Electrical Engineering Department

California Polytechnic State University

Senior Project First Draft Report

Iridium ADC

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Contents

1. Abstract

Today's modern digital audio systems are pushing performance boundaries. Most high quality digital to analog converters for audio are capable of 24 bit 96 kHz conversion. Professional audio interfaces frequently use 24 or 32 bit 192 kHz sample rates. These systems are able to achieve a dynamic ranges greater than 100 dB, and distortion on the magnitude of single parts per million. This project proposes a high resolution analog digital converter (ADC) to measure and characterize these types of devices.

The proposed system will be capable of 24 bit conversion and an extended frequency range of up to 2 MHz. This allows for a theoretical Dynamic range of over 140 dB, ensuring the systems noise performance is limited by other factors. The extended frequency response offers several benefits:

1. Measurement of distortion products that occur on fundamental frequencies above 10kHz. Even though these products are not necessarily audible, they should be observed if present.
2. Observation of out of band oscillations or other noise. Various issues in a device could result in unintentional self oscillation which will likely be at a greater frequency than conventional audio measurement equipment operating at a maximum of 192kHz can observe.
3. Measurement of non audio signals. Industrial, scientific, and medical equipment may use ultrasonic equipment, and vibrational or resonant analysis may produce signals that go well beyond 20 kHz.

The digitized data will be transferred over USB. Identification as a USB Audio Class device, the system can be used with existing software such as ARTA labs, or Rightmark audio analyzer. However the companion project to this is a free, open source, audio analysis software. In addition to displaying the FFT of the signal, it can measure distortion and frequency response. The program will be extensible with custom scripts and that makes it ideally suited to use within research based fields.

2. Background

High quality audio is a field full of interesting challenges. Audio reproduction involves maintaining a flat response across three decades of bandwidth. Additionally, human hearing has an incredibly broad dynamic range. When designing and building these devices a very sensitive, stable, and transparent measurement equipment must be used.

The Iridium ADC fits these needs and more by supplying a high quality 24 bit converter with a bandwidth greatly in excess of what is normally required for audio. This allows an engineer to perform tests that they can not do with ordinary systems, and allows the Iridium ADC to be used in for measurement in other engineering and scientific fields.

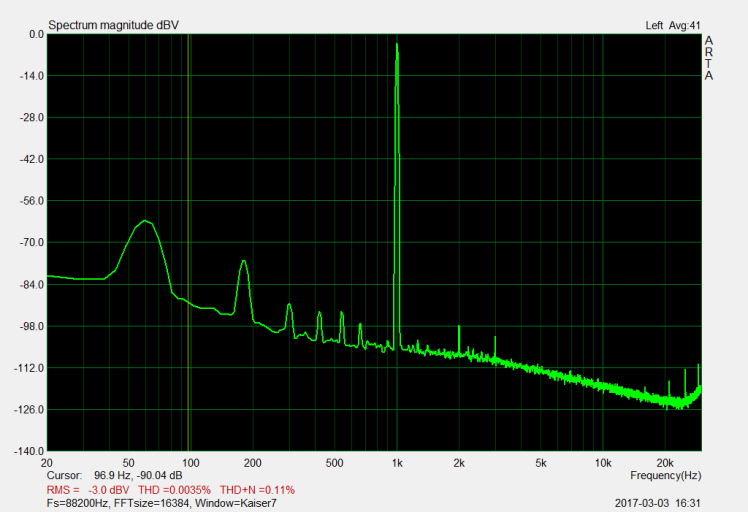


Figure 1: A measurement of total harmonic distortion at 1 kHz using ARTA.

Many audio quality measurement are performed in the frequency domain, and the first step in that analysis is to convert the analog signal to a digital one. Metrics such as frequency response, signal to noise ratio, and, as seen in figure 1, harmonic distortion are often easier to perform in the frequency domain. However to accurately characterize an analog system using these digital tools, an accurate and precise ADC must be used.

What makes an ADC precise and accurate. ADCs have several key qualities. Bit depth determines the number of signal magnitude levels that are available. Since the lowest noise floor that can be achieved is equal to one bit of conversion, this also sets the theoretical dynamic range. A 24 bit converter has a theoretical dynamic range of $20\log(2^{24}) = 144 dB $. The sample rate determines the maximum frequency that can be accurately measured. This has an available sample rate of 4 MSPS, allowing for measurement of frequencies up to 2 MHz. ADC's hav two types of non linearities, integral non-linearity (INL), and differential non-linearity (DNL) as seen in figure 2.

