Bus Protocol Triggering and Decoding Solution

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1 Overview

Currently, countries around the world are vigorously developing new energy, and the development direction of various industries has clearly shifted towards intelligence, digitization, networking, and energy efficiency. With the continuous enrichment of electronic product functions, various bus protocols have emerged to meet communication needs between these electronic devices. Common ones include I^2C, CAN, LIN, FlexRay, CAN FD, SENT, USB, etc. These protocols enable efficient information exchange between different devices, promoting the collaborative work of the entire system.

Rapid technological development constantly increases the variety and complexity of bus protocols. Bus protocol triggering and decoding on oscilloscopes is a key technology, primarily used to parse communication protocols between different bus systems for corresponding testing, debugging, and troubleshooting, driving the industry towards greater intelligence, efficiency, and sustainability.

2 Challenges

With the widespread application of bus protocols across various fields, especially in automotive and embedded systems, the performance requirements for decoders are also increasing. The data transmission speed, data volume, and complexity of bus protocols make real-time, accurate decoding crucial. Any decoding delay or error can significantly impact system control and even cause safety issues. Differences in bus protocol implementations by different manufacturers also increase decoding difficulty. This means decoders need not only the ability to parse standard protocols but also to adapt to various non-standard or specific implementations. Furthermore, modern electronic products often use multiple bus protocols simultaneously, placing higher demands on decoder compatibility and flexibility. In resource-constrained embedded systems, memory capacity and processor speed can become bottlenecks for decoding. Therefore, decoder algorithms and data structures must be optimized to minimize resource consumption while maintaining decoding accuracy and real-time performance.

In this context, digital oscilloscopes have become an essential tool for engineers conducting bus protocol testing. Oscilloscopes not only capture and analyze signals on the bus but also, through built-in decoding functions, convert raw signals into readable protocol data. This is extremely beneficial for quickly locating and solving problems, optimizing system performance, and developing new bus protocols. Common bus protocol types are as follows:

- **Embedded/IC Interface Protocols: I^2C, SPI, UART, USB2.0**
- **Automotive Bus Protocols: CAN, LIN, FlexRay, CAN FD, SENT**
- **Video/Audio Protocols: I^2S**
- **Wireless/RF Protocols: Manchester, MIL-STD-1553B, ARINC429**

3 Solution

SIGLENT oscilloscopes play a vital role in electronic measurement and debugging, providing engineers with bus protocol triggering and decoding functionality. The figure below summarizes the protocol decoding capabilities of SIGLENT's existing products:

	I^{2}C / SPI / UART / CAN / LIN	CAN FD	FlexRay	I^{2}S	SENT	Manchester	MIL-STD-1553B	ARINC429	USB2.0
SDS7000A	√	√	√	√	√	√	√	√	√
SDS6000 Pro	√	√	√	√	√	√	√	√	
SDS6000L	√	√	√	√	√	√	√		
SDS3000X HD	√	√	√	√	√	√	√	√	
SDS2000X HD	√	√	√	√	√	√	√		
SDS1000X HD	√	√	√						
SDS800X HD	√								
SDS5000X	√	√	√	√	√		√		
SDS3000X	√	√	√	√			√		√
SDS2000X Plus	√	√	√	√	√	√	√		
SDS2000X-E	√								
SDS1000X-E	√								
SDS1000X-C	√								
SDS1000X-U	√								

1.1 Embedded/IC Interface Protocol Triggering and Decoding

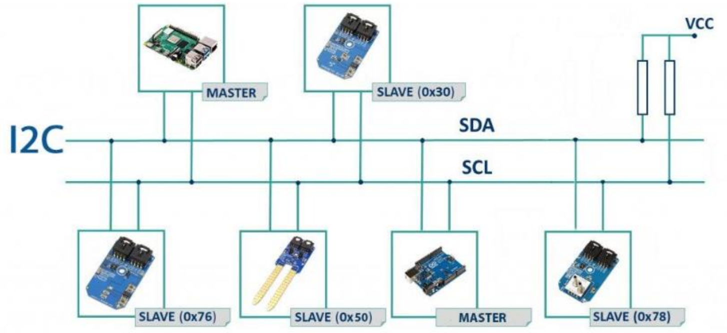
For embedded system and integrated circuit designers, the performance and stability of Embedded/IC interface protocol buses (such as I^{2}C, SPI, UART, USB) are crucial. These buses are responsible for transmitting data and control signals between chips, boards, or systems and external devices. Their proper operation has a decisive impact on the performance and reliability of the entire system. To ensure these interfaces work correctly, designers need to conduct detailed testing and debugging on them.

SIGLENT oscilloscopes' advanced triggering and decoding functions provide significant assistance in testing and debugging Embedded/IC interface protocol buses. They can accurately capture electrical signals on the interface bus and display them visually as waveforms. They allow simultaneous observation of multiple signal lines in a bus system, enabling timing relationship analysis between signals, providing a deeper understanding of the interface bus communication, ensuring interface stability and performance meet design requirements, accelerating product development cycles, and improving product quality.

3.1.1 I^{2}C

The I^{2}C bus (Inter-Integrated Circuit) is an important serial communication protocol. This protocol uses only two signal lines—the Serial Data Line (SDA) and Serial Clock Line (SCL)—to achieve bidirectional communication between multiple devices. The design intent of the

I^{2}C bus was to reduce the number of internal connections in complex electronic systems (like televisions) and lower manufacturing costs. By adopting a two-wire communication method, it effectively simplifies the connection complexity between devices. This has led to the widespread use of the I^{2}C bus in communication between microcontrollers and various peripheral devices, including data exchange between sensors and microcontrollers, read/write operations of memory chips, control of peripheral devices, and communication with display controllers.

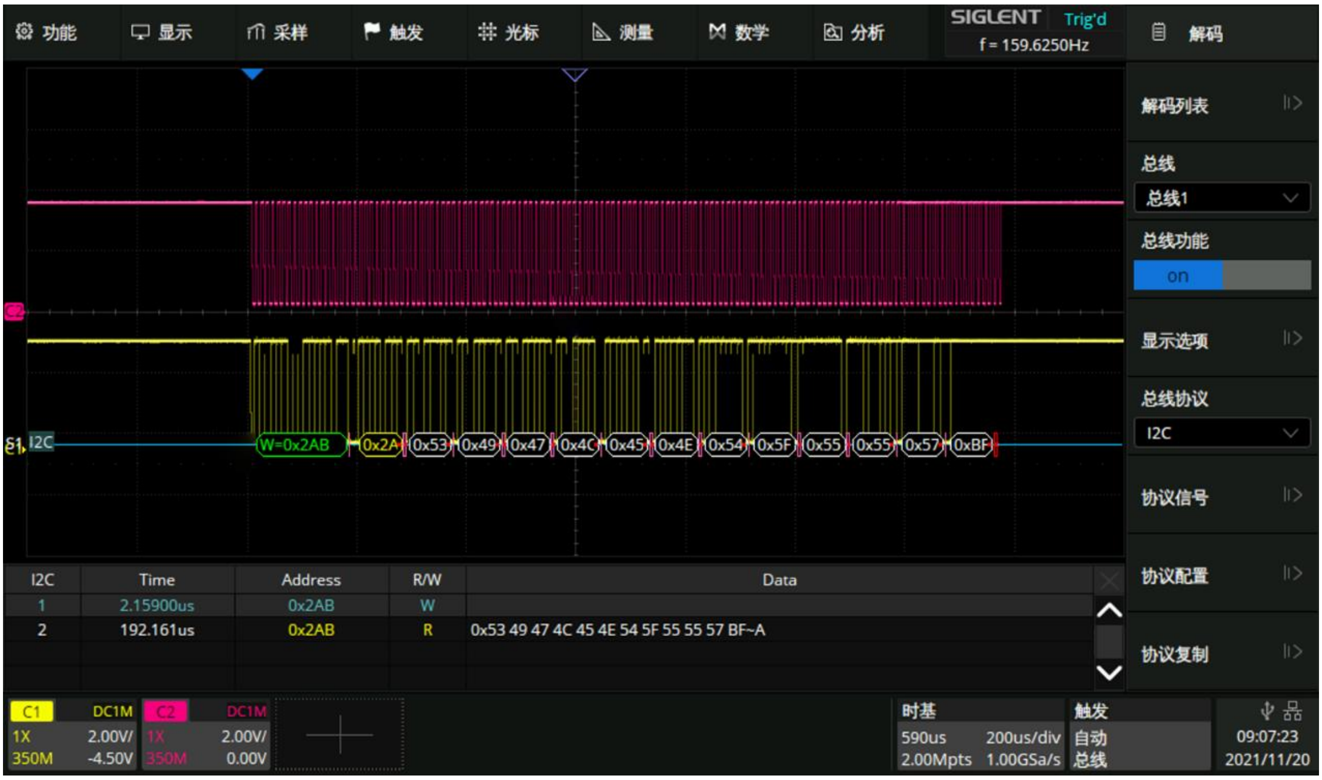


SIGLENT oscilloscopes provide triggering and decoding functions for the I^{2}C protocol. Taking the SDS3000X HD series oscilloscope as an example:

