CoreStar OMNI-200 ASME/JEAG Calibration Software Rev 6.4

August 5, 2008

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1 Purpose

This document describes the software used to perform ASME Article 8 Appendix II and JEAG 4208 calibration of a CoreStar OMNI-200 tester.

The OMNI-200 calibration software automatically performs all the required measurements. However, this is only a convenience and a user can perform all of the steps manually if desired. This document contains all the information required to do so.

2 Installation

To install the calibration software, insert the EddyVision 6.4 CD into your CD drive and follow the instructions to install the software.

3 Equipment Required

1. Agilent 34410A LXI frequency counter.
2. Agilent 33220A LXI function generator.
3. CoreStar OMNI-200 ASME/JEAG calibration block.

4 Quick Start

This section outlines the steps to calibrate an OMNI-200 tester using the software described in this manual.

The following preliminary steps need only be done once:

1. Start the calibration software `omni200_cal.exe`. You must have a valid HASP protection key with the OMNI-200 ASME/JEAG calibration software option enabled.

2. Configure the set of measurements to be performed for each part of the calibration.

3. Make sure the IP addresses for the frequency counter and function generator match those shown in the setup tab. Configure each instrument to have a fixed IP address compatible with your network (see the respective Agilent manuals for details) and then type these values into the calibration software.

4. Connect the function generator, and frequency counter to the LAN.

5. Choose the type of report (JEAG or ASME).

The following should be done for each OMNI-200 unit that must be calibrated:

1. Connect the OMNI-200 tester to the LAN.

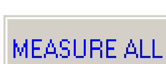
2. Make sure the IP address of the tester matches the value shown in the OMNI-200 Unit frame of the setup tab.

3. Connect the CoreStar ASME/JEAG calibration block to the tester.

4. Connect a cable from the Generator-In connector on the cal block to the Output connector on the Agilent 33220A Function Generator.

5. Connect a cable from the Drive-Out connector on the CoreStar cal block to the Input connector on the Agilent 34410A Frequency Counter.

6. Choose the current ambient temperature in the cal software.

7. Hit the 

button to perform that calibration. This will perform the entire calibration in a few minutes.

8. Repeat steps 6 and 7 for another temperature if desired.
9. Choose **File | Save** to save the raw .cal report to any desired directory.
10. Choose **File | Export** to create a text file report.

5 Setup Screen

To start the calibration software, run `omni200_cal.exe` program. This can be done by using *Start | Programs | EddyVision 6.4 | OMNI-200 ASME JEAG*. This will display the setup screen.

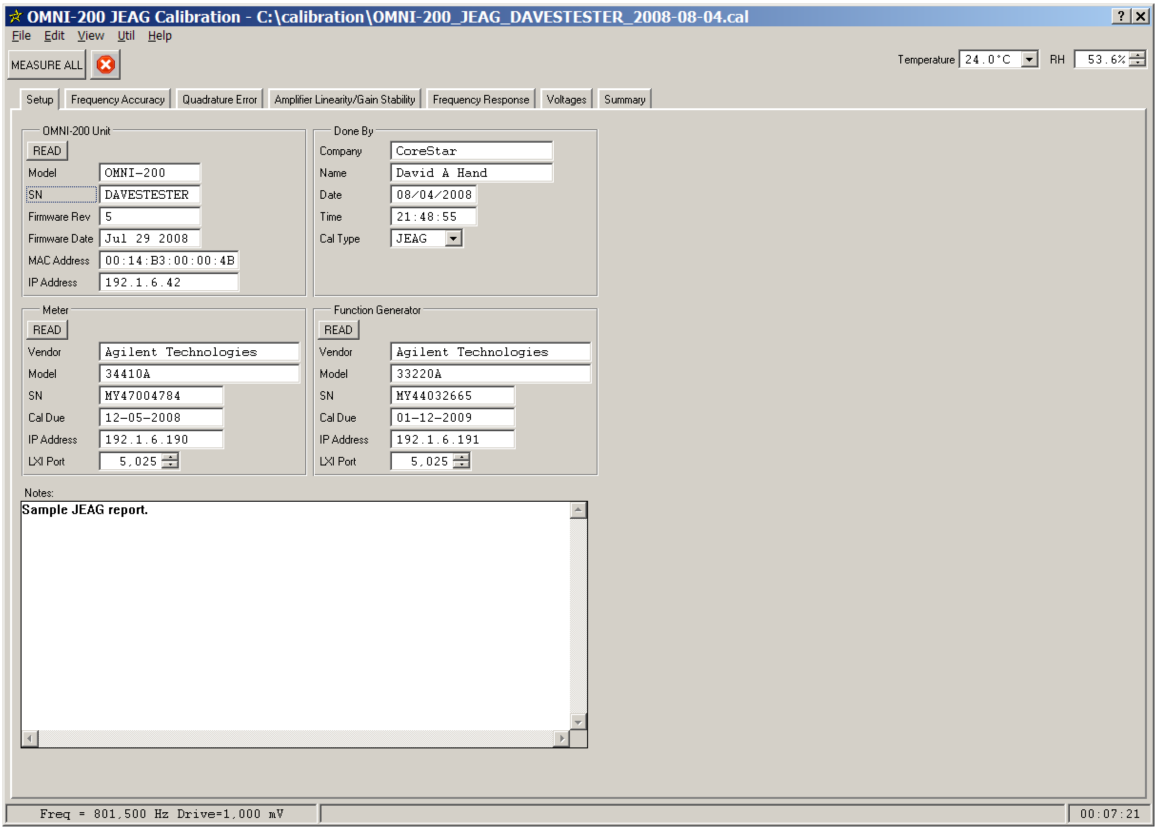


Figure 5-1 Setup Tab

5.1 Caption

The caption shows the name of the program, "*OMNI-200 JEAG Calibration*", along with the current calibration file. The name of the file includes the report type, serial number of the tester, and the date when the calibration is performed.

5.2 Menus

5.2.1 File | New

This option clears the current report.

5.2.2 File | Open

Used to open another OMNI-200 calibration file.

5.2.3 File | Save

Saves the current calibration to a .cal file. The .cal file contains all the raw measurements used to create the summary report (see section 5.2.5). If everything passed, it will also store the calibration information to the tester. This includes the SN, date, and type of calibration (i.e. JEAG or ASME).

5.2.4 File | Save As

Used to save the calibration to another name.

5.2.5 File | Export

This will export the results of the calibration to a text file. The default name and directory of the text file will be the same as the .cal file but with a .txt extension. The exported report will be opened in WordPad where it can be printed. To avoid wrapping, print it on 11x17" paper in landscape mode.

5.2.6 File | Export All

The same as **File | Export** except that the vertical and horizontal parts of each measurement are included in the report.

5.2.7 File | Store To Tester

This will store the date and type of calibration to the tester.

5.2.8 Edit | Undo

Used to undo changes such as MEASURE ALL.

5.2.9 View | Tester Config

Displays the tester configuration associated with the current measurement in the usual OMNI-200 configuration dialog. This feature can be used by a user who wishes to verify the calibration manually.

The configuration can be saved to an OMNI-200 configuration file and opened in the usual EddyVision acquisition software. Turn the tester on and set the frequency counter or function generator to the desired values. A circle will be displayed in the lissajous. The diameter of the circle is the voltage measurement.

5.2.10 Util | IP Setup

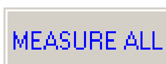
Displays the OMNI-200 IP Setup dialog. This shows all OMNI-200 testers on the LAN and allows setting their IP addresses.

5.2.11 Util | Show Keys

Displays the CoreStar HASP protection key dialog.

5.3 Button Bar

5.3.1 MEASURE ALL

Clicking the 

button will cause the entire calibration to be performed automatically. It will perform the following steps:

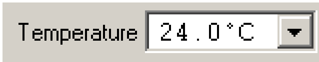
1. Read the setup information.
2. Perform the frequency accuracy measurements.
3. Measure the quadrature error.
4. Measure the amplifier linearity and gain stability.
5. Measure the frequency response.
6. Measure the brick voltages.
7. Display a summary of the results.

The user must set the IP addresses of the OMNI-200 tester, Frequency Counter, and Function Generator prior to starting the calibration.

5.3.2 Cancel

Clicking the  button cancels any measurements in progress.

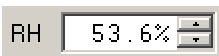
5.3.3 Temperature



This drop down will select which temperature is currently being measured. The user should select the current temperature and perform the entire set of measurements.

The default temperatures are 24.0°C and 46.0°C. These can be changed by clicking on the temperature and typing the new value.

5.3.4 RH



Displays the Relative Humidity for the current temperature. This is not measured automatically by the system.

5.4 Setup Tab

This tab displays information about the equipment being used and the person performing the calibrations.

