Third-Party Research & Development
Technical Discourse

cirQED™ Rotation Analyzer 2.0: The Tool of Choice for Evaluating and Characterizing the Performance of Rotary Sensors

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BRIEF

cirQED™ Rotation Analyzer is a PC-based tool used to evaluate the performance of a wide variety of rotary devices. cirQED™ RA runs under all Windows operating systems currently supported by Microsoft Corporation. It is installed and run as a COM Add-in under Microsoft® Excel, which simplifies data acquisition and processing and extends the functionality of the instrument. This intimate relationship permits cirQED™ software to directly access a number of powerful Microsoft Excel Functions, including those built-in and the data analysis tools, i.e., the work functions available in the Analysis ToolPak Add-in. cirQED™ software provides the data and parameters for each analysis, the Excel tools employed use the appropriate statistical or engineering macro functions, and cirQED™ software formats and displays the results in tables and charts. This paper discusses several applications and some of the major operational features for the latest release of cirQED™ RA system, i.e., version 2.0. Included in these discussions are procedures and techniques for acquiring the type of sensor data needed to thoroughly test and characterize the performance of a rotary sensor, i.e., steady-state output signal responses with angular displacement, and dynamic output signal responses (time and frequency domain) with rotation speed.

cirQED™ Rotation Analyzer 2.0 – Solid Hardware With Application Flexibility

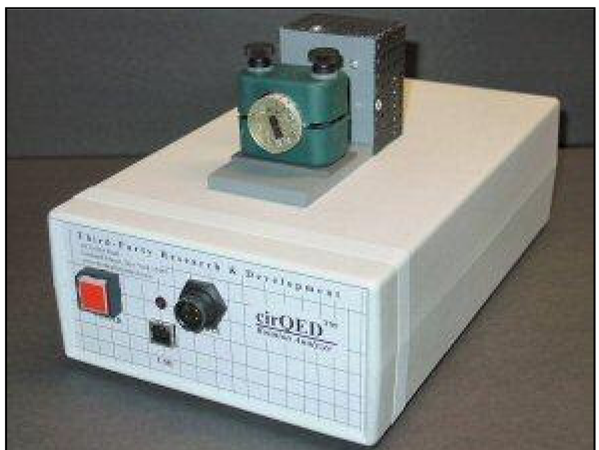

Figure 1. cirQED™ RA 2.0

Figure 1 shows the essential relationship of the major instrument parts used for both steady-state and dynamic testing. All of the various major instrument parts are integrated into and/or onto one small sturdy enclosure, which simplifies sensor testing and minimizes the amount of office or lab space that's required. The subassemblies and their relationship in the instrument are discussed and shown in considerable detail in the Instruction Manual (P.N. 062-IM-001-01), which is shipped with a unit. Figure 1 shows the cirQED™ instrument enclosure, including the stepper drive assembly (with heat shield) that is used to automatically rotate the shaft to fixed angular displacements, sensor clamp assembly, coupling link, and sensor cable connector. A sincos HallPot® rotary sensor, without connecting cable attached, is shown mounted in the sensor clamp. A power cable on the back panel (not visible) mates to a standard 120 volt wall jack. A USB jack on the front panel allows direct cable connection to a USB port on a PC or a USB hub. A lit LED above the USB jack indicates a live connection . A variety of sensor cables are available off-the-shelf that meet connection needs for many sensors and others can be custom made.

The sensor connector and cable supplies a well-regulated +5.000 volt DC signal and a ground connection to a rotary sensor (typically a HallPot® Angle Sensor, Sin-Cos HallPot® Resolver, or Resistor-Based Potentiometer) and two input data channels. The instrument has two major data acquisition modes: Steady-state Readings of Sensor Output with Stepped Angular Displacement and Dynamic Readings of Sensor Output with Continuous Rotation.

Sensor output measurements with angular displacement is done by physically coupling a sensor to the system stepper motor and making electrical connection with a sensor cable . Under software control, the instrument automatically steps (400-3200 steps per revolution) the sensor shaft through one or more revolutions and acquires, stores, and processes 12 bit analogs of the sensor output voltages at each step.

