Monterey Bay Aquarium Research Institute

Shark Café Cam: The Journey to Open Source (DRAFT)

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ABSTRACT

Awareness for white shark (*Carcharodon carcharias*) conservation has been increasing. With new studies conducted in the last ten years, researcher are detecting behaviors that prompt the question, what is happening underwater? Behavior-triggered animal tags with video recording capabilities have been developed to try and glimpse under the surface activity. These systems are expensive and niche due to their novelty. This pushed the MBARI engineers, which helped develop one of the first iterations of this camera, to open source a behavior triggered animal camera with the purpose of offering a lower cost version, gaining community collaboration, and making the information available to biologist researchers. This summer I was trained in software and electrical engineering to gain the skills necessary to open source this build. We created, and are in the process of publicizing the Shark Café Cam GitHub.

INTRODUCTION

As animal endangerment awareness and advocacy increases in the ocean there is a need for understanding movement and behavior of a variety of species (Friedrich et al., 2014). Knowledge that's been kept out of reach due to the inability to track what happens with marine animals over time, distance, and depth (Jewell et al. 2019). This was true for the very popular great white shark (*Carcharodon carcharias*). Twenty years ago little was known about them. In 2012 Dr. Sal Jorgensen published an article showing white shark migration to an area between the coast of California and Hawaii and vertical movement while in the area. This area was named the White Shark Café.

Wanting to learn more Dr. Salvador Jorgensen went to MBARI for help with designing a device that would allow him to record video of white sharks the White Shark Café. In this area white sharks gather every year for several weeks. During their stay they were found to exhibit a strange diving behavior in which they dive down to 250m then rapidly swim back up to near surface and repeat. MBARI engineers Thom Maughan and Larry Bird teamed up with Dr. Jorgensen to build device capable of attaching onto a shark and record video when they are exhibiting this behavior.

A few years later Maughan and Bird decided to try and open source the material for building the behavior triggered camera with the goal of making the information available to everyone.

This year I joined their team to help document the procedure for building the camera. With no prior experience in software and electrical engineering every step I took and documented in the open source would be more relatable and closer to the knowledge level of a biologist wanting to build the camera.

MATERIALS AND METHODS

Building a Component Based Foundation in Electronics and Software

We started with individual components, resistors, diodes, and batteries. A component was studied, implemented into a circuit and tested in various ways. Once a component was understood, we'd move on to the next. For software we began with Arduino example code 'Blink' and 'hello world.'

Batteries, current, and resistance

We began with a red LED and a 9v battery. The first task was to find a way to turn the LED on. The LED was connected straight to the battery, blown, and then disconnected. Battery temperature was monitored through an infrared FLIR camera and the results were recorded and discussed. Then, current, voltage and resistance were introduced. Datasheets were introduced and found for the LED and the battery.

$$V= IR$$

V(volts)=I(amps)R(resistance) was used to calculate resistance needed for the 15mA red LED and 9v battery. A 600Ω resistor was chosen.

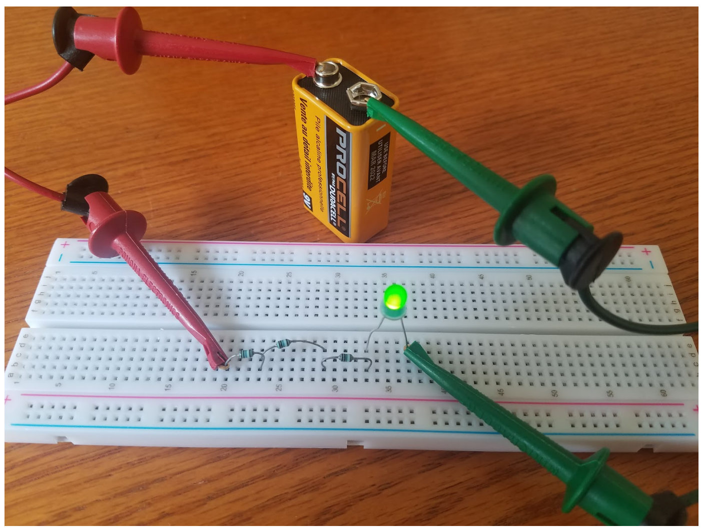

Figure 1: Above, 600 ohms of resistance gained by combining three 200ohm resistors in series, a green LED that takes 15-20mA and a 9v battery in a circuit. Alligator clips allow connection to be established between the battery, the resistors, and the LED, the green wire is (-), and the red is (+).

