Laboratory Report

Phase sensitive experiments and introduction of low temperature physics

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Objectives:

1. To understand the concept of a Lock-In amplifier and apply it to a simple electronics problem.

2. To find the critical temperature of the given material using a cooling source (Liquid He is used)

Apparatus required:

Theory:

A lock-in amplifier can identify and analyze extremely tiny AC signals, as low as a few nanovolts, even when they are masked by noise sources that are millions of times larger. It isolates the signal component at a certain reference frequency and phase using a method known as phase-sensitive detection. Typically, lock-in amplifiers use a phase-locked loop (PLL) locked to an external frequency reference ω to create their own internal reference signal.

Block diagram of a Lock-In amplifier
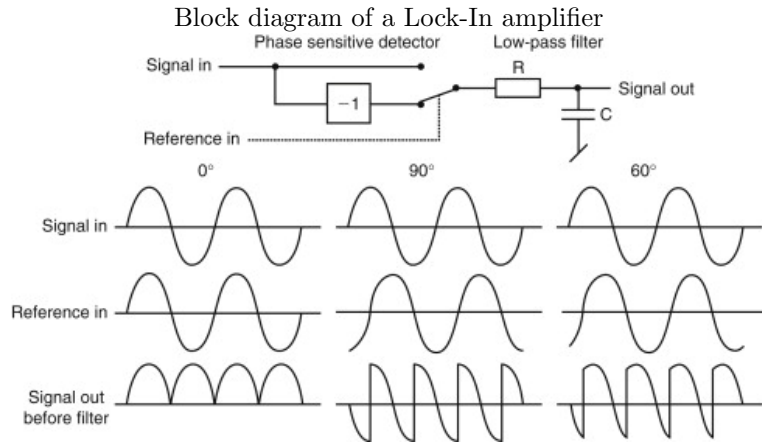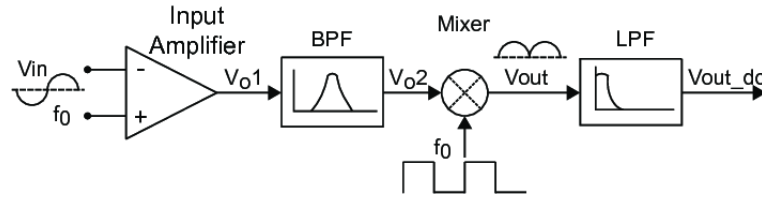
Signal processing of a Lock-In amplifier
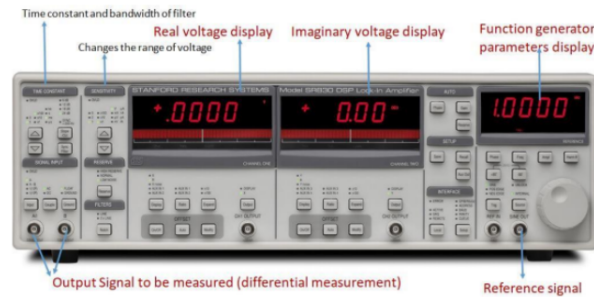
Labeling of our Lock-In amplifier

Parameters

$$\text{In phase component} = V_0 cos\theta$$
$$\text{Out of phase component} = V_0 sin\theta$$
$$\text{Magnitude of signal} = V_0$$
$$\text{Phase} = arctan\left(\frac{Y}{X}\right)$$

Observations:

## Finding the Resistance and Inductance of the given coil

We have the following data

Frequency (Hz)	Phase 1 (mV)	Voltage 1 Re (mV)	Voltage 1 Im (mV)	Voltage 2 Re(μV)	Voltage 2 Im(μV)	Phase 2
200	-179.98	5.082	0	147.85	0	13.32
400	-179.98	5.081	0	148.38	-18.1	13.29
600	-179.98	5.081	0.007	148.4	-21.9	13.29
800	-179.98	5.08	0.01	148.27	23.3	13.29
1000	-179.98	5.08	0.014	148.3	23.51	13.29
1200	-179.98	5.08	0.018	148.44	23.3	13.29
1400	-179.98	5.082	0.018	148.87	22.81	13.29
1600	-179.98	5.082	0.021	149.09	22.11	13.29
1800	-179.98	5.081	0.021	149.34	21.34	13.29
2000	-179.98	5.081	0.024	149.59	20.45	13.29

