Chapter 7
USB Connectivity for Harnessing High-Quality Digital Sensor Data

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Abstract In recent years, an increasing number of digital sensors and signal conditioner devices have adopted the USB Audio format [1] as their core communication protocol. The USB device naming introduces a novel method for retrieving sensor calibration making it easier to identify devices, scale, and acquire accurate sensor data. Software applications across various platforms can be optimized for seamless communication with these digital sensor products, eliminating the need for proprietary drivers as the USB audio protocol is either native or readily available on all popular operating systems such as Windows, Linux, macOS, Android, and iOS. Last but not least, the USB device name is readily available in all these applications while other USB parameters can be more complicated to access. While there are multiple possible technological implementations to accomplish digital sensing, the USB connectivity is unique on its natural plug-and-play capabilities facilitating the interface with the sensors while revolutionizing the way in which data is captured, calibrated, shared, and utilized across multiple platforms.

Keywords Digiducer · SmartSensors · Calibration · USB · DigiDAQ

Historical Context: TEDS and IEEE 1451.4

To appreciate the current landscape of digital sensors, a brief examination of Transducer Electronic Data Sheets (TEDS) as per IEEE 1451.4 is warranted. Two decades ago TEDS provided the first framework for storing sensor data in a standardized format, allowing data acquisition systems to automatically retrieve sensor model number, serial number, and calibration information. This groundwork laid the path and inspiration for the most recent generation of digital products featuring embedded calibration information.

The USB Audio Format and its Impact

Digital sensing products such as the 333D01 Digiducer^{TM} and the 485B39 DigiDAQ^{TM} embody the principles of USB audio technology by embedding sensor calibration within the device name. These products utilize **digital counts** as the output unit that provides 24-bit high-resolution for data samples consistent with the sensor output.

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The following figure illustrates conceptually how the digital accelerometer sensitivity is defined:

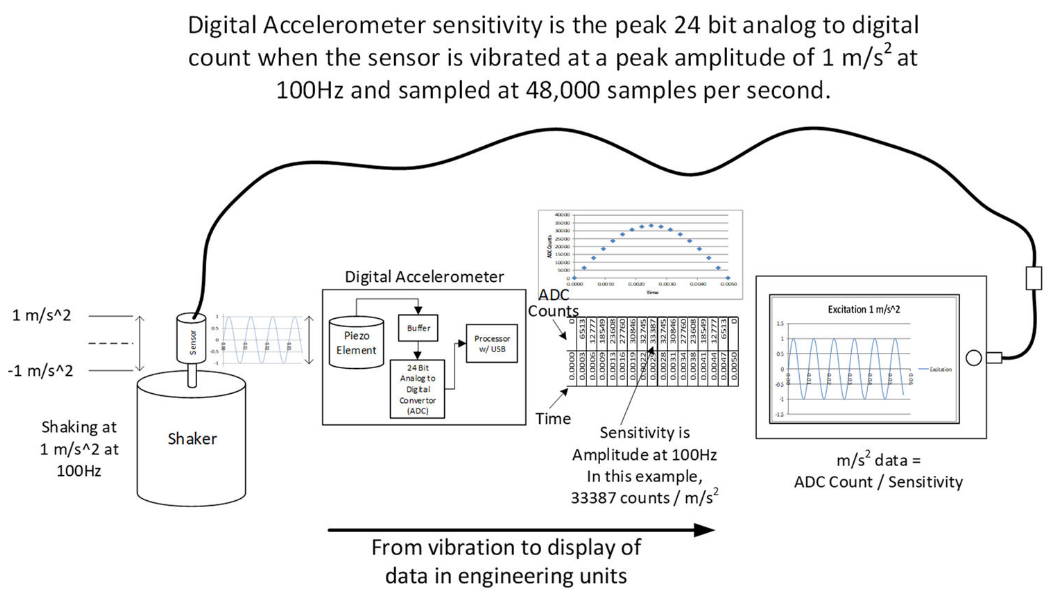

Fig. 1 Digital Accelerometer Sensitivity

The sensitivity information for the original model 333D01 Digiducer, for example, can be retrieved by simply decoding the data embedded in its device name. During calibration of the sensor, the sensitivity information is programmed into the name field of the USB descriptor. Specifically, for digital accelerometer products (Version 1 Format), the device name field format is:

