Two-channel underwater acoustic recorder

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Contents

1 Overview

This document describes the design and operation of a 2-channel acoustic recording system designed to be deployed at shallow depths ($\sim$ 10 m) and for limited duration ($\sim$ 10 hours). The total cost of all components is about $1500 US. The watertight housing was purchased from BlueRobotics, and the signal acquisition is largely handled by a TASCAM DR-40X handheld recorder. An Adafruit Feather microcontroller enables the TASCAM to be powered on and off, and recordings to be started and stopped, with a single external switch.

2 Design

2.1 Housing

The entire system is housed in a 4" diameter watertight enclosure (300 mm length) from BlueRobotics. The various internal components are fastened to a BlueRobotics electronics tray. New holes were drilled in the tray to fasten the TASCAM DR-40X and Adafruit Feather, while the Talentcell battery pack and High-impedance buffers were attached with Velcro strips.

2.2 Power distribution

The power source for the system is a Talentcell 12V 3000 mAh Lithium ion USB battery pack. This specific battery was chosen for two reasons. First, its form factor allows it to fit inside the pressure housing with the electronics tray installed. Second, it has a physical on/off switch and does not power off automatically after a period of no current draw. This is important because an important feature, because a USB pack that does power off automatically might shut down when the system is in sleep mode and then not allow it to wake and turn on when the switch is turned.

2.3 TASCAM control

A BlueRobotics switch on the outside of the watertight housing allows the user to start and stop recordings while in the field without opening the watertight housing. The switch is connected to an Adafruit Feather M0 Adalogger microcontroller, which turns the TASCAM on and off and starts and stops recordings.

2.3.1 Switch

The switch is open when the knob is loosened by being turned to the left, and connected when the knob is tightened by being turned to the right. (See figure 2). One terminal of the switch is connected to ground of the Feather, and the other is connected to an I/O pin set to input pull-up mode. The Feather detects changes in the position of the switch and then communicates to the TASCAM to tell it to turn on and start recording, or stop recording and turn off.

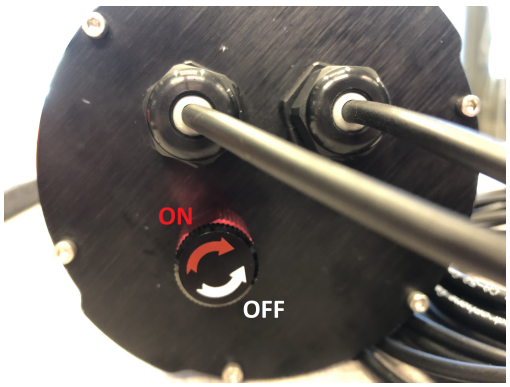

Figure 2: Picture of the end plate of the enclosure showing the switch and bulkhead penetrators.

