Squeezing the Most Out of a Dentifrice Filling Application

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NI Products Used:
LabVIEW 2011 for Windows
LabVIEW Real-Time
LabVIEW FPGA
LabVIEW MODBUS Library
Database Connectivity Toolkit
cRIO-9074
C-Series 9203 (3) – Analog Input
C-Series 9425 (1) – Digital Input
9144 EtherCAT Chassis
C-Series 9265 (6) - Analog Output

Categories:
Automated Test
Advanced Control Systems

The Challenge
Replace existing PLC and Wonderware analog transducer data collection hardware/software on a dentifrice tube filling station with a system that could synchronously collect that data and acquire motion profile data via MODBUS TCP. The goal was to increase test speed/efficiency by cutting down the post-test 30-second+ data transfer times.

The Solution
Data Science Automation was able to create a system with custom timing and data collection that provided real-time data collection thus eliminating the post-test data transfer. DSA leveraged the technology of the Compact-RIO platform and the built-in LabVIEW TCP protocol and the free NI Modbus Library to provide this solution.

Introduction
Data Science Automation (DSA) is the premier National Instruments Alliance Partner. DSA integrates commercial off-the-shelf (COTS) components from automation technology vendors to create custom, adaptive automation solutions for a diversity of research, manufacturing, government and business operations to:

- acquire, analyze, present and manage data
- design, simulate, test and validate products
- monitor, predict, control and optimize processes
- invent, draft, prototype and build machines

for maximum productivity, quality, profit and understanding.
DSA is a certified member of the Control Systems Integrators Association (CSIA) and staffs multiple National Instruments Certified Training Centers with more certified LabVIEW Architects than other integrators.
DSA was chosen by this client because of our depth of experience with LabVIEW and National Instruments hardware – particularly the cRIO platform. The client was impressed by our track record which clearly demonstrated our ability to compound their investment through an adaptive solution.

Background
The main goal of this system was to replace a Wonderware based data collection system due to the long post test data transfer times. Dentifrice tube filling can occur in under one second and the customer desired a system that could collect data at 10 millisecond (ms) intervals in synchronization with the existing motion control system that was also collecting data at 10 ms intervals. Not only did these two systems need to

coordinate their data collection, but the data from the motion control system had to be collected via MODBUS TCP and packaged with the analog transducer data. While all this is occurring the system also needs to act as an analog signal splitter and replicate the analog input data to a legacy HMI system utilizing a WAGO I/O system.

Approach

The new system had to provide its own Graphical User Interface (GUI) that would allow the operator to select the formula information for the dentifrice being tested. This test system was important to the customer due to its use in replicating production line conditions and allowing for optimization of the dentifrice recipes, delivery nozzles, and pressures/temperatures without tying up the production equipment. Database connectivity was required to pull existing information associated with the formulator, recipe, and batch information. This data was also saved with the actual motion and analog transducer data on the system personal computer that acted as the main GUI for the operator of the system.

The solution was based around the Compact Reconfigurable Input Output (cRIO) hardware platform, leveraging the Field Programmable Gate Array (FPGA) technology on the backplane of the cRIO for the custom timing synchronization and high speed buffered analog data collection. In addition the master cRIO, an EtherCAT expansion chassis was utilized to act as the analog signal splitter for updating the existing WAGO HMI utilizing the appropriate analog output cards.

Basically the motion control system is collecting motion data for position, torque, velocity, and motor amps at 10 ms intervals. The 10 ms intervals are marked by pulses that are sent by the motion controller to the cRIO FPGA for controlling the synchronization and timing of the analog data acquisition. The analog cards utilized were the NI 9203 set to a time between conversions of 5 microseconds (μs). In order to reduce the amount of noise in the signal at the 10 ms pulse the analog data would be averaged over 25 readings making use of the Mean, Variance, and Standard Deviation FPGA Express VI provided by NI on the FPGA Math and Analysis palette. This provided a stable signal and the data from three of the analog input cards was able to be read in a 40 μs span. This data was then placed into the FPGA DMA for transfer to the Real-Time operating system code that was handling the communication via MODBUS to collect the associated motion data. A 10 ms interval was found to be too fast for the MODBUS TCP communication so the analog and motion data were collected into 5 sets of 10 ms data. The 50 ms interval allowed the MODBUS TCP communication to pull the 5 data sets from the motion system and combine it with the 5 sets of analog data and then push this to a consumer loop via RT FIFO. This consumer then published the data via TCP to the Windows based PC running the main data collection and GUI code for storage on the customer's network. Data was also split in this parallel process and sent to the EtherCAT analog output replication loop via an RT FIFO enabled Shared Variable. Only the latest data of the 5 sets of data is replicated over to the EtherCAT analog output loop as the timing restraints for this system were much more lax as it only drove the existing HMI screen. The analog output was performed utilizing NI 9265 4 Channel 16bit 20mA C-Series modules. Six of these modules were needed to replicate the 24 channels of analog input collected by the three eight channel NI 9203 +/- 20 mA Analog Input cards.