Dynamic output measurements at continuous shaft speed are conveniently done by physically coupling a rotary sensor to an external variable speed motor and making electrical connection to the cirQED™ Rotation Analyzer with a standard sensor cable . The speed of a DC motor used to acquire data shown in this paper varied directly with the magnitude of the applied voltage and provided speeds up to 19,680 RPM at 24 volts. Gearboxes may also be used to change the motor speed in fixed steps.

cirQED™ Rotational Analyzer – Powerful Software That's Easy To Use

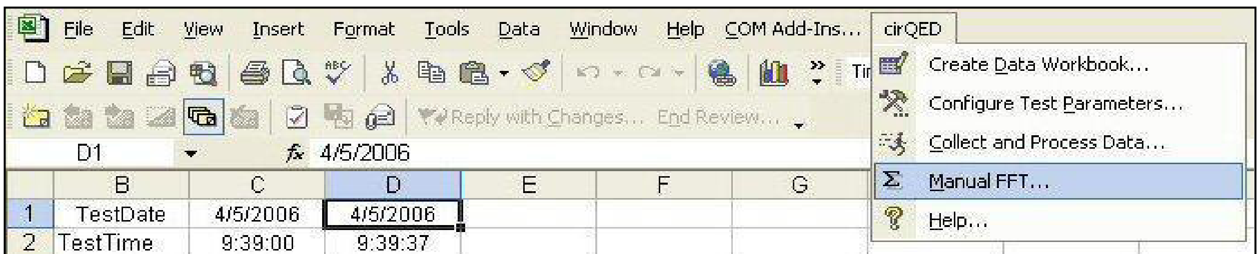

Figure 2. DropDown Menu in Excel for cirQED™ RA 2.0

As shown in Figure 2, cirQED drop down menu has five command buttons:

Create Data Workbook
Configure Test Parameters
Collect and Process Data
Manual FFT
Help

Create Data Workbook

This command creates and structures a workbook with three main worksheets: RawData, ProcessedData, and FFT.

Configure Test Parameters

Most of the test parameters and conditions are entered in the cirQED™ window shown in Figure 3. Test parameters include the number of data channels, data smoothing (by running average), using Autoselect to place data in columns, automatic charting, automatic FFT Analysis , setting the percent of rotational range for linear least squares fits with resistor-based potentiometers, test voltage units, setting the number of readings per full revolution, setting conditions for the AutoFind feature, and many more.

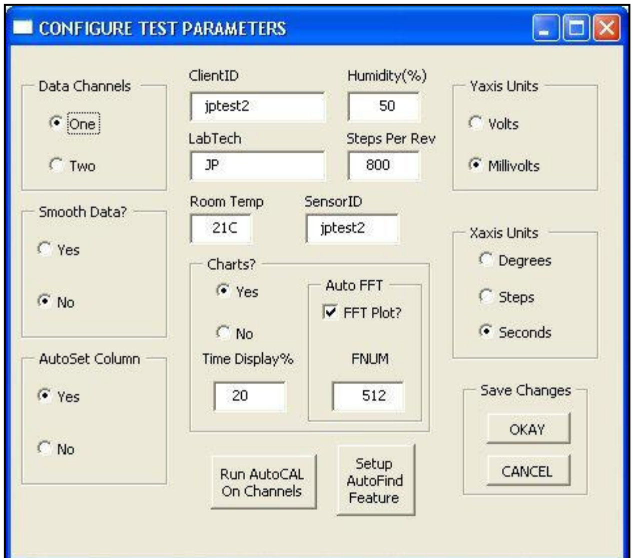

Figure 3. Configuring Test Parameters in cirQED™ RA

Collect and Process Data

As shown in Figure 4, the rotate Sensor and Collect Data Window has three main sections: Stepper Control, Rate & Time Control, and Other controls. The Stepper Control section permits locating a specific sensor shaft start position, either manually, using the Single or Multiple Steps button, or automatically, using the AutoFind button. When RUN TEST is pressed, the cirQED™ RA program steps the motor/sensor shaft to precise angular positions, acquires steady-state sensor output data at those positions, and records and processes the acquired data in the Excel workbook.

The Other controls permit selection of the type of Data Processing for a particular sensor type, setting a sensor or test ID number, and reading the current output values for each channel.

The Rate & Time Control Section Controls are used acquire dynamic performance data for sensors and/or other rotary devices that are rotated continuously. Pressing the RUN & RECORD button acquires12 bit analogs of the dynamic sensor output at the rate and total time selected by the user and records it directly into an Excel column. If AutoChart was selected on the Configure Test Parameters window, a chart of Amplitude versus Tine is created. Also, if the Ampliftude If FFT Plot is checked, as is shown in Figure 4, an FFT Analysis is also carried out and charts created.

