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Procedia Computer Science 93 (2016) 585 – 593

Procedia Computer Science

6th International Conference on Advances in Computing & Communications, ICACC 2016, 6-8 September 2016, Cochin, India

Significance of a low noise preamplifier and filter stage for under water imaging applications

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Abstract

High frequencies of the order of hundreds of kHz to MHz are employed for underwater imaging applications. Signal to noise ratios encountered for the front end receiver sections are seen to be very much reduced for these applications. Hence a low noise preamplifier and filter stage is very essential prior to the conventional antialiasing and digitization functionalities of the front end receivers. In this paper, an attempt is made to design and develop a low noise pre amplifier and filter to achieve a better SNR for the system. The pre amplifier stage designed is interfaced with hydrophones directly for gain and impedance matching purposes. The noise reduction is further achieved by means of a filter following the preamplifier stage which rejects the out of the band noise to an optimum level. Thorough study and analysis is carried out in this paper for the selection of low noise opamps, associated passive components and configuration of the preamplifier sections. Acoustic measurements are carried out for a sensor array of 150 kHz for evaluating the preamplifier and filter performance in the real scenario.

Peer-review under responsibility of the Organizing Committee of ICACC 2016

Keywords: Voltage noise;Current noise;Bandpass filter;Op-amp configuration

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Peer-review under responsibility of the Organizing Committee of ICACC 2016
doi:10.1016/j.procs.2016.07.241

1. Introduction

Imaging sonar operating in the very high frequency ranges has to be compact and portable as the application demands in certain cases. Hence the receiver section of imaging sonar is designed with a signal conditioner unit which comprises the following blocks namely preamplifier, filter, compact analog front end module (AFE) and a controller section.

Output from the sensor drives to a preamplifier and filter, which provides the complete analog signal conditioning functions required between a sonar hydrophone and an analog to digital converter (ADC) including a) conversion of impedance of the hydrophone to a lower value to match with the impedance of the measuring instrument used and b) amplification of the relatively weak output signal from the hydrophone. The critical features of the preamplifier include low input noise, high input impedance, high dynamic range and first stage gain.

The preamplifier output, which is a combination of signal and noise, goes to a filter, which filters out the noise outside the sonar frequency band and thus improves the Signal to Noise Ratio (SNR).The block diagram of a front end receiver for underwater imaging system is shown in Fig 1.

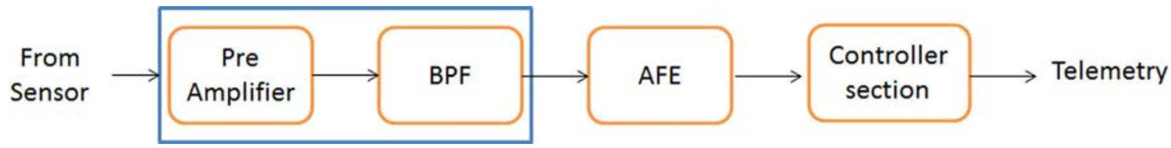

Fig 1: Block diagram of front end receiver of an underwater imaging sonar

The filtered output is fed to Analog Front-End (AFE) [4] solution, which is specifically designed for high frequency systems where high performance and compact size are required. It mainly integrates a low noise amplifier (LNA), voltage controlled attenuator (VCAT), programmable gain amplifier (PGA), low pass filter (LPF) and an analog to digital converter (ADC).

The controller section provides the logic controls for AFE and configures the data for interfacing with efficient telemetry schemes. The output from the controller is sent to the remote signal-processing unit using defined telemetry system.

This paper is dedicated to the design, development and testing of preamplifier and filter circuits preceding AFE and controller section.

2. Criticality of first stage preamplifier and filter section

Medical applications interfaces analog front end modules (AFE) comprising of antialiasing filters and ADCs directly with sensors for ultrasonic imaging purposes. The signal to noise ratios encountered by these applications are much better when compared to that of underwater applications mainly due to limited ranges of operation in the orders of centimeters of length. For underwater applications, as range increases signals get attenuated to a high degree due to the propagation losses depending on the conditions in which it is operated such as the ocean or turbid water environment. Also the sensitivity and capacitance of these very high frequency sensors are found to be reduced when compared with their low frequency counterparts. The reduced sensitivity further places restrictions on the availability of the minimum signal received by the systems in presence of ambient noise. Hence the signal encountered here should be enhanced to a sufficient level which can be taken by the conventional receiver systems to prevent the degradation