Beagle™ USB Protocol Analyzers / Linus Tech Tips

Company:
Linus Tech Tips

CHALLENGE

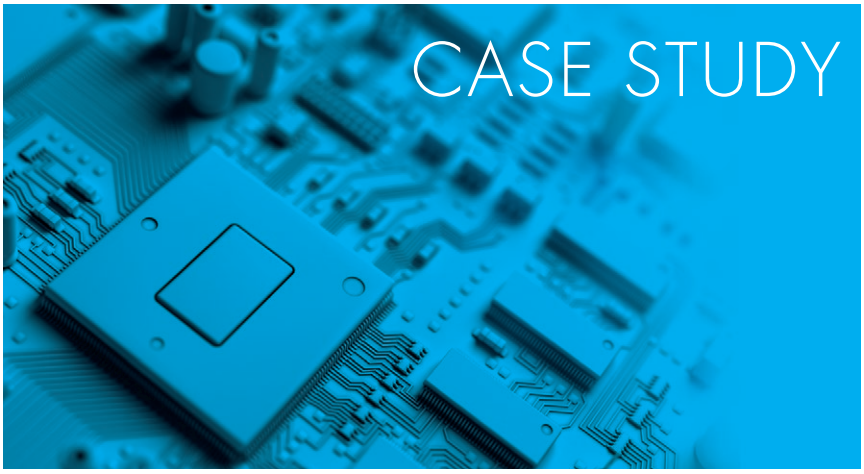
The Software Development/Engineering team is dedicated to automating their testing processes to minimize errors and enhance efficiency in the lab, with one focus on evaluating the performance of keyboards and mice. One testing scenario involves measuring end-to-end latency of these peripheral devices. However, isolating the peripheral device from the system to accurately measure its latency proved to be an obstacle. In addition, their team aimed to simulate keyboard input without burdening the test benches with excessive processes and to capture large amounts of USB data during the test simulation.

SOLUTION

By using the Beagle USB 480 Power Protocol Analyzer and Beagle USB 480 Protocol Analyzer, their team was able to overcome these obstacles. With the Beagle USB 480 Power Protocol Analyzer's digital inputs and real-time data capture capabilities, their team is now able to precisely measure the latency between a keyboard or mouse and the PC. Additionally, the Beagle USB 480 Protocol Analyzer is capable of recording hundreds to thousands of commands of keyboard input for playback.

BENEFIT

The Beagle USB 480 Power Protocol Analyzer's ability to identify endpoints and display USB packets in real time is crucial for identifying key presses and measuring latency across devices from various manufacturers, while the Beagle USB 480 Protocol Analyzer is capable of capturing and recording large amounts of data from keyboard input that is then used for playback to test keyboard performance in more complex scenarios.



Linus Tech Tips is an esteemed YouTube channel and media company that specializes in technology-related content. With a blend of informative yet entertaining presentation, this channel has become a trusted and reliable source for millions of subscribers, featuring consumer electronics reviews, various product tutorials, unboxings, and tech news updates.

To create this content, Linus Tech Tips utilizes a state-of-the-art lab that is equipped with a wide range of tools and equipment needed for testing, reviewing, and showcasing various products.

Linus Tech Tips relies on a well-rounded team to execute and produce their informative videos, with a division of engineers and software developers tasked with developing methodologies and procedures to thoroughly and autonomously test consumer electronics to help streamline their processes

Background/Problem

To maintain themselves as a benchmark for consumer electronics reviews, Linus Tech Tips expends their team of engineers and software developers to implement different methodologies to enhance testing procedures within their lab. With a focus on automating testing processes to minimize errors and ensure consistency, one of their primary objectives is to achieve reliable and repeatable measurements in different testing scenarios, including evaluating the performance of computer peripherals such as keyboards and mice.

This includes measuring end-to-end latency of these devices and capturing and recording USB data from keyboard input to playback for simulation testing. However, during these processes, they encountered setbacks that hindered their ability to efficiently evaluate device performance.

Latency

When using conventional methods to measure latency, which typically incorporate the entire system including the operating system, processor, graphics card, and display, they encountered a significant challenge: isolating just the peripheral device to accurately assess the latency of the device itself. Using these conventional methods, they would need to subtract the latency contributed by these other components within the system, which could disrupt a streamlined and simplified analysis.

