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Finemet Current Transformer Component Datasheet

Prepared for:	CBMM North America
	1000 Omega Drive
	Pittsburgh, PA 15205

Description of Device Under Test (DUT).

The current transformer is a measurement device which reduces high voltage currents to a lower value to provide a proper value of measuring current flowing through a current carrying conductor. The output is supplied into a resistive load such that the secondary core will saturate or cause failure into excessive voltage breakdown. Specifically, the current transformer is configured to be a toroidal current transformer, or the line that has the current flowing is the primary winding, and the voltage is read across the resistor. Compared in performance are two configurations with two core types: comparing a Silicon Steel Core with a Finemet Core.

Test Facility	
Test Laboratory	AMPED
Address	1435 Bedford Avenue
City, State, Zip Code	Pittsburgh, PA 15219
Phone	412-802-0988
Fax:	412-802-0779
Website:	https://pittamped.github.io

Test Personnel	
Name	Chris Bracken
Title	Research Associate
Signature	

Datasheet Revision History

Revision	Date	Description	Revised By
N / C	Date of Release	Initial Release	CSB (Initials of Revisor)
A	29MAR2023	Addition of tests and additional data added to report.	CSB

AMPED

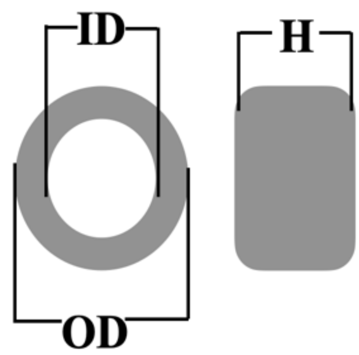
Revision: A

Core Specifications

Finemet Current Transformer

Dimensions			
Description	**Symbol**	**Sample Dimension (mm)** [1]	**Actual Dimension Used (mm)** [1]
Core Inner Diameter	ID	36.96	37.1
Core Outer Diameter	OD	51.53	52.3
Core Height	H	22.43	22.8

[1] Sample Dimension refers to the dimensions that include coating. These dimensions do not pertain to the effective area used, as this effective area was stated in the provided core manufacturer datasheet. A correction factor accounts for this where plausible, taking the ratio of Sample Dimension-to-Actual Dimension, multiplying the cross-sectional area with this term (See AMPED standard AMP-STD-0C for this calculation, and for other calculations).

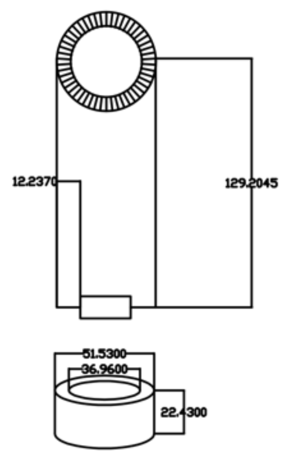


Magnetic Characteristics			
Description	**Symbol**	**Finished Dimension**	**Unit**
Effective Area	A_e	73	mm^2
Mean Magnetic Path Length	L_m	141	mm
Core Mass	C_M	0.0746	kg
Density	D	7350	kg / m^3
Lamination Thickness	L_M	0	µm
Chemistry	Finemet Material	**Grade**	
Anneal		**Impregnation**	Unimpregnated
Core Supplier	HITACHI	**Part Number**	FT-3K50T F5040GS
Wire Supplier	Remington Industries	**Wire Gauge**	30 AWG (Primary) 24 AWG (Secondary)

Configuration and Design.

All testing was performed using the mode(s) of operation and configuration(s) noted within the report. Individuals who designed or performed the testing provided the modes, configurations, and settings used to complete the evaluation. The actual test parameters are specified in the test data, in accordance with the test standard it was performed and evaluated along. The design is provided here. In particular, the design used off-the-shelf cores for the comparison between core types.

DUT				
Description	**Manufactured for**	**Model Number**	**Part Number**	**Serial Number**
Instrument Current Transformer	CBMM	N/A	N/A	N/A



Core and wire configuration for Finemet Current Transformer.

Table 1: Component Design Parameters.						
Primary Turns	1	Turn	Secondary Turns		50	Turns
Design Primary Current	100	A_{pk}				
Load Resistance	5	Ω	Load Resistor Design Heat Disspation (W)			
					at 60 Hz	8.49
					at 1000 Hz	9.99
					at 10000 Hz	10

Design Personnel	
Name	Mark A. Juds
Title	Research Associate
Signature	Mark A. Juds

Summary of Tests Performed and Results.

Table 2: Tests Performed and Results.				
Datasheet Section	**Test Description**	**Specification**	**Notes**	**Results**
IEEE C57.13-2016				
1.1	**Polarity. Subclause 8.3.**	IEEE C.57-13-2006	DC and AC Voltage.	Compliant.
	Excitation Current and Losses. Subclause 8.2.3.	IEEE C.57-13-2006	Excitation to 7 Amps.	
	Ratio and Phase Angle. Section 9.1.	IEEE C.57-13-2006	Calculated Transformer Ratio and Phase Angle of Waveforms.	
	Impedance Measurements. Section 9.3.	IEEE C.57-13-2006	Impedance Magnitude and Phase of Core and noted of DUT.	Compliant.
IEC 61869-1 / IEC 61869-2.				
	Magnetizing Inductance. Subclause 2B.2.2 / 2B.2.2.1	IEC 61869-1 / IEC 61869-2.	Inductance Measurements of core and noted of DUT.	
	A.C. Method: Remanence Factor. Subclause 2B.2.2 / 2B.2.2.3.	IEC 61869-1 / IEC 61869-2.	Results coincide to measurements from IEEE C.57.13-2016 Subclause 8.2.3.	

References.

Applicable Standards

Reference Specification Title	IEC 61869-1
	IEC 61869-2
	IEEE C57.13-2016

Section One: Polarity.
Electromagnetic Component Testing: Test Procedures and Results.

Purpose.
This test procedure is used to determine current transformer core polarity for wiring purposes, both with DC and AC Current.

Test Equipment.
The test equipment shall be used as follows:

Lab Asset Number	Description	Manufacturer	Model Number	Serial Number
WAV0003	Arbitrary Waveform Generator	Keysight Technologies	EDU33212A	CN61310043
AMP0001	High Speed Power Amplifier	NF Electronic Instruments	4025	4025-112
OSC0003	Oscilloscope (500 MHz)	Keysight Technologies	MSOX4054A	MY61260112
PRO0002	Differential Probe	Rigol	RP025D	2014187
PRO0005	AC / DC Current Probe	Keysight Technologies	1147B	JP61071359
MET0001	Digital Multimeter	Fluke	4025	4025-112
PS0004	GPD-Series Multi Output Programmable Linear D.C. Power Supply	GwInstek	GPD-43038	GE8916-315
LAB0001	Computer	AMPED	None	None

Test Procedures.

I. Polarity Testing – DC Voltage – Manual Procedure.

Per guidelines established from the IEEE C57.13-2016 standard, below is the procedure for manual operation of equipment for the DC Voltage Setup, to be applied as follows. For a more detailed and general procedure to apply the test, refer to the referenced standard described here.

a. Turn on the measurement equipment and allow sufficient time for stabilization (e.g. 20 minutes).
b. Be sure the current transformer is unloaded for these measurements.
   a. This is noted in the DUT Configuration table for this test below.
c. Set the DC Power Supply to setting suitable for current rating of wire used with Current Transformer.
   - The following settings were used for the testing, noted for replication:
     - Current. Set current limit to 3.2 A.
     - Voltage. Set the voltage limit to 15 V.
     - Wire Gauge. Use 30 AWG Magnet wire.
d. Connect the primary wire to the DC Power supply.
   - Be sure these are connected directly or a suitable connector is installed along the primary wire.
e. Connect the leads from the Multimeter to the output of the current transformer.

- Specify Multimeter Setting(s) relevant.
  - Measurements were performed with the Multimeter set at DC Voltage, and with the probes connected to the leads of the current transformer from alligator cable extensions.

f. Turn output of DC Power Supply on.
g. Observe the change in voltage polarity with applied voltage.
h. Turn DC Power supply output off upon completion of test.
   - If voltage transitions from a positive (+) to negative (-) polarity, mark the positive lead.
   - If voltage transitions from a negative (-) to positive (+), switch the leads at the current transformer and repeat the procedure of steps a-g.

II. Polarity Testing – AC Voltage – Manual Procedure.

Per guidelines established from the IEEE C57.13-2016 standard, below is the procedure for manual operation of equipment for the AC Voltage Setup, to be applied as follows. For a more detailed and general procedure to apply the test, refer to the referenced standard described here.

i. Turn on the measurement equipment and allow sufficient time for stabilization (e.g. 20 minutes).
j. Set the Arbitrary Waveform Generator to the following settings.
   - Begin with a low signal.
     - Frequency. Set frequency at 60 Hz. IEEE C57.13-2016 states frequency as specific operating point.
     - Amplitude. Begin with an amplitude value, in terms of peak-to-peak (V_{PP}), at 10 milli. Increase where deemed appropriate to make sure a fully functioning signal is observed in an acceptable tolerance.
       - Specific Test Levels:
       - 12 mV_{pp}: Finemet Current Transformer.

k. Set the Power Amplifier values.
   - Be sure to press input cable connected to on (usually A).
   - Press the desired gain. Performed in these tests at "X50".

l. Set the Oscilloscope to the following settings.
   - Specify Probe Attenuation.
     - Measurements were performed with a Keysight 1147B Current Probe has a fixed attenuation ratio of 0.1 V/A and cannot be changed.
     - Voltage Probe from Rigol, the RP1025D, was used for measurements, and has fixed attenuation ratio of 200:1 after calibration. Probe with Asset Number PRO0002 was used to acquire data the waveform.
   - The data was captured with High Resolution Settings under Waveform-Acquire Menu.

m. Turn output of Arbitrary Waveform Generator on.
n. Level the output voltage at the offset adjust with flat head screw driver, if possible. Note if probe does not have that capability.
   - For data presented, Voltage probe with asset number PRO0009 does not have the capability.

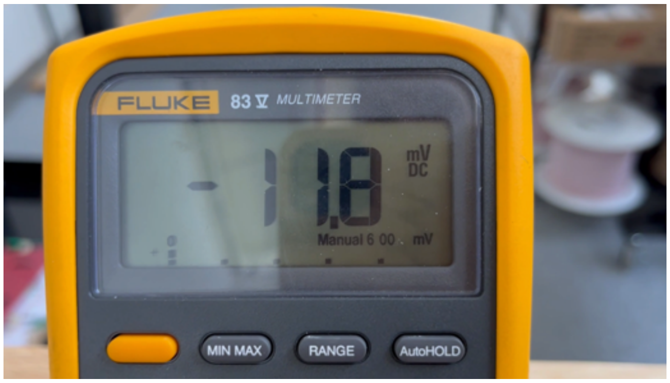
o. Examine the Waveform on the Oscilloscope read from the Current Probe on the input side and the Differential Probe on the Output Side.
   - Be sure to capture 3 - 5 periods of the excitation signal being applied.

p. Auto zero and Degauss the Current Probe before step i. Also Degauss where Average Current Waveform value climbs above an acceptable tolerance of +/- 10 mA.
q. Record relevant data for Data Presentation.
r. Turn off waveform generator upon completion.

Data Presentation.

In this section, data is presented as each section indicates below.

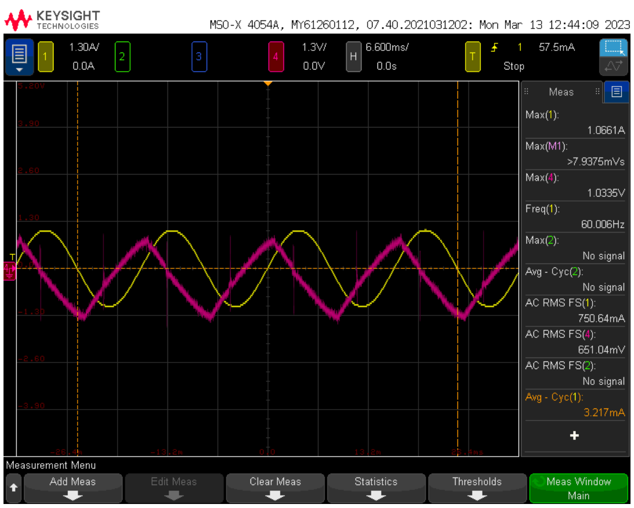
a. DC Voltage Results.

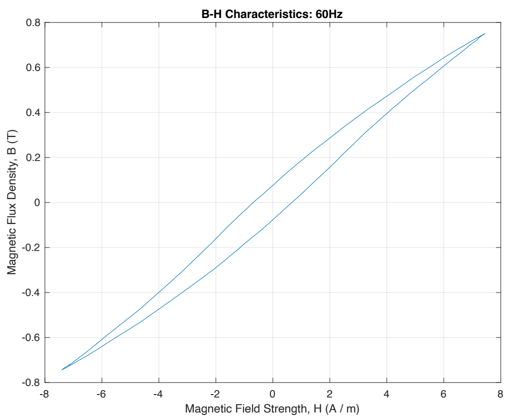
(a)	(b)
	

Finemet DC Voltage Reading with Output Pressed Off.

b. AC Voltage Results.

In this section, data is presented as each section indicates below.

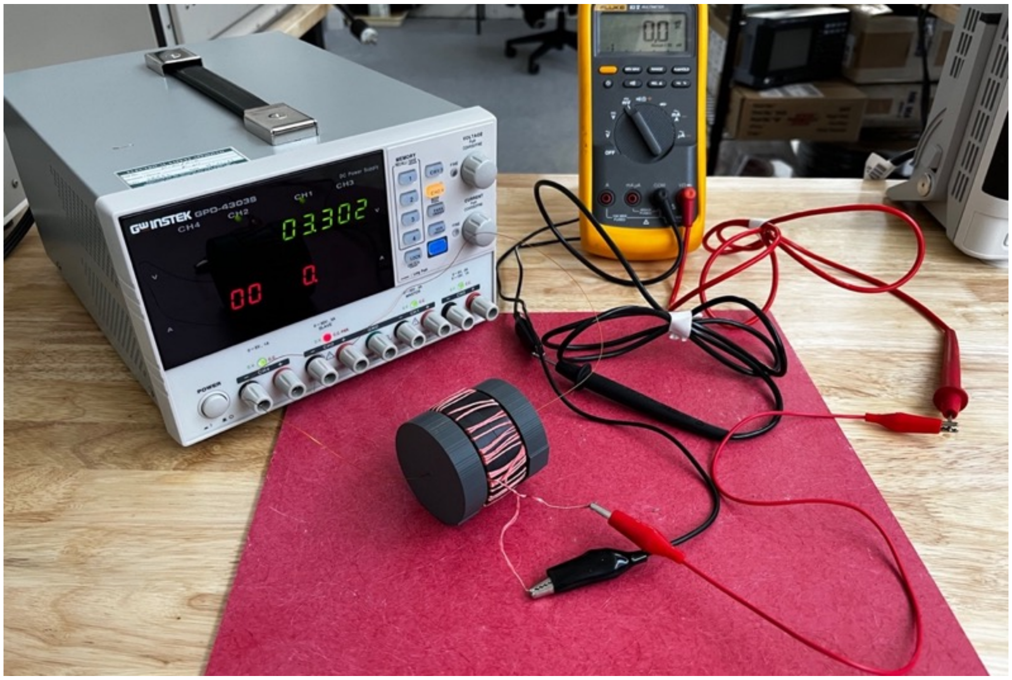




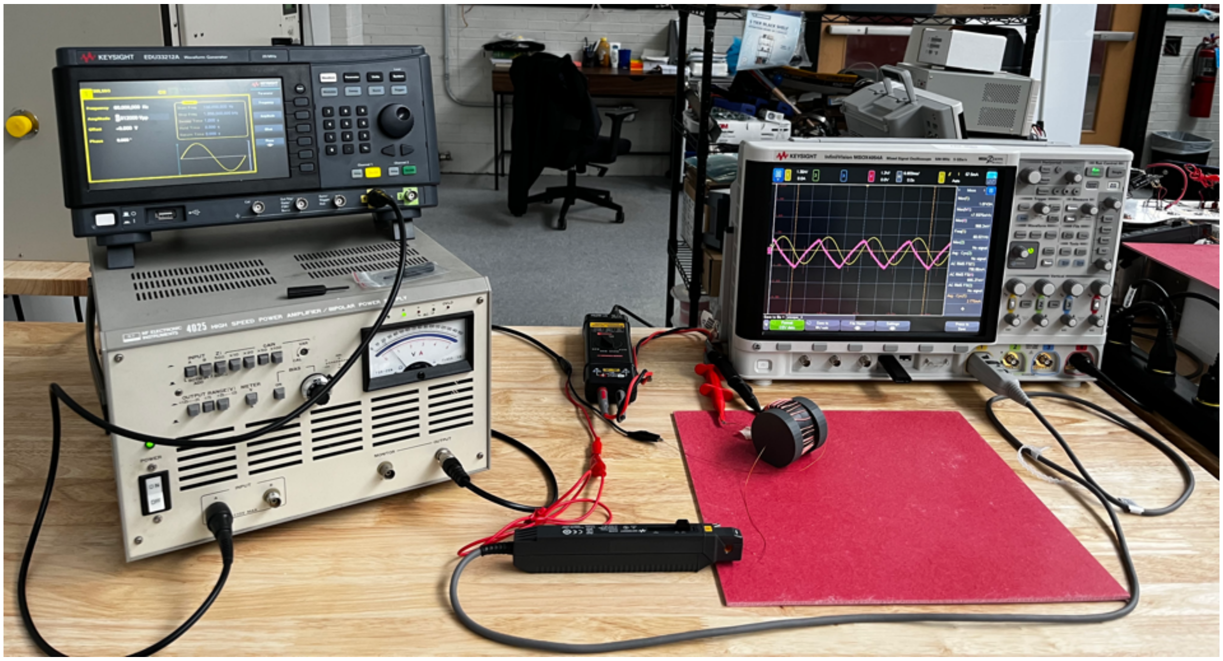
Sinusoidal Excitation Waveform and B-H Plot for Polarity: Finemet Current Transformer. Sinusoidal Signal. 12.00 mV_{pp} 60Hz, Amplifier Gain X50.