1.1.1.1 Table 1. I^{2}C Trigger and Serial Decode

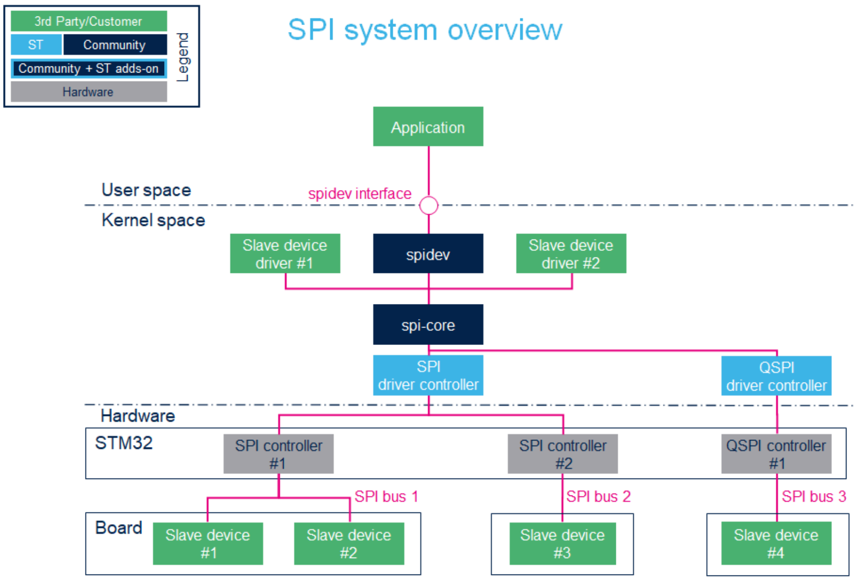
I^{2}C Signal Setup	Oscilloscope connects to the Serial Data Line (SDA) and Serial Clock Line (SCL).
	Set the threshold level for input signals.
	Set the source used for triggering or decoding.
	Synchronize signal settings and the bus between triggering and decoding.
I^{2}C Trigger	**Start Condition:** Triggers when SCL is high and SDA transitions from high to low.
	Stop Condition: Triggers when SCL is high and SDA transitions from low to high.
	Restart Condition: Triggers when another Start condition appears before a Stop condition.
	No ACK: Triggers when SDA data is high during the clock bit of any ACK.
	EEPROM Data Read: Triggers on finding the EEPROM control byte value (1010xxx) on the SDA line, followed by a read bit and an ACK bit.
	7-bit Address & Data: Triggers on a read or write frame in 7-bit addressing mode.
	10-bit Address & Data: Triggers on the ACK bit following the data if all bits in the pattern match.
	Data Length: Data length range is 1 to 12 bits. Triggers if the current trigger data meets the set length and the selected address bit length matches the signal.
I^{2}C Decode	**TIME:** Time tag. The horizontal offset of the current data frame header relative to the trigger position.
	Address: Address value, e.g., "0x50" indicates address 50, no ACK.
	R/W: Read address or write address.
	DATA: Data byte. One frame of decoded data corresponds to one row in the list.

I²C Decode Result:



3.1.2 SPI

SPI (Serial Peripheral Interface) is a synchronous serial communication protocol consisting of one master device and one or more slave devices. The master initiates synchronous communication with the slave(s) to complete data exchange. It is widely used in EEPROMs, Flash memory, Real-Time Clocks (RTCs), Analog-to-Digital Converters (ADCs), Digital Signal Processors (DSPs), and between digital signal decoders, where higher communication rates are required.

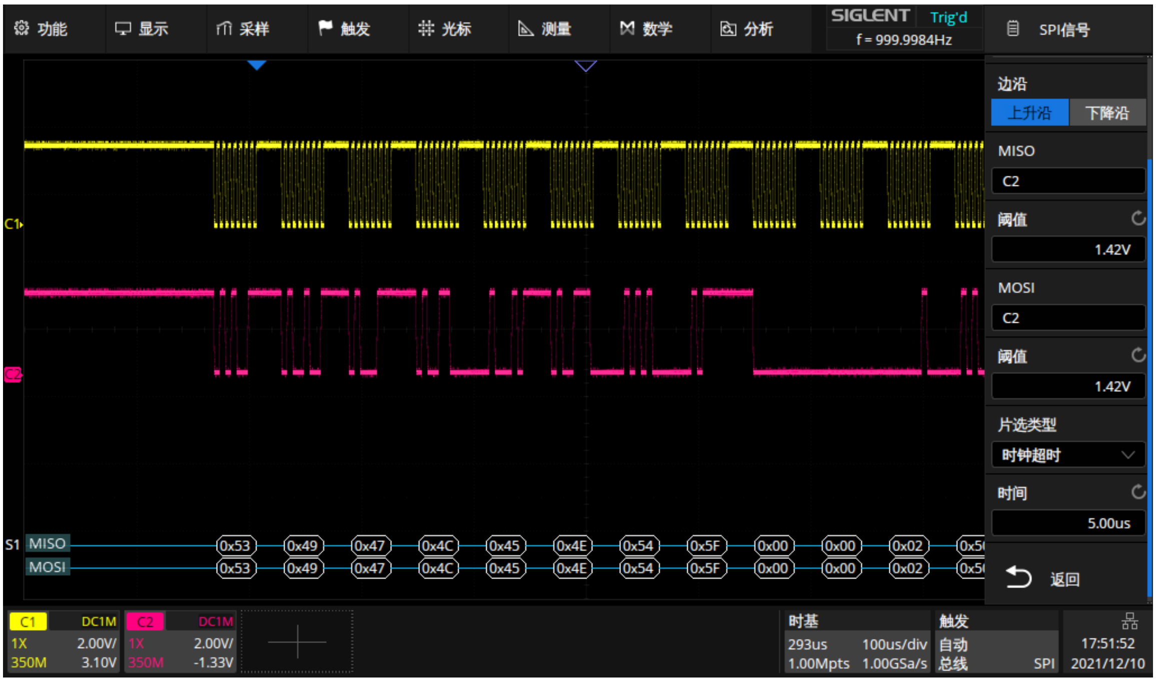


SIGLENT oscilloscopes provide triggering and decoding functions for the SPI protocol. Taking the SDS3000X HD series oscilloscope as an example:

1.1.1.2 Table 2. SPI Trigger and Serial Decode

SPI Signal Setup	Oscilloscope connects to Clock, MOSI data, MISO data, and Chip Select signals.
	Set the threshold level for each input channel.
	Set other signal parameters.
	Synchronize signal settings and the bus between triggering and decoding.
SPI Trigger	**Trigger Source:** MISO data or MOSI data.
	Data Length: Set the data length for each SPI frame, range 4 to 96 bits.
	Set triggering on specific data.
	Set bit stream format as Most Significant Bit (MSB) first or Least Significant Bit (LSB) first.
SPI Decode	**TIME:** Time tag. The horizontal offset of the current data frame header relative to the trigger position.
	Address: Address value, e.g., "0x50" indicates address 50, no ACK.
	R/W: Read address or write address.
	DATA: Data byte. One frame of decoded data corresponds to one row in the list.

