

Superconducting Coil Winding Machine Control System

J. M. Nogiec, S. Kotelnikov, A. Makulski, D. Walbridge, K. Trombly-Freytag
Fermi National Accelerator Laboratory, Batavia, IL 60510

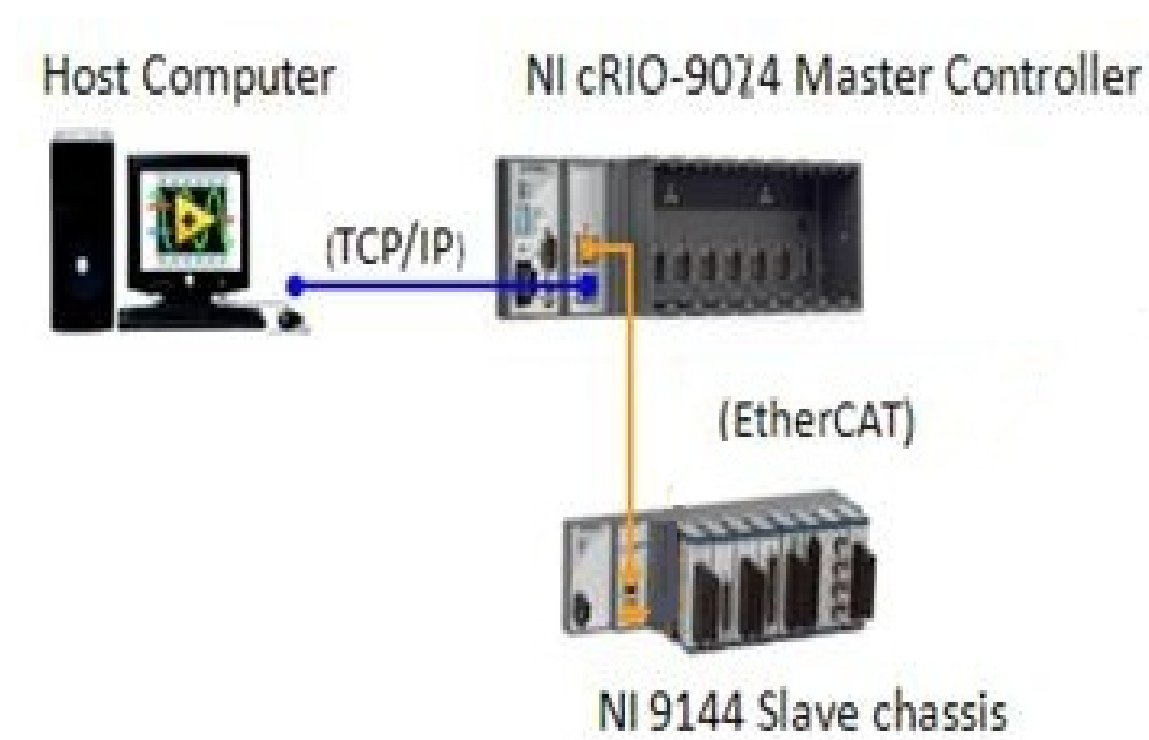
Machine



Coil winding machine

The winder machine is about 11 m long with a bridge that moves along a track and supports a rotating boom holding a spool of cable and providing cable tension. The coil being wound is supported by a mandrel.