Setup.

DC Voltage. Configure the test equipment as shown below, with one figure showing the actual test setup for the Magnesil Core and one for the Finemet Core.



Polarity Testing – DC Voltage. Typical Test Setup: Finemet Current Transformer.



Polarity Testing – AC Voltage. Typical Test Setup: Finemet Current Transformer.

Section Two: Excitation and Remanence.
Electromagnetic Component Testing: Test Procedures and Results.

Purpose.
This test procedure is used to determine current transformer Excitation and Remanence points at design frequencies and with fixed current.

Test Equipment.
The test equipment shall be used as follows:

Lab Asset Number	Description	Manufacturer	Model Number	Serial Number
WAV0003	Arbitrary Waveform Generator	Keysight Technologies	EDU33212A	CN61310043
AMP0001	High Speed Power Amplifier	NF Electronic Instruments	4025	4025-112
OSC0003	Oscilloscope (500 MHz)	Keysight Technologies	MSOX4054A	MY61260112
PRO0002	Differential Probe	Rigol	RP1025D	2014187
PRO0005	AC / DC Current Probe	Keysight Technologies	1147B	JP61071359
MET0001	Digital Multimeter	Fluke	4025	4025-112
PS0004	GPD-Series Multi Output Programmable Linear D.C. Power Supply	GwInstek	GPD-43038	GE8916-315
LAB0001	Computer	AMPED	None	None

Test Procedures.

I. Excitation and Remanence Testing – Manual Procedure.

Per guidelines established from the IEEE C57.13-2016 and IEEE 61869-2 standards, below is the procedure for manual operation of equipment for the AC Voltage Setup, to be applied as follows. For a more detailed and general procedure to apply the test, refer to the referenced standard described here.

c. Turn on the measurement equipment and allow sufficient time for stabilization (e.g. 20 minutes).

d. Set the Arbitrary Waveform Generator to the following settings.
- Begin with a low signal.
  - Frequency. Set frequency at 60 Hz. IEEE C57.13-2016 states frequency as specific operating point.
  - Amplitude. Begin with an amplitude value, in terms of peak-to-peak (V_{PP}), at 10 milli. Increase where deemed appropriate to make sure a fully functioning signal is observed in an acceptable tolerance.
    - Specific Test Levels:
    - Around 7 Amps measured from current probe.

e. Set the Power Amplifier values.
  - Be sure to press input cable connected to on (usually A).
  - Press the desired gain. Performed in these tests at “X50”.

f. Set the Oscilloscope to the following settings.
   - Specify Probe Attenuation.
     - Measurements were performed with a Keysight 1147B Current Probe has a fixed attenuation ratio of 0.1 V/A and cannot be changed.
     - Voltage Probe from Rigol, the RP1025D, was used for measurements, and has fixed attenuation ratio of 200:1 after calibration. Probe with Asset Number PRO0002 was used to acquire data the waveform.
   - The data was captured with High Resolution Settings under Waveform-Acquire Menu.

g. Turn output of Arbitrary Waveform Generator on.

h. Level the output voltage at the offset adjust with flat head screw driver, if possible. Note if probe does not have that capability.
   - For data presented, Voltage probe with asset number PRO0002 does not have the capability.

i. Examine the Waveform on the Oscilloscope read from the Current Probe on the input side and the Differential Probe on the Output Side.
   - Be sure to capture 3 - 5 periods of the excitation signal being applied.

j. Auto zero and Degauss the Current Probe before step i. Also Degauss where Average Current Waveform value climbs above an acceptable tolerance of +/- 10 mA.

k. Record relevant data for Data Presentation.

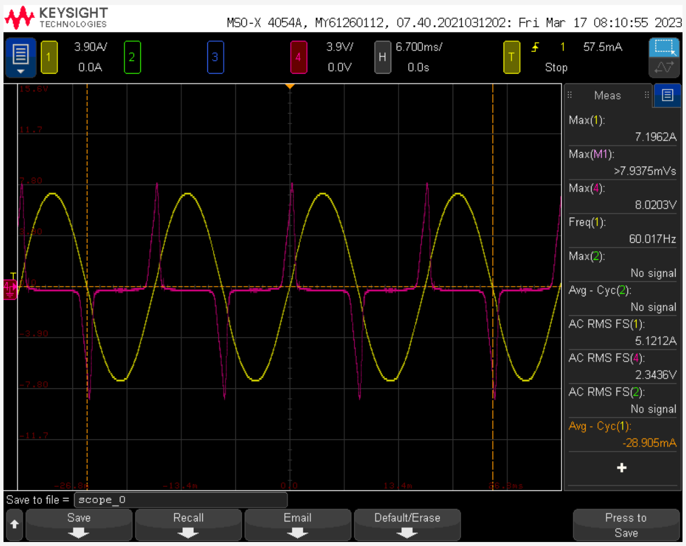
l. Turn off waveform generator upon completion.

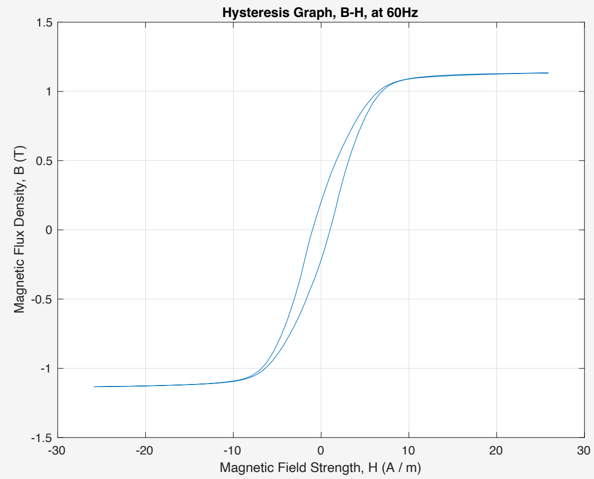
Data Presentation.

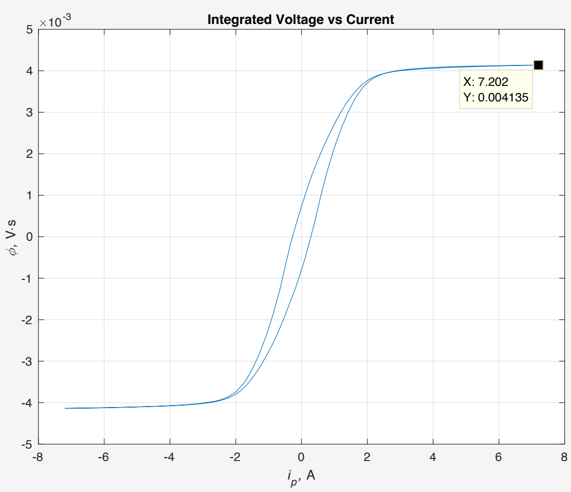
In this section, data is presented as each section indicates below.

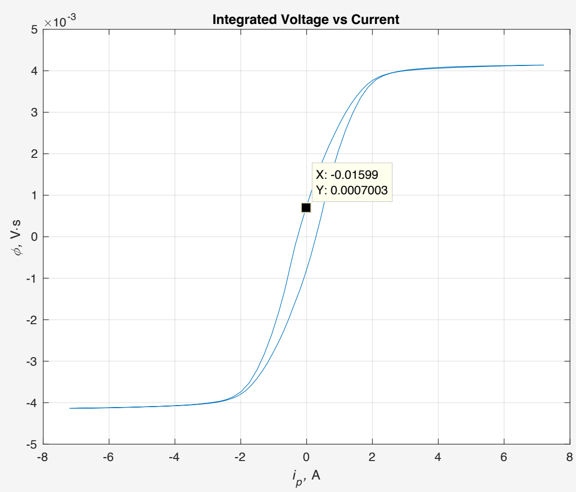
a. Sinusoidal Excitation.

Excitation Current, Losses, and Remanence Factor at 60 Hz.



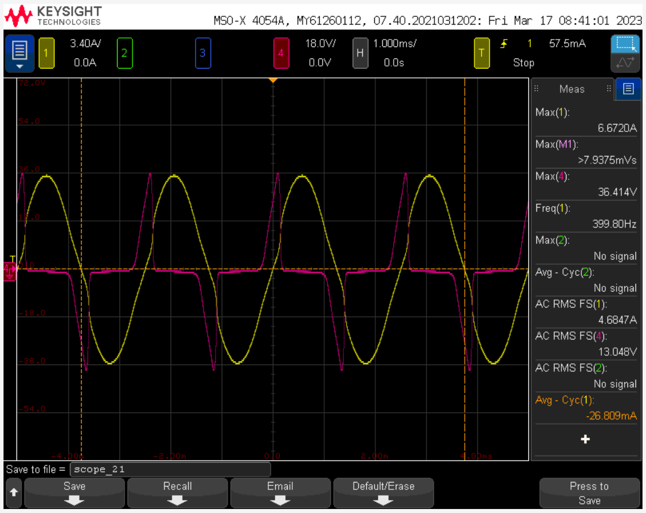


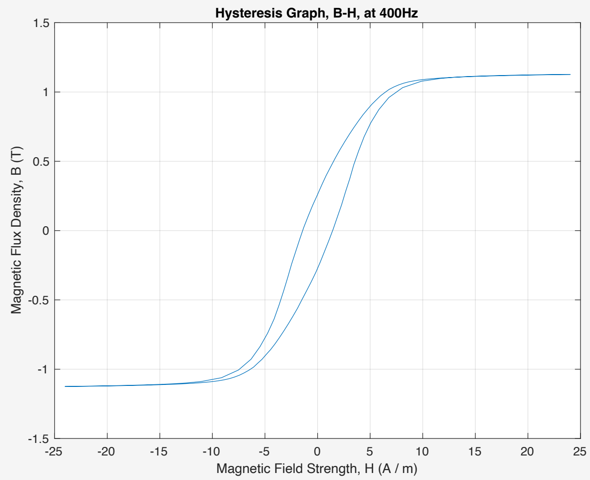


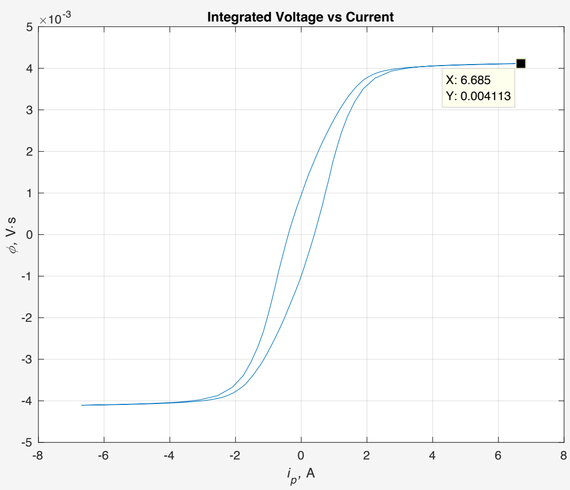


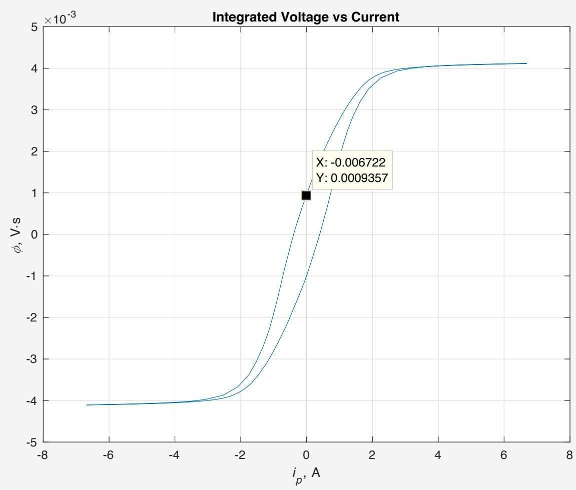
$K_R (= \phi_r / \phi_{sat})$	ϕ_r
0.1694	0.0007003
	ϕ_{sat}
	0.004135

Excitation Current, Losses, and Remanence Factor at 400 Hz.



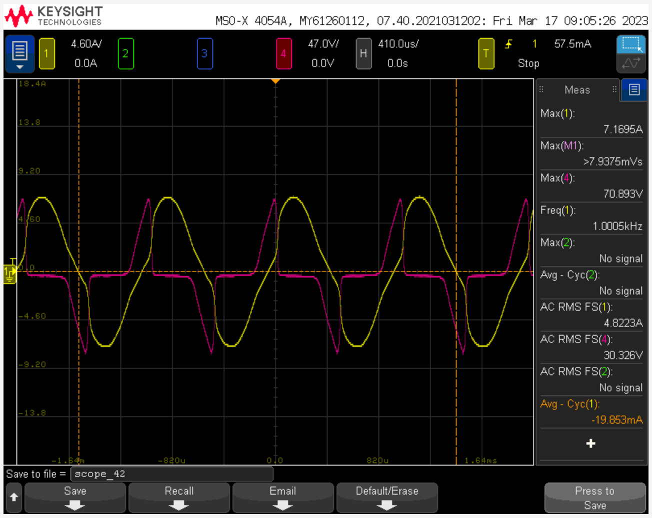


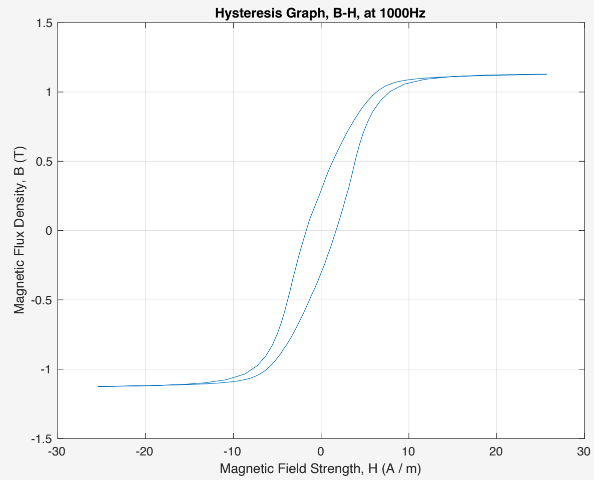


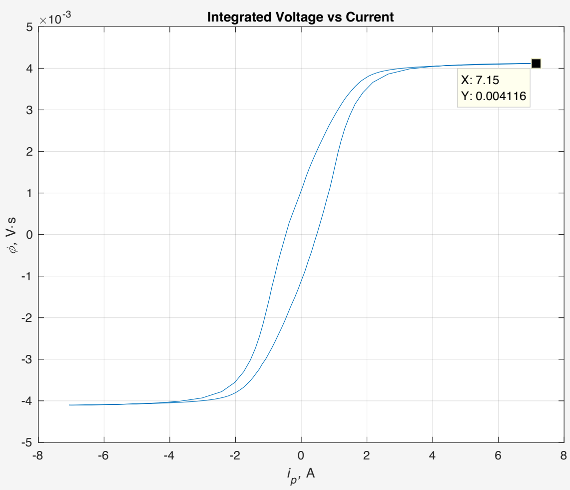


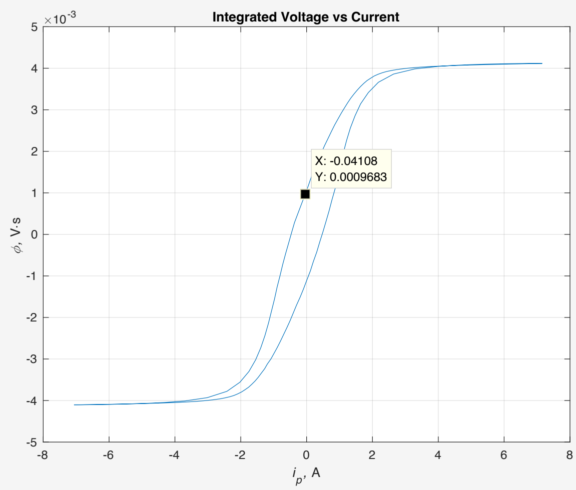
$K_R (=\phi_r/\phi_{sat})$	ϕ_r
0.2275	0.0009357
	ϕ_{sat}
	0.004113

Excitation Current, Losses, and Remanence Factor at 1000 Hz.