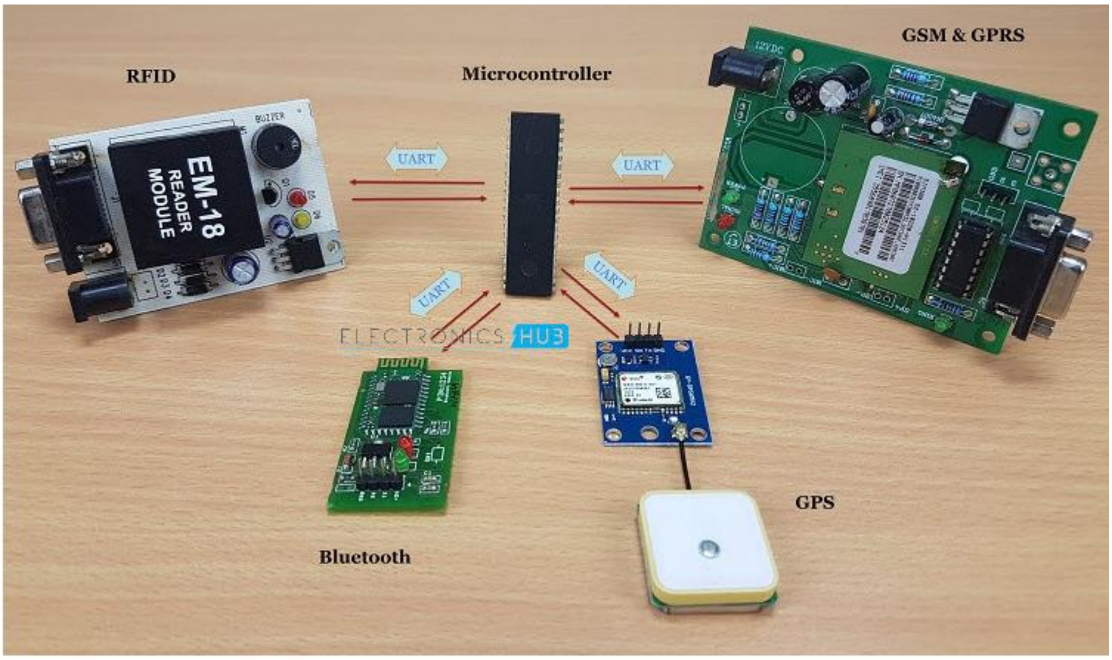
SPI Decode Result:



3.1.3 UART

UART (Universal Asynchronous Receiver/Transmitter) is a communication protocol, commonly referred to as a universal asynchronous transceiver. It is a key module for asynchronous communication between devices, primarily used for data transfer between computers and external devices.

The advantage of the UART protocol lies in its simplicity and ease of implementation. It does not require complex protocols or verification mechanisms, making it widely used in resource-constrained embedded systems. Additionally, the transmission distance of the UART protocol is relatively long, ranging from several meters to tens of meters, suitable for most application scenarios.

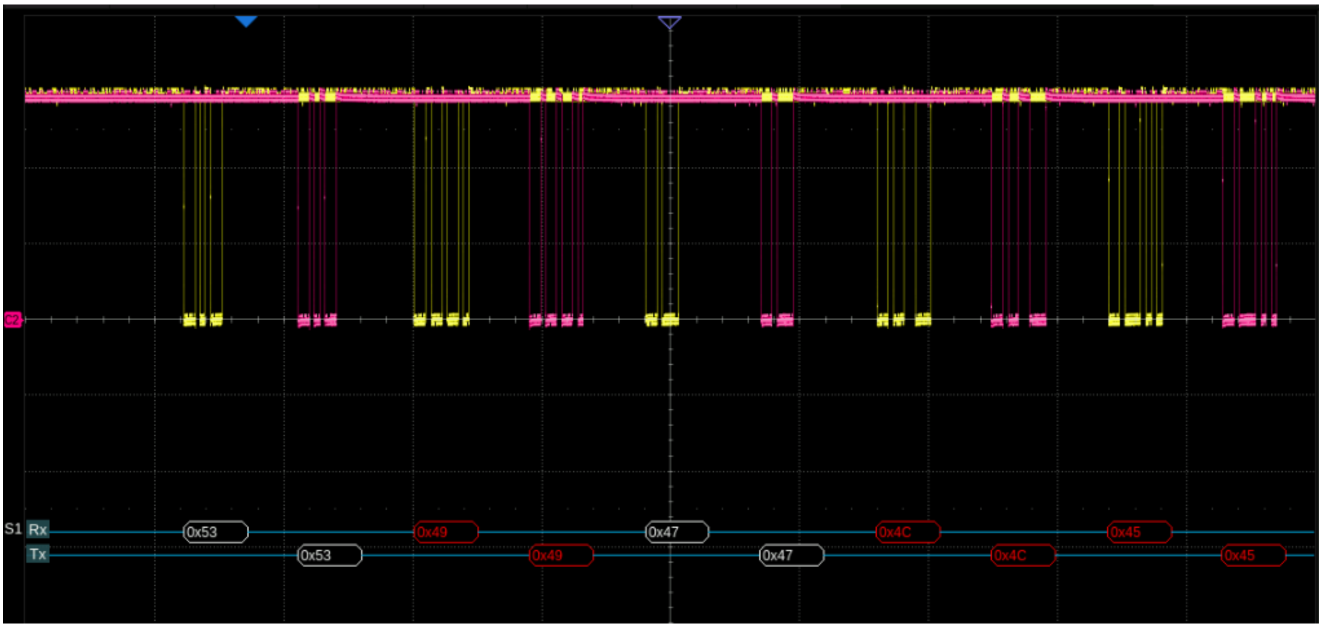


SIGLENT oscilloscopes provide triggering and decoding functions for the UART protocol. Taking the SDS3000X HD series oscilloscope as an example:

1.1.1.3 Table 3. UART Trigger and Serial Decode

UART Signal Setup	Oscilloscope connects to RX and TX signals.
	Set the threshold level for each input channel.
	Set other signal parameters.
	Synchronize signal settings and the bus between triggering and decoding.
UART Trigger	**Start Condition:** Triggers when a start bit appears on RX/TX.
	Stop Condition: Triggers when a stop bit appears on RX/TX.
	Data: Select a comparator and set corresponding data values to trigger the signal.
	Parity Error: Performs parity check on data according to the user-set parity type; triggers if the check value is incorrect.
UART Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	RX: Received data word.
	RX Err: Receive error type.
	TX: Transmitted data word.
	TX Err: Transmit error type.

UART Decode Result:

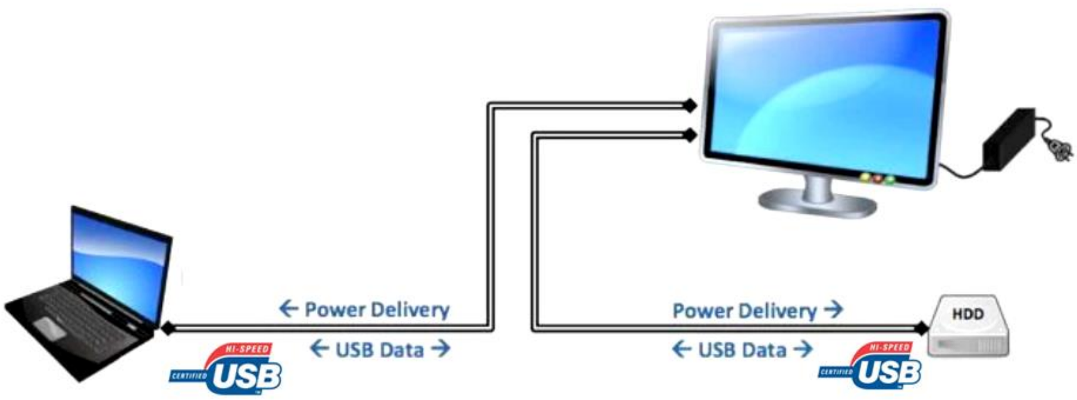


UART Decode List:

UART	Time	RX	RX Err	TX	TX Err
1	-24.2780us	0x53			
2	20.1392us			0x53	
3	65.3218us	0x49	Parity Err		
4	109.767us			0x49	Parity Err
5	154.861us	0x47			
6	199.305us			0x47	
7	244.460us	0x4C	Parity Err		

3.1.4 USB2.0

The USB2.0 protocol (Universal Serial Bus 2.0) is a universal serial bus standard supporting high-speed data transmission. It is a high-speed data transmission technology using a 4-wire system. Its transmission speed is fast, up to 480 Mb/s, with a theoretical rate of 60 MB/s. Due to its high transmission rate, support for hot-plugging, ease of expansion, simple power delivery, and good compatibility, it is widely used for connections and data exchange between computers and external devices.



SIGLENT oscilloscopes provide serial decoding functions for the USB2.0 protocol. Taking the SDS7000A series oscilloscope as an example:

1.1.1.4 Table 4. USB2.0 Trigger and Serial Decode

USB2.0 Signal Setup	Select signal speed: Low Speed (1.5Mb/s), Full Speed (12Mb/s), or High Speed (480Mb/s).
	Oscilloscope connects to USB2.0 signals.
	For Low Speed or Full Speed signals, set the D+ source, D- source, and corresponding thresholds.
	For High Speed signals, set the differential source.
	Set the signal source and threshold level.
USB2.0 Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	PID: Packet type.
	Address: Address. Only token packets have this field.
	Endp: Endpoint number. Only token packets have this field.
	Data: Data byte(s).
	Fr: Frame number. Only SOF packets have this field.
	CRC: Cyclic Redundancy Check.
	Error: Error.

USB2.0 Decode Result:

1.2 Automotive Bus Protocol Triggering and Decoding

Automotive serial buses (such as CAN, LIN, FlexRay, CAN FD, SENT) are important components of modern automotive electronic systems. They are responsible for transmitting data between various Electronic Control Units (ECUs) within the vehicle. To ensure the reliable and efficient operation of these buses in vehicles, electronic system designers need to conduct detailed testing and debugging of the bus physical layer.