Due to this, their team aimed to acquire a device that enabled them to gather precise latency measurements starting from the point of contact on the peripheral to the first signal detected on the wire.

Recording USB Traffic

To perform their keyboard simulations, they previously used the Windows API function SendInput to mimic keyboard input, and while this is adequate for functional testing (pass/fail), this method doesn't fully satisfy performance testing. For this testing, their goal is to treat their PC test benches as black boxes, which would require running minimal processes.

To achieve this, they offloaded the keyboard simulation process from the test bench by integrating a microcontroller or Raspberry Pi-like device acting as a Human Interface Device (HID). From here, they could send commands to the controller to send inputs to the test bench. This set up allowed them to perform simple sequences such as navigating a menu, but fell short when needing to stream hundreds or thousands of commands while navigating a level in a video game. Due to this need, they required a device to record and playback large amounts of keyboard inputs efficiently.

Using the Beagle USB 480 Power Protocol Analyzer for Latency Testing

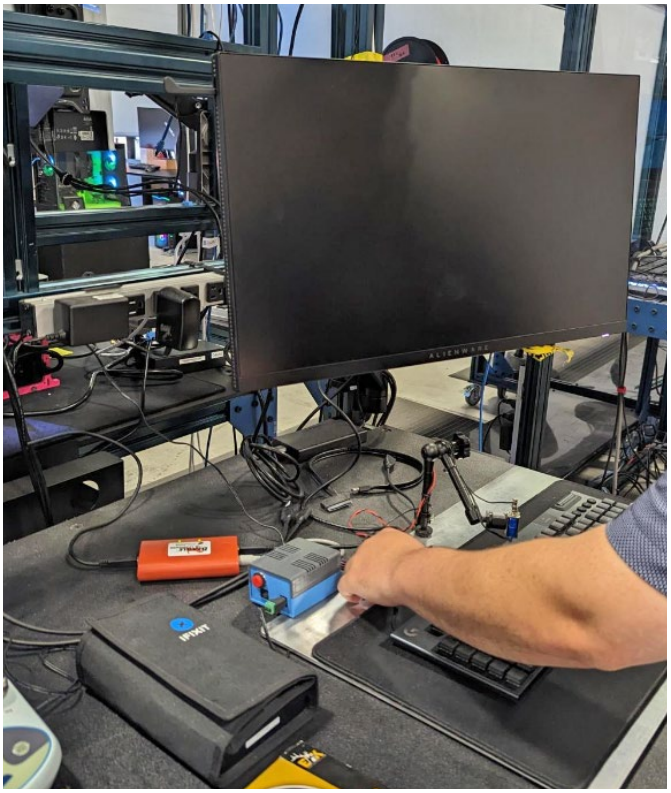
Measuring Latency to Determine Device Performance

One of their projects focused on testing and evaluating latency of various mice and keyboards, which plays a significant role in their performance.

Device latency refers to the delay or lag between a user's action, such as pressing a key on a keyboard or clicking a mouse, and the corresponding response or output from the device. It is measured in time and can affect the overall responsiveness and performance of the device. A lower latency indicates faster response times, while a higher latency can lead to delays and reduced efficiency. Therefore, having lower latency is crucial for real-time interactions such as typing or gaming.

Measuring Latency of Keyboards and Mice Using the Beagle USB 480 Power Protocol Analyzer

Their team acquired the Beagle USB 480 Power Protocol Analyzer to satisfy their latency testing requirements. This USB protocol analyzer captures and displays high-speed USB bus states and offers packet-level timing with 16.67 ns resolution.



Because the Beagle USB 480 Power Protocol Analyzer is a non-intrusive USB hardware analyzer, it is independent of the system under analysis, therefore has no effect on the bus it is monitoring. Alternative analyzer solutions, such as software-based USB analyzers, are dependent on the actual hardware of the host computer, even if they replace the USB software stack.

Being independent of the system allows for accurate measurements of latency without introducing additional variables or disruptions to the testing environment, ensuring that the results obtained are reliable and representative of real-world performance.

