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SERIAL BUS TRIGGER AND DECODE WITH R&S®RTO6 OSCILLOSCOPES

Instant insight meets in-depth information

- ► Trigger at protocol level
- ► View decoded packets
- ► Get time-correlated packet and signal views

AT A GLANCE

TRIGGER AND DECODE SERIAL BUSES

Add protocol triggering and decode capabilities to your oscilloscope.

Connect your oscilloscope to serial bus signals and trigger and decode at a packet level. Unlike dedicated protocol analyzers, oscilloscopes have minimal intrusion on serial bus signaling and correlate packet level measurements with physical layer signal parametric behavior. Use your oscilloscope for a system-level view of one or more serial buses time correlated with other system events. The R&S®RTO6 oscilloscope series includes trigger and decode options for the following:

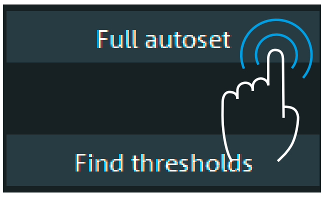
Serial trigger and decode software options	Included protocols
Low speed serial buses	I²C,SPI,RS-232/UART,I²S/LJ/RJ/TDM, Manchester/NRZ
Automotive protocols	CAN/LIN incl. CAN-dbc file import/CAN-FD, FlexRay™ incl. Fibex file import/SENT/CXPI
Aerospace protocols	MIL-STD-1553, ARINC 429,SpaceWire
Ethernet protocols	10BASE-T, 100BASE-TX,MDIO
MIPI RFFE	MIPI RFFE
Automotive Ethernet	IEEE 100BASE-T1, IEEE 1000BASE-T1
USB protocols	USB 1.0/1.1, USB 2.0/HSIC/USB 3.1 Gen 1, USB Power Delivery (USB-PD)/USB SSIC
MIPI M-PHY, D-PHY	MIPI D-PHY/M-PHY/UniPro/Decoding for DSI and CSI-2
PCI Express	8b10b (up to 6.25 Gbit/s)/PCI Express Revision 1.x/2.x

CONTENTS

DECODE AND INTERPRET PACKETS EASILY

Decode your serial bus instantly

Access the serial bus dialog directly from the main display by clicking on +Bus.



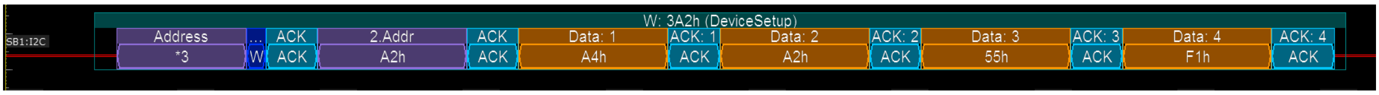
Full autoset for serial bus decoding

Reliable triggering and decoding requires setting correct signal thresholds. Accelerate your test setup with full autoset. With one click, the oscilloscope performs the following for a quick decode setup:

- Executes "Autoset" for horizontal and vertical scales
- Adjusts horizontal scale to display at least one frame or packet
- Executes "Auto thresholds" to determine thresholds
- If necessary, performs bit rate estimation
- Sets default protocol trigger (at frame start for example)
- Turns on protocol decoder

Easily visualize your decoded packets

Color-coded packet fields make quick visualization of specific attributes in decoded messages easier. For example, a parity bit with an error in a UART frame or a missing NACK bit in an I²C frame are marked red.

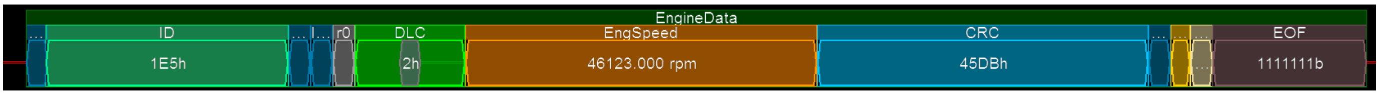


Color-coded packet fields

Protocol-specific symbol labels

Label lists allow decoded data to be interpreted into symbol names, making it easier to identify protocol-specific messages. Load label lists as .csv or .ptt files.

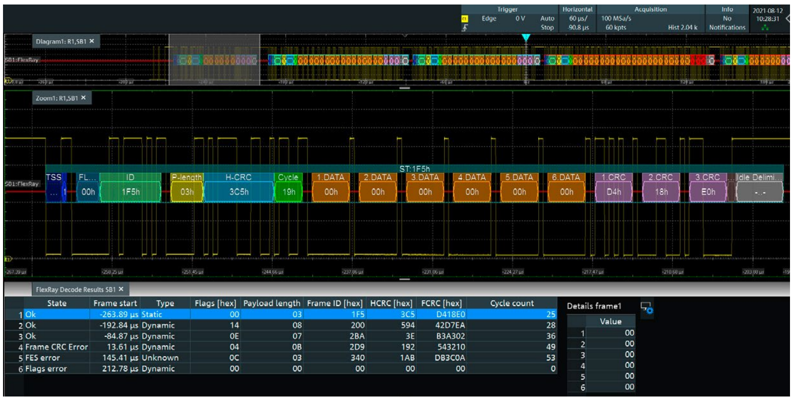
The symbol names appear both in the decoded table and on the waveform as frame captions of the decoded signal. The R&S®RTO6 can do this for all protocols using ID or address identification. In the following example, the CAN DBC file is used to extract physical values such as engine speed from the CAN raw data.



Decode layer with CAN symbols

User-oriented screen setup

The vertical and horizontal control knobs or the touch screen can be used to zoom in and out from the decoded layer. The R&S®SmartGrid function can rearrange the windows displayed on the screen to best fit your viewing preferences. The decoded bus can be overlaid on the captured signal and/or displayed in a separate result table window.



	State	Frame start	Type	Flags [hex]	Payload length	Frame ID [hex]	HCRC [hex]	FCRC [hex]	Cycle count
1	Ok	-263.89 µs	Static	00	03	1F5	3C5	D418E0	25
2	Ok	-192.84 µs	Dynamic	14	08	200	594	42D7EA	28
3	Ok	-84.87 µs	Dynamic	0E	07	2BA	3E	B3A302	36
4	Frame CRC Error	13.61 µs	Dynamic	04	0B	2D9	192	543210	49
5	FES error	145.41 µs	Unknown	0C	03	340	1AB	DB3C0A	53
6	Flags error	212.78 µs	Dynamic	00	00	00	00	00	0

Details frame1

	Value
1	00
2	00
3	00
4	00
5	00
6	00

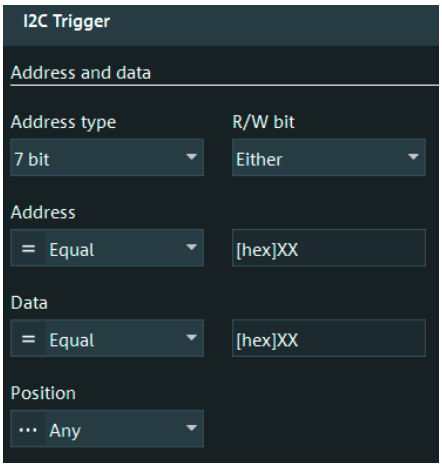
Customized screen setup

RELIABLY TRIGGER ON AND CAPTURE YOUR SERIAL BUS

Packet-level, protocol-aware triggering

R&S®RTO6 oscilloscopes incorporate an integrated circuit with built-in protocol-aware triggers. Use these to isolate and capture specific events of interest.

Designed by engineers with deep knowledge of each supported protocol, the serial bus applications provide the most flexible triggering capability in the industry. Choose from a wide range of serial bus trigger types. Select the specific trigger you need, including triggering on bus errors.



I2C Trigger

Address and data

Address type: 7 bit

R/W bit: Either

Address: = Equal [hex]XX

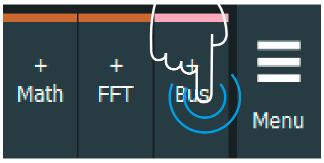
Data: = Equal [hex]XX

Position: ··· Any

I²C triggering example

Hardware-based triggering

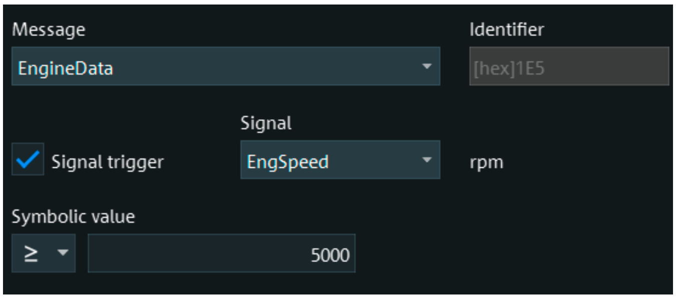
Hardware-based triggering uses dedicated hardware to look for the trigger event in the serial bus for fast and accurate triggers to detect rare signal faults and implement a variety of complex protocol trigger conditions on the R&S®RTO6.



Direct access to serial bus dialog

Trigger on symbol data

Once the symbol names are uploaded, they easily trigger on the protocol-specific symbol data.



Message: EngineData

Identifier: [hex]1E5

☑ Signal trigger

Signal: EngSpeed rpm

Symbolic value: ≥ 5000

Trigger on symbol data

ANALYZE YOUR SERIAL BUS EFFICIENTLY

Capture more packets with deep memory

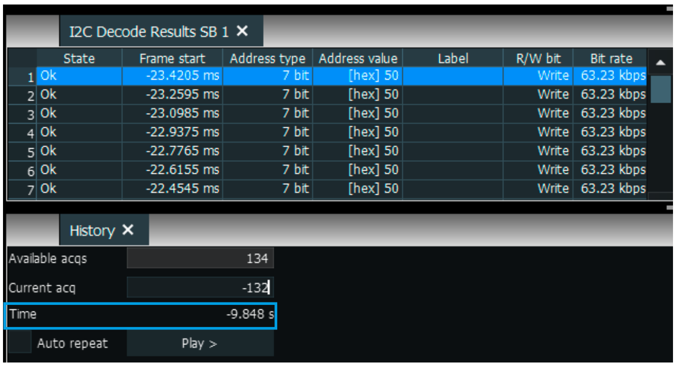
Need to capture long time periods? Deep memory can capture more packets. With a memory depth of up to 2 Gpoint, R&S®RTO6 oscilloscopes can capture long time periods where cause and effect are spaced over time. Signal detail is time-correlated with packet content for fast debugging.