The code on the cRIO is designed to be independent and replicate the data out over the analog output EtherCAT system when the PC is not up and running. This allows the system to be utilized with the existing PLC set-up and ELAU motion configuration code without involving the data collection system. This allowed the customer to reuse the existing hardware system while only upgrading the data collection system.

Functionality on the PC side is mainly driven by the data acquisition on the cRIO system. Once the operator selects the Formulator, Batch, and Formula number from the Database populated ring controls and selects one of three production systems to be replicated the data collection can be started. Data files created using LabVIEW were easily able to be matched to the customers existing CSV template. In addition to the 10 ms data collection that drives the analog and MODBUS collection there is also a digital trigger line that is monitored with the analog data that indicates to the data collection system on the PC whether any subset of data should be included in the data file. The customer was only interested in recording data after one of the main motion systems had moved away from "home" and the dentifrice was actually being pumped.

Improving the Bottom Line
The provided system allowed the customer to collect data in a streaming method live during a dentifrice tube filling test. This substantially cut down on test time as originally the data had to be stored on the PLC ELAU controller and then transferred via Wonderware to the original system PC, a process which was described as taking at least thirty seconds to possibly over a minute depending on the size of the tube and the fill speed selected. This long data transfer time was per each tube tested. The operator could originally not test a second tube until the system was done the data transfer.

The NI hardware based, DSA architected solution now allows the customer to collect data while the test is running, completely removing the post test data transfer process. The operator is now able to test tubes back to back without having to perform data transfer procedures. This has reduced the overall test time per tube filled by over 95%, making a machine that was dreaded to use into a key piece of R&D equipment.

NI products made the implementation of this solution possible, especially the cRIO platform with the ability to create custom timing and triggering algorithms to allow the motion system to drive the synchronization timing of the analog data collection on the cRIO system. The small footprint of the cRIO platform was also key in this implementation as it was able to be fit into a small cabinet on the existing machine without increasing the footprint of the overall hardware.

Time was saved in utilizing the RT controller of the cRIO to communicate with the pre-written MODBUS library. This allowed for easy integration to communicate to the existing motion controller PLC and for the cRIO to poll buffered motion data. Not having to recreate the base level functionality of MODBUS TCP was a definite benefit.

The ability of the cRIO to run headless and perform the synchronization, data collection, data replication was important from the standpoint of minimizing operator training on a new system. The cRIO was a transparent insert into the system when the operators were utilizing the existing WAGO and PLC code to configure the motion profiles of the system to match the production equipment they were prototyping. This is the same control system utilized on the production line so it was key to not add an additional difference in the performance of test system configuration in order to preclude the time and expense impact of operator retraining.

Contact Information
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Additional Materials
Captions

