Keysight Technologies

Decoding NFC-F Communication Based on Manchester-encoded ASK Modulation

Using Keysight InfiniiVision X-Series Oscilloscopes

Application Note

![KEYSIGHT TECHNOLOGIES — Unlocking Measurement Insights]

Introduction

Decoding NFC-F communication and verifying proper exchange of data between poller and listener devices is often required during the turn-on and debug phase of development. NFC-F is based on amplitude-shift keying (ASK) modulation with Manchester encoding. Keysight's InfiniiVision 3000T X- and 4000 X-Series oscilloscopes can automatically demodulate and then decode NFC-F (212 kbps) and NFC-F (424 kbps) communication between polling and listening devices if licensed with the user-definable Manchester/NRZ trigger and decode option (DSOXT3NRZ/DSOX4NRZ).

This application note begins with an overview of Manchester encoding and explains how to capture NFC signals using an RF "pick-up" antenna. This document then provides step-by-step instructions on how to setup the oscilloscope to properly decode and trigger on NFC-F poller and listener communication for two specific cases. CASE 1 documents how to decode and trigger on NFC-F (212 kbps) signals based on "obverse" polarity encoding with both poller and listener modulation "within" the non-modulated carrier amplitude. CASE 2 documents how to decode and trigger on NFC-F (424 kbps) signals based on "reverse" polarity encoding with poller modulation "within" the non-modulated carrier amplitude and listener modulation "above" the non-modulated carrier amplitude.

Manchester Encoding Overview

NFC-F (212 kbps) and NFC-F (424 kbps) are based on amplitude shift keying (ASK) with Manchester encoding. With Manchester encoding, bit transitions near the mid-point of bit durations (bd) determine the polarity of the transmitted and/or received bit. For NFC obverse (normal) polarity encoding, rising transitions of modulation in the middle of each bit duration correspond to logic "0's" while falling transitions correspond to logic "1's", as shown in the modulated waveform of Figure 1. Transitions at or near bit boundaries are ignored. For NFC reverse polarity encoding (not shown), rising transitions translate into logic "1's" and falling transitions translate into logic "0's".
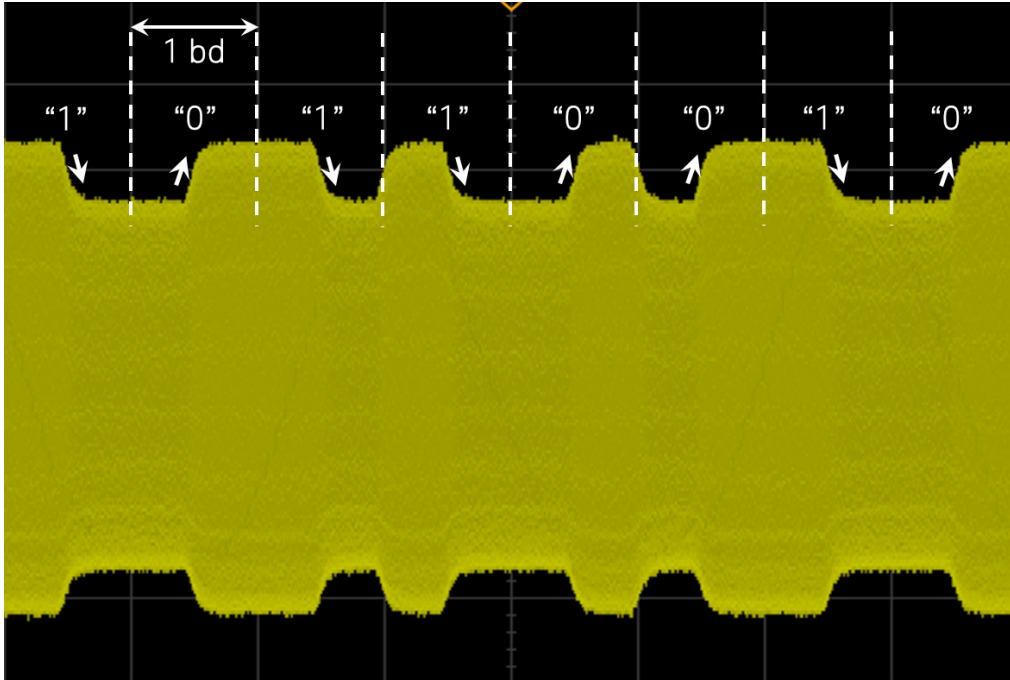