Zoom coupling

An easy-to-read table shows all detected events with timestamps. Easily navigate between captured search events with zoom coupling. Select a frame and the corresponding zoom window will be automatically displayed.

Segmented memory extends capture time

Segmented memory can capture more packets in an acquisition. Segmented memory stores packets around successive triggers, without having to store the dead time between packets. This significantly reduces the blind time to as low as 300 ns. Use the history player to see the decoding for each segment.



I2C Decode Results SB 1

	State	Frame start	Address type	Address value	Label	R/W bit	Bit rate
1	Ok	-23.4205 ms	7 bit	[hex] 50		Write	63.23 kbps
2	Ok	-23.2595 ms	7 bit	[hex] 50		Write	63.23 kbps
3	Ok	-23.0985 ms	7 bit	[hex] 50		Write	63.23 kbps
4	Ok	-22.9375 ms	7 bit	[hex] 50		Write	63.23 kbps
5	Ok	-22.7765 ms	7 bit	[hex] 50		Write	63.23 kbps
6	Ok	-22.6155 ms	7 bit	[hex] 50		Write	63.23 kbps
7	Ok	-22.4545 ms	7 bit	[hex] 50		Write	63.23 kbps

History

Available acqs: 134

Current acq: -132

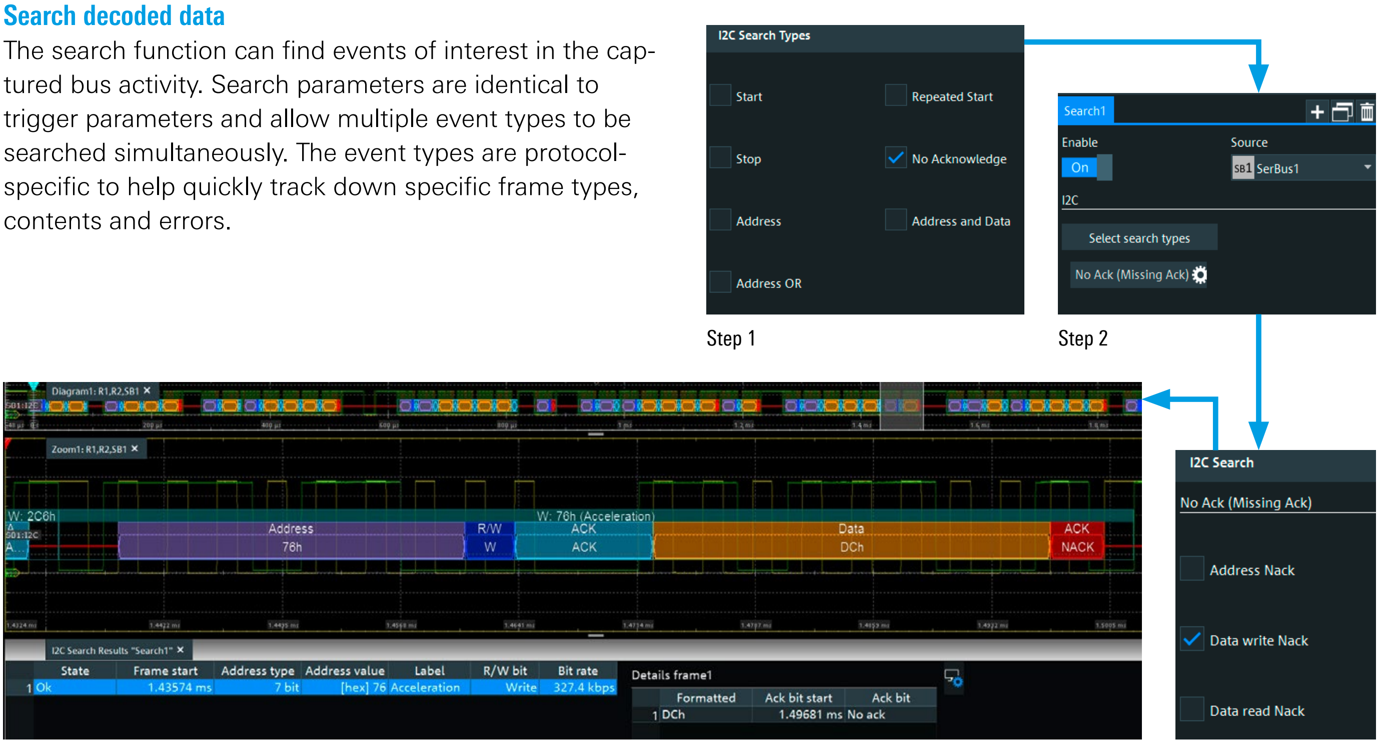
Time: -9.848 s

Auto repeat

10 s of I²C bus activity captured using segmented memory (see blue framed area)

Search decoded data

The search function can find events of interest in the captured bus activity. Search parameters are identical to trigger parameters and allow multiple event types to be searched simultaneously. The event types are protocol-specific to help quickly track down specific frame types, contents and errors.



I2C Search Types

□ Start	□ Repeated Start
□ Stop	☑ No Acknowledge
□ Address	□ Address and Data
□ Address OR	

Step 1

Search1

Enable: On

Source: SB1 SerBus1

I2C

No Ack (Missing Ack)

Step 2

I2C Search Results "Search1"

	State	Frame start	Address type	Address value	Label	R/W bit	Bit rate
1	Ok	1.43574 ms	7 bit	[hex] 76	Acceleration	Write	327.4 kbps

Details frame1

	Formatted	Ack bit start	Ack bit
1	DCh	1.49681 ms	No ack

I2C Search

No Ack (Missing Ack)

□ Address Nack

☑ Data write Nack

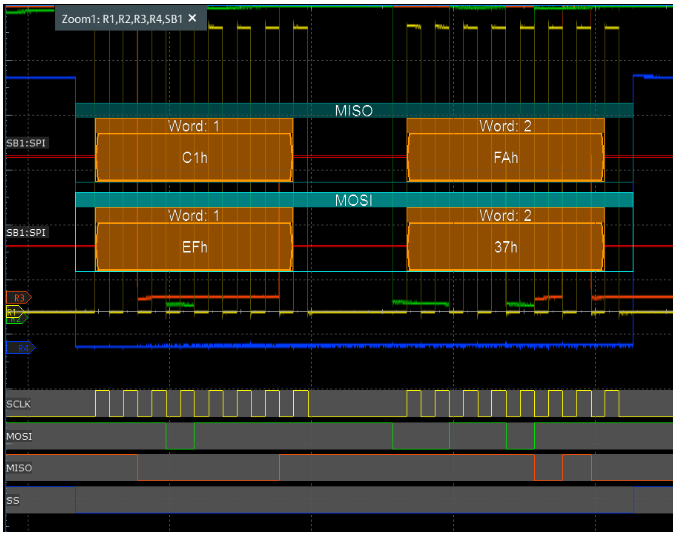
□ Data read Nack

Step 3

I²C "No ACK" search options and results

Binary representation

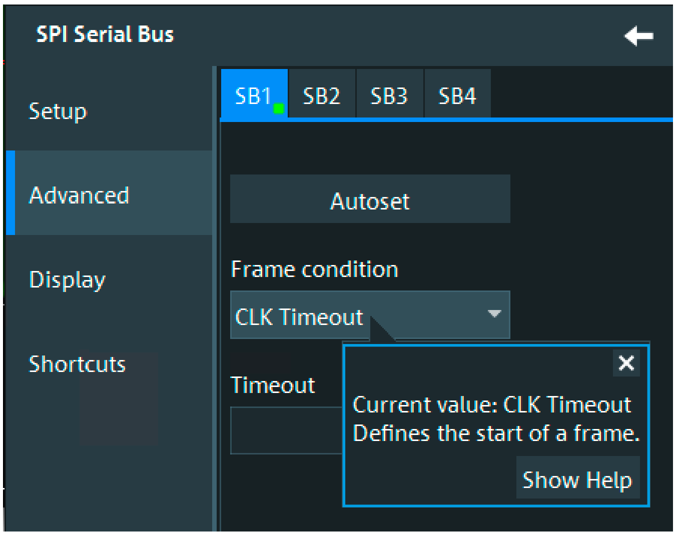
Get a binary representation of your bus signals to find and debug signal integrity issues. Adjust threshold lines and observe the change in binary signal representations.



Binary representation of SLK, MOSI, MISO and SS signals for SPI bus debugging

Context-sensitive help

Activate 'Help' and a brief description of every parameter setting appears. Click 'Show help' for a more detailed description of this parameter and the corresponding SCPI command.



Frame condition: CLK Timeout

Timeout

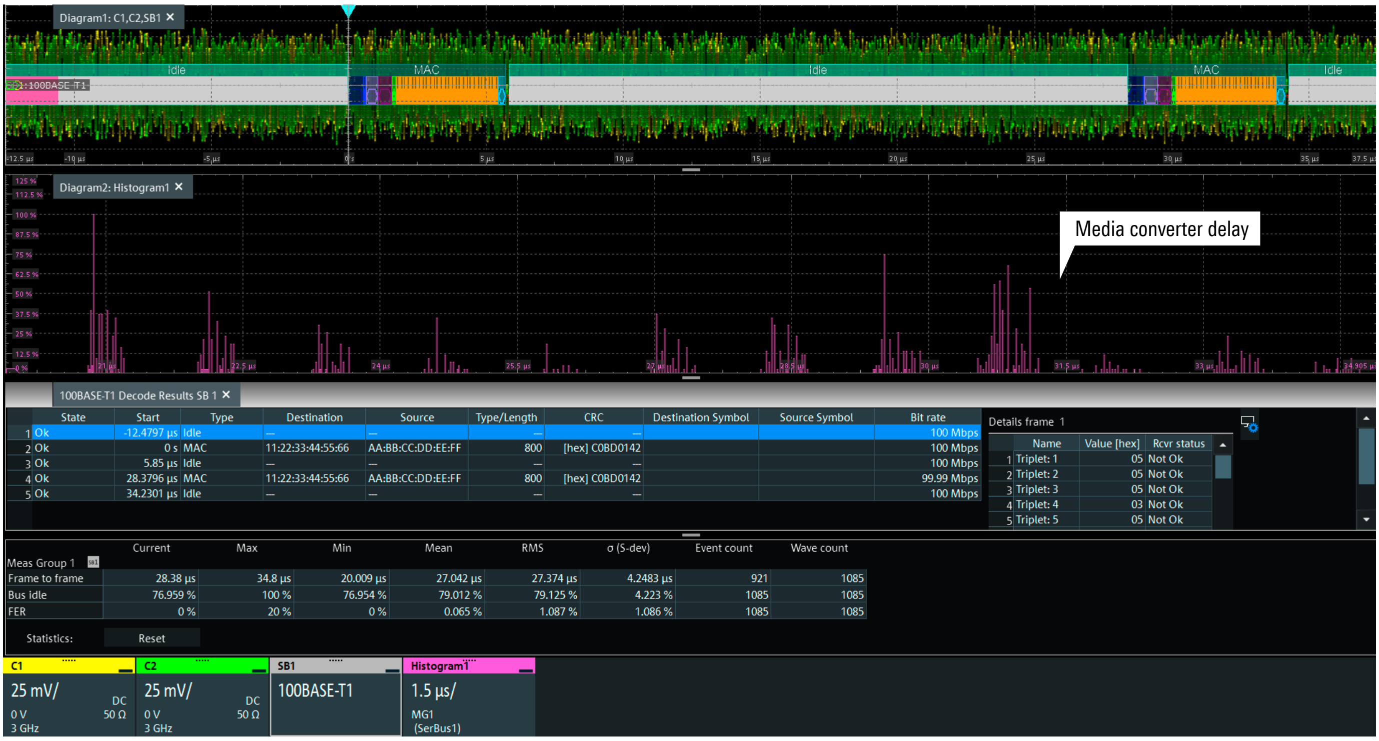
Current value: CLK Timeout
Defines the start of a frame.

