Wireless Microphone Project

1) Project Overview

This project develops a wireless microphone system that captures high-quality audio using a dynamic microphone, processes it through the PCM1808EVM (a 24-bit stereo ADC), and transmits it wirelessly via Bluetooth Low Energy (BLE) using the nRF5340DK. The system aims to achieve a sampling rate (fs) of 24 kHz in mono mode (576 kbps) to fit within the nRF5340's BLE throughput (~1–1.3 Mbps), ensuring a cost-effective and reliable solution for speech applications.

2) System Architecture

1. Audio Capture:
    - A dynamic microphone feeds an amplified signal (via a preamp circuit) to the PCM1808EVM.
    - The PCM1808 ADC converts the analog signal to 24-bit digital audio at fs, outputting stereo data via I2S in slave mode.
2. Data Processing:
    - The nRF5340DK receives I2S data through its I2S peripheral, configured as the master.
    - Data is processed and prepared for BLE transmission.
3. Wireless Transmission:
    - The nRF5340DK (BLE peripheral) transmits audio data to another nRF5340DK (BLE central) via BLE.
    - Mono and low bit-rate is preferred to avoid compression and ensure reliable transmission.

3) Proof of Concept (PoC)

The PoC validates the system with the following components and setup:

1. BLE Communication:
    - One nRF5340DK as BLE peripheral (transmitter).
    - One nRF5340DK as BLE central (receiver).
2. Audio Capture:

- PCM1808EVM ADC board with 24-bit resolution and I2S data output.
- Dynamic microphone with a preamp circuit (non-inverting op-amp, 50–100x gain for 5–20 mV RMS).

3. Power Supply:
    - Bench power supply for stable operation of the EVM, preamp, and microphone bias (if needed).

4) Components

1. 2x nRF5340DK: One for BLE peripheral, one for BLE central.
2. 1x PCM1808EVM: 24-bit stereo ADC for audio capture.
3. 1x Dynamic Microphone: Low-cost audio input.
4. 1x Preamp Circuit: Non-inverting op-amp to amplify microphone signal.
5. 1x Bench Power Supply: Powers the system components.

5) Technical Specifications

PCM1808EVM (I2S Slave)

- Mode: I2S slave, controlled by nRF5340DK (master).
- Sampling Rate (fs): 9800 Hz
- Resolution: 24 bits per sample.
- I2S Format: 64-BCK/frame (32 bits/channel, with padding).
- System Clock (SCKI/MCLK): 384 fs = 384 × 9800 = 3763200 Hz.
- Word Select (WS/LRCLK): WS = fs = 9800 Hz.
- Bit Clock (BCK): 64 × 9800 = 627200 Hz (64-BCK/frame).
- Data Output:
    - Mono: One 32-bit sample per frame (32 bits).
    - Stereo (optional): Two 32-bit samples per frame (64 bits: left + right).
- Configuration:
    - FMT = 0 (I2S, 24bit).
    - MD0/MD1 = 0/0 set for slave mode (per EVM jumpers).

I2S Interface

- Channels: Mono (preferred, one channel active) or stereo (two channels).
- Frame Structure: Each frame contains one sample (mono) or two samples (stereo) at WS rate.

nRF5340DK (BLE and I2S)

- I2S Master:
  - Configures WS, BCK, and MCLK.
  - Receives 24-bit (32 bits with zero padding per channel) stereo samples via I2S.
- BLE:
  - Maximum practical throughput: ~1–1.3 Mbps (2M PHY, 251-byte MTU, 7.5 ms connection interval).

6) Constraints

- Audio quality needs fs to be about 10x higher frequency (let's assume 1000 Hz).
- BLE Throughput: Limited to ~1–1.3 Mbps practically.

7) nrf I2S frequencies formulas

Master Clock setting value (no unit)

$$MCK_{calc} = 4096 \cdot \left\lfloor \frac{MCK_{req} \cdot 1048576}{source + \frac{MCK_{req}}{2}} \right\rfloor$$

Master Clock actual value (Hz)

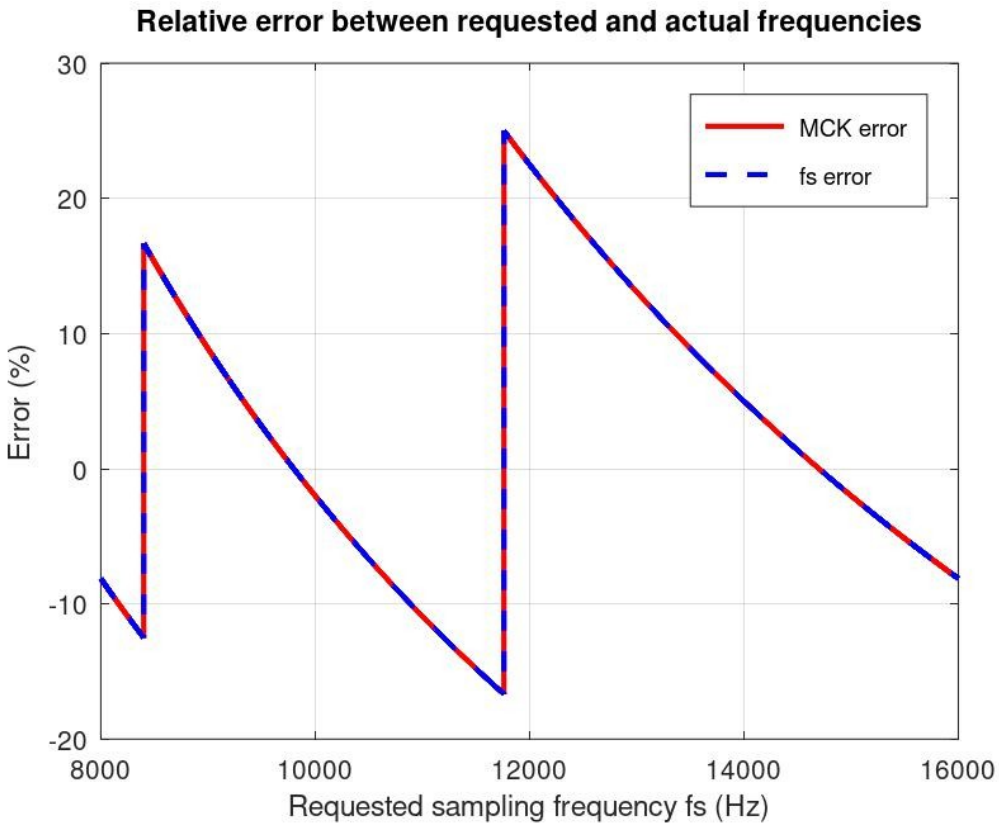
$$MCK_{actual} = \frac{fsource}{\left\lfloor \frac{1048576 \cdot 4096}{MCK_{calc}} \right\rfloor}$$

Master clock error (%)

$$MCK_{err} = 100 \frac{MCK_{actual} - MCK_{req}}{MCK_{req}}$$

8) Implementation

Via Ocatve I calculated the optimal values in order to don't have errors between required frequencies and actual ones.



1. CHANNEL_NUM = 2
2. WORD_SIZE = 32 bit
3. fs = 9800 Hz
4. RATIO = 384
5. fMCK = RATIO*fs = 3763200 Hz
6. BCK = WORD_SIZE*CHANNEL_NUM*fs = 627200 Hz