Beagle USB 480 Protocol Analyzer / Convergence Instruments

Company:
Convergence Instruments

CHALLENGE

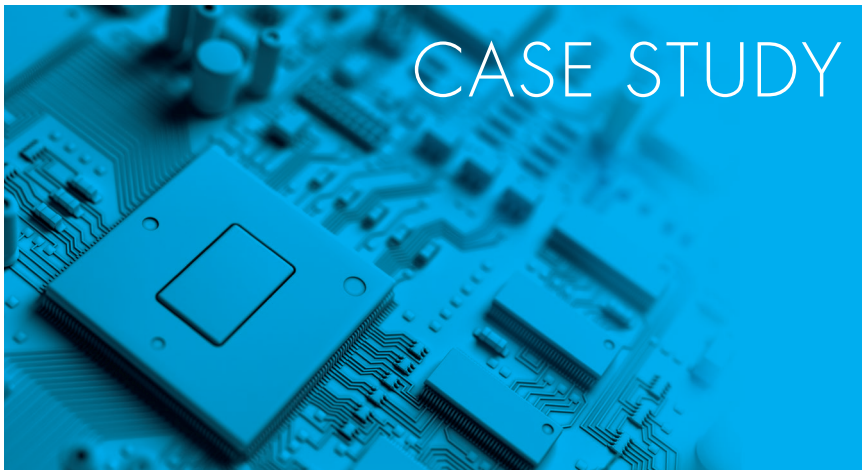
Because the ACAM_64 Acoustic Camera is a composite USB device that includes multiple interfaces with their own descriptor information, this invoked design challenges as well as a need to ensure that all three interfaces worked together properly and could be serviced by the MCU without timing issues.

SOLUTION

The Beagle USB 480 Protocol Analyzer was used in all development phases including testing, debugging, and final validation of the ACAM_64 Acoustic Camera. With this tool, they could easily start capturing USB data and descriptor information between the camera and host.

BENEFIT

By providing detailed insights into the USB data exchanges and enumeration process between the camera and host, this USB analyzer has allowed their team to easily pinpoint protocol violations and enumeration errors, which has greatly accelerated and simplified the development and debugging process for this product.



Convergence Instruments is a global designer and producer of affordable, high-performance solutions used to acquire and analyze data detected from motion, vibration, and acoustic measurements within systems. They offer small but powerful data loggers with embedded acoustic and vibration measurement capabilities that process and analyze sound and motion/vibration data signals. Additionally, their company offers an acoustic camera that allows users to find, measure, track, and record sources of sound. These solutions are available for both the consumer market and a wide variety of commercial/professional OEM markets.

When developing their **ACAM_64 Acoustic Camera**—a composite USB device with three separate interfaces—Convergence Instruments performed product testing, debugging, and final validation to determine that all interfaces worked together concurrently without issues. To do this, their team used the Beagle USB 480 Protocol Analyzer to gather USB data and its different descriptor classes to verify there were no data or enumeration errors.

Background/Problem:

Convergence Instruments develops and produces an acoustic camera, called ACAM_64. This camera is a composite USB device with three interfaces, each with a different USB interface descriptor, including CDC and Audio types.

Enumeration Process and Descriptors

A composite USB device is a single piece of hardware that connects to a host computer through a single USB cable, but acts as though it contains multiple independent USB devices. A composite USB device supports more than one USB device class.

A USB device class is a particular code defined within a USB device that is used by the host to identify a peripheral's functionality and to load the appropriate driver based on this information. Classes can be defined as groups of similar devices, including Audio and Human Interface Devices (HID).

In order for the host to identify the peripheral's USB class, an enumeration process is prompted upon connection. During this process, the host obtains the peripheral's descriptor information, including the Device Descriptor, Configuration Descriptors, Interface Descriptors, and endpoints, to learn about the device and how to communicate with it. There are two places on a device where class code information can be placed, including the Device Descriptor and Interface Descriptors.