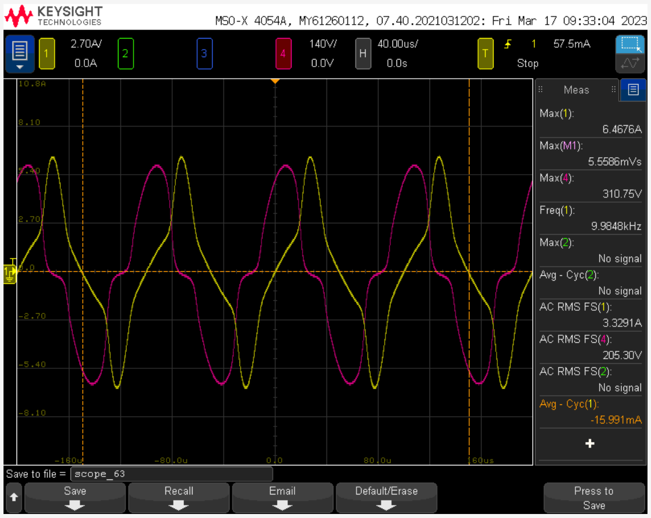


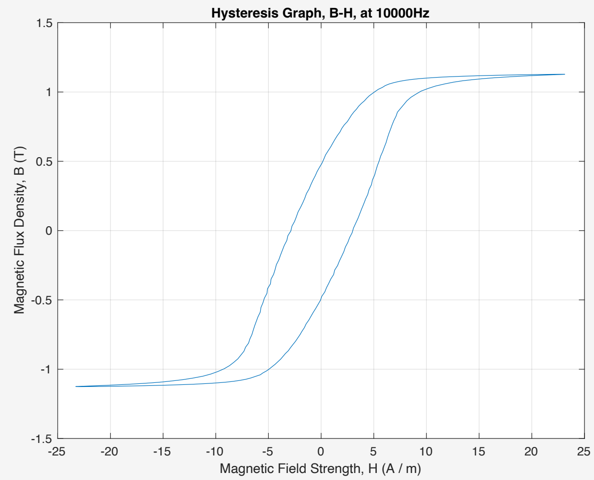


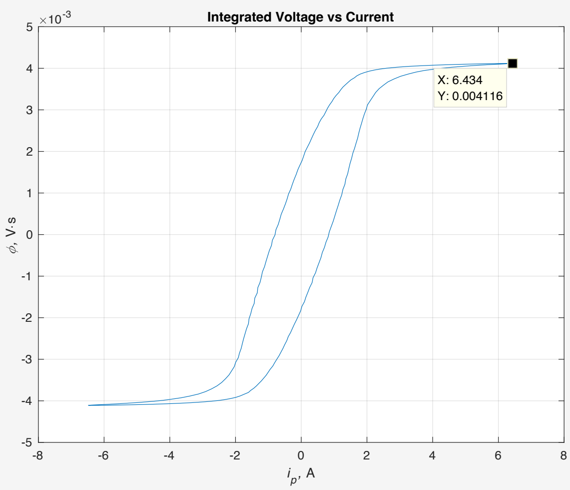


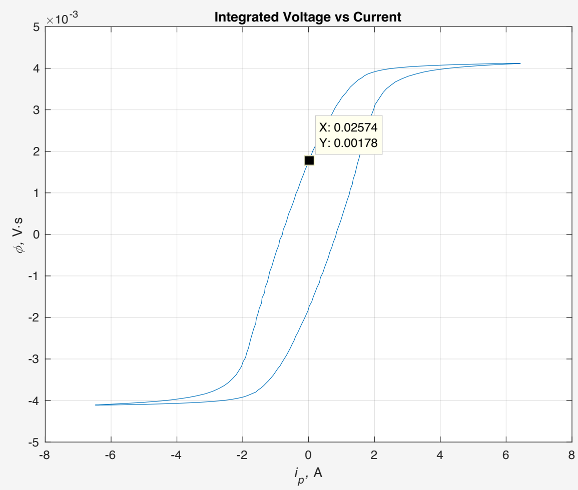
$K_R(=\phi_r/\phi_{sat})$	ϕ_r
0.2353	0.0009683
	ϕ_{sat}
	0.004116

Excitation Current, Losses, and Remanence Factor at 10000 Hz.





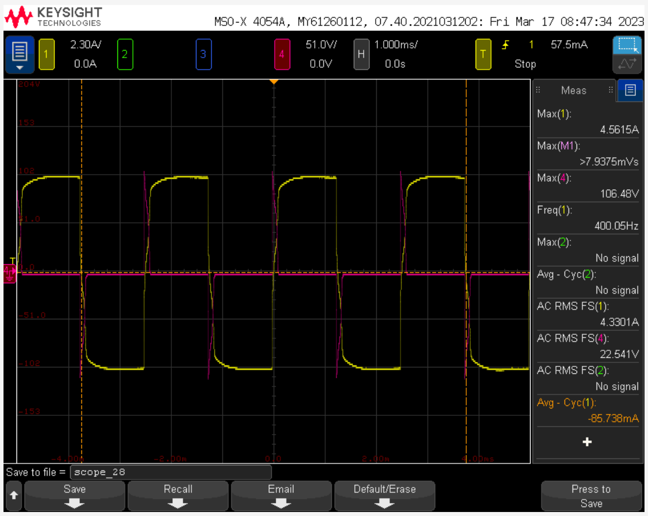


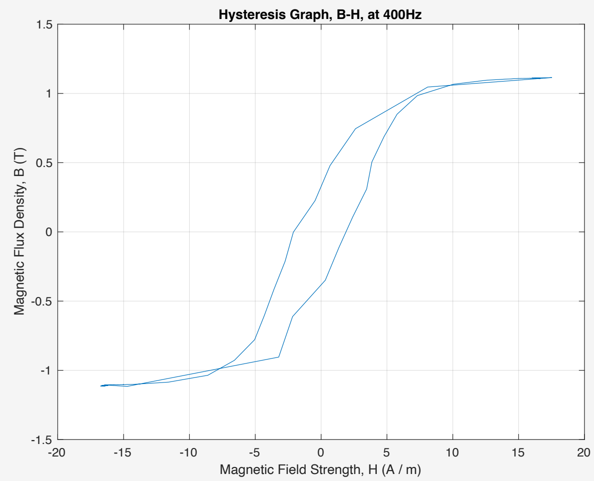


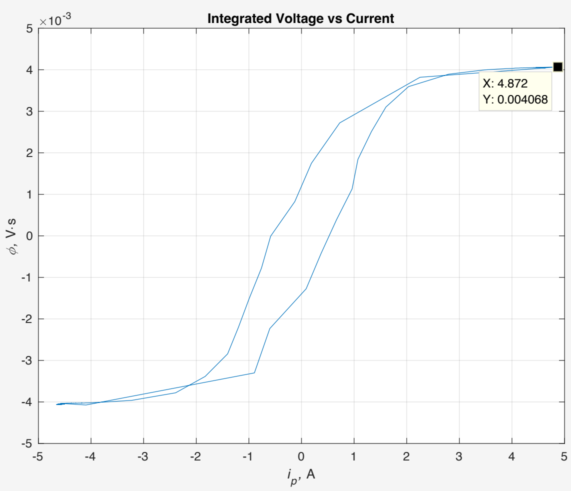
$K_R(=\phi_r/\phi_{sat})$	ϕ_r
0.4325	0.00178
	ϕ_{sat}
	0.004116

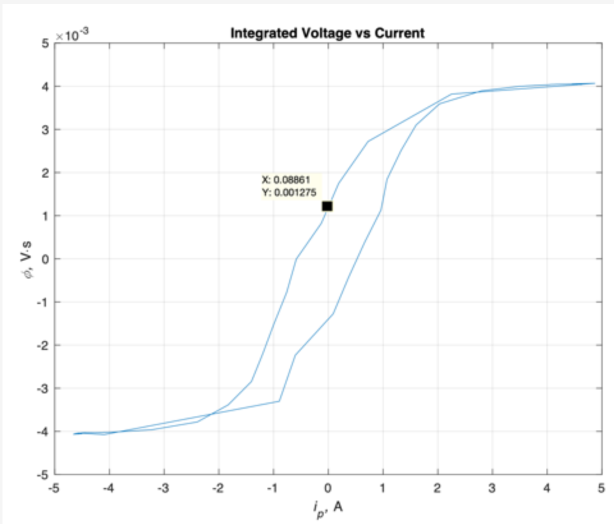
b. Square Excitation.

Excitation Current, Losses, and Remanence Factor at 400 Hz.



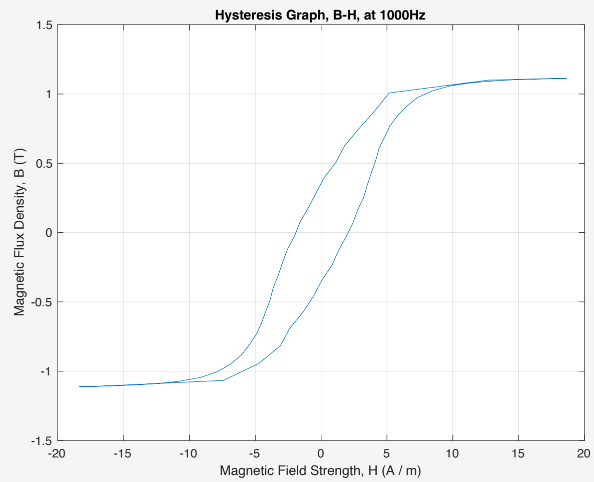


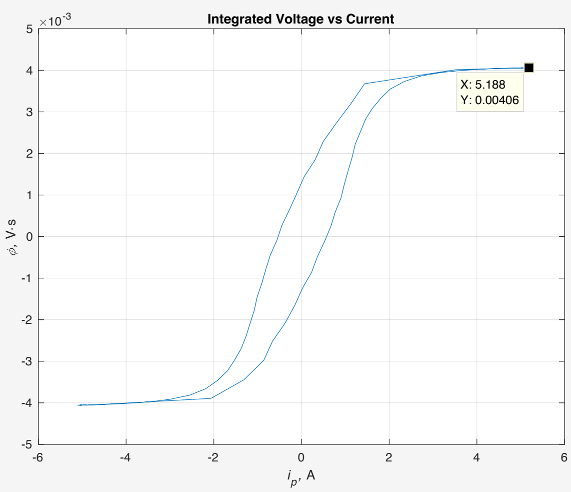


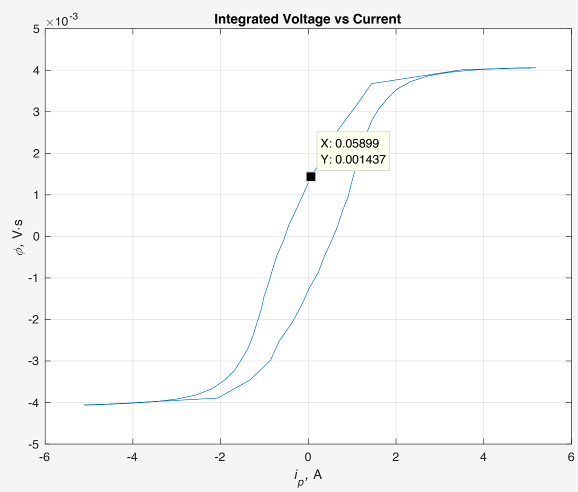


$K_R (=\phi_r/\phi_{sat})$	ϕ_r
0.31342	0.001275
	ϕ_{sat}
	0.004068

Excitation Current, Losses, and Remanence Factor at 1000 Hz.

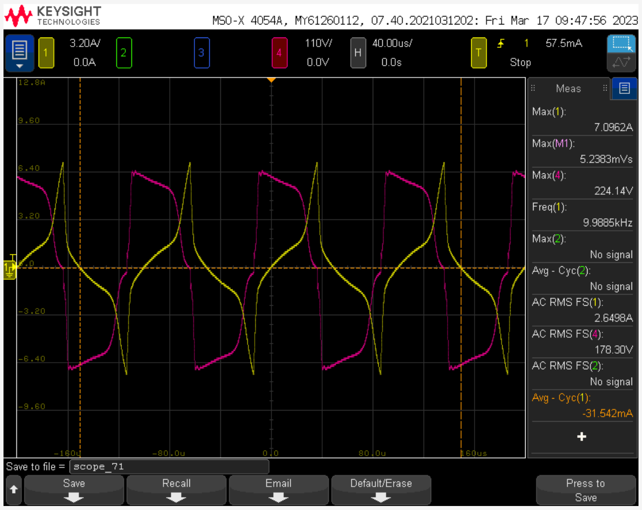


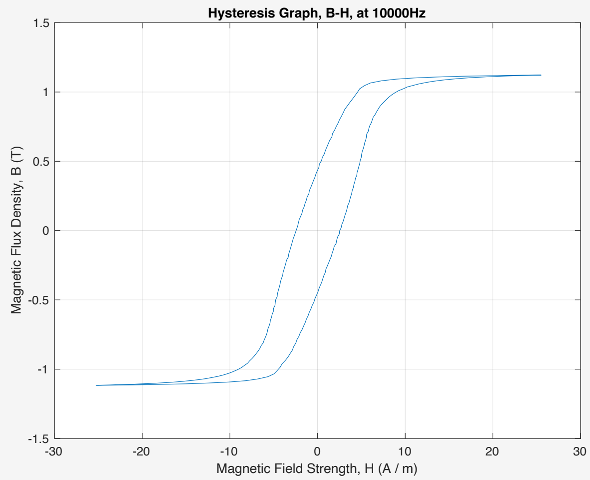


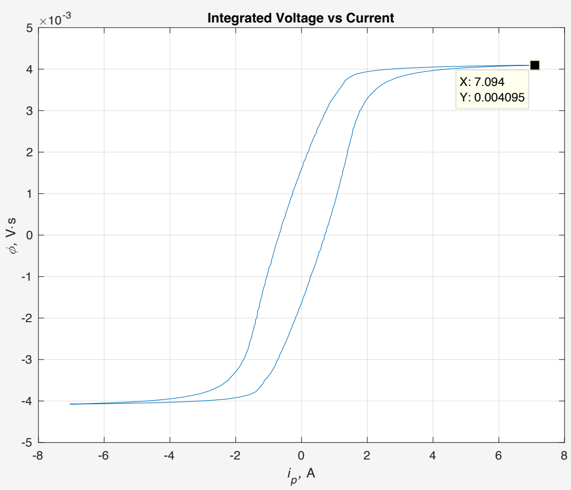


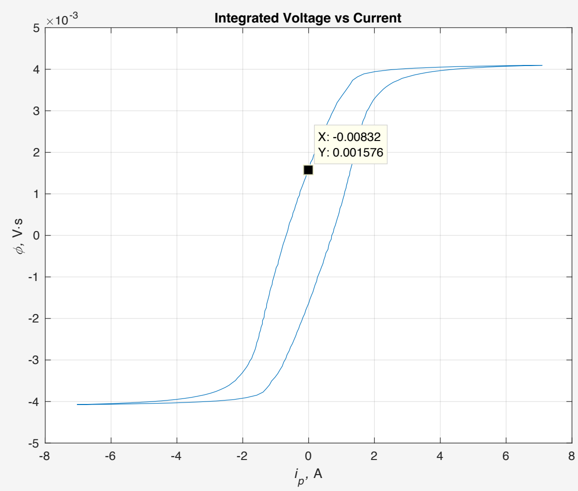
$K_R(=\phi_r/\phi_{sat})$	ϕ_r
0.3539	0.001437
	ϕ_{sat}
	0.00406

Excitation Current, Losses, and Remanence Factor at 10000 Hz.





