

MICRONOR

Positioning Gold Standard Software

Instruction Manual

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Revision A, 11/14/2014
For EC-TD5325 PGS Software V1.32

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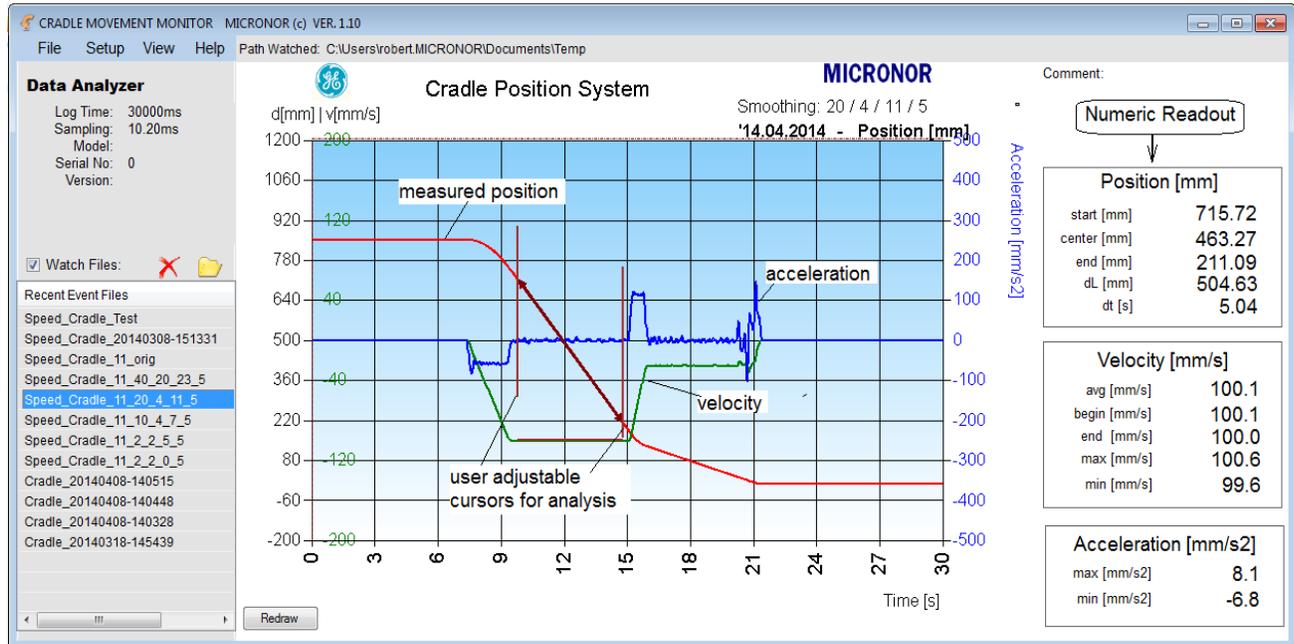
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UNITED STATES OF AMERICA

Revision History

Document Revision	PGS Software Release	Date	Description
A	1.30	7/17/2014	Release for production
B	1.31	10/7/2014	Added more measurement capabilities and filtering methods.
C	1.32	11/19/2014	Added Time Verification in Encoder tab Added debug field for serial connection Various clean-up (logo appearance etc.)

POSITIONING GOLD STANDARD SOFTWARE (PGS)

PGS is the PC Software used to capture, monitor and analyze the position of the cradle within an MRI machine. The PGS derives the position information from the MICRONOR MR338 MRI compatible Fiber Optic Absolute Sensor. During a capture sequence it continuously monitors and logs in real-time the position at a predetermined time interval. The acquisition timing is controlled by the sensor controller (MR330) and is quartz crystal accurate to within 100ppm. The high resolution and fast update rate of the sensor makes it possible to derive accurate velocity and acceleration information from the position signal.



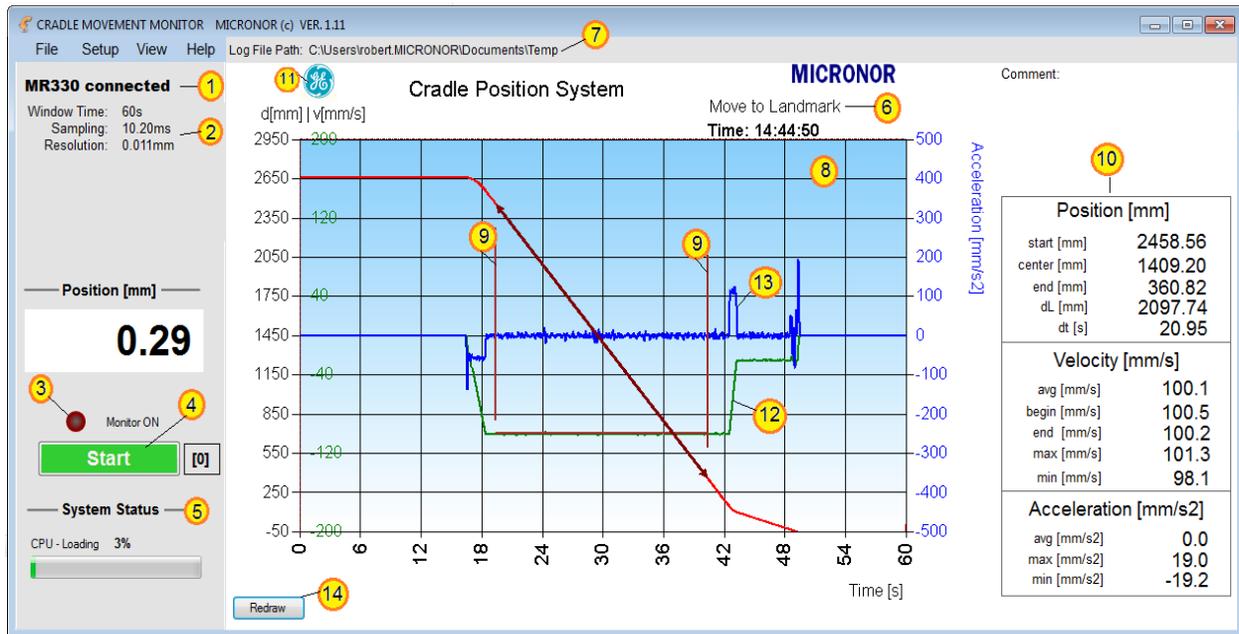
FEATURES

- ✚ Sample Rate User Setting typical 1ms, 2ms, 5ms, 10ms, 20ms etc
- ✚ Calculates Angular Speed and Acceleration after each acquisition cycle.
- ✚ User configurable acquisition parameters.
- ✚ User interactive cursor settings for data analysis.
- ✚ Data File Log in Excel compatible coma delimited ASCII (*.CSV)
- ✚ Configurable smoothing filter parameters.
- ✚ Configurable File Path
- ✚ Graphic Output File for each event
- ✚ Print from Software
- ✚ Output Graph in many graphics formats (bmp, png, jpg, ..)
- ✚ Zoom and Capture Real-Time Data to Clipboard wit copy to Excel
- ✚ Built-In ZapView™ Diagnostics for MR330 Controller Unit
- ✚ Three modes of operation: Normal Data Acquisition, Data Analysis, Simulator
- ✚ Automatic Graph Update when using Remote Computer(s) create Event file

Compatible with Windows XP and Windows7

➔ Prerequisite is a multicore CPU "core i5" or better , at least 4gb RAM

DESCRIPTION OF CONTROLS



1. Mode Indication: When in Normal Data Acquisition Mode this field shows the type of hardware controller attached to the PC and communication established i.e “MR330 connected” or “MR320 connected”. When in Analyzer Mode “Data Analyzer” is shown and when in Simulation Mode “Simulate” is shown.
2. Setup Information: These are the setup parameters which all can be set by the user. See SETUP and Parameter configuration.
3. Monitor Status LED indicates the status. While capturing data is activated this LED will blink.
4. START / STOP button. When clicked will start the data stream from the controller (MR330) and the position data is graphed. Capturing will stop after the predetermined time has elapsed.
5. System Status will a.) shows the actual position in mm and b.) display PC computer (CPU) loading. Computer loading may be high when installed on an older type CPU and when high acquisition cycle of less than 10ms is selected. With a heavy stream of incoming data (every 1ms) a PC computers with only one CPU core can get overloaded. It is recommended that PC’s with at least 2 CPU cores are used. The lower the sampling period and the longer the monitor window is, the more work the PC has to do. If CPU loading is high, increase sampling time and/or make the monitor window shorter in time.
6. User definable field, it may be used to describe the subject test or other useful information relating to the test. Use Setup – Parameters menu to edit this text. This information will appear within all files including the saved graphics and is tied to the data.
7. File Path where the data files will be stored. This path can be edited in the File – Default _Path menu.

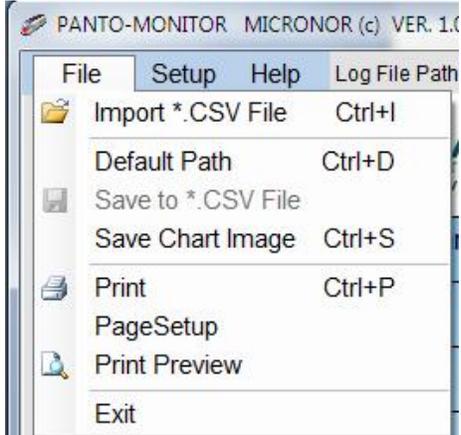
8. Monitoring Window. The graph window is capable of displaying position, velocity and acceleration. The scale can be defined in the parameter setup menu. Velocity and Acceleration are calculated as the first and second derivative of the measured position.

When left clicking and holding the mouse button a time slice can be highlighted and zoomed into for closer data inspection. This feature is only available in the data analyzing mode. It is de-activated when monitoring real-time data.

When right clicking on the Monitor Window a pop-up menu appears with three choices

- a.) Copy graph, this is convenient to take a pictorial snap-shot. The picture can be pasted into other documents such as a MS Word document. Note that keyboard command ctrl-c will also copy the graph with its current content. This command is always available even when monitoring live data.
 - b.) Zoom Graph puts the Monitoring Window into a zoom mode. Use the horizontal scroll bar to find the data points of interest.
 - c.) Copy data to Clipboard is a very helpful utility. It allows the user to capture the numerical data into the PC clipboard for directly pasting into an Excel spreadsheet. For instance the user can zoom in to a specific area and copy the content to the clip board and then paste it to an Excel sheet for analysis.
9. Upon completion of an acquisition cycle the software automatically places user cursors on the graph. These cursors can be positioned in order to measure specific areas of the graph.
 10. Numeric Data readout. These readouts are dependent of the measurement cursors within the graph. For instance the field "start" is the measured position at the location of the left cursor. See section ???? for more detailed description.
 11. The users company logo maybe displayed in the title location. In the parameter setup menu is a checkbox for activating the logo display.
 12. Velocity. Calculated from position: $V [mm/s] = dP/dt$
 13. Acceleration. Calculated from velocity: $A [mm/s^2] = dV/dt$
 14. Redraw button. Click here for re-calculating and drawing the data. This is typically necessary after changing parameters.

File – Menu



Import *.CSV file allows previously captured data files to be imported into the Monitor Window for more detailed analysis.

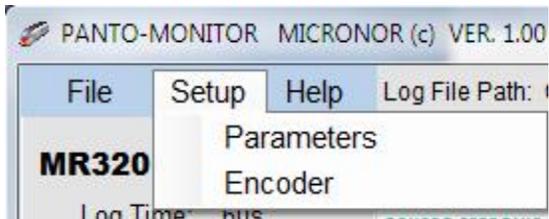
Default path can be set here. This is the path where the event data files will be stored.

Save to *.CSV File is only active in Analysis mode and when a data file has been imported previously.

Save Chart Image allows for saving of the Monitoring Window Picture Image in various common picture formats such as jpg, bmp, png, gif etc.

The chart image can also be printed to a windows compatible printer connected to the PC.