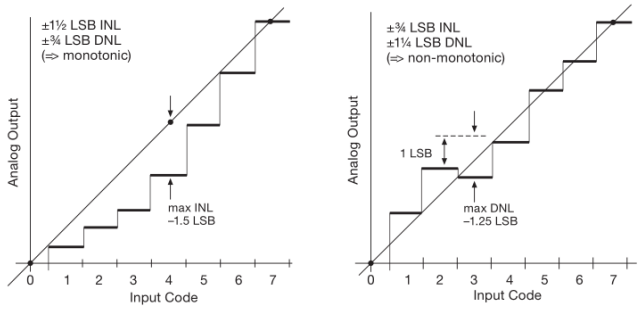


Figure 2: Diagram of INL (left) and DNL (right), from *The Art of electronics, 3rd* by Horowitz and Hill

INL determines the maximum deviation from a straight line over all conversion levels while DNL determines the maximum step change from each level to adjacent levels. The delta-sigma topology that lies at the core of the Iridium ADC features guaranteed monotonicity for less than 1 bit DNL. Delta-sigma converters also feature very low INL with 3 ppm typical.

3. Overview of the Need

3.1 Product Description

The Iridium ADC is a 24 bit, 4 MSPS, analog to digital converter. It has two extremely low noise balanced input channels. The stable, calibrated reference voltage makes it suitable for measurement of absolute (instead of relative) signal levels. It features a bandwidth greatly in excess of existing audio measurement solutions. The data is transferred over USB to a computer where it identifies itself as a USB Audio Class Device. This makes it easy to process and analyze the data using an array of already available tools. The Iridium ADC allows for very sensitive measurement with minimal setup and at a lower cost.

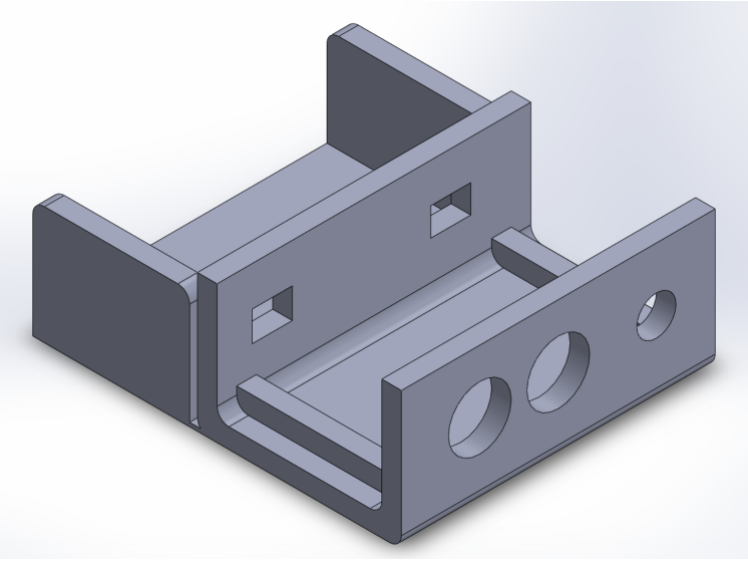


Figure 3: Model of enclosure.

The Iridium ADC is a low profile box with inputs on the front panel. It features two balanced inputs for low noise stereo measurement capability. The front panel controls include:

Front Panel:

- 2 XLR 1/4" combo balanced inputs.
- Impedance switch for high and low input impedance.
- Power switch.

Rear panel:

- USB output
- Power input.

3.2 Product Technology/Market Research

For audio analysis the current market leader is Audio Precision. Their audio measurement systems are the industry standard for professional audio companies. But their equipment carries with it a heavy price tag, reaching into the thousands or tens of thousands of dollars. Common lab equipment for electrical engineering can not be used either. Oscilloscopes simply sacrifice sensitivity for bandwidth. Most oscilloscopes on the market offer 8 bit converters, and suffer from a correspondingly large noise floor. Even the best high resolution oscilloscopes only offer 12 bit conversion, unable to even measure the aged CD standard of 16 bit audio. Additionally, oscilloscopes are not designed for measurements like distortion that are ideally suited to the frequency domain.