Beagle USB 480 Power Protocol Analyzer Set Up and Application

To measure the latency between when a key on a keyboard or a mouse button is pressed (which closes an electrical circuit) and when the corresponding signal is received by the computer through a USB bus, their team utilizes the Beagle USB 480 Power Protocol Analyzer's digital inputs and real-time bus monitoring capabilities.

To achieve this, they first connect a digital input from the Beagle USB 480 Power analyzer to a solenoid. When a key on the keyboard is pressed, it completes a circuit, triggering the solenoid to contact the key cap. This action is marked as T1, representing the start of the latency measurement.

By using the Beagle USB 480 Power analyzer with the Data Center Software to monitor the signals being transmitted, their team is able to identify endpoints and read the first USB packet that corresponds to the key just pressed on the keyboard. Once this packet is detected, it is marked as T2, representing the end of the latency measurement.

By measuring the time difference between T1 and T2, they can accurately determine the latency from when the key was pressed to when the corresponding USB signal was received by the computer.

Their keyboard latency test code is available on their Github.

By automating this process while gathering precise measurements, they have significantly advanced their latency testing procedures, saving hours previously spent in the lab performing alternative methods such as counting frames from high-speed camera footage. This new method has also enabled them to effectively analyze a wide range of keyboards and mice from various manufacturers, enabling comprehensive testing across the board.

Using the Beagle USB 480 Protocol Analyzer to Record and Playback Keyboard Inputs

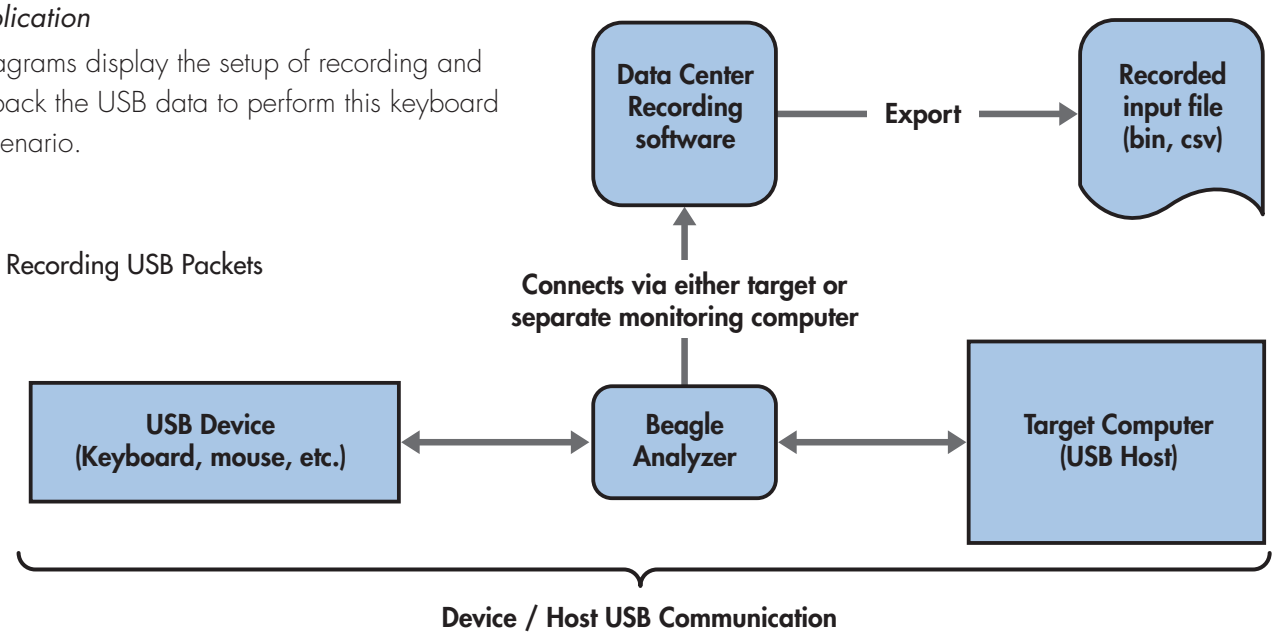
The Engineering/Software Development team also acquired the Beagle USB 480 Protocol Analyzer to capture and record the USB data from keyboard keypresses which they subsequently store in a tidy format that they load onto the microcontroller and play back to the test bench.

