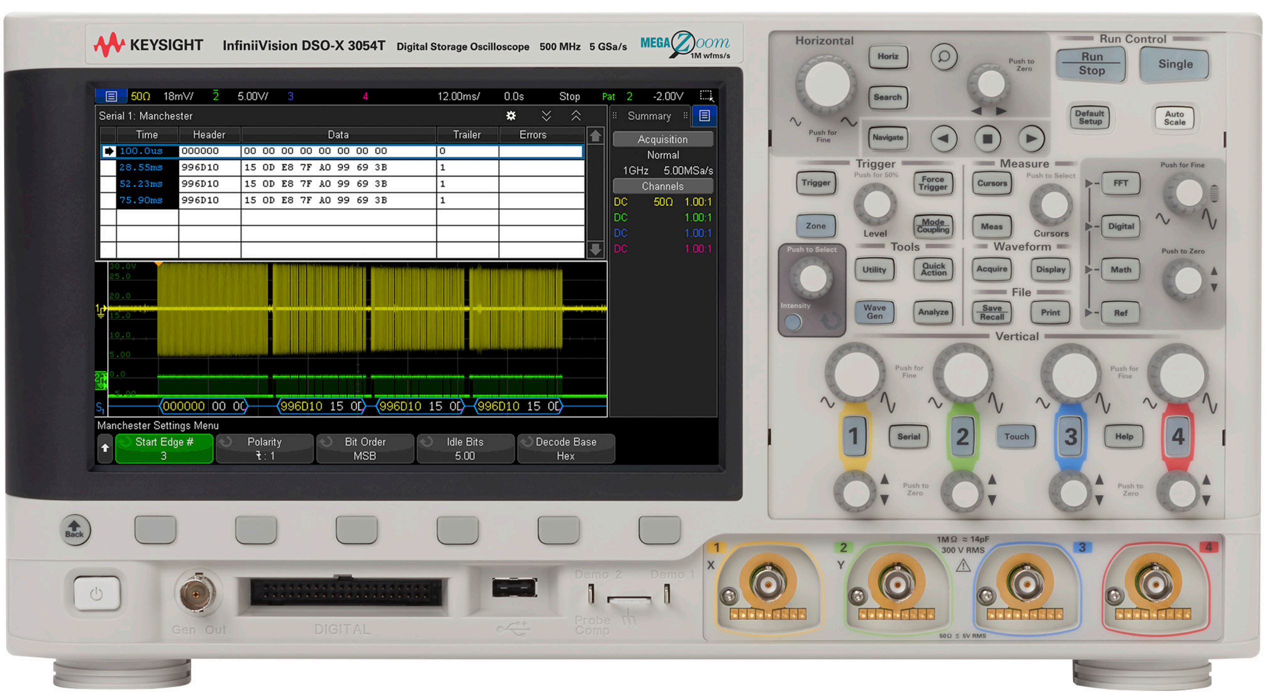
Keysight Technologies
Decoding Automotive Key Fob Communication based on Manchester-encoded ASK Modulation

Using Keysight InfiniiVision X-Series Oscilloscopes

Application Note



KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Introduction

Decoding amplitude-shift keying (ASK) key fob communication based on Manchester encoding is sometimes necessary during the turn-on and debug phase of key fob development. Decoding key fob RF-bursted packets requires demodulation prior to digital decoding. Since protocol decoding in Keysight's InfiniiVision X-Series oscilloscopes is based on hardware technology (real-time decoding), demodulation must be performed in hardware. InfiniiVision oscilloscopes can digitally demodulate key fob RF signals within the scope itself —in a roundabout way — using a special trigger mode and a trigger output signal.

This application note provides an overview of Manchester encoding, along with instructions on how to probe and capture key fob signals; hardware demodulate each burst/packet; and, set up the scope to decode each transmitted message at data rates ranging from 2 kbps up to 5 Mbps using the User-definable Manchester/NRZ Trigger and Decode option (DSOXT3NRZ/ DSOX4NRZ) on Keysight's InfiniiVision 3000T and 4000A X-Series oscilloscopes.

Manchester Encoding Overview

Although some key fobs are based on frequency shift keying (FSK), most key fob serial communications are based on amplitude shift keying (ASK) with Manchester encoding. With Manchester encoding, bit transitions near the mid-point of bit periods determine the polarity of the transmitted and/or received bit. A rising transition/edge in the middle of a bit period typically corresponds to a logic “0” while a falling transition during the middle of a bit period corresponds to logic “1” as shown in the demodulated waveform timing diagram of Figure 1. Transitions at or near bit boundaries are ignored.