Setup Menu

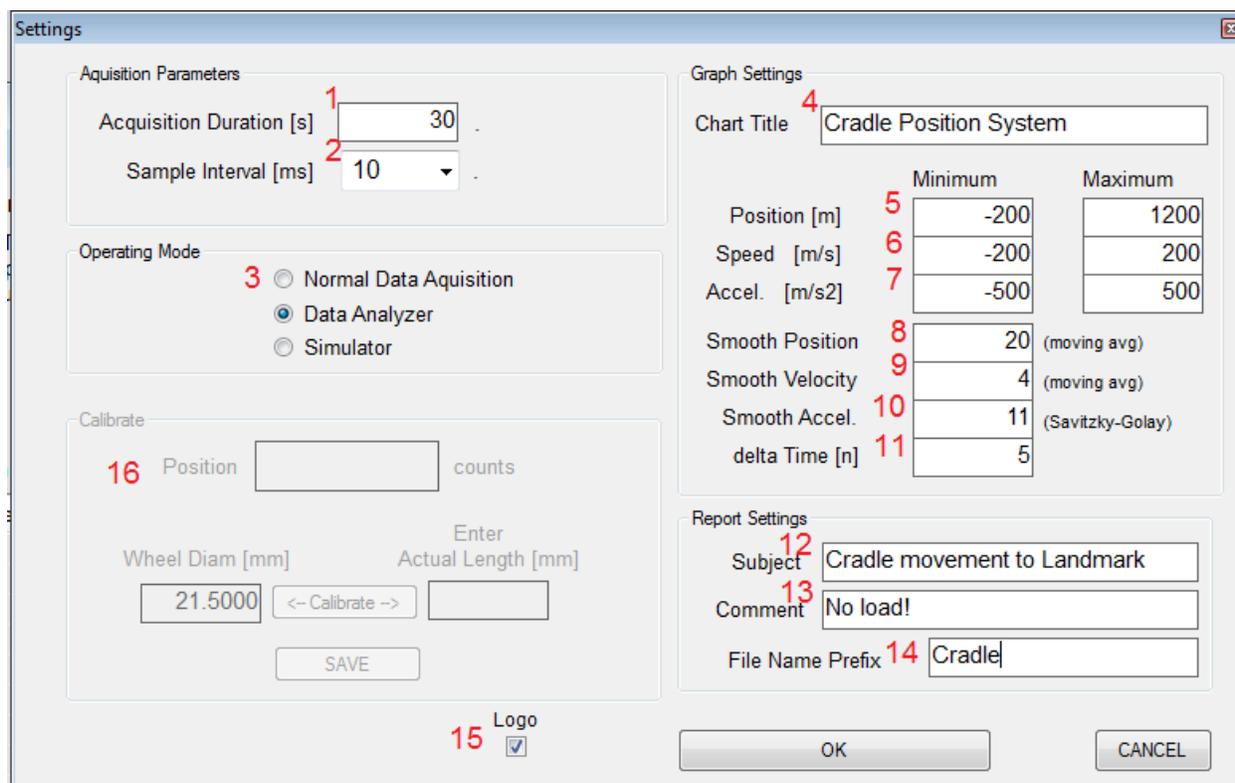


Parameters are used to configure the CRADLE-MONITOR Software. Acquisition speed, acquisition time window, graphing range, filtering coefficients etc.

Encoder is used to set the Encoder position to a specific point and to check proper operation of the encoder. Encoder is only available when the proper hardware is connected.

Setup – Parameters

The Software Parameter Settings affect the performance of the data logger. The user should set these parameters specifically for the particular application.



1. The Acquisition Duration time defines "Monitor Window" length in seconds. It is the time duration of one recording. The acquisition starts when the user clicks the "START" button and ends when the pre-set time has elapsed. The software allows for approx. 5% longer acquisition than programmed. This is intentional, so that the user can click the start button and then start the movement of the cradle.
2. Sample Interval defines how often a position snapshot will be taken. The user should carefully plan the number of samples along with the Monitor Window time, because it affects how many data points will be stored for each event. The fastest sampling rate for the MR330 will be 0.85ms while the fastest. For cradle movements an acquisition time of 10.2ms is recommended.
3. Operating Modes: The normal operating mode is used where the system records real-time data. Naturally, the MR330 Sensor must be connected to the PC computer running CAPTURE-MONITOR software. The Data Analyzer mode is used where the stored data files need to be analyzed. No connection to hardware is required. Simulator mode is used to simulate real-time data gathering without having hardware available. It is a convenient feature to get acquainted with the software while not having hardware available.
4. Chart Title is a user-editable text that will appear as the Title in the Data files and the strip chart recorder.
5. Position [Scale] is the Y-Axis for position measurement. Set it suitable for the application and change in position to be measured.

- ° Tip: The Y Axis may be changed later after the data acquisition is completed to a more suitable setting, by retrieving the data and redraw the graph.
- 6. Speed [Scale] is the Y-Axis for Speed Indication.
- 7. Acceleration [Scale] is the Y-Axis for Acceleration Indication.
- 8. Smoothing Filter for position. The measured position is being “smoothed” to reduce measurement noise. This number determines the number of acquisition points the moving average window is being applied to. The higher this number is the stronger the influence of the filter effect. Typical number is between 10 and 20. See more details “Moving Average Filter”. To turn OFF the averaging set this number to 1.
- 9. Smoothing Filter for velocity. The velocity data is the first order derivative of the position data. In order to minimize velocity “noise” or ripple the calculated data can be “smoothed” to reduce the effect of the derivative. This number determines the number of acquisition points the moving average window is being applied to. The higher this number is the stronger the influence of the filter effect. Typical number for treating velocity data are between 4 and 8. See more details “Moving Average Filter” To turn OFF the averaging set this number to 1.
- 10. Smoothing Filter for acceleration. The acceleration data is the second order derivative of the position data. In order to minimize acceleration ripple the calculated acceleration data can be “smoothed” to reduce the effect of the derivative calculation. Typically the acceleration data includes “high frequency” components. For instance when starting a cradle movement there must be an instant of acceleration. Thus a typical moving window averaging process would “wash out” the acceleration data and thus is not desirable. The filter algorithm employed here is a “Savitzky-Golay” filter. The number entered into field 10 determines the order of the SG filter. In order to keep the filter symmetrical only odd numbers in the range of 5 to 23 are allowed here. See more details under “Savitzky-Golay Filter”. To turn OFF the filter set this number to 0.
- 11. Delta Time is the distance between the acquisition points used when calculating the derivative for velocity and acceleration. The number entered here is the number of acquisition points. For instance is the acquisition time is 10.2ms and delta time is set to 5 then the velocity calculation is using a time span of $5 * 10.2\text{ms} = 51\text{ms}$ for the calculation. See more information under velocity/acceleration calculation.
- 12. Subject is a user editable text that will appear on all recordings. It is intended for the user to define the test subject. This field will help identifying the test. It is also advisable to change the file header for different test series.
- 13. Comment is an extra user editable text that will appear within the data file recordings.
- 14. File Prefix is important to keep recorded data files separated from each other. It is up to the user to define a meaningful File Prefix. Output file names are generated as follows:

PPPP_yyyymmdd-hhmmss.CSV

Where: PPPP is the user defined file prefix
 yyyy year recorded with full 4 digits
 mm month of recording
 dd day of recording
 hh hours of recording
 mm minute of recording
 ss second of recording

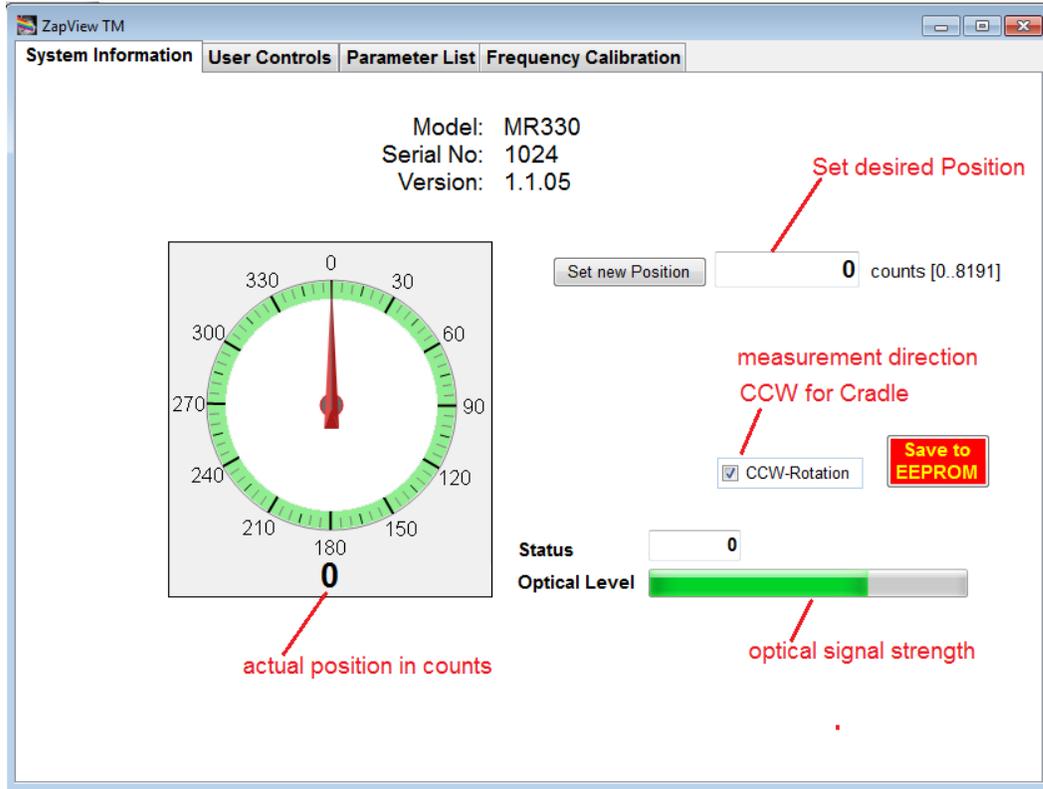
The date and time stamp in the file name is the time when the data acquisition ends.

15. Logo, when checked will display the company logo.
16. The calibration section is used to calibrate the “string” length to an absolute standard. This area is typically disabled and only available when an “access code” is entered. See calibration instructions for more details.
17. **OK** button is to accept changes and exit the Parameter Settings screen. If you wish to exit without accepting edited values click on the **CANCEL** button.

SETUP – Encoder

MR330 – Setup Screen

The MICRONOR MR330 Fiber Optic Absolute Position Sensor is a very accurate measuring device. It resolves one turn into 13950 counts (~14 bits) resolution. In order to satisfy many diverse applications the system has a host of user parameter settings. CRADLE-MONITOR implements a reduced sub-set of the setup possibilities.



The ZapView™ software supplied with the system is more comprehensive and should be used for applications other than using the CRADLE-Monitor. Once the system is mechanically installed the position should be calibrated at the home or Zero position. The main screen does have a button [0] and performs the same function. If, for some reason, the position should be set to other than 0 position this screen allows for any arbitrary position setting. Calculate the position count form mm as follows:

$$C_p = R[\text{mm}] / (D_{\text{wheel}} * \text{Pi}) * 13950$$

The wheel diameter D_{wheel} is the calibration value.

The direction of rotation defines if distance is positive, or negative, as the string pulls out of the unit. For the cradle measuring system it is CCW. If you change any setting the red button “Save to EEPROM” will appear. Click tis button to commit the changes to the controller EEPROM.

Please consult the MR330 instruction manual for more information on the operation of the MR330 absolute position sensor functions.

MR330 – Timing / Frequency Calibration (EC-TD53250

Description of MICRONOR EC-TD5325 Data Acquisition and derived Speed Measurement.

When the MICRONOR EC-TD5325 fiber optic measuring system is operated in conjunction with the Gold Standard software the position, speed and acceleration of the patient cradle are monitored. The absolute position accuracy is calibrated using a comparison to standard length gauges traceable to NIST.