Multimeters were introduced as a testing tool to measure voltage, current, and resistance.

Microcontrollers as programmable batteries

To learn how software interacts with hardware in an embedded system a microcontroller was used. The Adafruit Feather M0 was selected for its low cost, low power consumption, integrated SD card reader, and most importantly because it uses the same processor as the shark café cam board. The arduino IDE was installed to allow for communication with the board. To test communication, we called the digitalWrite function to turn the built-in LEDs on and off.

```
digitalWrite(LED_BUILTIN, HIGH);
```

Figure 2: An Arduino function that turns the built-in LED on.

A "hello world" prompt was also sent to the serial monitor to test for serial communication.

Figure 3: 'Hello World' text printed on the Arduino serial monitor. The text confirms successful communication between the board and your computer.

Understanding written schematics

Schematic symbols for electrical components were looked up on a need-to-know basis as circuit communication and recording became important.

'Blink'

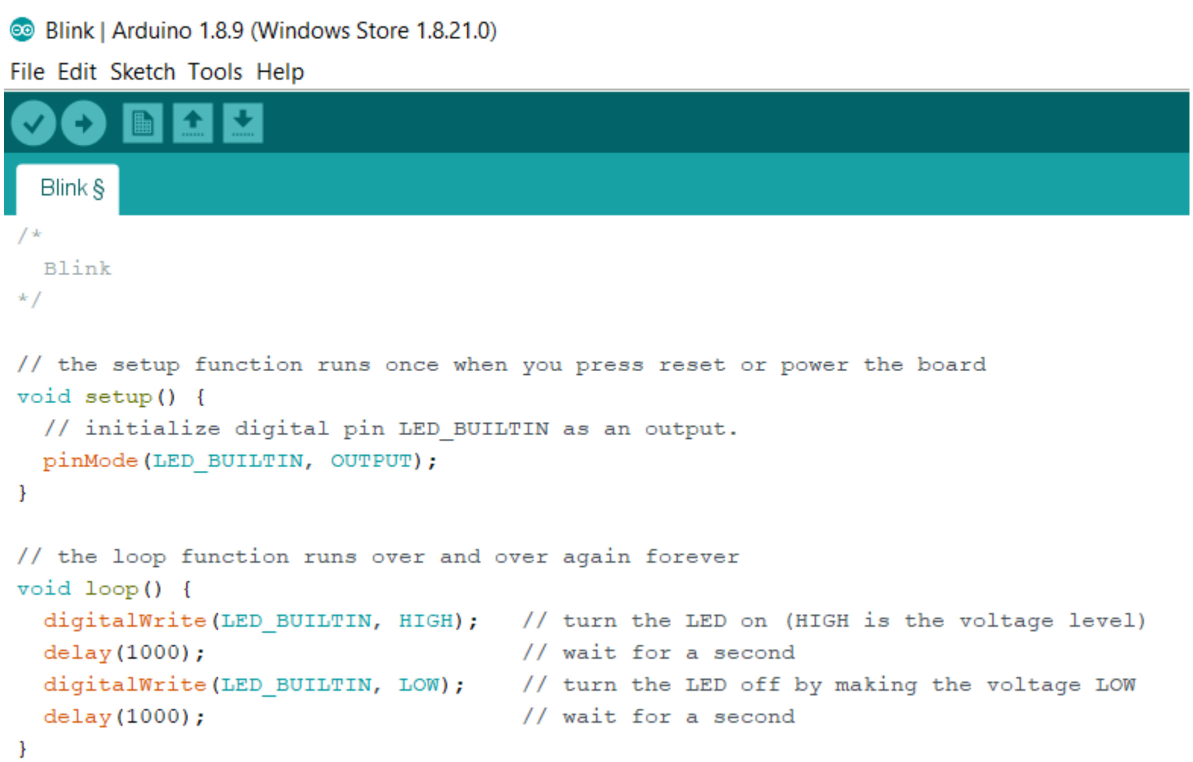

Figure 4: Arduino example code 'Blink' as seen on the Arduino programming environment.