Context-sensitive help messages (see blue framed area)

Bus analysis

Additional bus measurements are available are available for most common buses, including Ethernet. To analyze bus timing, measure the frame-to-frame time and display it as a track or histogram. Automatically measure the time between trigger packets or the time difference between frames. Further analyze your bus by measuring various bus error statistics as frame error rates. See the list of additional measurements in the table.

Protocol measurements for bus analysis	
Frame to frame	time difference between two frames
Trigger to frame	time between a defined frame and the next trigger signal
Field value	value of a field in current acquisition
Gap	measures a gap or period at which the bus is idle; distance of a gap can only be measured between two identified frames
Main bit rate	bit rate as defined by the standard
Second bit rate	additional bit rate, protocol dependent; for example: Data rate for the CAN-FD protocol
Bus idle	calculates bus idle time for quick evaluation whether the bus is running at its limits or if more communications are possible
Frame count	number of all frames within the acquisition window
Frame error count	sum of all frames with errors within the acquisition window
Frame error rate	sum of all frames with errors divided by all frames within the acquisition window.
Consecutive frame error rate	measures the rate at which at least two consecutive frames have an error



100BASE-T1 Decode Results SB 1

	State	Start	Type	Destination	Source	Type/Length	CRC	Destination Symbol	Source Symbol	Bit rate
1	Ok	-12.4797 µs	Idle	—	—	—	—			100 Mbps
2	Ok	0 s	MAC	11:22:33:44:55:66	AA:BB:CC:DD:EE:FF	800	[hex] C0BD0142			100 Mbps
3	Ok	5.85 µs	Idle	—	—	—	—			100 Mbps
4	Ok	28.3796 µs	MAC	11:22:33:44:55:66	AA:BB:CC:DD:EE:FF	800	[hex] C0BD0142			99.99 Mbps
5	Ok	34.2301 µs	Idle	—	—	—	—			100 Mbps

Details frame 1

	Name	Value [hex]	Rcvr status
1	Triplet: 1	05	Not Ok
2	Triplet: 2	05	Not Ok
3	Triplet: 3	05	Not Ok
4	Triplet: 4	03	Not Ok
5	Triplet: 5	05	Not Ok

Meas Group 1	Current	Max	Min	Mean	RMS	σ (S-dev)	Event count	Wave count
Frame to frame	28.38 µs	34.8 µs	20.009 µs	27.042 µs	27.374 µs	4.2483 µs	921	1085
Bus idle	76.959 %	100 %	76.954 %	79.012 %	79.125 %	4.223 %	1085	1085
FER	0 %	20 %	0 %	0.065 %	1.087 %	1.086 %	1085	1085

Statistics: Reset

C1	C2	SB1	Histogram1
25 mV/ DC 0 V 50 Ω 3 GHz	25 mV/ DC 0 V 50 Ω 3 GHz	100BASE-T1	1.5 µs/ MG1 (SerBus1)

Example of bus timing measurements on a 100BASE-T1 bus

PROTOCOLS

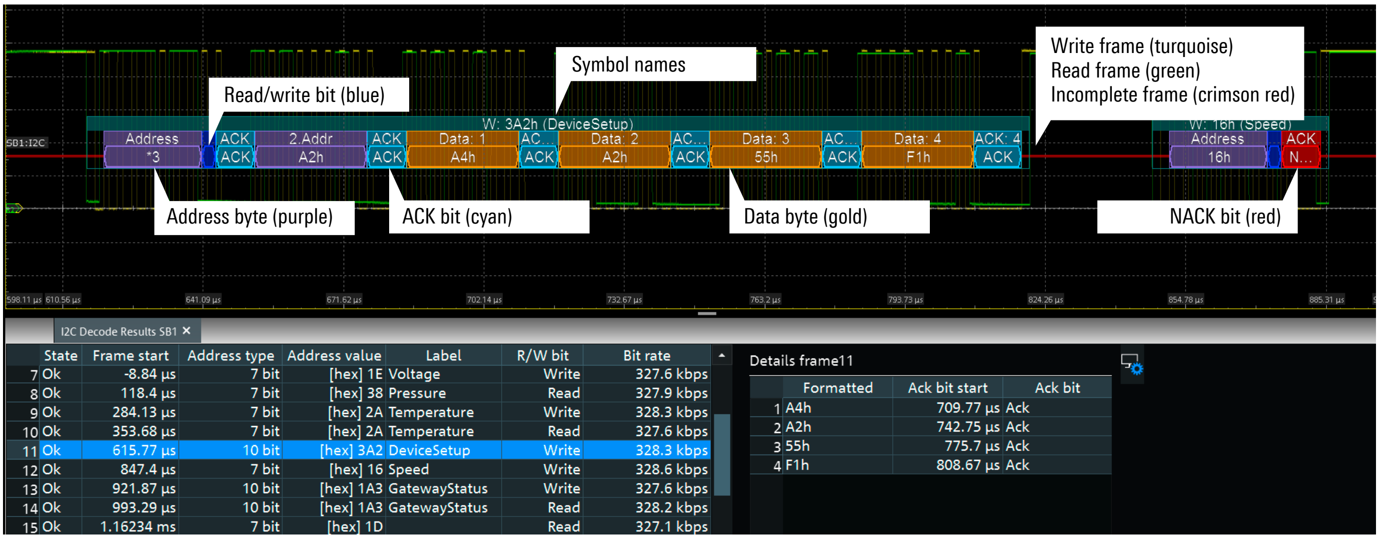
I²C PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K510 low speed serial bus option supports I²C triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding for protocol fields is protocol-specific and simplifies interpretation of the visual display. The I²C decode data layer is highly customizable and may include:

- Binary signal representation of SCL (clock) and SDA (data) signals
- Symbol names (if corresponding .csv and .ptt files are loaded)
- Any of the data formats: hex, octal, binary, ASCII, decimal (signed and unsigned)



I2C Decode Results SB1

	State	Frame start	Address type	Address value	Label	R/W bit	Bit rate
7	Ok	-8.84 µs	7 bit	[hex] 1E	Voltage	Write	327.6 kbps
8	Ok	118.4 µs	7 bit	[hex] 38	Pressure	Read	327.9 kbps
9	Ok	284.13 µs	7 bit	[hex] 2A	Temperature	Write	328.3 kbps
10	Ok	353.68 µs	7 bit	[hex] 2A	Temperature	Read	327.6 kbps
11	Ok	615.77 µs	10 bit	[hex] 3A2	DeviceSetup	Write	328.3 kbps
12	Ok	847.4 µs	7 bit	[hex] 16	Speed	Write	328.6 kbps
13	Ok	921.87 µs	10 bit	[hex] 1A3	GatewayStatus	Write	327.6 kbps
14	Ok	993.29 µs	10 bit	[hex] 1A3	GatewayStatus	Read	328.2 kbps
15	Ok	1.16234 ms	7 bit	[hex] 1D		Read	327.1 kbps

Details frame11

	Formatted	Ack bit start	Ack bit
1	A4h	709.77 µs	Ack
2	A2h	742.75 µs	Ack
3	55h	775.7 µs	Ack
4	F1h	808.67 µs	Ack

I^{2}C specifications	
I^{2}C protocol configuration	addressing scheme: 7 bit or 10 bit
	read/write bit: included in address or separate field
	threshold levels: manual setting or auto threshold
	bit rate: auto-detected (up to 6.5 Mbps)
I^{2}C sources (clock and data)	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 also used
	reference and math waveforms (for decoding)
I^{2}C trigger (hardware-based)	trigger events: ▶ Start ▶ Repeated start ▶ Stop ▶ Missing ACK: address NACK, data write NACK, AND/OR data read NACK ▶ Address OR: up to 4 OR-ed address values ▶ Address and data
	address setup: ▶ 7 bit or 10 bit ▶ Value: hex, decimal, octal, ASCII or binary ▶ Condition: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Read/write bit: included in address or in a separate field
	data setup: ▶ Pattern: up to 8 byte, hex, octal, binary, ASCII, signed, unsigned ▶ Condition: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Offset within frame: 0 byte to 4095 byte
I^{2}C decode	decode display: ▶ Display type: decoded bus, logical signal, bus + logical signal, tabulated list, decode layers ▶ Color coding: frame, start/restart, address, read/write bit, data, ACK/NACK, stop, error ▶ Additional layers for binary values and symbols
	decode table fields: state, frame start, address type (7 bit or 10 bit), address value, label, read/write bit, ACK bit, ACK bit start, bit rate
	decoded data format: hex, octal, binary, ASCII, signed, unsigned, symbolic names
I^{2}C search	event: combination of start, repeated start, stop, missing ACK, address, data, address and data
	events setup: same as trigger event setup
I^{2}C bus measurements	frame to frame, trigger to frame, field value, gap, main bit rate, bus idle time, frame count, frame error count, frame error rate, consecutive frame error rate