The speed is derived as the derivative of position data and time span of the position samples.

$$\text{velocity} = \Delta d / \Delta t$$

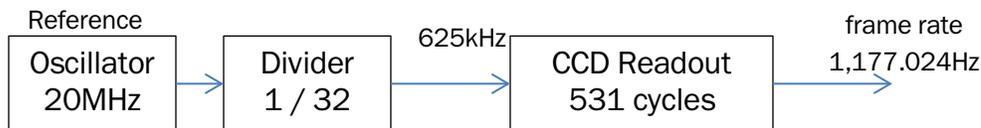
Distance d is the calibrated distance travelled within the given time span t. In order to certify traceability of the speed measurement, the source of the time span measurement must be calibrated and traceable to NIST

When making real-time measurements using a PC operating under Microsoft Windows several factors must be considered.

- a.) MS Windows is not a real-time operating system.
- b.) Communication via Serial interface or USB interface introduces timing latency and is generally not predictable.
- c.) PC clocks are generally not very accurate and require periodic synchronization. A personal computer is usually not part of an on-going calibration program where the timing and other functions of a PC are certified to Standards such as NIST.

For the above reasons, the MICRONOR EC-TD5325 Position Measuring System does not rely on the PC timing for position, velocity and acceleration data.

The MR330 controller (electronic interface to the EC-TD5325 sensor) utilizes a powerful micro-controller running real-time firmware. The MR330 controller unit continuously acquires position data at a fixed and accurate time interval of 849.6µs (1.17702kHz). This acquisition timing interval is derived from the internal crystal oscillator operating at 20.000MHz. The 20 MHz frequency is divided by 2⁵ (32) generating 625kHz CCD read-out pixel clock. The internal CCD readout requires 531 cycles. Therefore the frame rate is 625kHz / 531 = 1,1770245kHz (849.6µs interval). Within this document, we refer to it as the **frame rate**.



A new position value is generated at the crystal controlled frame rate. The user defines via the software how often to transmit each position value. For instance when 10.2ms is chosen, every 12th frame cycle the position information is transmitted to the PC via the serial or the USB interface.

Because the position information is sent to the PC at the frame rate dictated by the MR330 controller (not by the PC), the timing information is independent of the PC clock and is independent of the latency time incurred through serial transmission. The PC has a deep internal FIFO buffer of up to 65k bytes for the position readings. The Gold Standard Positioning software periodically reads this buffer and plots the data in exact sequence and according to the time interval the data points were generated.

The MICRONOR MR330 controller has a built-in high precision, crystal oscillator operating at 20MHz (part number CWX813-020.0M 20MHz +/- 25ppm specified over the temperature range of -20° C to +70° C). The frame rate is derived from that highly precise and stable crystal oscillator.

In order to calibrate the system for speed accuracy, the 20MHz frequency must be measured using a NIST traceable frequency counter.

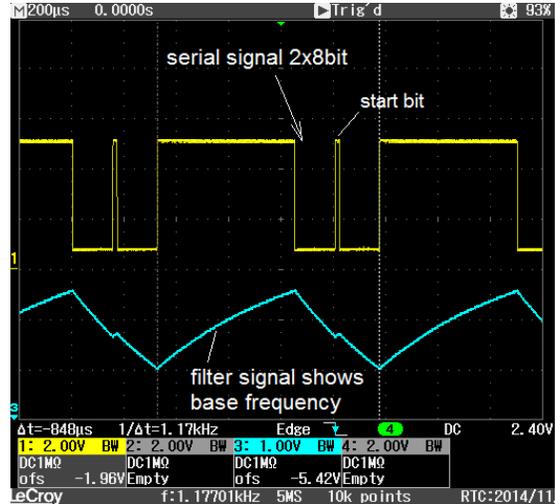
Position measurement is accurate to within 0.5mm over the span of 3700mm. In percentage that is 0.0135%. The precision of the time reference should obviously be the same accuracy or better. The manufacturer's specification for the crystal oscillator is ± 25 ppm which is equivalent to $\pm 0.0025\%$. Taking into account other factors, Micronor recommends to test and calibrate the frequency standard to 0.01%.

Procedure:

The internal oscillator is used as the timing reference for outputting the serial data at a precise predetermined interval.

This test procedure is based on electronically tapping into the serial interface signal. An external Frequency Counter is used to measure the frequency of the serial data packet.

Using the Positioning Standard Software the MR330 controller unit is commanded to send one 16bit data packet every 849.6 μ s (1,177.0245Hz). When the data is exactly &H0000 (zero) the signal appears as shown in the picture. The center peak is the start bit of the data. This peak is filtered out and the resulting waveform (Trace B) can easily be measured by a frequency counter instrument.



Micronor provides the model EC-TD5325-9 interface that must be used for this calibration.

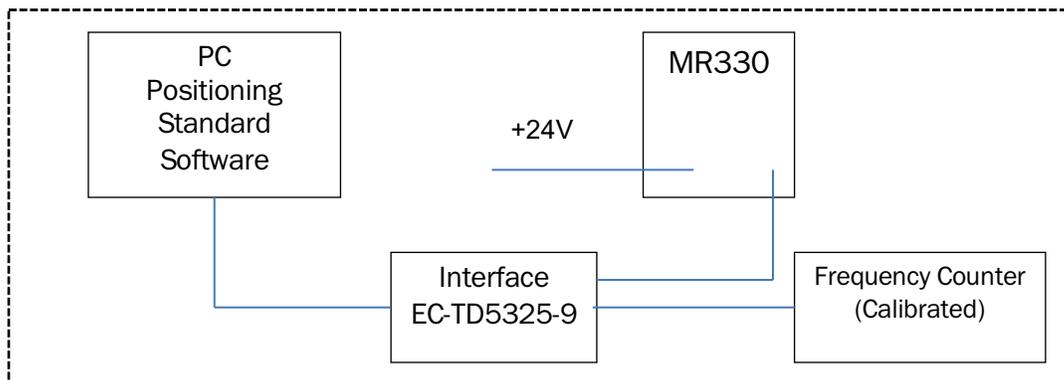
When the MR330 firmware version is 1.1.06 or lower. For firmware version 1.1.07 or higher, the test signal is available at the connector J1 pin1. (No special interface cable is required).



Required Material and Instrumentation:

- MR330 unit to be calibrated
- EC-TD5325-9 USB-Serial Interface with frequency counter filter.
- EC-TD53 Positioning Software Version 1.32 or higher.
- PC capable of running Positioning Software

Setup Diagram



Calibration Steps:

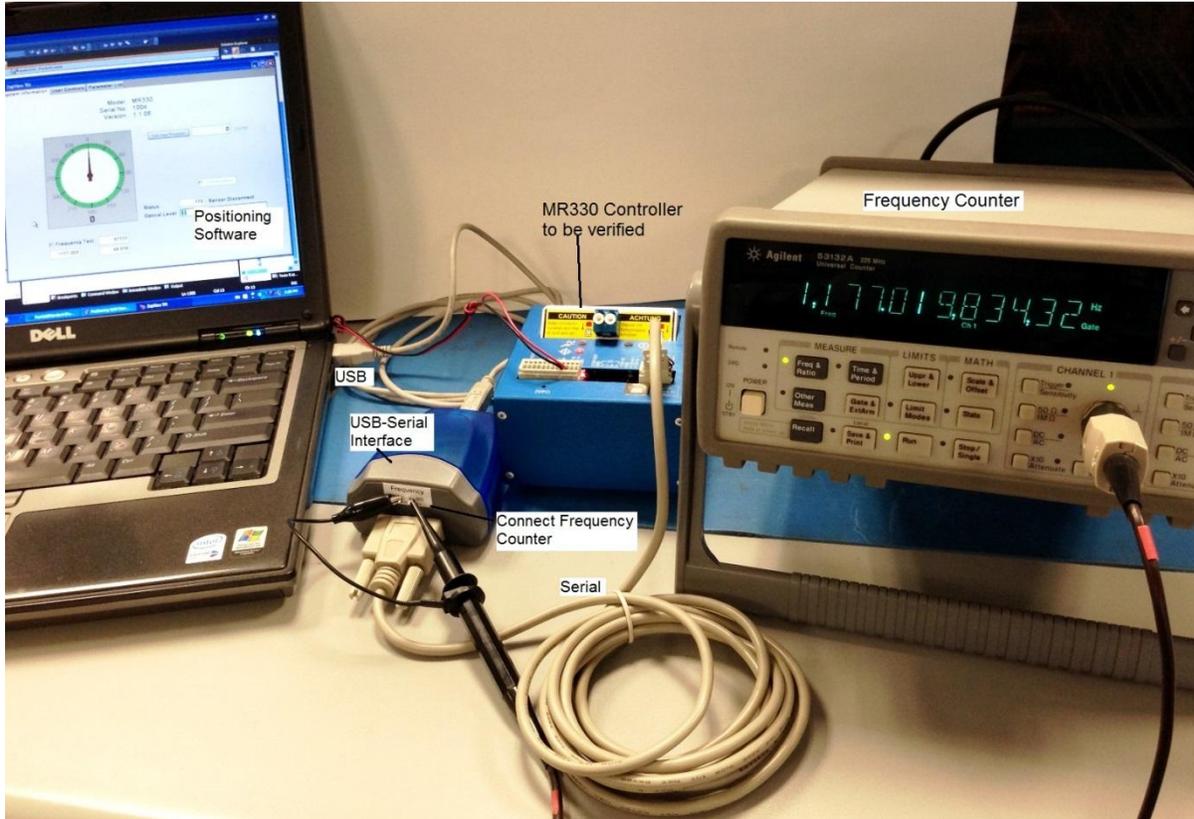
Connect the PC to the MR330 controller unit using the special USB-Serial Interface (EC-TD5325-9).

Connect the Frequency Counter to the USB-Interface.

Do NOT connect the fiber optic sensor!

Start the Positioning Software.

Verify the controller MR330 is connected.



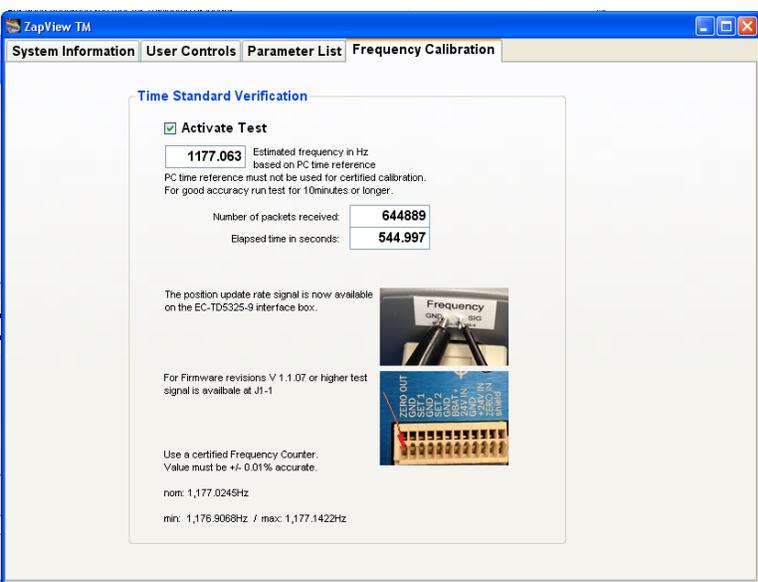
In Within the Positioning Software
 Select Setup – Encoder – Frequency Calibration
 Click on Activate Test

The external frequency counter now measures the output frequency which must be within $\pm 0.01\%$.

Maximum: 1,177.1422
 Nominal: 1,177.0245
 Minimum: 1,176.9068

Unclick the checkbox Activate Test.
 Calibration is complete.