Many scientific pursuits also require characterizing high dynamic range broadband signals. Mechanical resonance, vibrational modes, biological signaling, and ultrasonic inspection are all fields that could benefit from having a measurement device such as this. The range of signal inputs that can be taken without adjustment of any front end or external amplifier makes the Iridium ADC useful for production line QA or signal integrity verification. Currently there is no available device that combines this level of dynamic range with this range of bandwidth.

4. Customer Archetype

The Iridium ADC is a tool that allows engineers, product developers, and researchers to obtain and process the data that they need to. The user of this device may fit into several categories.

Small audio companies.

The market for small audio companies has been expanding. Increasingly, independent companies like Schitt audio are becoming the choice for home audio enthusiasts. Guitar effect pedals has seen an explosion in the number of companies developing and (successfully) selling pedals that take on all sorts of mixtures of digital and analog processing. Driven by the presence of mobile audio devices courtesy of our phones, a resurgence in popularity of high end headphones has spurred a market devoted to headphone amplifiers.

Many of these companies have product lines developed just one or two engineers on a shoe string budget. Many probably develop entirely by ear because there are no currently available solutions for audio measurement under the cost of one thousand dollars. By providing a much larger bandwidth than typical audio analysis devices, The Iridium is able to investigate the characteristics of switch mode power supply noise, out of band distortion products, EMI pickup, self oscillation, and more signals that would not be shown on most audio targeted device. By making the tools available, the Iridium ADC allows these engineers the tools to close the feedback path on these devices, thereby reducing development time, improving the performance, and accurately report technical specifications.

Scientific Research

The Iridium ADC can function as a multiuse data acquisition system. There are many signals similar to audio present in natural phenomenon and useful in scientific or industrial research. The ability to measure signals of a few microvolts and of a several volts simultaneously can open up the ability of a researcher to collect data and perform the cleanup and filtering in the digital domain. The bandwidth allows for research into both ultrasonic and subsonic bands. Accurately and confidently measure signals that could not be captured on most traditional lab equipment.

5. Market Description

The Iridium ADC is enabled by the development of several integrated circuits.

Balanced inputs with selectable impedance allow for selection of lowest self noise or best transfer of signal from higher impedance sources. The low noise front end is enabled by the series of difference amplifiers produced by THAT corp. The THAT 1200 Balanced Line Receiver IC is able to condition the incoming with a minimum of added noise while providing up to 90dB of common mode noise rejection.

This feeds into the impressive Texas Instruments ADS1675 delta-sigma ADC capable of 24 bit conversion with a bandwidth of 1.7 MHz. This chip allows for guaranteed monotonic conversion across all 24 bits, with the addition of excellent linearity of conversion that comes along with delta-sigma converters. A calibrated voltage reference ensures that converted data is based on a known standard. All of this is controlled by a microcontroller that converts the I^2C data to USB Audio class PCM and powered by a low noise, linear power supply for clean, quiet, smooth power.

Presently, the devices produced by Audio Precision are best in class devices. But only their most expensive model has a bandwidth exceeding 90 kHz, and their cheapest unit cost several thousand dollars. Many consumer audio interfaces offer 24 or even 32 bit converters, and can offer sample rates of up to 192 kHz while maintaining distortion figures down to just a few parts per million. This is similar to Audio Precision, and they do this for just a few hundred dollars. Their usefulness for is limited for because they do not offer a stable or known reference voltage. They must be calibrated with each use and the reference tends to drift heavily with temperature and age.

As a small, potential driven company, The Iridium ADC can serve it's small audio company customers by being on itself. The same drivers that have allowed the explosion of companies specializing in audio can allow us to serve their needs.

The cost to performance ratio of this device make it able to target markets too small for larger devices to go after.

Audio measurement is currently underutilized in the hobby community. By encouraging and supporting the DIY community we can establish a name in the audio development community. This can lead to an opportunity in getting companies as customers when they are small but growing.

Cost to enter market is small, but entrance is not easy. There are limited marketing opportunities for these markets. Advertisement can be performed in trade journals. Dealing directly with specialty retailers is essential.