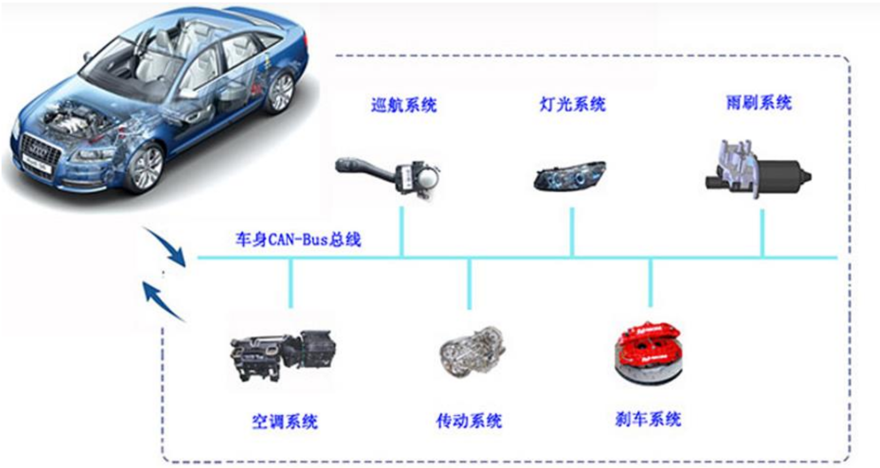
During the physical layer testing and debugging of automotive serial buses, a large amount of data needs to be captured, decoded, and analyzed to accurately understand the communication on the bus. Relying solely on manual processing is not only inefficient but also difficult to ensure accuracy. Oscilloscopes are important tools for electronic system designers in testing and debugging the physical layer of automotive serial buses. They can improve testing efficiency, shorten development cycles, and ensure the reliable operation of automotive serial buses.

SIGLENT oscilloscopes assist electronic system designers in testing and debugging automotive serial buses, helping to capture and analyze signals on the bus. The oscilloscope's triggering function can capture specific events or frames on the bus, such as start bits, end bits, error frames, etc. The decoding function converts captured raw data into easily understandable protocol information, such as frame ID, data fields, check bits, etc. This allows designers to intuitively view and analyze bus communication without manually processing large amounts of raw data. Furthermore, SIGLENT oscilloscopes support simultaneous testing and debugging of multiple automotive serial bus protocols, displaying the communication status of multiple buses on one screen, facilitating cross-bus analysis and debugging, and aiding in judging the operating state of the bus physical layer.

3.2.1 CAN

CAN (Controller Area Network) is a serial communication protocol. Its characteristics, such as high-speed transmission, broadcast communication, multi-master communication, and differential signal transmission, make it an efficient, reliable, and secure communication protocol, widely used in various control systems in the automotive and industrial fields.

The original goal of the CAN bus protocol was to achieve comprehensive control of vehicle driving status and implement various functions. To achieve this, various controller units use sensors and bus technology for data collection and exchange, such as engine speed, vehicle speed, and fuel level. This enables controller units to determine vehicle status and driver intent for precise vehicle control. The CAN bus was designed to provide efficient, reliable, and real-time communication between these controller units.

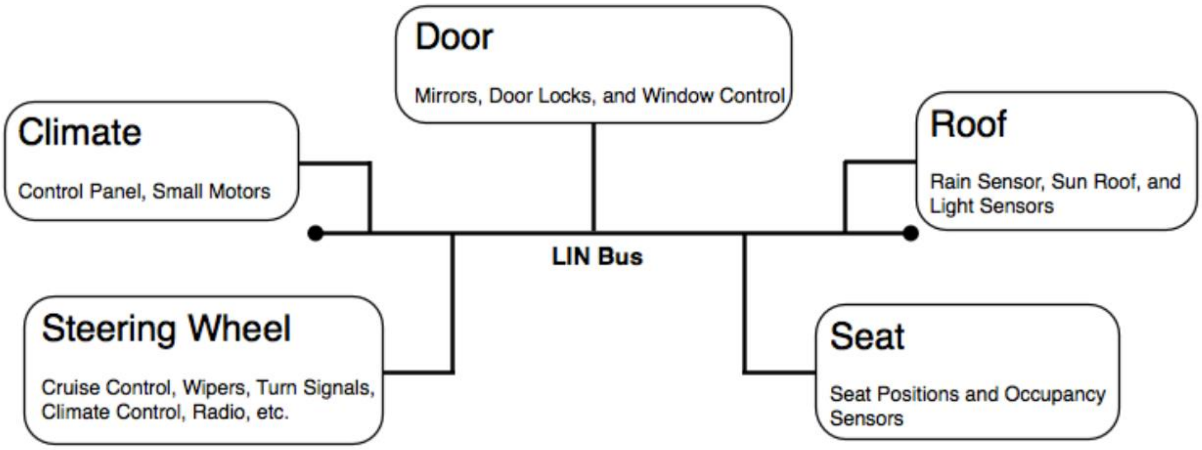


SIGLENT oscilloscopes provide triggering and decoding functions for the CAN protocol. Taking the SDS6000 Pro series oscilloscope as an example:

1.2.1.1 Table 5. CAN Trigger and Serial Decode

CAN Signal Setup	Oscilloscope connects to CAN_H and CAN_L signals.
	Set the threshold level for each input channel.
	Set the source used for triggering or decoding.
	Set the baud rate parameters for the CAN bus.
	Synchronize signal settings and the bus between triggering and decoding.
CAN Trigger	**Start Condition:** Triggers at the beginning of a frame.
	Remote Frame: Triggers on a remote frame with a specified ID.
	ID: Triggers on a data frame matching the specified ID.
	ID + Data: Triggers on a data frame matching both the specified ID and data.
	Error Frame: Triggers on an error frame of the CAN signal.
CAN Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	Type: Frame type. Can display Data frame ("D") or Remote frame ("R").
	ID: Frame ID. Automatically detected as 11-bit or 29-bit frame.
	Length: Data length.
	Data: Data byte(s).
	CRC: Cyclic Redundancy Check.
	Ack: Acknowledge bit.

CAN Decode Result:



3.2.2 LIN

LIN (Local Interconnect Network) is a low-cost serial communication network for distributed electronic systems in automobiles. It is mainly used for various simple control tasks within the vehicle, such as window control, sunroof operation, seat adjustment, door lock control, air conditioning systems, and lighting equipment—low-speed and low-cost application scenarios.

Taking a door control system as an example, doors are typically equipped with components such as door locks, window glass switches, window lift motors, and control buttons. Only one LIN network is needed to interconnect these components, greatly simplifying wiring complexity and reducing costs.

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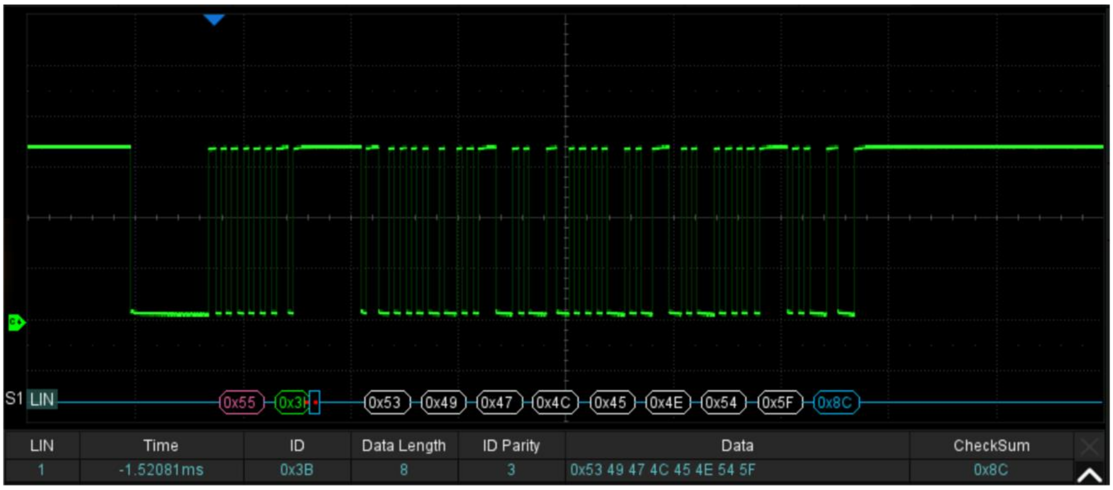
SIGLENT oscilloscopes provide triggering and decoding functions for the LIN protocol. Taking the SDS6000 Pro series oscilloscope as an example:

1.2.1.2 Table 6. LIN Trigger and Serial Decode

LIN Signal Setup	Oscilloscope connects to the LIN signal.
	Set the threshold level for each input channel.
	Set the source used for triggering or decoding.
	Set the baud rate parameters for the LIN bus.
	Synchronize signal settings and the bus between triggering and decoding.
LIN Trigger	**Break:** Triggers at the beginning of a frame.
	ID: Triggers when a frame whose detected ID equals the set value is detected. Range: 0x00 to 0x3f.
	ID & Data: Triggers when a frame whose detected ID and data equal the set values is detected.
	Data Error: Triggers on an error frame of the LIN signal.
LIN Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	ID: Frame ID.
	Data length: Data length.
	ID Parity: ID parity check.
	Data: Data byte(s).
	Checksum: Data checksum.

