

High Level Design: FALCON

EE 41430-01

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1 - Introduction

The Falcon team's project is the design and implementation of a high frequency sound capture system with the purpose of recording the echolocation sound pulses that bats produce when they fly around in swarms. The goal of the design is to provide stereo sound synchronized to a video feed with all of the hardware in a small enough package to fit in a backpack for a trained falcon. The audio and video information is hopefully going to shed light on how bats communicate in swarms, recognize their own signals, and keep from jamming each other's signals.

2 - Problem Statement and Proposed Solution

The problem that we are trying to solve is how to collect and store real time high frequency sound data at a manageable size and weight footprint. The way we intend to solve this problem is the use of a high frequency microphone, band pass filtering, active gain amplifiers, a PIC microprocessor, and an SD card or similar flash storage system. The system will gather raw data from the microphone and store it in the memory device to be synthesized by a computer after the data run is finished.

3 - System Requirements

The requirements of our system are based on sampling speed and the size of the components in the system. The signals we are trying to process are between 10 and 100 kHz sound waves. We have to implement a band-pass filter in order to isolate this frequency range for data collection. To accurately sample the signal the system requires a 200ksps sampling speed. This means that we have a maximum average byte throughput of around 5 μ s from sample to write. Power is not a big concern for the system as the PIC, microphone, and op amps are relatively low current and voltage and the audio runs are only 15-20 minutes at a time. For total weight the design requirement is ~25g total for our audio processing subsystem. The system is going to be installed on a custom PCB that will be put inside a custom falcon backpack. The processing the PIC is responsible for is the analog-to-digital conversion of the mic voltage data and the SPI-based writing to the memory system.

4 - System Block Diagram

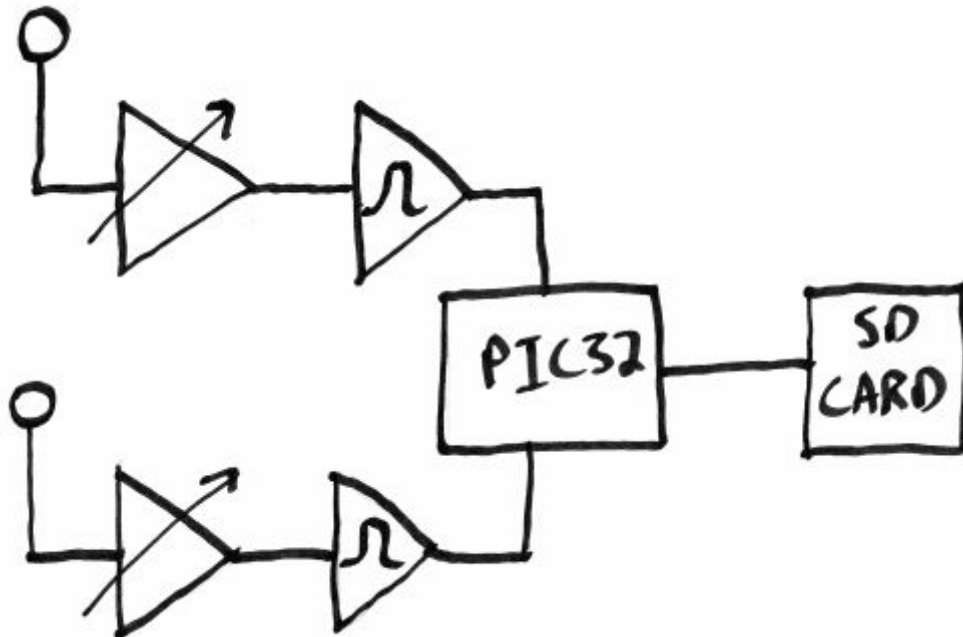


Figure 1 - Audio system with two microphones to pick up data and an microSD card to store it in.