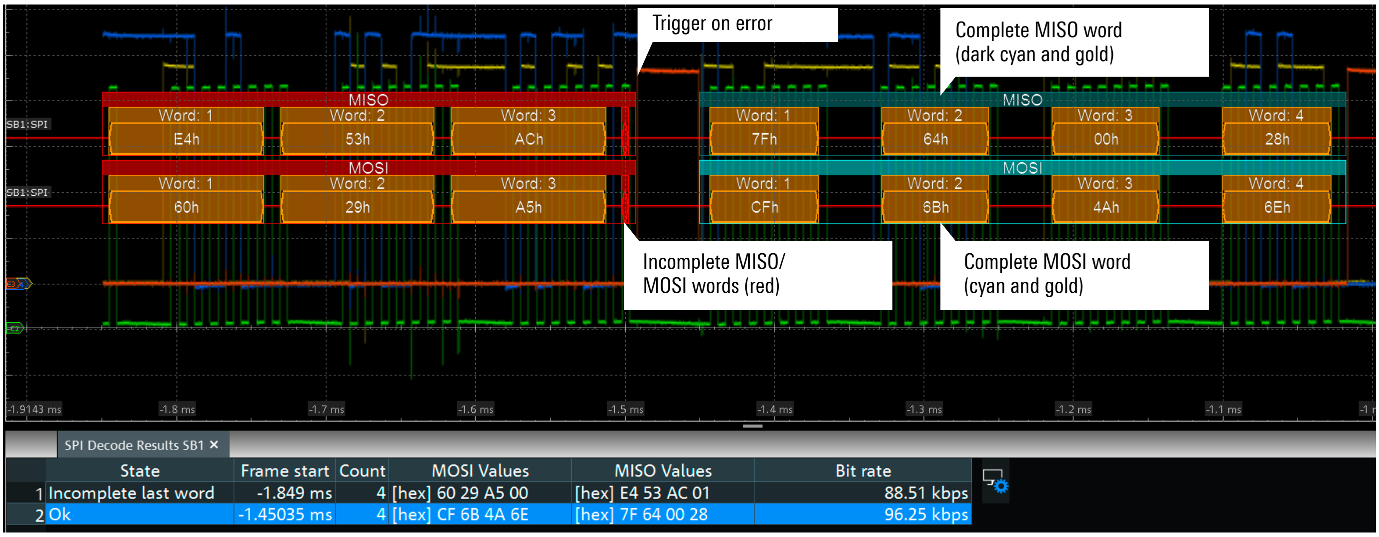
SPI PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K510 low speed serial bus option supports SPI triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding of SPI decode layer is protocol-specific and simplifies interpretation of the visual display. The SPI decode data layer is highly customizable and may include:

- Binary signal representation of the SCLK, MISO, MOSI and SS messages
- Any of the data formats: hex, octal, binary, ASCII, decimal



Trigger on error

Complete MISO word (dark cyan and gold)

Incomplete MISO/ MOSI words (red)

Complete MOSI word (cyan and gold)

	State	Frame start	Count	MOSI Values	MISO Values	Bit rate
1	Incomplete last word	-1.849 ms	4	[hex] 60 29 A5 00	[hex] E4 53 AC 01	88.51 kbps
2	Ok	-1.45035 ms	4	[hex] CF 6B 4A 6E	[hex] 7F 64 00 28	96.25 kbps

SPI specifications	
SPI protocol configuration	type: 2-wire, 3-wire and 4-wire SPI
	bit rate: auto-detected, up to 50 Mbps
	bit order: MSB first or LSB first
	word length: 4 bit to 32 bit
	frame condition: SS or clock timeout
	MOSI/MISO/SS polarity: active high or active low
	clock polarity: falling/rising edge, idle low/high, 1st/2nd edge
	threshold levels: manual setting or auto threshold
SPI sources (clock, MOSI/MISO, SS)	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 also used
	reference and math waveforms (for decoding)
SPI trigger (hardware-based)	trigger events: ► Frame start (SS or CLK timeout) ► MOSI and/or MISO
	data setup: ► Search mode: word-aligned or bit-aligned ► Condition: =, ≠ ► Value: up to 256 bit, hex, decimal, octal, ASCII or binary ► Offset within frame: 0 bit to 32 767 bit
SPI decode	decode display: ► Display type: decoded bus, logical signal, bus + logical signal, tabulated list, decode layers ► Color coding: frame, word, error ► Additional layers for binary values
	decode table fields: state, frame start, count, MOSI values, MISO values, bit rate
	decoded data format: hex, decimal, octal, binary, ASCII
SPI search	event: start of frame, MOSI and/or MISO
	events setup: same as trigger event setup
SPI bus measurements	frame to frame, trigger to frame, field value, gap, main bit rate, bus idle time, frame count, frame error count, frame error rate, consecutive frame error rate

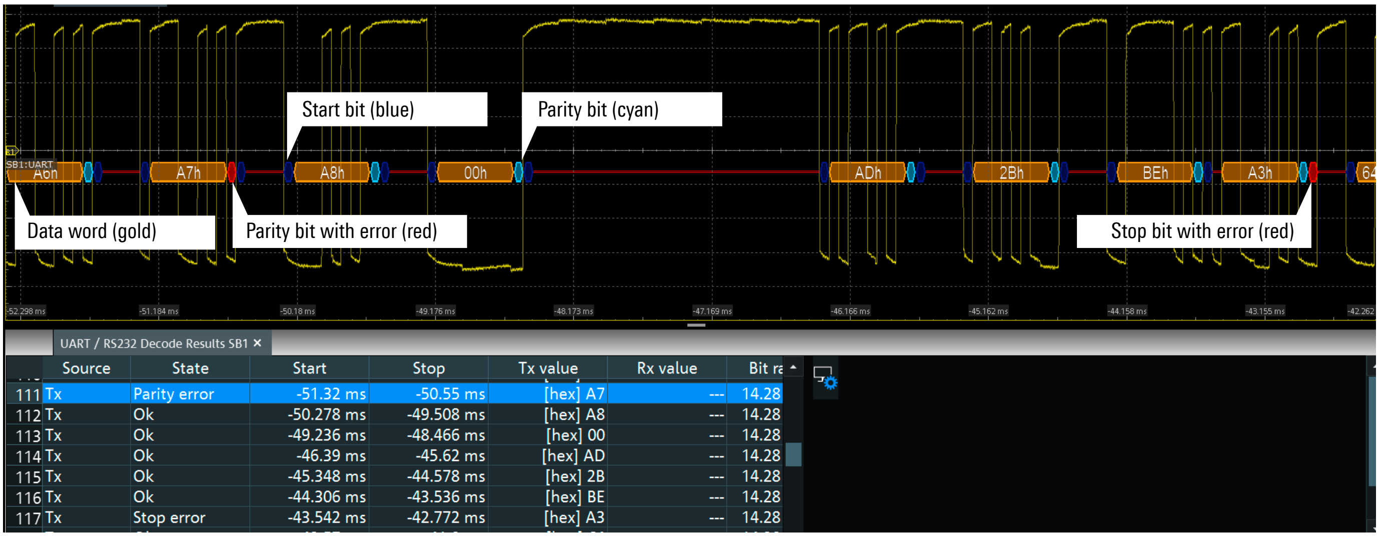
UART/RS-232 PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K510 low speed serial bus option supports UART/RS-232 triggering and decoding.

Protocol-specific visual display of decoded packets

The color-coding of fields is protocol-specific and simplifies interpretation of the visual display.
The UART/RS-232 decode data layer is highly customizable and may include:

- Any of the data formats: hex, octal, binary, ASCII, decimal



Start bit (blue)

Parity bit (cyan)

Data word (gold)

Parity bit with error (red)

Stop bit with error (red)

UART / RS232 Decode Results SB1 ×

	Source	State	Start	Stop	Tx value	Rx value	Bit ra
111	Tx	Parity error	-51.32 ms	-50.55 ms	[hex] A7	---	14.28
112	Tx	Ok	-50.278 ms	-49.508 ms	[hex] A8	---	14.28
113	Tx	Ok	-49.236 ms	-48.466 ms	[hex] 00	---	14.28
114	Tx	Ok	-46.39 ms	-45.62 ms	[hex] AD	---	14.28
115	Tx	Ok	-45.348 ms	-44.578 ms	[hex] 2B	---	14.28
116	Tx	Ok	-44.306 ms	-43.536 ms	[hex] BE	---	14.28
117	Tx	Stop error	-43.542 ms	-42.772 ms	[hex] A3	---	14.28

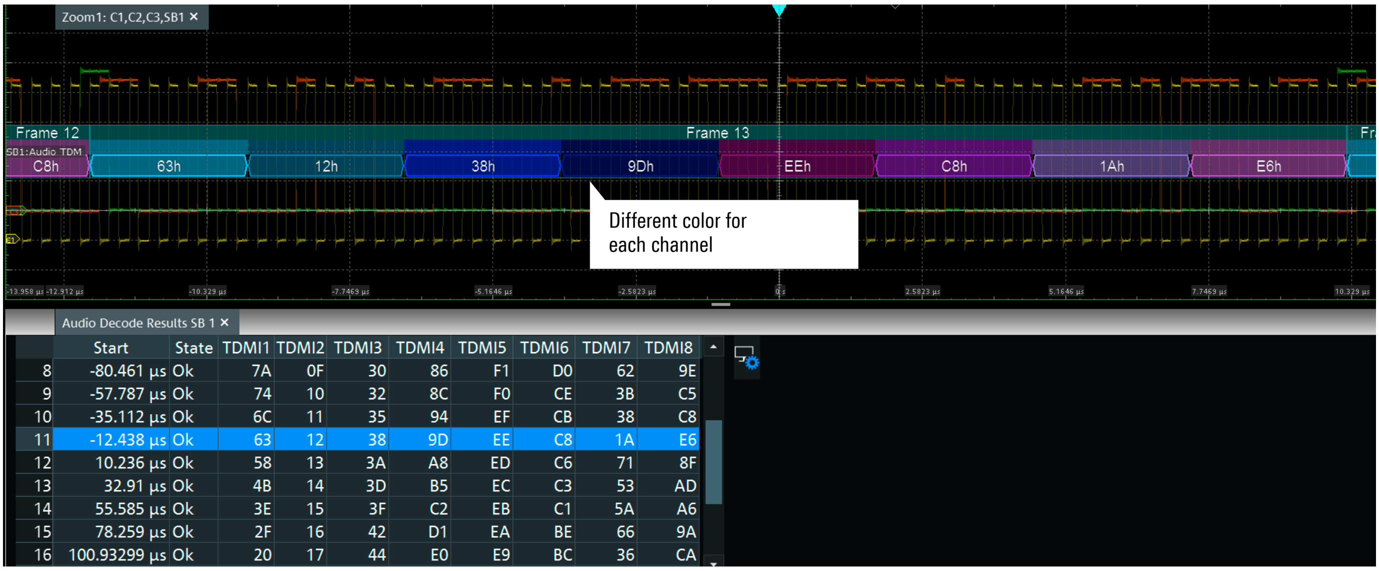
UART/RS-232 specifications	
UART protocol configuration	supports: RS-232, RS-422 (with differential probing), RS-485 (with differential probing), UART (all that conform to the oscilloscope application parameters)
	bit rate: enter manually or choose predefined values, 300 bps to 20 Mbps
	number of bits: 5 bit to 9 bit
	bit order: LSB first, MSB first
	stop bit: 1, 1.5 or 2 bit periods
	end of packet: word, timeout, none
	polarity: idle high or idle low
	parity: none, odd, even, mark, space, don't care
	threshold levels: manual setting or auto threshold
UART/RS-232 sources (TX and RX)	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 also used
	reference and math waveforms (for decoding)
UART/RS-232 trigger (TX or RX; hardware-based)	trigger events: ► Start bit ► Packet start ► Data ► Parity error ► Break condition ► Stop error
	data setup: ► Condition: =, ≠ ► Value: up to 256 bit, hex, decimal, octal, binary or ASCII ► Offset within frame: 0 bit to 32 767 bit
UART/RS-232 decode	decode display: ► Display type: decoded bus, logical signal, bus + logical signal, tabulated list, decode layers ► Color coding: data, parity bit, start error, parity error, stop, error ► Additional layers for binary values
	decode table fields: source, state, start, stop, TX value, RX value, bit rate
	decoded data format: hex, decimal, octal, binary, ASCII
UART/RS-232 bus measurements	frame to frame, trigger to frame, field value, gap, main bit rate, bus idle time, frame count, frame error count, frame error rate, consecutive frame error rate