MMMMMMs1NNNNNNAAAAABBBBBYYMMDD

Where:

- MMMMMM is 6 digit model number (333D01, 633A01, 333D04, ...)
- s is space
- 1 is single character format definition. This indicates an accelerometer is being defined
- NNNNNN is 6 digit serial number
- AAAAA is 5 digit sensitivity value in counts / (m/s^2) for channel A
- BBBBB is 5 digit sensitivity value counts / (m/s^2) for channel B
- YY is the last two digits of the year (00-99) with actual year being 20YY.
- MM is the month number (1-12).
- DD is the day (1-31)

Essentially, software applications can access this information and use it to scale the acquired data into calibrated engineering units for display and analysis.

The 485B39 DigiDAQ on the other hand converts ICP® (or IEPE) sensor signals from voltage to digital samples. Instead of being limited to only a single axis of acceleration data, the digital signal conditioners interfaces to the wide family of ICP sensors. Sensor types include piezoelectric accelerometers, force, microphone, and tachometer sensors. The device has 2 channels of phase coherent data. The implementation and processing are similar to the digital accelerometers. The applicable units are, in this case, Digital Counts / Vpeak, instead of Digital Counts / m/s^2. The 485B39 can serve as the digital interface for a large range of dynamic sensors offering high-quality dynamic data for a variety of applications. It should be noted that the DigiDAQ only has calibration to volts. The sensitivity for the sensor connected to the DigiDAQ needs to be known and used to scale from volts to engineering units. A Version 2 Format (Voltage) is defined and used by the digital signal conditioner products [2].