5.4.1 OMNI-200 Unit

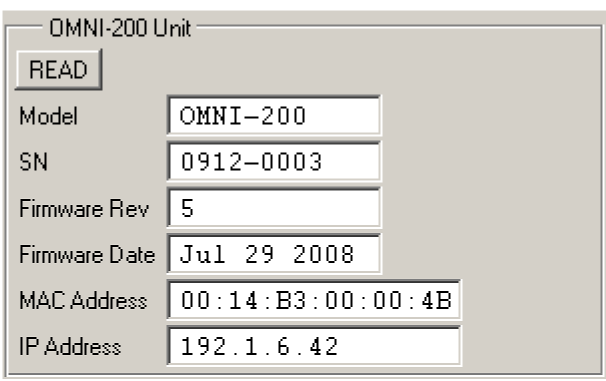


Figure 5-2 OMNI-200 Tester Unit Information

The user must enter the correct IP address for the OMNI-200 unit being calibrated. Then click the READ button to read the SN and other information from the unit.

The SN can be edited and stored to the tester (see section 5.2.3).

5.4.2 Done By

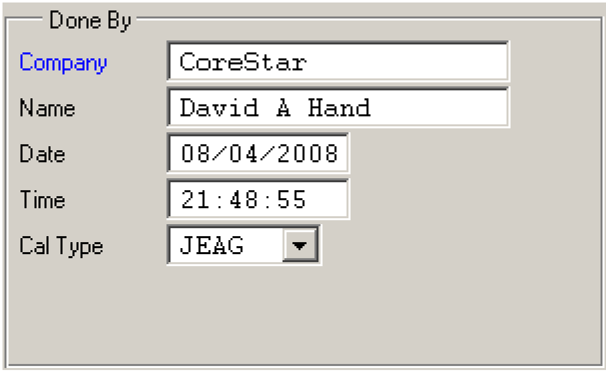


Figure 5-3 Done By Information

The user should enter his Company, his Name, and select the Cal Type (either ASME or JEAG). The Data and Time will be filled in automatically.

The only difference between ASME and JEAG modes is the tolerance for the amplifier linearity. It is 5% for ASME and 2% for JEAG. It will also change the default name for the report.

5.4.3 Meter

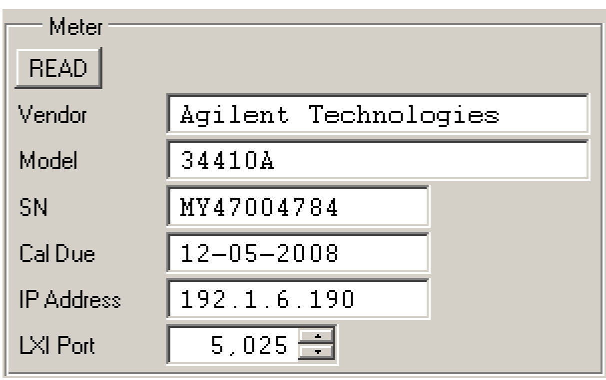


Figure 5-4 Frequency Counter Information

Enter the correct IP Address and Cal Due date for the frequency counter. Then click the **READ** button to read the SN and other information from the instrument.

5.4.4 Function Generator

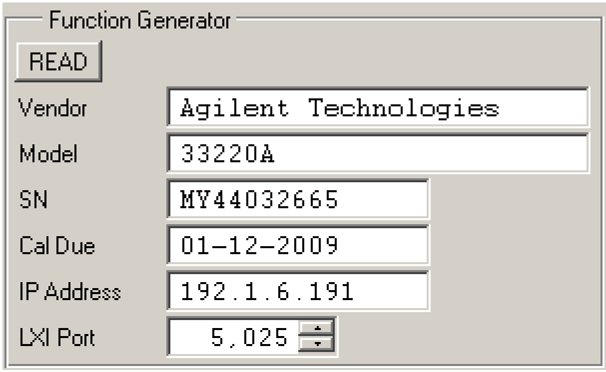


Figure 5-5 Function Generator Information

Enter the correct IP address for the function generator along with the Cal Due date. Then click the READ button to read the SN and other information directly from the instrument.

5.4.5 Notes

Type in any desired notes to be stored with the report.

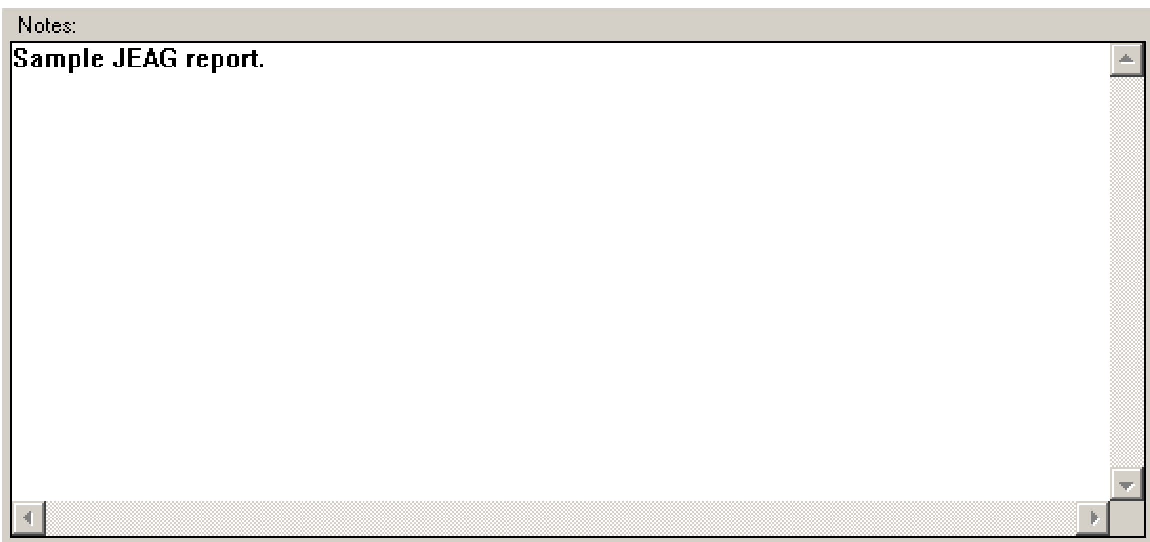


Figure 5-6 User Notes

6 Frequency Accuracy

Click the **Frequency Accuracy** tab to measure the frequency accuracy.

LINE	FREQUENCY (Hz)	D	DRIVE 1			DRIVE 2			DRIVE 3			DRIVE 4		
			FREQ (Hz)	DIFF (Hz)	ERROR (%)	FREQ (Hz)	DIFF (Hz)	ERROR (%)	FREQ (Hz)	DIFF (Hz)	ERROR (%)	FREQ (Hz)	DIFF (Hz)	ERROR (%)
1	10,000	✔	9,999.9	−0.1	0.001	9,999.9	−0.1	0.001	9,999.9	−0.1	0.001	9,999.9	−0.1	0.001
2	20,000	✔	19,999.8	−0.2	0.001	19,999.8	−0.2	0.001	19,999.8	−0.2	0.001	19,999.8	−0.2	0.001
3	25,000	✔	24,999.7	−0.3	0.001	24,999.7	−0.3	0.001	24,999.7	−0.3	0.001	24,999.7	−0.3	0.001
4	50,000	✔	49,999.5	−0.5	0.001	49,999.5	−0.5	0.001	49,999.5	−0.5	0.001	49,999.5	−0.5	0.001
5	100,000	✔	99,999.0	−1.0	0.001	99,999.0	−1.0	0.001	99,999.0	−1.0	0.001	99,999.0	−1.0	0.001
6	200,000	✔	199,998.0	−2.0	0.001	199,998.0	−2.0	0.001	199,998.0	−2.0	0.001	199,998.0	−2.0	0.001
7	300,000	✔	299,997.0	−3.0	0.001	299,997.0	−3.0	0.001	299,997.0	−3.0	0.001	299,996.9	−3.1	0.001
8	400,000	✔	399,996.0	−4.0	0.001	399,996.0	−4.0	0.001	399,996.0	−4.0	0.001	399,995.9	−4.1	0.001
9	500,000	✔	499,995.0	−5.0	0.001	499,995.0	−5.0	0.001	499,994.9	−5.1	0.001	499,994.9	−5.1	0.001
10	600,000	✔	599,994.1	−5.9	0.001	599,994.0	−6.0	0.001	599,993.9	−6.1	0.001	599,993.9	−6.1	0.001
11	700,000	✔	699,993.1	−6.9	0.001	699,993.0	−7.0	0.001	699,992.9	−7.1	0.001	699,992.9	−7.1	0.001
12	800,000	✔	799,992.3	−7.7	0.001	799,992.0	−8.0	0.001	799,982.0	−18.0	0.002	799,991.7	−8.3	0.001
*														

Table 6-1 Frequency Accuracy

6.1 Choosing Frequencies

To choose a set of frequencies, type them into the **FREQUENCY** column. Click in the "*" above the scrollbar to add rows, or right-click to remove them.

6.2 Making a Measurement

To manually measure the frequency accuracy of a given OMNI-200 driver, click in the title area of the column for that drive.

Click here to measure the frequencies for DRIVE 1.

DRIVE 1		
FREQ (Hz)	DIFF (Hz)	ERROR (%)
9,999.9	−0.1	0.001
19,999.8	−0.2	0.001

6.3 Results Display

There are three result fields for each driver. The **FREQ** column shows the actual measured frequency. The **DIFF** column is the difference between the measured frequency and the nominal frequency in the **FREQUENCY** column. The **ERROR** column shows the percent error given by:

$$error = 100\frac{F_{MEAS} - F_{NOMINAL}}{F_{NOMINAL}}$$

Whenever all four drivers have been measured for a given frequency, a check mark will appear in the **D** (i.e. Done) column.

