CASE STUDY: Synchronized Motor Test Stand Controls Using LabVIEW FPGA

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NI Products Used: PXIe-8101 RT Controller, PXI-7841R, LabVIEW-RT, LabVIEW-FPGA

Industry: Structural Test of High Speed Motor Components.

Application Area: Machine Design and Structural Test

The Challenge: Generate multiple high-speed synchronized vibration control signals based on rotational shaft position with dynamic user-configurable force vectors.

The Solution: Employ LabVIEW-FPGA software to rapidly develop code for reading quadrature encoders and generating synchronized control signals using LabVIEW-RT and PXI-7841R FPGA hardware to satisfy tight and demanding timing requirements.

Overview:

Digalog Systems Inc. is an ISO 9001:2008-registered supplier of solutions for test and measurement applications across a broad spectrum of industries including medical, automotive, aerospace, power switching and distribution, transportation, and electronics manufacturing.

Digalog was selected to develop control software for a High Speed Motor Test Stand. Digalog was selected for this project because of Digalog’s status as a National Instruments Alliance Partner as well as their close geographical proximity with their customer, due to the requirement for extensive on-site development work and collaboration. In addition, Digalog was chosen for our ability to provide a high level of software application programming expertise. Digalog’s engineers hold multiple levels of LabVIEW certifications and have extensive experience in developing test and data acquisition solutions across multiple industries.

Technical Challenge:

The challenge was to read a quadrature encoder signal and generate four (4) synchronized analog waveforms, derived from the shaft position of a rotating motor which could reach a rotational velocity of 25,000 RPM. The analog output waveforms themselves, with a full-scale range of +/-10V, needed to be user-programmable ranging from static to custom vibration profiles all configurable dynamically.

The original Motor Test Stand hardware design called for a pair of PXI DAQ cards, one with digital counter inputs for encoder signals and one for Analog Outputs, with timing and control handled within LabVIEW-RT using DAQmx I/O controls. Early analysis quickly revealed that this hardware design suffered with unacceptable speed, timing, and performance limitations.
Application Description:

The Test Stand hardware selected consists of a National Instruments Real-Time FPGA device (PXI-7841R) capable of generating four (4) synchronized analog output signals, based on the angular position of a motor shaft. The shaft’s position is monitored by a quadrature rotary encoder outputting 200 pulses per revolution on each channel (A & B) along with a reset index pulse (Z), providing a resolution of 0.45° or 800 counts per revolution. The rotational pulse counts were used as index pointers for an 800-element lookup table of analog output voltage values in the range of -10.0V to +10.0 volts. In addition to rotational control setting the Lookup table index, the FPGA code also required static fixed frequency control. When configured for static mode, for non-rotational control, a Fixed Frequency rate is used to generate a similar 800-count index value based on user-programmable timing parameters.

The LabVIEW FPGA application software architecture contains four (4) parallel loops (Quadrature Encoder, Fixed Frequency, Lookup Table AO, and User Interface). The three encoder signals are read by a trio of digital resource channels (DIO_0-2) and are decoded into a corresponding index value in the range of 0 to 799. The lookup table Analog Output (AO) loop uses this index value to independently update four analog output channel values based on lookup table values configured within four FPGA memory blocks. The Dynamic Mode variable selects either the Encoder or Fixed Frequency as the Table Index source.
The Dynamic Mode selection control allows four values: Disabled, Configuration, Encoder, and Fixed Frequency. In Disabled mode, the four analog output (AO) channels take their default value (Default_AO) which is typically 0.0 volts. In the Configuration mode, the user can change the Lookup Table and Fixed Frequency values. When the Dynamic Mode is set to “Encoder,” the motor encoder’s position value provides the index to the Lookup Table. The “Fixed Frequency” mode allows for table index generation independent of the motor rotation position. The Fixed Frequency loop lets the user configure non-rotational settings for frequency and number of cycles or the option to run in a continuous loop.

The User Interface control loop handles communications between the Host application and the FPGA. It can be used to set the dynamic mode or the read-back status, and for programming of the lookup table and fixed frequency parameters.
Application Interface

The Windows user interface (UI) provides control and configuration of the FPGA functionality running on the Real-Time system. Operation of the Motor Test Stand can be initiated or stopped from the user interface. The Lookup Table values for each of the 4 channels can be independently configured to use standard sine, square, triangle, and ramp waveform types, as well as importing arbitrary waveforms saved to file. The user interface can also be used to monitor the FPGA status and to read back the programmed waveforms.
Advantages of Using the National Instruments Platform

Digalog’s status as a National Instruments Silver Alliance Partner, our demonstrated LabVIEW expertise and our extensive experience with utilizing NI hardware and software products across a wide gamut of measurement applications, made the NI platform the obvious choice. Using LabVIEW FPGA facilitated rapid application development and the re-use of existing FPGA code modules for the encoder. LabVIEW FPGA also provided the advanced control over timing and synchronization needed to meet the demanding requirements of the overall application. While the FPGA hardware (PXI-7841R) was not in the original budget, the hardware cost was offset by the dramatic reduction in programming time and the higher quality control achieved, amply justifying its inclusion in the project.

The common LabVIEW knowledge base between Digalog and their customer contributed substantially to the full and successful realization of this complex project with its highly demanding requirements for timing synchronization and user configurable functionality. To ensure the customer was able to confidently take ownership, Digalog provided full application documentation, source code, along with on-site training.

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