A/D Noise and Spikes with ESP32 and WLED

By: Andrew Tuline

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Introduction

During the development of our sound reactive fork of WLED, we are increasingly encountering a high number of spikes and more noise during our A/D sampling. Interestingly, these anomalies don't appear when a basic sound sampling sketch is loaded on the ESP32. This paper investigates this phenomenon with the use of both analog and digital microphones and a simple sketch and compared with WLED.

As for the ESP8266, we had previously experienced multiple issues when sampling on an ESP8266 with SR WLED and especially in AP mode. As a result, a dedicated ESP8266 branch was created that provide basic sampling and volume reactive sketches only. It has not been tested for this report.

Microphones Tested

Microphone	**Description**
Analog MAX9814	Configured @40dB gain and default AGC.
Analog MAX4466	Using default pot configuration.
Analog INMP411	
Digital INMP441	I2S digital microphone.
Digital ICS-43434	I2S digital microphone.

Microcontrollers Tested

Microcontroller	**Description**
ESP32	LOLIN D32 board.
ESP32	Serg74's ICS-43434 board.

Sketches Used

Sketch	**Description**
Basic A/D sampling	With ESP32 only.
Basic I2S Sampling	With ESP32 only.
SR WLED dev branch	With ESP32 only.

Ambient Noise

Using Android phone with 'Decibel X PRO', the average ambient noise in the room was measured at about 38dB and was consistent during times of no movement or outside interference. According to that program, it was measured as Quiet Home or Quiet Whisper and goes up to about 80dB when talking.

There were no unknown dB spikes detected during this environment overview test.

A Note on Microphones

During testing, it was evident that not all batches of analog microphones behaved consistently, and I have several of each type. As a result, I will be selecting microphones with the best behavour from those batches.

ESP32

The focus for this test is the ESP32 since we are using it to perform sampling at a high rate in order to use it with the arduinoFFT() sound library. As a result, those signals need to be 'untouched' prior to processing by the FFT routines.

Wiring

In order to facilitate rapid connection/disconnection of microphones to multiple microcontrollers, I'm using (less than optimal) Dupont connectors.

Sketches Used

For the analog microphones, I am just sampling the ADC port (pin 36) and directly printing the sampled value to the Arduino Serial Plotter.

```
int micIn = analogRead(MIC_PIN);
Serial.println(micIn);
```

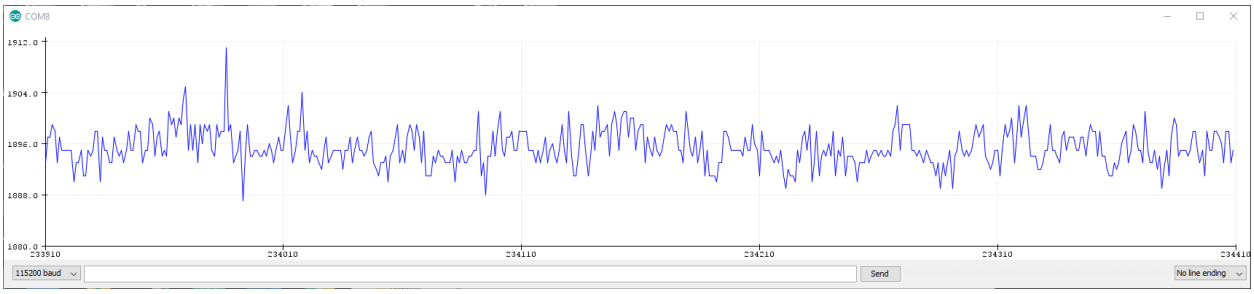
The basic sampling sketch required for the I2S digital microphones are more complicated and the resultant 32 bit signal is shifted right by 16 bits with this calculation:

```
        micData = abs(digitalSample >> 16);
        Serial.println(micData);
```

ESP32 Ambient Noise (sample sketch)

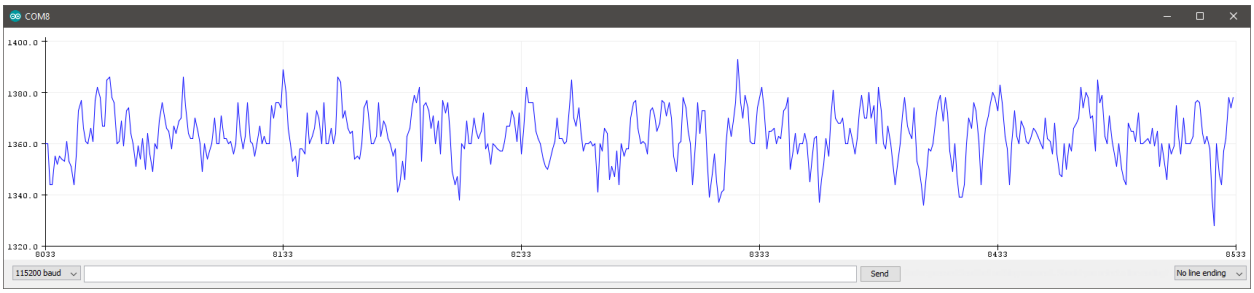
These samples are taken in a ‘quiet’ room. Any speech or other noise would create a signal significantly larger signal which would be automatically re-scaled to fit the graph.