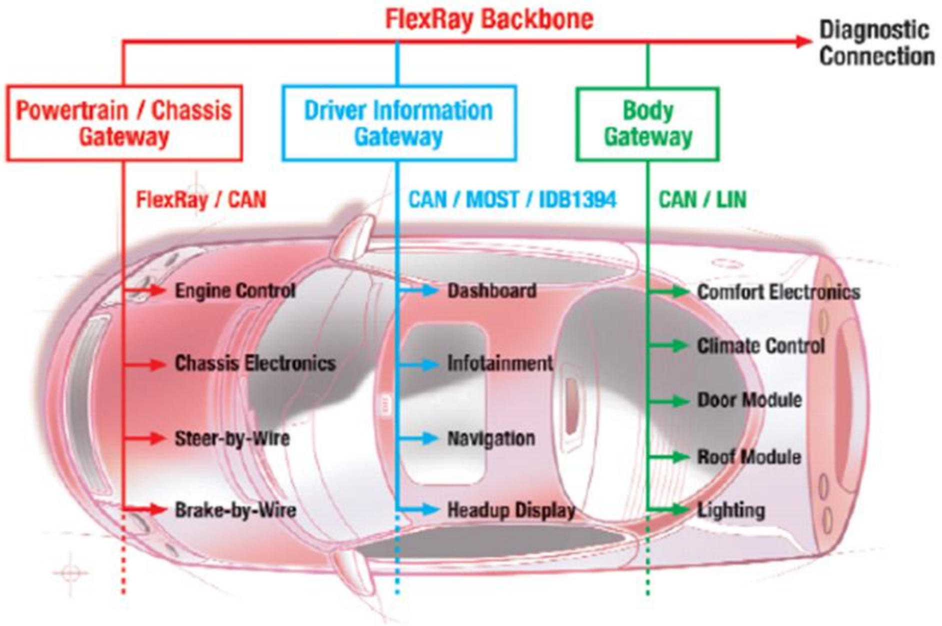
LIN Decode Result:



3.2.3 FlexRay

The realization of high-end vehicle performance relies on the precise synchronization of numerous sensors, actuators, and ECUs. These components need to exchange data in real-time and efficiently to ensure excellent vehicle performance under various driving conditions. However, the traditional CAN protocol, due to its inherent bandwidth limitations, can no longer meet the stringent requirements of advanced vehicles for data transmission rates and real-time performance.

To address this challenge, the FlexRay protocol emerged. It is specifically designed to meet the communication needs of critical applications such as drive-by-wire (e.g., steer-by-wire, brake-by-wire) and advanced driver assistance systems (e.g., for engine, transmission). The FlexRay protocol provides higher bandwidth, lower latency, and stronger synchronization capabilities, ensuring seamless collaboration between various systems within the vehicle.

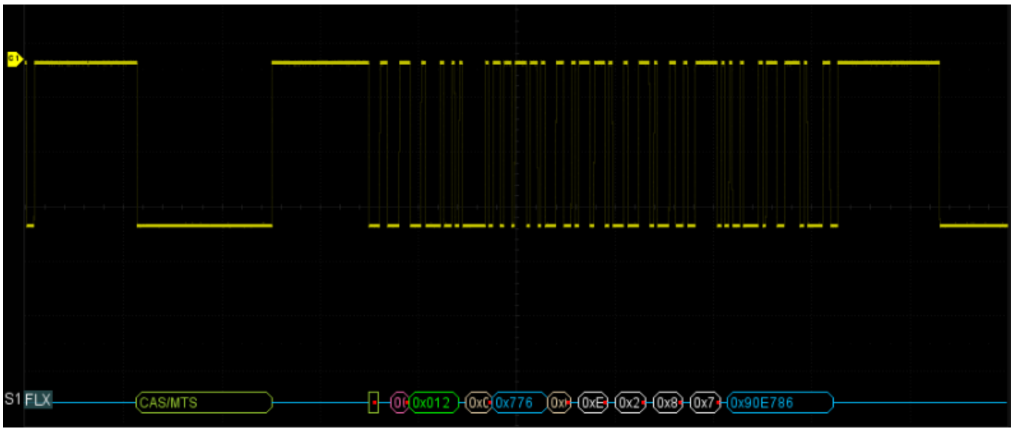


SIGLENT oscilloscopes provide triggering and decoding functions for the FlexRay protocol. Taking the SDS7000A series oscilloscope as an example:

1.2.1.3 Table 7. FlexRay Trigger and Serial Decode

FlexRay Signal Setup	Oscilloscope connects to the FlexRay signal.
	Set the threshold level for the input channel.
	Set the source used for triggering or decoding.
	Set the baud rate parameters for the FlexRay bus.
	Synchronize signal settings and the bus between triggering and decoding.
FlexRay Trigger	**Start:** Triggers on the transmission start sequence.
	Frame: Triggers on a frame on the bus.
	Symbol: Triggers on CID (Channel Idle Delimiter), CAS/MTS (Collision Avoidance Symbol/Media Access Test Symbol), and WUS (Wakeup Symbol).
	Error: Triggers on bus errors, including Frame Start error, Byte Start error, Frame End error, Header CRC error, Data CRC error.
FlexRay Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	FID: Frame ID. Symbols occupy a separate row in the list.
	PL: Payload length.
	HCRC: Frame header CRC.
	CYC: Cycle count.
	Data: Data byte(s).
	FCRC: Frame data CRC.

FlexRay Decode Result:

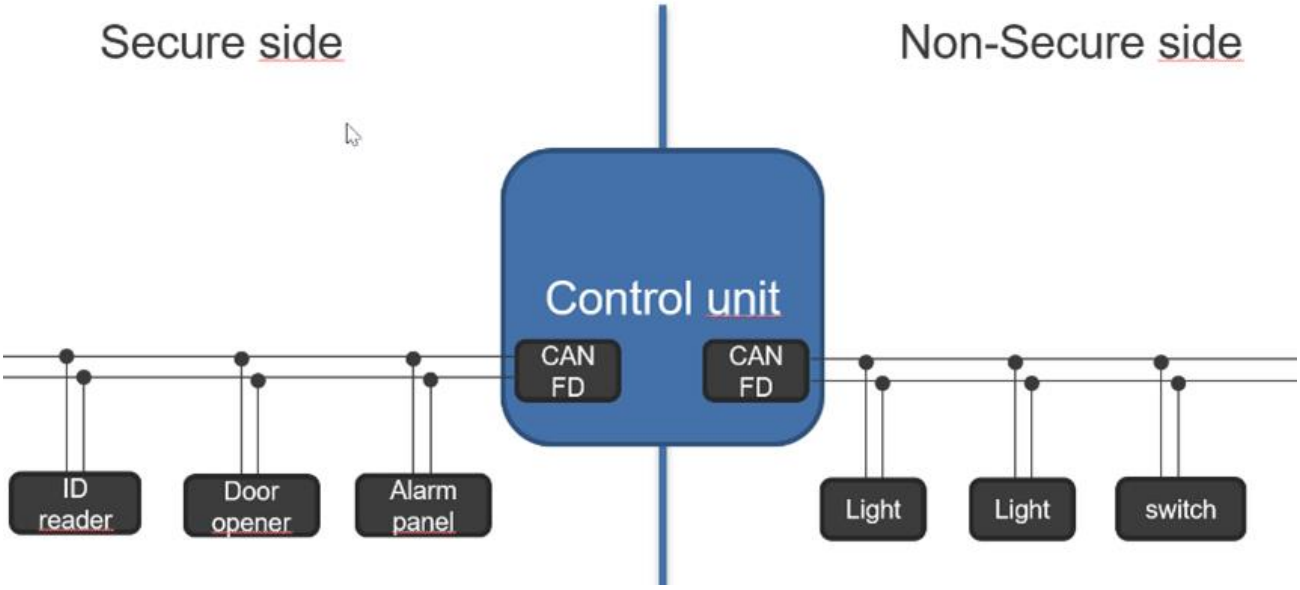


FlexRay Decode List:

FLX	Time	FID	PL	HCRC	CYC	Data	FCRC
1	-83.0406us	0x012	0x02	0x776	0x0C	0xEE 0x23 0x8C 0x7E	0x90E786
2	-25.0160us	CAS/MTS					
3	-1.40820us	0x012	0x02	0x776	0x0C	0xEE 0x23 0x8C 0x7E	0x90E786
4	56.6174us	CAS/MTS					
5	80.2240us	0x012	0x02	0x776			

3.2.4 CAN FD

CAN FD (CAN with Flexible Data-rate) is an upgraded version based on the CAN bus protocol. Compared to traditional CAN, the CAN FD protocol has stronger data processing capabilities and more efficient communication mechanisms. It improves error handling, better coping with various abnormalities during communication, ensuring data accuracy and integrity. Besides automotive electronics, it is also suitable for industrial automation, smart homes, and other fields.