Note: The Software displays the transmission frequency measured against the PC clock. This is not a traceable calibration, however, it generally is well within the accuracy requirement of the system. Generally, the frequency read-out of the certified frequency counter must be used



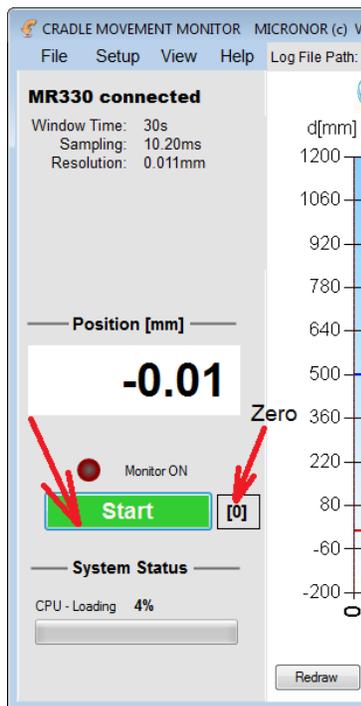
Position Monitoring

When in Normal Mode and connected to the MICRONOR MR330 Fiber Optic Encoder System the PC software is ready to acquire data.

A typical measurement sequence is:

1. Set Cradle to starting position
2. Make sure parameter settings for scale time duration etc. are as desired.
3. Click “Start” button
4. Start Cradle movement.
5. Wait for pre-programmed acquisition time to elapse.
6. Software will automatically calculate and graph velocity and acceleration.
7. Data is automatically saved to computer hard disk.
8. Manipulate data as desired. You may save data under a different file name if required.

In the following a typical data capture sequence is described:



Make sure the System parameters are set as required by the application.

If necessary reference the zero position by clicking on the button [0] next to the start button.

Click the START button and the system will start monitoring data indicated by the moving red line.

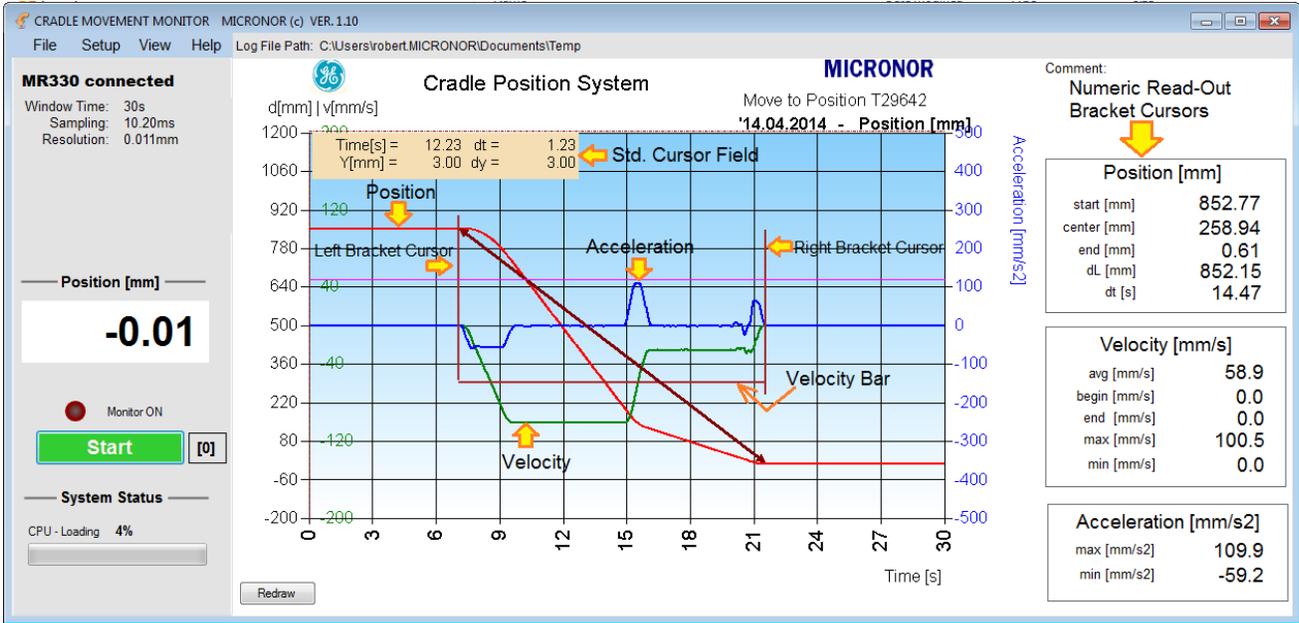
If the graphical strip chart remains blank then the data stream from the MR330 Controller did not start properly. This could either be because there is no connection to the MR330 Controller or the USB Latency time may not be set properly. Please see Installation instructions.

The Monitor LED starts blinking and the strip chart starts filling in with the position information.

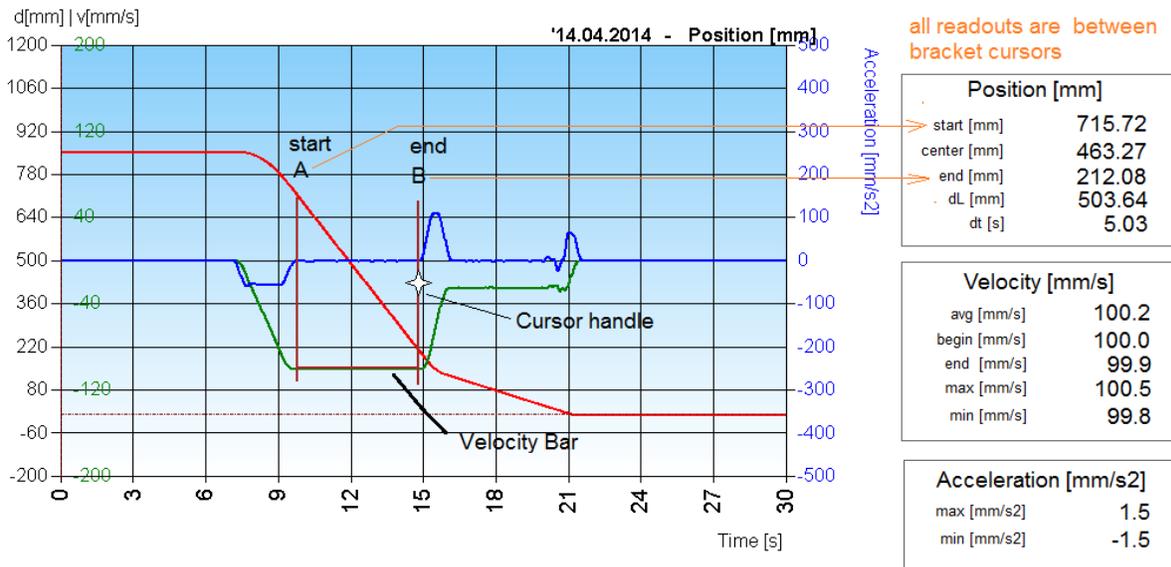
During Data acquisition, only the red position data is charted.

Once the test sequence is completed i.e. acquisition time has elapsed, then the velocity and acceleration data are calculated and graphed.

User may stop acquisition by clicking on the “STOP” button. Remaining data is being filled in with 0.0 position values.



The red trace is the position data. The green trace is the velocity data. The blue trace is the acceleration data.



The software places two bracket cursors onto the graph. The bracket cursors can be manipulated by the user for obtaining specific measurement values within the graph.

For instance the average speed during the first phase of movement can be measured by placing the cursor left and right of the “flat” part of the velocity data. The numeric readouts on the right hand side will now provide all numeric data between the left and right bracket cursor. Average velocity readout is derived from the calculation distance dL divided by the time dt.

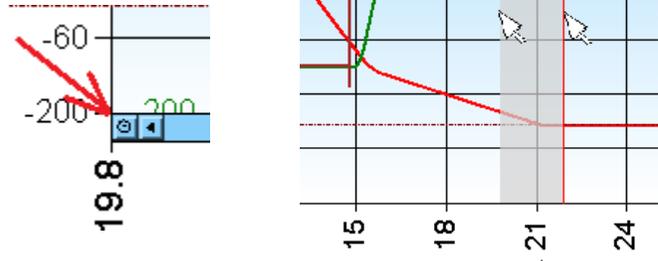
In this case $503.64\text{mm} / 5.03\text{s} = 100.2\text{mm/s}$.

- ° Tip: For documentation purposes the user may save the graph picture by going to Menu File, save Chart Image, or by simply by <ctrl>-S key.

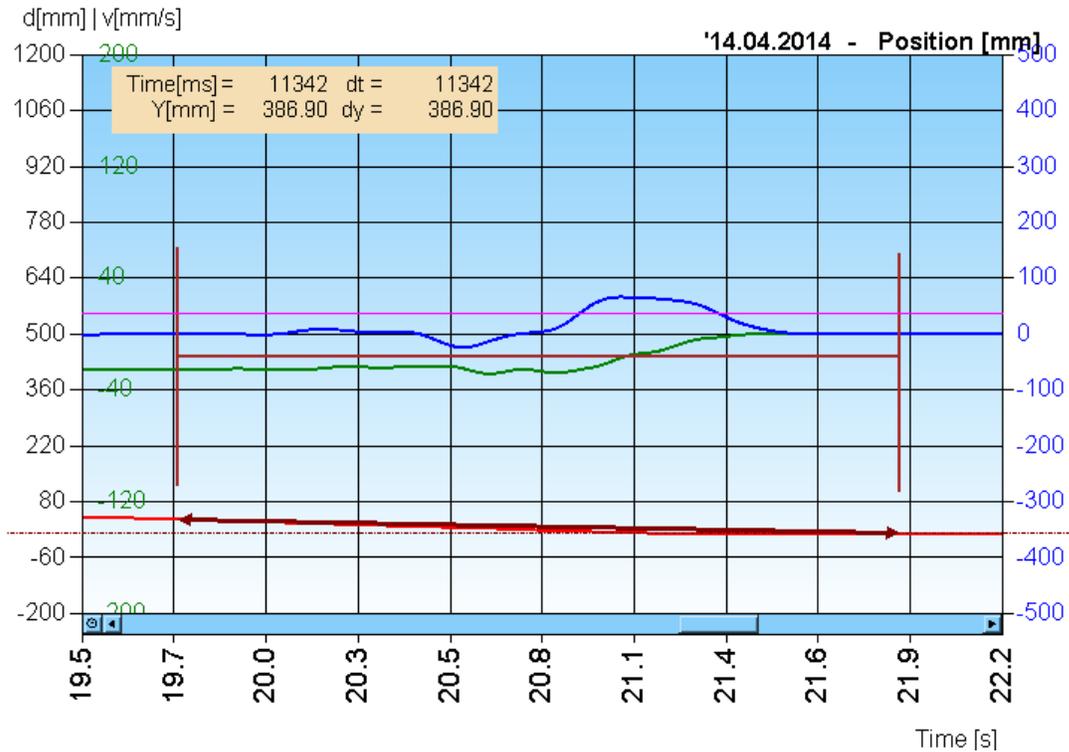
Graph Zooming

For analyzing details within the graph the user may zoom by placing the mouse pointer to the left of the beginning of the area of interest and drag the mouse across the area of interest.

The graph will now expand to this new defined area. To zoom back to the normal size click the small ellipsis on the lower left hand of the graph.



In the example here we zoomed in around the end of the movement where the cradle moved toward the home position and clicked into the home position detent.



The detent causes some “jerking” in the movement which can be clearly seen in the velocity and acceleration data.

The graph depicted above was treated with substantial averaging and thus the acceleration data is “washed out” we can make the movement better visible by changing the graph parameters.

Changing Graph Parameters

Changing the graph parameters is possible after the data acquisition. The software will not alter or change the original position data, thus the user can always go back and analyze data using different settings.

Assuming we want to have a closer look at the change in speed when the cradle slows down going to the home position around the 15 second time.