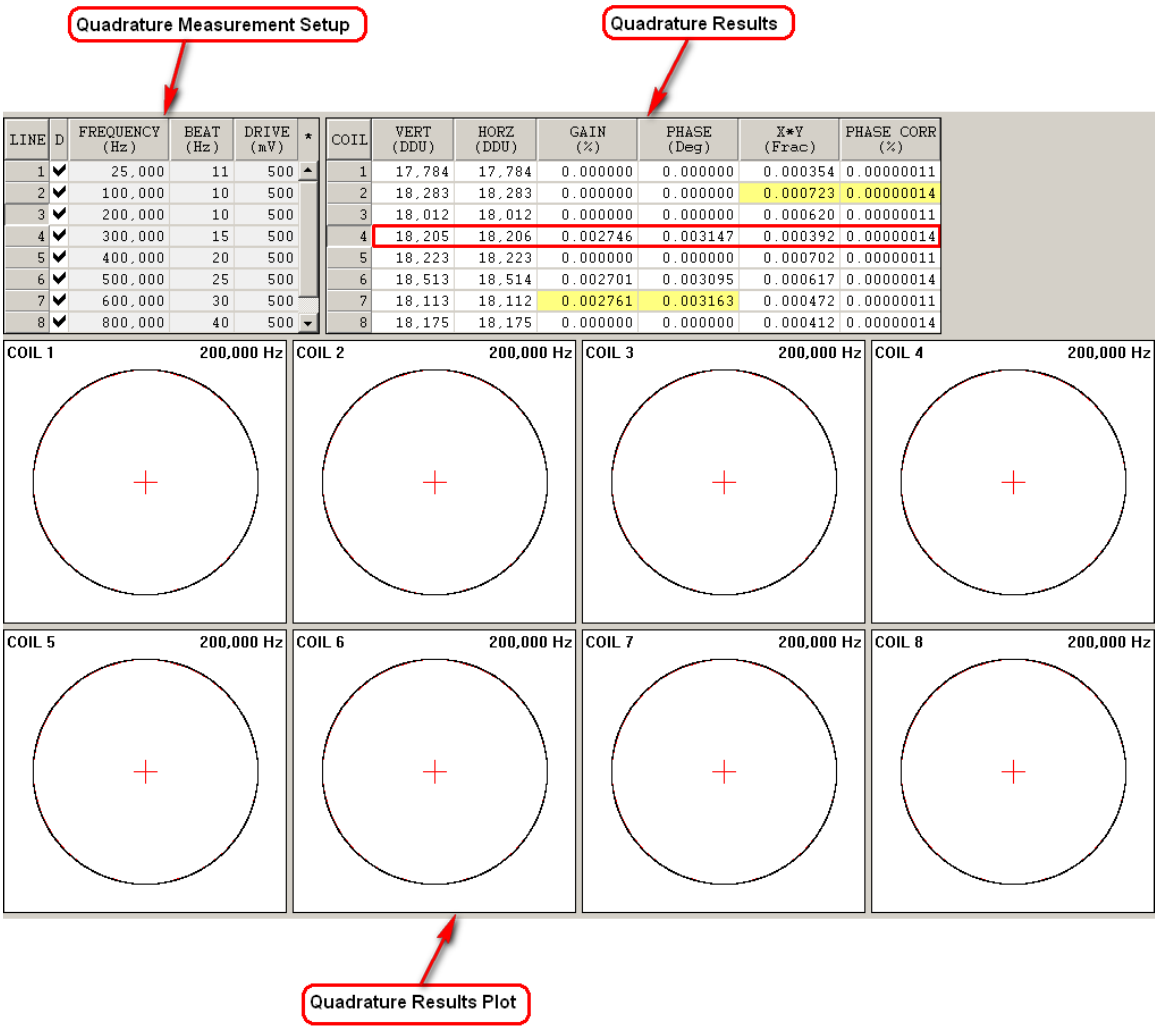
Note in Table 6-1 that the **DIFF** field is all of the same sign and the **ERROR** values are all about 0.001%. This is to be expected. The OMNI-200 uses a 66 MHz clock oscillator accurate to one part in 100,000. The sinusoidal drive output is generated by DDS technology and any errors are due to inaccuracies in the clock.

6.4 Manual Method

To manually verify the frequency, select a frequency and choose **View | Tester Config**. Save the configuration to a file and open it in EddyVision acquisition. Turn on the tester and read the frequency from the frequency counter front panel.

7 Quadrature Error

Click the **Quadrature Error** tab to measure quadrature error.



LINE	D	FREQUENCY (Hz)	BEAT (Hz)	DRIVE (mV)
1	✔	25,000	11	500
2	✔	100,000	10	500
3	✔	200,000	10	500
4	✔	300,000	15	500
5	✔	400,000	20	500
6	✔	500,000	25	500
7	✔	600,000	30	500
8	✔	800,000	40	500

COIL	VERT (DDU)	HORZ (DDU)	GAIN (%)	PHASE (Deg)	X*Y (Frac)	PHASE CORR (%)
1	17,784	17,784	0.000000	0.000000	0.000354	0.00000011
2	18,283	18,283	0.000000	0.000000	0.000723	0.00000014
3	18,012	18,012	0.000000	0.000000	0.000620	0.00000011
4	18,205	18,206	0.002746	0.003147	0.000392	0.00000014
5	18,223	18,223	0.000000	0.000000	0.000702	0.00000011
6	18,513	18,514	0.002701	0.003095	0.000617	0.00000014
7	18,113	18,112	0.002761	0.003163	0.000472	0.00000011
8	18,175	18,175	0.000000	0.000000	0.000412	0.00000014

Figure 7-1 Quadrature Error Tab

7.1 Theory of Operation

The OMNI-200 uses digital demodulation and thus has zero actual quadrature error. Quadrature error in analog systems is a result of differences in gain and phase offset of the X and Y channels. In a digital system, this cannot occur since the X and Y use identical digital multipliers and filters.

Although ASME II-860.1.2 says that digital elements need not be calibrated, JEAG does not have this exception and so we have provided it in order to comply. It is also useful to verify that there are no errors in the firmware logic.

To perform the measurement, the function generator is set to a frequency slightly higher than the demodulation frequency. For example, if the frequency is 200,000 Hz, and the beat frequency is 10 Hz, the function generator will output 200,010 Hz. During demodulation, the 200,010 Hz input is multiplied by 200,000 Hz demodulation frequency which will result in the sum and difference frequencies of 10 Hz and 400,010 Hz. The 400,010 Hz is eliminated by the demodulation filters and all that is left is the 10 Hz beat frequency.

Ideally, the X and Y channels will be varying sinusoidally at the beat frequency of 10 Hz, and with the same amplitude, but 90° out of phase:

$$X = A\cos(\omega t)$$
$$Y = A\sin(\omega t)$$

Since $X^2 + Y^2 = A^2\cos^2(\omega t) + A^2\sin^2(\omega t) = A^2$, it should draw a circle of radius A at a rate of 10 times a second.

However, in analog systems it can occur that the gains of the X and Y channels are not the same and also one could introduce a phase offset relative to the other:

$$X = A\cos(\omega t)$$
$$Y = B\sin(\omega t + \phi)$$

Eliminating *t* gives:

$$\frac{X^2}{A^2} - 2\frac{X}{A}\frac{Y}{B}\sin(\phi) + \frac{Y^2}{B^2} = \cos^2(\phi)$$

In the case $A = B$ **and** $\phi = 0$, this gives a circle. Note that it is quite possible for the X and Y channels to have the same amplitude, and yet have a very large quadrature error due to a nonzero relative phase offset. The OMNI-200 calibration software checks for both.

The PHASE field is:

$$error = \left| 2(45 - \tan^{-1}(V/H) \right|$$

where V is the amplitude of the Y channel and H of the X. This is not a very meaningful number, but is provided as a comparison to other systems. If V = H, this will be zero.

The GAIN field is:

$$error = 100\frac{|V - H|}{V + H}$$

This is a measure of the difference between the amplitude of the X and Y channels and will be zero if they are the same.

Note that the values displayed for the quadrature error are not precisely zero. Even though digital demodulation has zero quadrature error, there is a small amount of noise in the system. For a 14-bit ADC, an error of even a single DDU (Digital Data Unit) will cause an error of around 1/8000 or 0.013%. Due to the random nature of the noise, this tends to cancel out and the actual errors are much smaller, but not exactly zero. Thus the small nonzero quadrature errors are actually a measure of noise in the system.

As noted above, in addition to verifying that the X and Y channels have the same amplitude, we must verify that they are 90° out of phase. To do this, we take advantage of the fact that integrating the following over an integral number of periods:

$$\int_0^{2\pi N} \sin(\theta + \phi)\cos(\theta)\,d\theta = 0$$

if and only if $\phi = 0$. The X*Y column is computed as:

$$error = \frac{\sqrt{\left|\sum_{i=0}^{N-1} X_i Y_i\right|}}{NAB}$$

where N is the number of data points in some integral number of revolutions (i.e. beats), A is the amplitude of the X channel, and B is the amplitude of the Y channel.