SIGLENT oscilloscopes provide triggering and decoding functions for the CAN FD protocol. Taking the SDS6000 Pro series oscilloscope as an example:

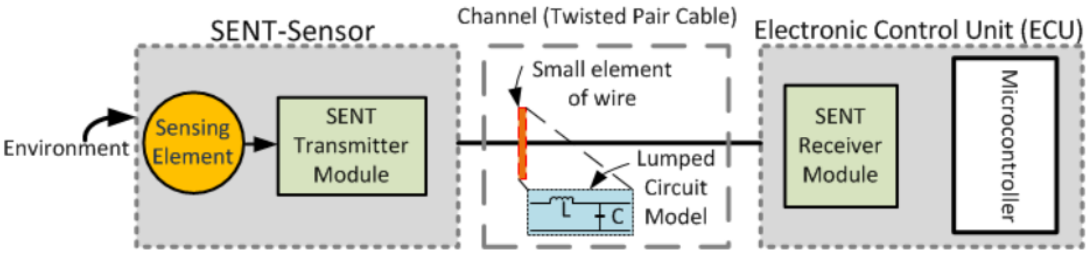
1.2.1.4 Table 8. CAN FD Trigger and Serial Decode

CAN FD Signal Setup	Oscilloscope connects to the CAN FD signal.
	Set the threshold level for each input channel.
	Set the source used for triggering or decoding.
	Set the baud rate parameters for the CAN FD bus.
	Synchronize signal settings and the bus between triggering and decoding.
CAN FD Trigger	**Start Condition:** Triggers at the beginning of a frame.
	Remote Frame: Triggers on a remote frame with a specified ID.
	ID: Triggers on a data frame matching the specified ID.
	ID + Data: Triggers on a data frame matching both the specified ID and data.
	Error Frame: Triggers on an error frame of the CAN FD signal.
CAN FD Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	Type: Frame type: Std, Ext, FD Std, FD Ext, Std RTR, Ext RTR.
	ID: Frame ID.
	Length: Data length.
	Data: Data byte(s).
	CRC: Cyclic Redundancy Check.
	Ack: Acknowledge bit.

CAN FD Decode List:

CAN FD	Time	Type	ID	Length	Data	CRC	ACK
1	-190.506us	FD Std	0x66	0x08	0x0A 1B 2C 3D 4E 5F 60 71	0x9ADA	yes
2	-95.5054us	FD Std	0x66	0x08	0x0A 1B 2C 3D 4E 5F 60 71	0x9ADA	yes
3	-505.600ns	FD Std	0x66	0x08	0x0A 1B 2C 3D 4E 5F 60 71	0x9ADA	yes
4	94.4942us	FD Std	0x66	0x08	0x0A 1B 2C 3D 4E 5F 60 71	0x9ADA	yes
5	189.496us	FD Std	0x66	0x08	0x0A 1B 2C 3D 4E 5F 60 71	0x9ADA	yes

3.2.5 SENT



SENT (Single Edge Nibble Transmission). The SENT protocol is a simple and effective communication protocol for transmitting data over a network. It is lightweight, easy to implement and extend, suitable for various application scenarios such as sensor signal transmission in automotive electronics.

SIGLENT oscilloscopes provide triggering and decoding functions for the SENT protocol. Taking the SDS6000 Pro series oscilloscope as an example:

1.2.1.5 Table 9. SENT Trigger and Serial Decode

SENT Signal Setup	Oscilloscope connects to the SENT signal.
	Set the threshold level for the input channel.
	Set the source used for triggering or decoding.
	Set the message format, etc., for the SENT bus.
	Synchronize signal settings and the bus between triggering and decoding.
SENT Trigger	**Start Position:** The oscilloscope will trigger at the beginning of a message (after 56 sync clocks).
	Fast Channel: Triggers when the Status & Communication nibble and data byte(s) match the specified values.
	Slow Channel: Triggers on slow channel information.
SENT Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	Sync: Sync pulse (displayed only for fast channel).
	State: Status & Communication nibble (displayed only for fast channel).
	ID: Frame ID (displayed only for slow channel).
	Data: Data nibble(s).
	CRC: CRC check.
	Pause: Pause pulse.
	Error: Error.

SENT Decode Result:

1.3 Video/Audio Protocol Triggering and Decoding

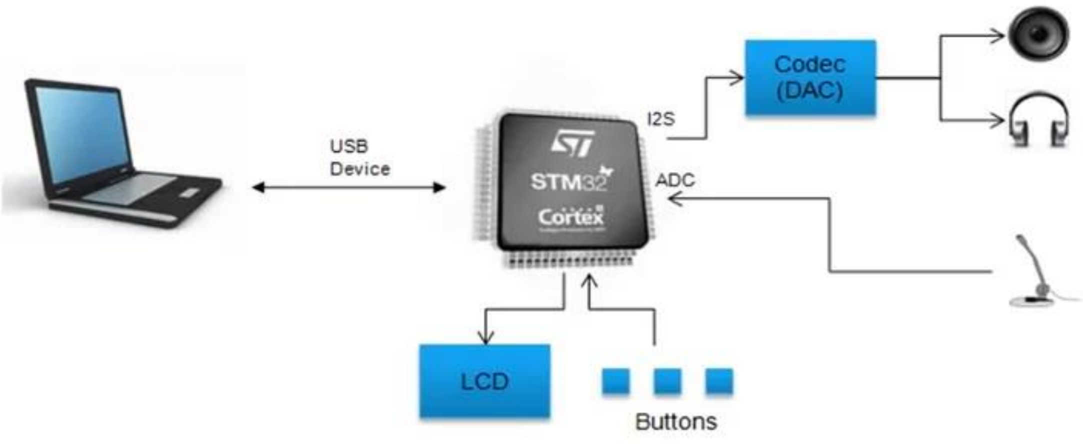
Video/Audio protocols such as I²S, RTMP, HLS, etc. Each protocol has its specific application scenarios and advantages. They provide a unified communication standard for different devices and systems, ensuring interoperability and compatibility, which is crucial for the operation of modern multimedia communication and entertainment systems. They ensure reliable data transmission and a high-quality user experience and can be widely used in scenarios requiring high-quality audio transmission.

For video/audio protocols, signal quality directly affects user experience and transmission effectiveness. Observing and measuring signal waveforms is crucial for video/audio protocols because characteristics such as the waveform and glitches directly impact video and audio quality and performance. Through an oscilloscope, engineers can clearly see these characteristics, thereby determining whether signal quality and performance meet requirements.

SIGLENT oscilloscopes help engineers observe, measure, analyze, and optimize video/audio signals, understand signal quality, make corresponding adjustments and optimizations, and ensure the clarity and continuity of video/audio signals. When equipment fails, by observing signal waveforms and measuring signal parameters on the oscilloscope, they can determine the location and cause of the fault and perform corresponding repairs and maintenance to restore normal equipment operation.

3.3.1 I²S

The I²S protocol (Inter-IC Sound), also known as the Inter-IC Sound bus, is a bus standard developed for audio data transmission between digital audio devices. It is characterized by simplicity, efficiency, and strong scalability and is widely used in audio systems, automotive audio, portable devices, and embedded systems. Its high-quality audio transmission capability and standardized nature make audio data transmission between different devices simpler and more efficient.



SIGLENT oscilloscopes provide triggering and decoding functions for the I²S protocol. Taking the SDS3000X HD series oscilloscope as an example:

1.3.1.1 Table 10. I²S Trigger and Serial Decode

I²S Signal Setup	Oscilloscope connects to the Frame Clock (WS), Bit Clock (BCLK), and Serial Data (Data) signals.
	Set the threshold level for each input channel.
	Set other signal parameters.
	Synchronize signal settings and the bus between triggering and decoding.
I²S Trigger	**Data:** Select a comparator and set corresponding data values to trigger the signal.
	Mute: Triggers on a mute signal.
	Clip: Triggers on a clip signal.
	Glitch: Triggers on a glitch in the audio signal.
	Rising Edge: Triggers on a signal greater than the threshold setting.
	Falling Edge: Triggers on a signal less than the threshold setting.
I²S Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	Type: Channel type: Left CH for left channel, Right CH for right channel.
	Data: Data byte(s), displayed in true form.
	Complemental Code: Data byte(s), displayed in two's complement form.
	Error: Error.