We change settings as follows:

- Position Scale: -100, 600
- Velocity Scale: -200, 0
- Acceleration Scale: -200, +200
- Position Filter: 16
- Velocity Filter: 8
- Acceleration Filter: 15
- Delta Time: 5 (no change)

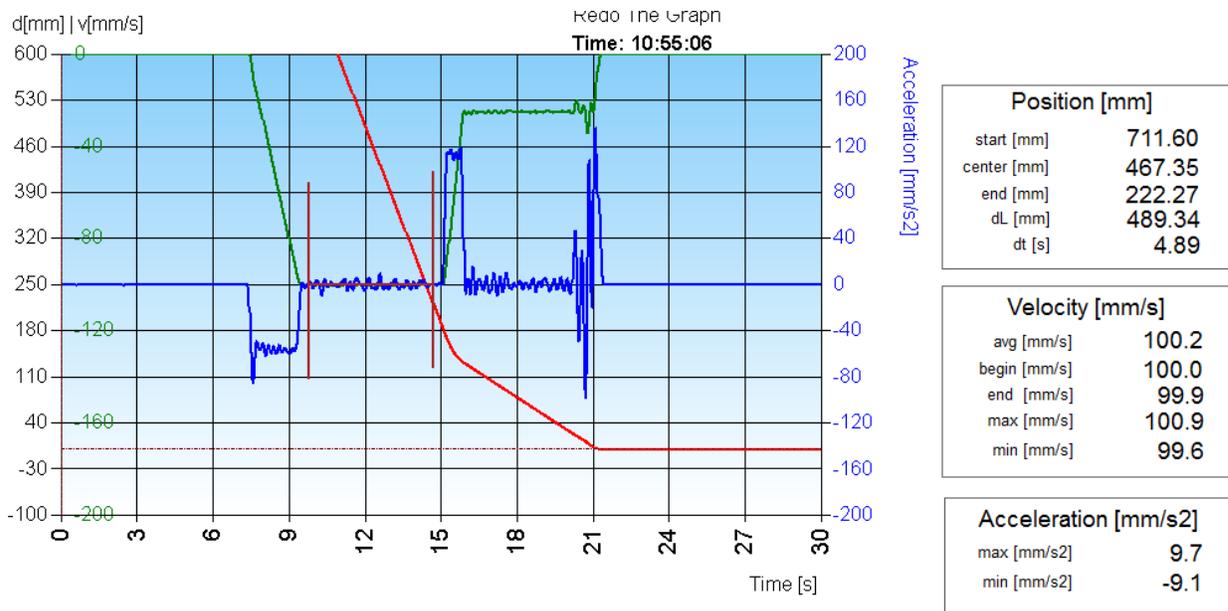
After exiting the Parameter Settings Screen the graph will be erased. Click "Redraw" to paint the graph again with the new settings.

Graph Settings

Chart Title:

	Minimum	Maximum
Position [m]	-100	600
Speed [m/s]	-200	0
Accel. [m/s ²]	-200	200
Smooth Position	16	(moving avg)
Smooth Velocity	8	(moving avg)
Smooth Accel.	15	(Savitzky-Golay)
delta Time [n]	5	

The new graph will look like this:



The change in vertical scale expands the details and the change in filter coefficients depicts the movement more realistic.

The numeric readout to the right are providing same information as before.

- ° Tip: For documentation purposes the user may save the graph picture by going to Menu File, save Chart Image, or by simply by <ctrl>-S key.

Comma Delimited Data File *.CSV

The data is saved as a comma delimited ASCII file, often referred to as CSV file. This format is readable using any text editor and it can be directly imported to MS Excel.

	A	B	C	D
1	Head Rotation System - by MICRONOR			
2	Title	Head Rotation System		
3	Date	'1.12.2012		
4	Time	'11:27:02		
5	Subject	P1		
6	Comment	xx		
7	Path	C:\		
8	File	HRS_20121201-112702.csv		
9	Duration [ms]	1000		
10	Sampling Interval [r	1		
11	Trigger Level [?]	25		
12	Pre-Trigger [ms]	400		
13	Y-Scale [?]	-5	95	
14	Y-Velocity [rad/s]	-10	40	
15	Y-Acceleration [rad,	-1000	500	
16	Model	MR330	1.1.00	0

Content of the CSV file when opened with Excel. User defined texts appear in header of the file.

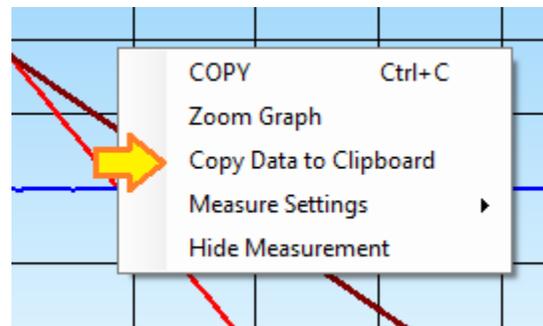
The first column is the time in milliseconds. The absolute time of the trigger event is given on line 4.

Name	Date modified	Type
Train_20120802-082345.csv	8/2/2012 8:24 AM	Microsoft Office ...
Train_20120802-082345.png	8/2/2012 8:24 AM	PNG image
Train_20120809-175735.csv	8/9/2012 5:58 PM	Microsoft Office ...
Train_20120809-175735.png	8/9/2012 5:58 PM	PNG image
Train_20120809-175757.csv	8/9/2012 5:58 PM	Microsoft Office ...

There are always two files associated

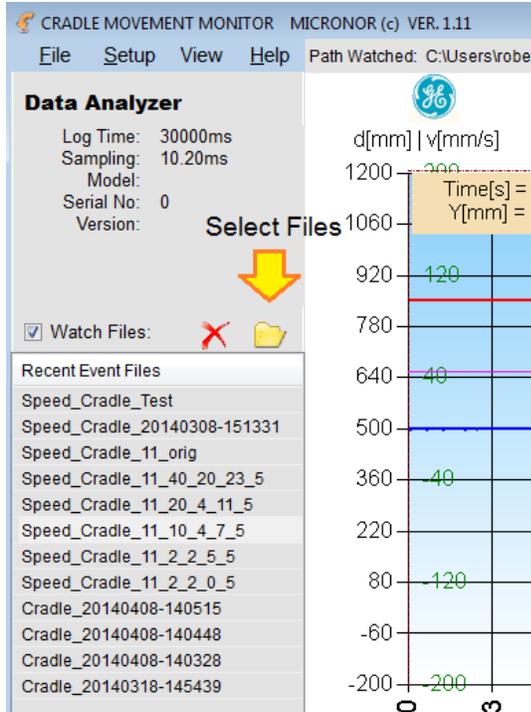
with one event logged to the disk drive. One is a pictorial graph and the other is a *.csv file with all data points listed.

Sections of data may be exported by right click the mouse button and select the menu item "Copy Data to Clip Board". Windows clipboard can now export that data to applications such as Excel, Word, Notepad etc. Applications accepting text data will be able to import the data. The data fields are "TAB" separated.



DATA ANALYZER MODE

The Data Analyzer mode turns off communications with the MR330 Controller. This mode is intended to be used Off Site for analyzing Data that has been previously recorded.



The screen will not have any monitoring LED's or position showing.

The first thing the user would typically do is to define the default directory and import a series of files to be worked on.

Click on the file folder icon and select the desired files. Once a group of files has been imported to the list, click on any file to graph the measurement data.

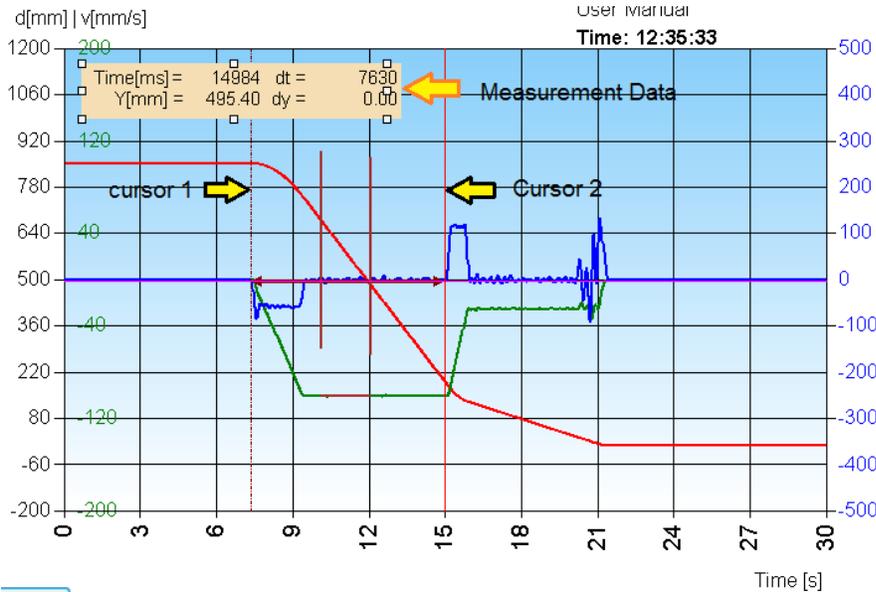
Manipulate the data in any desirable fashion and then save the results as graph file or as a new data file by choosing the file menu on the top menu bar.

The red X will only clear the file list. It will not delete any file or data.

COPY or CTRL-C copies the graphical depiction of the graph including the numeric readouts. The picture of the graph is copied to the Clipboard and can be pasted into most any Windows software programs such as MS Word or MS excel.

MEASURING GRAPHED DATA

The standard cursor/measure function allows for measurement of a captured trace. The measurements are application independent. With a trace displayed on the graph, position the cursor to any desirable position and click the left mouse button to position the cross-hair cursor. The measurement field will display the absolute Y axis value and time position as well as the relative (delta) distance from the previous cursor position.

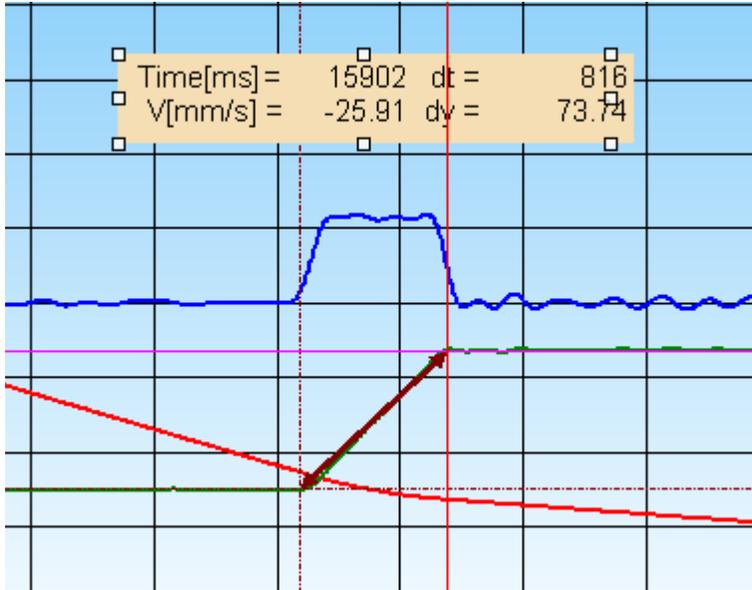
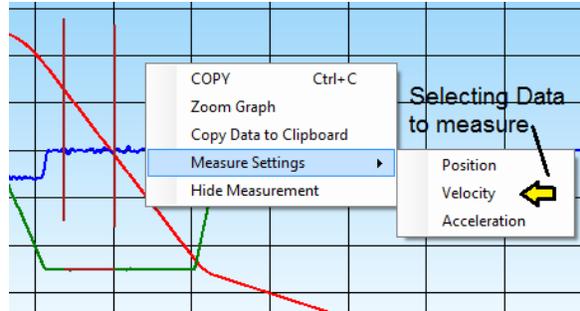


The example above shows how to measure the time from the start of the movement to the deceleration point. The elapsed time is 7630ms (7.63s). If we want to measure both the time span and the change in position then place the cursors over the position trace.



To make the same measurements applied to velocity or acceleration then first select the data to work on. Click the right mouse button

Once the data is selected then the readout will be related to the particular set of data.



The cursor measurement is being applied to velocity data.