Where 1 indicates the Lock-In Amplifier linked to the converter and 2 indicates the Lock-In Amplifier linked to the coil.
We get the current to be 0.5082 mA. So the resistance of the coil is

$$R_{coil} = \frac{Voltage(Real)\ 2}{Current} = 0.292 \pm 0.001\Omega$$

Inductance can be found out by plotting the Voltage 2 (Imaginary) with Frequency and getting the slope.
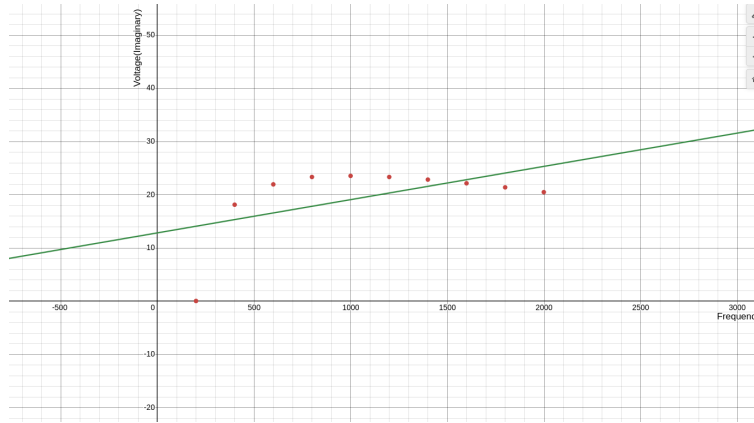

We have the slope=L*I=0.0062±0.0035

$$\implies L = \frac{0.0062}{I} = 12\mu H$$

Error in Inductance =6.7 μ H
The reason for the high error value is due to the fact that as we go to higher and higher frequencies, there can be many other sources of error, which may play a part. So we must use lower frequencies to measure inductance.

Detection of the Critical temperature of the chip

We perform the experiment and get the critical temperature plots as follows
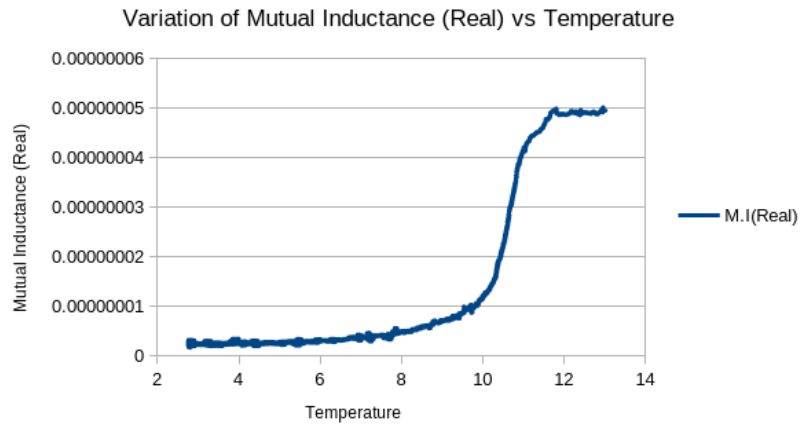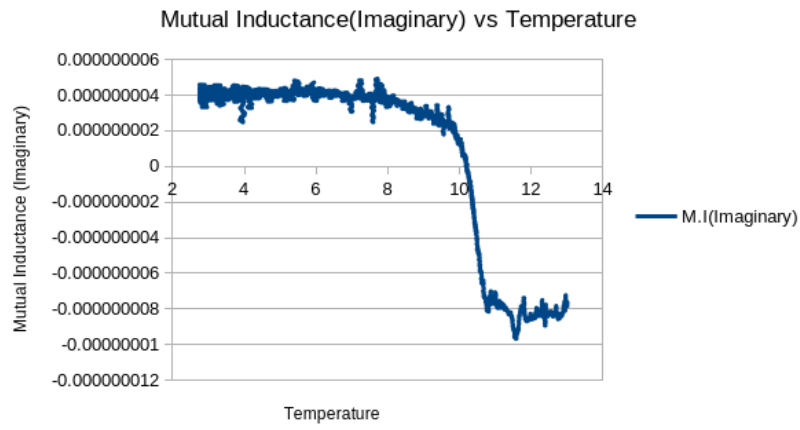
Plot of Mutual Inductance versus the temperature of both parts.

We are getting the critical temperature of 10.410 K. But then we were expecting a critical temperature of 11.2 K. What is more surprising is that there is some deviation in the real and imaginary values, and in the imaginary part, the mutual inductance didn't rise back up.