on onboard sensor and GPS data.

The increase in global trade has elevated the importance of accurately monitoring and tracking marine assets. The Department of Homeland Security (DHS) developed the Marine Asset Tag Tracking System (MATTS) to make maritime shipments more secure and turned to iControl, Inc., to develop a system that would meet demanding DHS criteria.

The government agency needed a system beyond anything previously developed – a reliable and secure system with a power supply that could sustain itself for three to five years without a battery change.

Our company had successfully deployed tracking and monitoring systems in mobile and remote applications for nearly five years. Our technology has been implemented in aerospace, facilities management, water monitoring, and oil and gas installations. With the help of the NI MATRIXx family of products, which we have used in the past for a variety of installations, we met the DHS challenge well ahead of schedule, securely, and with high reliability.

We used MATRIXx to analyze, simulate, and test MATTS. The system includes shipboard satellite gateways, container tracking computers (TAGs), and a secure Internet data center.

The container TAG is a miniature sensor, data-logging computer, radio transceiver, and inertial-assisted GPS tracking system. The TAG inertial estimator accurately resolves container locations even when sporadic or multipath reflections corrupt GPS signals. Inertial-corrected GPS eliminates the requirement for a port or ship to record container location. An iControl TAG can store its location history with no supporting infrastructure. The container location and history are reported when the TAG is within 2 km of an Internet-equipped ship or dock. Self-contained, low-cost satellite gateways will be installed on each container ship and ports will eventually be equipped with Internet-linked gateways to provide real-time container tracking for inventory management.

The MATRIXx product family was instrumental in the analysis and verification of our MATTS concept. We used MATRIXx to simulate ship dynamics, evaluate power scavenging technologies, design power management logic, and design and implement state estimation algorithms for location.

Developing the Critical Power Management System

One of the most important aspects of this system is the three to five years of operating life without a battery change. To implement the complex power management system, iControl used the MATRIXx SystemBuild graphical framework tool to simulate the power control logic.

The TAG power management system is a multistate system that uses a low-power CMOS timer (1 µA) to periodically wake the radio receiver. During normal (nonmoving) operation, the container TAG wakes up the communication receiver to “listen” for a network radio “RF carrier” from the ship (or dock) gateway.

In addition to the periodic wake up from the CMOS timer, the TAG accelerometers remain powered during all operations (approximately 3 μA). The accelerometers monitor the container for large movements that may indicate the container is transitioning to a new state. If the measured acceleration exceeds a predefined threshold, the CPU powers up, latches power on, and propagates the measured motion. The minimum power state for the container TAG is approximately 4 μA (12 μW). A stationary TAG operating with a 1 A per hour battery (40 cm^3) could operate for approximately eight years. Obviously, a container TAG will not remain stationary for its entire life cycle. For normal operations, the container will periodically report status or recompute its position while in motion. The relative duration of container movement and status reporting is small but not insignificant when compared to stationary states.

Power Scavenging and Ship Modeling

To augment the TAG power management system, we investigated power scavenging from the TAG's surrounding environment to determine if any scavengers could generate enough power to recharge a battery for an extended life span. We evaluated energy sources such as ambient light, hull vibration, and the motion of the ship.

The inputs to simulation included ship dimensions, speed, heading, and random ocean waves. We used SystemBuild to build the models of the ship, environment, and scavengers. The internal calculations measured hull vibration and the ship's roll, pitch, and heave frequencies. The resulting energy induced motion in the scavengers, which included a microcantilevered vibrating beam, pendulum, and spring.

Although the simulation showed that the optimal scavenger design parameters required to match the excitation frequencies were not practical, we could generate a useful amount of power from the nonoptimal pendulum design. We determined that solar cells converting to ambient light were the best scavengers.

Power Management System Fueled by Ambient Light

We successfully designed a power management system with the assistance of the MATRIXx product family. Initial test of the final TAG prototypes indicate the power management system will achieve the simulated performance results. Based on these results, we also have determined that ambient light produced more power when compared to vibration-based energy scavenging. This result helped us cut 70 percent of our development time on the project by eliminating the need to further test energy scavenging options. Winning the project opened the doors to a promising and innovative opportunity for us.

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