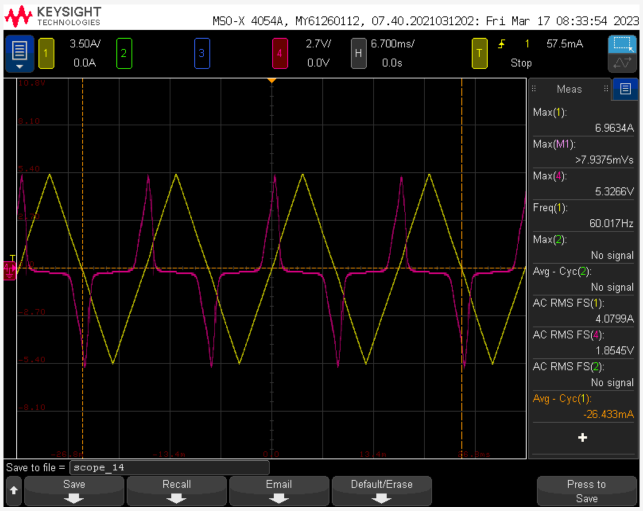


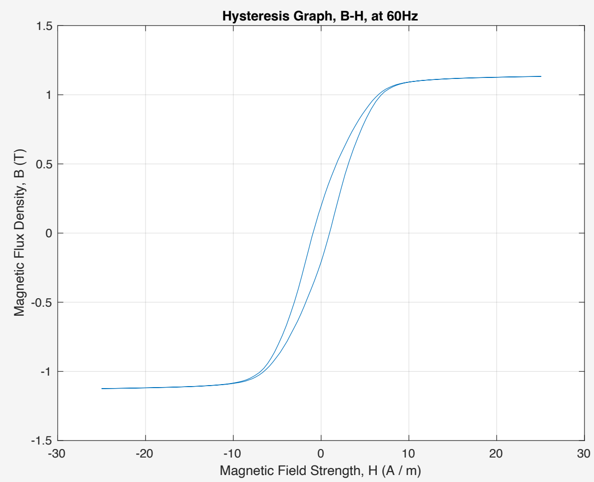


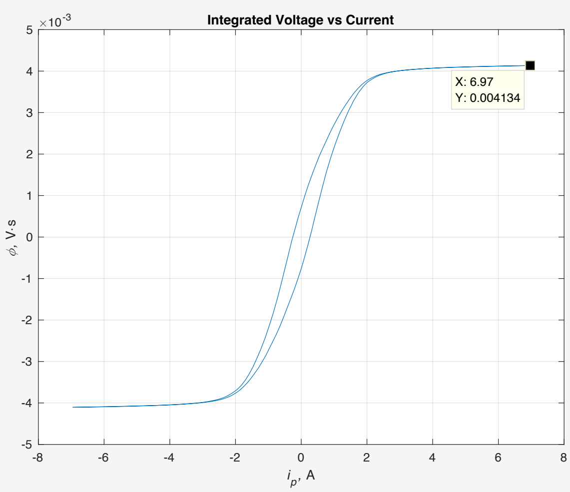
$K_R (=\phi_r/\phi_{sat})$	ϕ_r
0.3849	0.001576
	ϕ_{sat}
	0.004095

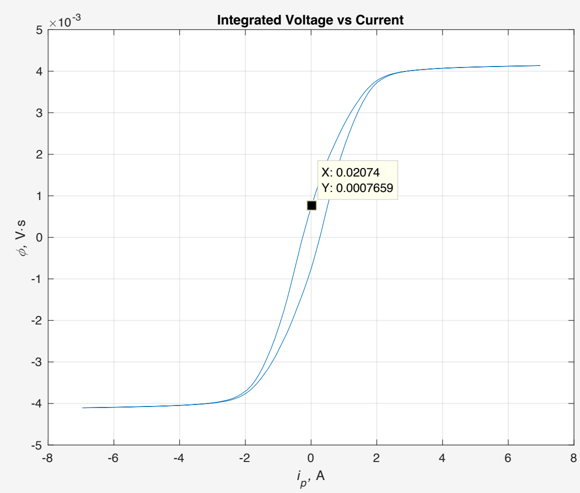
c. Triangular Excitation.

Excitation Current, Losses, and Remanence Factor at 60 Hz.



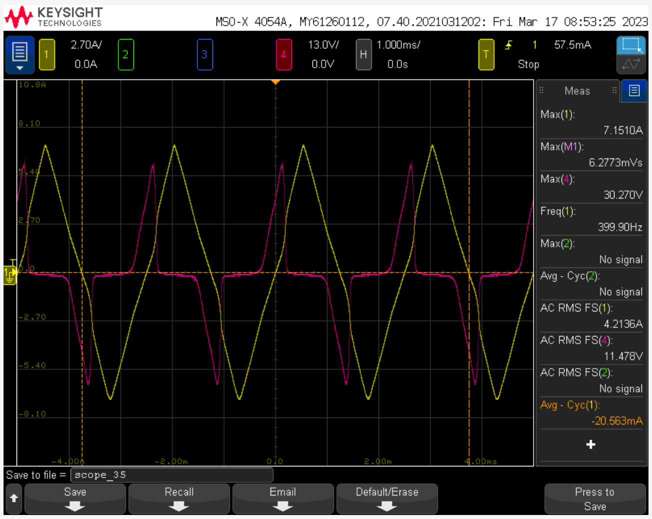


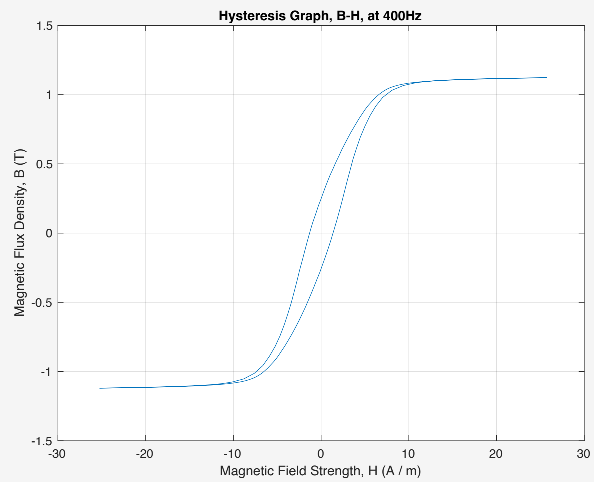


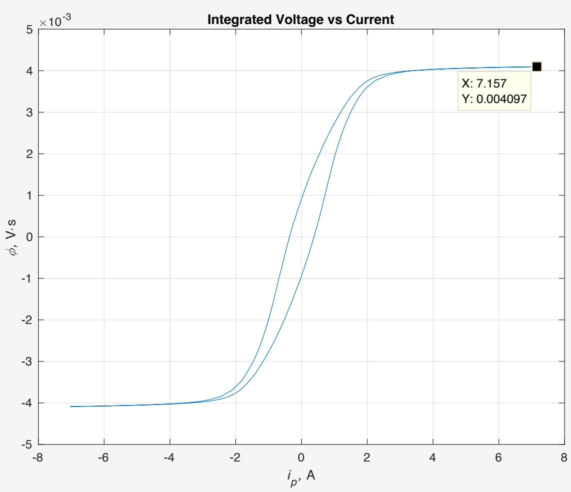


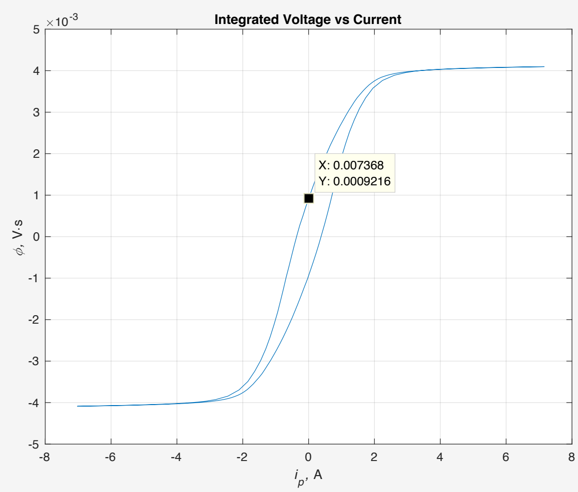
$K_R (= \phi_r / \phi_{sat})$	ϕ_r
0.1853	0.0007659
	ϕ_{sat}
	0.004134

Excitation Current, Losses, and Remanence Factor at 400 Hz.



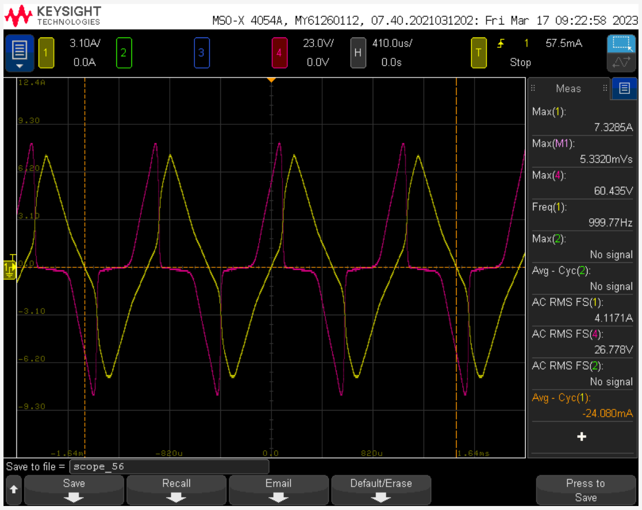


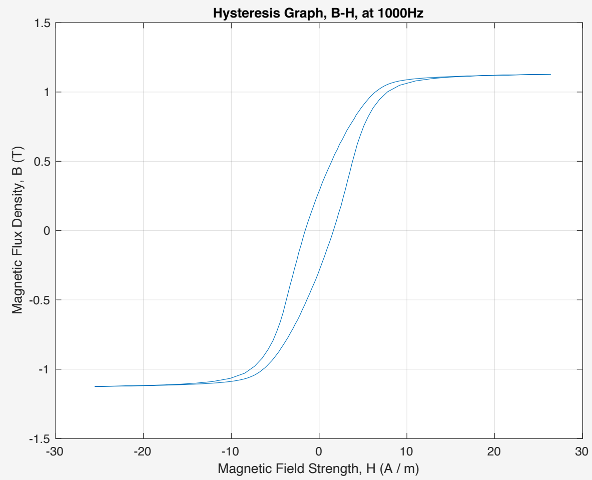


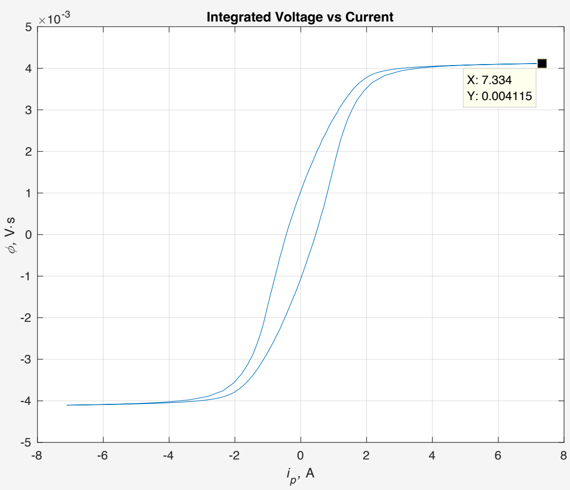


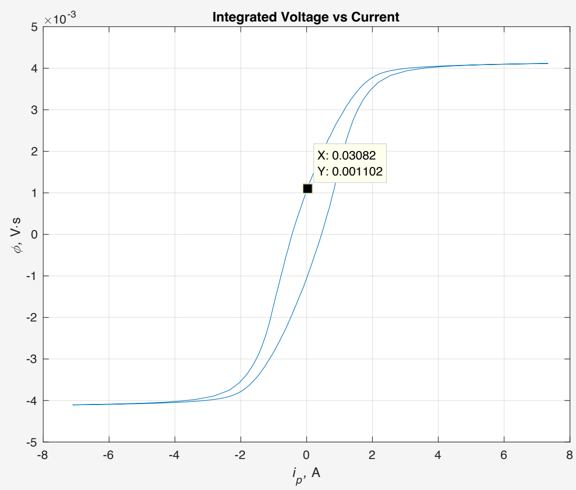
$K_R (=\phi_r/\phi_{sat})$	ϕ_r
0.2249	0.0009216
	ϕ_{sat}
	0.004097

Excitation Current, Losses, and Remanence Factor at 1000 Hz.



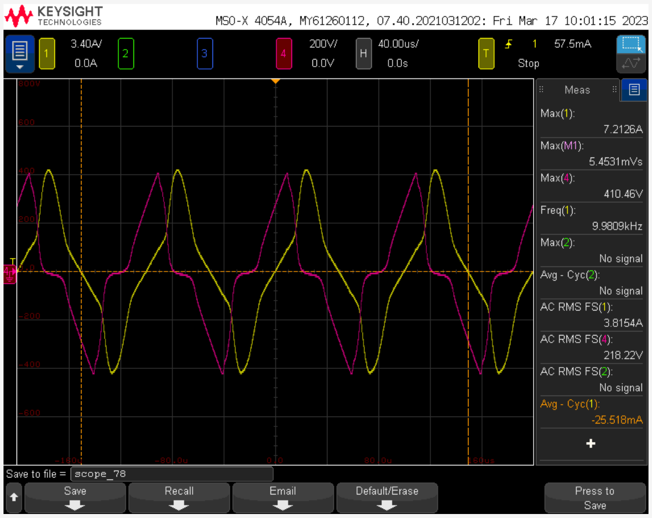


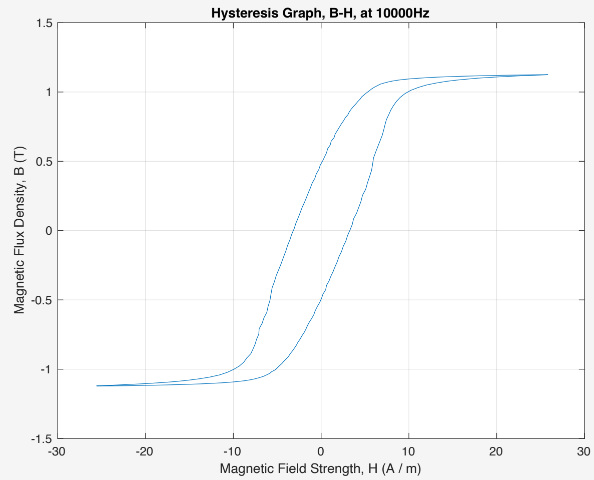


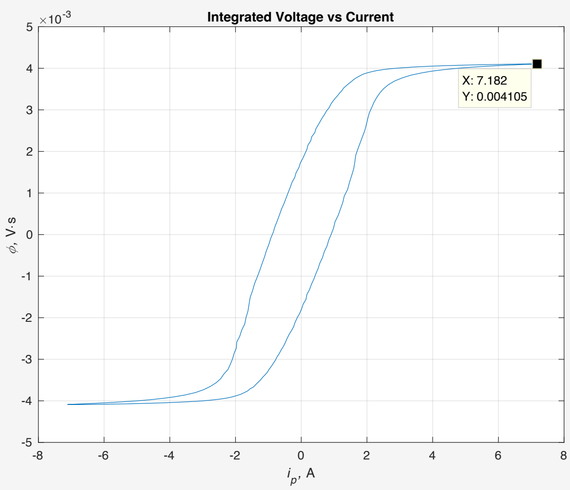


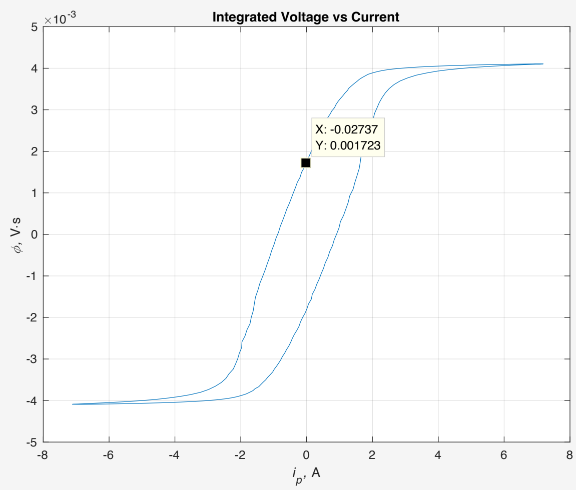
$K_R (=\phi_r/\phi_{sat})$	ϕ_r
0.2678	0.001102
	ϕ_{sat}
	0.004115

Excitation Current, Losses, and Remanence Factor at 10000 Hz.