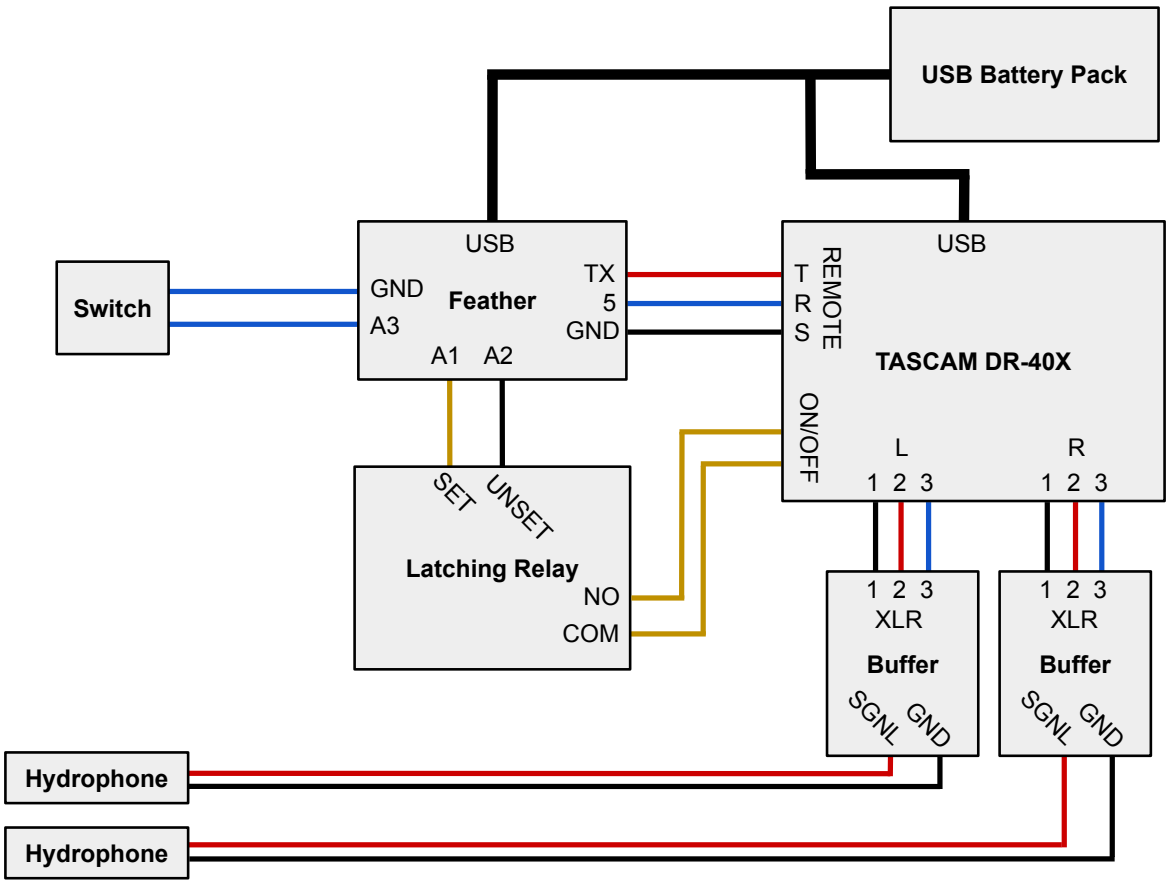

Figure 1: Schematic showing the connections between the various components of the underwater recorders. The thick black lines represent USB cables supplying power, while the thinner lines represent individual signal wires. T, R, S on the remote jack stand for Tip, Ring, Sleeve.

2.3.2 TASCAM on/off

Ordinarily, the TASCAM DR-40X requires a physical button press to turn on or off. In order to circumvent this, wires are soldered to each of the two contacts that are shorted by the physical button press (this requires some disassembly and reassembly of the TASCAM), and connected to the Latching Relay FeatherWing. This enables the Feather to turn the TASCAM power on and off by switching the relay between connected and open.

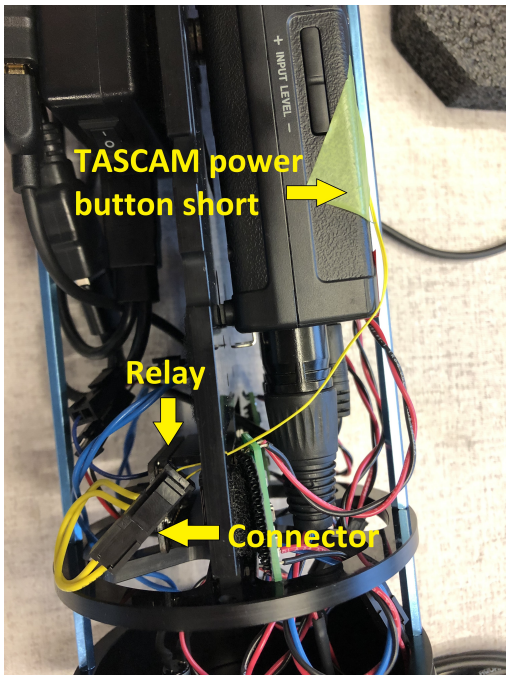

Figure 3: Picture showing the wires running from the relay to the TASCAM which enable the feather to turn the TASCAM on and off.

2.3.3 RC-10 remote emulator

The TASCAM DR-40X is designed to be controllable by a wired remote which plugs into a 1/8" jack port on the TASCAM. We made use of Christopher Willams' Github repository, `https://github.com/abbrev/tascam-rc-10-remote`, to allow the Adafruit Feather to emulate this remote and send commands to the TASCAM to start and stop recordings. The code running on the Feather is available from my own Github repository: `https://github.com/haydenallenjohnson/underwater_acoustic_recorder`.

