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An Improved Frequency Resolution Using a two Channel two Phase Microcontroller Lock-In Amplifier

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ABSTRACT

Frequency resolution is the smallest portion of change in resulted frequency can be detected.Generally traditional amplifiers which are used for amplification of signals lead to scenarios where the noise levels are in millivolt range and thus leading to poor signal-to-noise ratio. Here we are using two phase lock in amplifier with two channels to send the two different information at a time to improvise the frequency resolution andto generate two alternating voltages of same frequency.When there is a need to send information for long distances, we definitely use some techniques for the security purpose of data. But due to some external disturbances, noise is added to the information which makes the loss of information sometimes. At that time enhancement of frequency resolution plays a vital role by converting the analog information into digital information. The conversion of data happens when the sampling frequency must be twice the frequency of input signal.This helps in extraction of signal of interest at a specific frequency from an output signal which contains significant noise levels at other frequencies. This approach can also be applied in embedded design to measure frequency dependent sensors with high quality factor and also in scientific instrumentation such as scanning probe microscopes or even for educational purposes.

Key words –Frequency, lock-in, lock-in-amplifier, resolution, sampling, signal-to-noise ratio.

1.INTRODUCTION

Two-phase lock-in amplifiers are instruments that measure the amplitude and phase of amplitude modulated signals. It is used in multitude of experiments in science and technology in diverse scenarios. The most common application is in the improvement of the signal-to-noise ratio of an experiment. The lock-in exploits the limited bandwidth of noise and modulates the excitation source of the experiment in a different frequency to finally demodulate a cleaner response signal.

In this case, the dynamic reserve should be enhanced to better recover the signal from the noise. At different scenario, the LIA can be used to measure the frequency dependent response of devices and experiments. Different from the applications cited before, this application requires an instrument with enhanced frequency resolution and bandwidth of operation allied to the signal recovery capabilities.

The actual state of art commercial digital LIAs works in the tens of mega Hertz bandwidth and cost in the range of thousands of dollars. These instruments are power hungry equipment that uses field programmable gate arrays and or custom integrated circuits to achieve these high frequencies of operation. If the characteristics of the application requires lower bandwidth and/or low power consumption, microcontroller-based lock-in can have its niche since they have generally operated in lower frequencies than FPGAs. They are less flexible in operation, however, possessing advantage of significantly lower cost.

A sine wave excitation can be generated by direct digital synthesis and digital to analog converter. This approach generates a low distortion sine wave signal, frequency response proportional to sampling rate of digital to analog converter, but the speed of operation is limited. So, to overcome the lower speed of operation and need of fast external DACs, square wave can be used for demodulation and excitation in microcontroller LIAs. By using square wave demodulation or excitation, odd harmonics would appear and it can distort the output of signal lock-in.

In microcontroller, square wave is generated at timer peripheral. Frequency resolution of a signal generated by this has limited bandwidth. When high quality frequency resolution is required, square wave can be dithered to achieve better resolution. The process of square wave dithering consists of inclusion of minimum changes in the period of the signal to generate a fractional change n the principal harmonic frequency when the signal is averaged over suitable time. The square wave dithering is mainly used in pulse width modulation signals to enhance the dc component granularity.

It was shown that this process can also enhance the frequency resolution. The measurement of quartz tuning forks mechanical resonators is an example where high frequency resolution is required from a LIA. QTFs have been used in different applications as humidity and temperature sensing, density/viscosity sensors, as a probe in scanning probe microscopy, and in many other sensing applications. These devices are mass fabricated and inexpensive, and they also possess a high-quality factor, enabling sensitive resonant frequency measurements.

The high Q is the constraint that should be taken in account when choosing the LIA to measure QTFs. The range of frequencies that the resonance takes place is narrow, under few Hertz, consequently, finer frequency resolution is preferred instead of high dynamic reserve or high with high-frequency granularity with minimum external circuitry in a microcontroller, dithering the timer to achieve the required frequency steps needed to resolve the QTF sensors resonant curve.

EXISTING SYSTEM

In existing system lock in amplifier scheme has been implemented based in existing signal power amplifier. A radio frequency power amplifier is a type of electronic amplifier that converts a power radio frequency signal into a higher power signal. RF power amplifiers drive the antenna of a transmitter. Design goals often include gain, power output, power efficiency, linearity, input and output impedance matching, and heat dissipation.

A lock-in amplifier is a type of amplifier that can extract the signal with a known carrier wave from an extremely noisy environment. Depending on the dynamic reserve of the instrument, signals up to a million times smaller than noise components, potentially fairly close by in frequency, can still be reliably detected.