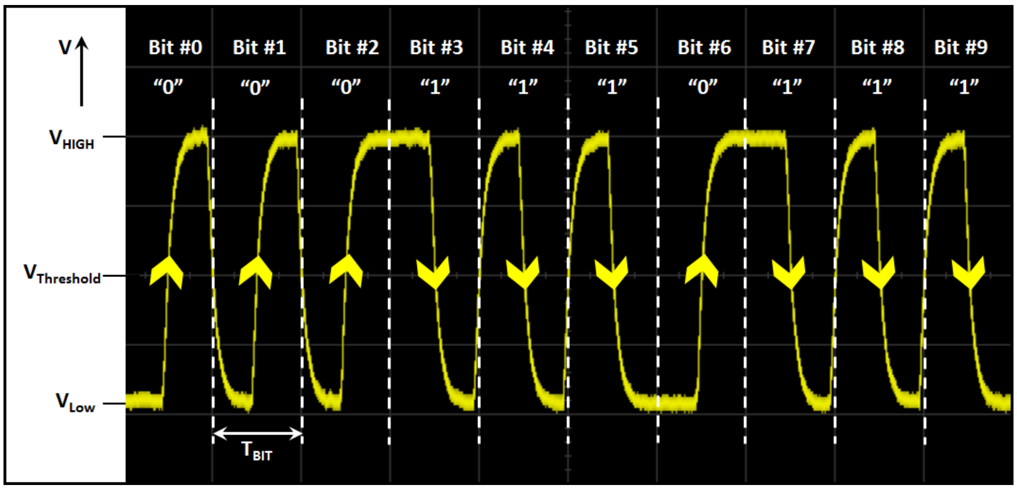


Figure 1. Bit polarities based on Manchester encoding.

Probing Key Fob Signals and Establishing Initial Setup Conditions

One method of “sniffing” key fob signals out of the air is to connect a loop antenna to a BNC cable that is then connected to an input channel of the scope as shown in Figure 2. For the key fob measurement example that we will show in this application note, we have connected this loop antenna to the scope’s channel-1 input with a 50-Ω termination. If you don’t have a loop antenna, you can create one by connecting the ground lead of a standard 10:1 passive probe to the probe tip. Note that since most key fobs are based on 315 MHz or 433.92 MHz RF carrier frequencies, an oscilloscope bandwidth of 1 GHz or higher is recommended.

Figure 2. Sniffing out key fob RF signals.

Since we will be working with single-shot occurrences of RF-bursted signals, establishing initial setup conditions (vertical scaling, horizontal scaling, and triggering) will be a bit of an iterative, trial and error process. Using a scope’s auto scaling feature is not an option since Auto Scale requires the input signal be repetitive.

You should begin with the scope in a **Default Setup** mode then select the horizontal menu to change **Time Ref** to **Left**. This will position the trigger reference point one division to the right of the left side of the display. The default trigger location on most of today’s digital oscilloscopes is center-screen, which means the scope captures half of the waveforms before the trigger event and the other half of the waveforms after the trigger event. Though, since key fob signals come in single-shot bursts, we will be setting up the scope to trigger on the first RF burst and then capture waveforms after the trigger event. Nothing occurs before the trigger (key fob button push).

Probing Key Fob Signals and Establishing Initial Setup Conditions (Continued)

With the scope **Auto** triggering on edges, begin pressing a button on your key fob while observing the scope's display. Initially you may see nothing. This is because the scope's **V/div** setting will probably be set too high. Begin reducing the **V/div** setting until you observe captured waveforms with approximately 4 to 5 divisions of peak-to-peak deflection as shown in Figure 3. With the scope auto triggering, these waveforms will vanish between presses of the key fob button which is okay for now. It is suggested that you also adjust the offset so the waveform is positioned closer to the top of the display. The lower portion of the display will be needed for a later waveform.

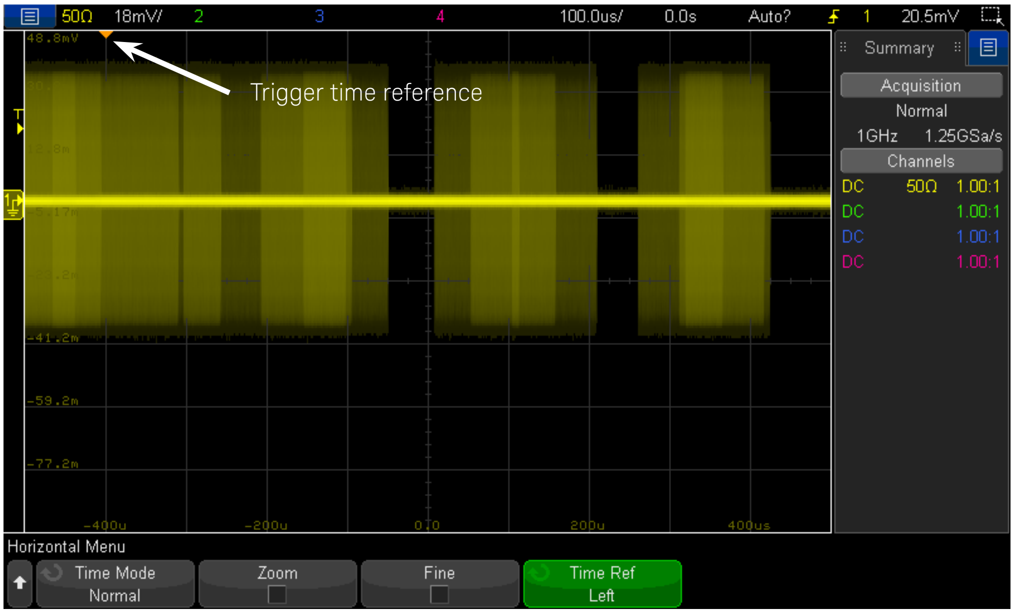


Figure 3. Establishing proper vertical scaling.