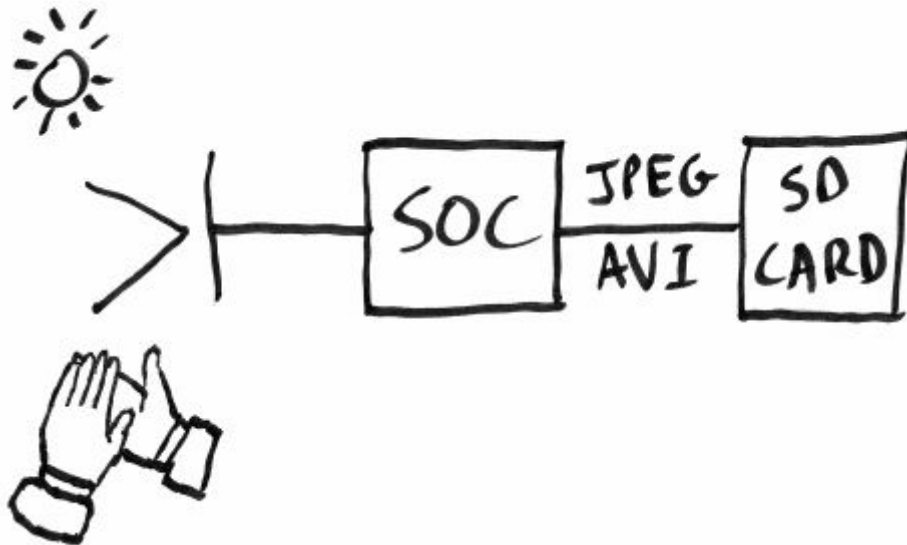


Figure 2 - Visual system to pick up data with a camera and to store it in a microSD card.

This system will consist of two major systems that must be synced at the end of the process. The first system will record audio data coming from the bat colony's communications, and the second system will record visual data from the bat colony's movements. Figure 1 shows two antennas picking up analog audio and sending it through an amplifier and filter before it

reaches the microcontroller's analog-to-digital system. Concurrently, the microcontroller will write the data to pages in an microSD card where it can be read from later. Figure 2 shows a camera picking up visual data and sending it to a system on a chip (SOC) that will convert it to a JPEG or AVI file. This data will be similarly stored in an microSD card, and a clap or light flash will help sync the distinct systems if there is no way to connect the systems. To meet our objectives, the audio system will need to sample at 200 kHz with 8-bit samples, and the visual system will need 8 frames per second with standard 8-bit pixel resolution. The following sections will break these two systems into subsystems and define their requirements.

Microphone: The microphone must capture and pass frequencies from 20-80 kHz which is the range that bats communicate within.