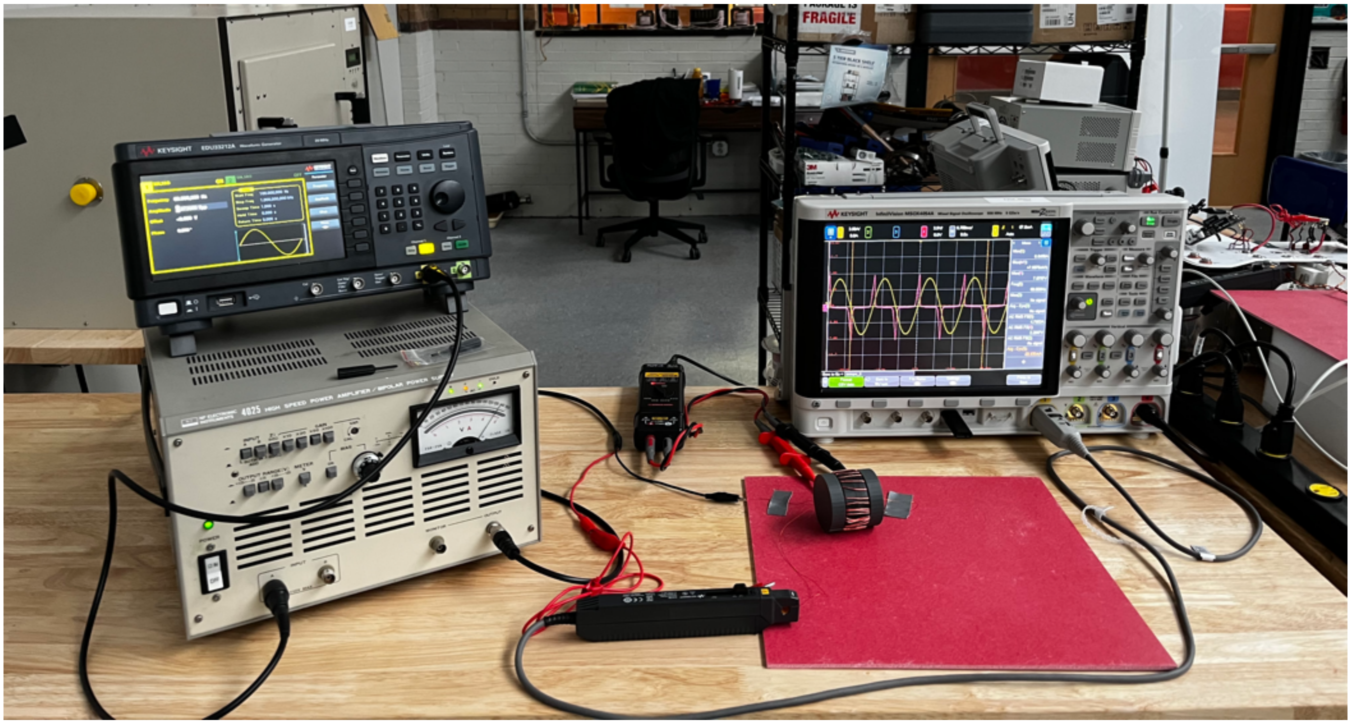




$K_R(=\phi_r/\phi_{sat})$	ϕ_r
0.4197	0.001723
	ϕ_{sat}
	0.004105

Setup.

DC Voltage. Configure the test equipment as shown below, with one figure showing the actual test setup for the Magnesil Core and one for the Finemet Core.



Polarity Testing – DC Voltage. Typical Test Setup: Finemet Current Transformer.

Section Three: Ratio and Phase Angle.
Electromagnetic Component Testing: Test Procedures and Results.

Purpose.
This test procedure is used to determine current transformer ratio and phase angle with points at design frequencies and with fixed current.

Test Equipment.
The test equipment shall be used as follows:

Lab Asset Number	Description	Manufacturer	Model Number	Serial Number
WAV0003	Arbitrary Waveform Generator	Keysight Technologies	EDU33212A	CN61310043
AMP0001	High Speed Power Amplifier	NF Electronic Instruments	4025	4025-112
OSC0003	Oscilloscope (500 MHz)	Keysight Technologies	MSOX4054A	MY61260112
PRO0003	10:1 200 MHz Differential Probe	Keysight Technologies	N2792A	PH61260009
PRO0005	AC / DC Current Probe	Keysight Technologies	1147B	JP61071359
MET0001	Digital Multimeter	Fluke	4025	4025-112
CAP0003	0.01 uF Capacitor	Cornell Dubilier Electronics (CDE)	SCRN244R-F	None
RES0001	5 Ohm Resistor	Riedon	UB15-5RF1	None
LAB0001	Computer	AMPED	None	None

Test Procedures.

I. Ratio and Phase Angle Testing – Manual Procedure.

Per guidelines established from the IEEE C57.13-2016 standard, below is the procedure for manual operation of equipment for the ratio and phase angle setup, to be applied as follows. For a more detailed and general procedure to apply the test, refer to the referenced standard described here.

m. Turn on the measurement equipment and allow sufficient time for stabilization (e.g. 20 minutes).
n. Set the Arbitrary Waveform Generator to the following settings.
   - Begin with a low signal.
     - Frequency. Set frequency at 60 Hz. IEEE C57.13-2016 states frequency as specific operating point.
     - Amplitude. Begin with an amplitude value, in terms of peak-to-peak (V_{PP}), at 10 milli. Increase where deemed appropriate to make sure a fully functioning signal is observed in an acceptable tolerance.
       - Specific Test Levels:
       - Around 5 Amps measured from current probe.
o. Set the Power Amplifier values.
   - Be sure to press input cable connected to on (usually A).
   - Press the desired gain. Performed in these tests at "X50".
p. Set the Oscilloscope to the following settings.

- Specify Probe Attenuation.
    - Measurements were performed with a Keysight 1147B Current Probe has a fixed attenuation ratio of 0.1 V/A and cannot be changed.
    - Voltage Probe from Keysight, the N2792, was used for measurements, and has fixed attenuation ratio of 5:1 after calibration with oscilloscope. Probe with Asset Number PRO0003 was used to acquire the data (60 Hz – 10 kHz).
- The data was captured with High Resolution Settings under Waveform-Acquire Menu.

q. Turn output of Arbitrary Waveform Generator on.
r. Level the output voltage at the offset adjust with flat head screw driver, if possible. Note if probe does not have that capability.
s. Examine the Waveform on the Oscilloscope read from the Current Probe on the input side and the Differential Probe on the Output Side.
    - Be sure to capture 3 - 5 periods of the excitation signal being applied.
t. Auto zero and Degauss the Current Probe before step i. Also Degauss where Average Current Waveform value climbs above an acceptable tolerance of +/- 10 mA.
u. Setup included correction components for DC Biasing part of the setup. See the test setup section for a diagram. Note a 5 Ohm Resistor was in parallel with one 0.01 uF Capacitor.
v. Record relevant data for Data Presentation.
w. Turn off waveform generator upon completion.

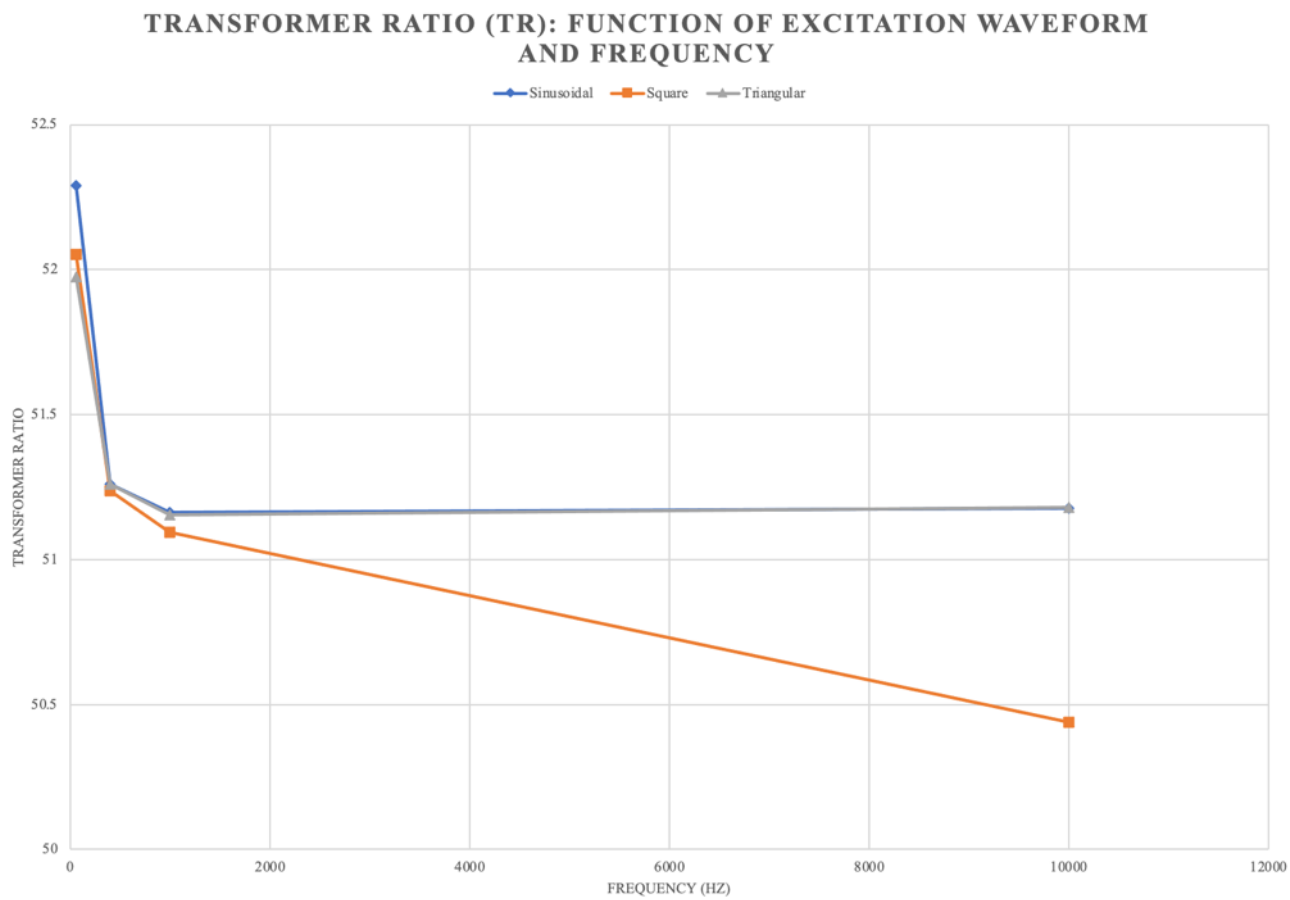
AMPED

Revision: A

Data Presentation.

In this section, data is presented as each section indicates below.

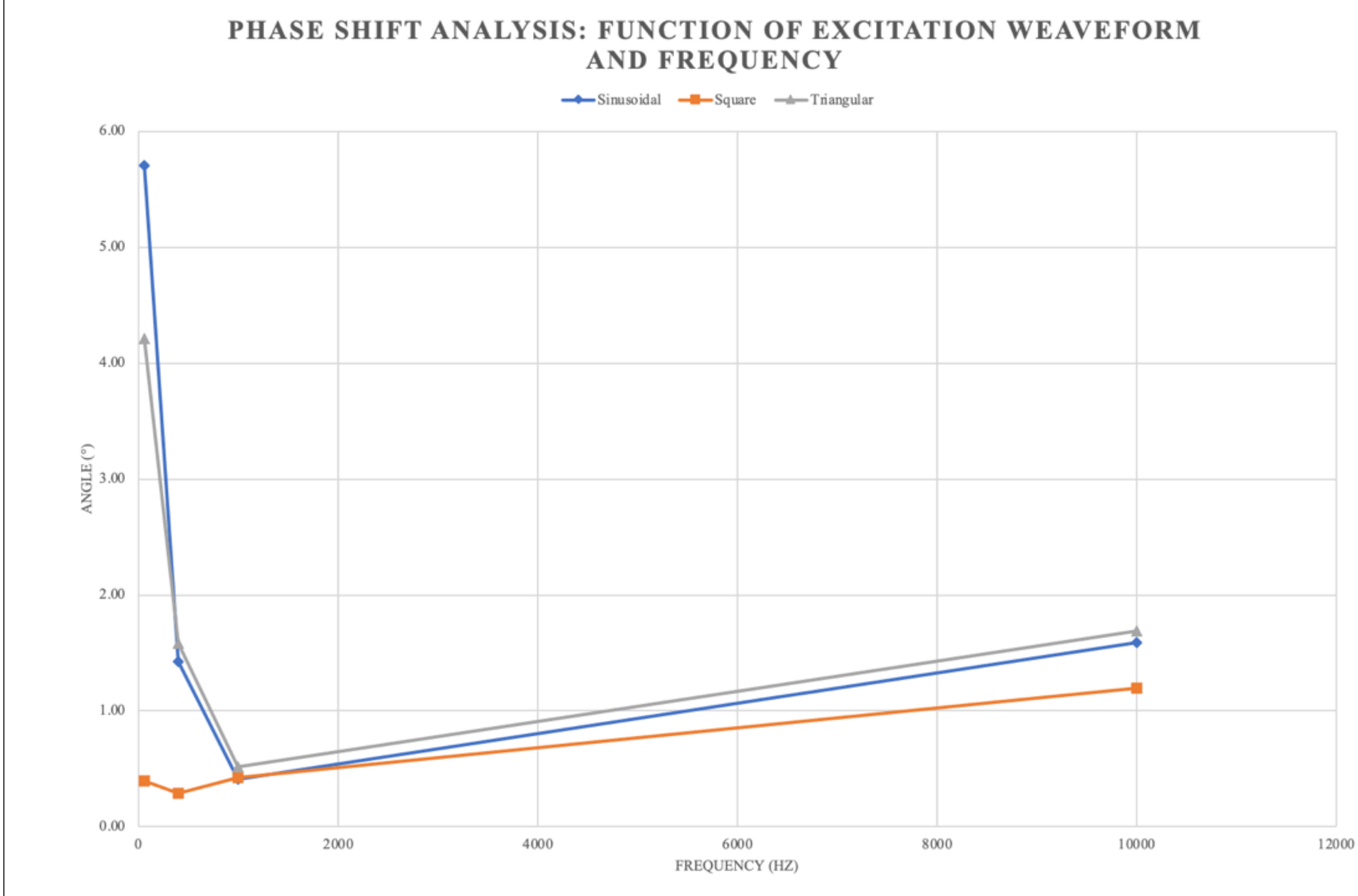
a. Transformer Ratio.



Transformer Ratio - as function of Waveform Class and Frequency.