An alternative method of setting up vertical scaling is to use the scope's untriggered **Roll** mode, which can be accessed in the **Horizontal** menu. After establishing optimum scaling while using **Roll** mode, return to the **Normal** timebase mode in order to set up triggering.

Next, set the trigger level in the upper half of modulation, press the **Single** acquisition front panel key on the scope, then press the key fob button again. The scope should now trigger on the first modulated pulse each time you press the key fob button as shown in Figure 4. This time the waveform should remain on screen between presses of the key fob button since the scope's single acquisition mode turns off auto triggering. The number of modulated pulses observed will depend on the baud rate of the key fob you are testing.

Probing Key Fob Signals and Establishing Initial Setup Conditions (Continued)

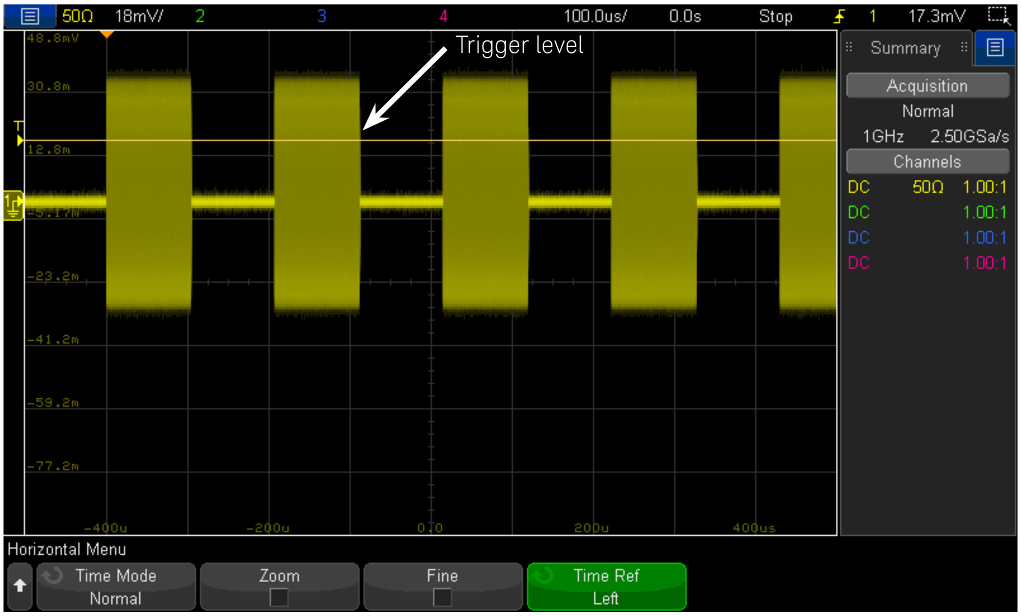


Figure 4. Synchronizing the scope's acquisition on the first modulated pulse.

At this point we need to change the timebase setting (sec/div) in order to capture a series of modulated bursts/packets. Again, this will be an iterative process of changing the timebase setting (typically to a longer time-span), pressing **Single** to arm the scope for a single-shot acquisition, and then pushing the key fob button until we find optimum timebase scaling. Figure 5 shows the capture and display of four bursts/packets of modulated pulses at **12 ms/div**. Note that the best timebase setting for your key fob measurement application will depend on your key fob's baud rate, length of packets, and number of consecutively transmitted packets with each button push.