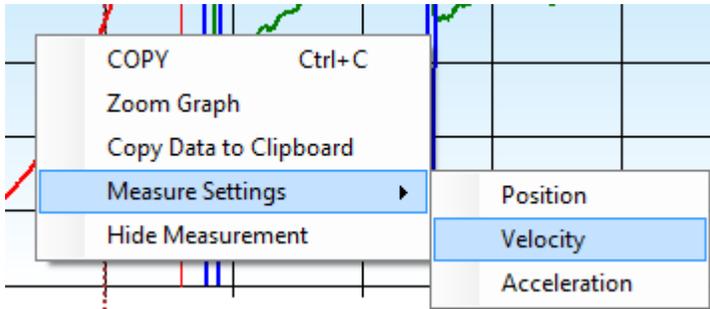
Note the Readout field has changed to v[mm/s] indicating the change in velocity as 73.74mm/s.

The measurement field maybe dragged to any point on the graph. Simply move the cursor over the measurement field and drag it to a desired location.

In order to hide the standard measurement cursors right click the mouse button and select "Hide Measurement".

Graph Measurement Menu

Mouse right click over the graph field brings up the Measurement Menu.



COPY allows the user to copy the entire graph to any Windows program accepting an image.

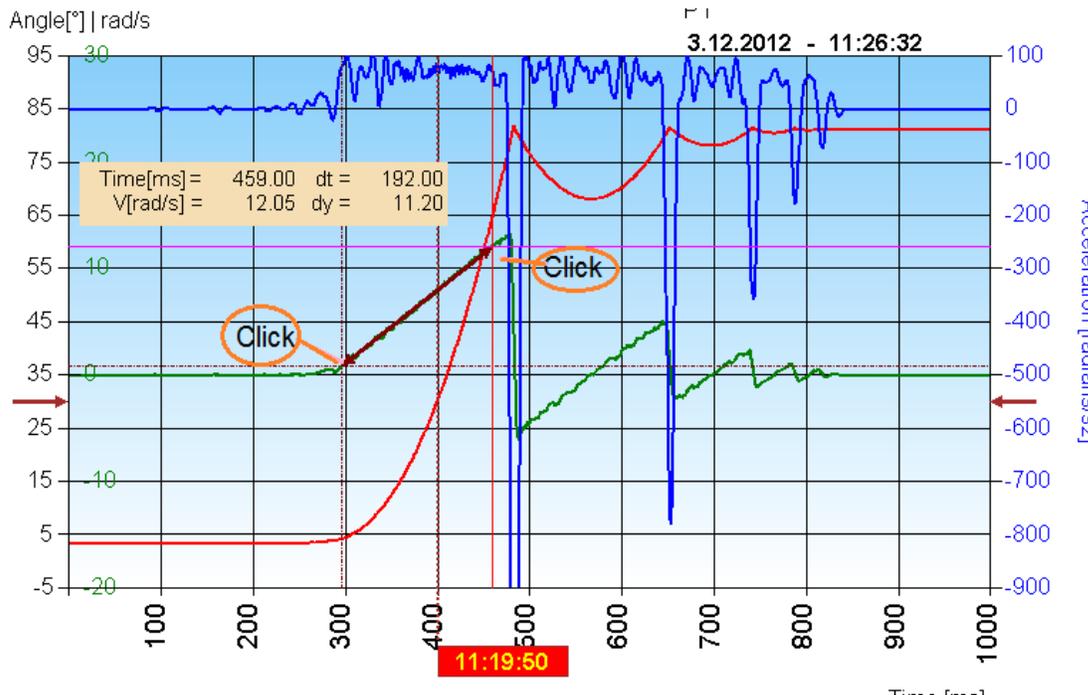
Zoom Graph will zoom in to the graph area

Copy Data to Clipboard allows the user to copy all the numeric data to an open Excel worksheet, or Word document, etc. Clicking on that field will copy the data to the Windows clipboard, then select the new

open document and click on “Paste” or “ctrl-V” and all the data will be pasted and formatted in columns and rows, ready for analyzing.

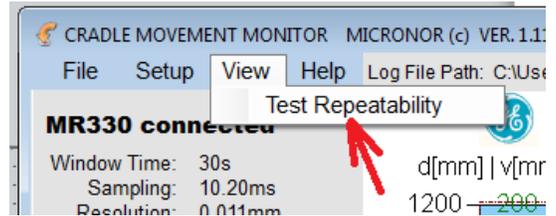
Measure settings allows the user to change the axis value displayed in the pop-up measurement field. When Velocity is selected the Y-Axis values displayed refer to the Velocity.

Example: After data has been captured, click the “STOP” button, Select Measure Settings-> Velocity. Select a portion on the velocity curve (green) as shown below.



Repeatability Test Window

For testing Position Repeatability select the “View” “Test Repeatability” option.



A pop-up window appears with an easy to read real-time position readout.

Samples	7	7
Mean	0.033	850.619
Std Dev	0.026	0.065

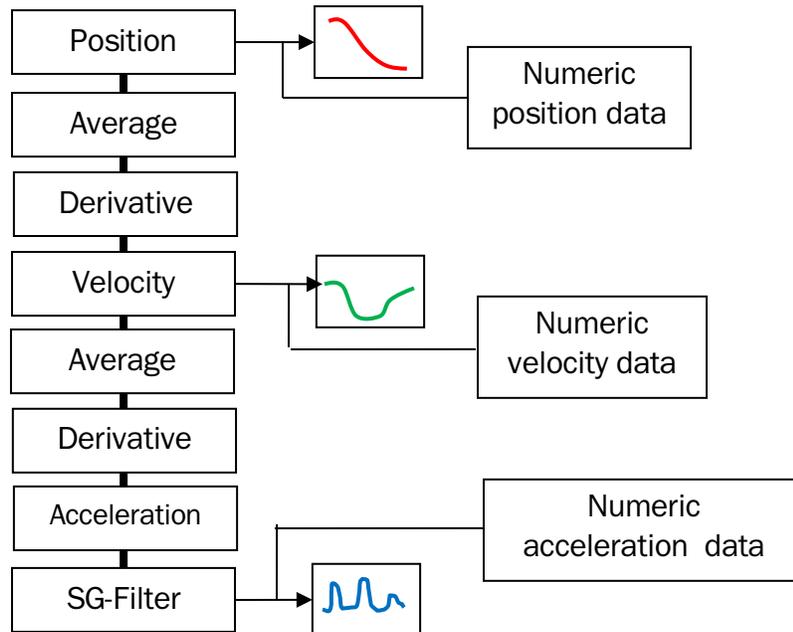
Whenever the system is at either Landmark or the Scan position click the respective button. The software automatically calculates the Mean and Standard Deviation of the measurement samples taken. A pictorial snapshot may be taken by clicking the "Copy as Image" button. The picture can then be pasted into a word or similar document. Similar the numeric data may be copied to an Excel file. Erase the data fields by clicking the "Clear" button.

Velocity and Acceleration Data Computation

The software logs the position accurately every 10.2ms (or as required) with a resolution 0.011mm (11µm). The timing is based on the controller (MR330) quartz crystal having an accuracy of 100ppm. This 'raw' data is saved in the second column of the data file (*.csv) exported from the software.

The velocity is the calculated first derivative of the position movement versus time in [mm/s]. This calculated data is exported in the 3rd column as part of the data file.

The acceleration is the calculated second derivative of the position movement versus time in [mm/s²]. This calculated data is exported in the 4th column as part of the data file.



Software algorithm for calculation velocity

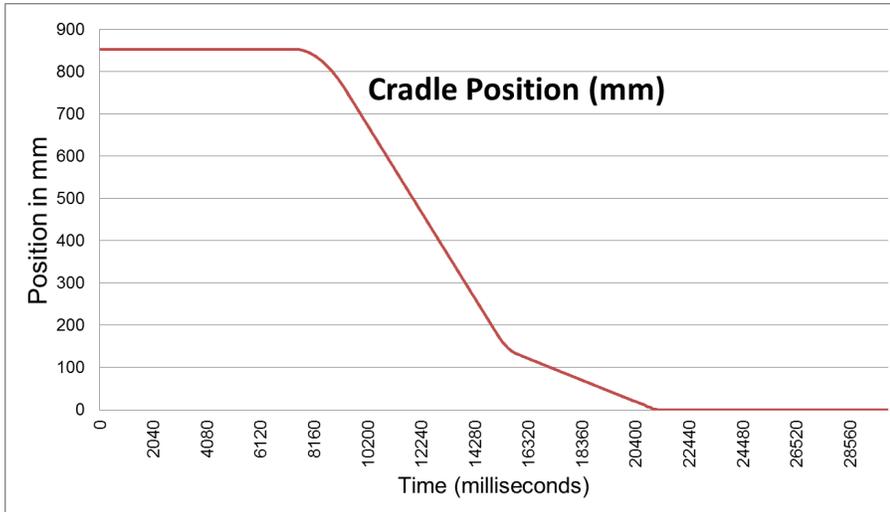
The velocity is the first derivative of the position data and is calculated as follows:

$$Y'_j = \frac{Y_{j+2} - Y_{j-3}}{5 \Delta X} \quad \text{for } 3 < j < n-2$$

Note: The time delta of 5 is chosen because the GE specification sheets call out to calculate the velocity over a span of 50ms. In our instance the delta is 51ms. This value may be changed in the software parameter settings.

Smoothing:

Before taking the derivative the position data is run through a moving averaging filter to smooth out any data acquisition noise. The position data is a low frequency function and an aggressive smoothing filter can be applied without negatively distorting the actual data.



The simple moving average (SMA) is calculated as follows:

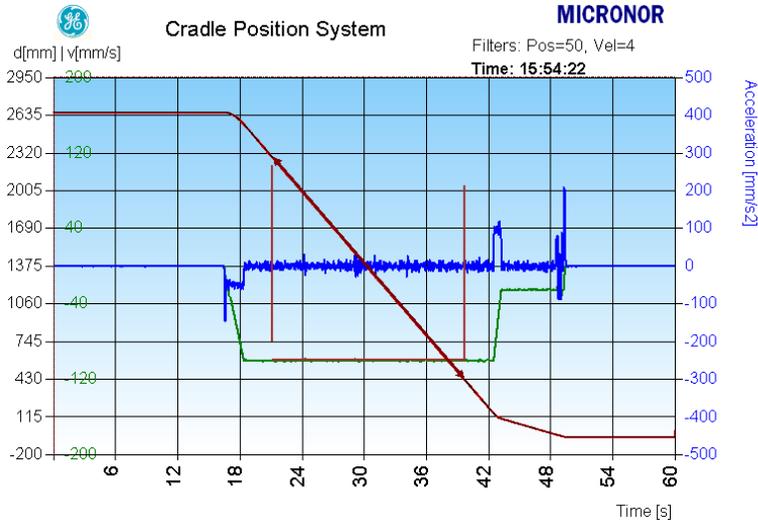
$$SMA = \frac{p_M + p_{M-1} + \dots + p_{M-(n-1)}}{n}$$

The averaging coefficient n is adjustable in the software separately for smoothing the position data and a second one for smoothing the velocity data. Since the velocity data is “higher” in frequency it is advisable to keep the velocity averaging lower.

The software applies the formula below:

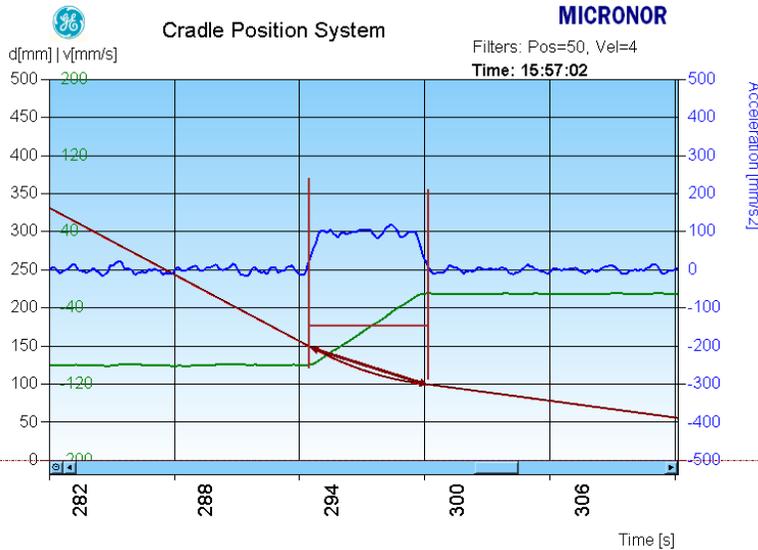
$$Y_j = \frac{\sum_{i=j-\frac{n}{2}}^{j+\frac{n}{2}} Y_i}{n}$$

The averaged value is placed in the center of the averaging thus no offset to the signal is generated.