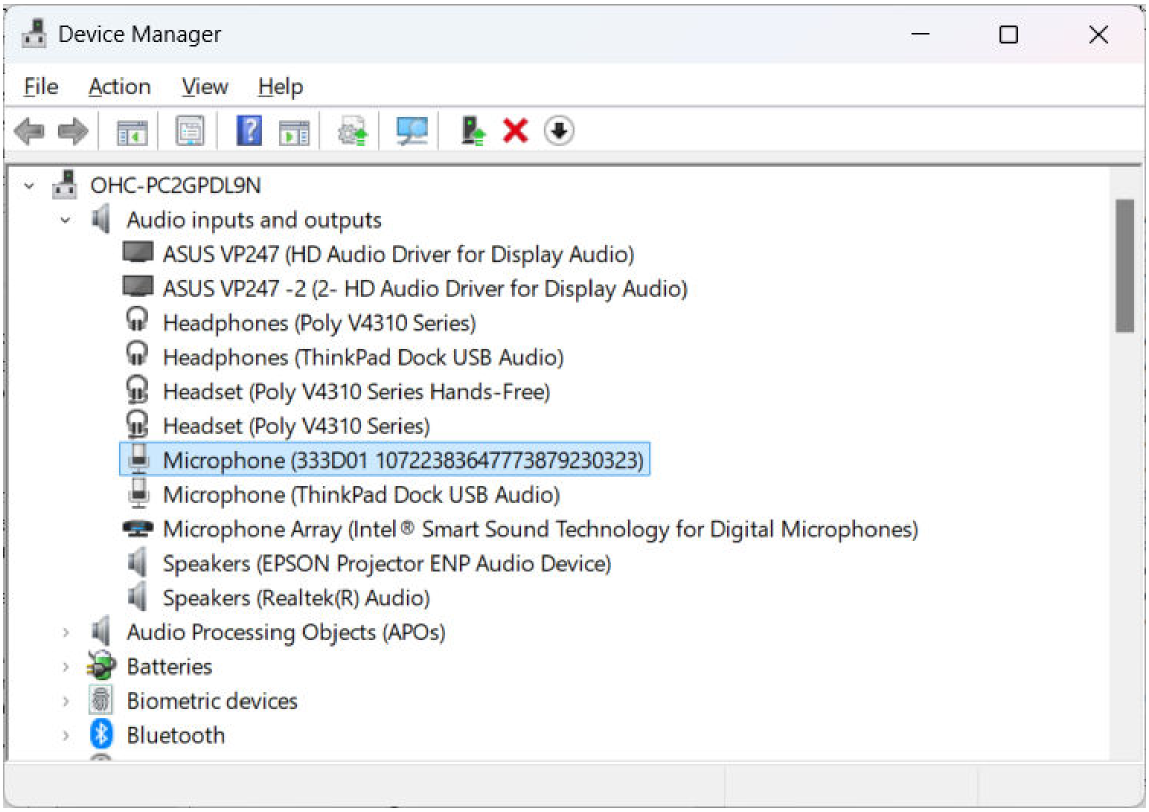

Fig. 2 A USB Digital Accelerometer shows up as an Audio Input Device under Microsoft Windows Device Manager

Conversion to Acceleration

The table below has typical conversions from digital sensitivity to the acceleration in g's:

From	Factor	Decimal	To
Integer Sample -2^{23} to $(2^{23}$-1)	$\frac{1}{\textbf{sensitivity}\left(\frac{counts}{\frac{m}{s^2}}\right) * 9.80665\left(\frac{\frac{m}{s^2}}{g}\right)}$	$\frac{0.10197}{\textbf{sensitivity}}$	g
Normalized-1.0 to 1.0MATLAB, M+P Smart Office	$\frac{2^{23}\left(\frac{counts}{signed\ full\ scale}\right)}{\textbf{sensitivity}\left(\frac{counts}{\frac{m}{s^2}}\right) * 9.80665\left(\frac{\frac{m}{s^2}}{g}\right)}$	$\frac{855400}{\textbf{sensitivity}}$	g

There are similar formulas to convert digital counts to volts for the digital signal conditioner [2].

Implementation and Practical Considerations

In implementing USB-connected digital sensors, developers must consider several factors, including phase synchronization and signal conditioning. The 485B39 DigiDAQ, for instance, is designed to minimize phase mismatch, making it suitable for applications where channel synchronization is critical. Unfortunately, getting consistent phase response between multiple USB devices remains a challenge.

Power consumption is another critical requirement when operating with mobile devices such as phones and tablets. It is important to keep the current and the power consumption under 100mA at 5V while working with Apple mobile devices. The low power and compact design implementation of the Digiducer and the DigiDAQ devices makes it compatible with the power requirements of all portable Apple iOS and Android based products in the market today.

This new class of digital products drastically reduces the implementation effort for enabling customer solutions. It is easy for existing application developers to add support, or for customers to use their programming environment and language of choice to develop their own custom applications.

Conclusion

The integration of USB Audio format connectivity in digital sensors offers a remarkable transformation in acquiring high-quality sensor data. These advancements provide robust, scalable, portable, and straightforward solutions for data collection, ensuring seamless integration across diverse operating systems. As technology progresses, digital implementations like the 333D01 Digiducer and 485B39 DigiDAQ underscores the ongoing journey towards simplicity and precision in sensor technology. The future undoubtedly holds further innovations in this realm, promising to refine how sensors are utilized in various applications.

References

1. "Universal Serial Bus Device Class Definition for Audio Devices" https://www.usb.org/document-library/audio-device-document-10 March 1998
2. Clary, Tom "USB Audio Interface Guide – MAN-0343" https://www.modalshop.com/docs/themodalshoplibraries/software/usb-audio-interface-guide-man-0343.pdfOctober 2022