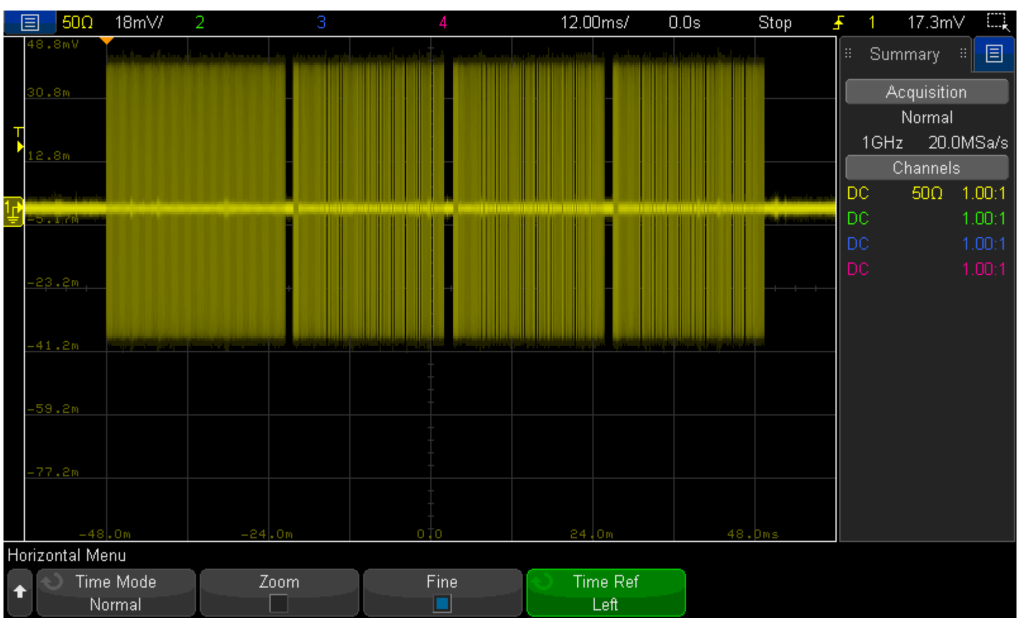


Figure 5. Capturing multiple key fob bursts.

Hardware Digital Demodulation

Before this signal can be decoded by the scope, it must be demodulated into a series of digital pulses. Demodulating this signal with the scope's hardware (not available on 6000 X-Series) is achieved by setting up a special trigger condition (pattern timeout) and then outputting the trigger signal to the scope's output trigger BNC on the back panel of the scope. We will then feed this time-correlated digital signal back into another channel of the scope for decoding.

To setup this special trigger mode, select the **Trigger** menu, then select to trigger on a **Pattern**. In the **Pattern** trigger menu, change the **Qualifier** to **Timeout**. Next, set up a 1-bit pattern telling the scope to trigger when analog channel-1 is low (0) after a minimum timeout. A good rule-of-thumb is to set the timeout value to approximately 1% of the data period. Since this key fob operates at 4.83 kbps, we have set the timeout value to "**> 2.00 µs**". This will help insure that random noise on the falling edges of modulation doesn't induce false triggers.

Next, press **Single** on the scope and then push a key fob button to insure that the scope triggers. The scope should trigger 2 µs after the first modulated pulse goes low as shown in Figure 6. Although it may appear as if this trigger condition didn't do anything different than the previous default edge trigger condition since the scope still triggers very close to the beginning of the first burst, the pattern-timeout trigger condition creates an inverted and digitally demodulated signal inside the scope that we will use next.

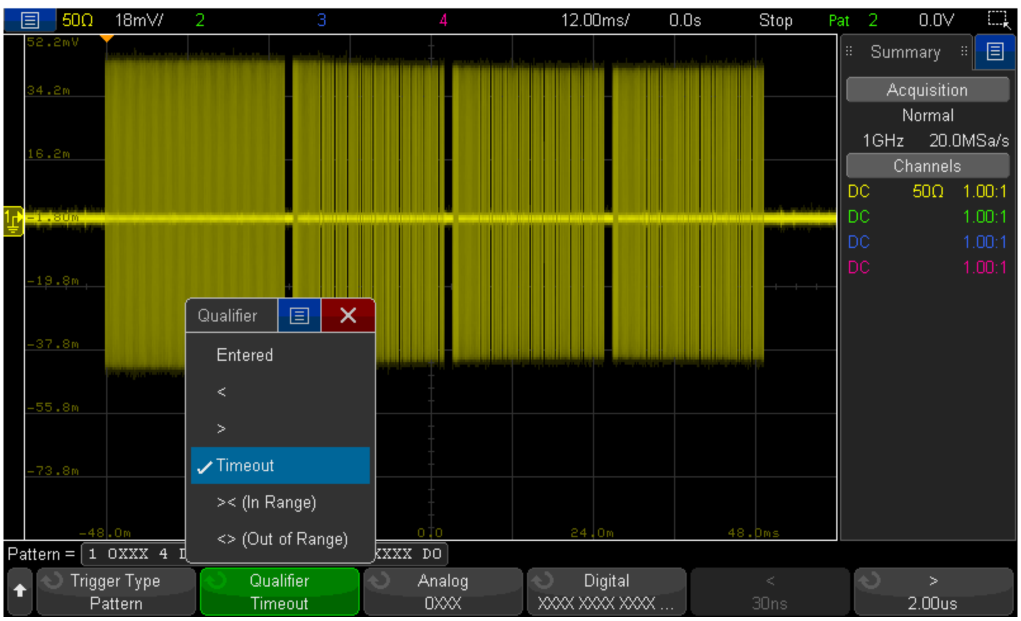


Figure 6. Triggering on a Pattern Timeout condition.