Analog INMP411



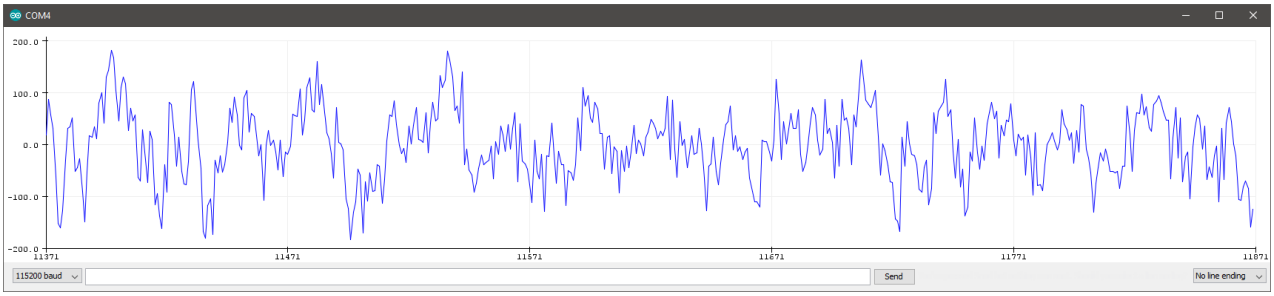
Noise is approximately 25 p-p.

Analog MAX9814 @40dB



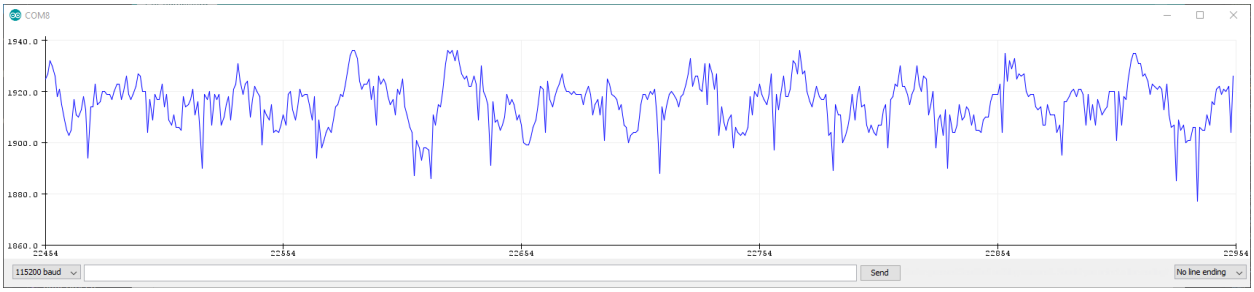
Noise is approximately 50 p-p.

Analog MAX9814 @60dB



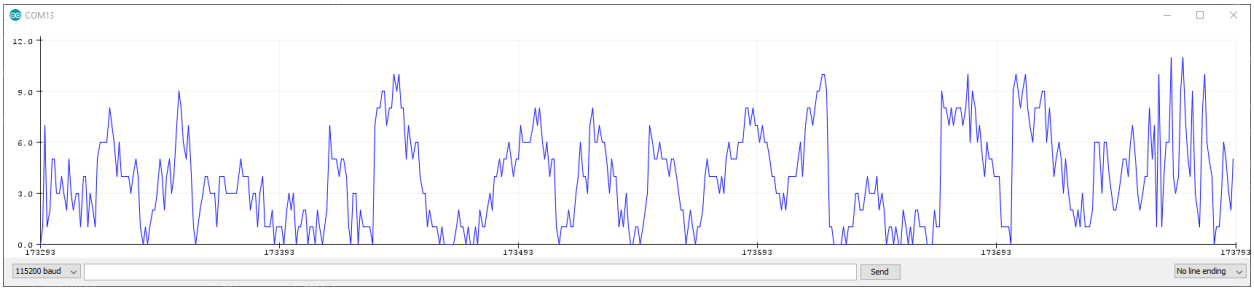
Noise is apprxoimately 400 p-p. THIS is why we highly recommend the MAX98414 configured for 40dB gain. This configuration will not be tested with WLED.

