Demo: MuLink: Compact Acoustic Transceivers for Underwater Environments

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ABSTRACT

Acoustic methods are commonly used for sensing and communications in the underwater environment. Various acoustic modems are commercially available, but these existing solutions tend to be large and consume a significant amount of power. Miniaturization of devices is a major trend, and it leads to several advantages, namely low cost, low power consumption, and small space requirements. We are developing a compact low-cost prototype design for a pair of acoustic transmitter and receiver units. The transmitter transmits a 161 kHz signal. The receiver measures the strength of the received signal. The immediate applications include acoustic waveform transmissions, ranging, and communications.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**; • **Hardware-Signal processing systems**;

KEYWORDS

Underwater acoustic communication, transducers, waveform transmissions, embedded systems

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1 SYSTEM DESCRIPTION

The MuLink device is comprised of a transmitter unit and a receiver unit. The transmitter unit emits a signal through a transducer, which is received by two transducers acting as hydrophone elements on the receiver unit. The signal takes a path from the transmitter to the receiver as depicted in Fig. 1. All three transducers have a resonant frequency of 161 kHz. and a bandwidth of approximately 10 kHz.

1.1 Transmitter Unit

1.1.1 Hardware. The transmitter unit features five components: a microcontroller, a real-time clock (RTC), and a 12-bit high-speed digital to analog converter (DAC), a battery, and a transducer. The 125 MHz Raspberry Pi Pico is used as the microcontroller. It is a compact-size, low-power dual-core processor featuring an RTC, an SPI controller, an I2C controller, and plenty of GPIO pins for interfacing with the DAC. The microcontroller sends digital samples to the DAC at a rate of 15.6 Msps paced by the RTC. The DAC converts the digital samples to corresponding voltages on the output terminals, which causes a signal to be emitted from the connected transducer.

1.1.2 Software. The microcontroller runs a program called *WaveGenerator.app*. This program calculates the samples that are sent to the DAC at startup. Once this calculation is finished, *WaveGenerator.app* begins sending the samples to the DAC in an infinite loop, using the RTC to pace the sending of the digital samples. A 161 kHz AC sine wave is generated at the output terminals of the DAC at 883 mVrms, which then gets emitted by the attached transducer.

1.2 Receiver Unit

1.2.1 Hardware. The receiver unit have seven major components: a microcontroller, a high-frequency analog-to-digital converter (ADC), an display screen, an operational amplifier circuit, a battery, and two high-frequency transducers. As in the transmitter unit, the Raspberry Pi Pico serves the microcontroller. The acoustic signal is first collected by the receiving transducers, which convert the acoustic signals to electrical signals. The electrical signals are then fed into the operational amplifier circuit, which has a gain of approximately 50 dB. The amplified signals then flow to the inputs of the ADC and then are processed by the microcontroller.

1.2.2 Software. The microcontroller contains two programs which alternate between processing signals from transducer 1 and 2 for receiving diversity: *ADCCapture.app* and *FFT.app*. *ADCCapture.app* triggers the ADC to sample at 500 ksps until the ADC accumulates 256 samples. The captured 256 samples are then passed to *FFT.app*, which performs a Fast Fourier Transform on these samples. *FFT.app* takes the highest value from a narrow band of frequencies around 161 kHz, and displays the raw captured values for transducer 1 and 2 on an attached information display. The raw FFT values displayed on the screen correlate linearly with the voltage in Vrms of the 161kHz component of the amplified signal.

As distance between transmitter and receiver increases, the FFT output value decreases accordingly. We can use this relationship to roughly estimate the relative distance between the transmitter and receiver units.

1.3 Test Results

To test the measurement capabilities of the devices, we conducted tests in a lake environment, where a PVC pipe was used to hold two receiver transducers approximately 1 meter away from one another,