To set up the scope to output the trigger signal to the trigger output BNC on the rear panel of the scope, select the **Utility** menu, then **Options**, then **Rear Panel**, and then select **Trigger Source**. Now connect a BNC cable from the trigger output BNC (back panel) to the channel-2 input of the scope.

Next, turn on channel-2, select **Invert** (to invert the inverted demodulated signal), and then set channel-2 vertical scaling to **5 V/div** with approximately **+10 V** of offset. This should position the demodulated waveform below the channel-1 RF modulated waveform.

Hardware Digital Demodulation (Continued)

Now press **Single** on the scope and then press the key fob button. You should observe a digitally demodulated representation of the key fob RF burst as shown in Figure 7. This is the signal that we will decode using the scope's Manchester decoder. If you look closely at the captured waveforms, you should see that the 1st burst appears slightly different from the 2nd, 3rd, and 4th burst for this particular key fob being tested and documented.

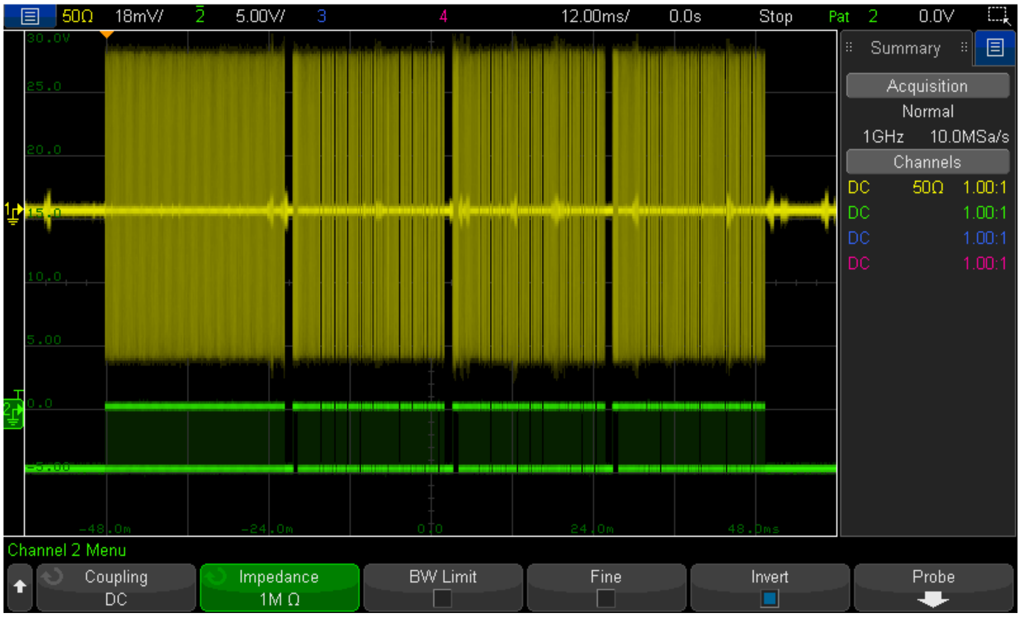


Figure 7. Displaying the digitally demodulated waveform on Ch-2.

Decoding the Digitally Demodulated Waveform

To decode the digitally demodulated signal that is now being captured by channel-2 of the scope every time the key fob button is pressed, first select the **Serial** menu and then select the **Manchester** decode mode. We will now progress from left to right to establish a variety of user-definable set up parameters in the **Signals, Bus Config,** and **Settings** sub-menus to define this Manchester-encoded and demodulated signal. Note that the specific parameters of the key fobs that you might be testing could be very different depending on the key fob and the protocol being used. The parameters that we will define in this document are specific to a key fob for a late model European vehicle.

In the **Signals** sub-menu, define the following parameters as shown in Figure 8.

- Source = 2 (channel-2)
- Threshold = ~-2.0 V (near the 50% level of the channel-2 waveform)
- Baud = 4.83 kb/s
- Tolerance = 20%

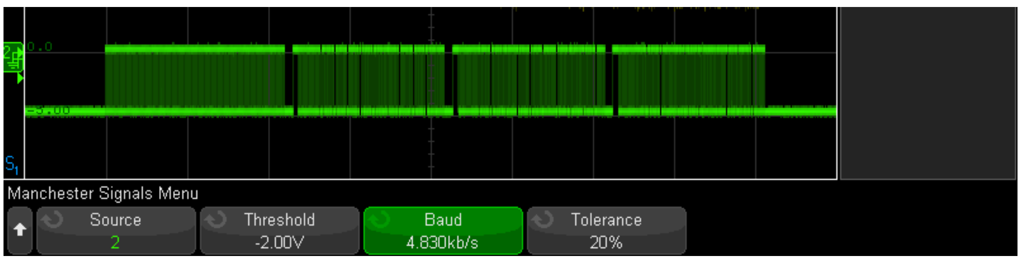


Figure 8. Establishing Manchester Signal parameters.