Figure 4: Picture of the 1/8" TRS jack cable which plugs into the TASCAM to allow the Feather to emulate the RC-10 remote.

2.4 Acoustic signals

2.4.1 Hydrophones

The acoustic data is collected by two Aquarian Scientific AS-1 hydrophones, which have a sensitivity of -208 dB referenced to 1 V/μPa. These hydrophones do not have preamplifiers installed, which allows us to obtain this low sensitivity value and avoid saturating the hydrophones themselves.

2.4.2 High-impedance buffers

To allow the unamplified hydrophones to drive the TASCAM inputs, the signals are fed into high-impedance unity-gain buffers, purchased from JLI Electronics. The buffers are powered by 24 V phantom power fed from the XLR inputs of the TASCAM.

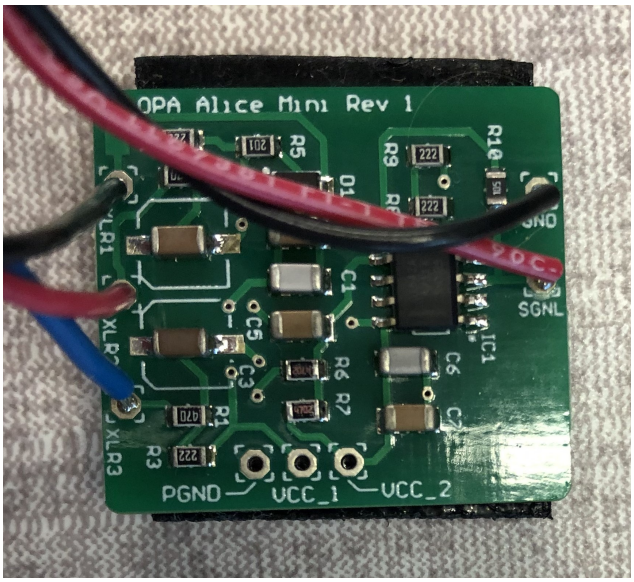

Figure 5: High-impedance unity gain buffer from JLI electronics, with wires connected to the terminals.

3 Operation

3.1 Initial setup

3.1.1 Internal AA batteries

The TASCAM DR-40X holds three AA batteries, which should be installed so that the recorder clock will not need to be reset every time the external battery pack is disconnected. The battery compartment is accessible from the back of the TASCAM. To access it, unscrew the 1/4-20 bolt holding the TASCAM in place. (Disconnecting the yellow power switch wires, the remote jack, and the XLR plugs is not strictly necessary, but will make the process easier.)

Once the internal batteries are inserted, disconnect the yellow power switch wires (if they haven't been disconnected already), and turn the TASCAM on by holding down the "Home" button for about 3 seconds. The TASCAM will prompt you to set the system time. As long as the internal batteries are not removed or exhausted, the time will not need to be set again. The TASCAM will also prompt you to accept phantom power; select "ENTER" for yes.

3.2 Settings

The suggested or required selections for relevant settings are listed in this section for reference purposes. Whether they are set by physical switches or through the user interface, all of these settings should retain their values even when the TASCAM is powered off and has its batteries removed.

3.2.1 External Input switch

The switch labeled "EXT IN" on the left side of the TASCAM should be set to "MIC + PHANTOM". This tells the TASCAM to take input from the XLR jacks, and to send phantom power over those inputs to power the buffers.

3.2.2 Input Level

The pair of connected buttons labeled "INPUT LEVEL" on the left side of the TASCAM is used to control the variable gain of the TASCAM. When one of them is pressed, a box which says "EXT IN LVL" and displays a bar with the current value will appear at the bottom of the screen. The input level can vary between 0 and 90, and should be chosen to be as high as possible without causing the signal to clip (this likely requires some empirical testing based on the specific application). See appendix A for details about converting the recorded signal to physical units.

Figure 6: TASCAM display when the input level is adjusted. The bar at the bottom appears temporarily and shows the current input level value on the right side.

3.2.3 REC SETTING

Accessed by clicking the "MENU" button, then selecting "REC SETTING".

"FORMAT" specifies the file format to use. Recommended setting is "WAV 16bit". Although 24-bit is an option, the extra 8 bits seem to just be system noise, and therefore only serve to increase file size without increasing the effective resolution.

