ECE 454: Senior Design Laboratory

M.E.L.O.D.I.C Project Proposal

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1 Introduction

1.1 Problem

A common problem associated with live performing is the rats' nest of audio and control cables required to run front-of-house (FOH) equipment, digital effects, and instruments. However, In recent times UHF, VHF, and ISM systems have taken mainstay in the industry. For a large performance, having a $10,000+ rack dedicated to wireless audio systems makes sense. For the performing musician on a budget, such as a small house band or coffee shop artist, professional UHF, VHF, and ISM systems are not feasible to operate. Although low-cost or used legacy systems are popular amongst amateur musicians, they often suffer from problems such as data packet collisions from co-existing network protocols, interference from existing UHF and VHF television bands, and/or lack of scalability or configurability.

1.2 Solution

In order to combat this, we are developing M.E.L.O.D.I.C. A low-cost, scalable, configurable, and high-fidelity wireless audio link that will be compatible with any system or instrument. We intend to use a COTS RF SOC (TI CC8530) commonly found in wireless headphones and karaoke systems. This chip is an attractive choice due to its operation in the ISM band, use of adaptive frequency hopping techniques for co-existence with other ISM devices, and configurable to either be an audio transmitter or receiver. Due to the configurability and low cost of the chip, our transmitter and receiver will have very similar circuit schematics, which will make it cheaper to manufacture multiple sets of transmitter and recievers.

1.3 Analysis of AFH vs FSK

Typical systems in the UHF and VHF range utilize M-Ary frequency shift keying or M-FSK to modulate the digital signal in the base-band. Our motivation to use AFH, a subset of FHSS, is the high probability of frequency dependent interference from other devices in the ISM band. Our choice of using the ISM band for this device is solely based on working around FCC licensing for the device, as the ISM band is 'open waters' in the FCC band. Ultimately, if we were to use the same type of modulation found in the UHF and VHF systems, there is a probability that the bands will overlap and there would be frequency dependent interference all throughout the channel. Below is the results from a simple python simulation. We plot the probability of frequency dependent interference vs SNR by taking both a randomized FHSS and OFDM spectra and a FSK and OFDM spectra and convoluting them with an AWGN channel. We then divide the powers between the FSK and FHSS against the OFDM and noise and determine the probability of frequency dependent interference. We then plot the probability of this frequency dependent interference over multiple values of SNR. As we can see in Fig 1, the probability is consistently lower for the FHSS waveform as compared to the FSK waveform against OFDM.

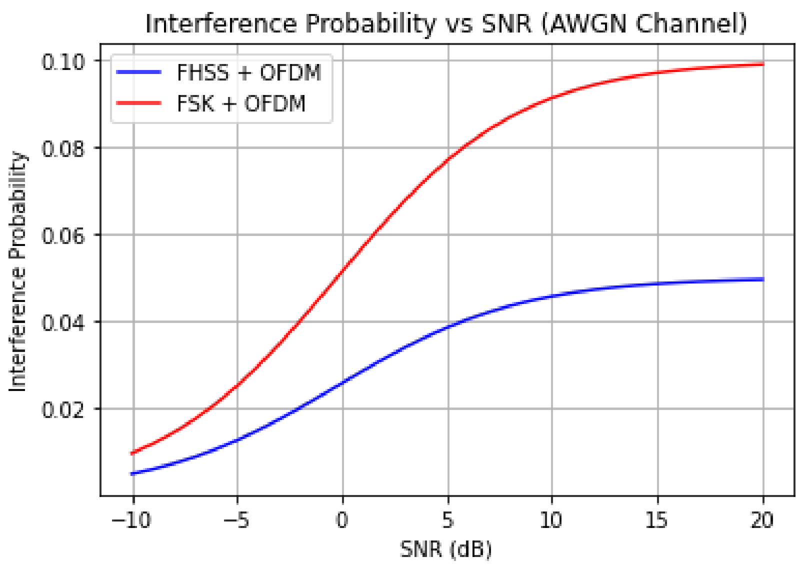

Figure 1: Probability of Frequency Dependent Interference versus SNR

1.4 High-level Requirements

At a fundamental level, all buttons (for now, power and pairing) should work as intended. Additionally, the system should also allow for monitoring power levels in each device (LEDs). Line/instrument-in line-out connection compatible with instruments. Coexistence with existing 2.4GHz protocols such as bluetooth and WLAN. Able to transmit lossless CD quality audio. Human-friendly enclosure with battery status LEDs and control buttons.