Press the **Back** key to return the main **Manchester** decode menu, then select the **Bus Config** sub-menu. Define the following parameters in the **Bus Config** sub-menu as shown in Figure 9:

- Sync Size = 15
- Header Size = 24
- # of Words = 8
- Data Word Size = 8
- Trailer Size = 1 (one parity bit)

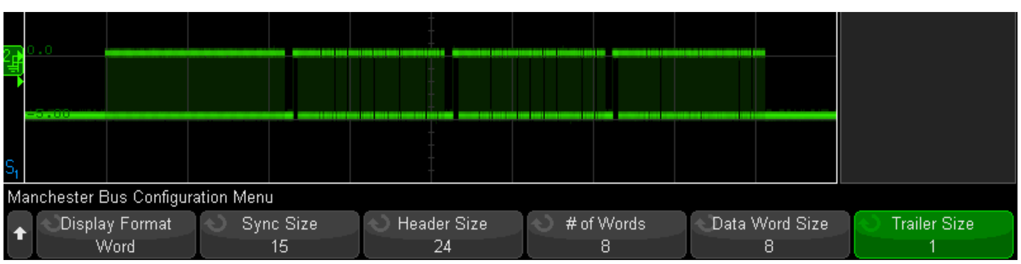


Figure 9. Establishing Manchester Bus Configuration parameters.

Decoding the Digitally Demodulated Waveform (Continued)

Note that if you don't know the number of bits and size of each of these fields for your key fobs, you can begin by setting Header and Trailer Size to 0 and then change the # of Words to **< auto >**. You can also select the **Bit Display Format** (binary), which will simply decode all bits as a stream of binary "1's" and "0's". Doing this might be useful to get started.

Now press the **Back** key to return the main **Manchester** decode menu, then select the **Settings** sub-menu. Define the following parameters in the **Settings** sub-menu as shown in Figure 10:

- Start Edge # = 3
- Polarity = Falling: 1 (falling edge = 1, rising edge =0)
- Bit Order = MSB (most significant bit transmitted first)
- Idle Bits = 5
- Decode Base = Hex

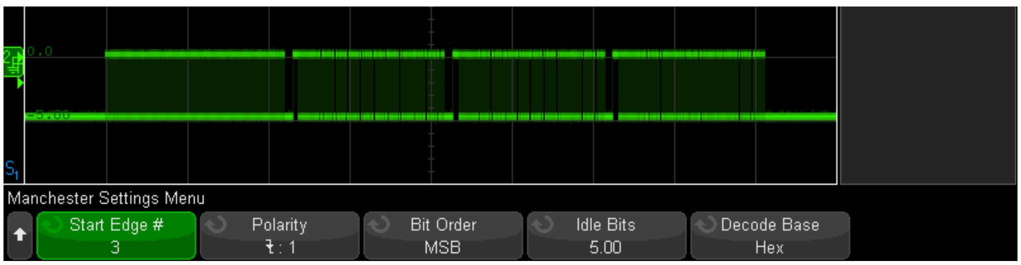


Figure 10. Establishing Manchester decode Settings parameters.

Now press **Single** on the scope and then press a key fob button. If Manchester decoding has been set up properly, we should observe a time-correlated decode trace below the waveforms as shown in Figure 11.

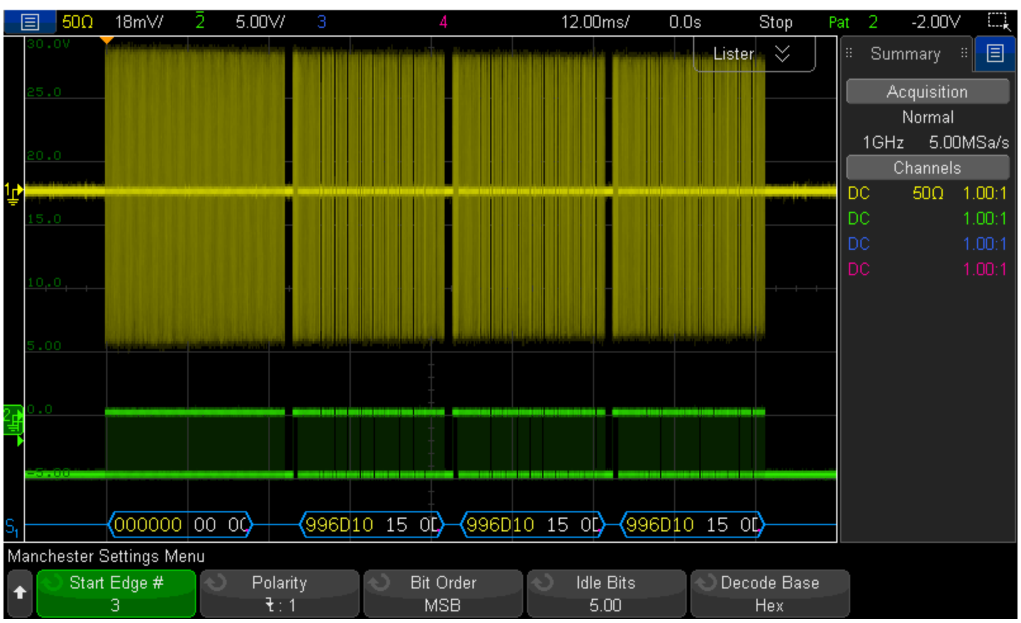


Figure 11. Decoding four key fob packets.

