Powder Core Inductor Datasheet

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

Description of Device Under Test (DUT).

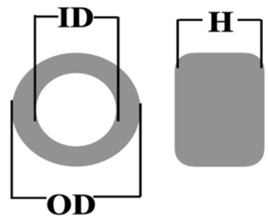
The Inductor is a device which stores energy in the form of magnetic energy when electricity is applied. Specifically, the inductor takes the electrical energy applied at the input, and converts the energy to magnetic energy, based on the geometry and material composition the device characterically possesses.Through the core material, most commongly iron, and the geometry of the wire, which is coiled, this manipulates these properties successfully. Compared in performance to another kind of inductor, this is designed and configured with a Powder Core of Kool Mu material.

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:	www.engineering.pitt.edu/AMPED

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)

Core Specifications

Dimensions				
Description	**Symbol**	**Sample Dimension (mm)***	**Actual Dimension Used (mm)***	
Core Inner Diameter	ID	56.46	57.15	
Core Outer Diameter	OD	104.69	101.6	
Core Height	H	69.85 [a]	66.04 [a]	

*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).

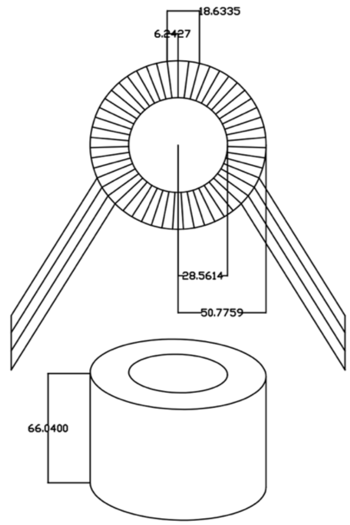
a. The height of one is 16.51 mm defined n the datasheet. The inductor contains four stacked, therefore, 16.51(4) 66.04 mm.

Magnetic Characteristics				
Description	**Symbol**	**Finished Dimension**		**Unit**
Effective Area	A_e	358		mm^2
Mean Magnetic Path Length	L_m	243		mm
Core Mass	C_M	2.0182608		kg**
Density	D	5800		kg / m^3
Lamination Thickness	L_M	0		µm
Chemistry	Al-Si-Fe		**Grade**	
Anneal			**Impregnation**	Unimpregnated
Core Supplier	MAGNETICS		**Part Number**	0077099A7
Wire Supplier	NEW ENGLAND WIRE TECHNOLOGIES		**Wire Gauge**	17 AWG

Unless explictly noted by the manufacturer, the **Core Mass shown was calculated multiplying the Effective Volume (the **Effective Area** multiplied **Mean Magnetic Path Length**), and the provided **Density** by the manufacturer, all in this table. The **Density** was provided from the manufacturer

Design

The design is provided here. In particular, the design used off-the-shelf cores for the comparison between core types.



TITLE Inductor - Powder Core		01 DRAWING NO.	MM UNITS	CSB DRAWN	25JAN2022 DATE
PURPOSE Application Testing	MAJ DESIGNER	1:1 SCALE	CBMM PROJECT	PRO CHECKED	-- REVISION

Number of Turns	17	Turn
Parallel Strands	3	A_{pk}
Inductance	100	uH
Fundamental Frequency	60	Hz
Fundamental Current	100	Amps

Harmonics Under Test

f	Current (A)
1 kHz	5
5 kHz	5
10 kHz	5
50 kHz	5

Design Personnel	
Name	Mark Juds
Title	Research Associate

Section One: Excitation Testing of Power Core Inductor with Amplifier: Test Procedures and Results.

Purpose.
This test procedure is used to measure the excitation and its efficiency between cores and between measurement of an known laboratory current probe with use of an amplifier.

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

Lab Asset No	Description	Manufacturer	Model No	Serial No
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	Differential Probe	Rigol	RP1025D	2014187
PRO0002	AC / DC Current Probe	Keysight Technologies	1147B	JP61071359
CAM0001	FLIR	FLIR	E6xt	639131495
LAB0001	Computer	AMPED	None	None

Test Procedures.
I. Excitation Testing of Powder Core Inductor – Low Signal with Amplifier Setup – Manual Procedure.
Per AMPED Standard AMP-STD-001A, below is the procedure for manual operation of equipment for the Low Signal 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. Set the Arbitrary Waveform Generator to the following settings.
- Begin with a low signal.
  - Frequency. Set frequency as initial starting point at 60 Hz. Increment based on the desired frequencies necessary to perform measurements.
  - 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.

c. 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".

d. Set the Oscilloscope to the following settings.
- Specify Probe Attenuation.
  - Measurements were perfomed 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 data from 60 Hz – 10 kHz.

- All data, 1 - 50 kHz data was captured with High Resolution Settings under Waveform-Acquire Menu.

e. Turn output of Arbitrary Waveform Generator on.
f. 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.

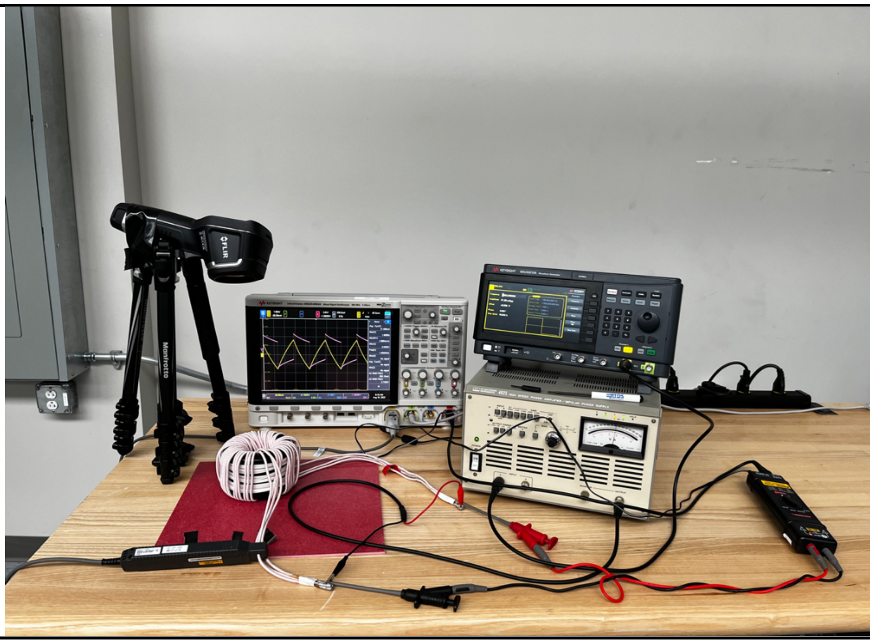
g. Place the leads of the differential probe on the leads of the inductor where remaining exposed conductor is exposed. Twist probe input leads as much as possible to reduce any irregular noise.
h. Measure the current of one strand of the wire. Multiply the measurement on the oscilloscope by three provides the full current through the wire.
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.
- Look for point of saturation for the core. This can be visually examined when the waveform's maximum value no longer increases. Square becomes more in a curve. See Data Presentation for examples.
- Magnetic Flux Density is optional for oscilloscope waveforms but recommended.