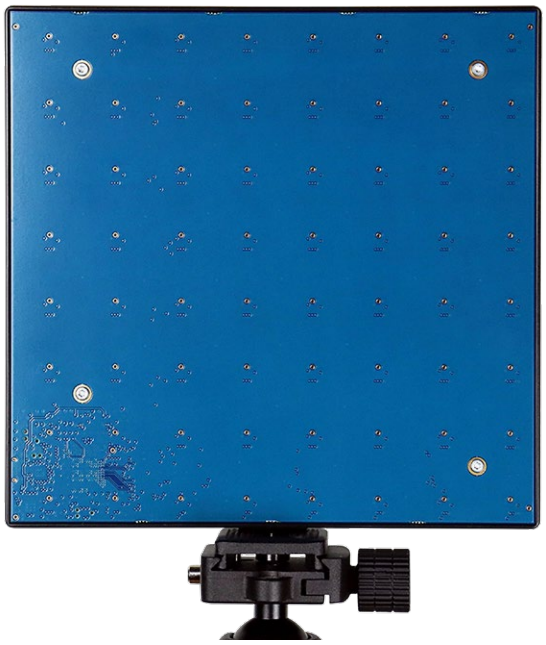
The Device Descriptor is the first descriptor read by the host. The Device Descriptor provides the host with information about the device, including the VID/PID (Vendor ID (VID) Product ID (PID), the USB specification the peripheral complies with, and how many possible configurations are available on the device. Once this has been processed, the host then reads all of the Configuration Descriptors.

A peripheral device may have more than one configuration where each device configuration is assigned a number, however most devices include just one. This Configuration Description allows the host to determine the number of interfaces that are in the configuration.

A device may have one or more interfaces as well. An Interface Descriptor provides the details of the function of the product, including the number of endpoints on the device and endpoint descriptors. The endpoint provides insight into where a packet is coming from or going to. For instance, by looking at the Interface Descriptors, the host will know it's an audio interface and then look at the two endpoint descriptors to know which endpoints to send and receive audio data to/from.

Sometimes, USB interfaces may have alternate settings, which are different choices for parameters of the interface. This can be used to control individual endpoints in various ways, such as reserving different amounts of USB bandwidth for the device. For example, an audio or video interface usually has the default interface using no bandwidth; then the host selects this alternate interface (SET_INTERFACE) to enable bandwidth usage.

About the Camera and Its Interfaces



The ACAM_64 is an 8×8 microphone array and real-time beamformer. It can build a 32×32 pixel image of sound sources in real time, with adjustable frequency response within 1 kHz to 8 kHz.

Mentioned previously, the ACAM_64 Acoustic Camera has three interfaces. Two of these include Audio and CDC types.

The CDC interface allows the instrument to be controlled and images to be retrieved using an open protocol based on virtual COM port. This protocol can be used on any platform that has a generic USB CDC driver, including Windows, Linux, and Mac OS.

Through the USB-Audio interface, the instrument can stream audio to the host platform and is seen by the host as a USB microphone. That audio signal is the output of the beamformer and can be steered digitally to any azimuth and elevation in the field of view of the camera. Using the provided Windows application, the beamformer can even track any acoustic source in the field of view. The USB-Audio interface works on any platform that has a generic USB-Audio driver, including Windows, Linux, and Mac OS.

Designing and Debugging the Camera

When designing this camera, there was a challenge when it came to ensuring that each of the three interfaces worked together seamlessly and could be serviced simultaneously by the microcontroller unit (MCU) without timing issues. This posed new design challenges at the descriptor level. In addition, two of these interfaces (CDC and Audio) needed to be validated on Windows, Linux, and Mac OS operating systems.

In order to determine these components operated together correctly, their team required a tool to capture Full-speed USB traffic and the corresponding descriptor information between a host and the camera to gain insight into data packets exchanged on the bus, any protocol violations, and enumeration errors.

Technical Approach:

Convergence Instruments utilized the Beagle USB 480 Protocol Analyzer and Data Center Software to capture and monitor USB traffic being sent to and from the ACAM_64 acoustic camera to a host machine.

The Data Center Software is a graphical user interface (GUI) used in conjunction with the Beagle USB 480 Protocol Analyzer to allow users to view device details and the captured USB data in real time.

Within the software, there are multiple features that are helpful in debugging composite USB devices:

The Bus Pane found in the Navigator window of the Data Center Software shows the devices that have been detected on the serial bus and provides detailed device information including addresses, configurations, and endpoint descriptors. The packets and bytes columns list the number of packets and bytes that have been sent or received from each endpoint, interface, configuration, and entire device. This pane also provides statistics and enumeration details of the devices and bus transactions.

By default, the Data Center Software uses configuration descriptor information captured during the enumeration phase to configure class-level decoding of USB traffic. However, through the Configuration Management interface, users can apply arbitrary configuration descriptors to the captured USB device data. This provides a custom class-level decoding experience within the set of USB classes supported by the software.