The Arduino IDE sketch example ‘blink’ was used to test output control by pins on the board, builtin LED communication, and time modulation. ‘Blink’ uses the ‘digitalWrite’ function to set a pin output to HIGH, waits a specified time then sets the output to LOW and waits again. The sketch involves two output calls and two delays in loop.

Time Modulation and Analog vs. Digital signals

With access to the board, an LED was connected in series to an output pin and ground. ‘Blink’ was used to test the LED. The time delay for the on time was decreased. A voltmeter’s leads were connected to the output pin and ground to measure voltage throughout the decreasing on delay. Voltage was recorded as delay was decreased. The delay was reduced until the LED appeared to be off to the naked eye. Then, the same procedure was repeated for the off delay time without changing the on delay until the LED appeared to stay on. Voltage was recorded.

```
analogWrite(LED, 150);
```

Figure 5: An Arduino function that sends a specific amount of power to ‘LED.’

Next, a new sketch was built and a function named ‘analogWrite’ was used to set the LED to a specific brightness between values 0 and 255. Voltage was measured through a range of ‘analogWrite’ values. The ‘analogWrite’ function was switched back to the ‘digitalWrite’ function and a potentiometer (10kΩ pot) was introduced into the circuit. The pot was turned as voltage was measured across the LED. Voltage values were recorded.

After the time modulation tests, digital and analog signals were introduced as a topic to research. Following a basis of knowledge on electrical signals the oscilloscope was introduced as a testing tool to view electrical signals. An oscilloscope reads in voltage over time.

To continue learning about signal, the ‘blink,’ ‘analog control,’ and pot tests were repeated with an oscilloscope connected to the output pin and ground instead of a voltmeter. Voltage over time was measured. Signal waves were compared for ‘blink,’ 'analog control,' and pot. Pulse width modulation as a means to imitate analog control was researched.

Switches and Input/Output (I/O)

A circuit was built with an output pin on the Feather M0 as a battery, a button as a switch, and an LED as an indicator of a closed (current flow) or open circuit (no current flow). The button was pushed to light the LED. Then, a second button was incorporated in parallel.

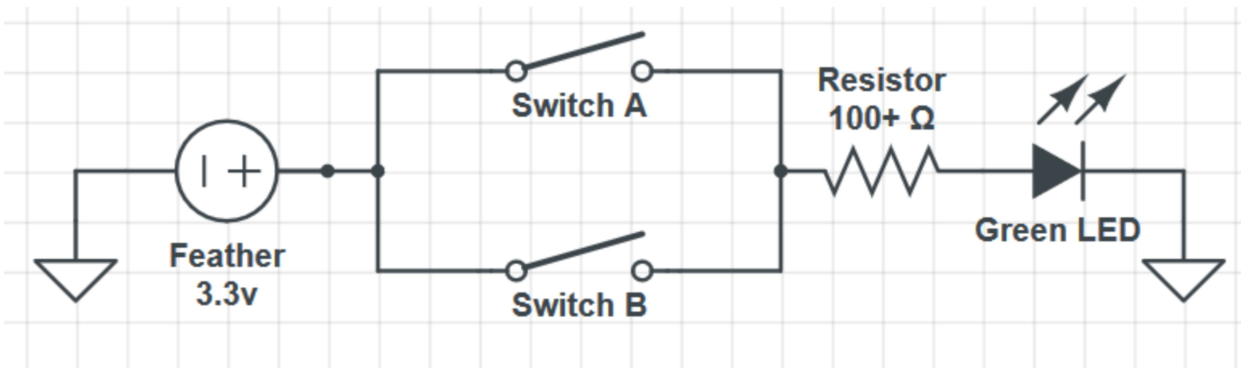

Figure 6: A circuit schematic depicting the Feather M0 microcontroller connected to two switches in parallel, a resistor, and a green LED.