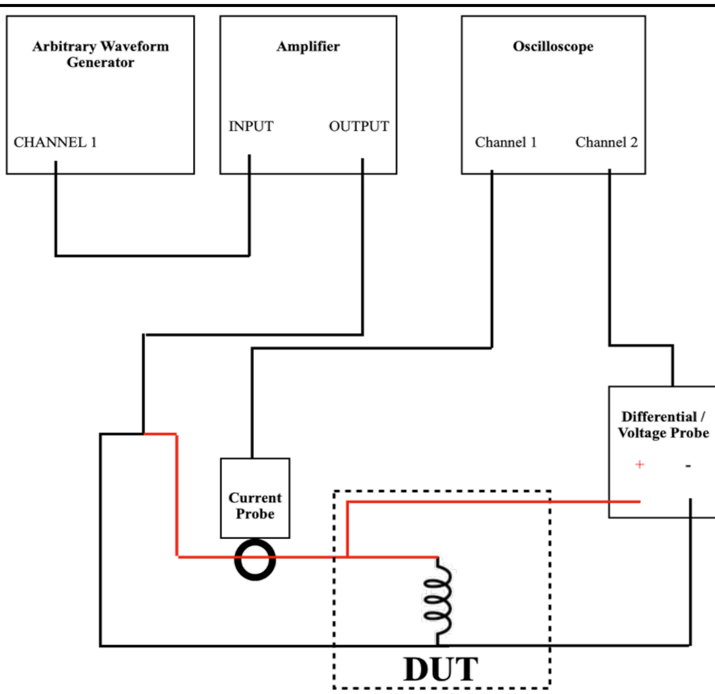
j. Auto zero and Degauss the Current Probe before step i. Also Degauss where Average Current Waveform value climbs above an acceptable tolerance of +/- 10 mA.
k. Let the signal output remain, and record data for 6 minutes, taking data of maximum temperature reading after every minute, using an Infrared Imaging Source or equivalent.
l. Turn off output once time of six minutes has been reached.
m. Record relevant data for Data Presentation.

Setup.

Excitation Testing with Amplifier. Configure the test equipment as shown below, with one figure showing the actual test setup, and another as the block diagram.



Current Transformer Testing - Low Voltage with Amplifier. Typical Test Setup.



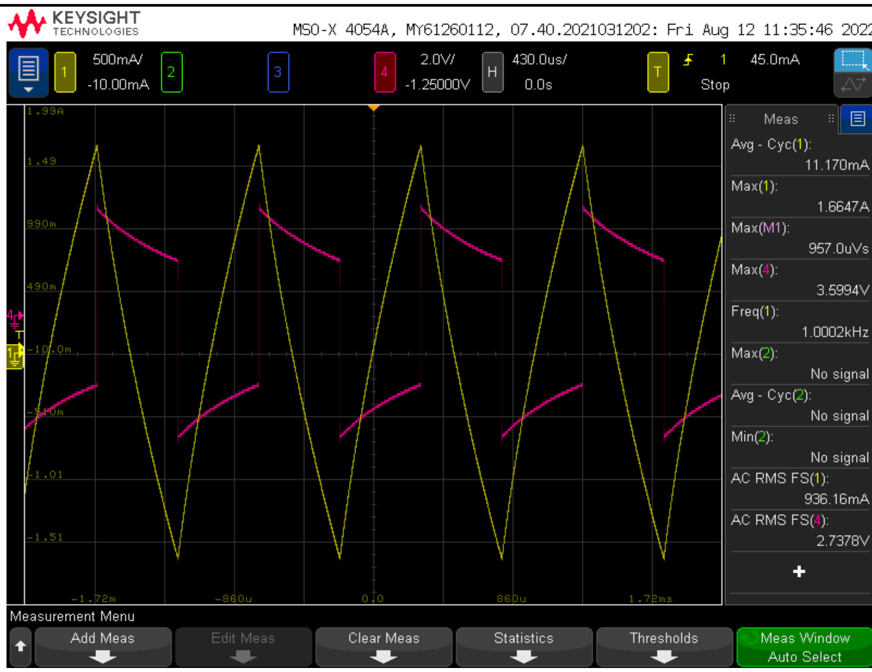
Current Transformer Testing - Low Voltage with Amplifier. Typical Test Setup: System Block Diagram.

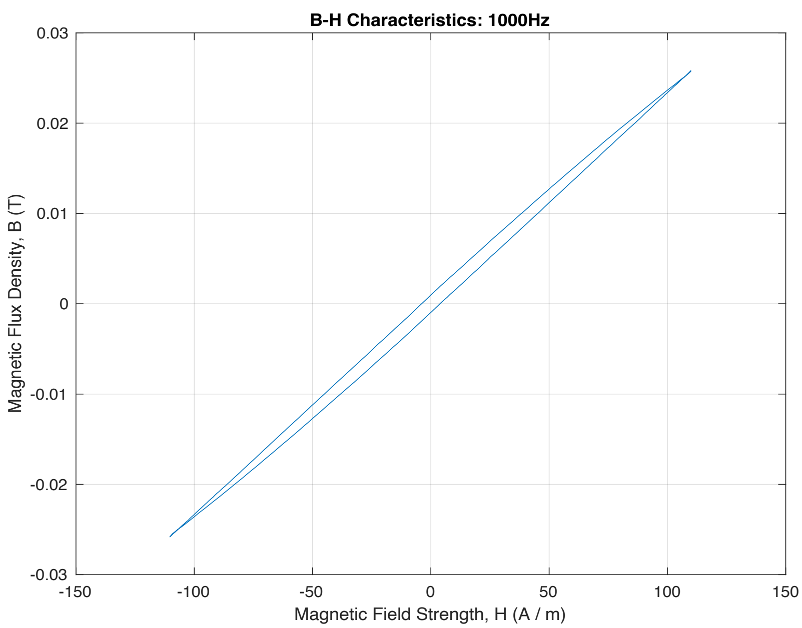
Data Presentation.

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

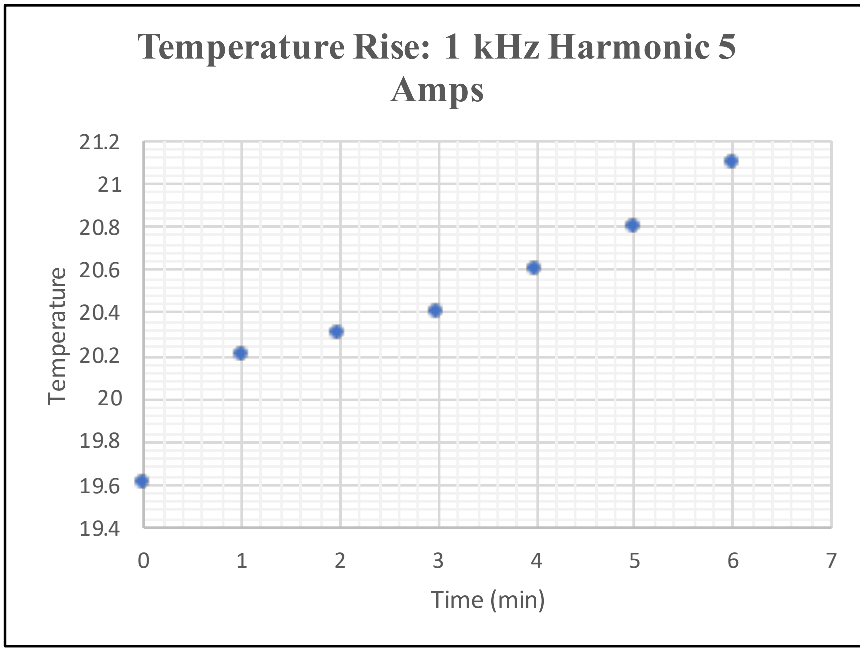
a. Device Characteristic Trends at Specified Harmonics of 60 Hz Fundamental.