I^2S Decode List:

I2S	Time	Type	Data	Complemental Code	Error
1	-1.99274ms	Left CH	0x17	00010111	
2	-1.49276ms	Right CH	0x00	00000000	
3	-992.737us	Left CH	0x17	00010111	
4	-492.762us	Right CH	0x00	00000000	
5	7.26200us	Left CH	0x17	00010111	
6	507.237us	Right CH	0x00	00000000	
7	1.00726ms	Left CH	0x17	00010111	

1.4 Wireless/RF Protocol Triggering and Decoding

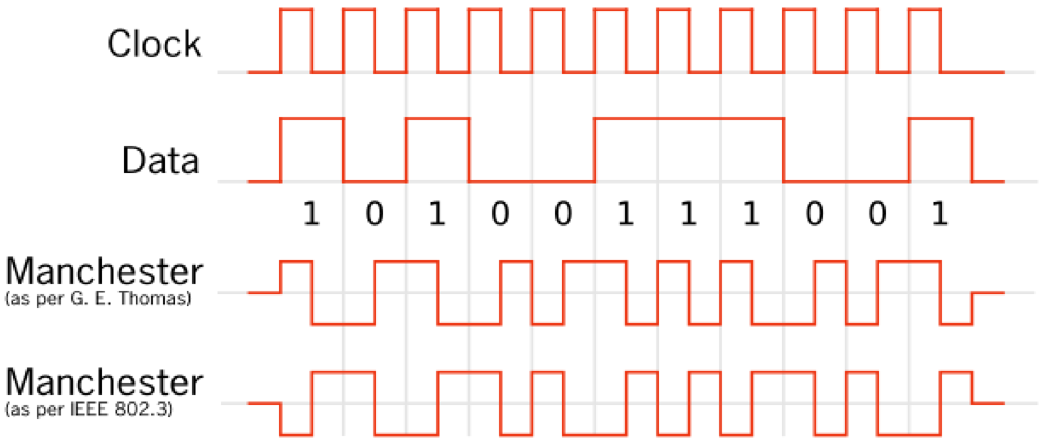
Wireless/RF protocols are specifications and standards that allow electronic devices to communicate via radio waves. These protocols cover multiple layers from the physical layer to the data link layer, specifying signal modulation methods, frequency, transmission rates, data formats, and connection and handshake processes between devices, effectively providing wide coverage and high-capacity communication services.

In wireless/RF protocol analysis, engineers need to understand specific signal events and data transmission processes to improve system stability and reliability. SIGLENT oscilloscopes can capture key information such as specific transition edges or data bits in encoded signals through their precise triggering functions. Through decoding functions, captured encoded signals can be converted into readable data formats, helping engineers monitor and analyze signals in real-time, understand various parameters and states during the communication process, and quickly locate and debug problems.

3.4.1 Manchester

The Manchester protocol is a serial communication protocol standard based on Manchester encoding. Manchester encoding is a coding method with self-synchronization capability and good anti-interference performance. Its great flexibility in parameter settings allows it to exhibit good performance in many applications. This protocol represents logical values through specific level transitions during data transmission and ensures at least one level transition within each clock cycle. This transition not only transmits data but also implicitly transmits clock information, so Manchester encoding is also called self-clocking encoding.

The Manchester protocol is typically used in applications requiring high reliability and synchronization accuracy, such as local area networks, industrial control networks, and some professional bus systems. In these systems, correct data transmission and clock synchronization are crucial, and the Manchester protocol provides these characteristics through its unique encoding method. Additionally, because Manchester encoding has a level transition in each clock cycle, it has some resistance to noise and interference on the line, allowing the Manchester protocol to maintain relatively stable communication performance even in harsh electromagnetic environments.

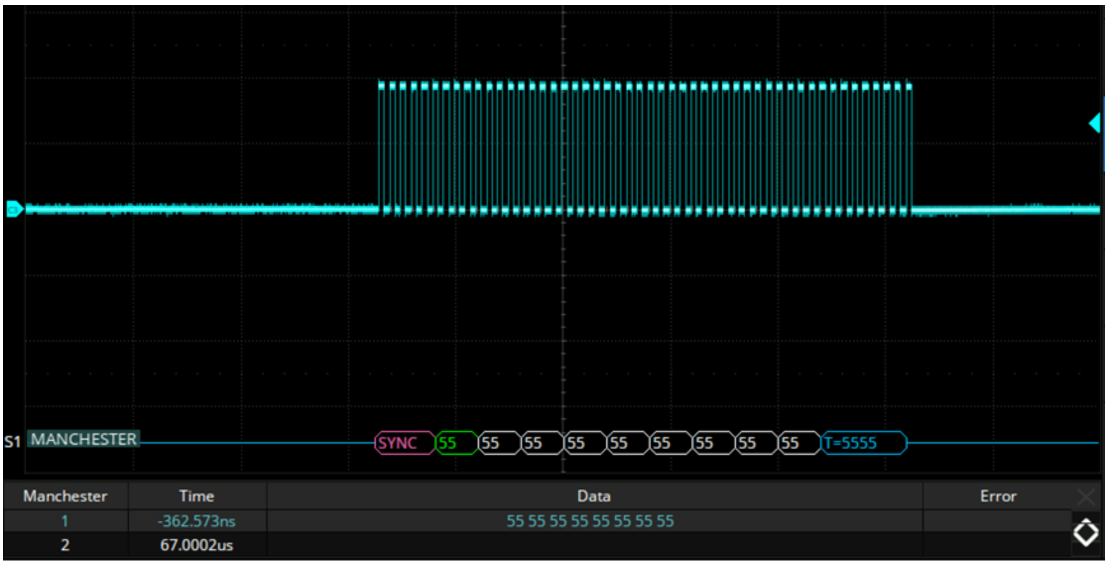


SIGLENT oscilloscopes provide decoding functions for Manchester. Taking the SDS7000A series oscilloscope as an example:

1.4.1.1 Table 11. Manchester Decode

Manchester Signal Setup	Oscilloscope connects to the Manchester signal.
	Set the threshold level for the input channel.
	Set the source and threshold level used for decoding.
Manchester Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	Data: Data byte(s).
	Error: Error.

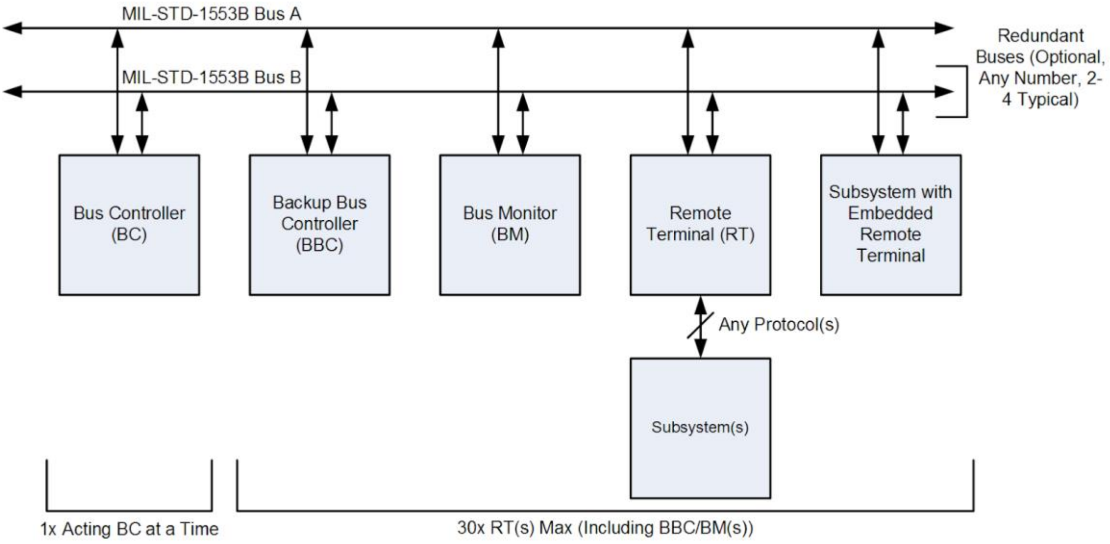
Manchester Decode Result:



3.4.2 MIL-STD-1553B

MIL-STD-1553B is a standard multiplexed data bus system. It is primarily used in complex systems requiring high reliability and real-time data transmission to achieve data transfer and communication between various devices.