6. Business Model Canvas

Key Partners

- Small Audio Companies
- Scientific Researchers

Key Activities

- Journals and trade papers
- Online enthusiast forums

Key Resources

- Prototype cost is not especially expensive, and does not require any custom tooling, however this not a consumer device, so the BOM cost is significant, and includes some high per-unit costs.
- App Notes and technical papers on low noise, low distortion design
- *Time*

Value Proposition

- Measure and characterize audio systems, perform scientific measurement, and view signals in real time.
- Wide bandwidth for measuring broad set of data.
- Wide dynamic range for sensitive measurements.
- High precision, repeatable measurement.
- Lower cost than competing systems.
- Computer based system for easy acquisition and processing of data.

Customer Relations

- Work with customers to develop measurement capabilities that meet their needs.
- Offer direct support in developing methods and techniques of measurement.

Channels

- Direct sales model.
- Targeted marketing through trade journals, online forums, and youtube channels.

Customer Segments

- Small audio companies
- Scientific and medical research
- Engineering teams that perform frequency domain analysis.

Cost Structure

- Funding for building and testing several prototypes.
- Direct sales requires some warehousing and shipping fees, but this is reduced by the low expected volume.

Revenue Stream

- Direct Sales of units
- Subscription based support system.

7. Marketing Requirements

The customers for the Iridium ADC need the device to be high performance, reliable, robust, and accurate. These manifest as a system with balanced inputs, low noise, high bandwidth, and with a stable reference. For ease and flexibility of use, the unit should be compact and self contained and provide the most common input types. The ideal form factor would be similar to many audio interfaces and the Audio Precision line of analyzers, such as those in Figure 4

Figure 4: A consumer audio interface from Focusrite and a professional Audio Analyzer from Audio Precision

7.1 Marketing Data Sheet

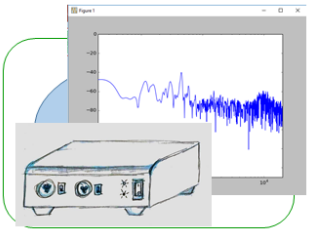
Product/Project Name: Iridium ADC and Clear Box FFT Analyzer

Unmet Customer Need: Low cost (100's of dollars) precision Data acquisition. Modern, efficient, software for collecting and analyzing real time signals.

Unique Value Proposition: Free, open source software can be used with existing consumer hardware. Iridium ADC is the companion and provides a calibrated, high performance input.

Target Customer: Small audio companies and enthusiastic hobbyists.

Positioning: There is no free open source software for audio analysis, and certainly none with companion interfaces.



Pricing and Availability:
- Iridium ADC: $500
- Clear Box FFT Analyzer: Free!
- Senior Project Expo Spring 2017

Product Objectives:
- Take hobby market for audio analysis.
- Create easy to use software.
- Extend to educational market

Customer Benefits:
- Access to audio analysis can shorten development and debugging cycles of products.
- Lower cost gets the equipment in the hands of more people.

Sustainable Differentiation:
- Free software creates name recognition and should become hobbyist standard.
- Additional features can be implemented software side.
- Possible commercial paid licensing/ subscription basis.

Disruptive Go-to-Market:
- Paid marketing in hobby forums
- Unpaid non traditional media through engineering or audio focused YouTube channels, and podcasts.

7.2 Marketing Requirement Table

Importance	Marketing Requirement	Justification
High	Low noise	Low Self noise preserves as much of the available dynamic range as possible. This enables measurement of signal than span from a few microvolts to several volts.
High	High bandwidth	Bandwidth allows for measurement of signal and products that are beyond the scope of other signal analyzers.
High	Low Distortion	Attempting to measure device that have very low distortion requires a measurement unit with even lower distortion.
High	Stable, known reference	This allows for confidently transforming the relative measurement of decibel-full scale into an absolute voltage level. This is a large part of what separates this from the available consumer level devices.
High	Balanced inputs	Essential for eliminating noise pickup from sources with very low output levels. Professional audio systems are nearly always differential.
Medium	Built in power supply	A completely integrated power supply makes for a cohesive, professional product. It also allows for complete control over the power quality, while using an external supply may result in use of a noisier or insufficient supply.
Medium	USB Audio Class Device	Allows device to be cross platform, using drivers already integrated into most systems. Alternative data transfer requires writing and maintaining our own driver.
Low	Switchable Input Impedance	Lower input impedance may provide lower self noise, at the expense of less signal from high impedance sources.
Low	Robust input protection	Use the ADC without concern for damage caused by large signal pulses.

8. References

TBD