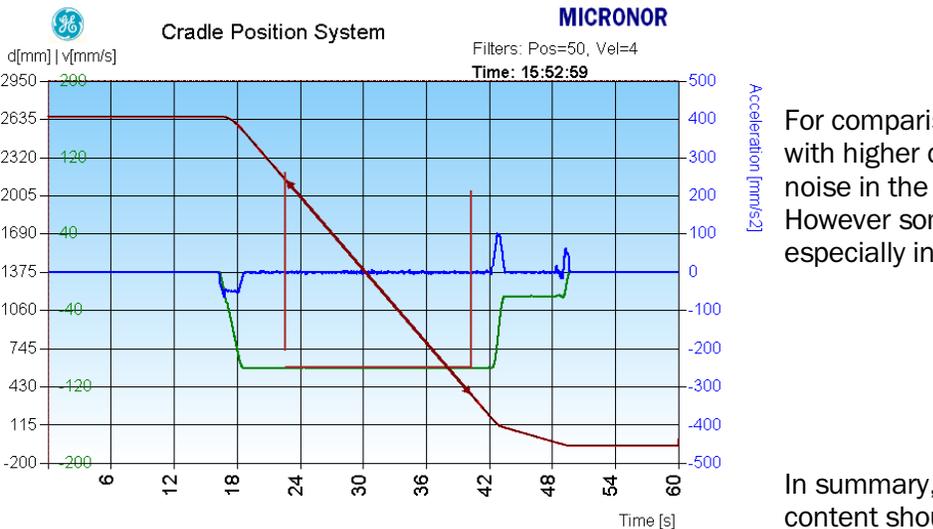


For this graph the Position signal was smoothed with $n = 50$
And the velocity signal was smoothed with $n=4$
The acceleration data is not smoothed at all.

The high frequency components are well preserve while the noise is tolerably low.



Zooming to the slowdown motion shows how well maintained the system is. The onset of the deceleration is perfectly marked by the acceleration data (blue curve).

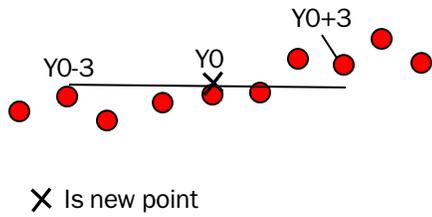


For comparison the same data has been treated with higher degree of smoothing clearly reducing the noise in the velocity and acceleration data. However some of the high frequency components, especially in the acceleration data are now rounded.

In summary, the position data with low frequency content should be smoothed heavily while smoothing the derivative functions lightly will produce best results.

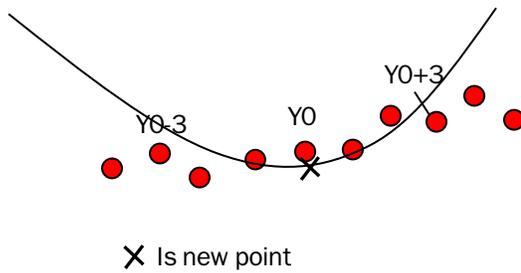
Moving Average Algorithm

The software calculates the moving average as follows:



Savitzky-Golay Algorithm

For the Savitzky-Golay filter a polynomial of n^{th} degree is applied and curve fit to n points. In general the SG filter reduces noise while maintaining higher frequency features.



References:

Savitzky-Golay Numerical Solutions Third Edition

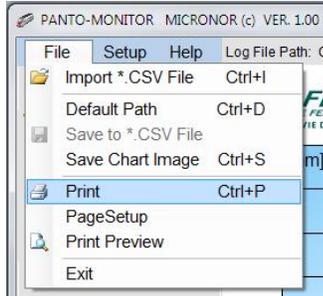
<http://www.jonsson.eu/programs/cweb/sgfilter/>

<https://www.planet-source-code.com/vb/scripts/ShowCode.asp?txtCodeId=3051&lngWId=1>

<http://www.centerspace.net/company/about-us/>

PRINTING GRAPHS

Strip Chart window graphs can be output directly to a Windows compatible printer.



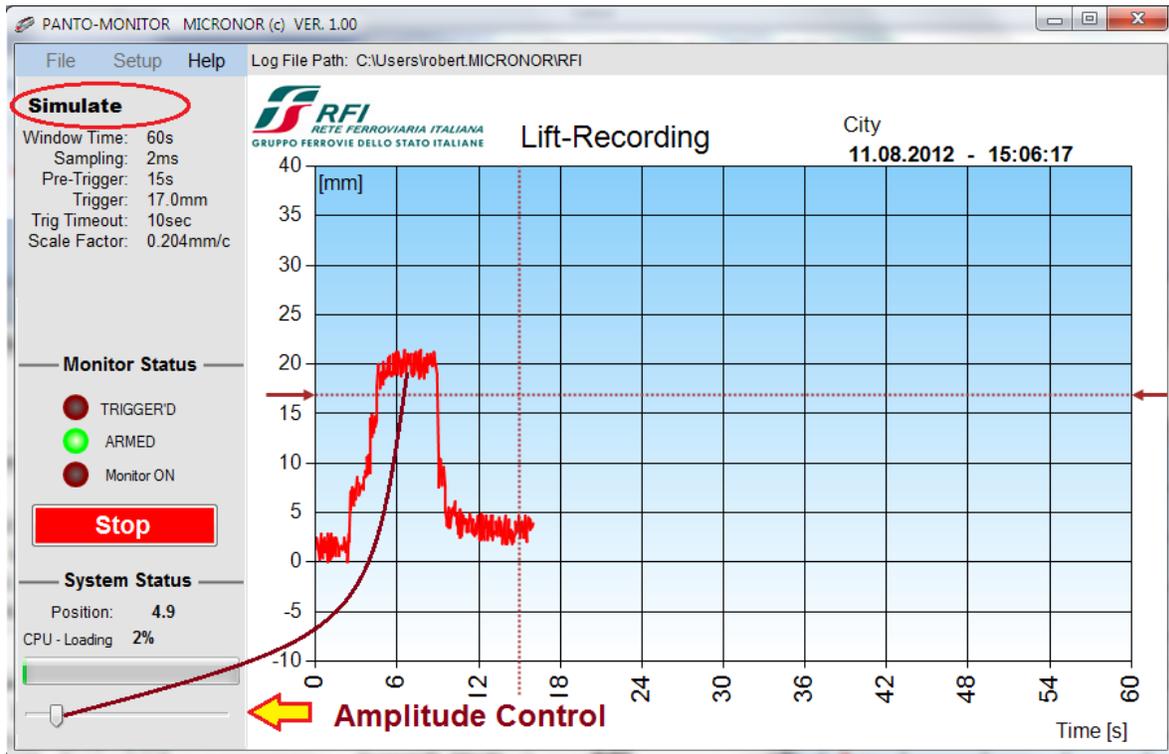
Under the File menu select Print. Select desired printer and send the document to the printer. For clarity color printers work best.

Most likely before printing you want to setup the printer and setup the page with appropriate margins etc.

SIMULATE MODE

The simulate mode is used for familiarization and setup of the software.

Data is generated using a random number generator. However the user can control the contact wire height with a slider on the bottom left of the screen. Functions and operation of the PCS-MONITOR software remain the same as when connected to the hardware.



Calibration Procedure

The String Encoder must be regularly checked and calibrated to assure proper function and accuracy of the measuring device.

The software supports and facilitates the calibration.

For detailed instructions please refer to the MICRONOR Document:

EC-TD5325 – Calibration Instructions

MR330 – Setup Parameters and Settings

This is an abbreviated description of the output settings for the MR330. For detailed information on the MR330 unit consult the MR330 Instruction Manual.

For the Cradle Monitor System to function properly the following MR330 parameter must be set:

Turn Counter: 7
Resolution: 14
Calibration Value: typical range is 48.4mm to 48.6mm
If these values are not set as shown the unit will not function properly.

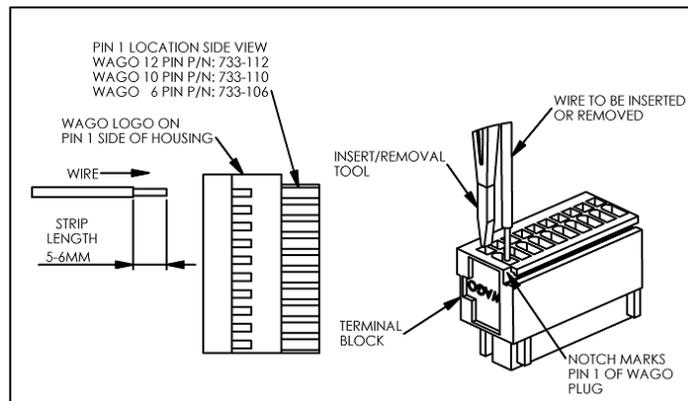
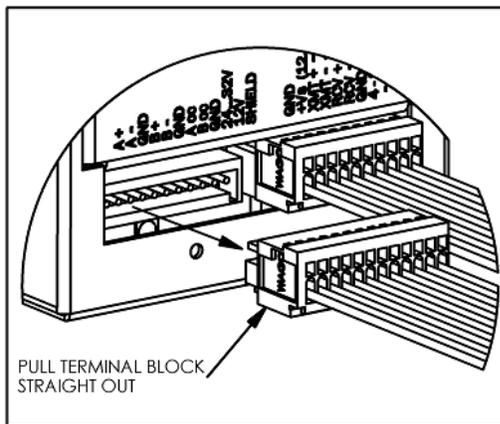
MR330 Electrical Connections

J1 Connections and Power Supply	
1	ZERO OUT
2	GND
3	Set Point 1
4	GND
5	Set Point 2
6	GND
7	BAT+
8	24V
9	GND (power)
10	+Vs (power) (15V to +32V)
11	ZERO IN
12	Shield

J2 Connections Data SSI and Analog Output	
1	±10V position output
2	GND
3	SSI Clock +
4	SSI Clock -
5	SSI Data +
6	SSI Data -
7	+24V IN
8	GND
9	4-20mA out +
10	4-20mA out -

J3 Connections RS422/485 Serial I/O	
1	GND
2	+5V Out (10mA max, power for MR232-1 RS232 Adapter)
3	TX+ →
4	TX- →
5	RCV+ ←
6	RCV- ←

Electrical Connections are made via the three WAGO type plug-in terminals. These terminal connectors are non-screw connections and accept wires from AWG20 through AWG 28 or 0.5mm² to 0.08mm². The WAGO terminal blocks are a convenient way to pre-wire harnesses.



LED - Indicators

- ① The controller PWR LED will light up. A steady light indicates proper operation and the sensor is installed correctly. (Blinking of this LED indicates an error condition. codes)

The ZERO indicator LED will be On when the position sensor is at 0 position.



The RUN indicator LED will be ON whenever the sensor is in motion.

Status information is provided by a blinking PWR LED.

Blinks	Code Description
Steady ON	System is ok. Shaft position within measuring range
1	Outside Range for Turn-Restore
2	Bad position signal. -> Sensor may need to be "paired" to the controller box
3	No optical signal, i.e. Fiber disconnected
4	System Problem

Block-Diagram

As the block diagram shows, the position signal is routed to all the various output interfaces built into the unit.