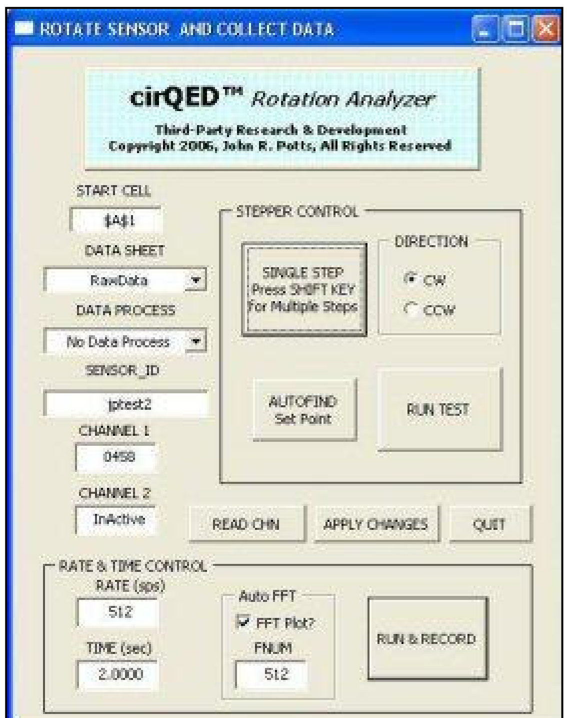

Figure 4. Collect and Process Data

For more details about cirQED™ RA FFT Analysis, see the following technical notes in the TECHIQUES and DOWNLOADS sections of www.thirdpartyresearch.com :

Application of cirQED™ RA for FFT Analysis

Part I – Identifying Real And Aliased FFT Components

Part II – Complex Signals, Spectral Leakage, Windowing Functions, and Indirect Analysis

Manual FFT

MANUAL FFT on the **cirQED DropDown Menu** in Excel displays a single-page window containing the parameters required to do FFT on a column of discrete data which has been typed or pasted into column E of sheet FFT of the activeworkbook, starting at E2. The maximum Sample Rate for data collected with cirQED™ RA is 25,000 dps, which by, Nyquist principle, permits FFT analysis of component frequencies as high as 12,500 Hz corresponding to a maximum rotation speed of 750,000 RPM. Manual FFT operations are applied for an FFT technique called Windowing, in the cirQED™ RA System, which is discussed in Part II of the technical notes referred to above. Manual FFT can also be applied to do an FFT Analysis and create FFT Spectral and Time charts for any data set which meets basic criteria needed to satisfy the FFT algorithm.

Help

General technical help not found in the manual or elsewhere, and Contact Information are found by selecting HELP.