To record USB traffic, they connect the Beagle USB 480 Protocol Analyzer to the USB device (mice or keyboard) and the USB host (target computer). The Beagle USB 480 analyzer is then connected to either a target or separate monitoring computer to run the Data Center Software that allows them to interface with the Beagle USB 480 analyzer. The Data Center Software captures the USB communication that occurs between the keyboard device and the host, which can be exported and saved into different file formats that can be used for further analysis, including .csv, .bin, and .xml.
These files serve as the foundation for creating scripts that send commands to the microcontroller, enabling precise replay of the recorded USB traffic.

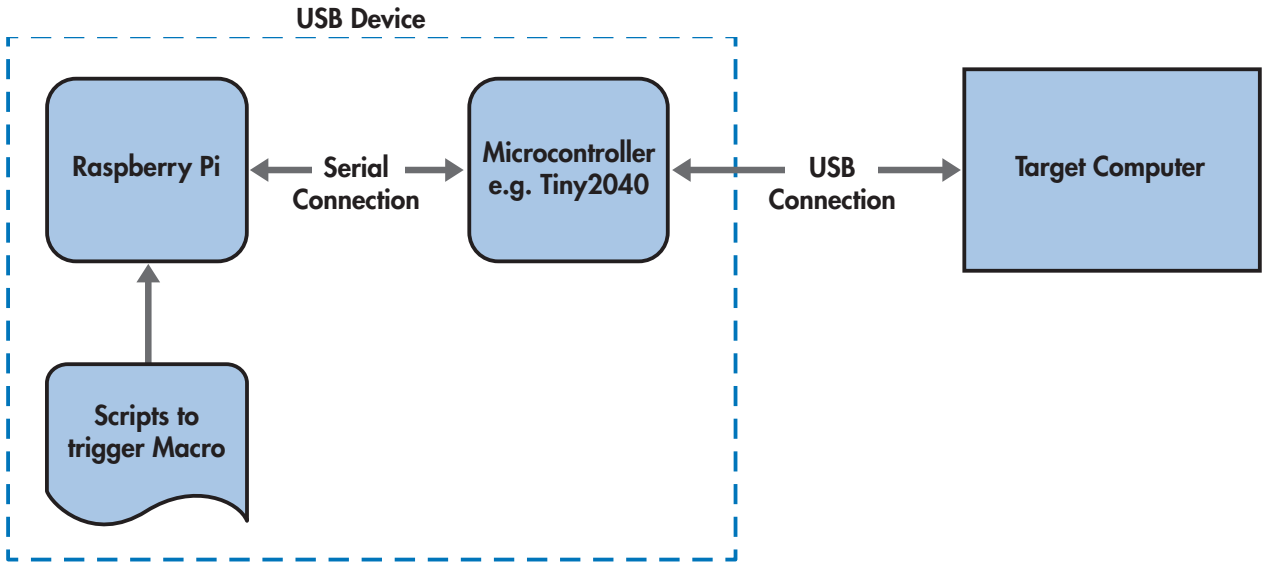
The primary use case for this solution is to record game play input through single player levels of various games and then replay it back after reloading the level. This would allow them to reliably and repeatedly benchmark the same path through the level.

Beagle USB 480 Protocol Analyzer Set Up and Application

These diagrams display the setup of recording and playing back the USB data to perform this keyboard testing scenario.