Excitation Signal	Frequency	Primary Current i_p (RMS)	Secondary Voltage V_s (RMS)	Burden Resistance	Secondary Current i_s (RMS)	Transformer Ratio (i_p/ i_s)
Sinusoidal	60	3.5766	0.35567	5.2	0.06839808	52.2909439
	400	3.5831	0.36348	5.2	0.0699	51.260372
	1000	3.6129	0.36721	5.2	0.07061731	51.1616786
	10000	3.5104	0.35668	5.2	0.06859231	51.1777504
Square	60	3.9362	0.39322	5.2	0.07561923	52.0528966
	400	3.9542	0.40131	5.2	0.077175	51.2367995
	1000	3.9349	0.40047	5.2	0.07701346	51.0936649
	10000	3.8167	0.39349	5.2	0.07567115	50.4379781
Triangular	60	2.9328	0.29342	5.2	0.05642692	51.9751891
	400	2.9436	0.29861	5.2	0.057425	51.2599042
	1000	3.0231	0.30731	5.2	0.05909808	51.1539488
	10000	2.879	0.29251	5.2	0.05625192	51.1804725

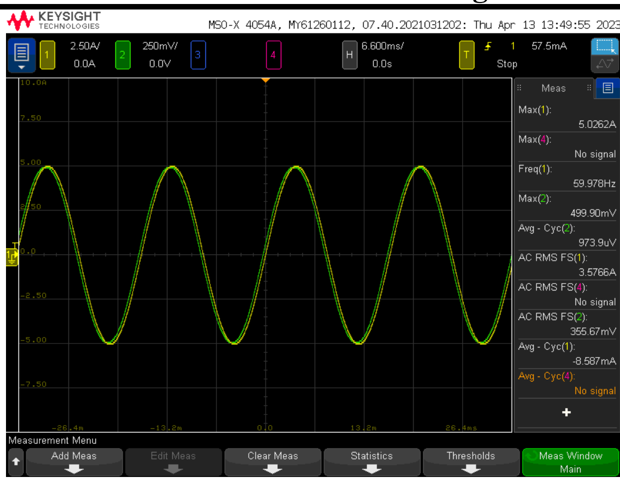
b. Phase Angle.

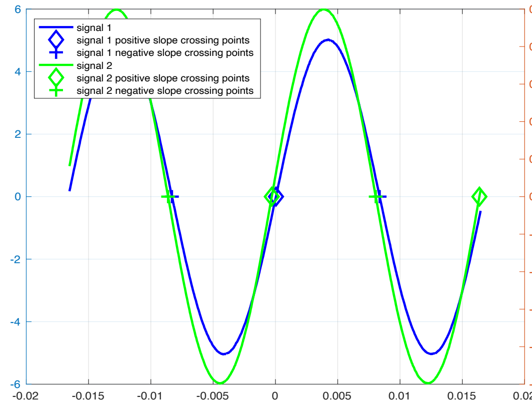


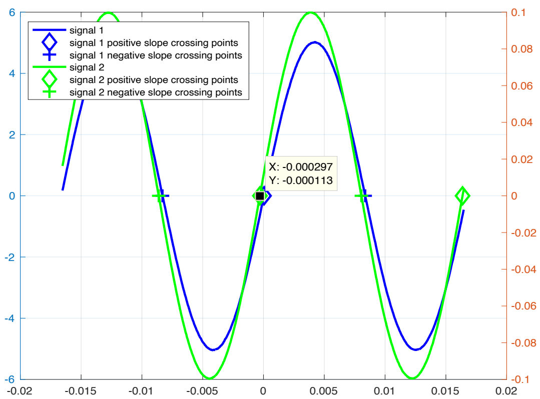
Phase Angle - as function of Waveform Class and Frequency.

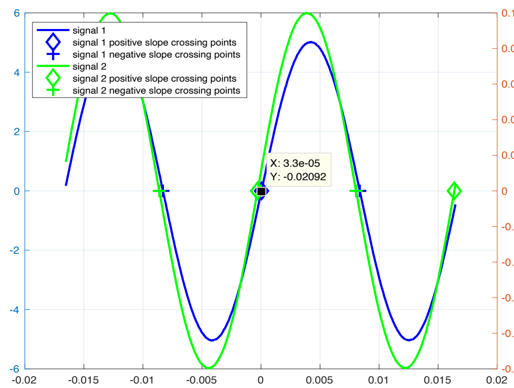
Excitation Signal	Frequency (Hz)	Phase Angle (°)
Sinusoidal	60	5.70
	400	1.43
	1000	0.41
	10000	1.59
Square	60	0.39
	400	0.29
	1000	0.42
	10000	1.20
Triangular	60	4.21
	400	1.58
	1000	0.52
	10000	1.69

Phase Angle at 60 Hz: Sinusoidal Excitation.



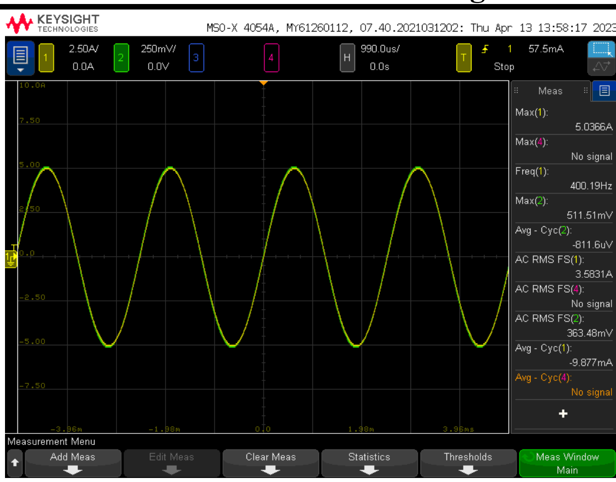


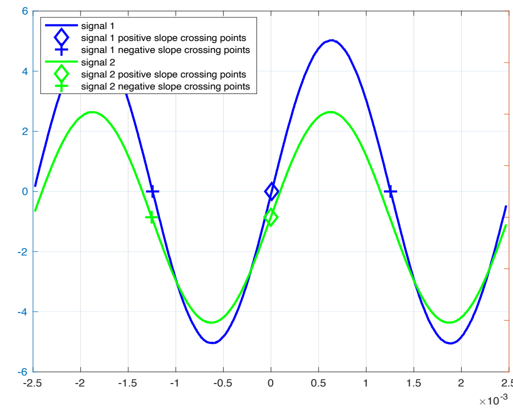


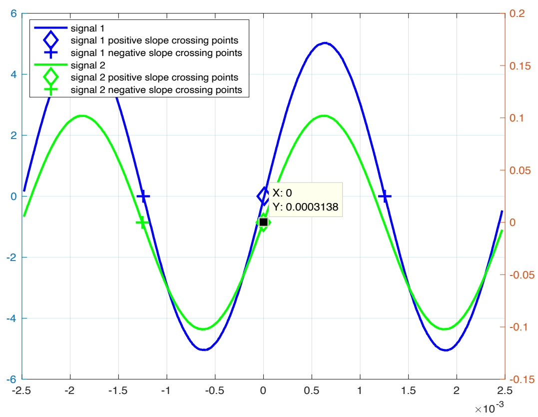


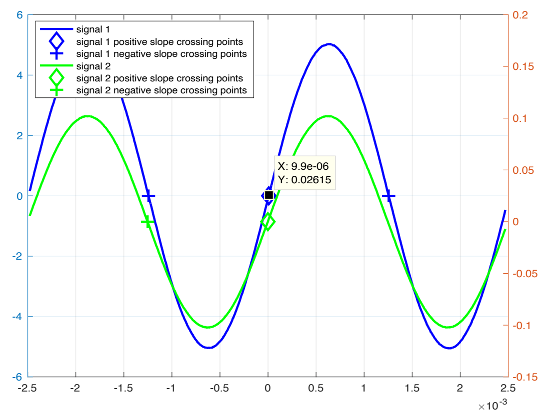
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
5.70	0.000033	0.000264	60
	t_2	T (1/f)	
	0.000297	0.016666667	

Phase Angle at 400 Hz: Sinusoidal Excitation.









<table>
<tr><th>Φ_S(=Δt/T)°</th><th>t_1</th><th>Δt (t_2-t_1)</th><th>f</th></tr>
<tr><td rowspan="3">1.43</td><td>0</td><td>0.0000099</td><td rowspan="3">400</td></tr>
<tr><td>t_2</td><td>T (1/f)</td></tr>
<tr><td>0.0000099</td><td>0.0025</td></tr>
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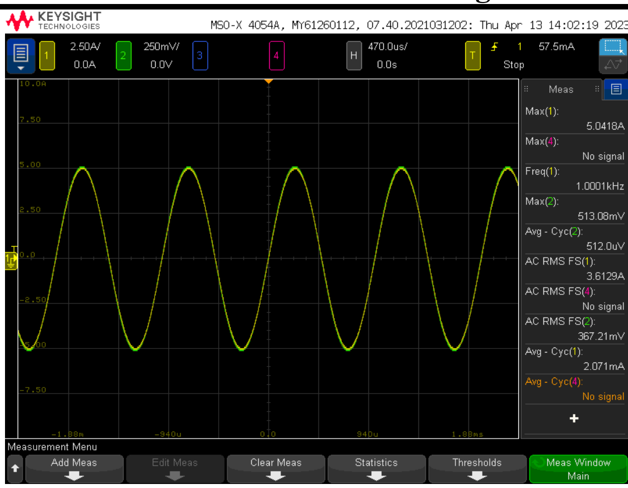
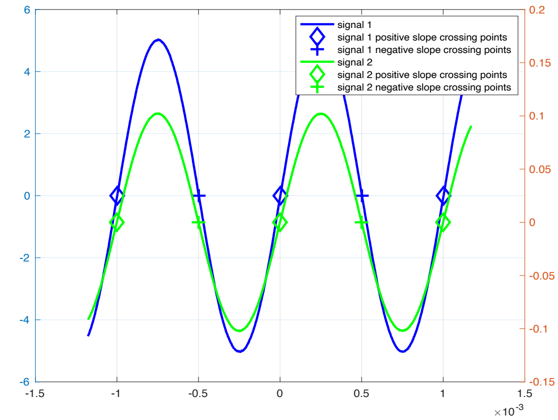
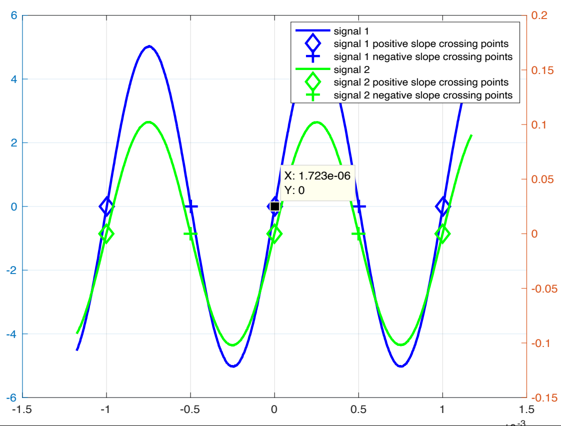
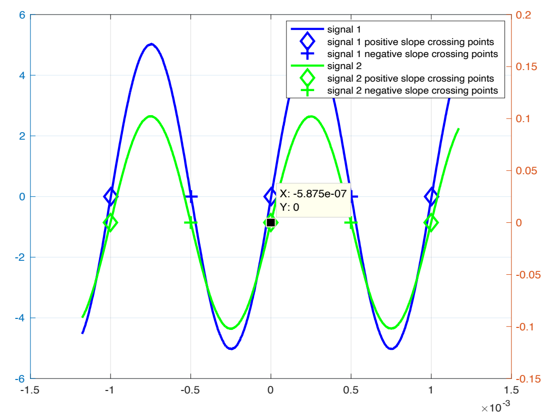
Phase Angle at 1 kHz: Sinusoidal Excitation.



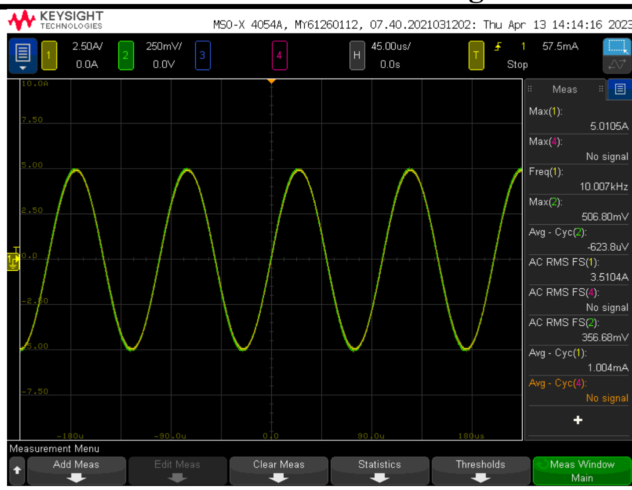


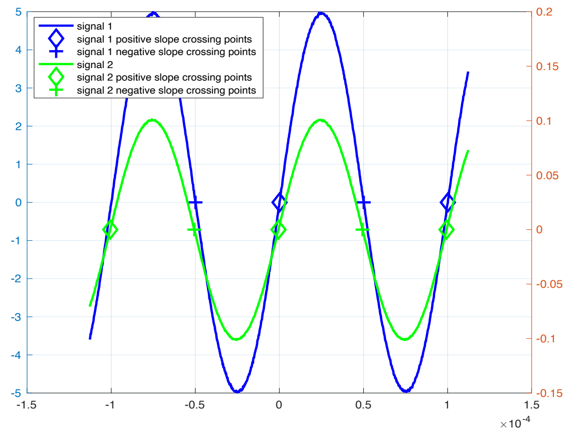


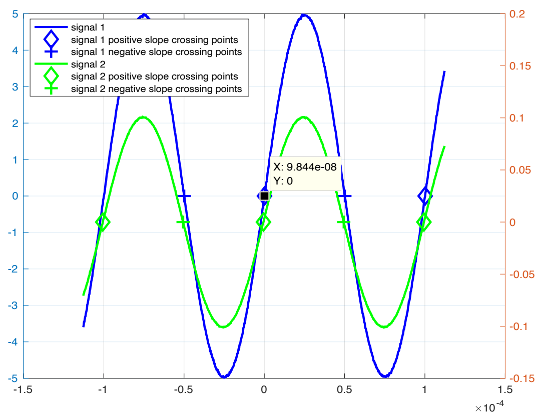


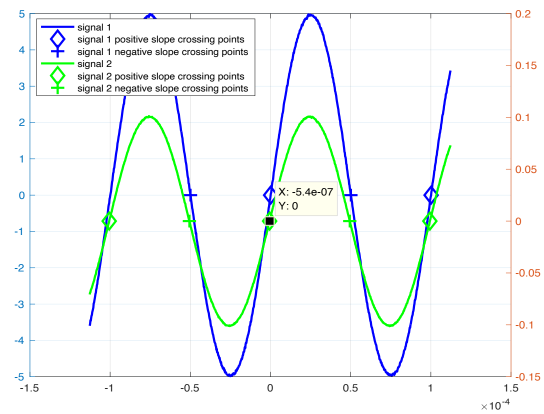
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
0.41	5.875E-07	1.1355E-06	1000
	t_2	T (1/f)	
	0.000001723	0.001	

Phase Angle at 10 kHz: Sinusoidal Excitation.