Clicking on a device will show a summary of the descriptor information below the tree in the Enumeration tab. Expanding a device will reveal a hierarchy of descriptor information from the device, configuration, interface, and endpoint descriptors. Clicking on any level of the tree will show a parsed view of those descriptors and any child descriptors.

Debugging ACAM_64 within Data Center Software

During the testing and debugging phases, Convergence Instruments used the Beagle USB 480 Protocol Analyzer to connect in line between the acoustic camera and the host machine to capture all USB communication between the two. This allowed them review the enumeration and USB data exchanges to determine whether the MCU could effectively communicate with each different interface without any protocol errors or timing issues.

For instance, one of their focuses was debugging the data packets between the Audio interface and the host.

"The Beagle 480 Protocol Analyzer is so easy to setup and use. The data is presented in such a clear and easy to read manner, yet it has powerful capabilities. This is one of the best USB analyzers that we have used during development."

— Bruno P., Director and Senior Designer

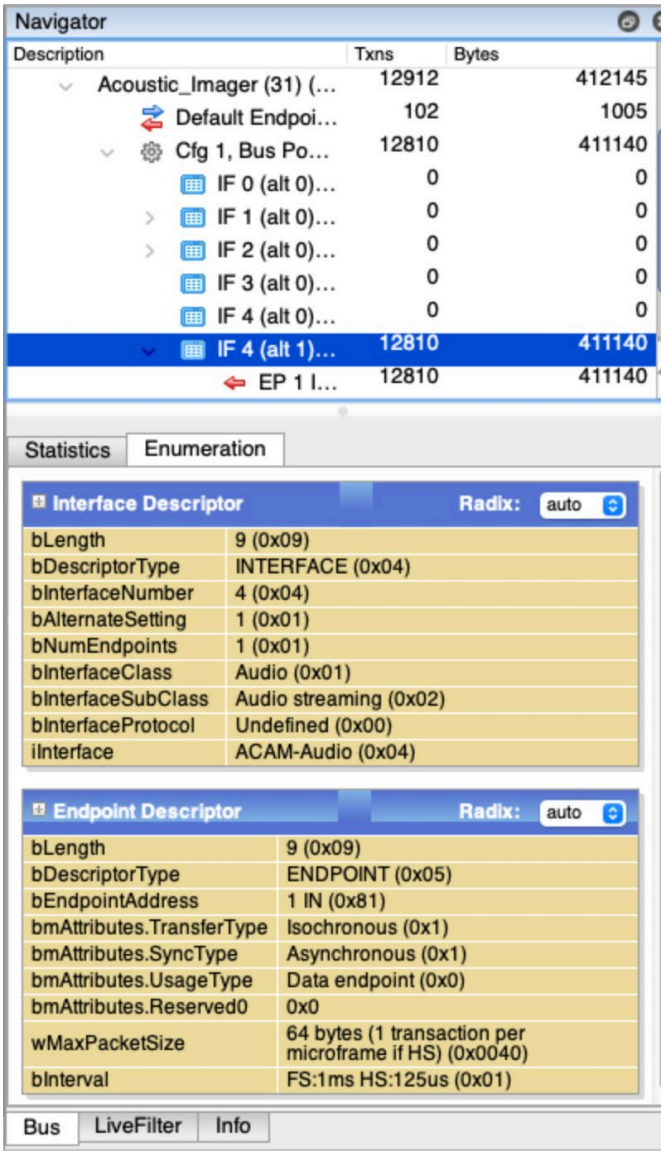
For this, they used the Beagle USB 480 analyzer to capture the audio stream on the wire, exported that to a binary file, and performed a bit-level comparison to the file recorded by the host at the application level.