Analog MAX4466



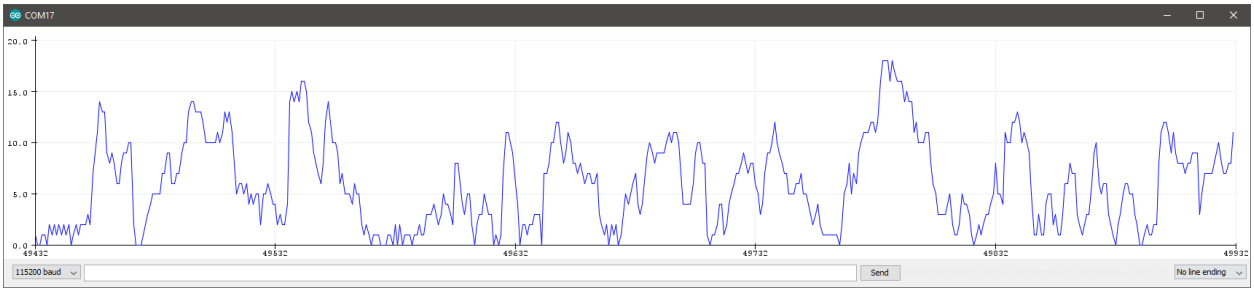
Noise is approximately 50 p-p.

Digital INMP441



Noise is about 20 p-p.

Digital ICS-43434



Noise is about 20 p-p.

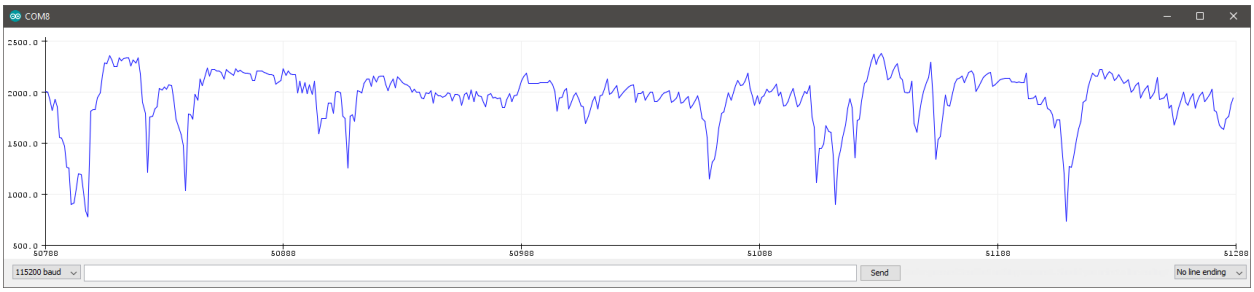
ESP32 Ambient Noise Results

The results of the ESP32 sample sketch appear to have no significant anomalies, although the MAX4466 does seem to have a lot of dropouts.

ESP32 running SR WLED 0.11 dev branch

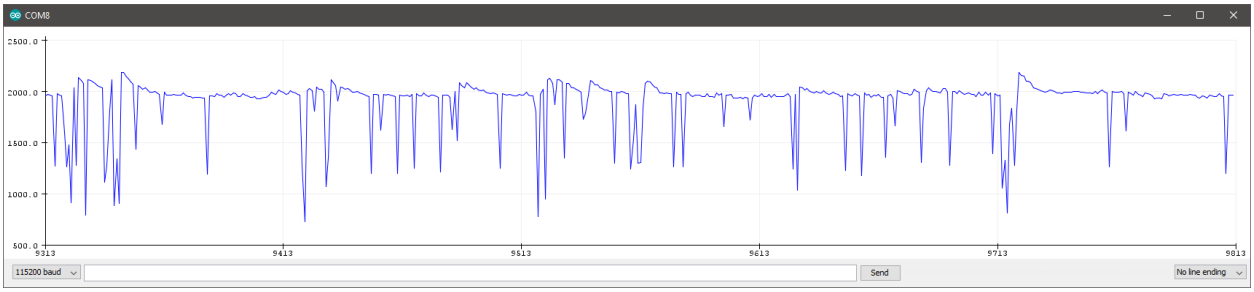
For this test, I am immediately printing out the sampled values from the loop within audio_reactive.h.

INMP411



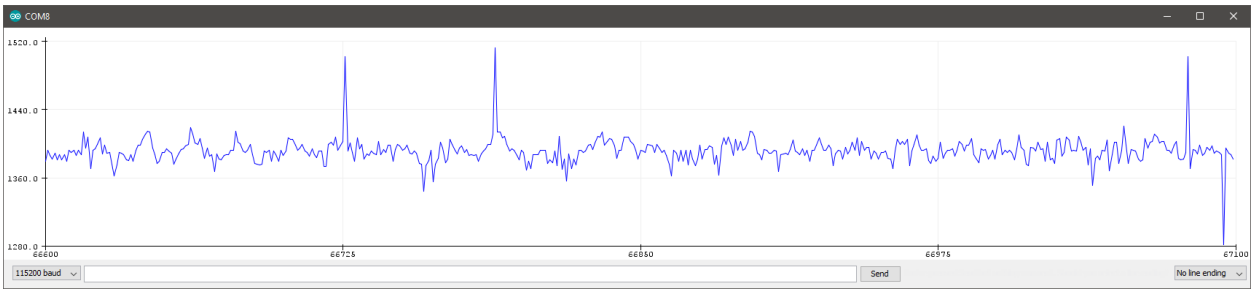
Noise has increased by a huge amount from 25p-p to include spikes that increase it to over 1000 p-p.