The system is put in place for distorting the original signal and in a way simulates a real-life system under test or measurement. It has a simple inverting adder that attenuates the signal by a factor of 100 and adds a white Gaussian noise set of power. The white Gaussian noise generated by passing a pseudorandom variable to a DAC by means of a microcontroller code written to send pre calculated values of a WGN variable.

For the noise hence generated, we have the value of the noise variance given by: σnoise = σ*(Vref/256) where σ is the variance of computer-generated WGN and Vref/256 is the scaling factor that converts the 8-bit numbers via the DAC and the I to V converter to voltage. Thus the output of the test block is inverted signal of Vsig attenuated by a factor of 100 with cyclo-stationary White Gaussian Noise of mean -Vref/2 and variance (127/3)*(Vref/256) = Vref/6.

We need to remove all frequency components in the input signal at the odd harmonics of the reference otherwise these will also get heterodyned to DC when mixing is done via the switching operation. As long as we are filtering the signal, we can also amplify the signal as amplifying the signal at an earlier stage is better as compared to amplifying it later after our system components have added further noise to the signal. Thus, our signal pre-processing block comprises of LNA followed by a band pass filter centred at the reference frequency.

The centre frequency of the Sallen key can be changed imply by changing the resistor value R. For this we used digital potentiometer ICs from Analog electronics that can be controlled by I2c protocol from a microcontroller. For this we also wrote an automatic frequency detection code that would detect the frequency of the reference signal.

Then we can accordingly set the value of R for the centre frequency. The overall performance of the pre-processing block at different centre frequencies. The phase detection is performed by switching the output of the pre-processing block on two parallel channels with switching signals 90 degrees out of phase. Simple MOSFET switches were employed for this purpose. They were chosen as they add much lower noise to the output as compared to other options like the analog switches and have fast enough switching for our frequencies of interest.

Toggling the each of the falling and rising edge of the signal gives two signals of frequency which are 90 degrees out of phase. Thus, to generate the required switching signals we need a 2f frequency wave. We obtain this by passing the reference frequency to a PLL with a divide by 2-counter in the feedback. Thus,the PLL gives a 2f frequency locked in phase with this reference.

The toggling is then done by simple edge triggered toggle flip flops operating at clocks 180 degrees out of phase. Using the PLL, though simple, has the advantage of giving phase jitters and limited lock range which forces us to change a capacitor to switch between ranges. In the case of digital LIAs, a similar process is made. The main difference is that an acquired signal is converted to digital data before the convolution process is made, and the internal reference signal is digital too. An Analog to Digital Converter is used to convert the read signal.

Obviously, the converted resolution is related to the application requirements or the desired precision for the experiment. The internal reference consists of a sine or cosine waveform generated by an internal algorithm that may be stored in a Look-up-table. As in the case of read signal, the reference signal resolution is also related to the specific applications or the desired precision.

PROPOSED SYSTEM

Optimum signal recovery under noisy environments is a very significant problem that the modern research focuses upon. Traditional amplifier designs do not provide satisfactory results in a highly degraded noise scenarios as they give very low noise signal power levels. The prime reason behind it is that traditional amplifier designs do not single out the specific frequency component of our interest.

Such amplifiers lead to scenarios where the noise levels are in milli-volt range whereas the signal levels are in microvolt range and thus leading to poor signal-to-noise ratio.In the field of communication, the signals get degraded when they are allowed passed through the channel. The signals which are weak may not reach the receiver as the noisy channel conditions degrade the original signal up to extreme case.

So, a digital LIA can be used for the recovery of the weak signals at the receiver. LIA is used for the null detection in AC bridge measurement systems. The lock-in amplifier implemented in a microcontroller-based DSP is inexpensive, portable and customizable.The implementation of digital LIA is feasible only when the frequency of the reference signal is in the range of a few kilohertz. In that case the analog signal can be converted into digital signal by using ADCs and DSPs. To convert an analog signal into digital signal the sampling frequency must be at least twice the frequency of the input signal.

However, if frequency of the reference signal is in megahertzrange, then applying ADC and DSP on such signal may not be feasible due to the technical.A lock-in-amplifier is a device which can extract a signal of interest at a specific frequency from an output signal which significant noise levels at other frequencies.

A lock-in-amplifier is to increase the signal to the input signal at a specific frequency and by filtering the other frequencies which contains the noise.An input signal is given to amplifier which amplifies the signal strength. And thereby it is given to band pass filter which filters the unwanted frequencies according to the data send. The summer is attached to this band pass filter which sums up the reference signal and the band pass filter output. The output of this summer is given to the low pass filter which helps in filter the noise in the data received.

ADVANTAGES

The advantageby improving the frequency resolution is removing the distortion from a signal. By applying the sampling frequency, twice the frequency of the input signal, results in better understanding of the signal and also helps in increasing the signal strength. It also helps in removing the noise levels at different harmonic levels.