2 Design

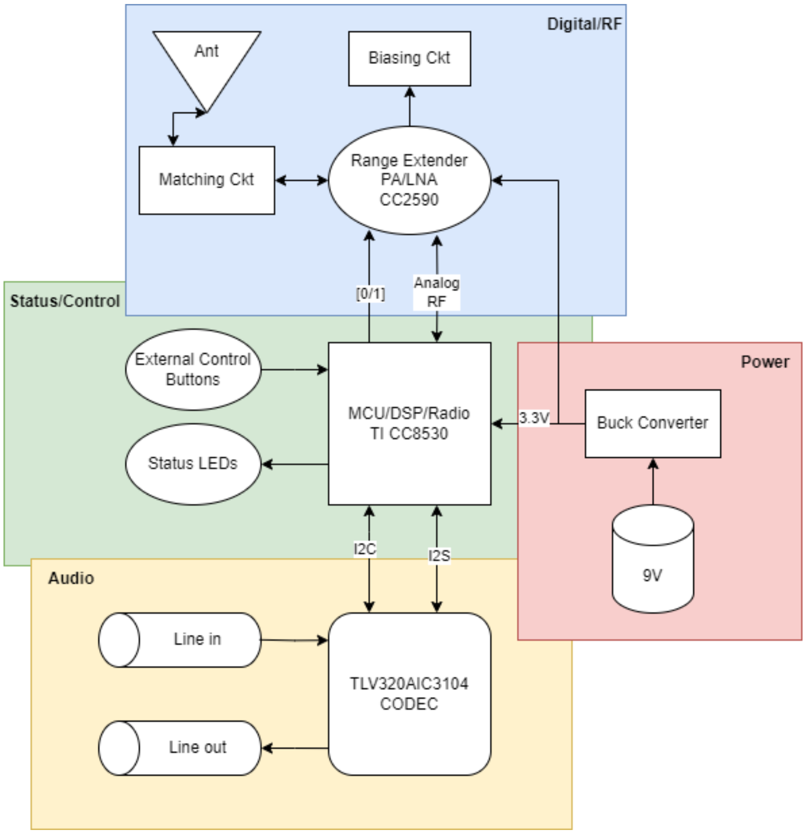

Figure 2: Block Diagram

2.1 Subsystem Overview

2.1.1 Power

The main power supply for our device will be a 9V battery. This will then be brought down to the 3.3V that the CC8530 RF SoC needs, using a variable duty ratio buck converter. The buck will operate using TI's 10-V hysteretic PFET buck controller, LM3475. This will allow the system to operate for an extended time with a constant output as the 9V slowly loses charge. In order to minimize noise created by the converter an ample sized output capacitor must be selected as well as a slightly lower operating frequency. In addition to this a PGate resistor as well simple RC filter across the output diode will help keep noise levels minimal.

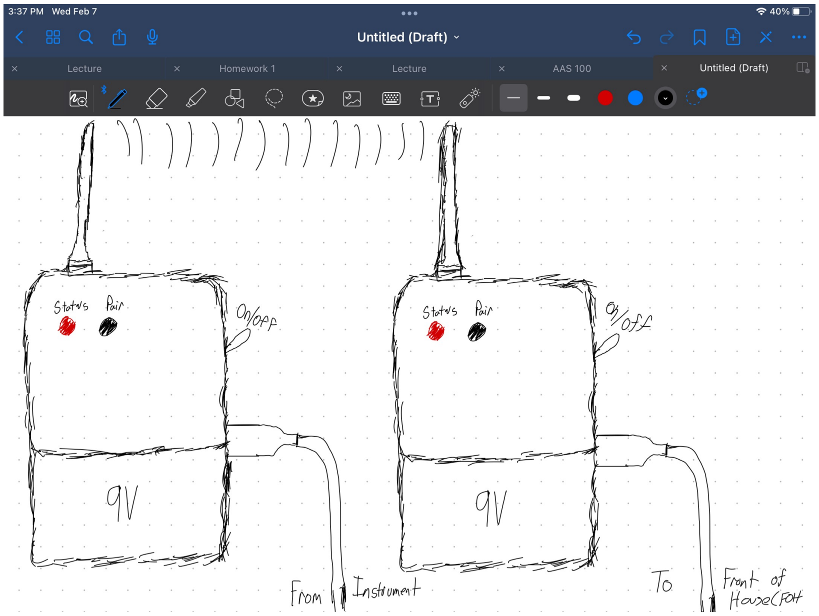

Figure 3: Sketch of M.E.L.O.D.I.C. Device (Initial Concept)

2.1.2 Audio

In order to be compatible with a wide range of instruments and devices, the M.E.L.O.D.I.C will take in both line and instrument level inputs. Line level is typically between 4 & -10dB, while the instrument level is around -30dB. Because of this, we will implement a pre-amp as well as bypass switch before the signal reaches the CODEC.