An additional check is performed; to verify that the X and Y channels are indeed sinusoidal in time. Since the data samples are taken at equal time increments, there should be a linear relationship between the phase angle of an X Y sample and the sample index. In other words, the circle should be traced out at a constant speed.

The standard statistical measure of the linearity between two variables is the correlation coefficient r. If this r = 1, the variables are exactly linearly related, if r = 0, they are unrelated. The value displayed in the PHASE CORR column is:

$$error = 100 * (1 - r)$$

where r is the correlation coefficient of the phase angle of the n’th sample and n.

7.2 Quadrature Measurement Setup

The user can enter any number of frequencies to measure by typing in the **FREQUENCY** column.

LINE	D	FREQUENCY (Hz)	BEAT (Hz)	DRIVE (mV)	*
1	✔	25,000	10	500	
2	✔	100,000	10	500	
3	✔	200,000	10	500	
4	✔	300,000	15	500	
5	✔	400,000	20	500	
6	✔	500,000	25	500	
7	✔	600,000	30	500	
8	✔	800,000	40	500	

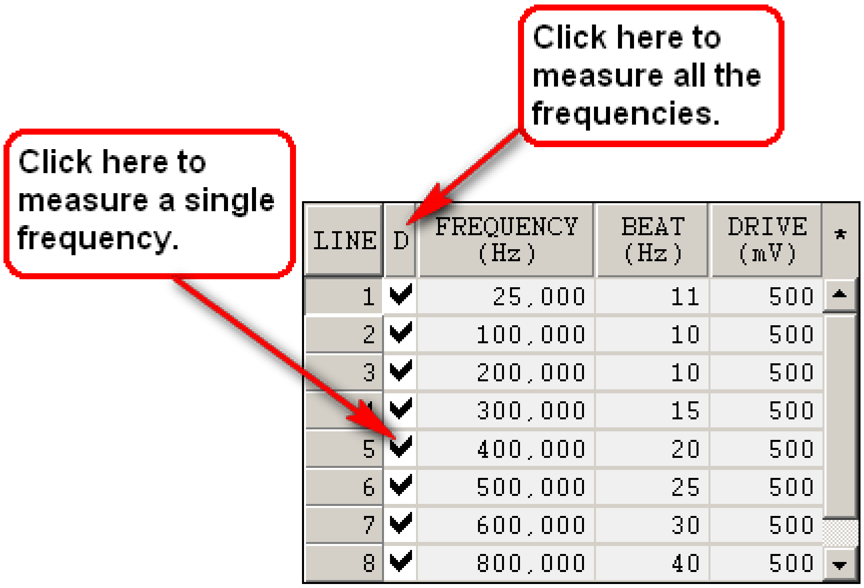
Table 7-1 Quadrature Measurement Setup

The **BEAT** frequency will automatically be filled in, although the user can change it if desired. By default, it is chosen to be 5 times the frequency divided by 100,000. Since the accuracy of the OMNI-200 frequency output is one part in 100,000, this avoids the possibility that the Function Generator will produce a frequency exactly matching the OMNI-200.

The **DRIVE** field is the drive in mV used for the given frequency.

7.3 Making a Measurement

To measure the quadrature error for a given frequency, click in the **D** column of the given row. Whenever the measurement is complete, a check mark will be displayed. To measure all the frequencies at once, click in the title of the **D** column.



LINE	D	FREQUENCY (Hz)	BEAT (Hz)	DRIVE (mV)	*
1	✔	25,000	11	500	
2	✔	100,000	10	500	
3	✔	200,000	10	500	
4	✔	300,000	15	500	
5	✔	400,000	20	500	
6	✔	500,000	25	500	
7	✔	600,000	30	500	
8	✔	800,000	40	500	

Figure 7-2 Performing quadrature measurements.

7.4 Quadrature Results Table

COIL	VERT (DDU)	HORZ (DDU)	GAIN (%)	PHASE (Deg)	X*Y (Frac)	PHASE CORR (%)
1	17,726	17,726	0.000000	0.000000	0.000458	0.00000004
2	18,203	18,202	0.002747	0.003148	0.000090	0.00000003
3	17,953	17,954	0.002785	0.003191	0.000481	0.00000004
4	18,141	18,141	0.000000	0.000000	0.000393	0.00000003
5	18,152	18,151	0.002755	0.003157	0.000045	0.00000004
6	18,414	18,413	0.002715	0.003112	0.000523	0.00000003
7	18,035	18,034	0.002772	0.003177	0.000131	0.00000004
8	18,103	18,102	0.002762	0.003165	0.000282	0.00000003

Table 7-2 Quadrature Results

The **HORZ** and **VERT** fields are the amplitudes of the X and Y eddy current signals. They are the width and height of the circles.

The results table shows the worst case errors for the currently select frequency. The meaning of each field is explained in section 7.1. For each row, the value with the maximum error will be highlighted in yellow.

7.5 Quadrature Results Plot

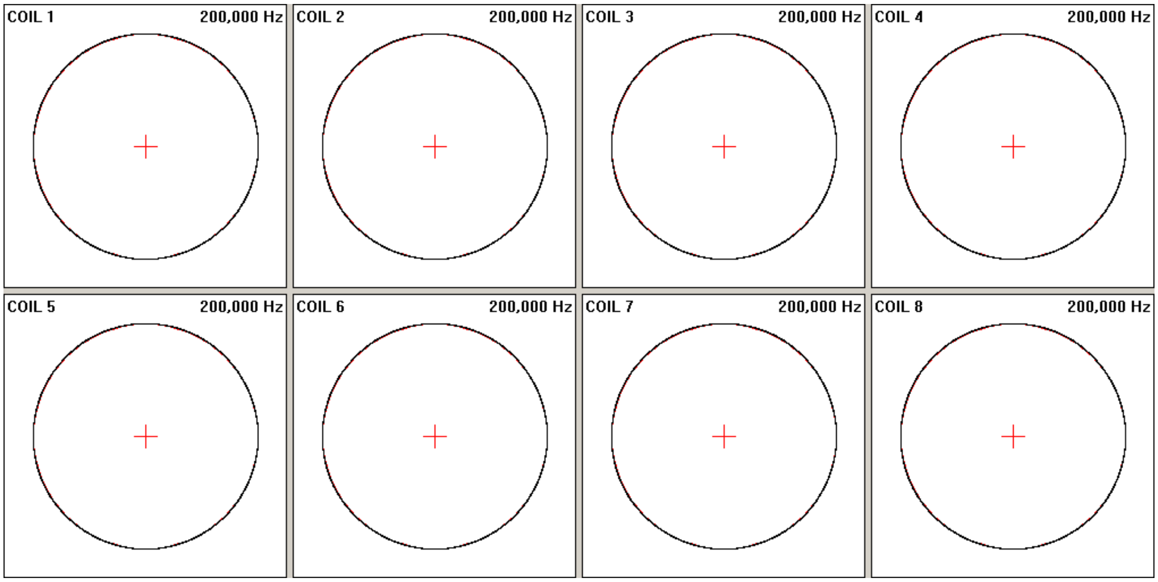


Figure 7-3 Quadrature Data Display

This is a visual display of the data acquired during the quadrature error measurement. It is the same as a lissajous display in the acquisition software. For each eddy current sample, the X value is displayed on the horizontal axis and the Y value is displayed on the vertical axis. There is a red circle whose radius is the average of the actual measurements. The black lines are the actual measured data samples. Ideally, the data will exactly cover the red circle.