Decoding the Digitally Demodulated Waveform (Continued)

For this particular key fob, the first transmitted burst is a wake-up sync packet. At the front-end of the 2nd, 3rd, and 4th burst is a preamble/sync field before the actual Manchester-encoded message is transmitted. Determining the 1st bit to decode (Start Edge #) is one of the most important set up parameters and is sometimes the most difficult to determine. There are often non-Manchester timed bits that can occur between the beginning of the burst and the beginning of the message.

Figure 12 shows a zoomed view of the beginning of the 2nd burst with the Manchester decode display set to “Bit” format in order to decode individual “1’s” and “0’s”. For this key fob, the number of idle bits must be set higher than the length of the first demodulated pulse, but less than the time between bursts. The preamble/sync field begins on the 3rd detected edge (counting rising and falling edges), and then the header field begins after 15 sync bits. Alternatively, we could have skipped the preamble/sync bits by setting the sync field size to “0” and then set the start edge number to “32”.

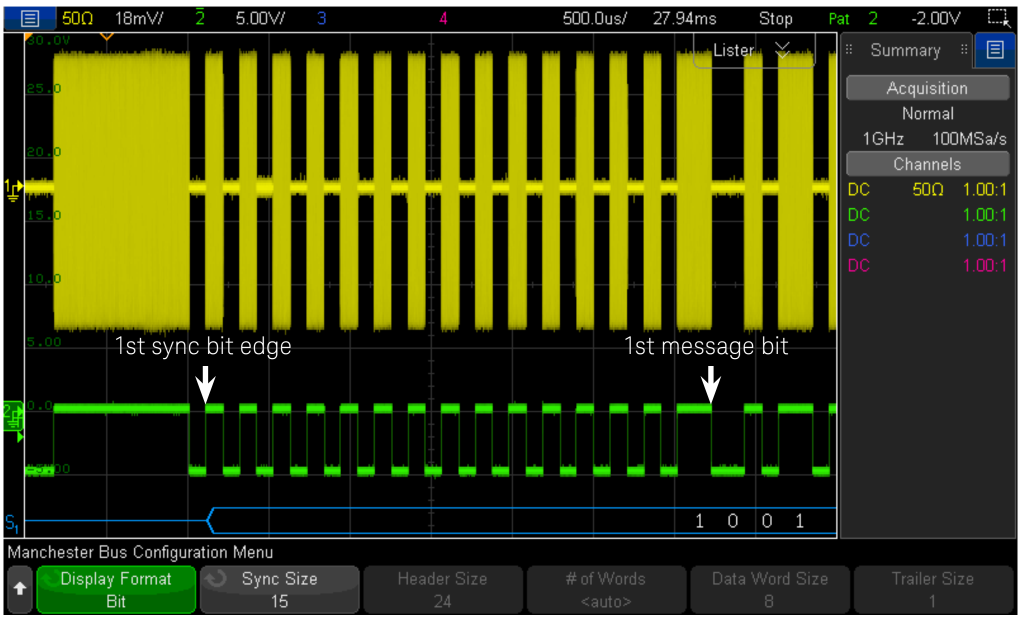


Figure 12. Zooming in to determine which edge begins the message.

Decoding the Digitally Demodulated Waveform (Continued)

Viewing all decoded bits within the time-correlated decode trace below the waveform is not always possible due to the density of bits relative to the scope's timebase setting. But if you turn on the protocol "Lister" display as shown in Figure 13, you'll be able to see all decoded bits. We can now see that the key fob first transmits a wake-up sync burst consisting of all zero's followed by three bursts with the same exact code. However, the next time the key fob button is pressed, the code changes (rolling/hopping codes).