MIL-STD-1553B employs a time-division command/response multiplexed data bus, capable of connecting up to 31 remote terminals. It has three terminal types: Bus Controller (BC), Remote Terminal (RT), and Bus Monitor (BM). The Bus Controller is responsible for controlling bus operations, Remote Terminals are devices connected to the bus, and the Bus Monitor is used to monitor data transmission on the bus. Additionally, MIL-STD-1553B uses a redundant channel design, improving system fault tolerance and reliability. This design allows automatic switching between the two channels, avoiding system failure caused by a single point of failure.

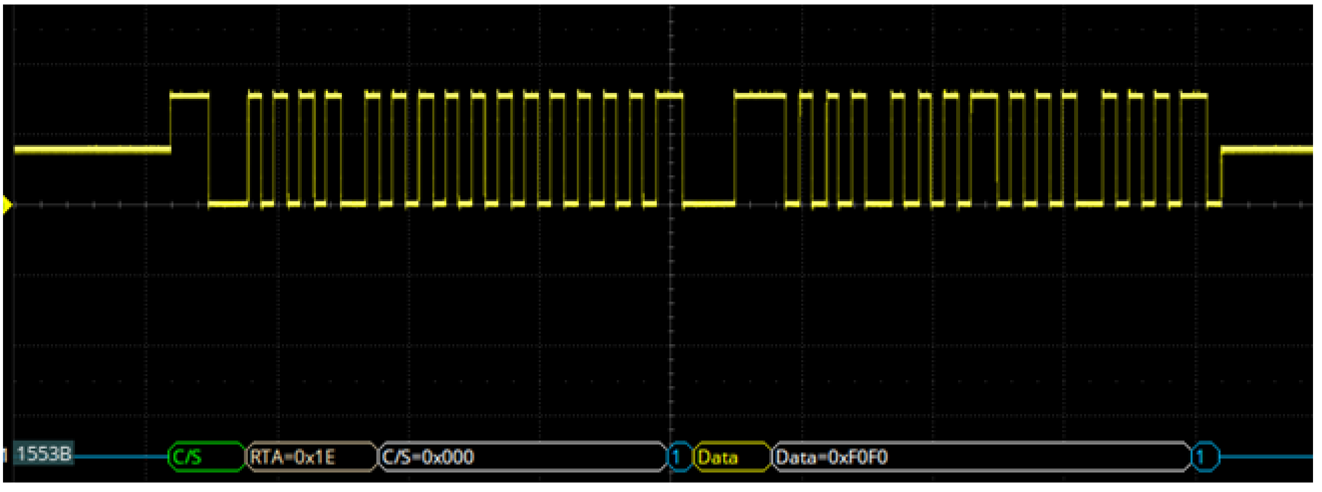


SIGLENT oscilloscopes provide triggering and decoding functions for the MIL-STD-1553B protocol. Taking the SDS7000A series oscilloscope as an example:

1.4.1.2 Table 12. MIL-STD-1553B Trigger and Serial Decode

MIL-STD-1553B Signal Setup	Oscilloscope connects to the MIL-STD-1553B signal.
	Set the threshold level for the input channel.
	Set the source and threshold level for the signal.
MIL-STD-1553B Trigger	**Trigger by Transmission Message Format.**
	Trigger by Word Format.
	Trigger by Error.
	Trigger by Time Interval.
MIL-STD-1553B Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	RTA: Remote Terminal Address from C/S (Command/Status) word.
	Type: Word type.
	Data: Data byte(s).
	Error: Error.

MIL-STD-1553B Decode Result:



MIL-STD-1553B Decode List:

1553B	Time	RTA	Type	Data	Error
1	-2.99040us	0x1	Cmd/Status	0x631	
2	27.0088us	0x1	Cmd/Status	0x0	Parity
3	47.0402us		Data	0x8888	

3.4.3 ARINC 429

The ARINC 429 protocol, fully named Digital Information Transport System (DITS), is a digital communication protocol. This protocol specifies the requirements for digital information transmission between equipment and systems. It adopts differential data transmission, which can maintain data transmission stability in complex electromagnetic environments. It also uses twisted pair as the transmission medium and the differential signal method to effectively cancel external interference, further enhancing data transmission reliability.

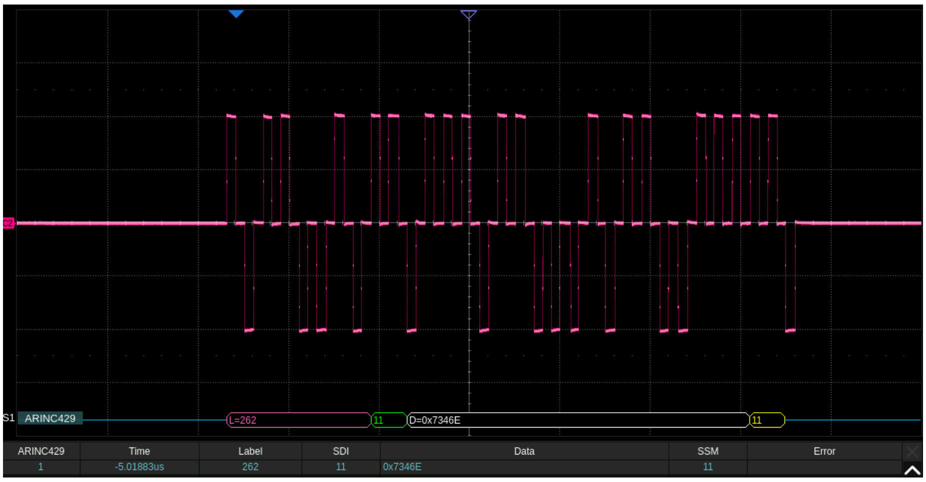
In terms of communication structure, the ARINC 429 protocol uses a point-to-point transmission form, meaning one transmitter can connect to up to 100 receivers. This structure enables effective information transfer between multiple devices, meeting the data transmission needs of complex systems. It is suitable for various application scenarios requiring high-speed, accurate data transmission.

SIGLENT oscilloscopes provide triggering and decoding functions for ARINC 429. Taking the SDS7000A series oscilloscope as an example:

Table 13. ARINC 429 Trigger and Serial Decode

ARINC 429 Signal Setup	Oscilloscope connects to A-line and B-line signals.
	Set the threshold level for each input channel.
	Set the source used for triggering or decoding (A-line, B-line, or A-B).
ARINC 429 Trigger	**Word Start:** Triggers at the start of a word.
	Word End: Triggers at the end of a word.
	Label: Triggers when the specified label value appears.
	Label + Data: Triggers when the specified label and other word fields appear.
	Error: Triggers on an error frame.
	Any Bit: Triggers when any bit forming the eye diagram appears.
	Any 0 Bit: Triggers when any bit with a value of 0 appears.
	Any 1 Bit: Triggers when any bit with a value of 1 appears.
ARINC 429 Decode	**Time:** Time tag. The horizontal offset of the current data relative to the trigger position.
	Label: Label, in octal format, used to identify the data type. Indicates the subsystem associated with the transmitted data on the aircraft.
	SDI: Source/Destination Identifier.
	Data: Data byte(s).
	SSM: Sign/Status Matrix, used to describe the nature of the transmitted data.
	Error: Error.

ARINC 429 Decode Result:



4 Summary

The protocol triggering function of SIGLENT oscilloscopes ensures accurate capture and display of specific protocol signals in complex signal environments, greatly improving the efficiency and accuracy of signal analysis. The protocol decoding function can extract information from various parts of the bus, allowing users to more conveniently obtain the specific content contained in a certain part of the serial bus, which is crucial for in-depth understanding and analysis of the bus system's operating status. SIGLENT oscilloscopes are an efficient and accurate tool for contemporary electronic engineers and researchers, helping them better understand and analyze complex signal environments.

关于鼎阳

鼎阳科技（SIGLENT）是通用电子测试测量仪器领域的行业领军企业，A股上市公司。

2002年，鼎阳科技创始人开始专注于示波器研发，2005年成功研制出鼎阳第一款数字示波器。历经多年发展，鼎阳产品已扩展到数字示波器、手持示波表、函数/任意波形发生器、频谱分析仪、矢量网络分析仪、射频/微波信号源、台式万用表、直流电源、电子负载等基础测试测量仪器产品，是全球极少数能够同时研发、生产、销售数字示波器、信号发生器、频谱分析仪和矢量网络分析仪四大通用电子测试测量仪器主力产品的厂家之一，国家重点“小巨人”企业。同时也是国内主要竞争对手中极少数同时拥有这四大主力产品并且四大主力产品全线进入高端领域的厂家。公司总部位于深圳，在美国克利夫兰、德国奥格斯堡、日本东京成立了子公司，在成都成立了分公司，产品远销全球80多个国家和地区，SIGLENT已经成为全球知名的测试测量仪器品牌。

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