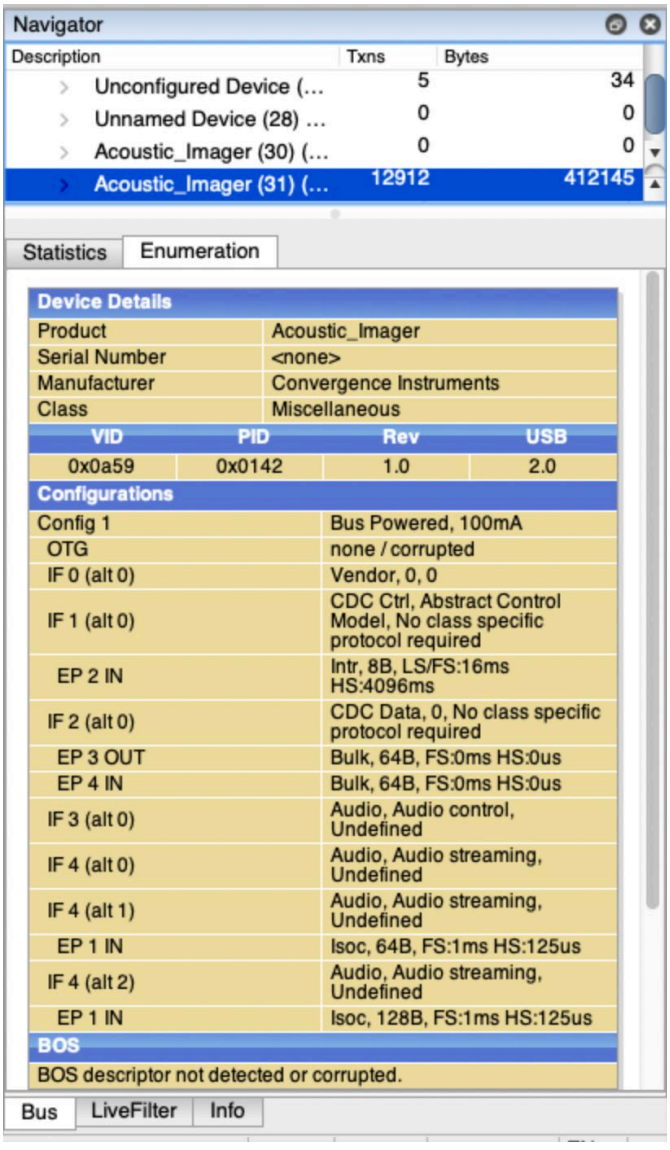
Bus Pane: Enumeration and Statistics Panes

Using the Enumeration tab, Convergence Instruments was able to review the device's details and configurations captured upon enumeration. Here, the software captured different configurations that included multiple interfaces and interface alternatives, including the Audio and CDC interfaces mentioned earlier.

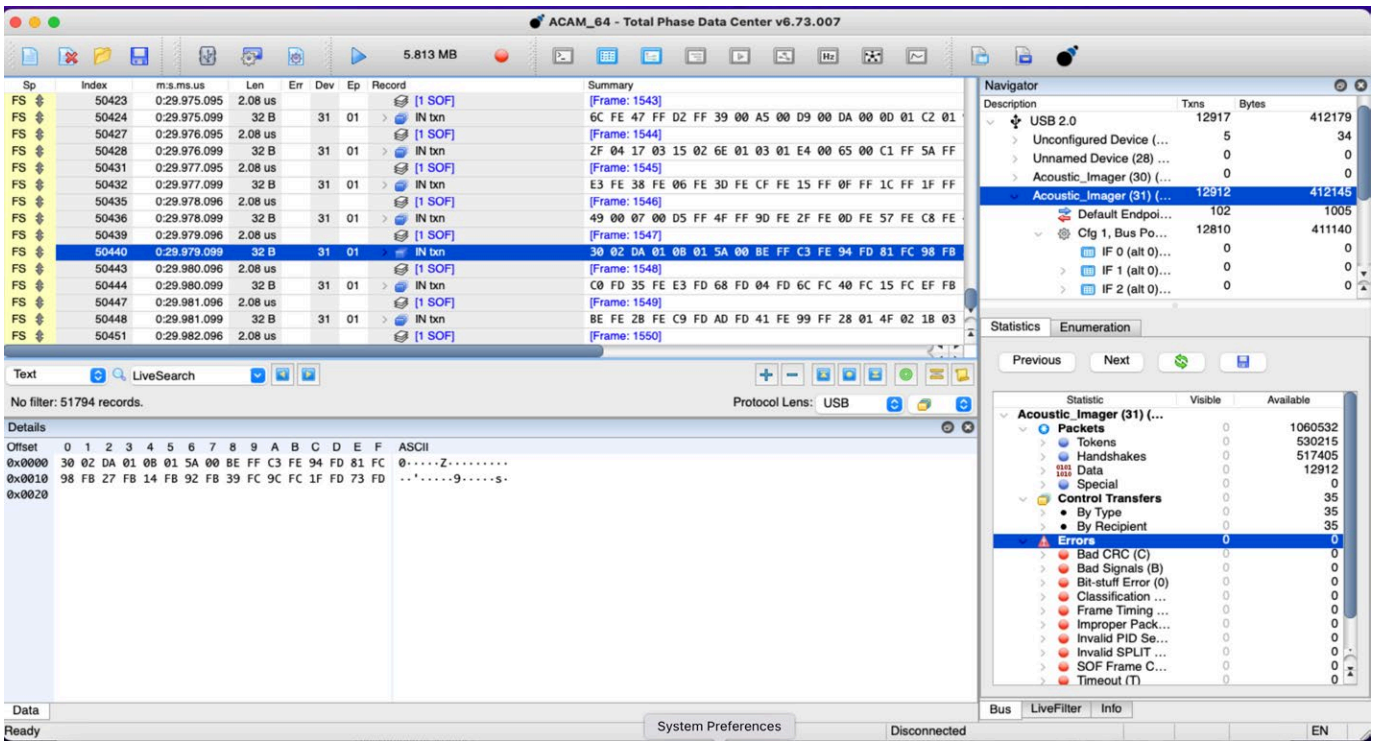
In this tab, they could view the Endpoint numbers and directions (EP1 IN and EP1 OUT), as well as the alternate interfaces (alt x) detected on the device.