Playing Back USB Packets

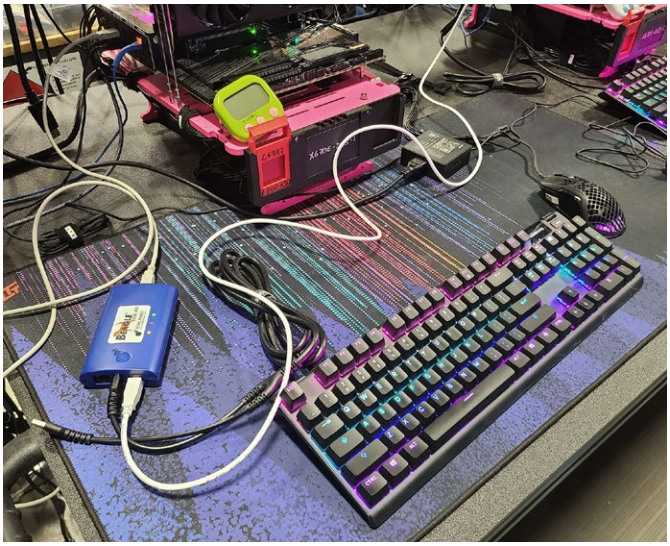


"The Beagle USB 480 Protocol Analyzer and Beagle USB 480 Power Protocol Analyzer have transformed our testing procedures for measuring latency of USB devices and recording USB captures between USB devices to use for playback. With its real-time data capture capabilities, we can now swiftly capture USB communication, identify endpoints, read packets, and measure latency with unmatched accuracy. This tool has allowed us to streamline our workflow, saving us countless hours of work."

— Nikolas Harris, Software Architect LTT Labs

Real-Time Data Capture in the Data Center Software

Within the Data Center Software, the Engineering/ Software Development team uses various features to help them test and evaluate device performance.



Transaction Window

For one, the Transaction window displays the transactions captured on a serial bus in real time. With the Beagle USB 480 Protocol Analyzer's on-board 64 MB buffer with sustained bursts of 480 Mbps, it is able to capture thousands of USB transactions at a time with no loss of data.

When capturing packets over the USB protocol, the application groups related packets under a single transaction entry in the window. When a transaction is selected, detailed information about that transaction is displayed in the Details window, the Info pane, and the Bus pane.

The timestamp column within the Transaction window can be configured to display timestamps at millisecond (min:sec.ms), microsecond (min:sec.ms.µs), or nanosecond (min:sec.ms.µs:ns) resolution. This exact timing provides the required data needed for them to perform latency calculations with pinpoint accuracy.

Sp	Index	m:s.ms.us	Len	Err	Dev	Ep	Record	Summary
HS	1969	0:04.015.734	34 B		55	00	Get String Descriptor	Index=2 Length=255
HS	1983	0:04.016.006	83 ns				[1 SOF]	[Frame: 1040.7]
HS	1984	0:04.015.909	18 B		55	00	Get String Descriptor	Index=1 Length=255
HS	1998	0:04.016.131	125 us				[2 SOF]	[Frames: 1041.0 - 1041.1]
HS	1999	0:04.016.154	34 B		55	00	Get String Descriptor	Index=3 Length=255
HS	2000	0:04.016.154	8 B		55	00	SETUP txn	80 06 03 03 09 04 FF 00
HS	2004	0:04.016.158	34 B		55	00	IN txn [28 POLL]	22 03 30 00 30 00 30 00 33 00 31 00 37 00
HS	2009	0:04.016.300	0 B		55	00	OUT txn	
HS	2013	0:04.016.381	250 us				[3 SOF]	[Frames: 1041.2 - 1041.4]
HS	2014	0:04.016.623	0 B		55	00	Set Configuration	Configuration=1
HS	2024	0:04.016.756	1.99 s				[15999 SOF]	[Frames: 1041.5 - 993.3] [Periodic Timeout]
HS	2025	0:06.016.855	1.99 s				[15999 SOF]	[Frames: 993.4 - 945.2] [Periodic Timeout]
HS	2026	0:08.016.954	1.01 s				[8153 SOF]	[Frames: 945.3 - 1964.3]
HS	2027	0:09.036.056	1 B		55	00	Get Max LUN	Max LUN = 0
HS	2041	0:09.036.193	2.50 ms				[21 SOF]	[Frames: 1964.4 - 1967.0]
HS	2042	0:09.037.570	36 B		55	01	Inquiry [0]	Passed
HS	2058	0:09.038.818	5.75 ms				[47 SOF]	[Frames: 1967.1 - 1972.7]
HS	2059	0:09.043.570			55	01	Test Unit Ready [0]	Failed
HS	2070	0:09.044.694	2.00 ms				[17 SOF]	[Frames: 1973.0 - 1975.0]
HS	2071	0:09.045.570	18 B		55	01	Request Sense [0]	Sense Key = UnitAttention (Passed)