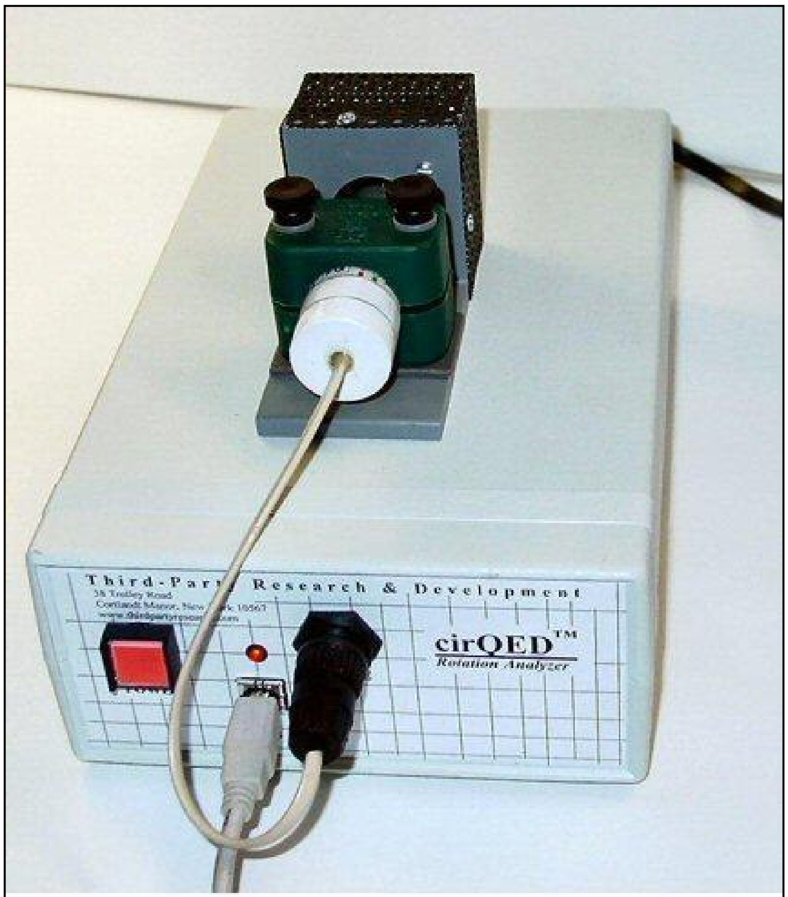

Figure 5. Configured for Auto-Acquisition

DATA ACQUISITION AND EVALUATION OF STEADY-STATE RESPONSES

Figure 5 shows cirQED™ RA system hardware configured to automatically acquire characteristic sensor data with angular displacements over one or more shaft revolutions. The setup is straightforward and involves mounting a sensor in an appropriate clamp (many sizes are available), coupling the sensor shaft to a stepper motor, and plugging in a sensor cable.
Also shown in Figure 6, are the USB cable for connection to a tower or notebook computer and power cable, visible at the far end of the enclosure.
The software configuration is generally a three step process: Create an Excel Workbook, Configure Test Parameters, and Collect and Process Data. Often, the first two steps need to be done only occasionally.

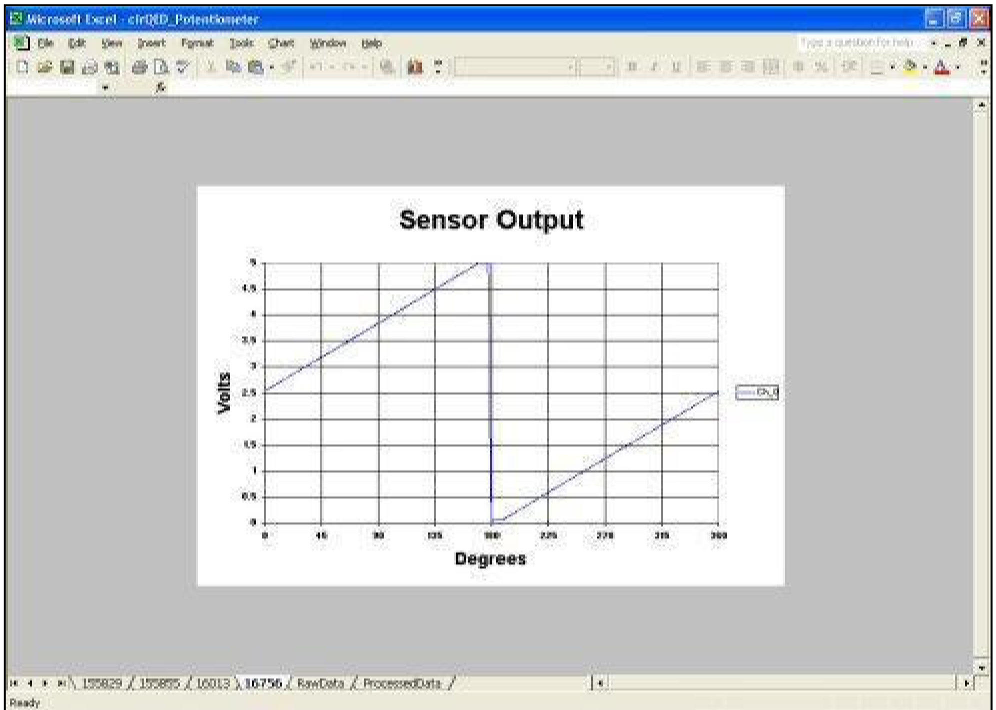

Figure 6. 5kohm 1-Turn Resistance-Based Pot

Figure 6 is a plot of steady-state output, in volts, with angular displacement of the shaft in degrees, for a 5000 ohm resistance-based rotary potentiometer. The starting point for acquiring data was selected as the midpoint, i.e., the shaft position where the output was 2.5 volts, and the direction of rotation was selected to be clockwise. These conditions are convenient for determining the useful range of rotation for the pot. The useful operational range was determined by custom cirQED™ RA processing software to be 94% or ~338 degrees. Linearity was excellent and determined to be on the order of a few tenths percent over the entire range.

Figure 7 is a plot of steady-state output, in volts, for both channels of a dual HallPot® sensor. The data shown was acquired with a cirQED™ setting of 400 data points/revolution. Additional processing to math model behavior was done using Excel Solver Function using the HallPot® raw sensor data acquired. The procedure and results of performing least squares fits to the following math models, using Solver Function, on the individual sin and cos output signals, are available under the DOWNLOADS section of www.thirdpartyresearch.com :

Eo = A*sin((pi*Angle/180)) +C 'for the sine output

Eo =A*sin((pi*Angle/180)+B)+C 'for the cosine output,

Where A, B, C are fitted coefficients.