We are considering two different formats of audio streaming for the M.E.L.O.D.I.C device, both supported by the CC8530. PCM16 offers uncompressed, lossless CD-quality 16-bit data. PCME24 offers compounded 24-bit data and a 15-bit signal-to-noise ratio. Both formats implement error concealment mechanisms in marginal RF conditions so that no break in audio is heard. In theory, PCME24 allows for more dynamic range as opposed to PCM16, but the PCM16 offers a better signal-to-noise ratio. We will decide on which format to use based on testing.

We will be using Texas Instruments' TLV320AIC3204 Ultra Low Power Stereo Audio Codec to convert our analog audio into digital audio. This is done through the use of the codec's built-in DAC. The stereo audio DAC provided by the codec supports data rates ranging from 9khz to 198khz. As one our requirements, we wanted to be able to transmit CD quality audio (44.1khz/16-bit). As explained in the previous paragraph, the CC8530 supports 16-bit audio transmission and up to 198khz data rates. We are confident that we will be able to meet our requirement with these specifications.

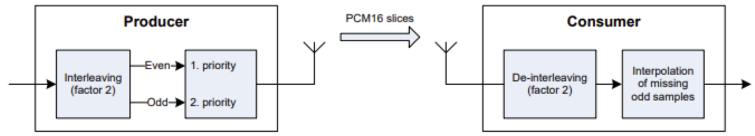

Figure 4: PCM16 Processing Diagram

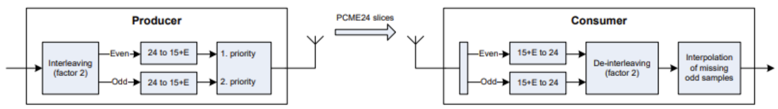

Figure 5: PCME24 Processing Diagram

2.1.3 Digital/RF

The Digital/RF subsystem is composed of CC8530 RF SoC, CC2590 BLE range extender, RF matching/balancing circuitry, and RF amplifier biasing circuitry. The CC8530 would provide the needed components to act as both a host for the audio subsystem and the digital radio. The included Cortex ARM-M3 processor core will handle general management functions and act as a host to the radio co-processor, audio co-processor, and audio codec.

The CC8530 can perform in autonomous mode, which will decrease the amount of needed components by acting as both the micro-controller and radio peripheral. The included GPIO pins on the SOC are directly connected to the Cortex ARM-M3 processor, so we would be able to control the device by including status LEDs and buttons. The SoC also features pin-outs for an I2S and I2C connection, which are needed to control and receive audio data from the codec.

The SOC features a digital radio that will perform normal digital communications functions and output an analog wireless signal to the CC2590 BLE range extender. It will also act as a host for the BLE range extender and determine whether a power amplifier or a low noise amplifier will be needed to perform the transceiver's assigned function. Care will be taken to ensure that we have a simultaneous conjugate match between the high-frequency circuit components of the system. Some of the considerations would be the transmission line type, width and thickness of the strip, and length of the strip.

From the CC2590, there would possibly be circuitry for balancing and matching the output to the antenna, the inclusion of this would be determined by 1-port S-Parameter readings of the device while it is active. If both the antenna and CC2590 are conjugate matched, then we would not need to include this circuitry. However, if they are not, a T-network or Pi-network would be needed to have a conjugate match over the required bandwidth.

2.2 Subsystem Requirements

Power

- The buck converter must provide stable 3.3V from the 9V battery.
- The output of the buck must have minimal noise and ground noise as to not interfere with device operations.
- The battery must be easily accessible to be able to be replaced when needed.
- The battery must be able to last a minimum of 12hrs with adequate charge.

Audio

- Convert line in analog audio into digital audio that can be transmitted by the RF subsystem.
- Convert digital audio provided by the RF subsystem into an analog CD-quality audio stream.

Digital RF

- Successfully utilize AFH to minimize frequency dependent interference from coexisting wireless protocols and data packet collisions between multiple devices.
- Coherent human-device interface, ease of use utilizing only LED's, buttons, and encoders for simplistic operation.
- The RF SOC acts as the audio CODEC master, and handles all aspects of digital audio transmission without extra IC's.
- Ability to perform with 2 instrument links at the same time.

3 Ethics and Considerations

3.1 FCC Regulations

One concern with designing a digital wireless communication system was aligning with FCC regulations and the FCC band plan. If we were to design our system around the same frequencies as existing systems, we would need to license our device to work in that band. Specifically UHF and VHF equipment used in the live audio industry has privately licensed bands with the FCC or are licensed around the same bands as terrestrial television. Since we are using an RF SOC specifically made for wireless digital audio streaming, we do not have to worry about licensing the device with the FCC since the device has already been tested and approved to be used in the ISM band.

3.2 Environmental Concerns

One concern with using a 9V battery is the potential environmental damage they might cause when they are thrown away. We plan on using Alkaline 9V batteries which is a safer alternative to lithium ion batteries, which are known to have a negative impact on the environment when thrown away.