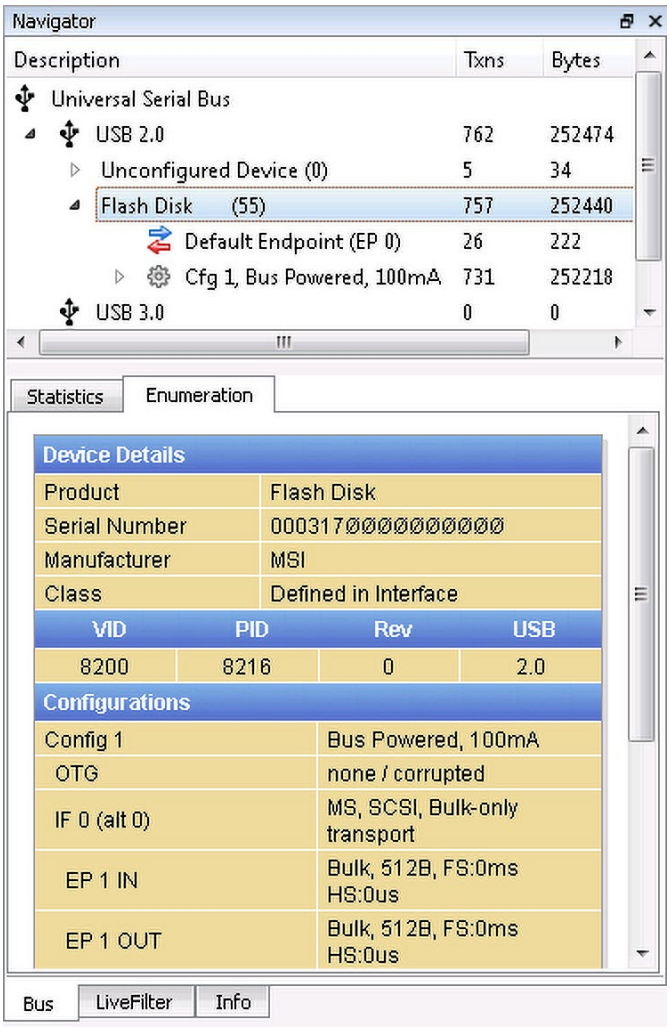
Text LiveSearch

No filter: 5890 records. Protocol Lens: USB

Bus Pane

The Navigator window provides tools that allow users to quickly find relevant data, one of them being the Bus Pane. This shows all devices that the Beagle USB 480 analyzer has detected on the bus during a capture, as well as the address(es), endpoint(s), enumeration information, and statistics corresponding to that device.

As USB devices typically have multiple endpoints, each serving a specific purpose such as transferring data, receiving commands, or handling interrupts, identifying certain endpoints has helped their team to isolate and measure the latency associated with different types of data transfers or interactions.



Conclusion

The Software Development/Engineering teams at Linus Tech Tips have greatly benefited from using the Beagle USB 480 Power Protocol Analyzer and Beagle USB 480 Protocol Analyzer as these tools have drastically improved their efficiency and accuracy of performing different testing scenarios on keyboards and mice. With the ability to directly capture USB data packets in real time within the Data Center Software, they are now able to streamline their testing approaches and focus more on analysis and execution.

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. This USB analyzer captures and interactively displays High-speed USB bus states and traffic in real time with timing at 16.7 ns resolution and comes complete with software and royalty-free API. Thanks to an on-board 64 MB buffer, sustained bursts of 480 Mbps traffic can be captured with no loss of data.

The Beagle™ USB 480 Power Protocol Analyzer is a non-intrusive High-speed USB 2.0 bus monitor that captures and interactively displays High-speed USB bus states and traffic in real time up to 480 Mpbs with timing at 16.7 ns resolution. This USB analyzer also enables VBUS current and voltage measurement with one-click correlation to protocol-level activity, includes enhanced USB 2.0 advanced triggering, and offers an extra-large hardware buffer.





ABOUT TOTAL PHASE

Total Phase is a leading provider of embedded systems solutions for engineers all over the world. Our mission is to provide intelligent visibility into embedded systems by creating affordable, high quality, and powerful solutions for anyone working in the embedded systems industry.

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