Hydrophones

We use our hydrophones to locate the pinger in the pool, which can be utilized for localization purposes.

Introduction

The purpose of this page is to describe how the arrival times are acquired on a number of hydrophone channels. This documentation does *not* describe how that information is turned into bearings or how it is used in localization.

The arrival time calculations tend to be complicated by noise, which means that it is not possible to trivially detect rising edges. The ping can be thought of as an identical signal arriving slightly later on each of the hydrophones. In order to accurately calculate the time differences between each signal, a cross correlation is used. A cross correlation essentially slides one signal over the top of another, and at the point where the signals maximally overlap, the amount of shifting needed is equal to the time delay of the signal.

Further simplifications can be applied to the problem as well. By ensuring that the hydrophones are close enough, it can be guaranteed that the arrival time difference will never exceed one half wavelength. Therefore, the cross correlation only needs to be completed within +/- half a wavelength. The signals occur at a maximum frequency of approximately 40KHz, which means that the arrival time difference can never exceed approximately 12.5 microseconds. This means that the hydrophones must be spaced within 1.8cm of each other due to the speed of sound in water.

Now that the theoretical aspects are out of the way, the foundation of the problem starts to take shape. 1) Acquire signals on all four hydrophones (one reference and 3 along each X, Y, and Z axis) 2) Cross-correlate the X, Y, and Z axis signals against the reference to calculate time of flight delay.

The cross correlation step is simple mathematics. Note that cross-correlation boils down to multiplying individual points of two signals together and accumulating, so if the signals are big it can take quite a bit of time. We will discuss how to handle this later.

The main difficulty exists in sampling the signals. It is important that samples are taken simultaneously on each of the hydrophones and that the signals are sampled fast enough to ensure that the precision in time of flight is accurate enough (for example, at a sampling frequency of 1MHz, the time of arrival can never be more precise than a signal microsecond). Therefore, the system must be capable of simultaneously sampling four channels at a minimum rate of 1MHz.

Hardware

Device	Part Number	Datasheet
Processor Carrier Board	MicroZed	Datasheet
Main Processor	XC7Z010	Datasheet
Hydrophones	AS-1	Datasheet
Analog-to-Digital Converter	LTC2171-14	Datasheet

System Design