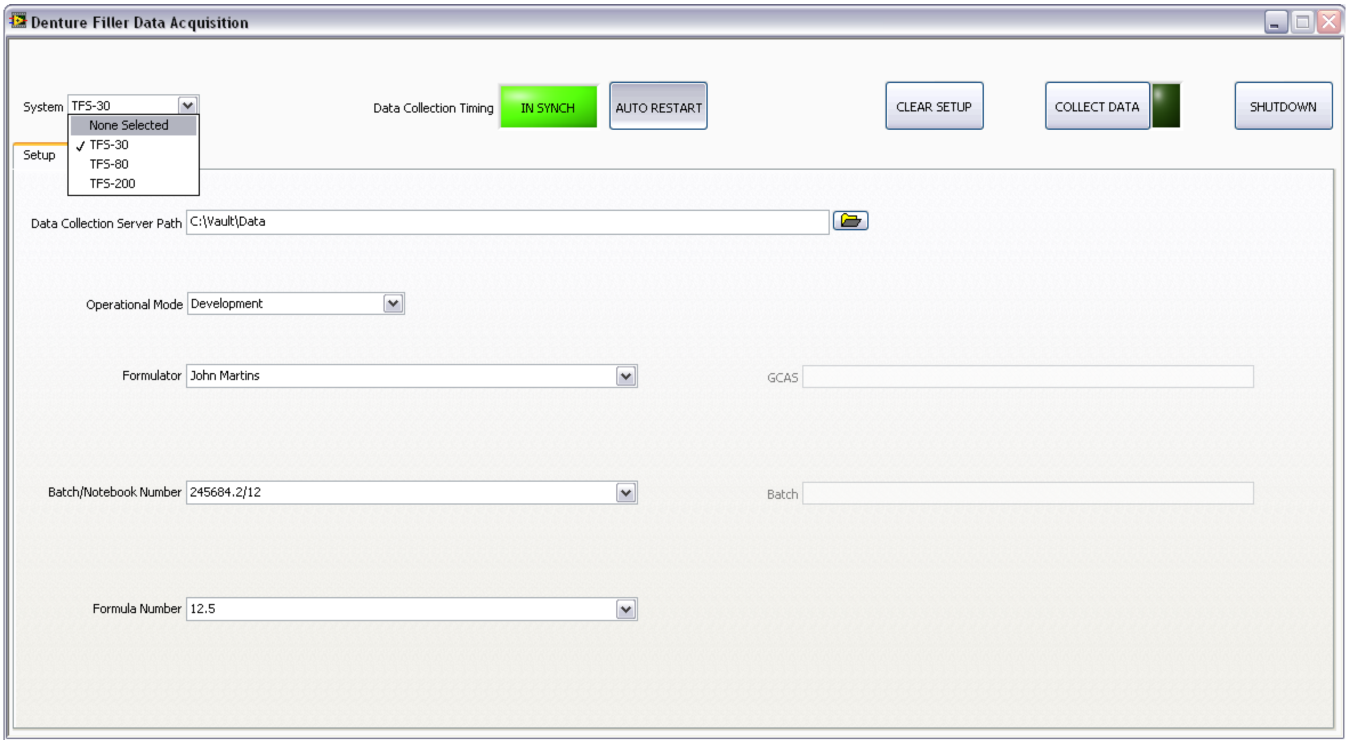

Figure 1 - Configuration Screen. This is where the operator selects database provided lists of Formulators, Batches, and Formula Numbers that the system is going to be used to test.

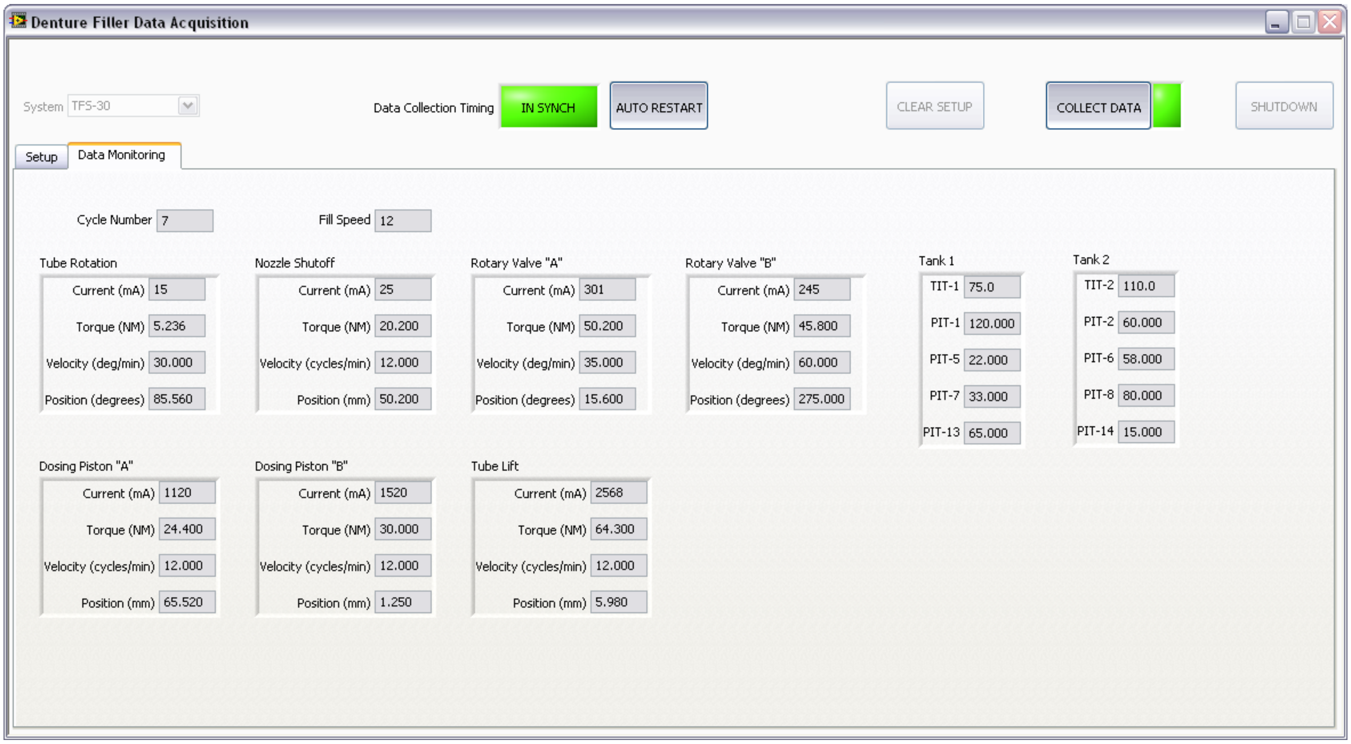

Figure 2 – Data Monitoring Screen. This screen provides live data to the operator while the system is up and running, regardless of whether data collection is set to record to file.

Figure 3 - Dentifrice