AUDIO PROTOCOLS TRIGGER AND DECODE

The R&S®RTO6-K510 low speed serial bus option supports audio protocols triggering and decoding.

Protocol-specific visual display of decoded packets

The color-coding of protocol fields is protocol-specific and simplifies interpretation of the visual display. The audio decoded data shows each channel in a different color.



Different color for each channel

	Start	State	TDMI1	TDMI2	TDMI3	TDMI4	TDMI5	TDMI6	TDMI7	TDMI8
8	-80.461 µs	Ok	7A	0F	30	86	F1	D0	62	9E
9	-57.787 µs	Ok	74	10	32	8C	F0	CE	3B	C5
10	-35.112 µs	Ok	6C	11	35	94	EF	CB	38	C8
11	-12.438 µs	Ok	63	12	38	9D	EE	C8	1A	E6
12	10.236 µs	Ok	58	13	3A	A8	ED	C6	71	8F
13	32.91 µs	Ok	4B	14	3D	B5	EC	C3	53	AD
14	55.585 µs	Ok	3E	15	3F	C2	EB	C1	5A	A6
15	78.259 µs	Ok	2F	16	42	D1	EA	BE	66	9A
16	100.93299 µs	Ok	20	17	44	E0	E9	BC	36	CA

Audio protocols specifications	
Audio signal types	▶ I^{2}S standard ▶ Left justified (LJ) ▶ Right justified (RJ) ▶ Time division multiplexed (TDM)
Audio sources (clock and data)	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), additionally use logic channels D0 to D15
	reference and math waveforms (for decoding)
Audio protocol configuration	clock polarity: rising edge or falling edge
	word select line polarity: normal or inverted
	data polarity: active high or active low
	threshold levels: manual setting or auto threshold
Audio trigger (hardware-based)	trigger events: ▶ Data ▶ Window ▶ Frame condition ▶ Word select ▶ Error condition
	data setup: ▶ Data pattern of an audio channel up to 4 byte ▶ Condition: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Value: hex, decimal, octal, ASCII or binary
	window setup: ▶ Word count of data pattern of an audio channel up to 4 byte ▶ Condition: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Value: hex, decimal, octal, ASCII or binary ▶ Word length: 1 word to 1 000 000 words
	frame condition setup: ▶ Combination of audio channels in a frame up to 4 byte ▶ Condition: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Value: hex, decimal, octal, ASCII or binary
	word select setup: ▶ Positive or negative slope
	error condition setup: ▶ Source of word select
Audio decode	decode display: ▶ Display type: decoded bus, logical signal, bus + logical signal, tabulated list, decode layers ▶ Color coding: audio frame, frame error, incomplete frame
	decode table fields: state, start, audio channel
	decoded data format: hex, unsigned decimal, signed decimal (two's complement), octal, binary, ASCII
Audio protocol measurements	audio display: display of audio waveform for specified audio channels
	long-term display: history of selected audio data as trace against measurements, waveforms and time index

CUSTOMIZED MANCHESTER AND NRZ PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K510 low speed serial bus option supports customized Manchester and NRZ triggering and decoding.

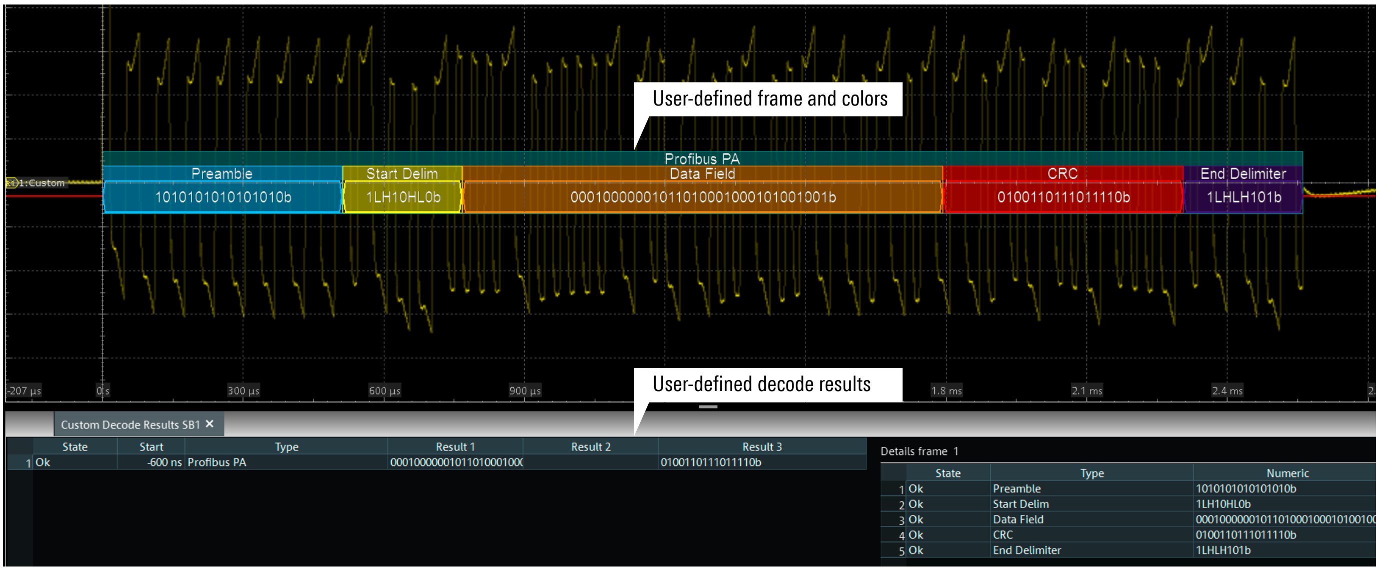
Customized protocol frame setup

Input a customized protocol frame manually or upload a file. Each packet in the frame may be described by the following parameters:

- Field name (user-defined name)
- Bits (length in bit)
- Condition (for example a specific pattern)
- Format (the data format for the condition value)
- Bit order (most significant or least significant bit first)
- Color (user-defined color)
- Result (sets whether this should be displayed in the decode table results)

Customized Manchester and NRZ protocol-specific visual display of decoded packets

The color-coding of the Manchester and NRZ decode layer is protocol-specific and simplifies interpretation of the visual display. You can define the colors in the decode data layer and choose which data is displayed in the decode table.



User-defined frame and colors

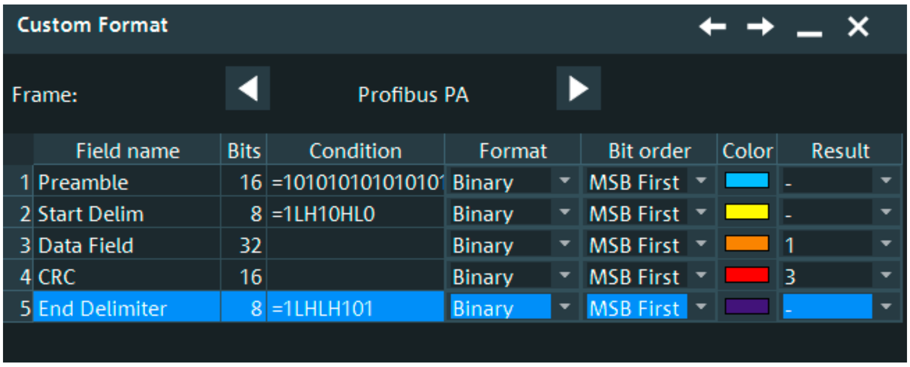
User-defined decode results

	State	Start	Type	Result 1	Result 2	Result 3
1	Ok	-600 ns	Profibus PA	000100000001011010001000		0100110111011110b

Details frame 1

	State	Type	Numeric
1	Ok	Preamble	1010101010101010b
2	Ok	Start Delim	1LH10HL0b
3	Ok	Data Field	000100000001011010001000101001001
4	Ok	CRC	0100110111011110b
5	Ok	End Delimiter	1LHLH101b

Custom trigger and decode for profibus PA



Frame: Profibus PA

	Field name	Bits	Condition	Format	Bit order	Color	Result
1	Preamble	16	=101010101010101	Binary	MSB First	🟦	-
2	Start Delim	8	=1LH10HL0	Binary	MSB First	🟨	-
3	Data Field	32		Binary	MSB First	🟧	1
4	CRC	16		Binary	MSB First	🟥	3
5	End Delimiter	8	=1LHLH101	Binary	MSB First	🟪	-