1 kHz



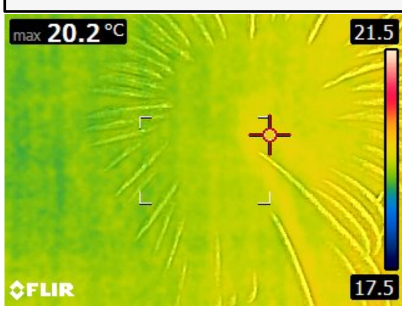


(a) Square Excitation Waveform. Square Signal. 61.5 mV$_{pp}$ 1 kHz, Amplifier Gain X50.
(b) BH Plot of 1 kHz Harmonic..

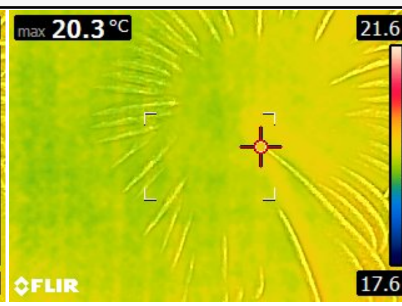


Time (min)	Tmax (°C)
0	19.6
1	20.2
2	20.3
3	20.4
4	20.6
5	20.8
6	21.1

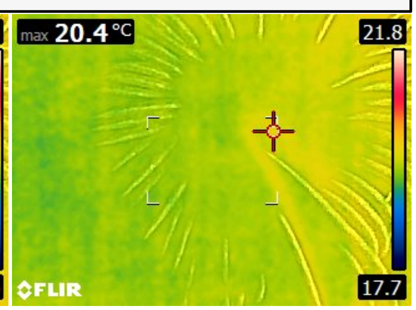
Temperature Rise and Time Images.



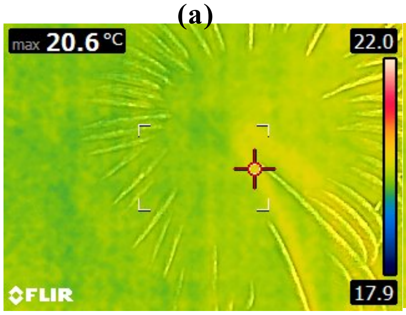
(a)



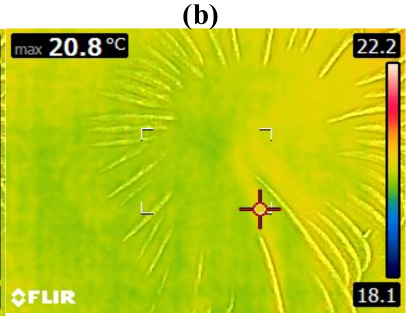
(b)



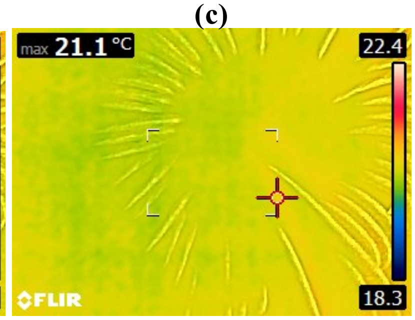
(c)



(d)



(e)



(f)

Temperature IR Images at (a) 1 min, (b) 2 min, (c) 3 min, (d) 4 min, (e) 5 min, (f) 6 min.

Section One: Excitation Testing of Power Core Inductor with H-Bridge: Test Procedures and Results.

Purpose.

This test procedure is used to measure the excitation and its efficiency between cores and between measurement of an known laboratory current probe with use of an H-Bridge system.

Test Equipment.

The test equipment shall be used as follows:

Lab Asset No	Description	Manufacturer	Model No	Serial No
WAV0003	Arbitrary Waveform Generator	Keysight Technologies	EDU33212A	CN61310043
PS0004	GPD-Series D.C. Power Supply	GwInstek	GPD-43038	GE8916-315
PS0003	Programmable AC/DC Power Supply	California Instruments	AST 1501	174A01046
OSC0001	Digital Oscilloscope (200 MHz)	Keysight Technologies	DSOX3024T	MY60104039
PRO0006	AC / DC Current Probe	Keysight Technologies	1147B	JP61071359
PRO0009	Differential Probe	Rigol	RP1100D	20180742
SYS0001	Low Voltage H-Bridge Excitation System	AMPED	UB15-5RF1	None
CAM0001	FLIR	FLIR	E6xt	639131495
LAB0001	Computer	AMPED	None	None

Test Procedures.

I. Excitation Testing of Powder Core Inductor – Low Signal with H-Bridge Setup – Manual Procedure.

Per AMPED Standard AMP-STD-001B, below is the procedure for manual operation of equipment for the Low Signal 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. Set the Arbitrary Waveform Generator to the following settings.

- Begin with a low signal.
  - Frequency. Set frequency as initial starting point at 60 Hz. Increment based on the desired frequencies necessary to perform measurements.
  - Amplitude. Begin with an amplitude value, in terms of peak-to-peak (V_{PP}), at 5. Increase where deemed appropriate to make sure a fully functioning signal is observed in an acceptable tolerance.

c. Set the DC Power Supply settings.

- Channel 1, for the SiC Modules, is set to 24 V_{DC}, 3.2 A.
- Channel 2, for the Fans, is set to 12 V_{DC}, 1 A.

d. 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 PRO0009 was used to acquire data.
  - Voltage Probe from Rigol, the RP1100D, was used for measurements, and has fixed attenuation ratio of 1000:1 after calibration.
  - All data was captured with High Resolution Settings under Waveform-Acquire Menu.

e. Set the voltage on the programmable Power Supply for the Capacitor.

- Be sure the voltage set is for DC.
- Set the voltage range for lower values.
  (250 V rather than 500 V). This provides higher current flexibility.
- Set for a low voltageto begin with, between 0.5 V and 1 V.

f. Place the Inductor leads right at the H-bridge output. Tighten to H-Bridge as much as possible.
g. Place the leads of the differential probe on the leads of the inductor where remaining exposed conductor is exposed. Twist probe input leads as much as possible to reduce any irregular noise.
h. Measure the current of one strand of the wire. Multiply by three provides the full current through the wire.
i. Turn output of Arbitrary Waveform Generator on.
j. Turn the DC Power Supply On.
k. Turn the programmable DC Power Supply on.
l Level the output voltage on the oscolloscope 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.