"SAMPLE" specifies the sampling rate. Recommended setting is "96k", for 96 kHz.

All other settings other "REC SETTING" should be set to "OFF". (The "AUTO REC" and "AUTO TONE" level settings still show up even if they are set to off, but they don't matter.)

3.2.4 I/O SETTING

Accessed by clicking the "MENU" button, then selecting "I/O SETTING".

"LEVEL MODE" should be set to "MANUAL", and all others should be set to "OFF".

3.2.5 File names

Path: MENU/OTHERS/FILE NAME. Allows you to specify the naming convention for audio files.

3.2.6 System date and time

Accessed by selecting "MENU", then "OTHERS", then "DATETIME". Allows you to set the system time.

3.2.7 Phantom power voltage

Accessed by selecting "MENU", then "SYSTEM". "PHANTOM VOLT" should be set to "24V".

3.2.8 REMOTE

Accessed by selecting MENU/OTHERS/REMOTE. "CONTROLLER" should be set to "RC-10".

3.2.9 REC MODE

Accessed by pressing the "REC MODE" button on the front face of the TASCAM. "REC MODE" should be set to stereo to record on both channels, and "SOURCE" should be set to "EXT IN L/R". "MS DECODE" should be set to "OFF".

3.3 Pre-deployment

Before deploying the recorder:

- Charge the Talentcell USB battery pack (5 green dots indicates a full charge) and place its switch in the "on" position.
- Ensure that the TASCAM and the Feather both have their USB cables plugged in to the battery pack.
- Check that all signal wires are connected.
- Make sure there is an SD card loaded into the TASCAM and that it has adequate storage space available.
- Check the O-rings on the flanges and clean, apply grease, and/or replace as necessary.
- Close the pressure case. By unscrewing the switch all the way and pulling it out, a make-shift pressure release valve can be created. (Remember to put the switch back in and tighten it most of the way.)

3.4 Deployment

3.4.1 Start recording

Twist the external switch clockwise ("righty-tighty") until it becomes tight. This will trigger the start-up sequence from the Feather which will turn on the TASCAM, accept phantom power, and tell it to start recording by clicking "RECORD" twice. The entire process takes about 15 seconds. You can watch the TASCAM screen to verify that it has started recording. The red light around the record button will be illuminated continuously, and there will be a timer counting up from zero on the display.

Figure 7: TASCAM display after the first (real or simulated) press of the "record" button. The red light around the "record" button will be flashing, but the tascam is not yet recording.

Figure 8: TASCAM display after the second (real or simulated) press of the "record" button. The red light around the "record" button will be solidly illuminated, and the recording time clock will be counting up. The TASCAM is now recording.

3.4.2 Stop recording

Twist the external switch counter-clockwise ("lefty-loosey") about 1/2 turn or more. This will trigger the shut down sequence from the Feather, which will tell the TASCAM to stop recording and then turn off. The shut down sequence takes about 15 seconds.

3.4.3 Troubleshooting in the field

In the event that the TASCAM fails to turn on and/or start recording when the switch is turned to the "on" position, the recording can be started manually by opening the BlueRobotics case, disconnecting the yellow wires and the remote jack, and using the TASCAM interface directly to power it on and start the recording. The case can then be sealed and the system deployed.

3.5 Post-deployment

After deploying the recorder:

- Rinse off the casing and hydrophones with fresh water.
- Download the data from the SD card.
- Charge the Talentcell USB battery pack.

A TASCAM gain

The TASCAM has an adjustable input level setting, discussed in section 3.2.2. To calibrate the system and determine the gain as a function of input level, we fed a generated sinusoidal signal of known amplitude and 1 kHz frequency through a capacitor and into the signal input of the high-impedance buffer (with the ground connected as well). The results of this calibration are shown in figure 9. The gain of the combined buffer and TASCAM system G as a function of the input level L is well-approximated by equation 1,

$$G(L) = 1.816(1.059)^L. \tag{1}$$

The pressure at the hydrophone can then be computed from the measured signal at the TASCAM v as

$$p = \frac{10^{(-S_{\mathrm{dB}}/20)-6}}{G(L)} v, \tag{2}$$

where S_{dB} is the hydrophone sensitivity in units of dB referenced to 1 V/μPa. (Note that v here is defined such that it has a range of -1 to 1, which is how wav files are read by some software, including MATLAB. In other cases it may be necessary to divide the raw output by the number of bits.)