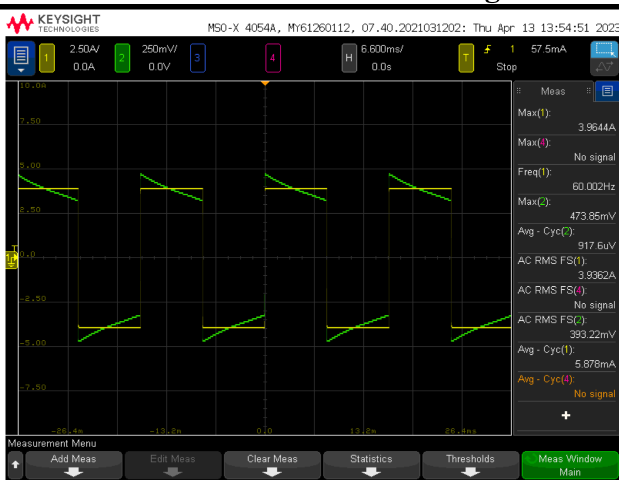


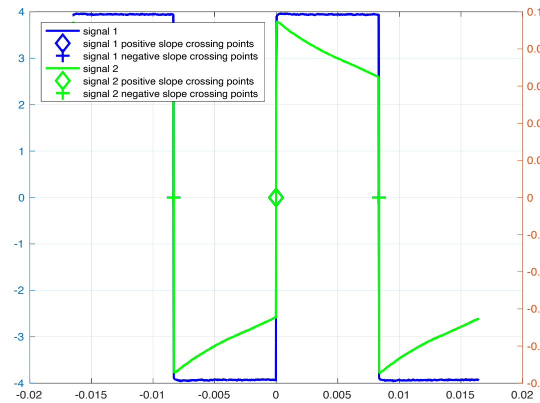


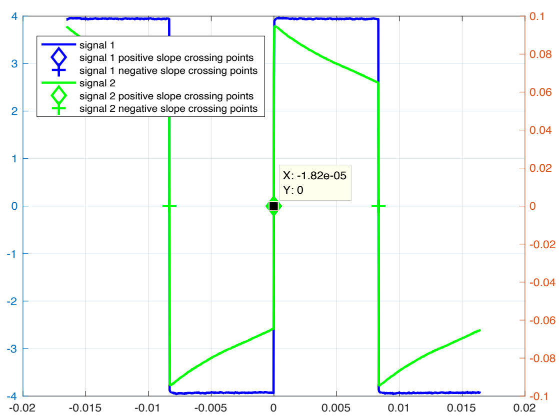


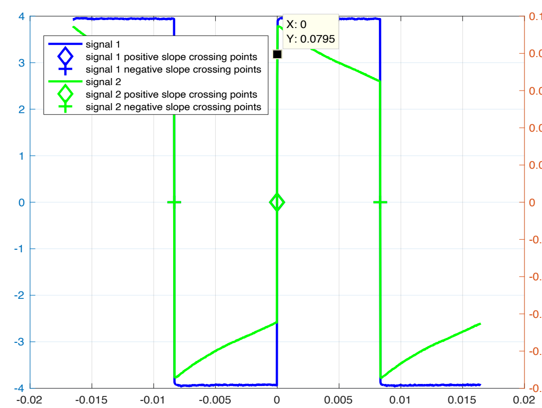
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
1.59	9.844E-08	4.4156E-07	10000
	t_2	T (1/f)	
	0.00000054	0.0001	

Phase Angle at 60 Hz: Square Excitation.



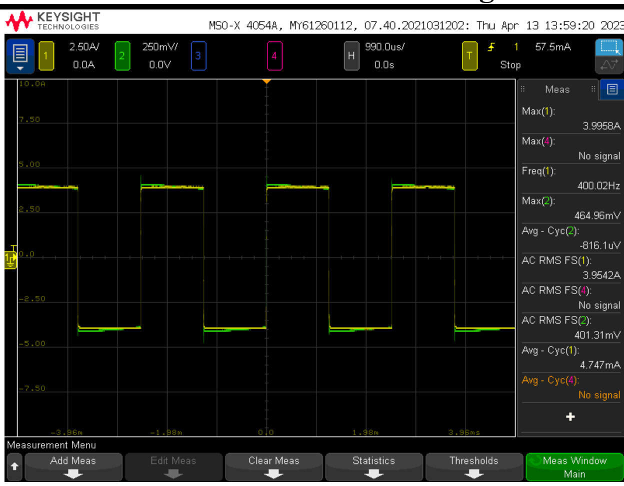


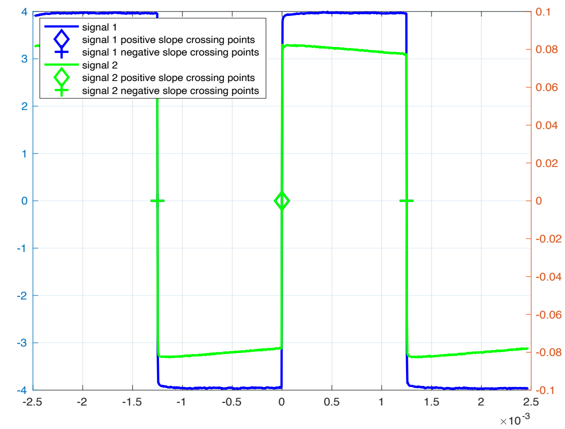


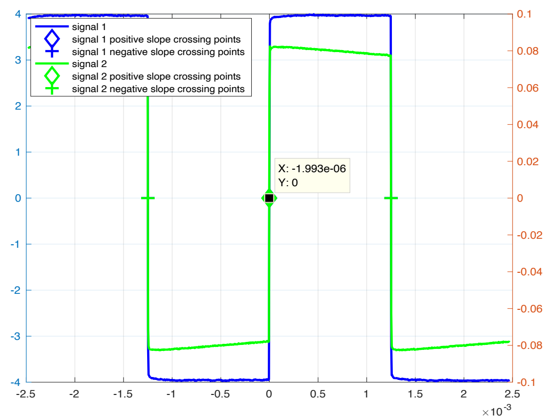


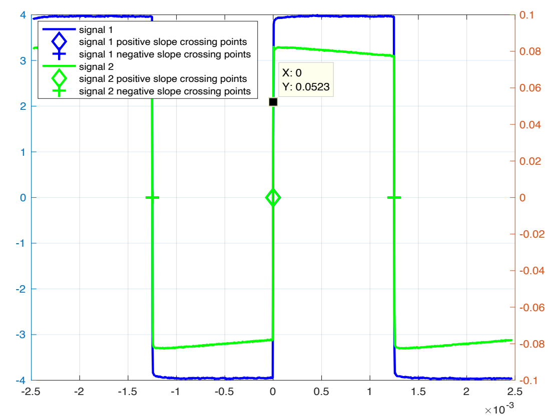
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
0.39	0	0.0000182	60
	t_2	T (1/f)	
	0.0000182	0.016666667	

Phase Angle at 400 Hz: Square Excitation.



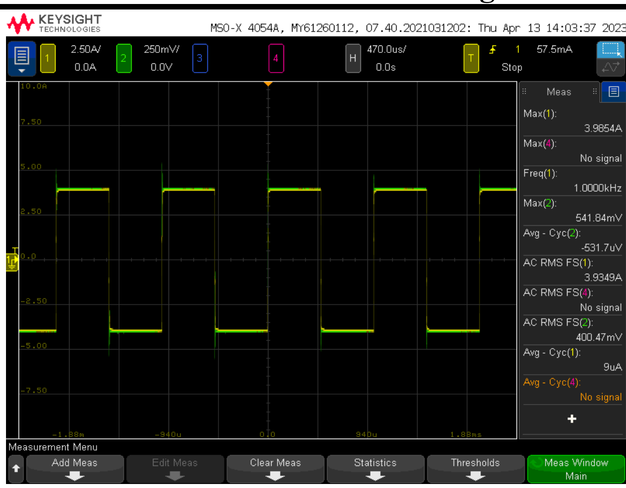


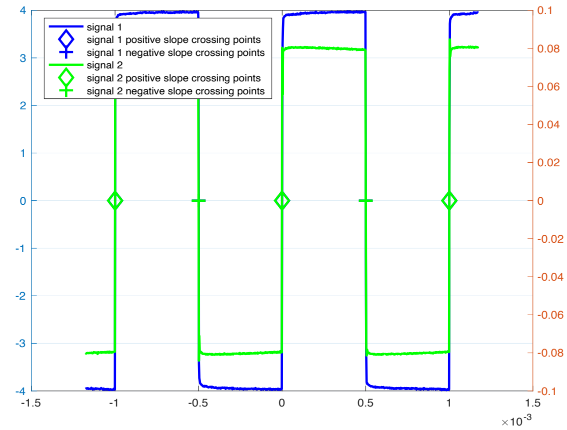


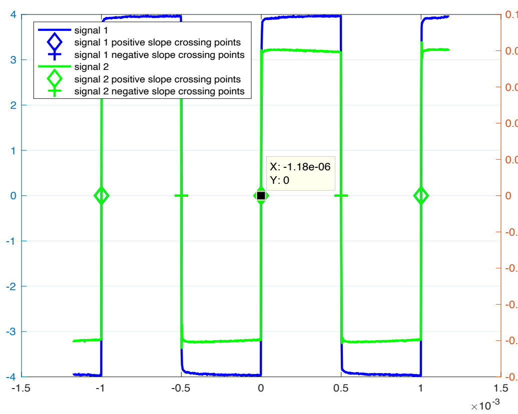


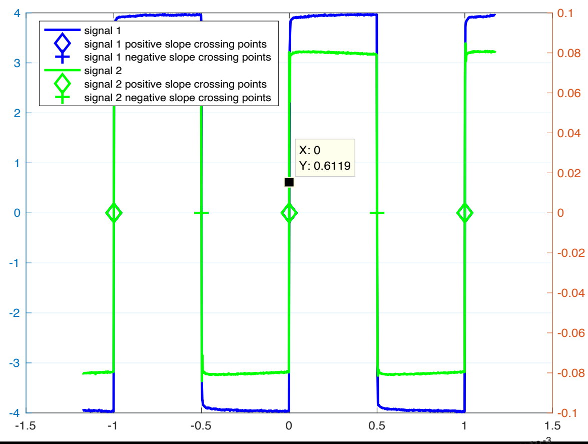
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
0.29	0	0.000001993	400
	t_2	T (1/f)	
	0.000001993	0.0025	

Phase Angle at 1 kHz: Square Excitation.



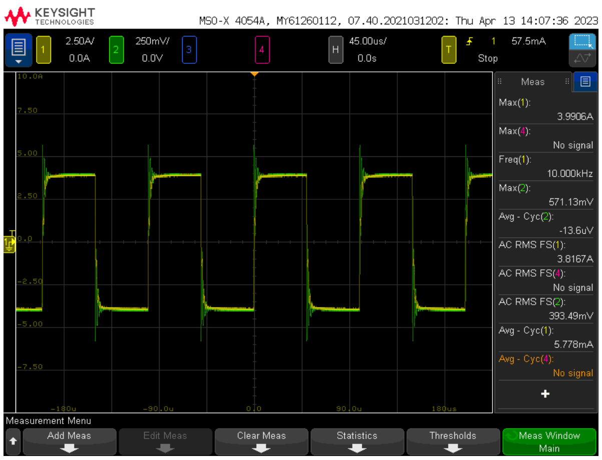


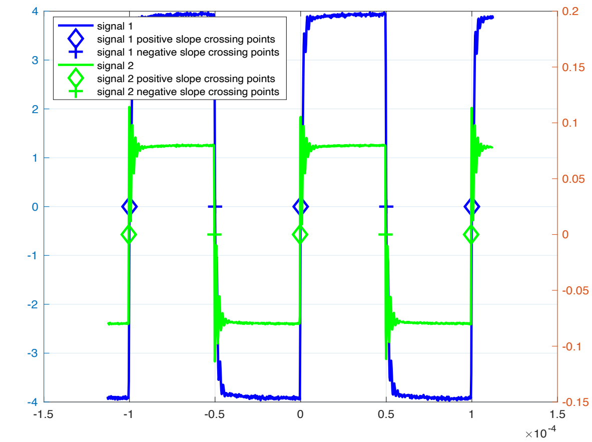


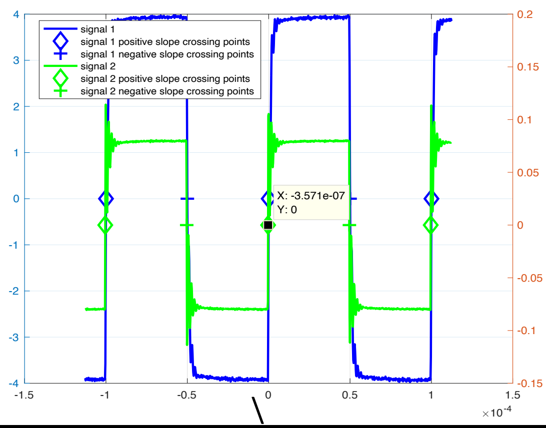


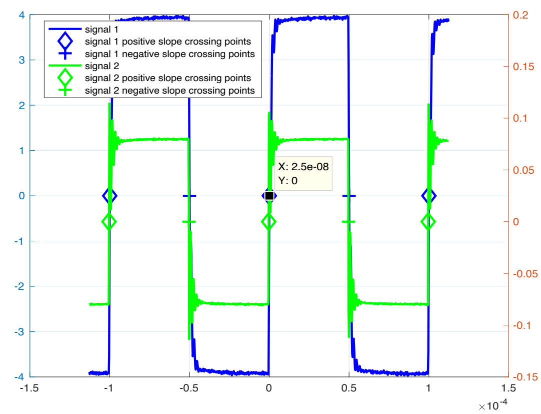
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
0.42	0	0.00000118	**1000**
	t_2	T (1/f)	
	0.00000118	0.001	

Phase Angle at 10 kHz: Square Excitation.



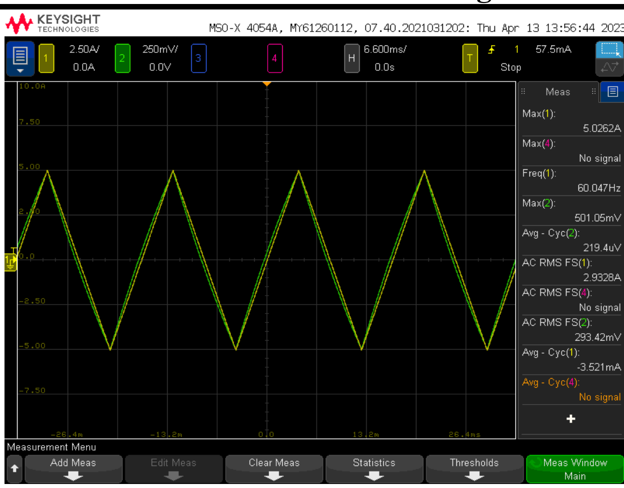


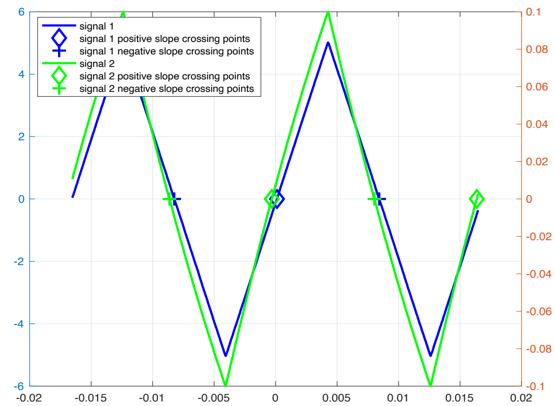


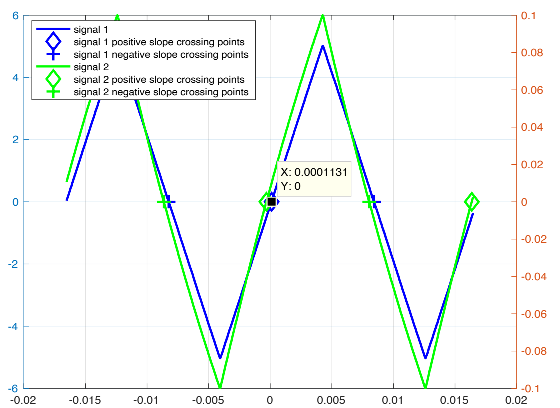


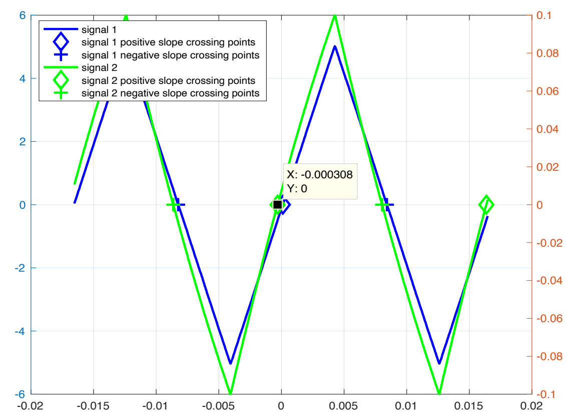
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
1.20	0.000000025	3.321E-07	**10000**
	t_2	T (1/f)	
	3.571E-07	0.0001	

Phase Angle at 60 Hz: Triangle Excitation.