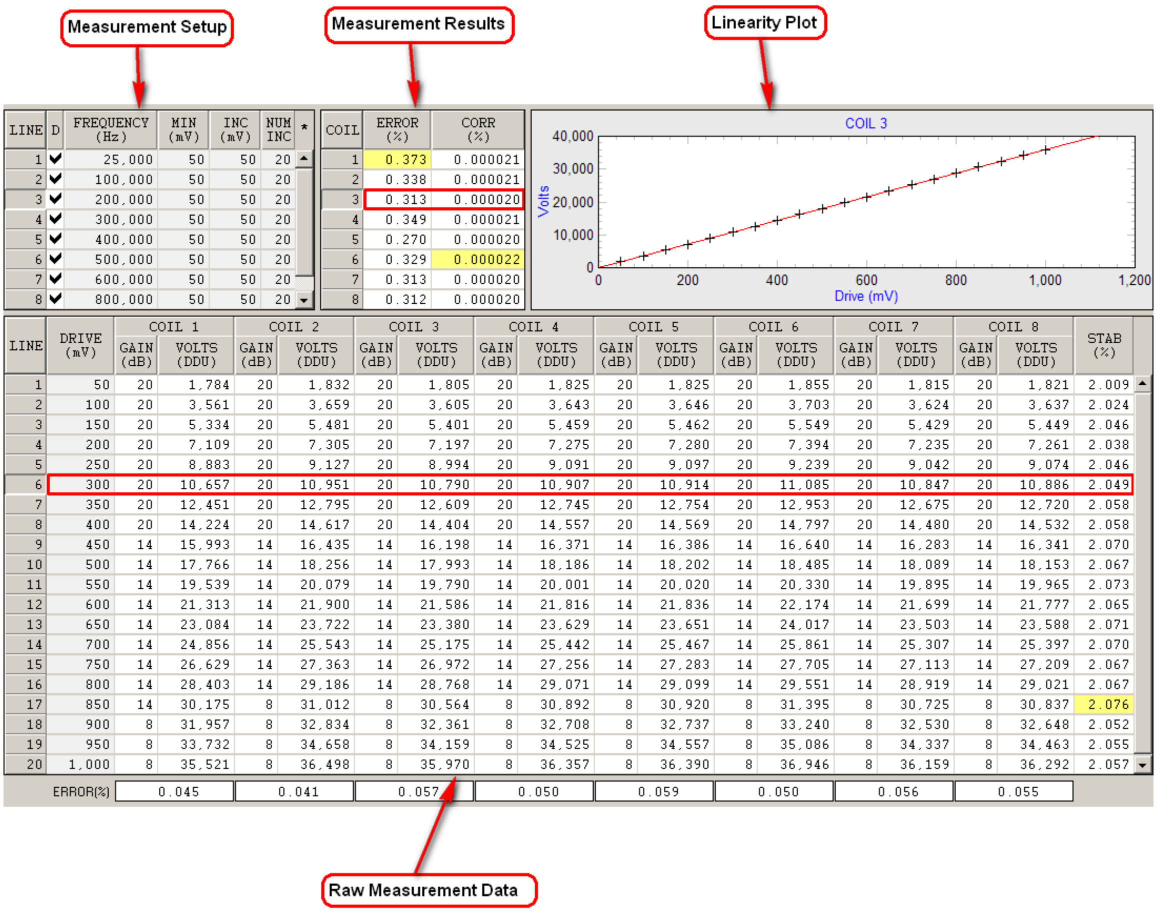
The number of data samples in the circle is equal to the sample rate divided by the beat frequency. If this is small, the circles will be replaced by straight lines.

7.6 Manual Method

To manually verify the quadrature results, select a frequency and choose **View | Tester Config**. Save the configuration to a file and open it in EddyVision acquisition. Set the function generator to the required frequency and drive and turn the tester on. You will see circles displayed as above.

8 Amplifier Linearity/Gain Stability

Click the **Amplifier Linearity/Gain Stability** tab to measure amplifier linearity and gain stability.



LINE	D	FREQUENCY (Hz)	MIN (mV)	INC (mV)	NUM INC	*
1	✔	25,000	50	50	20	
2	✔	100,000	50	50	20	
3	✔	200,000	50	50	20	
4	✔	300,000	50	50	20	
5	✔	400,000	50	50	20	
6	✔	500,000	50	50	20	
7	✔	600,000	50	50	20	
8	✔	800,000	50	50	20	

COIL	ERROR (%)	CORR (%)
1	0.373	0.000021
2	0.338	0.000021
3	0.313	0.000020
4	0.349	0.000021
5	0.270	0.000020
6	0.329	0.000022
7	0.313	0.000020
8	0.312	0.000020

LINE	DRIVE (mV)	COIL 1		COIL 2		COIL 3		COIL 4		COIL 5		COIL 6		COIL 7		COIL 8		STAB (%)
		GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	
1	50	20	1,784	20	1,832	20	1,805	20	1,825	20	1,825	20	1,855	20	1,815	20	1,821	2.009
2	100	20	3,561	20	3,659	20	3,605	20	3,643	20	3,646	20	3,703	20	3,624	20	3,637	2.024
3	150	20	5,334	20	5,481	20	5,401	20	5,459	20	5,462	20	5,549	20	5,429	20	5,449	2.046
4	200	20	7,109	20	7,305	20	7,197	20	7,275	20	7,280	20	7,394	20	7,235	20	7,261	2.038
5	250	20	8,883	20	9,127	20	8,994	20	9,091	20	9,097	20	9,239	20	9,042	20	9,074	2.046
6	300	20	10,657	20	10,951	20	10,790	20	10,907	20	10,914	20	11,085	20	10,847	20	10,886	2.049
7	350	20	12,451	20	12,795	20	12,609	20	12,745	20	12,754	20	12,953	20	12,675	20	12,720	2.058
8	400	20	14,224	20	14,617	20	14,404	20	14,557	20	14,569	20	14,797	20	14,480	20	14,532	2.058
9	450	14	15,993	14	16,435	14	16,198	14	16,371	14	16,386	14	16,640	14	16,283	14	16,341	2.070
10	500	14	17,766	14	18,256	14	17,993	14	18,186	14	18,202	14	18,485	14	18,089	14	18,153	2.067
11	550	14	19,539	14	20,079	14	19,790	14	20,001	14	20,020	14	20,330	14	19,895	14	19,965	2.073
12	600	14	21,313	14	21,900	14	21,586	14	21,816	14	21,836	14	22,174	14	21,699	14	21,777	2.065
13	650	14	23,084	14	23,722	14	23,380	14	23,629	14	23,651	14	24,017	14	23,503	14	23,588	2.071
14	700	14	24,856	14	25,543	14	25,175	14	25,442	14	25,467	14	25,861	14	25,307	14	25,397	2.070
15	750	14	26,629	14	27,363	14	26,972	14	27,256	14	27,283	14	27,705	14	27,113	14	27,209	2.067
16	800	14	28,403	14	29,186	14	28,768	14	29,071	14	29,099	14	29,551	14	28,919	14	29,021	2.067
17	850	14	30,175	8	31,012	8	30,564	8	30,892	8	30,920	8	31,395	8	30,725	8	30,837	2.076
18	900	8	31,957	8	32,834	8	32,361	8	32,708	8	32,737	8	33,240	8	32,530	8	32,648	2.052
19	950	8	33,732	8	34,658	8	34,159	8	34,525	8	34,557	8	35,086	8	34,337	8	34,463	2.055
20	1,000	8	35,521	8	36,498	8	35,970	8	36,357	8	36,390	8	36,946	8	36,159	8	36,292	2.057
	ERROR(%)	0.045		0.041		0.057		0.050		0.059		0.050		0.056		0.055		

Figure 8-1 Amplifier Linearity/Gain Stability

8.1 *Theory of Operation*

The amplifier linearity is a measure of the linearity of the measured voltage vs. the input for a given coil. The gain stability is a measure of the gain of coils relative to each other at a given drive and frequency. This screen measures both at the same time.

The linearity error for a given coil is computed as follows. First compute the gain for each drive value by taking Volts / Drive. For example, the gain at 100 mV for COIL 1 above is G=1.771 / 0.100 = 17.71, at 200 mV it is 3.534/0.200=17.67, and so forth. The average over all drive values, Gavg, is computed. Then for a given drive value, the error is:

$$error = 100\frac{G_{DRIVE} - G_{AVG}}{G_{AVG}}$$

The overall linearity error for the given coil is the largest of these errors.

This is a very poor measure of linearity, but is provided to comply with ASME and as a comparison to other vendors systems. It is a poor measure because the errors will become arbitrarily large as the minimum drive is decreased. In fact, at zero, any voltage, no matter how small, would erroneously result in an infinite error.

For example, consider a system with a nominal gain of 2.0 over an input range of 0 to 10V, but with output errors of 1 µV. So the ideal is Vout = 2.0 * Vin, but Vout varies by 1 µV. Most people would consider this very linear. At a drive Vin=1.0 V, Vout = 2.000001V gives G=2.000001. But at Vin=0.0000001, Vout=0.0000012 gives G=12. G can be made arbitrarily large as Vin decreases. This is an extreme example intended to illustrate the point.

So in addition to the above measure of linearity, CoreStar has added the standard statistical measure for linearity; the correlation coefficient r of the Vout vs. Vin (i.e. VOLTS field vs. DRIVE field). For a given coil, r is computed as:

$$r = \frac{\sum_{i=1}^{n}(V_i - \overline{V})(D_i - \overline{D})}{(n-1)s_V s_D}$$

$$s_V = \sqrt{\frac{\sum_{i-1}^{n}(V_i - \overline{V})^2}{n-1}}$$

$$s_D = \sqrt{\frac{\sum_{i-1}^{n}(D_i - \overline{D})^2}{n-1}}$$

8.2 Measurement Setup

LINE	D	FREQUENCY (Hz)	MIN (mV)	INC (mV)	NUM INC	*
1	✔	25,000	50	50	20	
2	✔	100,000	50	50	20	
3	✔	200,000	50	50	20	
4	✔	300,000	50	50	20	
5	✔	400,000	50	50	20	
6	✔	500,000	50	50	20	
7	✔	600,000	50	50	20	
8	✔	800,000	50	50	20	
*						

Table 8-1 Linearity/Stability Measurement Setup

To create the set of frequencies used for this test, click in the **FREQUECY** column and type in the values. The function generator will start at the drive value in the **MIN** column, incrementing the output each time by the value in the **INC** column, the number of times specified in the **NUM INC** column. The complete set of drive values used will be shown in the raw data table.

The user may change the drive values and number of increments by left and right clicking in the appropriate fields.