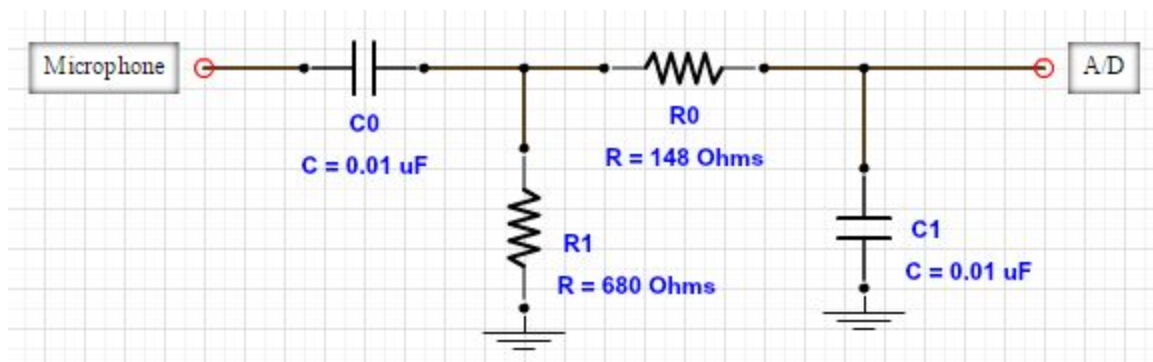
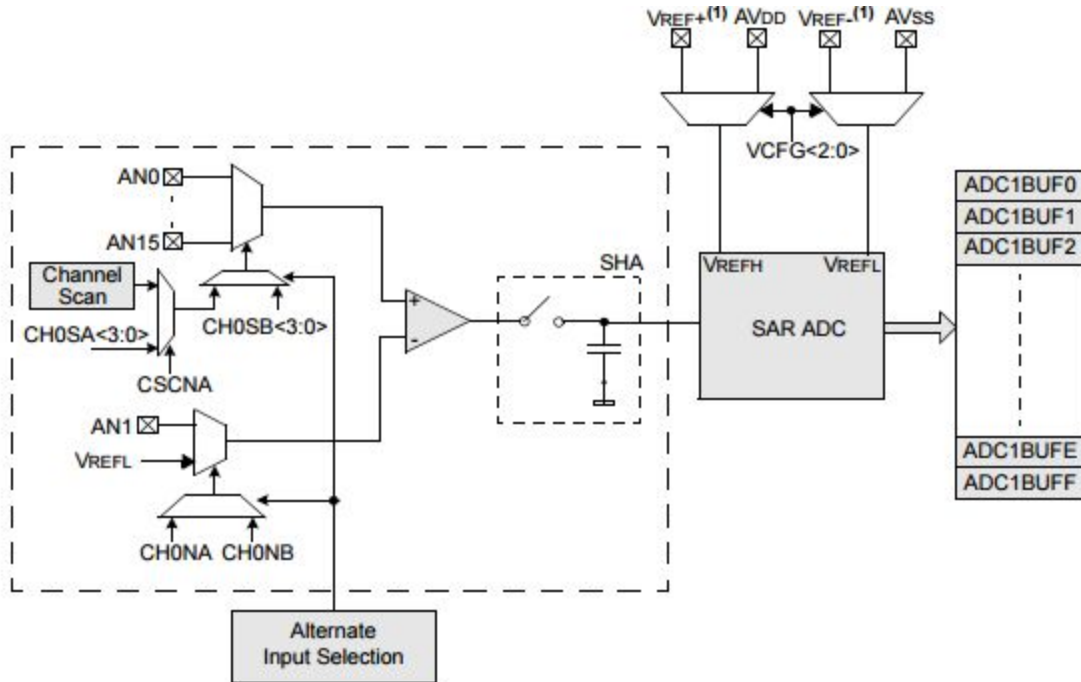


Figure 3 - Passive filter to attenuate signals outside the colony's range

Amplifier and Filter: The filter will be a passive bandpass design with cutoff frequencies of 10 kHz and 100 kHz. The amplifier will be a simple op-amp design with automatic feedback control to deal with the large range of volume possible from the variable distance of the falcon to the bats.



Note 1: VREF+ and VREF- inputs can be multiplexed with other analog inputs.

Figure 4 - ADC hardware showing the need to use alternate sampling of two inputs.

ADC: Figure 4 shows the ADC hardware in the PIC32 microcontroller. The hardware needs to be able to sample at 200 kHz for each microphone. Given the hardware setup, we must alternate sampling two analog pins which increases the required sampling rate to 400 kHz to capture the inputs simultaneously. With the ground of the microphone and PIC connected, V_{dd} and GND of the PIC will serve as reference voltages.

SPI: The PIC must be able to write data to flash memory at a rate comparable to 400 kbps to keep up with the measured data from the microphones. Thus, the clock speed will likely need to be at least 40 MHz to execute the transmissions quickly. Also, the PIC will need enough I/O pins to control the ADC and SPI.

PIC: The microcontroller will need to accomplish the ADC and SPI above at a low power so that the battery weight is minimized. Also, we will choose the smallest chip possible that meets our specifications to reduce chip weight.

Flash: The flash memory needs to be able to write data faster than 400 kbps and have enough memory to hold 15-20 minutes of uncompressed audio and video. Initial calculations give values around 1-2 GB for audio and another few GB for video because of the low resolution required.