Each sensor output showed basic sinusoidal behavior with angular displacement. The maximum error in Eo estimated using the fitted equations over 0-360 degrees was about 1.5 %,. The estimated phase error was about one degree.

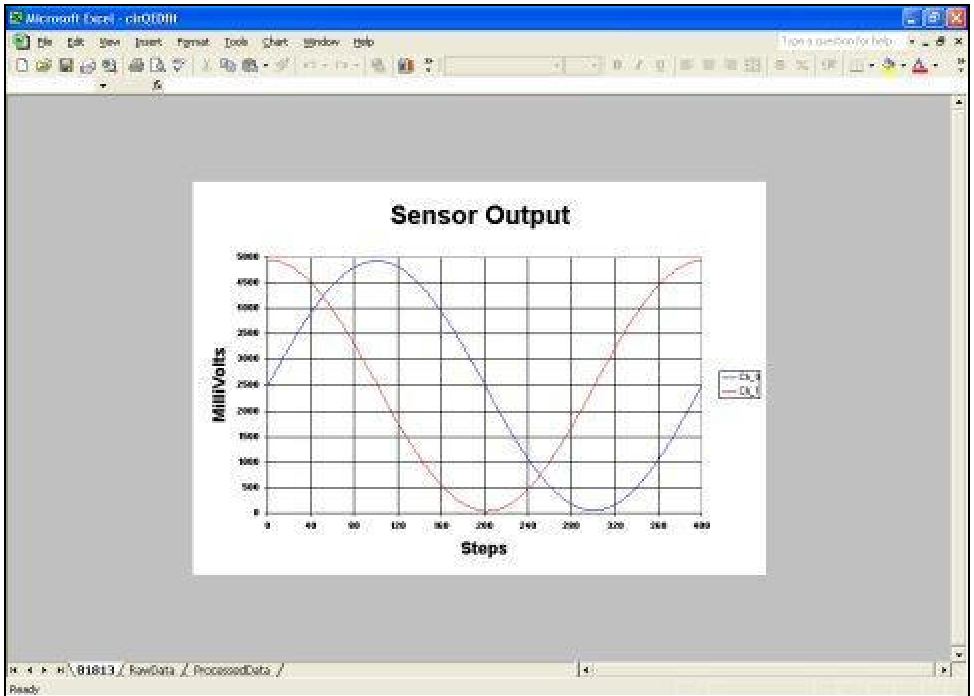

Figure 7. HallPot® with Dual Output

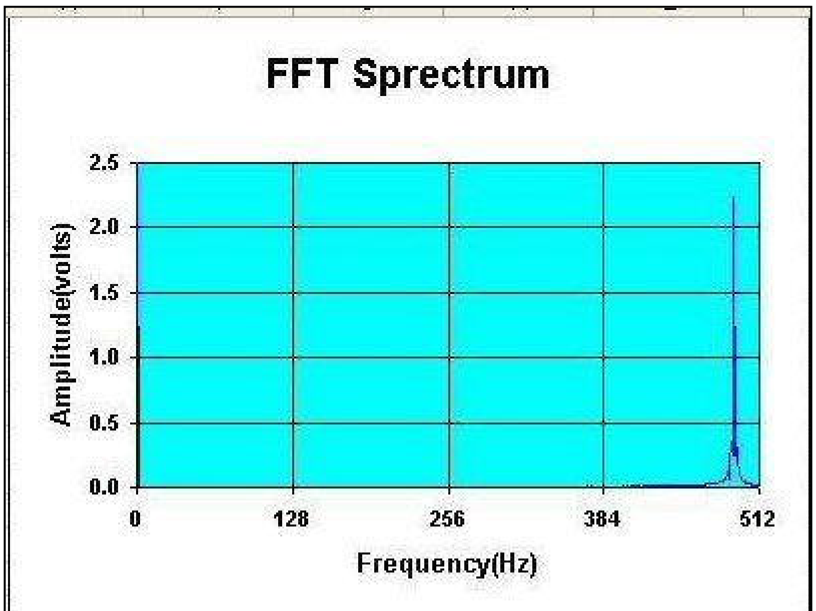

Figure 8. HallPot® at 29,460 RPM

Dynamic Responses of Sensors – Performance with Rotation Speed

Figure 8 shows a single frequency component at 494 Hz from FFT Analysis on a 2.0 second sample of 1024 discrete output readings from the sine output of the same HallPot® sensor run at very high speed (CAUTION…this speed is not recommended by the manufacturer). The signal amplitude was identical to that found at lower speeds. See the TECHNIQUES section on www.thirdpartyresearch.com for more details concerning the cirQED™ RA FFT feature.