8.3 Raw Measurement Data

LINE	DRIVE (mV)	COIL 1		COIL 2		COIL 3		COIL 4		COIL 5		COIL 6		COIL 7		COIL 8		STAB (%)
		GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	GAIN (dB)	VOLTS (DDU)	
1	50	20	1,778	20	1,824	20	1,799	20	1,819	20	1,820	20	1,847	20	1,807	20	1,815	1.958
2	100	20	3,552	20	3,645	20	3,595	20	3,634	20	3,636	20	3,688	20	3,612	20	3,627	1.970
3	150	20	5,321	20	5,463	20	5,387	20	5,445	20	5,447	20	5,527	20	5,413	20	5,433	1.995
4	200	20	7,091	20	7,280	20	7,181	20	7,255	20	7,259	20	7,365	20	7,213	20	7,242	1.999
5	250	20	8,862	20	9,099	20	8,973	20	9,067	20	9,072	20	9,205	20	9,015	20	9,050	2.003
6	300	20	10,632	20	10,916	20	10,765	20	10,879	20	10,885	20	11,044	20	10,816	20	10,857	2.005
7	350	20	12,423	20	12,755	20	12,580	20	12,712	20	12,720	20	12,905	20	12,639	20	12,687	2.007
8	400	20	14,193	20	14,572	20	14,372	20	14,522	20	14,531	20	14,743	20	14,439	20	14,494	2.006
9	450	14	15,958	14	16,385	14	16,162	14	16,331	14	16,345	14	16,581	14	16,237	14	16,300	2.024
10	500	14	17,727	14	18,201	14	17,955	14	18,142	14	18,157	14	18,418	14	18,038	14	18,107	2.022
11	550	14	19,496	14	20,017	14	19,745	14	19,952	14	19,969	14	20,256	14	19,839	14	19,914	2.024
12	600	14	21,266	14	21,835	14	21,538	14	21,762	14	21,781	14	22,095	14	21,639	14	21,722	2.023
13	650	14	23,034	14	23,650	14	23,329	14	23,572	14	23,593	14	23,932	14	23,440	14	23,527	2.023
14	700	14	24,804	14	25,467	14	25,122	14	25,383	14	25,405	14	25,772	14	25,240	14	25,336	2.024
15	750	14	26,575	14	27,286	14	26,915	14	27,195	14	27,219	14	27,611	14	27,042	14	27,145	2.023
16	800	14	28,343	14	29,103	14	28,707	14	29,004	14	29,031	14	29,449	14	28,844	14	28,951	2.027
17	850	14	30,112	8	30,923	14	30,498	8	30,821	8	30,846	8	31,287	14	30,643	8	30,762	2.032
18	900	8	31,889	8	32,741	8	32,292	8	32,633	8	32,659	8	33,125	8	32,444	8	32,569	2.012
19	950	8	33,660	8	34,559	8	34,088	8	34,446	8	34,474	8	34,965	8	34,247	8	34,381	2.015
20	1,000	8	35,444	8	36,391	8	35,893	8	36,271	8	36,301	8	36,818	8	36,063	8	36,202	2.015
	ERROR(%)	0.052		0.044		0.060		0.051		0.070		0.059		0.059		0.062		

Table 8-2 Amplifier Linearity/Gain Stability Raw Data

The raw data table shows the measured values for each coil at each drive for the currently select frequency. For each coil, there are two fields. The **GAIN** field shows the gain in dB of the dynamic gain amplifier. This is just for reference purposes. The **VOLTS** column shows the measured amplitude at the given drive divided by 1000.

The **STAB** column shows the gain stability for the given drive value. This is computed by finding the average voltage over all coils for the given drive and then finding which coil deviates the most from that average. The gain stability error for that drive value is then:

$$error = 100\frac{MAX(V_{COIL} - V_{AVG})}{V_{AVG}}$$

At the foot of the raw data table, there are a set of fields that show the amplifier linearity error for the given coil at the currently highlighted drive value.

8.4 Linearity Results Table

COIL	ERROR (%)	CORR (%)
1	0.291	0.000019
2	0.213	0.000017
3	0.209	0.000018
4	0.243	0.000017
5	0.251	0.000016
6	0.262	0.000018
7	0.186	0.000017
8	0.242	0.000017

Table 8-3 Linearity Results

The **ERROR** column of the results table shows the worst case linearity error for each coil.

The worst case of all the coils is highlighted in yellow.

8.5 Linearity Results Plot

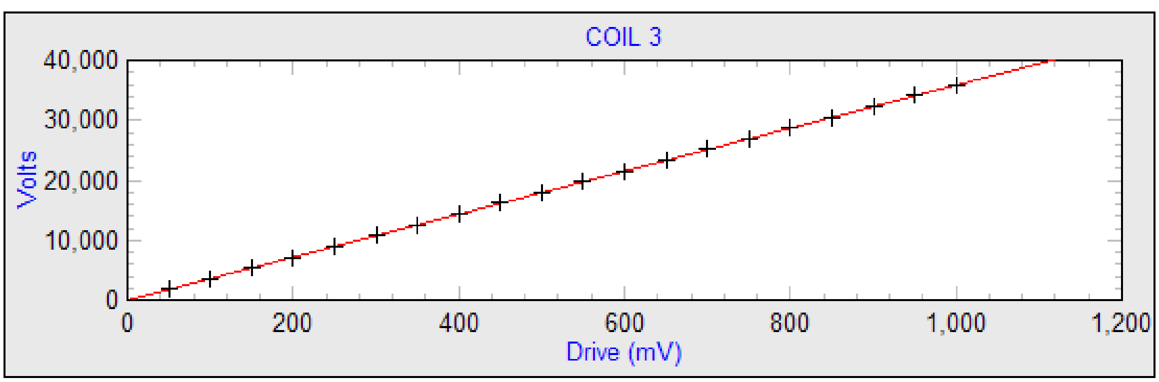


Figure 8-2 Linearity Results Plot

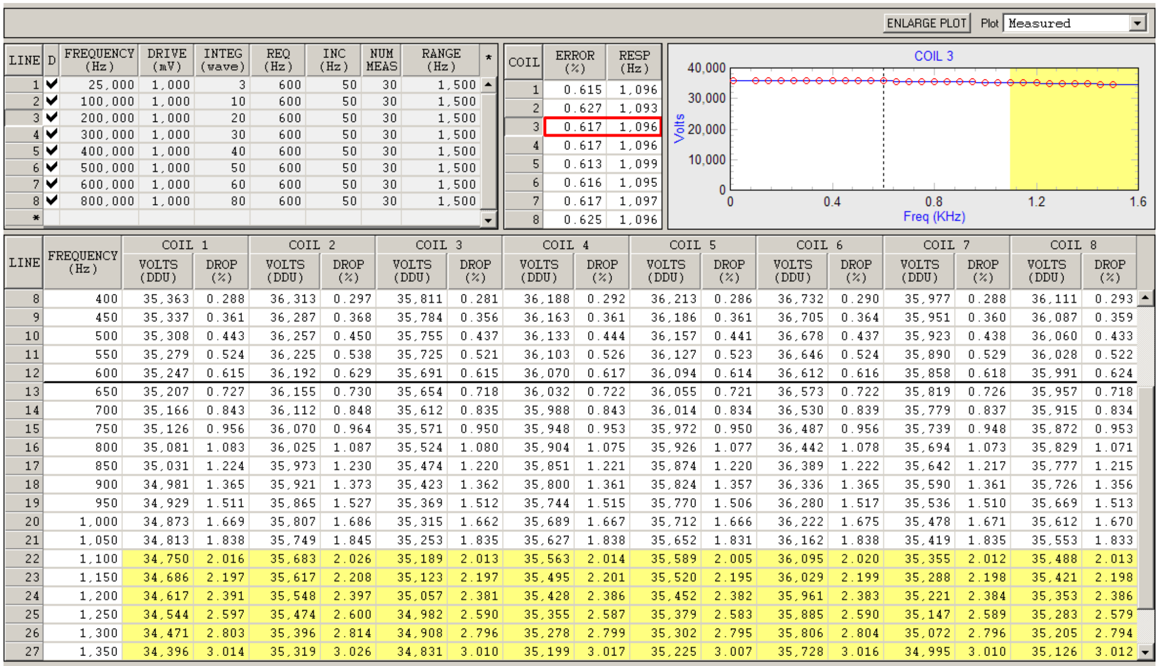
This is simply a plot of all the measured voltages vs. drive for the currently selected row in the results table. The red line is a least squares fit of these values.

8.6 Manual Method

To manually measure the amplifier linearity and gain stability, select a frequency and choose **View | Tester Config**. Save the configuration to a file and open it in EddyVision acquisition. Turn the tester on and set the function generator to the required values. Measure the size of the displayed circles for each value of the generator drive.

9 Frequency Response

To measure frequency response, click on the **Frequency Response** tab.