For the AS-1 hydrophones with $S_{\mathrm{dB}} = -208$, equation 2 becomes

$$p = \frac{25119}{G(L)} v. \tag{3}$$

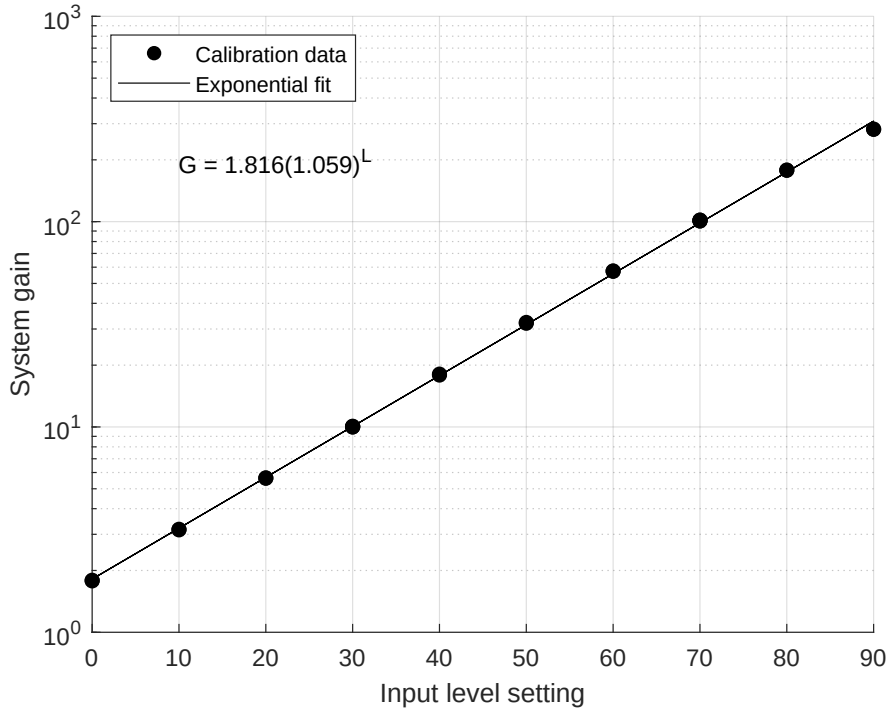

Figure 9: TASCAM and buffer combined gain G as a function of the TASCAM input level setting L. The circles represent data points where the gain was measured, and the line is an exponential fit to this data.

B List of components

B.1 BlueRobotics

- 4" Diameter Watertight Enclosure (300 mm length). `https://bluerobotics.com/store/watertight-enclosures/wte-vp/#tube`
- Switch. `https://bluerobotics.com/store/comm-control-power/switch/switch-10-5a-r1/`
- Electronics Tray (4" series). `https://bluerobotics.com/store/watertight-enclosures/locking-series/wte4-etray-r1/`

B.2 Electronics

- TASCAM DR-40X handheld recorder. `https://tascam.com/us/product/dr-40x/top`
- Adafruit Feather M0 Adalogger. `https://learn.adafruit.com/adafruit-feather-m0-adalogger/overview`
- Adafruit Latching Mini Relay FeatherWing. `https://www.adafruit.com/product/2923`
- JLI Electronics High-impedance Buffer (x2). `https://www.jlielectronics.com/diy-accessories/p48-hi-z-piezo-buffer/`

B.3 Other

- Aquarian Scientific AS-1 Hydrophone (x2). `https://www.aquarianaudio.com/as-1-hydrophone.html`
- Plastic submersible cord grips (x2). `https://www.mcmaster.com/products/glands/compact-plastic-submersible-`

- Talentcell Rechargeable 12V 3000 mAh Lithium ion battery pack. https://www.amazon.com/TalentCell-Rechargeabl
dp/B01M7Z9Z1N/ref=asc_df_B01M7Z9Z1N?tag=bingshoppinga-20&linkCode=df0&hvadid=80058245652972&
hvnetw=o&hvqmt=e&hvbmt=be&hvdev=c&hvlocint=&hvlocphy=&hvtargid=pla-458365783058449 9&psc=
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