By clicking a device and expanding it within the Navigator pane, they were able to review a hierarchy of descriptors captured from the detected devices, configurations, interfaces and interface alternatives, and endpoints. This pane provides the number of packets and bytes sent and received by each. The Enumeration tab provides the corresponding descriptor information. As seen in this example, when clicking on IF 4 (alt 1), Convergence Instruments could review details on the interface and endpoint descriptors for the Audio interface and see the number of packets and bytes sent from it.





Within the Transaction window of the software, Convergence Instruments was also able to review the data exchanges between the host and the acoustic camera in real time and gain insight into the data packets that were sent and received from a specific endpoint, as well as detect any protocol errors.



Using the Beagle USB 480 Protocol Analyzer to Debug the Camera

The Beagle USB 480 Protocol Analyzer can non-intrusively capture and monitor High-speed USB 2.0 traffic (up to 480 Mbps) in real time and offers real-time USB class decoding.

Convergence Instruments chose this USB protocol analyzer for testing and debugging their USB device for various reasons:

- It is easy to set up and use. For any device conditions they needed to check, they were able to quickly set up the analyzer and begin capturing the USB data packets within seconds.
- It is a compact tool that does not require external power.
- It decodes descriptors in an intelligible manner that greatly facilitates detection of enumeration errors.
- It offers high-level class decoders that automatically highlights protocol violations.
- The packet timing allows a precise measurement of USB bandwidth. This is especially important for the Audio-class interface.



- It can run on a circular buffer for an indeterminate amount of time that allowed them to run the analyzer for hours or days when trying to catch a rarely occurring problem.
- They were able to archive .tdc files to document the development and refer to them later. This can be helpful after a firmware change.
- It is supported on various operating systems including Windows, Linux, and Mac OS, which allowed them to validate two interfaces (CDC and Audio) on each.
- It is offered at an affordable price point.

Conclusion:

By using the Beagle USB 480 Protocol Analyzer, Convergence Instruments was able to easily debug and verify USB communication sent between a host and their Acoustic Camera ACAM_64. Using this tool, their team quickly captured data, reviewed descriptor information and any enumeration errors, and was able to capture limitless amounts of data using the circular buffer to find specific but sporadic errors. These capabilities allowed them to efficiently develop and debug their acoustic camera and conclude that the MCU could properly communicate with each interface within the camera as expected.

Product Brief:

The Beagle USB 480 Protocol Analyzer is a low-cost, non-intrusive High-speed USB 2.0 bus monitor that includes real-time USB class-level decoding. The Beagle USB 480 analyzer is capable of capturing and interactively displaying High-speed USB bus states and traffic in real time with timing at 16.7 ns resolution. With an on-board 64 MB buffer, sustained bursts of 480 Mbps traffic can be captured with no loss of data. Additionally, this analyzer offers High-speed USB chirp detection, automatic speed detection, hardware-based packet suppression, and digital inputs and outputs for synchronizing with external logic.



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