User-defined profibus PA frame

Custom: Manchester and NRZ specifications	
Bit encoding	▶ Manchester, Manchester II ▶ NRZ clocked, NRZ unclocked
Manchester/NRZ sources (data, clock for NRZ clocked)	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 (only for NRZ) also used
	reference and math waveforms
Custom protocol setup	▶ Data polarity (Manchester): normal or inverted ▶ Data polarity (NRZ): active high or active low ▶ Data idle polarity (NRZ unclocked): idle low or idle high ▶ Clock polarity (NRZ clocked): idle low or idle high ▶ Clock phase (Manchester/NRZ clocked): first edge or second edge ▶ Timing settings - Bit rate (optional for Manchester/Manchester II, mandatory for NRZ unclocked) - Gap time (optional for Manchester/Manchester II/NRZ clocked, mandatory for NRZ unclocked) ▶ Thresholds: manual setting or auto threshold
Custom frame format	▶ Frame ▶ Multiple frame management ▶ Frame identification and sync ▶ Variable length frames ▶ Variable number of cells ▶ Cells: name, size (bits), numeric format, bit order, color
Custom filter configuration	to display only selected events
Manchester/NRZ triggering capabilities	frame start: ▶ Gap, start bit
	pattern: ▶ Data value: binary or hexadecimal ▶ Data position: =, ≥, in range
	advanced: ▶ Frame type: frame type (with OR combinations), frame fields (with AND combinations) ▶ Error type: CRC error AND parity error ▶ Frame field data ▶ Data count condition: =, ≠, <, ≤, >, ≥, in range, out of range
Custom: Manchester/NRZ decode	decode display: ▶ Display type: decoded bus, logical signal, bus signal, tabulated list, result details, decode layers ▶ Color coding: according to cell configuration table ▶ Decoded data format: according to cell configuration table ▶ Decode table fields: state, start, stop, type, result 1 (1st field content), result 2 (2nd field content), result 3 (3rd field content)

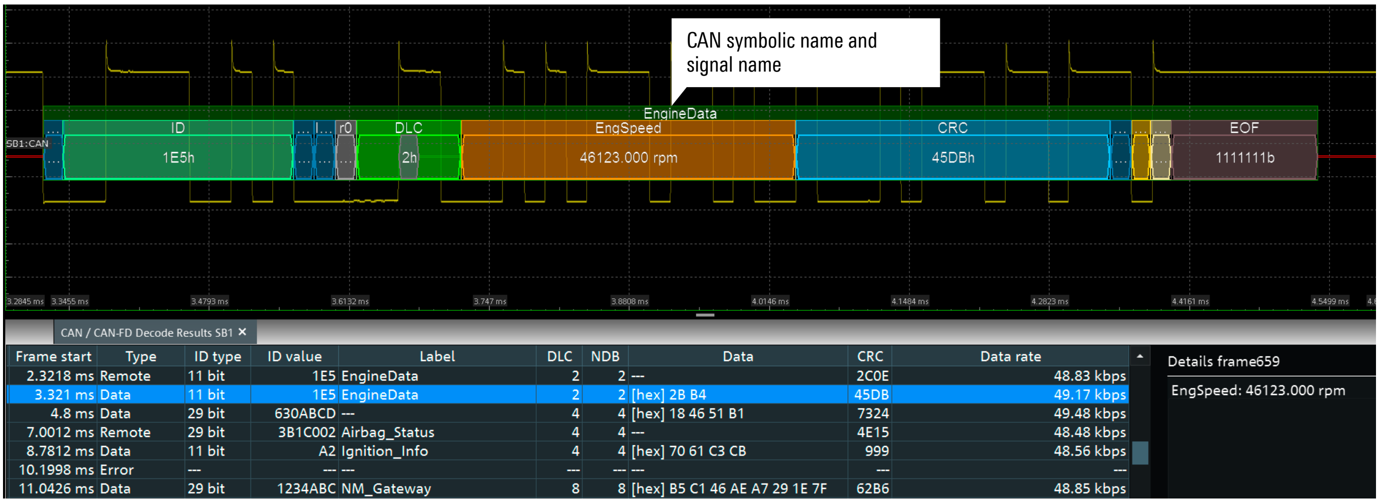
CAN PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K520 automotive protocol option supports CAN including CAN-dbc file import/CAN-FD triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding for protocol fields is protocol-specific and simplifies visual display interpretation. The CAN decode data layer is highly customizable and may include:

- Binary signal representation of the CAN signal
- Symbolic names (with CAN-dbc file import)
- Any of the data formats: hex, octal, binary, ASCII, decimal (signed and unsigned)


CAN symbolic name and signal name

Frame start	Type	ID type	ID value	Label	DLC	NDB	Data	CRC	Data rate
2.3218 ms	Remote	11 bit	1E5	EngineData	2	2	---	2C0E	48.83 kbps
3.321 ms	Data	11 bit	1E5	EngineData	2	2	[hex] 2B B4	45DB	49.17 kbps
4.8 ms	Data	29 bit	630ABCD	---	4	4	[hex] 18 46 51 B1	7324	49.48 kbps
7.0012 ms	Remote	29 bit	3B1C002	Airbag_Status	4	4	---	4E15	48.48 kbps
8.7812 ms	Data	11 bit	A2	Ignition_Info	4	4	[hex] 70 61 C3 CB	999	48.56 kbps
10.1998 ms	Error	---	---	---	---	---	---	---	---
11.0426 ms	Data	29 bit	1234ABC	NM_Gateway	8	8	[hex] B5 C1 46 AE A7 29 1E 7F	62B6	48.85 kbps

Details frame659

EngSpeed: 46123.000 rpm

CAN specifications	
CAN protocol configuration	protocol: CAN, CAN-FD
	signal type: CAN_L, CAN_H
	bit rate: 100 bps to 1 Mbps (CAN), 10 kbps to 15 Mbps (CAN-FD)
	sampling point: 5 % to 95 % within bit period; independent settings for arbitration phase and data phase
	device list: associate frame identifier with symbolic ID, load DBC file content
	threshold levels: manual setting or auto threshold
CAN sources	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 also used
	reference and math waveforms (for decoding)
CAN trigger (hardware-based)	trigger events: ▶ Start of frame ▶ Frame type ▶ Identifier ▶ Identifier and data ▶ Error condition: CRC error, form error, bit stuffing error AND/OR ACK error
	identifier setup: ▶ Frame type: data, remote or both ▶ Identifier type: standard or extended ▶ Transfer: little-endian, big-endian ▶ Condition: =, ≠, <, ≤, >,≥, in range, out of range
	data setup: ▶ Pattern: up to 8 byte in the complete data range ▶ Value: hex, decimal, octal, binary, ASCII, symbolic DLC value ▶ Condition: =, ≠, <, ≤, >,≥, in range, out of range ▶ Offset within frame: 0 byte to 4095 byte
CAN decode	decode display: ▶ Display type: decoded bus, logical signal, bus + logical signal, tabulated list, decode layers ▶ Color coding: start of frame, identifier, FD bits, DLC, data payload, CRC, end of frame, error frame, overload frame, CRC error, bit stuffing error ▶ Additional layers for binary values
	decode table fields: state, frame start, ID type, ID value, label, DLC, NDB, data, CRC, data rate
	decoded data format: hex, decimal, octal, binary, ASCII, symbolic
CAN search	event: start of frame, frame type, identifier, identifier and data, error condition
	events setup: same as trigger event setup
CAN bus measurements	frame to frame, trigger to frame, field value, gap, main bit rate, second bit rate, bus idle time, frame count, frame error count, frame error rate, consecutive frame error rate

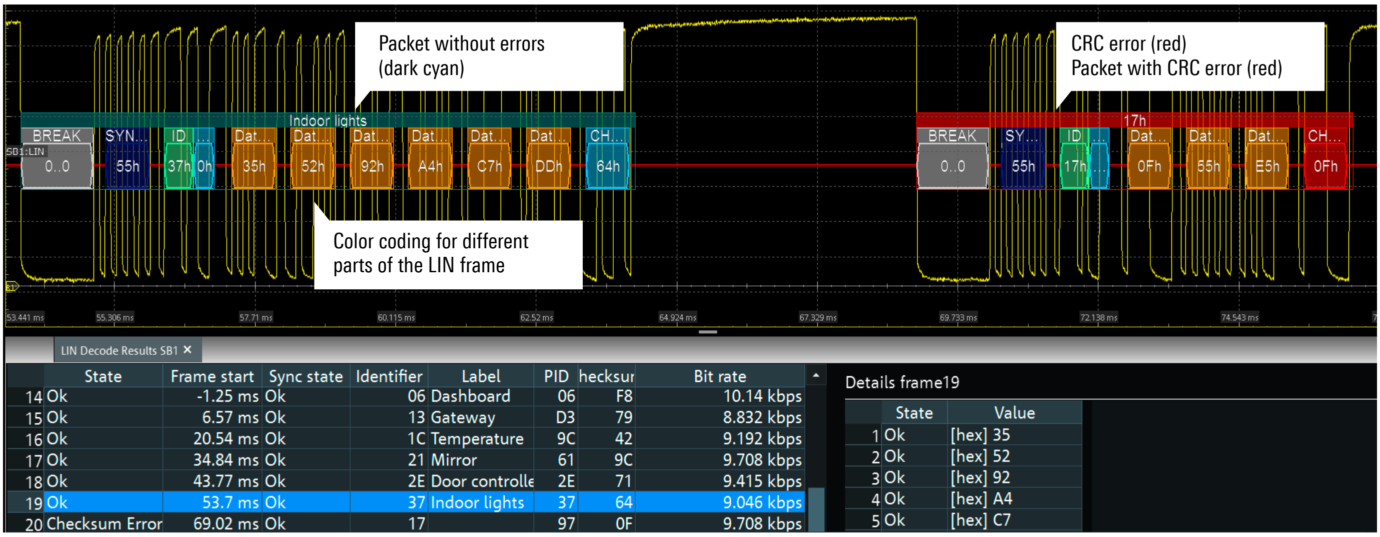
LIN PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K520 automotive protocol option supports LIN protocol triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding for protocol fields is protocol-specific and simplifies interpretation of the visual display. The LIN decode data layer is highly customizable and may include:

- Binary signal representation of the LIN signal
- Symbolic names
- Any of the data formats: hex, octal, binary, ASCII, decimal (signed and unsigned)



Packet without errors (dark cyan)

CRC error (red)
Packet with CRC error (red)