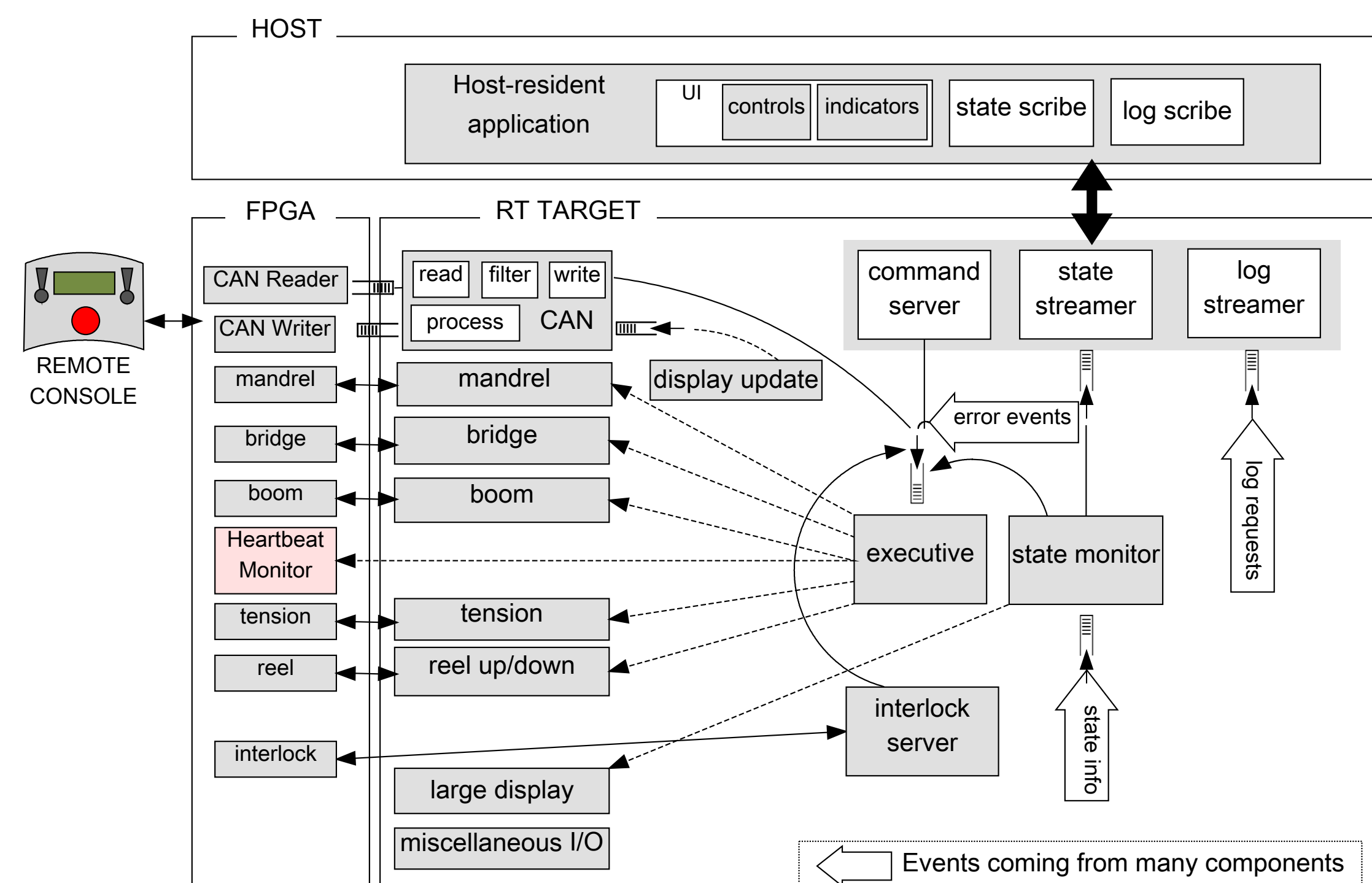
Computers and Instrumentation



Computer and instrumentation

- Host computer
- cRIO crate with I/O modules with processor running RTOS
- EtherCAT extension crate with additional I/O modules
- CAN bus radio-receiver to transfer data from the remote console.

Software Organization



Software modules distributed among Host, R/T Target and FPGA

HMI Layer - modules residing on the host computer implementing user interface and data storage.

Operational Logic Layer - modules that provide operational logic residing on the Real-Time target computer.

Direct Control Layer - FPGA code that interfaces I/O signals and implements fast and deterministic behaviour, such as motion control, motion synchronization, tension and reel regulation, and interlocks.

Hardware Layer – actual hardware elements including motors, sensors, actuators, and switches.

Control Algorithms

- PID control with feed forward to control tension
- Decentralized algorithm to regulate speed and synchronize the motion of multiple motors
- On/off reel height regulation algorithm using optical cable sensors
- Overtension protection and cable disconnection detection mechanisms

Machine Operation



Touchscreen GUI's, including the main screen, tension, and mandrel position



View of the mandrel from the boom

Cable reel and tension system

Remote console

Safety Features

- Redundant failsafe system
- Interlock system
- Heartbeat system
- Motion limit switches
- Over tension protection
- Safety push buttons
- Sensor touch edges
- Acoustic warning signals
- Cable disconnection detection
- Signal lights
- Safety line

Summary

The Spirex coil winder has been equipped with a new control system. Its major components include the bridge, mandrel, boom, tensioning system and reel, which are driven by servomotors. The control system regulates the motor speed, tension and reel position, monitors the distance based on encoder readouts, monitors the end switches, and controls the brakes. It also synchronizes the motion of motors on the same axis for the bridge and the mandrel.

The machine can be operated from both a computer touch-screen interface and a wireless remote control unit. The control system includes a failsafe, redundant safety system with interlocks, including protection for the operator, the machine, and the superconducting cable.