Image Sensor: Because the image does not need to be high resolution, the image sensor only needs to be 8 fps and less than 100x100 pixels. Thus, the weight and cost will be more important factors for the sensor.

System on a Chip: The SOC needs to be able to encode the video feed to MPEG at a rate consistent with the acquisition and at low power. However, the low image quality will likely not restrict our choices and cost/weight will again be a bigger concern.

5 - High Level Design Decisions

Microphone: The MEMS SPU0410LR5H-QB sensor runs on low current and has a flat frequency response at our desired band.

Filter and Amplifier: We will be building a passive filter (resistors and capacitors) and an automatic gain control with the amplifier that responds faster than the falcon can fly.

Microcontroller - XLP MCU PICs provide low power 16-bit microcontrollers that will be necessary for our application. We need only a few I/O pins so we will select a model that minimizes size and power usage.

microSD card - SanDisk sells microSD cards with over 8 GB of data which should be sufficient. They can write 16 MB/s which will be more than sufficient for our application. However, the weight will be an issue at 8 gram.

Battery - Sparkfun sells lithium ion batteries which should have the highest energy per gram out of other types of batteries. The 1 Ah battery weighs 22 g which is much more than we can allow for the battery. Thus, we will likely get a battery with 250 mAh and try to reduce our power usage to meet it because it will weigh less than 8 grams.

Camera - Prof. Kloepper is providing the camera that she would like to use, but it will be stripped down to its bare components.

SOC - SOC Technologies sells encoders which we will be able to use in the design. Prof. Stevenson is still deciding on the SOC that he wants us to use so this decision is up in the air.

6 - Open Questions

There are several aspects of this project that we have not completely realized yet. One of the biggest stretch goals that we are looking at for this project is the synchronization of video and audio data recorded by the falcon's pack. One relatively crude solution involves clapping in front of the camera, and then synchronizing the sound and video of the clap after data acquisition. A more elegant solution would be to regularly blink an LED in the video that would simultaneously send data to the microphone. Our uncertainty of how other parts will be incorporated in the pack prevent us from finalizing a specific design for synchronization.

As is stated above, we have not decided on a specific power source for the project. The battery specifications are entirely dependent on the supply voltages for the different components we will be powering, the current draw they need, and the length of time we will be powering them for. Not all of these specifications have been finalized yet, so we will have to confirm which parts we will use first before deciding on a battery.

Furthermore, one of the most essential operations we will have to perform is dumping the audio and video data from the pack into an SD card. This is something that we are unsure of how to accomplish. At the time of writing, we can record data from the microphone and display the amplitude values of the waveforms on PuTTY software, but we must manually export the data to MatLab to show the Fourier Transforms of the data. This is useful to see the frequencies that the microphone is recording, but we must manually save the data externally. We would like for the data to be saved automatically into an SD card inserted into the PIC32, and for the microcontroller to create discrete data files for each different recording.

7 - Major Component Costs

Below is a table specifying the costs of the major components that we will be incorporating into the package:

Name	Description	Quantity	Cost (USD)
MEMS SPU0410LR5H-QB	Low-power microphone	1	\$0.85
PIC16F1824T-I/SL	16-bit microcontroller	1	\$1.24
Printed Circuit Board	Custom Designed PCB from 4PCB	5	\$33.00
SanDisk 8GB microSDHC	MicroSD Card	1	\$8.84
Filter and Amplifier	Misc. Electrical Components	N/A	\$2.00
Total	-	-	\$177.93

Table 1- Major Cost Components

8 - Conclusions

In conclusion, we have a fairly concrete idea of how we will implement a system that will allow us to record the high frequency communications emitted within a dense colony of bats that prevent them from colliding with each other and environmental obstacles. In the end, we hope to

design and build an electronics package small and light enough to be attached onto a live falcon that will fly around a swarm of bats emerging from a tunnel. The recorded data will hopefully reveal methods on how military drones could fly in swarms without any problems.