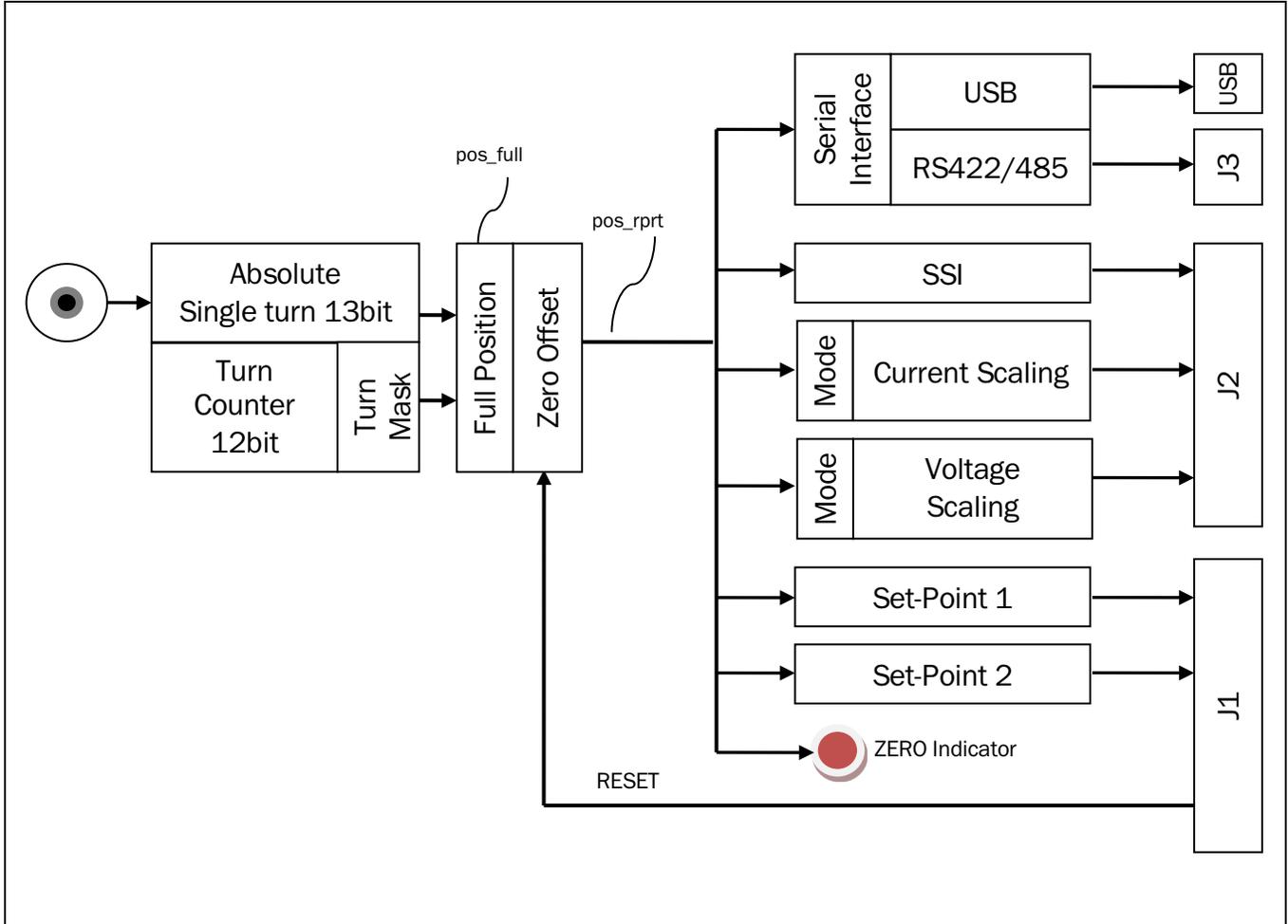


Figure 1. Block Diagram of MR330 System

Voltage Output

The analog output voltage is derived from the position signal and maybe freely scaled by the user. There are four distinct modes:

- Mode 0: OFF, voltage is always 0
- Mode 1: Single-turn 0V to +10V
- Mode 2: Scalable 0V to +10V
- Mode 3: Scalable -10V to +10V

MODE 1 automatically sets the Scale to 8192. It outputs 0V when position is 0 and +10V when position is 8191. Output wraps around back to 0V when one turn completes. This wrap around occurs regardless of the Turn Mask setting.

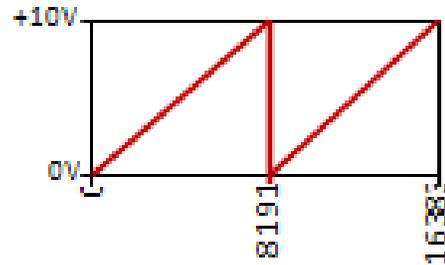


Figure 2 Mode 1 Voltage Output

MODE 2 lets the user program the output voltage based on a scale value. The output is 0 when the position is 0 and will reach +10V when the position reaches the scale value. The full 25bit range is available for scaling. When setting this mode up the user should also take into account what should happen when the position reaches maximum or minimum values. The MR330 system determines the wrap-around point based on the available position range, which is based on the turn mask setting n . The $Count_{max}$ is then 2^n



Figure 3 Mode 2 Voltage Output

$$P_w = \frac{(Count_{max} - Scale)}{2} + Scale$$

The wrap point P_w is determined based on the formula above. Essentially it is the midpoint between the un-used range.

MODE 3 is very similar to mode 2 but it makes use of the negative output voltage capability of the MR330. The output voltage follows the position output with 0 position being -10V and when the Scale value is reached the output is 0V and with position twice the scale value the output is +10V. Mode 3 is ideal when the voltage should swing positive or negative around a predetermined home position. In that case the Reset Value of the MR330 should be set to the same value as the scale. When the sensor is in the home position that is then equal to the scale value and the voltage output will be 0V. When the sensor turns CCW the voltage will start going negative and vice versa when the sensor turns CW the voltage will go positive.

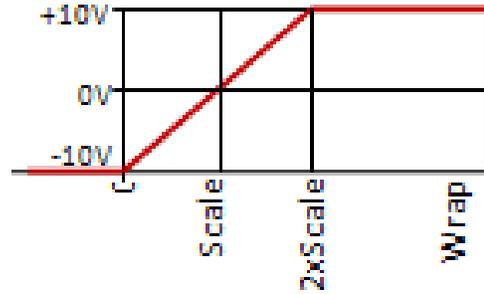


Figure 4 Mode 3 Voltage Output

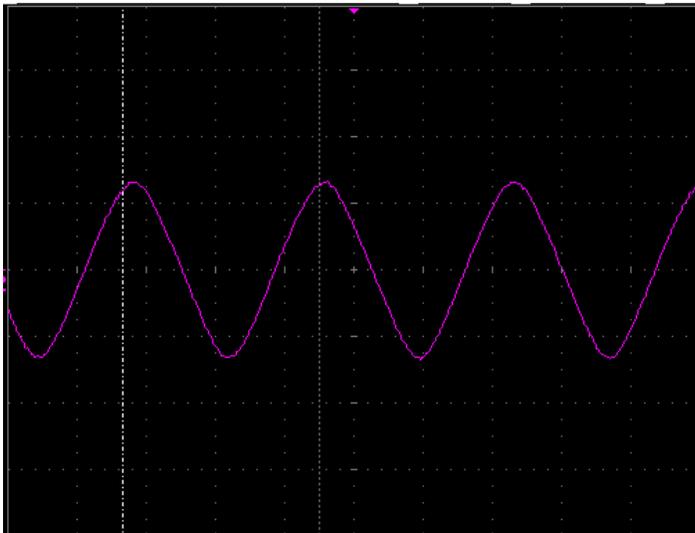
As in mode 2 the system also determines a wrap around point based on the turn counter setting.

$$P_w = \frac{\text{Count}_{\max}}{2} + \text{Scale}$$

The Wrap point P_w is in the middle of the un-used range of the sensor. The maximum position range is determined by the Turn Counter setting.

Output Frequency

The voltage output follows the position in real time with a delay of approximately 800us from when the actual position was reached. The update rate of the D/A converter is 850us.



V: 2V/DIV
H: 50ms/DIV

Analog Output while input shaft is being oscillated with an amplitude of $\pm 45^\circ$ at a frequency of 7Hz.
 $\odot = 44.3r/s$

Figure 5 Analog Output with an oscillating shaft input

In ZapView™ select page: ‘Voltage Output’

MODBUS commands:

Address	Register	Description
0x200	0x201	Voltage Mode
0x201	0x202	Voltage Scale

For the cradle movement system it could make sense to use the voltage output as a distance readout. The scale would have to be programmed based on the calibration factor.

For instance the desired Voltage output could be 1V per meter and an assumed calibration value of 48.5mm.

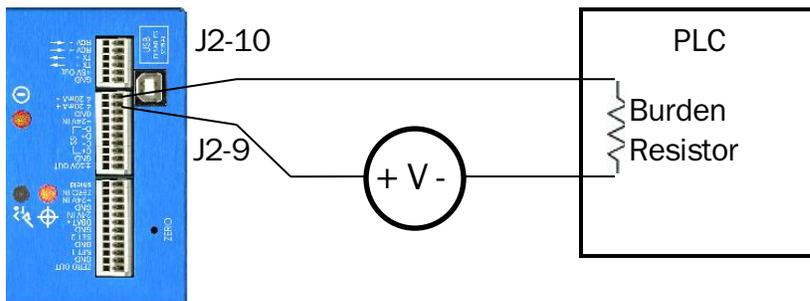
Voltage readout scale: $= 13950 * 10V / (D[m] * \pi) = 915,551 \text{ pulses/m}$

Please note that the voltage output is analog and has a resolution of 12bits and an accuracy of ~ 0.5% full scale only. The readout will not be as accurate as what is obtained by digital readout.

Fast changes in position can also be graphed using the PGS-MONITOR software by setting the acquisition time to the highest speed at 0.85ms.

Isolated Current Output (4-20mA)

The isolated current output is derived from the position signal and may be freely scaled by the user. Since the output is isolated from the rest of the circuitry, it must be loop powered:



There are three selectable output modes:

- Mode 0: OFF, current is less then 300uA
- Mode 1: Single-turn 4mA to 20mA
- Mode 2: Scalable 4mA to 20mA

MODE 1 automatically sets the Scale to 8192. It outputs 4mA when position is 0 and 20mA when position is 8191. Output wraps around back to 4mA when position changes from 8191 to 0 at the completion of one turn. This wrap around occurs regardless of the Turn Mask setting.

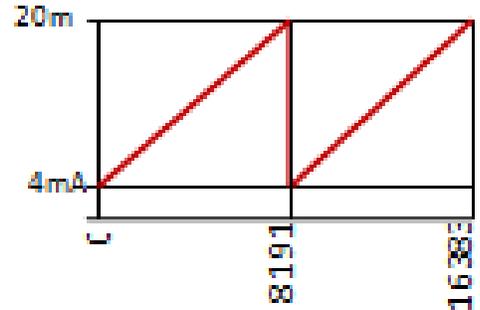


Figure 6 Mode 1 Current Output

MODE 2 The user programmable scale defines the position where 20mA output current is reached. The full 25bit range is available for scaling. When setting this mode, the user should also take into account what should happen when the position reaches maximum or minimum values. The wrap-around point is based on the available position range, which is based on the turn mask setting n. The Count_{max} is then 2ⁿ

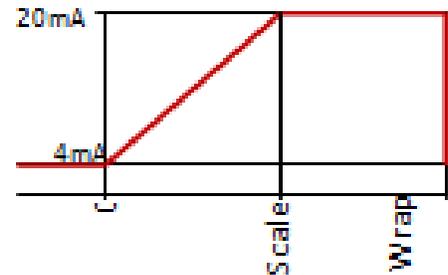


Figure 7 Mode 2 Current Output

$$P_w = \frac{(\text{Count}_{\text{max}} - \text{Scale})}{2} + \text{Scale}$$

The wrap point P_w is determined based on the formula above. It is the midpoint between the un-used range.

In ZapView™ select page: ‘Current Output’

MODBUS commands:

Address	Register	Description
0x204	0x205	Current Mode
0x205	0x206	Current Scale