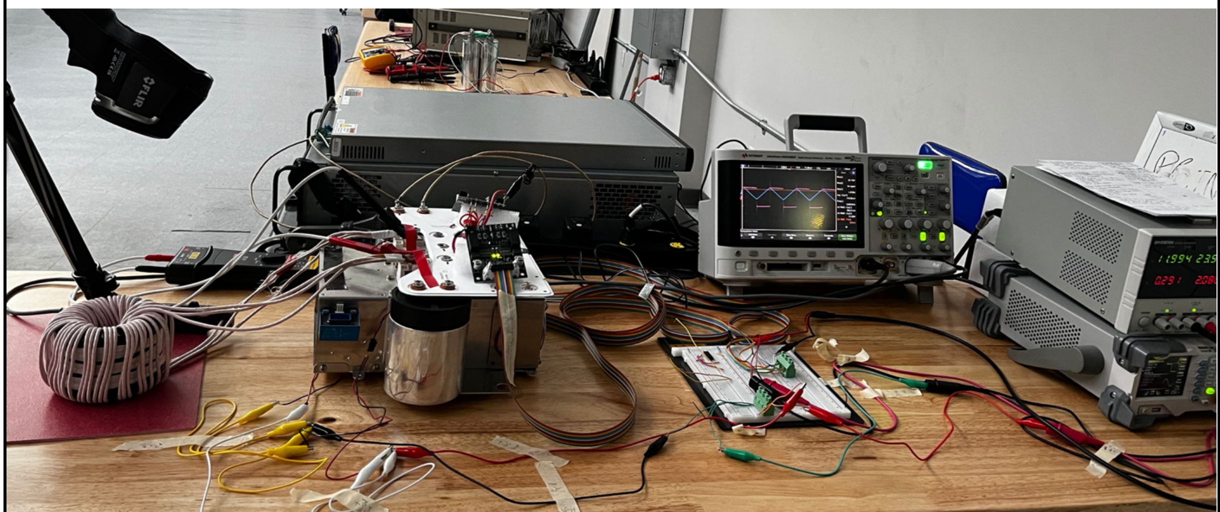
m. Examine the Waveform on the Oscilloscope read from the Current Probe on the input side and the Differential Probe on the Output Side.

- Be sure to capture 2 - 5 periods of the excitation signal being applied.

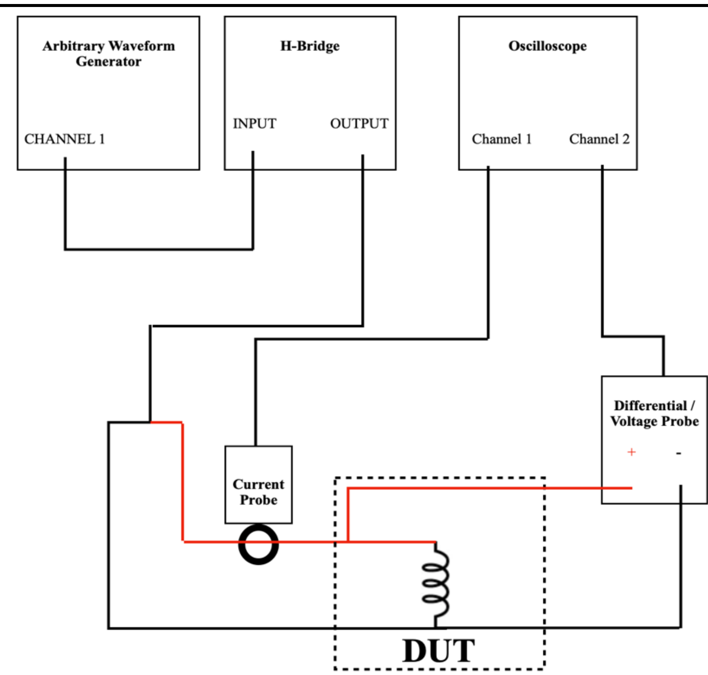
n. Auto zero and Degauss the Current Probe before step i. Also Degauss where Average Current Waveform value climbs above an acceptable tolerance of +/- 10 mA.
o. Let the signal output remain, and record data for 6 minutes, taking data of maximum temperature reading after every minute, using an Infrared Imaging Source or equivalent.
p. Turn off output once time of six minutes has been reached.
q. Record relevant data for Data Presentation.

Setup.

Square Excitation Testing with H-Bridge. Configure the test equipment as shown below, with one figure showing the actual test setup, and another as the block diagram.



Current Transformer Testing - Low Voltage with H-Bridge. Typical Test Setup.



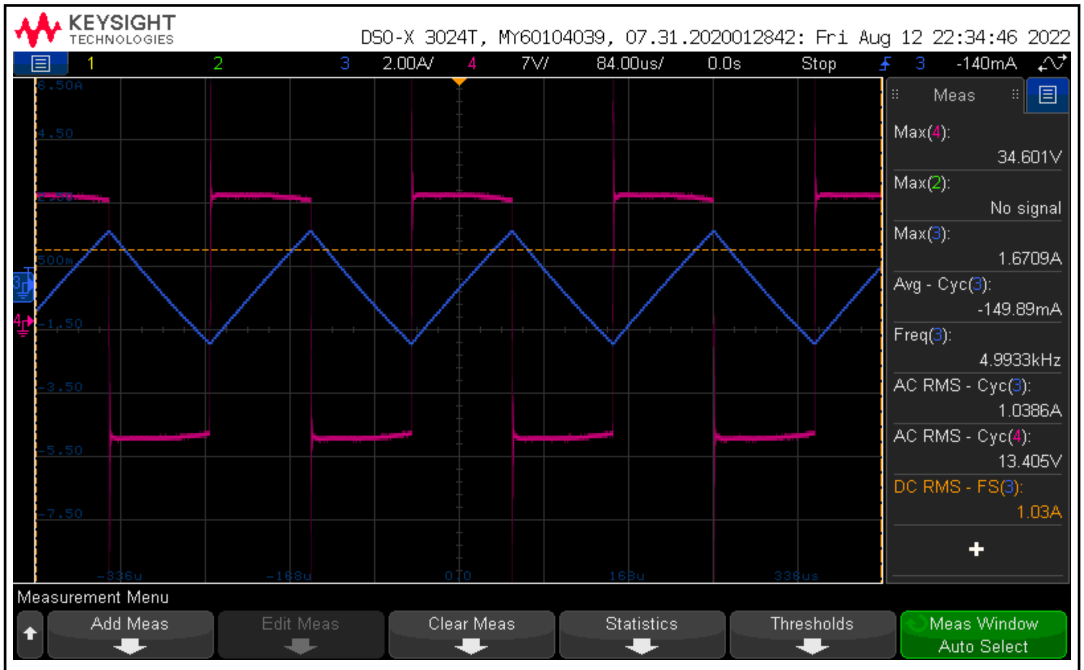
Core Loss Testing - Low Voltage with H-Bridge. Typical Test Setup: System Block Diagram.