Buttons were pressed alternatively and jointly to light the LED. This was repeated with two buttons in series.

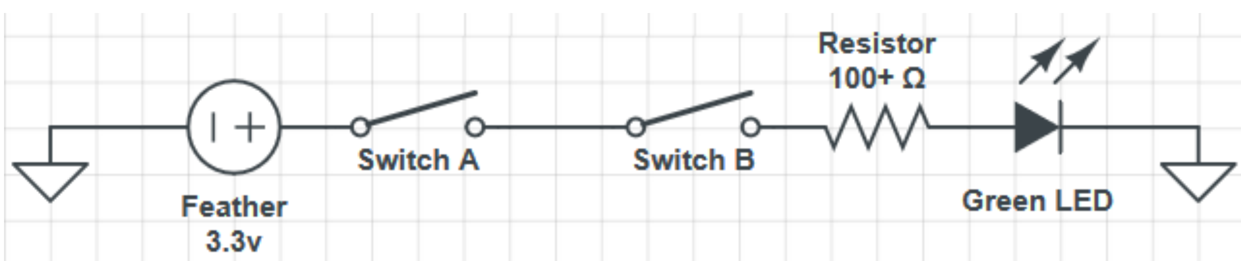

Figure 7: A circuit schematic depicting the Feather M0 microcontroller connected to two switches in series, a resistor, and a green LED.

Logic tables were created for each scenario. Then, the wire running to ground in the circuit was redirected to an input pin to measure voltage. The buttons were pressed alternatively and then jointly, first in parallel and then in series, while the input pin measured voltage digitally.

Transistors as electrical switches

A transistor as an electrical switch was researched. A toilet lever was compared to a transistor to elucidate flow threshold.

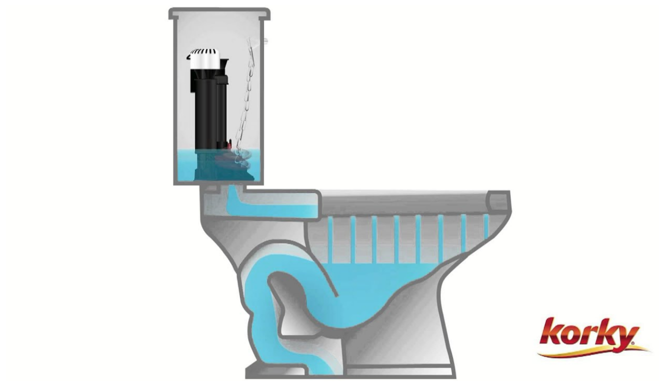

Figure 8: A cross section of a toilet while it is being flushed. The flow of water through the pipes is similar to the flow of current through a transistor.

A logic level transistor (can be triggered by microcontroller voltage) was chosen and its respective datasheet was looked up and obtained to figure out pin designations.

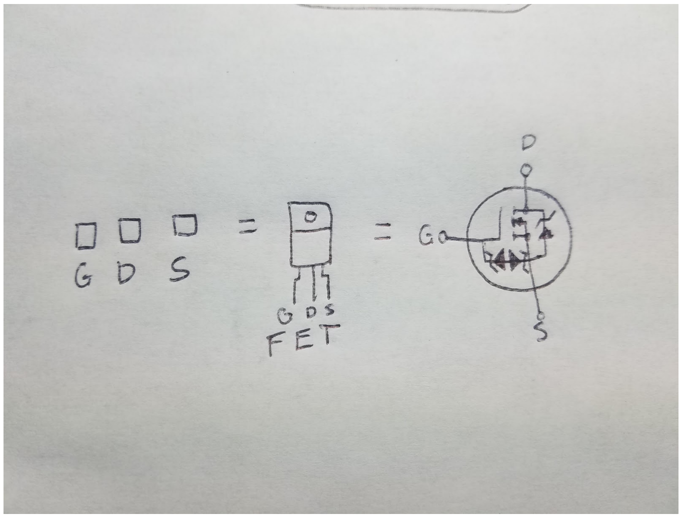

Figure 9: A drawing of a field effect transistor seen in three different ways: as pins, an eye view representation, and the internal schematic.