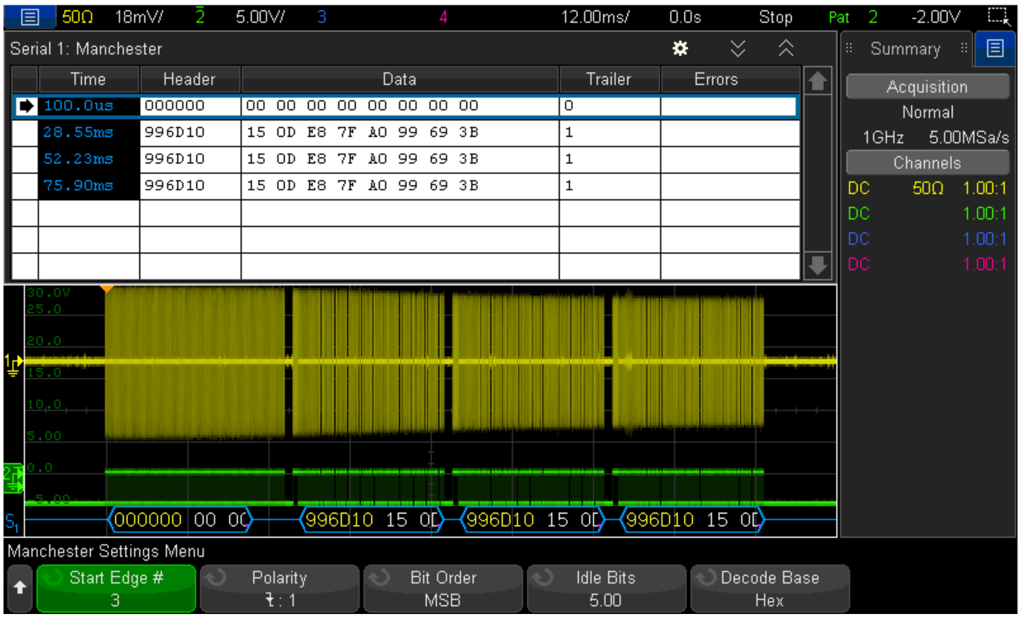


Figure 13. Key fob transmits a synchronization burst followed by three bursts with the same encoded message.

Summary

Using Keysight's User-definable Manchester/NRZ Serial Trigger and Decode option on an InfiniiVision 3000T or 4000A X-Series oscilloscopes can help you test and debug automotive key fobs based on Manchester-encoding. Keysight also offers other licensed options that are commonly used for automotive measurement applications including CAN, CAN FD, LIN, FlexRay, SENT, I^2C, SPI, etc. To learn more about testing automotive serial buses, refer to documents in **Related Literature** section at the end of this application note. To view short videos focused on automotive measurement applications, go to **www.keysight.com/find/scopes-auto**.

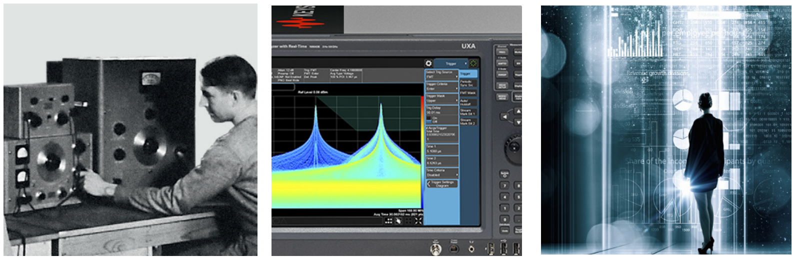
Related Literature

Publication title	Publication number
InfiniiVision 3000T X-Series Oscilloscopes - Data Sheet	5992-0140EN
InfiniiVision 4000 X-Series Oscilloscopes - Data Sheet	5991-1103EN
Serial Bus Options for InfiniiVision X-Series Oscilloscopes - Data Sheet	5990-6677EN
Oscilloscope Measurement Tools to Help Debug Automotive Serial Buses Faster - Application Note	5991-0512EN
Using Oscilloscope Segmented Memory for Serial Bus Applications - Application Note	5990-5817EN

To download these documents directly, insert the publication number in the URL:
http://literature.cdn.keysight.com/litweb/pdf/XXXX-XXXXEN.pdf

Evolving

Our unique combination of hardware, software, support, and people can help you reach your next breakthrough. We are unlocking the future of technology.



From Hewlett-Packard to Agilent to Keysight

myKeysight

myKeysight
www.keysight.com/find/mykeysight
A personalized view into the information most relevant to you.

KEYSIGHT SERVICES
Accelerate Technology Adoption.
Lower costs.

Keysight Services
www.keysight.com/find/service
Our deep offering in design, test, and measurement services deploys an industry-leading array of people, processes, and tools. The result? We help you implement new technologies and engineer improved processes that lower costs.

Three-Year Warranty
www.keysight.com/find/ThreeYearWarranty
Keysight's committed to superior product quality and lower total cost of ownership. Keysight is the only test and measurement company with three-year warranty standard on all instruments, worldwide. And, we provide a one-year warranty on many accessories, calibration devices, systems and custom products.

Keysight Assurance Plans
www.keysight.com/find/AssurancePlans
Up to ten years of protection and no budgetary surprises to ensure your instruments are operating to specification, so you can rely on accurate measurements.

Keysight Channel Partners
www.keysight.com/find/channelpartners
Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

www.keysight.com/find/DSOXT3NRZ
www.keysight.com/find/DSOX4NRZ
www.keysight.com/find/scopes-auto

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas	
Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444
Asia Pacific	
Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 11 2626
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100
Europe & Middle East	
Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-2-23-17)

DEKRA Certified
ISO9001 Quality Management System

www.keysight.com/go/quality
Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2015
Quality Management System

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights

Published in USA, April 3, 2017
5992-2260EN
www.keysight.com