LINE	D	FREQUENCY (Hz)	DRIVE (mV)	INTEG (wave)	REQ (Hz)	INC (Hz)	NUM MEAS	RANGE (Hz)
1	✔	25,000	1,000	3	600	50	30	1,500
2	✔	100,000	1,000	10	600	50	30	1,500
3	✔	200,000	1,000	20	600	50	30	1,500
4	✔	300,000	1,000	30	600	50	30	1,500
5	✔	400,000	1,000	40	600	50	30	1,500
6	✔	500,000	1,000	50	600	50	30	1,500
7	✔	600,000	1,000	60	600	50	30	1,500
8	✔	800,000	1,000	80	600	50	30	1,500
*								

COIL	ERROR (%)	RESP (Hz)
1	0.615	1,096
2	0.627	1,093
3	0.617	1,096
4	0.617	1,096
5	0.613	1,099
6	0.616	1,095
7	0.617	1,097
8	0.625	1,096

LINE	FREQUENCY (Hz)	COIL 1		COIL 2		COIL 3		COIL 4		COIL 5		COIL 6		COIL 7		COIL 8	
		VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)
8	400	35,363	0.288	36,313	0.297	35,811	0.281	36,188	0.292	36,213	0.286	36,732	0.290	35,977	0.288	36,111	0.293
9	450	35,337	0.361	36,287	0.368	35,784	0.356	36,163	0.361	36,186	0.361	36,705	0.364	35,951	0.360	36,087	0.359
10	500	35,308	0.443	36,257	0.450	35,755	0.437	36,133	0.444	36,157	0.441	36,678	0.437	35,923	0.438	36,060	0.433
11	550	35,279	0.524	36,225	0.538	35,725	0.521	36,103	0.526	36,127	0.523	36,646	0.524	35,890	0.529	36,028	0.522
12	600	35,247	0.615	36,192	0.629	35,691	0.615	36,070	0.617	36,094	0.614	36,612	0.616	35,858	0.618	35,991	0.624
13	650	35,207	0.727	36,155	0.730	35,654	0.718	36,032	0.722	36,055	0.721	36,573	0.722	35,819	0.726	35,957	0.718
14	700	35,166	0.843	36,112	0.848	35,612	0.835	35,988	0.843	36,014	0.834	36,530	0.839	35,779	0.837	35,915	0.834
15	750	35,126	0.956	36,070	0.964	35,571	0.950	35,948	0.953	35,972	0.950	36,487	0.956	35,739	0.948	35,872	0.953
16	800	35,081	1.083	36,025	1.087	35,524	1.080	35,904	1.075	35,926	1.077	36,442	1.078	35,694	1.073	35,829	1.071
17	850	35,031	1.224	35,973	1.230	35,474	1.220	35,851	1.221	35,874	1.220	36,389	1.222	35,642	1.217	35,777	1.215
18	900	34,981	1.365	35,921	1.373	35,423	1.362	35,800	1.361	35,824	1.357	36,336	1.365	35,590	1.361	35,726	1.356
19	950	34,929	1.511	35,865	1.527	35,369	1.512	35,744	1.515	35,770	1.506	36,280	1.517	35,536	1.510	35,669	1.513
20	1,000	34,873	1.669	35,807	1.686	35,315	1.662	35,689	1.667	35,712	1.666	36,222	1.675	35,478	1.671	35,612	1.670
21	1,050	34,813	1.838	35,749	1.845	35,253	1.835	35,627	1.838	35,652	1.831	36,162	1.838	35,419	1.835	35,553	1.833
22	1,100	34,750	2.016	35,683	2.026	35,189	2.013	35,563	2.014	35,589	2.005	36,095	2.020	35,355	2.012	35,488	2.013
23	1,150	34,686	2.197	35,617	2.208	35,123	2.197	35,495	2.201	35,520	2.195	36,029	2.199	35,288	2.198	35,421	2.198
24	1,200	34,617	2.391	35,548	2.397	35,057	2.381	35,428	2.386	35,452	2.382	35,961	2.383	35,221	2.384	35,353	2.386
25	1,250	34,544	2.597	35,474	2.600	34,982	2.590	35,355	2.587	35,379	2.583	35,885	2.590	35,147	2.589	35,283	2.579
26	1,300	34,471	2.803	35,396	2.814	34,908	2.796	35,278	2.799	35,302	2.795	35,806	2.804	35,072	2.796	35,205	2.794
27	1,350	34,396	3.014	35,319	3.026	34,831	3.010	35,199	3.017	35,225	3.007	35,728	3.016	34,995	3.010	35,126	3.012

Figure 9-1 Frequency Response Tab

9.1 Theory of Operation

Eddy current testers such as the OMNI-200 drive eddy current probes with pure sine waves of some frequency F. If nothing is changing, the signal returned from the probe will be at that same frequency F. The demodulation process multiplies this signal by sine and cosine waves of that frequency producing waves at DC and twice F.

In practice, as the probe is moved past defects, the input signal is modulated and phase shifted, producing a small spread of frequencies about F. The tester must be able to detect this spread of frequencies and do so as linearly as possible.

To measure the frequency response, the function generator is made to output a set of frequencies starting near the drive frequency and incrementing in stages up to some desired value. Typically, as the frequency gets farther and farther from the drive frequency, the measured voltage will start to drop off.

9.2 Choosing Frequencies

The user may enter any number of frequencies to test (see Table 9-1).

The **DRIVE** is the output drive of the function generator and should be set to some reasonable value. **INTEG** is the number of waves used for demodulation. It is the same as the corresponding field in the OMNI-200 configuration dialog. The frequency response will decrease as this value is increased.

The **REQ** column is the required frequency response. ASME II-830.8(b) says this should be 10 times the maximum probe speed in in/sec, or 0.4 times the speed in mm/sec. The raw data table (see Table 9-2) will show a black line just below this value. The errors reported in the results table (see Table 9-3) are taken at this value.

INC is the value by which the frequency will be incremented for each measurement, and **NUM MEAS** is the total number of measurements. **RANGE** is just **INC** times the **NUM MEAS**. As **INC** and **NUM MEAS** are changed, the raw data table will be updated to reflect the new values.

LINE	D	FREQUENCY (Hz)	DRIVE (mV)	INTEG (wave)	REQ (Hz)	INC (Hz)	NUM MEAS	RANGE (Hz)	*
1	✔	25,000	1,000	3	600	50	30	1,500	
2	✔	100,000	1,000	10	600	50	30	1,500	
3	✔	200,000	1,000	20	600	50	30	1,500	
4	✔	300,000	1,000	30	600	50	30	1,500	
5	✔	400,000	1,000	40	600	50	30	1,500	
6	✔	500,000	1,000	50	600	50	30	1,500	
7	✔	600,000	1,000	60	600	50	30	1,500	
8	✔	800,000	1,000	80	600	50	30	1,500	
*									

Table 9-1 Frequency Response Measurement Setup

9.3 Raw Data Table

The raw data table shows the measurements made at each frequency. The **FREQUENCY** column is configured based on the values in Table 9-1. The first frequency is always set to as lower value in order to get as close to DC as possible.

The horizontal line separates frequencies below the required response and those above. Any values that exceed the tolerance will be highlighted in yellow.

LINE	FREQUENCY (Hz)	COIL 1		COIL 2		COIL 3		COIL 4		COIL 5		COIL 6		COIL 7		COIL 8	
		VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)	VOLTS (DDU)	DROP (%)
8	400	35,363	0.288	36,313	0.297	35,811	0.281	36,188	0.292	36,213	0.286	36,732	0.290	35,977	0.288	36,111	0.293
9	450	35,337	0.361	36,287	0.368	35,784	0.356	36,163	0.361	36,186	0.361	36,705	0.364	35,951	0.360	36,087	0.359
10	500	35,308	0.443	36,257	0.450	35,755	0.437	36,133	0.444	36,157	0.441	36,678	0.437	35,923	0.438	36,060	0.433
11	550	35,279	0.524	36,225	0.538	35,725	0.521	36,103	0.526	36,127	0.523	36,646	0.524	35,890	0.529	36,028	0.522
12	600	35,247	0.615	36,192	0.629	35,691	0.615	36,070	0.617	36,094	0.614	36,612	0.616	35,858	0.618	35,991	0.624
13	650	35,207	0.727	36,155	0.730	35,654	0.718	36,032	0.722	36,055	0.721	36,573	0.722	35,819	0.726	35,957	0.718
14	700	35,166	0.843	36,112	0.848	35,612	0.835	35,988	0.843	36,014	0.834	36,530	0.839	35,779	0.837	35,915	0.834
15	750	35,126	0.956	36,070	0.964	35,571	0.950	35,948	0.953	35,972	0.950	36,487	0.956	35,739	0.948	35,872	0.953
16	800	35,081	1.083	36,025	1.087	35,524	1.080	35,904	1.075	35,926	1.077	36,442	1.078	35,694	1.073	35,829	1.071
17	850	35,031	1.224	35,973	1.230	35,474	1.220	35,851	1.221	35,874	1.220	36,389	1.222	35,642	1.217	35,777	1.215
18	900	34,981	1.365	35,921	1.373	35,423	1.362	35,800	1.361	35,824	1.357	36,336	1.365	35,590	1.361	35,726	1.356
19	950	34,929	1.511	35,865	1.527	35,369	1.512	35,744	1.515	35,770	1.506	36,280	1.517	35,536	1.510	35,669	1.513
20	1,000	34,873	1.669	35,807	1.686	35,315	1.662	35,689	1.667	35,712	1.666	36,222	1.675	35,478	1.671	35,612	1.670
21	1,050	34,813	1.838	35,749	1.845	35,253	1.835	35,627	1.838	35,652	1.831	36,162	1.838	35,419	1.835	35,553	1.833
22	1,100	34,750	2.016	35,683	2.026	35,189	2.013	35,563	2.014	35,589	2.005	36,095	2.020	35,355	2.012	35,488	2.013
23	1,150	34,686	2.197	35,617	2.208	35,123	2.197	35,495	2.201	35,520	2.195	36,029	2.199	35,288	2.198	35,421	2.198
24	1,200	34,617	2.391	35,548	2.397	35,057	2.381	35,428	2.386	35,452	2.382	35,961	2.383	35,221	2.384	35,353	2.386
25	1,250	34,544	2.597	35,474	2.600	34,982	2.590	35,355	2.587	35,379	2.583	35,885	2.590	35,147	2.589	35,283	2.579
26	1,300	34,471	2.803	35,396	2.814	34,908	2.796	35,278	2.799	35,302	2.795	35,806	2.804	35,072	2.796	35,205	2.794
27	1,350	34,396	3.014	35,319	3.026	34,831	3.010	35,199	3.017	35,225	3.007	35,728	3.016	34,995	3.010	35,126	3.012

Table 9-2 Frequency Response Raw Data

9.4 Results Table

The **ERROR** column of the frequency response results table shows the error at the required bandwidth.