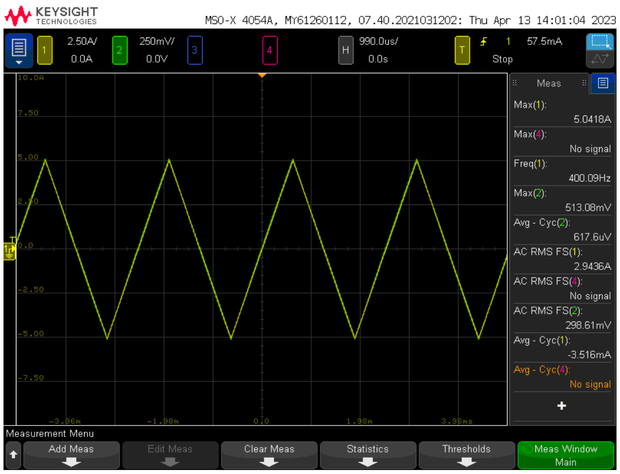


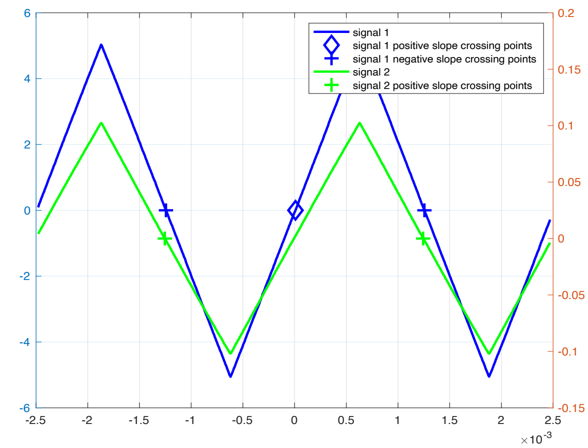


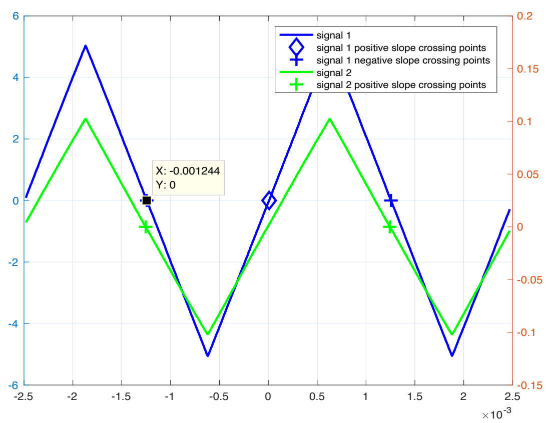


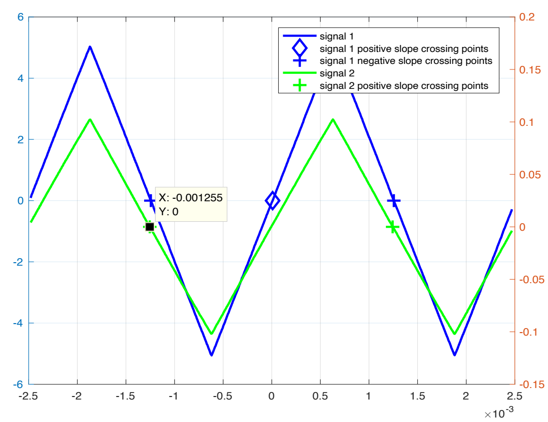
$\Phi_S(=\Delta t/T)°$	t_1	$\Delta t\ (t_2-t_1)$	f
4.21	0.0001131	0.0001949	**60**
	t_2	T (1/f)	
	0.000308	0.016666667	

Phase Angle at 400 Hz: Triangle Excitation.



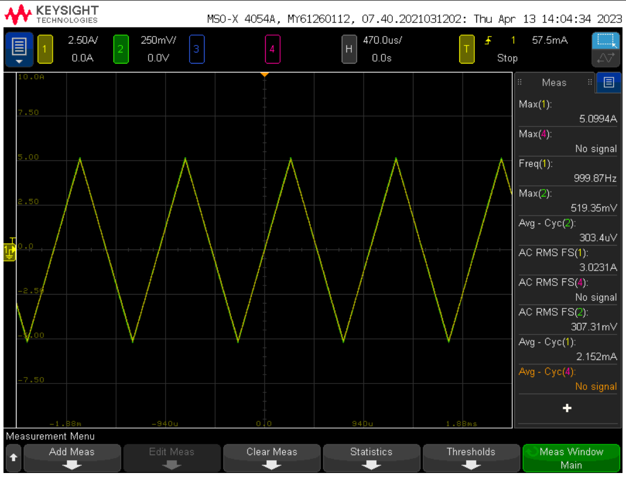


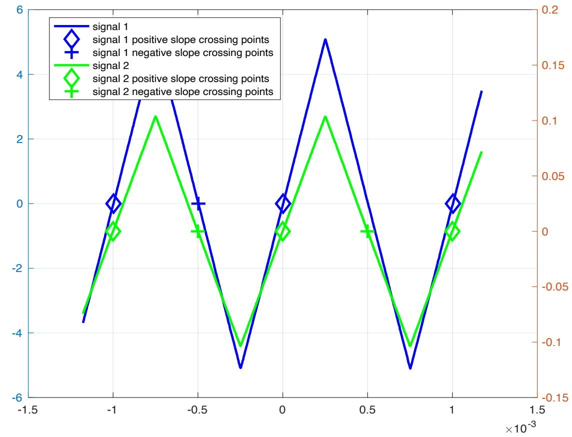


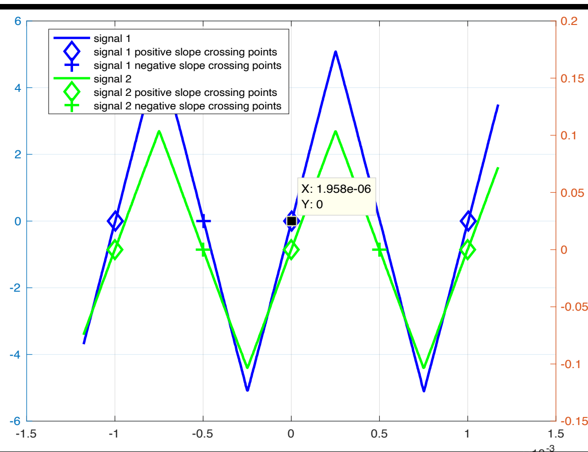


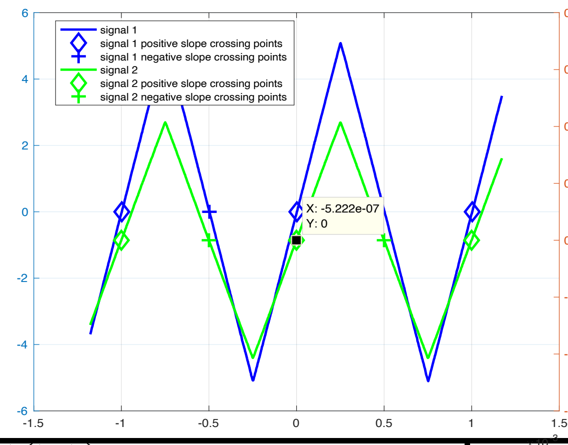
$\Phi_S(=\Delta t/T)°$	t_1	Δt (t_2-t_1)	f
1.58	0.001244	1.1E-05	400
	t_2	T (1/f)	
	0.001255	0.0025	

Phase Angle at 1 kHz: Triangle Excitation.



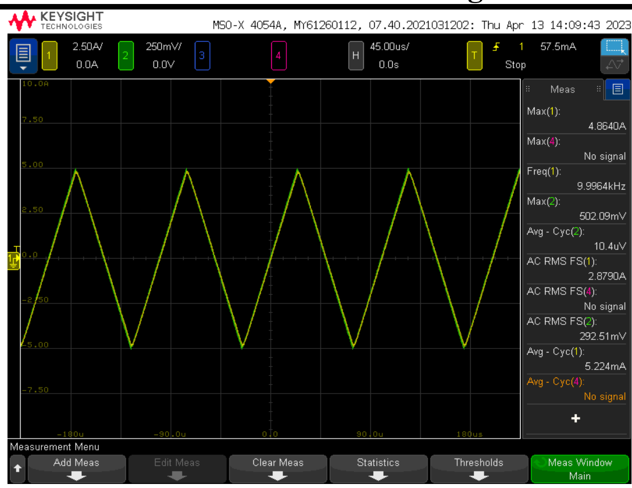


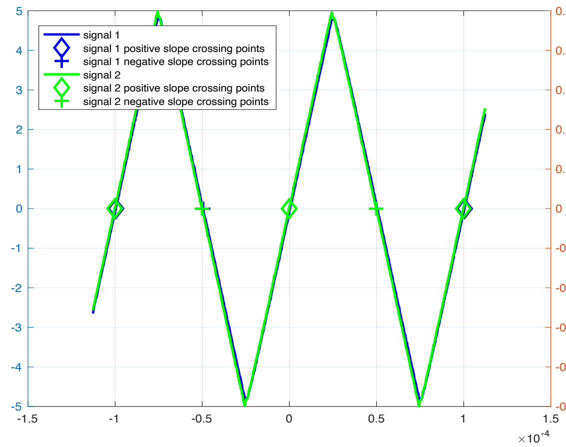


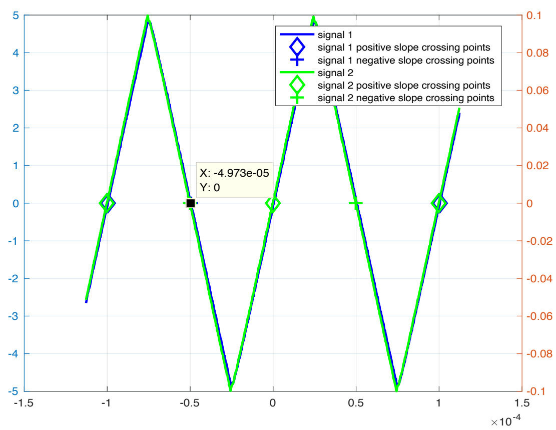


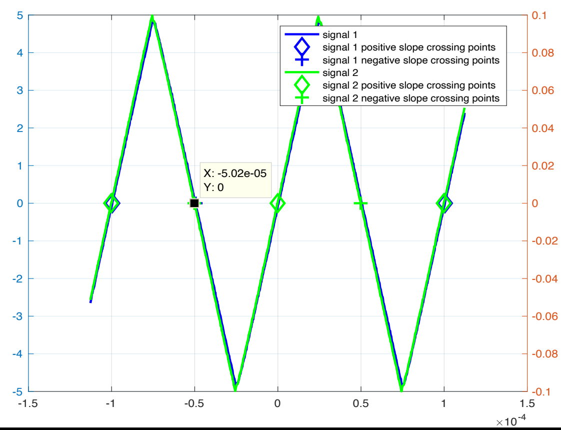
$\Phi_S(=\Delta t/T)°$	t_1	Δt (t_2-t_1)	f
0.52	5.222E-07	1.4358E-06	**1000**
	t_2	T (1/f)	
	0.000001958	1.584	

Phase Angle at 10 kHz: Triangle Excitation.









$\Phi_S(=\Delta t/T)°$	t_1	Δt (t_2-t_1)	f
1.69	0.00004973	4.7E-07	**10000**
	t_2	T (1/f)	
	0.0000502	0.0001	

Section Four: Impedance Measurements.
Electromagnetic Component Testing: Test Procedures and Results.

Purpose.
This test procedure is used to determine current transformer core impedance characteristics, with no load conditions.

Test Equipment.
The test equipment shall be used as follows:

Lab Asset Number	Description	Manufacturer	Model Number	Serial Number
ANA0001	Bode 100: Network Analyzer	Omnicron Lab	None	None
ADA0001	Bode 100: Impedance Adapter	Omnicron Lab	None	None
LAB0001	Computer	AMPED	None	None

Test Procedures.

I. Impedance Measurements – Manual Procedure.

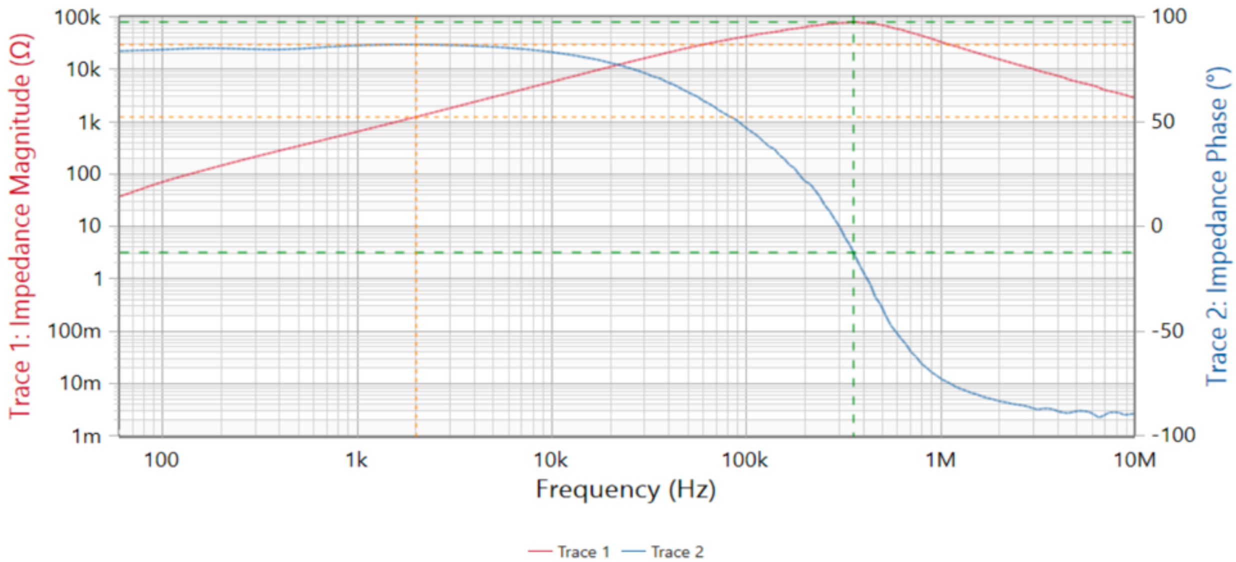
Per guidelines established from the IEEE C57.13-2016 standard, below is the procedure for manual operation of equipment for the Impedance Measurements Setup, to be applied as follows. For a more detailed and general procedure to apply the test, refer to the referenced standard described here.

a. Turn on the measurement equipment and allow sufficient time for stabilization (e.g. 20 minutes).
b. Be sure the current transformer is unloaded for these measurements.
c. Be sure the Bode 100 is connected to a computer for data acquisition.
d. Perform the internal calibration of the Network Analyzer.
    a. Three calibration configurations: Open Measurement, Short Measurement, and Load Measurement.
e. Perform the measurement, capturing the magnitude and phase response of the current transformer.
f. Connect the load leads of the current transformer to the fixture of the Bode 100.

Data Presentation.

In this section, data is presented as each section indicates below.

Measurement: Impedance Adapter



	Cursor 1	Cursor 2	Delta C2-C1
Frequency	359.104 kHz	2.002 kHz	-357.102 kHz
Trace 1	**Magnitude**	**Magnitude**	**Magnitude**
Measurement	79.697 kΩ	1.223 kΩ	-78.475 kΩ
Trace 2	**Phase (°)**	**Phase (°)**	**Phase (°)**
Measurement	-12.499 °	86.73 °	99.229 °

Sweep	
Start frequency:	60 Hz
Stop frequency:	10 MHz
Center frequency:	5 MHz
Span:	10 MHz
Sweep mode:	Logarithmic
Numer of points:	201

Calibration	Full-Range	User-Range
Impedance	Active	-

Hardware setup	
Device type:	Bode100R2
Serial number:	TE817K
Receiver bandwidth:	300 Hz
Output level:	13 dBm
DUT settling time:	0 ms

Setup.

Typical test setup shown below for impedance characteristics.

Impedance Testing. Typical Test Setup: Finemet Current Transformer.