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Low-Cost Hardware Solution for Signal Conditioning in Underwater Acoustic Communication Systems

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Abstract – In this paper, a low-cost hardware solution for signal conditioning in underwater acoustic communications systems is present. It allows the detection of PPM and FSK modulations and can be reconfigured or adapted to the working frequencies of the final acoustic application. The proposed solution is particularly relevant for acoustic monitoring systems requiring large-scale deployments.

Keywords: signal conditioning, underwater communications, acoustic receivers, modulations

I. INTRODUCTION

Acoustic modems are widely used underwater for their reliability, but their specialized hardware can be costly and restrict experimentation with different modulations. On the other hand, software-defined acoustic radios offer flexibility in signal processing but come with higher acquisition costs and energy consumption due to their computational demands [1].

In scenarios where off-the-shelf solutions don't fit budget constraints or specific requirements for large-scale deployments, custom-designed electronics optimized for simpler acoustic contexts can offer a balanced solution, providing functionality, performance, and cost-effectiveness.

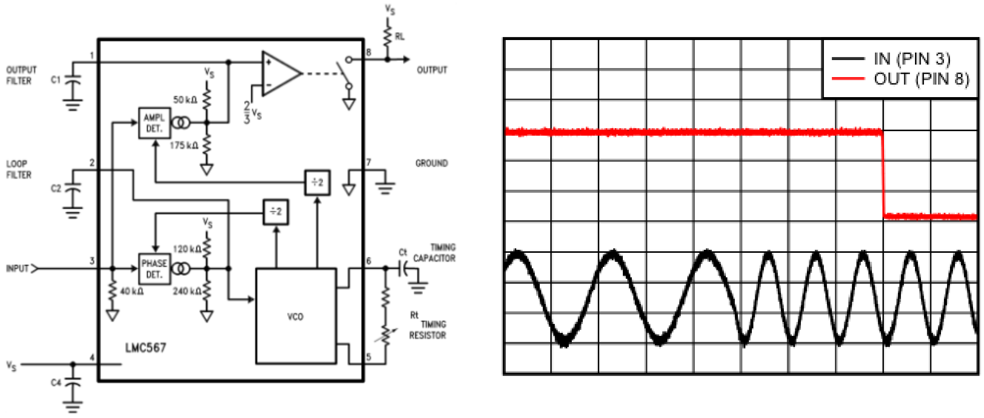
II. CARRIER DETECTION

The process of carrier detection can be implemented by software using techniques such as signal correlation, digital filters or FFT (Fast Fourier Transform) [2]. Some techniques may be less demanding in terms of power compared to others which may require more computational resources [3][4].

In this work, we propose to perform the carrier detection by hardware. The solution involves using integrated circuits designed for tone detection, such the LMC567 [5]. The IC is a low power, general purpose tone decoder that provides a digital signal when the tone is detected. The device consists of a twice frequency voltage-controlled oscillator (VCO) and quadrature dividers which establish the reference signals for phase and amplitude detectors. This chip is primarily used as tone decoder in a variety of applications such as telecommunication systems, DTMF (Dual Tone Multi-Frequency) detectors, remote controls and audio.

The LMC567 allows configuring the centre frequency of the detector 1Hz to 500 kHz, range that fully covers the spectrum of acoustic signal frequencies commonly used in acoustic communication systems, typically ranging from 20 kHz to 200 kHz.

With different external components - resistors and capacitors, the central detection frequency, bandwidth, and output delay can be configured, as can be observed in the following figure.



C_1 *tradeoff between slew rate and carrier ripple at the output comparator*

$$fo = \frac{1}{2.8 \cdot Rt \cdot Ct} \, [Hz]; \, BW = 0.5 \cdot fo \cdot C_2;$$

Fig 1 LMC567 Application schematic, involved equations and the output signal upon detecting the tone configured

III. HARDWARE SOLUTION

The proposed hardware consists of two amplifier stages before the tone detection is performed. The amplifier stages should be designed to amplify the range of frequencies of interest while maintaining a high signal to noise ratio (SNR). The tone detector circuit can be replicated to detect multiple carriers, thus covering different FSK modulation schemes. For single-carrier detection, such as PPM modulation, the design would be based on a single tone detector, as observed in Figure 2.

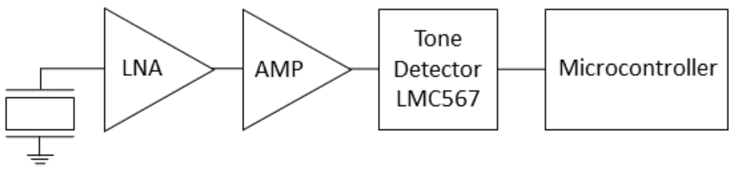


Fig 2 Proposed hardware solution based on: LNA (Low Noise Amplifier), AMP (Amplifier), Tone detector and microcrontoller

Minimal requirements are needed for the microcontroller. It should be capable of processing edge-triggered interrupts for signal transitions and computing signal time durations, tasks achievable with timers—capabilities readily available in even basic microcontrollers.

IV. CONCLUSIONS

The solution presented allows the detection of FSK or PPM signals across the spectrum of frequencies that are commonly used in underwater acoustic communications.

To set up the detector, only four components are required: resistors and capacitors according to the equations presented. To detect PPM signals, only one detector is needed. To detect FSK signals, are required as many detectors as carriers in the modulation.

This cost-effective solution is suitable for projects with tight budgets, especially those requiring extensive deployment of acoustic devices.

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