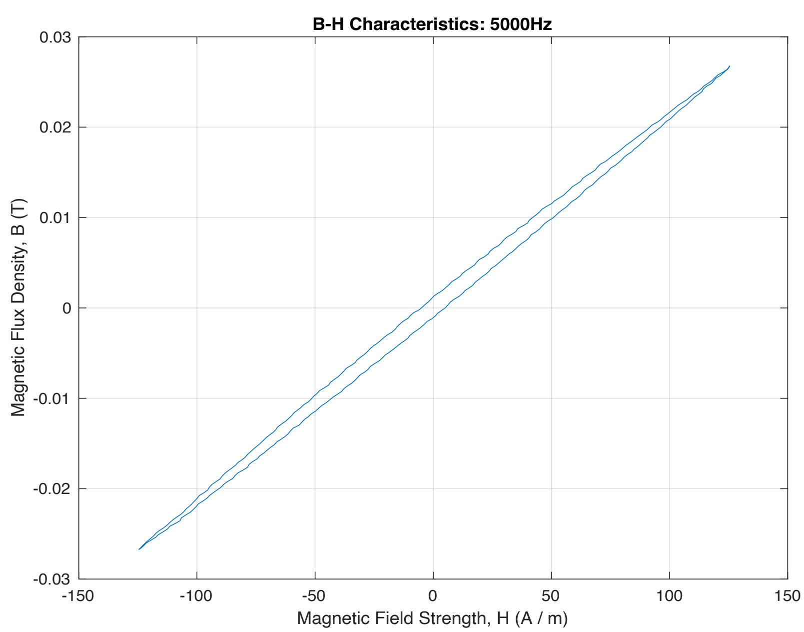
Data Presentation.

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

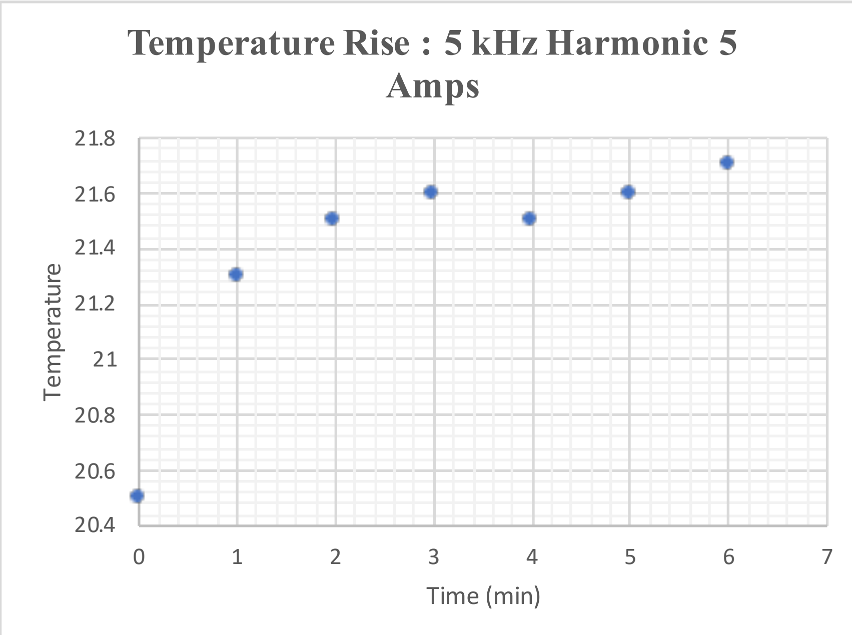
a. Device Characteristic Trends at Specified Harmonics of 60 Hz Fundamental.

5 kHz



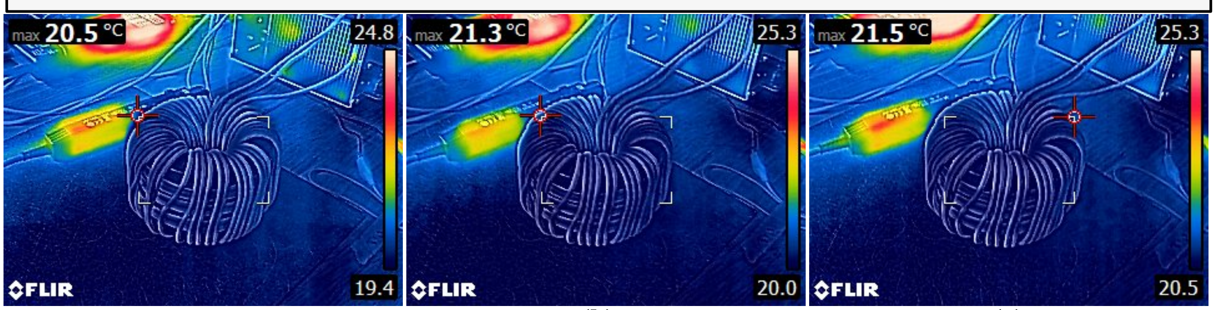


(a) Square Excitation Waveform. Square Signal. 5 V_{pp} 5 kHz, DC Power Supply Output 13.15 V, 0.104 A, Current Limit 12.12 A. (b) BH Plot of 5 kHz Harmonic..

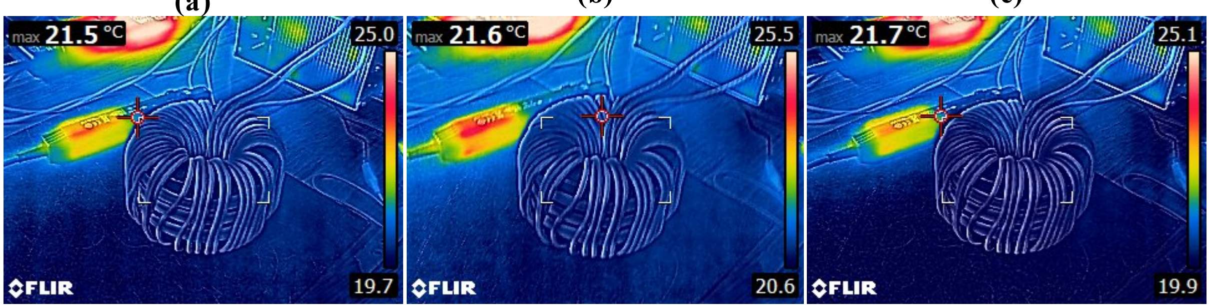


Time (min)	Tmax (°C)
0	20.5
1	21.3
2	21.5
3	21.6
4	21.5
5	21.6
6	21.7

Temperature Rise and Time Images.



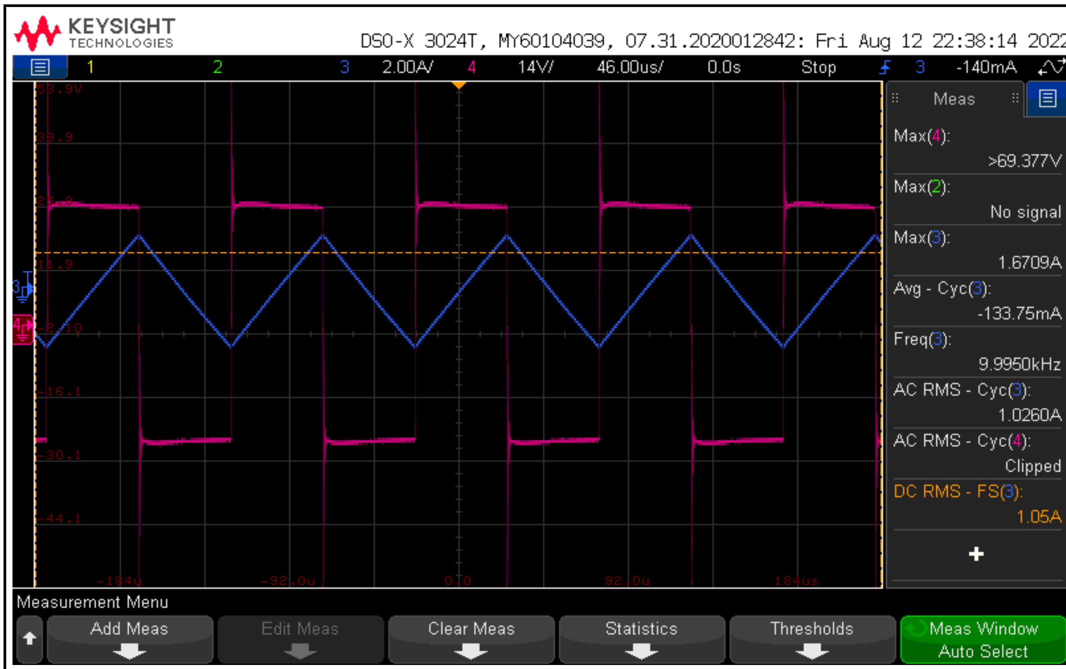
(a) (b) (c)