The **RESP** column shows the highest frequency that is within tolerance. This will be less than the actual response of the instrument if the range is too small.

COIL	ERROR (%)	RESP (Hz)
1	0.615	1,096
2	0.627	1,093
3	0.617	1,096
4	0.617	1,096
5	0.613	1,099
6	0.616	1,095
7	0.617	1,097
8	0.625	1,096

Table 9-3 Frequency Response Results

9.5 Frequency Response Plot

The frequency response plot displays the measured frequency response (red circles) and theoretical response (blue line) for a given coil selected in the results table.

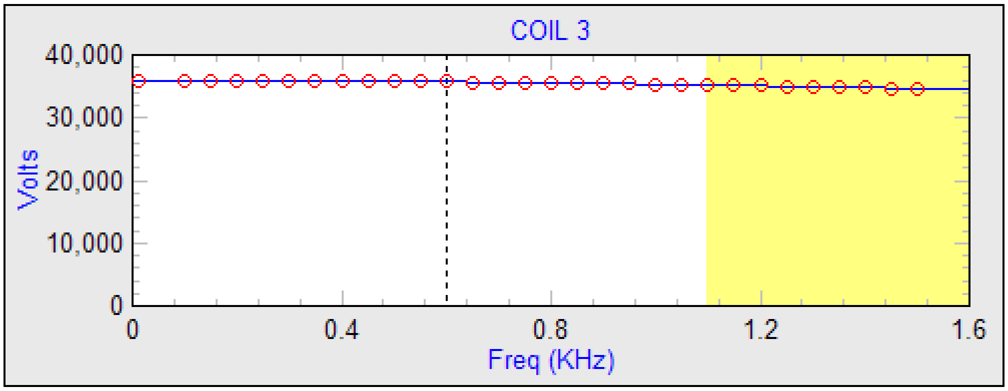


Figure 9-2 Frequency Response Plot

Portions shaded in yellow are parts where the response has dropped below the tolerance. The vertical black dotted line is at the required frequency response.

A larger version can be viewed by clicking the ENLARGE PLOT button:

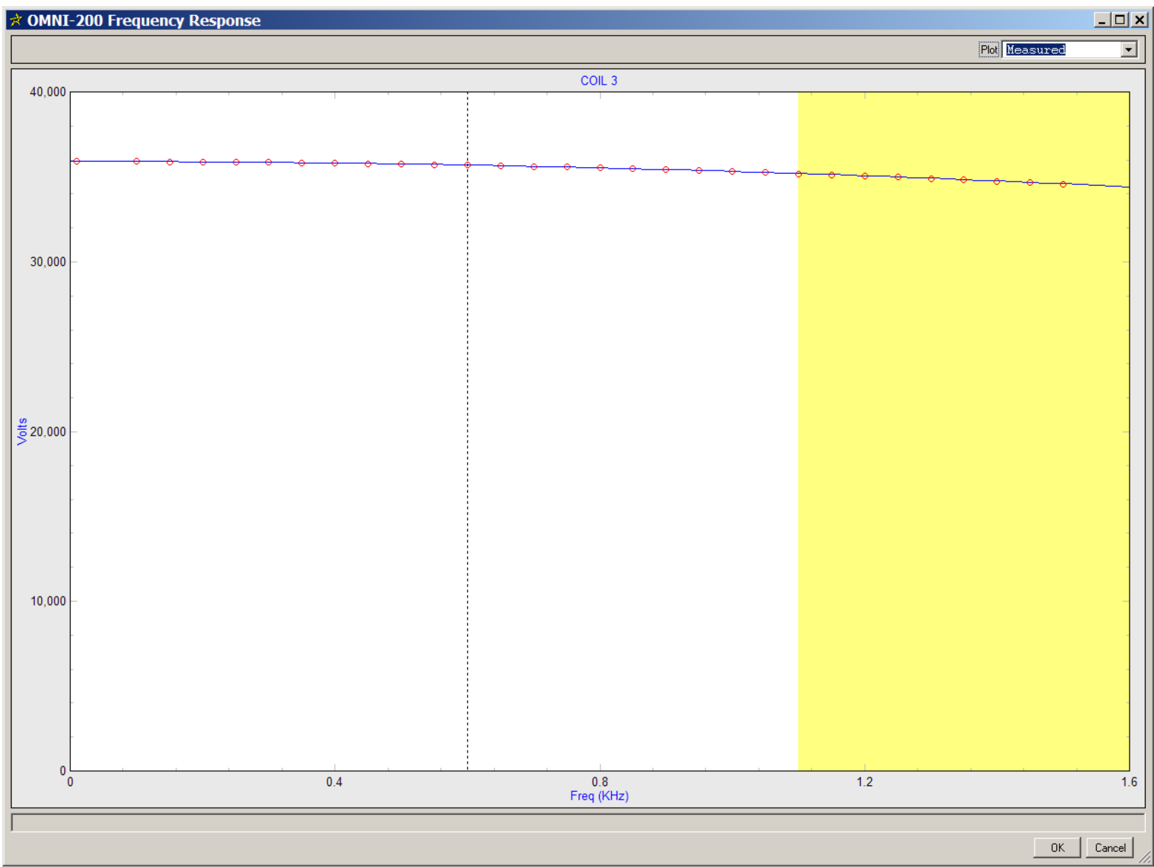


Figure 9-3 Enlarged Frequency Response

9.6 Manual Method

To manually measure the frequency response, select a frequency and choose **View | Tester Config**. Save the configuration to a file and open it in EddyVision acquisition. Turn the tester on and set the function generator to each beat frequency. Measure the diameter of the displayed circle for each.

10 Voltages

LINE	D	VOLTS (V)	ERROR (%)	DESCRIPTION
1	✔	14.950	0.334	+15V
2	✔	−15.032	0.212	−15V
3	✔	3.290	0.311	+3.3V

The Voltages tab shows the measurements of the tester power bricks.

11 Summary

Click on the Summary tab to see the overall results.

LINE	ITEM	TOL	TEMP 24.0°C		TEMP 46.0°C	
			ERROR	PASSED	ERROR	PASSED
1	Frequency Accuracy	±5.0%	0.001%	PASS		
2	Amplifier Stability	±5.0%	2.414%	PASS		
3	Quadrature Gain	±3.0%	0.011%	PASS		
4	Quadrature Phase	±5.0°	0.013°	PASS		
5	Quadrature X*Y	±3.0%	0.429%	PASS		
6	Frequency Response	±2.0%	1.707%	PASS		
7	Amplifier Linearity	±2.0%	0.429%	PASS		

Table 11-1 Report Summary

For each item, the **TOL** field shows the allowed tolerance. This may depend on the report type (i.e. ASME vs. JEAG).

For each temperature range, there are two fields. The **ERROR** field shows the worst case error for all measurements of that type. For example, the Amplifier Stability was measured at two frequencies and 10 different drive values. The worst case of all of those is reported in the summary. The **PASSED** column shows if the tester passed or failed the test.

12 Appendix A: Valid Input Values

This section gives the valid values for the setup tables for each type of measurement.

VALUE	MINIMUM	MAXIMUM	INCREMENT
FREQUNENCY	1,000 Hz	1,000,000 Hz	1,000 Hz
BEAT FREQUENCY	Maximum of 10 and 5.0e-5 x freq	10,000 Hz	1 Hz
DRIVE	10 mV	10,000 mV	10 mV

Table 12-1 Valid input values that apply to all measurements.

VALUE	MINIMUM	MAXIMUM	INCREMENT
MIN (mV)	10 mV	1,000 mV	10 mV
INC (mV)	10 mV	1,000 mV	10 mV
NUM INC	1	100	1

Table 12-2 Valid Values for Amplifier Linearity/Gain Stability

VALUE	MINIMUM	MAXIMUM	INCREMENT
INTEG (wave)	1	200	1
REQ (Hz)	1 Hz	10,000 Hz	1 Hz
INC (Hz)	1 Hz	10,000 Hz	1 Hz
NUM MEAS	2	1,000	1

Table 12-3 Valid Values for Frequency Response.