This approach can also be applied in embedded design to measure frequency dependent sensors. It is also used in scientific instrumentation such as scanning probe microscopes. It requires less bandwidth. It also works at low power consumption. It is low cost. It gives high performance. It is inexpensive, portable and customizable.

CONCLUSION

We can extract an original signal from a noisy environment without any loss of data with the help of two phase two channel lock-in-amplifier. Dithering is involved in this process and only at the times when the bit depth of a signal is being reduced. The disadvantage of the traditional amplifiers in which do not provide satisfactory results in a highly degraded noise scenarios is also resolved. Such noise scenarios lead to poor signal-to-noise ratio. It also resolved in by this approach and the signal-to-noise ratio is improved. Here we conclude that the enhancement of frequency resolution is achieved and the average error can be reduced with help of sine and cosine reference signals.

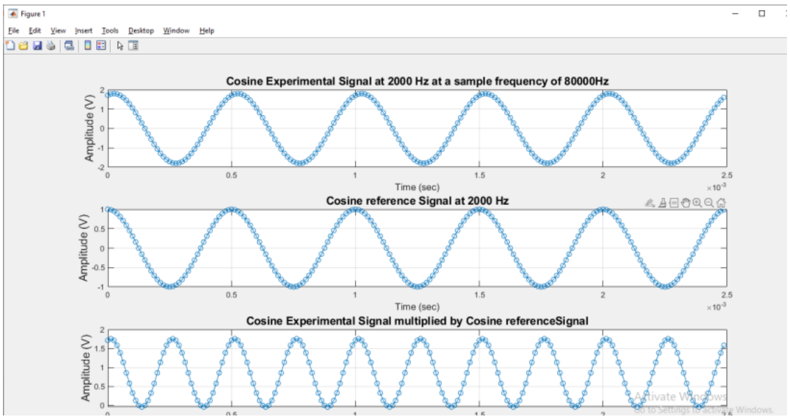

Fig. 5.1 Multiplication of cosine reference signal with cosine experimental signal

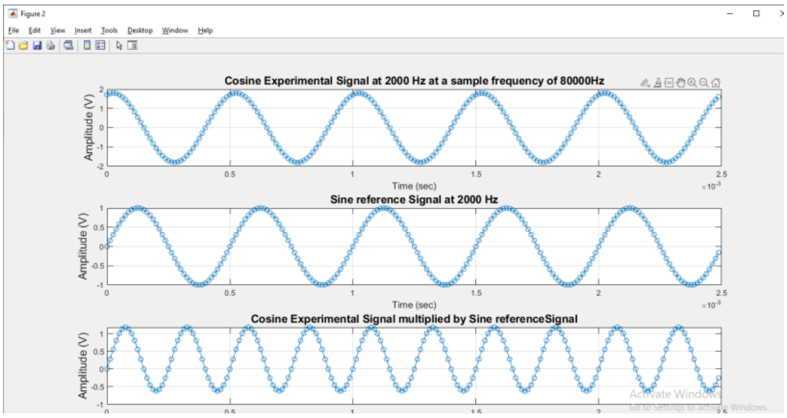

Fig. 5.2 Multiplication of sine reference signal with cosine experimental signal

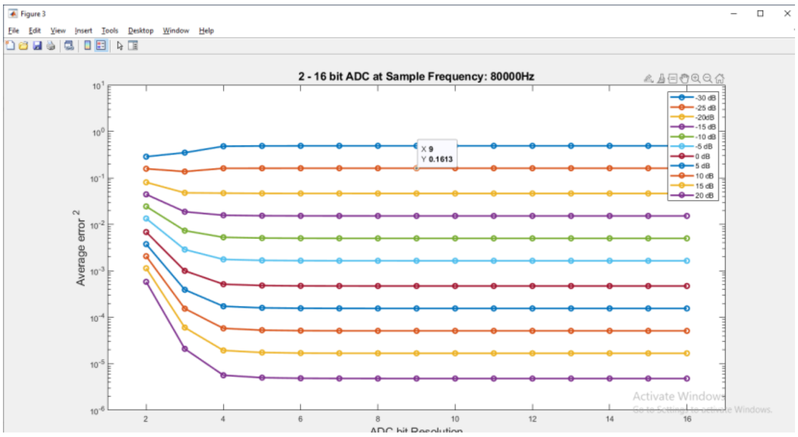

Fig. 5.3 ADC Bit Resolution Vs Average error

FUTURE SCOPE

The parameters of lock-in as gain, dynamic reserve and noise can be tailored using different input circuits and better ADCs, making this approach interesting for implementation of LIAs in embedded systems or in general experiments at the laboratory where an inexpensive lock-in with fine frequency resolution is needed.

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