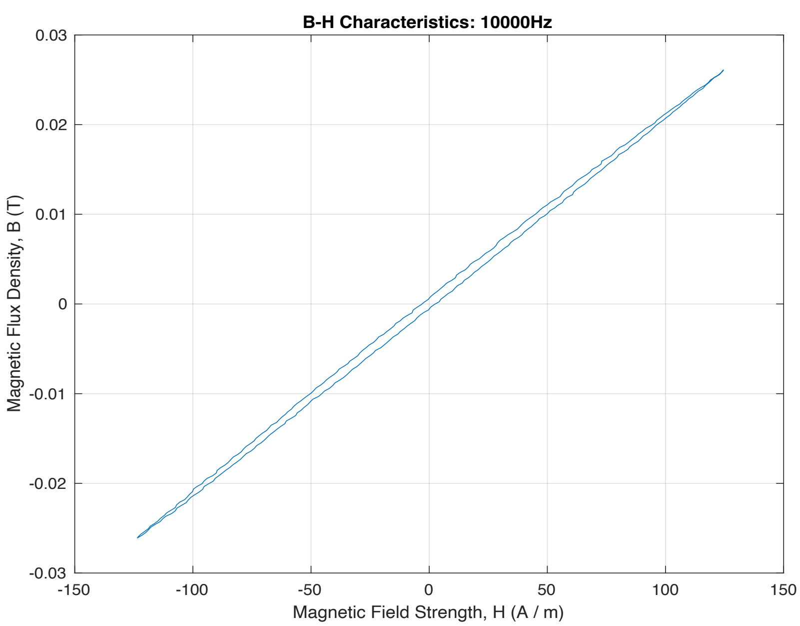


(d) (e) (f)

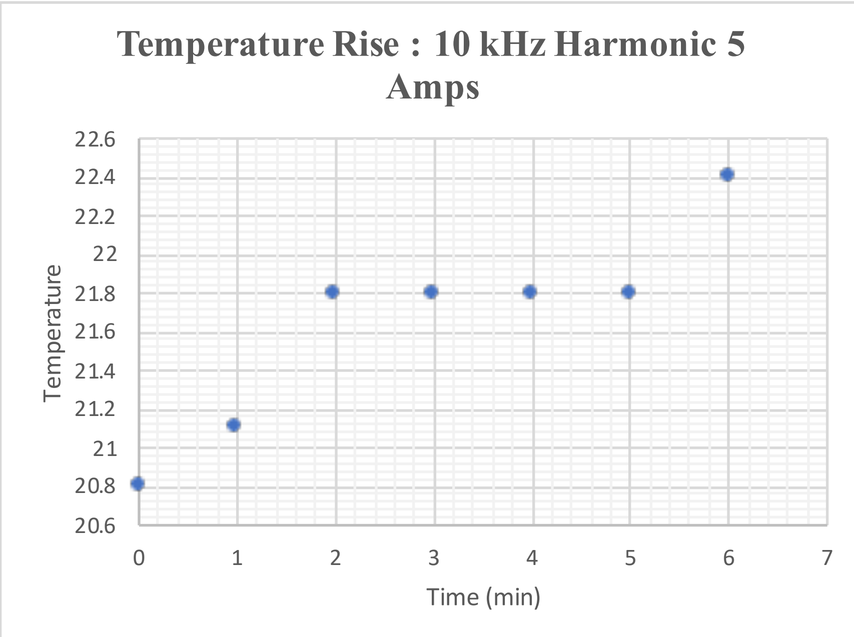
Temperature IR Images at (a) 1 min, (b) 2 min, (c) 3 min, (d) 4 min, (e) 5 min, (f) 6 min.

10 kHz



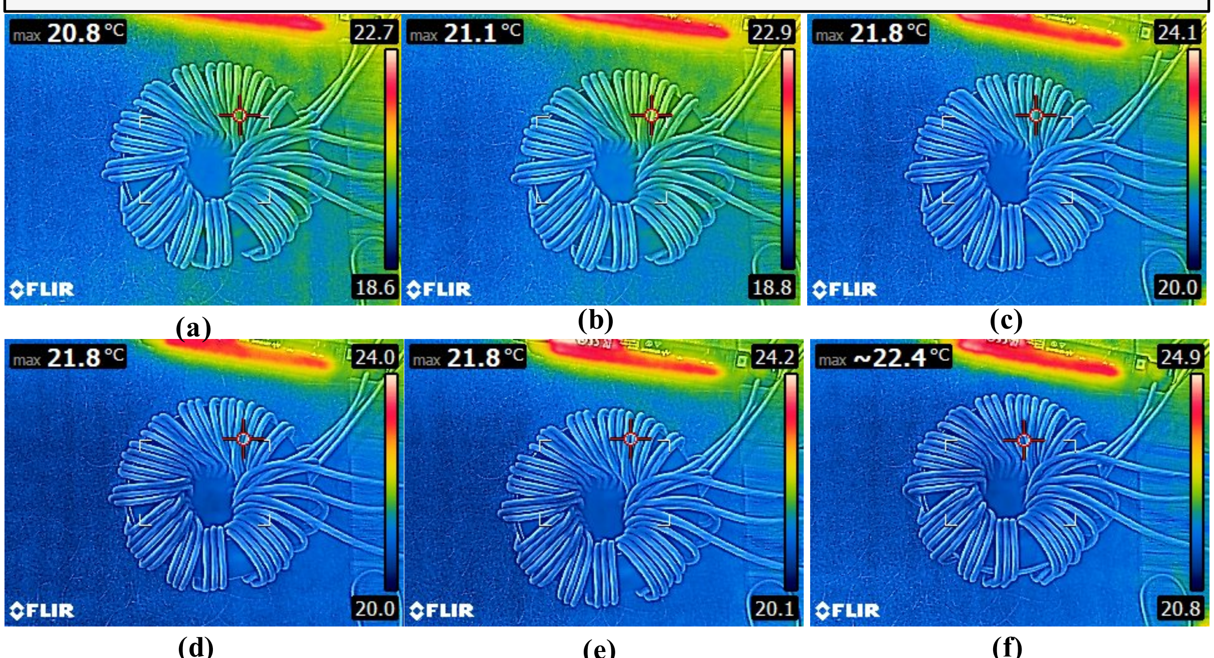


(a) Square Excitation Waveform. Square Signal. 5 V_{pp} 5 kHz, DC Power Supply Output 25.75 V, 0.240 A, Current Limit 12.12 A. (b) BH Plot of 5 kHz Harmonic..