The buttons from the I/O circuit were replaced with one transistor in series with the circuit, from drain to source, and the wire connected to input was directed to ground. Another output pin on the feather was directed to the gate. Power was output from drain to source to test for current flow. Then, ‘blink’ was used to alternate sending power to the pin connected to the gate of the transistor.

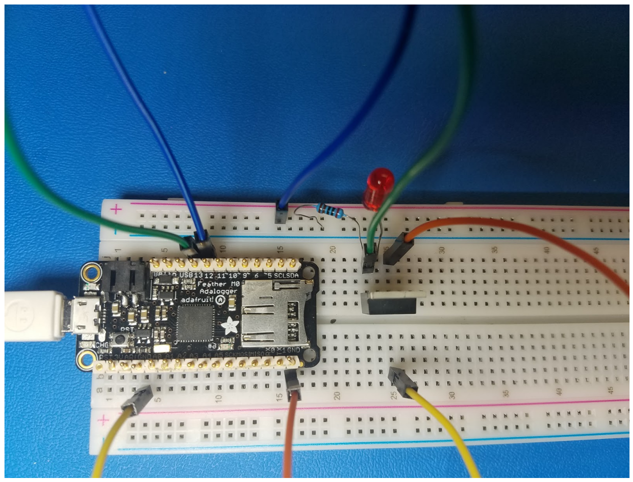

Figure 10: A Feather M0 connected to a transistor that switches the red LED on and off.

Camera modification

A Sony Drift HD camera was used for electrical trigger testing. The on/off button and the capture button were identified. The battery was removed. Then, the camera was taken apart with a Phillips screwdriver. The selected buttons were located under the housing.

Figure 11: A Sony Drift HD camera with the main housing removed.

Wires were soldered onto the sides of the buttons thus creating a bypass of the button. A multimeter was used to check for connectivity between the bypass wires when the button was pushed.

Figure 11: A Sony Drift HD camera with the main housing removed with wires soldered onto the sides of the ‘play’ button.

If the multimeter beeped when measuring connectivity the procedure was successful and these wires were connected to the drain and source of the transistors used in the LED circuit. A modified version of ‘blink’ was run to test the camera.

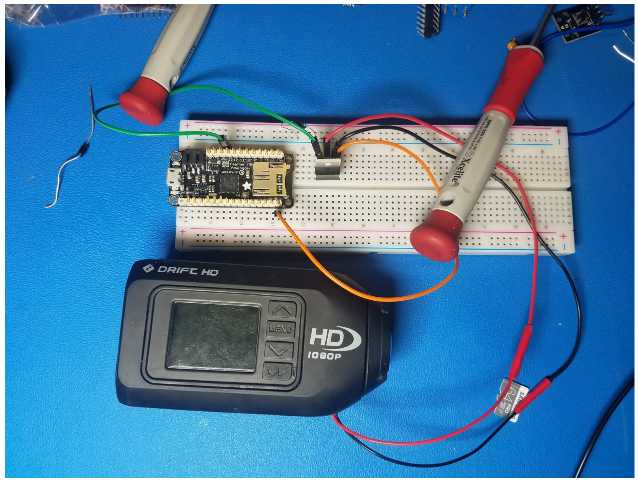

Figure 12: A Sony Drift HD camera connected to the transistor and Feather M0 in place of the red LED.

Next, a switch was connected to a separate set of input and output pins on the board to be able to turn the camera on with digital input from the switch.

Capacitors as short term batteries and signal smoothers

A capacitor was incorporated into the ‘blink’ circuit in parallel to the LED. Then, the capacitor was connected in series with the LED. An oscilloscope was used to measure voltage over time from the output pin to ground. The voltage over time wave was recorded.

Sensors and libraries

Sensors were collected and tested to learn about analog and digital input, I2C, UART, and SPI communication, and libraries.

