Electronics

Lock in amplifier

Problem 1.- To measure a signal from an atmospheric mass spectrometer you employ a lock-in amplifier and modulate the signal at 137Hz.

If you estimate that the amplitude of the signal is 14.5μV and that it is shifted 2.4ms with respect to the reference, what values do you expect to get in the X-channel (in phase with the reference) and Y-channel (at 90º from the reference)?

Solution: The period of the signal is $T = \frac{1}{f} = \frac{1}{137Hz} = 7.30ms$

This value corresponds to 360º, so the shift of 2.4ms is equivalent to

$$\theta = \frac{2.4ms}{7.30ms} \times 360^\circ = 118^\circ$$

And the signals in the two channels are:

$$S_X = S\cos\theta = 14.5\mu V \cos 118^\circ = -6.8\mu V$$
$$S_Y = S\sin\theta = 14.5\mu V \sin 118^\circ = 12.8\mu V$$

Problem 2.- A lock-in amplifier is used to measure a weak ultrasound signal of 70kHz. Channel X measures 3.5mV and channel Y -5.0mV.
Use the time shift with respect to the reference to calculate the distance travelled by the wave at the speed of sound of 1500 m/s between the source and detector.

Solution: We first calculate the phase shift in degrees.

$$\phi = \tan^{-1}\left(\frac{-5.0}{3.5}\right) = 305^\circ$$

Next, knowing the period, which is equivalent to 360º we can calculate the time.

$$\Delta t = \frac{305^\circ}{360^\circ} T = \frac{305^\circ}{360^\circ}\frac{1}{f}$$

Finally, to find the distance we multiply by the speed.

$$d = v\Delta t = \frac{305^\circ}{360^\circ}\frac{v}{f} = \frac{305^\circ}{360^\circ}\frac{1500 m/s}{70kHz} = 18.1\text{mm}$$

It is worth noticing that if the distance were longer by multiples of vT, we would not be able to distinguish that from this case. We are assuming that the travel time is less than a period.

Problem 3.- To run quality tests in the anti-reflecting coating of lenses, you use a detector to measure the intensity reflected by a lens. However, the test is done in a place where there is stray light. The signal is taken from a phototransistor, with a typical current of ~100μA, but the signal is only ~5% of this value.

Suggest a solution to discriminate the signal from the noise. Include the important details in the design including a diagram and the estimated cost.