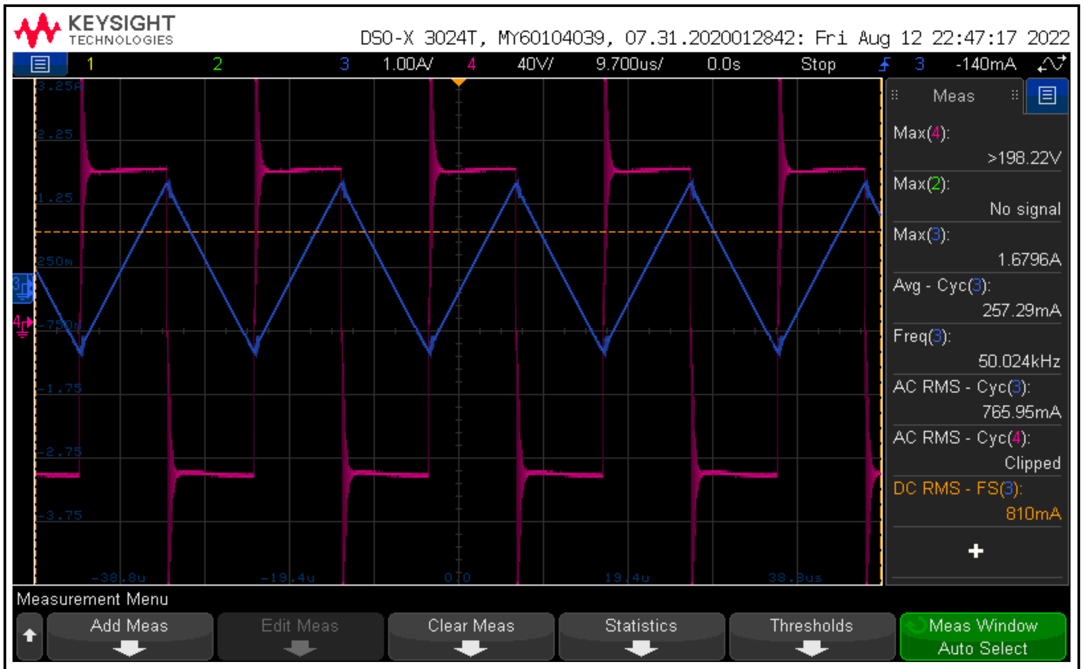
Time (min)	Tmax (°C)
0	20.8
1	21.1
2	21.8
3	21.8
4	21.8
5	21.8
6	22.4

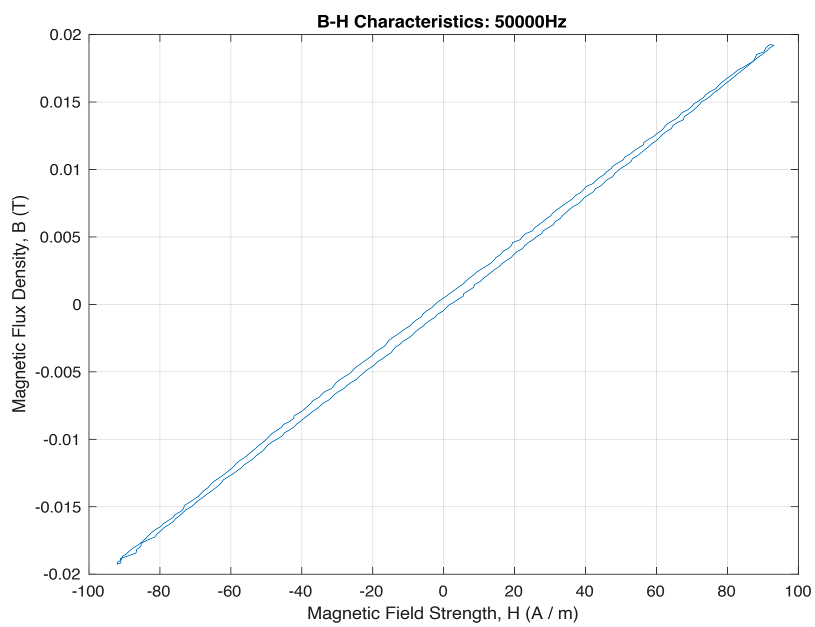
Temperature Rise and Time Images.



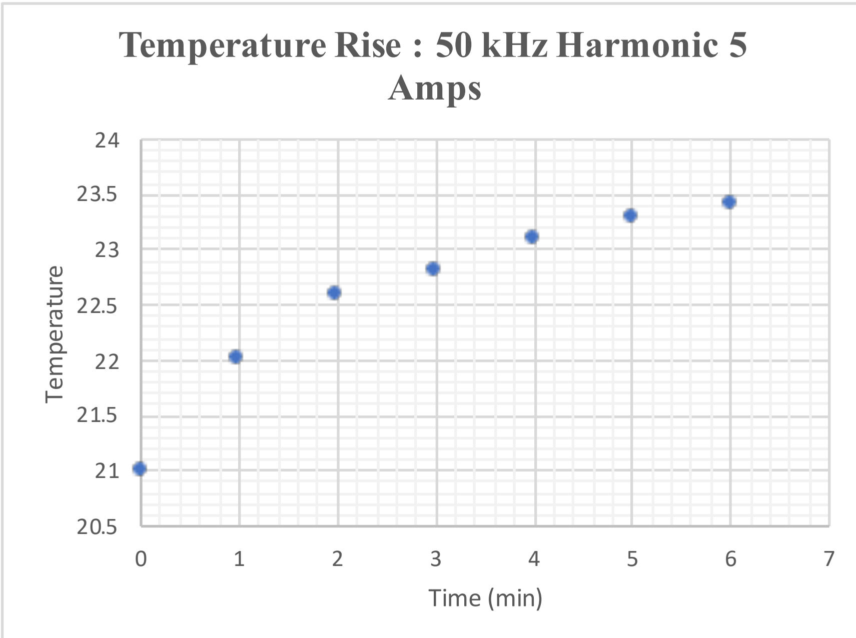
Temperature IR Images at (a) 1 min, (b) 2 min, (c) 3 min, (d) 4 min, (e) 5 min, (f) 6 min.