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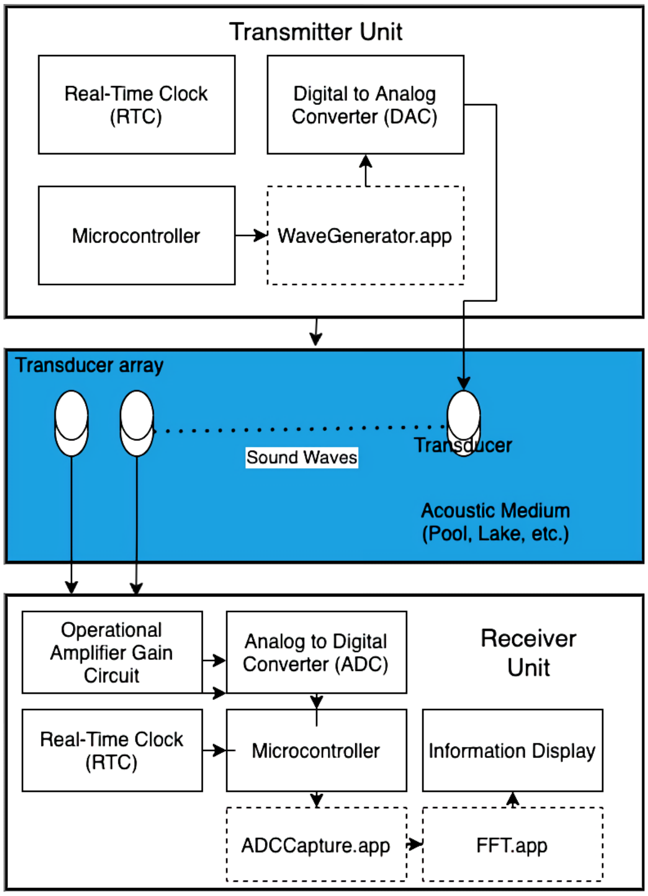

Figure 1: System diagram: Transmitter and receiver units.

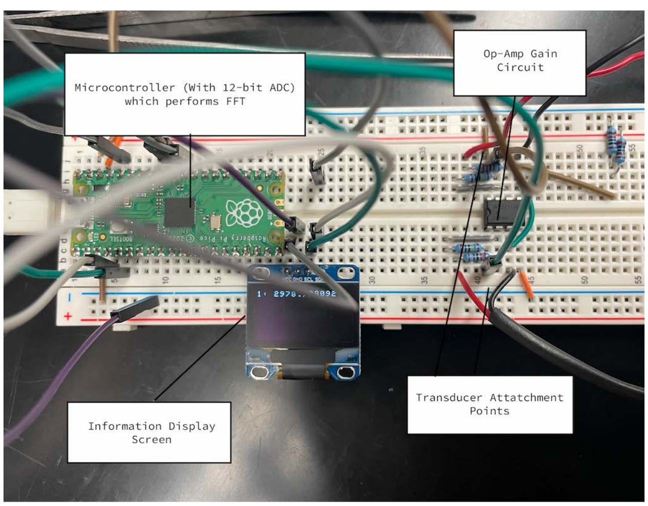

Figure 2: The receiver unit with major components labeled.

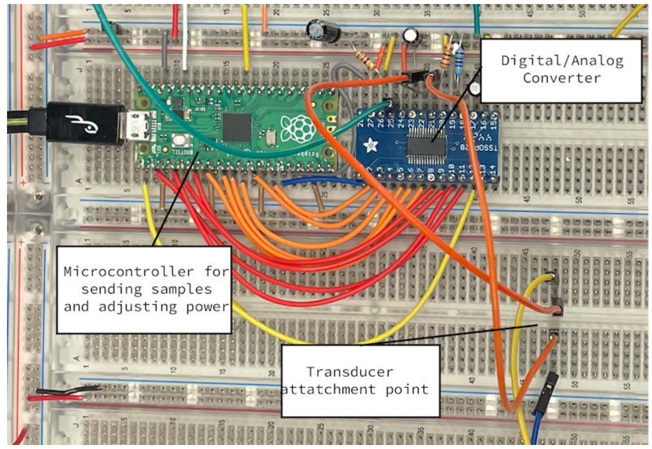

Figure 3: The transmitter unit with major components labeled.

with an additional PVC used to hold the transmission transducer separately. We were able to test the signal strength reception at a few known distances and compare them to levels measured by a wide-band digital hydrophone at the same distances. The current iteration of the transmitter reliably detected the transmitter signal at least 12 meters away from the source, with signal strength decreasing logarithmically over increased distances.

2 DEMONSTRATION PLAN

Our plan currently is to perform the demonstration in a swimming pool, if available. As an alternative away, we could use a tank to perform the demonstration. We will use a setup similar to our experimental setup to move the transducers, where we used a length of PVC pipe to manually position the transducers in the water. Our goal is to successfully demonstrate functions of the transmitter and receiver unit and their applications.

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