A HC-SR04 ultrasonic ranging module was connected to the Feather. It’s respective library was found and downloaded by looking up the part number online. The module was used to measure distance.

Figure 13: An image of a HC-SR04 generic ultrasonic ranging module.

The distance value was then used to control delay time between on and off of an LED to make it blink faster or slower. IMAGE

A MCP9808 temperature sensor was connected to the board. It's respective library was found and downloaded by looking up the part number online. The sensor was used to measure and record temperature.

Figure 13: An image of a MCP9808 'high accuracy' temperature sensor from Adafruit.

Camera Tag main board

Schematic, code, board

A (printed circuit board) PCB built by Thom Maughan was used (**image**). A schematic and some code were obtained for board configuration. Communication was tested by outputting power to an LED through address found on sample code. The built in transistors for camera triggering were addressed using the schematic and sample code. Triggering was tested by connecting them to an LED connected to a battery and outputting power. The LED and battery were replaced with the camera and triggered. Then, the schematic was used to obtain the part number for the Red Green Blue light sensor (RGB). Code was downloaded from the manufacturer's website and collated with the board address for the RGB found on the schematic. Values from the RGB were set to print to the serial monitor. A conditional statement was created to trigger the camera transistor when red light values were greater than either blue or green. The program was run and tested by shining colored lights at the RGB sensor. The same process was repeated for the 9DOF gyroscope, accelerometer, and compass (MPU). The MPU was tested by shaking and turning the board as a program printing MPU values was ran. The MPU was programmed to trigger the camera when an oscillating motion was observed by the MPU.

Documentation

GitHub was chosen as the open source platform for Tech Fest and the Shark Cafe Cam. Methods for formatting and organization of procedures were developed through the creation of the Tech Fest GitHub using markdown and html.

Figure 14: An image of html code on markdown, both raw (with a number one in front) and rendered.

HTML was selected for use with the shark cafe cam repository.

RESULTS

Electrical and Software Engineering

I am now able to develop and program simple behavior triggered animal tags using sensors, and microcontrollers. This knowledge extends to problem solving, prototyping, and project development applicable to a variety of embedded systems.

Shark Café Cam

Through the process of open sourcing the shark cafe cam we were able to program, build, and put together a camera triggered by lateral (x) rotation in combination with forward movement. The trigger movement would be akin to that of a snake swimming through water.

Figure legends (should be complete sentences and explain the figure completely) (Normal, Times New Roman, 10 pt)

Open Source

The Tech Fest google doc was made public and published on GitHub, https://github.com/practicaltech/TechFest, where it will continue to grow.

The Shark Cafe Cam GitHub is still underway. It will be made public on GitHub in late August to early September of 2019, https://github.com/thommaughan/sharkcafecam.

DISCUSSION

Tech Fest

Tech Fest and the Tech Fest google doc then GitHub were a natural product of the process of learning to build the shark café cam. Tech Fest allowed me to reinforce what I was learning, make sure I was able to convey that information, and then offer a means to practice open sourcing technical information.

Shark Café Cam

Going through the build I focused on the main board, its sensors, and its software as it was not feasible to learn all of the electrical components that make up the full tag with the allotted time. Regardless, the knowledge gained through the development of the board is applicable to the release, data transfer, and transducer components.

CONCLUSIONS/RECOMMENDATIONS

Shark Café Cam

The main board for the shark café cam and the Feather M0 share the same processor, therefore, prototyping on the Feather board is recommended before doing any testing on the actual shark café cam board.

Cam GitHub

More work will need to be done for the GitHub before its made public. This work will be completed over the next few weeks.

ACKNOWLEDGEMENTS

I'd like to thank MBARI as well as the brave Tech Festers, MBARI staff and interns, who chose to attend our first meeting. Your continued curiosity and interest sparked the growth and development of Tech Fest. Special thanks to the EE Tech Lab for their knowledge and electrical components.

I would like to thank George M. Matsumoto for making it possible for curious students to come to MBARI to learn and grow.

Thank you to MBARI and the Lucile and David Packard Foundation, without your support research like this would not be possible.

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