50 kHz



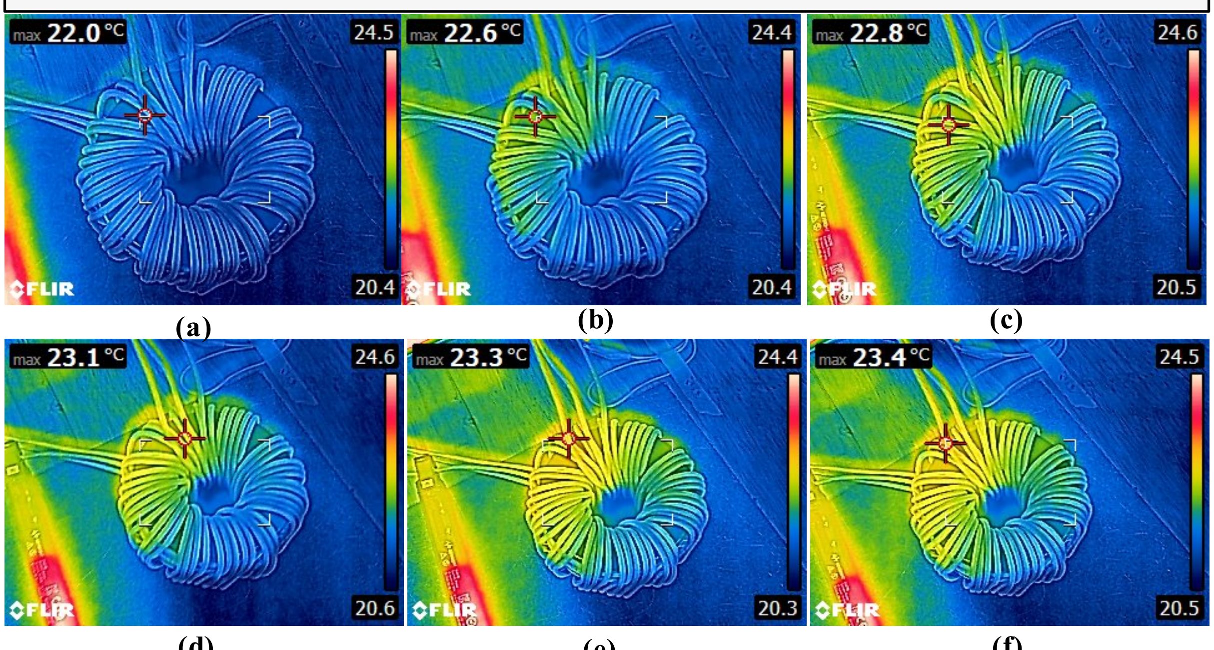


(a) Square Excitation Waveform. Square Signal. 5 V_{pp} 5 kHz, DC Power Supply Output 95 V, 3.3 A, Current Limit 12.12 A. (b) BH Plot of 5 kHz Harmonic..



Time (min)	Tmax (°C)
0	21
1	22
2	22.6
3	22.8
4	23.1
5	23.3
6	23.4

Temperature Rise and Time Images.



Temperature IR Images at (a) 1 min, (b) 2 min, (c) 3 min, (d) 4 min, (e) 5 min, (f) 6 min.

Section Three: Inductance Testing of Powder Core Inductor with LCR Meter: Test Procedures and Results.

Purpose.
This test procedure is used to measure the inductance and between measurement of an known laboratory LCR Meter for an Inductor.

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

Lab Asset No	Description	Manufacturer	Model No	Serial No
LCR002	LCR Meter (20 Hz - 1 MHz)	Keysight Technologies	E4980AL	MY54412304
LAB0001	Computer	AMPED	None	None

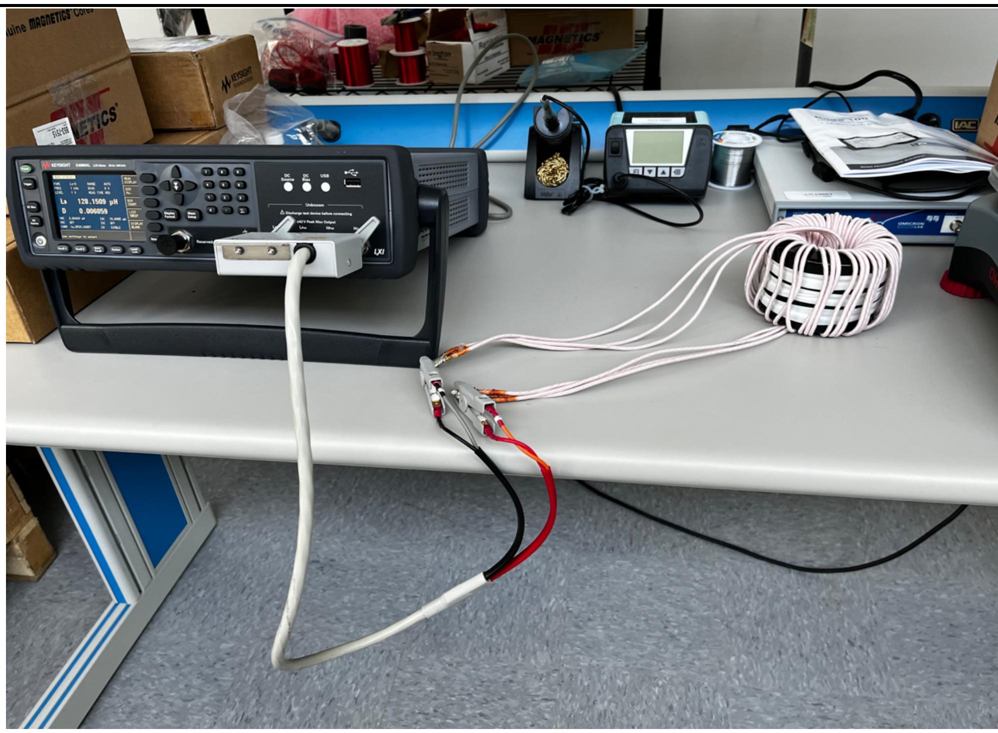
Test Procedures.

I. Inductance Testing - Powder Core with LCR Meter – Manual Procedure.

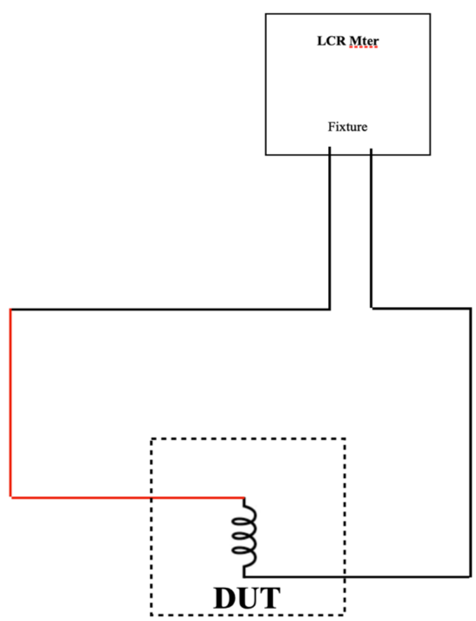
Per AMPED Standard AMP-STD-001, below is the procedure for manual operation of equipment for the Low Signal Setup, to be applied as follows. For a more detailed and general procedure to apply the test, refer to the referenced standard described here.

a. Turn on the measurement equipment and allow sufficient time for stabilization (e.g. 20 minutes).
b. Use the plate of the LCR Meter Fixture to zero the reading of the meter with the clips.
c. Set the LCR Meter to the following settings.
- Begin with a low signal.
  - Change the inductance to Series Inductance, L_s.
  - Input the frequency to 1 kHz.
  - Input the level to 1 V.

d. Connect the two clips from the LCR Meter to the DUT.
e. Record the reading.



Inductance Testing with LCR Meter. Typical Test Setup.



Inductance Testing with LCR Meter. Typical Test Setup: System Block Diagram.

LCR Meter Reading under Procedural Settings.