Color coding for different parts of the LIN frame

	State	Frame start	Sync state	Identifier	Label	PID	hecksur	Bit rate
14	Ok	-1.25 ms	Ok	06	Dashboard	06	F8	10.14 kbps
15	Ok	6.57 ms	Ok	13	Gateway	D3	79	8.832 kbps
16	Ok	20.54 ms	Ok	1C	Temperature	9C	42	9.192 kbps
17	Ok	34.84 ms	Ok	21	Mirror	61	9C	9.708 kbps
18	Ok	43.77 ms	Ok	2E	Door controlle	2E	71	9.415 kbps
19	Ok	53.7 ms	Ok	37	Indoor lights	37	64	9.046 kbps
20	Checksum Error	69.02 ms	Ok	17		97	0F	9.708 kbps

Details frame19

	State	Value
1	Ok	[hex] 35
2	Ok	[hex] 52
3	Ok	[hex] 92
4	Ok	[hex] A4
5	Ok	[hex] C7

LIN specifications	
LIN protocol configuration	protocol version: 1.3, 2.x or SAE J602; mixed traffic is supported
	bit rate: enter manually user-defined bit rate (in range from 1 kbps to 20 kbps) or choose from predefined standard bit rates (1.2/2.4/4.8/9.6/10.417/19.2 kbps)
	threshold levels: manual setting or auto threshold
LIN sources	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 also used
	reference and math waveforms (for decoding)
LIN trigger (hardware-based)	trigger events: ► Start of frame ► Identifier ► Identifier and data ► Wake-up frame ► Error condition: identifier parity error, sync field error AND/OR checksum error
	identifier setup: ► Range: 0 d to 63 d ► Value: hex, decimal, octal, binary, ASCII ► Condition: =, ≠, <, ≤, >,≥, in range, out of range
	data setup: ► Pattern: up to 8 byte in the complete data range ► Value: hex, decimal, octal, binary, ASCII ► Condition: =, ≠, <, ≤, >,≥, in range, out of range
LIN decode	decode display: ► Display type: decoded bus, logical signal, bus + logical signal, tabulated list ► Color coding: start of frame, frame identifier, data payload, checksum, error condition
	decode table fields: state, frame start, sync state, identifier, label, PID, checksum, bit rate
	decoded data format: hex, decimal, octal, binary, ASCII, symbolic
LIN search	event: combination of start of frame (sync break), identifier, identifier + data, wake-up frame, error condition
	events setup: same as trigger event setup
LIN bus measurements	frame to frame, trigger to frame, field value, gap, main bit rate, second bit rate, bus idle time, frame count, frame error count, frame error rate, consecutive frame error rate

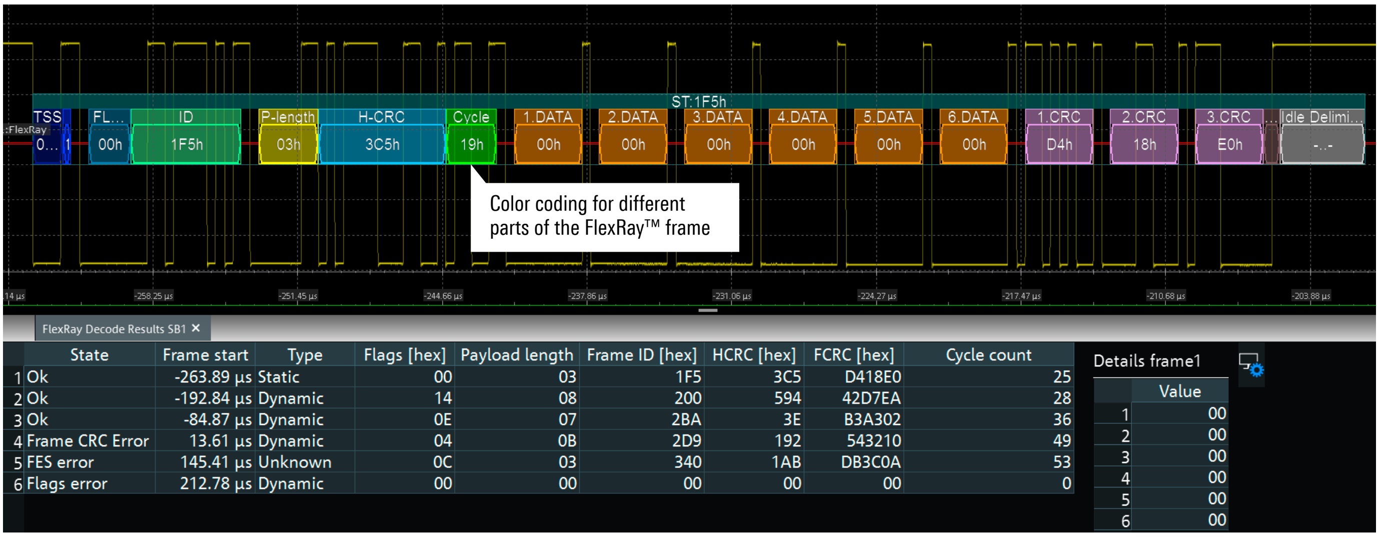
FlexRay™ PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K520 automotive protocol option supports FlexRay™ triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding for protocol fields is protocol-specific and simplifies interpretation of the visual display. The FlexRay™ decode data layer is highly customizable and may include:

- Binary signal representation of the FlexRay™ signal
- Any of the data formats: hex, octal, binary, ASCII, decimal (signed and unsigned)



Color coding for different parts of the FlexRay™ frame

	State	Frame start	Type	Flags [hex]	Payload length	Frame ID [hex]	HCRC [hex]	FCRC [hex]	Cycle count
1	Ok	-263.89 µs	Static	00	03	1F5	3C5	D418E0	25
2	Ok	-192.84 µs	Dynamic	14	08	200	594	42D7EA	28
3	Ok	-84.87 µs	Dynamic	0E	07	2BA	3E	B3A302	36
4	Frame CRC Error	13.61 µs	Dynamic	04	0B	2D9	192	543210	49
5	FES error	145.41 µs	Unknown	0C	03	340	1AB	DB3C0A	53
6	Flags error	212.78 µs	Dynamic	00	00	00	00	00	0

Details frame1

	Value
1	00
2	00
3	00
4	00
5	00
6	00

FlexRay™ specifications	
FlexRay™ protocol configuration	signal type: single-ended, differential, logic
	channel type: A, B
	bit rate: standard bit rates (2.5, 5.0, 10.0 Mbps)
	threshold levels: manual setting or auto threshold
FlexRay™ sources	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), additionally use logic channels D0 to D15
	reference and math waveforms (for decoding)
FlexRay™ trigger (hardware-based)	trigger events: ▶ Start of frame ▶ Identifier and data ▶ Symbol ▶ Wake-up frame ▶ Error condition: FSS error, BSS error, FES error, header CRC error AND/OR frame CRC error
	identifier setup: ▶ Indicator bits setup: payload preamble bit, null frame bit, sync frame bit and startup frame bit separately configurable (1, 0 or don't care) ▶ Condition: =, ≠, <, ≤, >,≥, in range, out of range ▶ Payload length condition: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Cycle count: =, ≠, <, ≤, >, ≥, in range, out of range ▶ Step parameter for selection of noncontiguous values within provided range
	data setup: ▶ Pattern: up to 8 byte ▶ Value: hex, decimal, octal, binary, ASCII ▶ Condition: =, ≠, <, ≤, >,≥, in range, out of range ▶ Offset within frame: 0 byte to 253 byte
FlexRay™ decode	decode display: ▶ Display type: decoded bus, logical signal, bus + logical signal, tabulated list ▶ Color coding: frame, frame header, identifier, payload length, header CRC, cycle count, data payload, frame CRC, error condition
	decode table fields: state, frame start, type, flags, payload length, frame ID, HCRC, FCRC, cycle count
	decoded data format: hex, decimal, octal, binary, ASCII, symbolic
FlexRay™ search	event: combination of start of frame, header+ data, symbol, wake-up, error condition
	events setup: same as trigger event setup

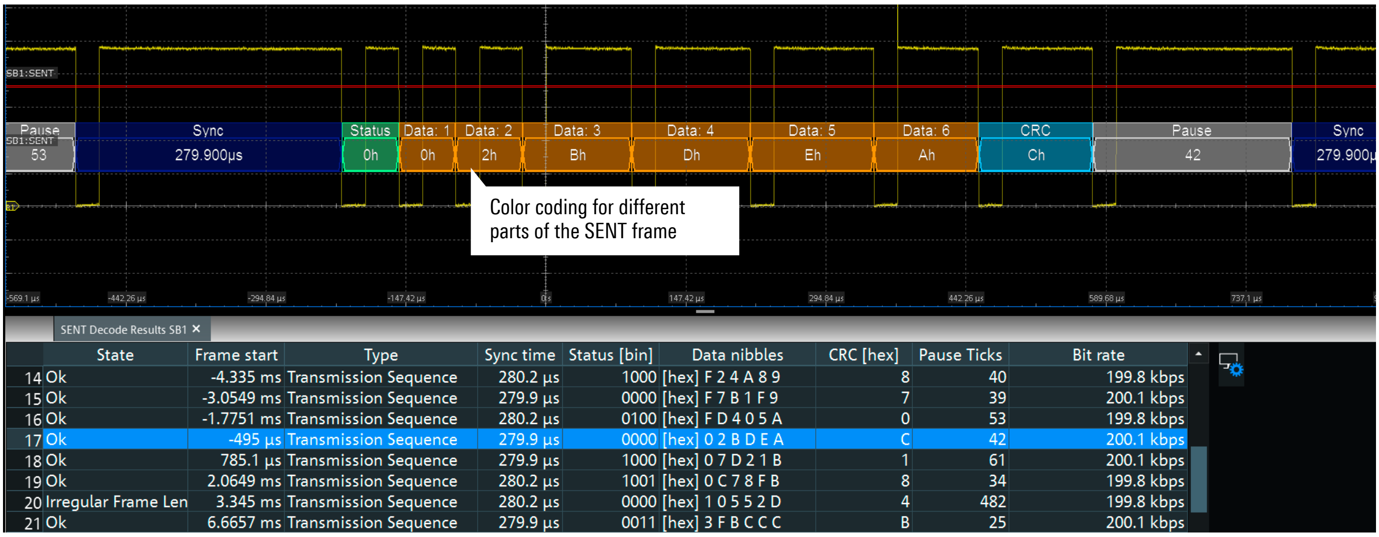
SENT PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K520 automotive protocol option supports SENT triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding for protocol fields is protocol-specific and simplifies interpretation of the visual display. The SENT decode data layer is highly customizable and may include:

- Binary signal representation of the SENT signal
- Any of the data formats: hex, octal, binary, ASCII, decimal (signed and unsigned)



Color coding for different parts of the SENT frame

	State	Frame start	Type	Sync time	Status [bin]	Data nibbles	CRC [hex]	Pause Ticks	Bit rate
14	Ok	-4.335 ms	Transmission Sequence	280.2 µs	1000	[hex] F 2 4 A 8 9	8	40	199.8 kbps
15	Ok	-3.0549 ms	Transmission Sequence	279.9 µs	0000	[hex] F 7 B 1 F 9	7	39	200.1 kbps
16	Ok	-1.7751 ms	Transmission Sequence	280.2 µs	0100	[hex] F D 4 0 5 A	0	53	199.8 kbps
17	Ok	-495 µs	Transmission Sequence	279.9 µs	0000	[hex] 0 2 B D E A	C	42	200.1 kbps
18	Ok	785.1 µs	Transmission Sequence	279.9 µs	1000	[hex] 0 7 D 2 1 B	1	61	200.1 kbps
19	Ok	2.0649 ms	Transmission Sequence	280.2 µs	1001	[hex] 0 C 7 8 F B	8	34	199.8 kbps
20	Irregular Frame Len	3.345 ms	Transmission Sequence	280.2 µs	0000	[hex] 1 0 5 5 2 D	4	482	199.8 kbps
21	Ok	6.6657 ms	Transmission Sequence	279.9 µs	0011	[hex] 3 F B C C C	B	25	200.1 kbps

SENT specifications	
SENT protocol configuration	serial protocol: none, short, enhanced
	clock period: 1 µs to 100 µs
	clock tolerance: 0% to 25%
	data nibbles: 1 to 6
	CRC version: Legacy (Feb 2008) and v2010/v2016 (latest)
	CRC calculation: SAE J2716 standard and TLE 4998X
	pause pulse: no, yes, for constant frame length
	frame length in clock ticks: 104 to 922 (applicable only when pause pulse = constant frame length)
SENT sources	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), additionally use logic channels D0 to D15
	reference and math waveforms (for decoding)
SENT trigger (hardware-based)	trigger events: ► Calibration or sync ► Transmission sequence ► Serial message ► Error condition: calibration pulse error, pulse period error, CRC error AND/OR irregular frame length error
	transmission sequence status nibble setup: ► Value: 0 to F ► Condition: =, ≠, <, ≤, >,≥, in range, out of range
	transmission sequence data nibbles setup: ► Value: 0 to F ► Condition: =, ≠, <, ≤, >,≥, in range, out of range
	serial message identifier setup ► Value: 00 to FF ► Condition: =, ≠, <, ≤, >, ≥, in range, out of range ► Identifier type: 4 bit and 8 bit (applicable only with enhanced serial protocol)
SENT decode	decode display: ► Display type: decoded bus, tabulated list ► Color coding: : transmission sequence: sync/calibration, status, data bits, CRC, pause pulse (optional), calibration pulse error, pulse period error, irregular frame length error and CRC error; serial message: identifier, data, CRC, form error, CRC error
	decode table fields: state, frame start, sync time, status, data nibbles, CRC, pause ticks, bit rate
	decoded data format: hex, decimal, octal, binary, ASCII
SENT search	event: calibration or sync, transmission sequence, serial message and error condition
	events setup: same as trigger event setup

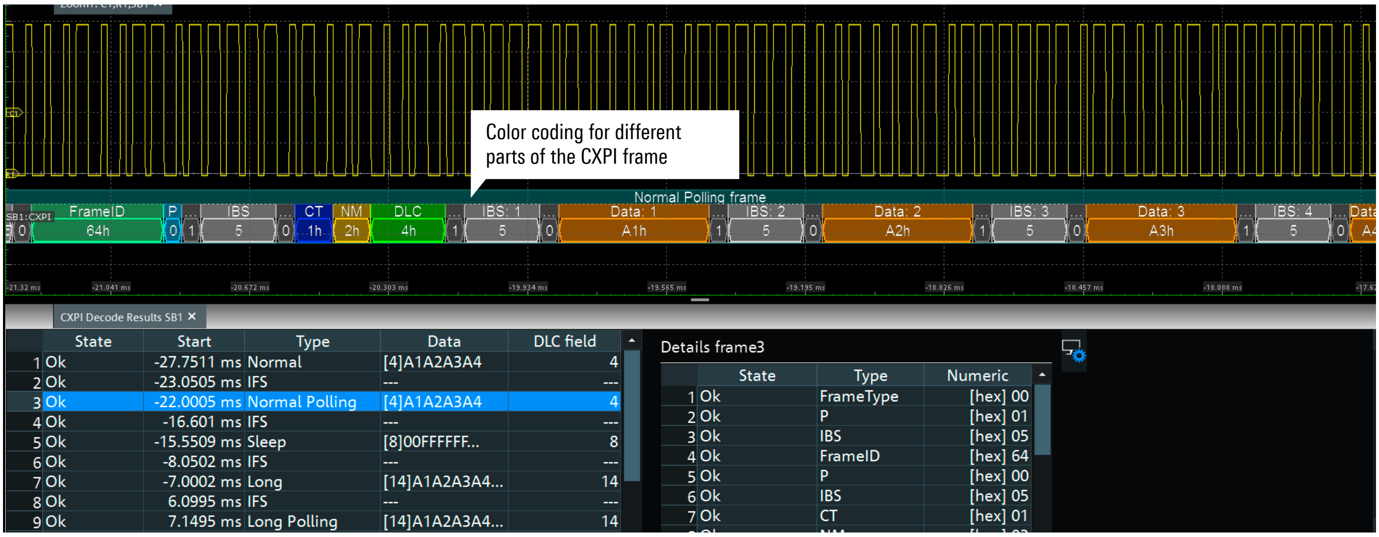
CXPI PROTOCOL TRIGGER AND DECODE

The R&S®RTO6-K520 automotive protocol option supports CXPI triggering and decoding.

Protocol-specific visual display of decoded packets

Color-coding for protocol fields is protocol-specific and simplifies interpretation of the visual display. The CXPI decode data layer is highly customizable and may include:

- Binary signal representation of the CAN signal
- Any of the data formats: hex, octal, binary, ASCII, decimal (signed and unsigned)



Color coding for different parts of the CXPI frame

	State	Start	Type	Data	DLC field
1	Ok	-27.7511 ms	Normal	[4]A1A2A3A4	4
2	Ok	-23.0505 ms	IFS	---	---
3	Ok	-22.0005 ms	Normal Polling	[4]A1A2A3A4	4
4	Ok	-16.601 ms	IFS	---	---
5	Ok	-15.5509 ms	Sleep	[8]00FFFFFF...	8
6	Ok	-8.0502 ms	IFS	---	---
7	Ok	-7.0002 ms	Long	[14]A1A2A3A4...	14
8	Ok	6.0995 ms	IFS	---	---
9	Ok	7.1495 ms	Long Polling	[14]A1A2A3A4...	14

Details frame3

	State	Type	Numeric
1	Ok	FrameType	[hex] 00
2	Ok	P	[hex] 01
3	Ok	IBS	[hex] 05
4	Ok	FrameID	[hex] 64
5	Ok	P	[hex] 00
6	Ok	IBS	[hex] 05
7	Ok	CT	[hex] 01

CXPI specifications	
CXPI protocol configuration	signal type: one channel
	bit rate: auto-detected/adjustable
	threshold levels: manual setting or auto threshold
	polarity: normal or inverted
	expected IBS length: 0 to 15
	expected IFS length: 16 to 100000
CXPI sources	analog channels: 1, 2, 3 or 4
	with R&S®RTO6-B1 mixed-signal option (MSO), logic channels D0 to D15 also used
	reference and math waveforms (for decoding)
CXPI trigger (hardware-based)	trigger events: ► Frame start ► Frame types with frame content ► Error condition
	frame types: normal, normal poll, sleep, long, long poll, PID, PTYPE, PTYPE+PID
	frame content (depending on frame type): frame ID, NW, CT, DLC, data pattern
	data setup: ► Pattern: up to 8 byte ► Condition: =, ≠, <, ≤, >,≥, in range, out of range ► Payload data index: =, <, ≤, >, ≥, in range
	error condition setup: IFS, IBS, CRC, length, parity, UART, DLC
CXPI decode	decode display: ► Display type: decoded bus, logical signal, bus + logical signal, tabulated list, details, decode layers ► Color coding: for different cell types
	decode table fields: state, start, type, data, DLC field
	decoded data format: hex, decimal, octal, binary
CXPI search	event: frame start, frame types with data, error types
	events setup: same as trigger event setup

ORDERING INFORMATION

Designation	Type	Order No.	
Serial trigger and decode software options			**Included protocols**
Bus analysis	R&S®RTO6-K500	1801.6864.02	
Low speed serial buses	R&S®RTO6-K510	1801.7019.02	I^2C, SPI, RS-232/UART, I^2S/LJ/RJ/TDM, Manchester/NRZ
Automotive protocols	R&S®RTO6-K520	1801.7025.02	CAN/LIN incl. CAN-dbc file import/CAN-FD, FlexRay™ incl. Fibex file import/SENT/CXPI
Aerospace protocols	R&S®RTO6-K530	1801.7031.02	MIL-STD-1553, ARINC 429, SpaceWire
Ethernet protocols	R&S®RTO6-K540	1801.7048.02	10BASE-T, 100BASE-TX, MDIO
MIPI RFFE	R&S®RTO6-K550	1801.7054.02	MIPI RFFE
Automotive Ethernet	R&S®RTO6-K560	1801.7060.02	IEEE 100BASE-T1, IEEE 1000BASE-T1
USB protocols	R&S®RTO6-K570	1801.7077.02	USB 1.0/1.1, USB 2.0/HSIC/USB 3.1 Gen 1, USB power delivery (USB-PD)/USB SSIC
MIPI M-PHY, D-PHY	R&S®RTO6-K580	1801.7083.02	MIPI D-PHY/M-PHY/UniPro/Decoding for DSI and CSI-2
PCI Express	R&S®RTO6-K590	1801.7090.02	8b10b (up to 6.25 Gbit/s)/PCI Express Revision 1.x/2.x
Trigger and decode bundle	R&S®RTO6-TDBDL	1801.7725.02	R&S®RTO6-K500/-K510/-K520/-K530/-K540/-K550/-K560/-K570/-K580/-K590