MAX4466



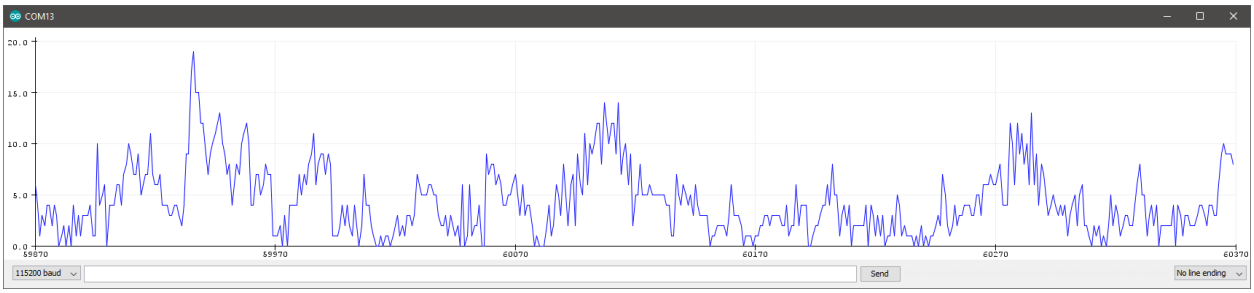
Noise has increased by a huge margin to almost 1000 p-p, and again, more spikes.

MAX9814 @40dB



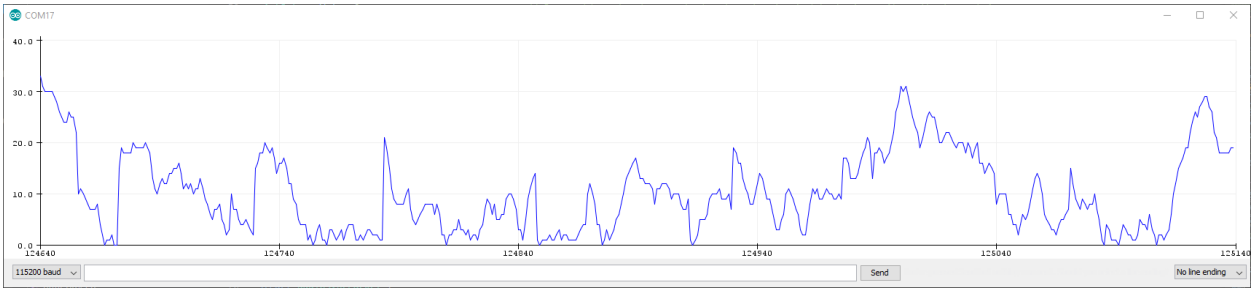
Noise has increased by a large margin and with several (but fewer) spikes throughout.

Digital INMP441



Noise is still about 20 p-p. This sampling is consistent with that of the basic I2S sampling sketch.

Digital ICS-43434



Noise is about 30 p-p and is, again, consistent with that of the basic I2S sampling sketch.

Observations

The recommended microphone configurations exhibited a peak-to-peak noise difference of up to 50 when running a basic sound sampling sketch. Once WLED was loaded, the peak-to-peak values for the analog microphones increased by a huge factor as well as a large number of spikes. The digital I2S microphones remained consistent throughout.

Conclusion

When I first started developing the sound reactive fork of WLED, I was just using the analog microphones and did not observe the significant background noise or spikes that we are now experiencing with SR WLED. Although it may be an issue with our sound reactive code, several reviews have not revealed anything that we may have done to cause this change of behaviour. As a result, I suspect this has something to do with the WiFi capabilities of the ESP32 when combined with the functionality of WLED (an internal hardware issue).

Although we can reduce the noise with some smoothing calculations for the volume (only) reactive effects, this is not an option for the FFT effects which rely heavily on the resultant waveforms for the FFT calculations.

Going forward, it seems that the only way to continue developing reliable FFT calculations and animations is to develop around one of of the I2S microphones and to 'hope for the best' with the others.

I look forward to having these observations debunked or confirmed.

References

In order to keep the setup simple, I have not implemented the recommendations from these references.

[ESP32 microcontroller generates noise on microphone - Electrical Engineering Stack Exchange]