Figure 1. NFC-F "obverse" bit polarities based on Manchester encoding.

Sniffing Out NFC Communication

One method of capturing and displaying NFC-F poller and listener communication on the oscilloscope is to use an NFC reference antenna, such as Keysight's N2116A programmable 3-in-1 NFC antenna shown in Figure 2 along with appropriate AWG stimulus and automated test software. But if you want to capture communication between two non-reference devices, the easiest way to do this is with a passive NFC calibration coil/antenna placed in the vicinity of paired NFC devices (poller and listener) as shown in Figure 3. In this example, an NFC-F tag (listener) has been placed onto the calibration coil and then a mobile phone (poller) has been placed approximately 5 mm above the tag. The output of the calibration coil is connected to one of the oscilloscope's inputs and terminated into 50 Ω. Although this technique of sniffing the RF signal out of the air will not provide calibrated reference power levels, it will allow you to validate modulated pulse wave shapes and timing between poller request and listener response communications as well as the ability to monitor specific decoded communication between the two devices, which is the focus of this application note.

If an NFC calibration coil is not available, you can create one by simply using a standard 10:1 passive probe with the ground lead connected to the probe tip.
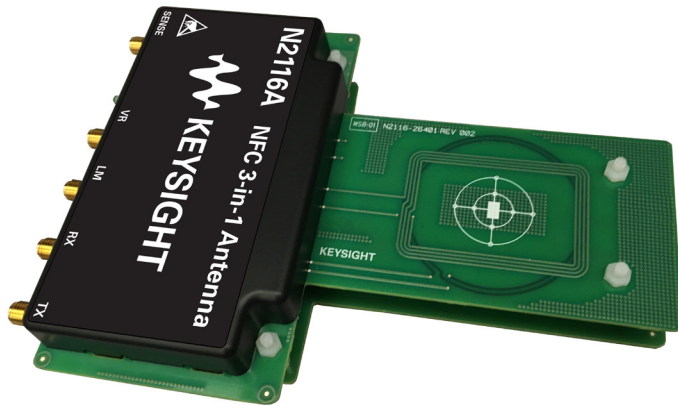

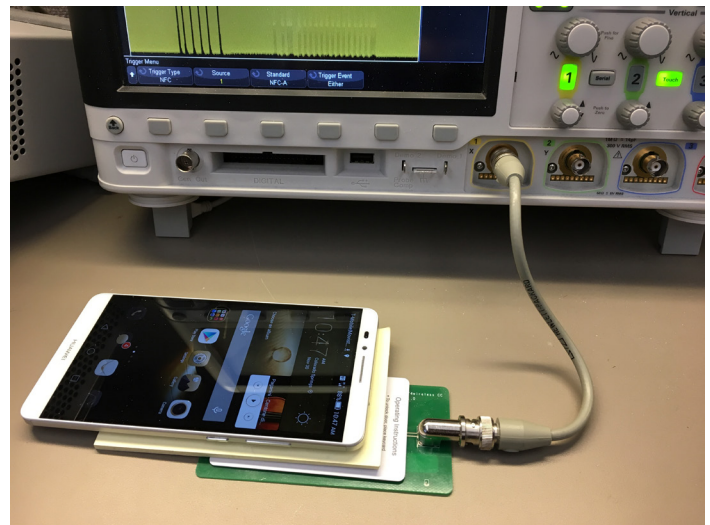Figure 2. Keysight's N2116A programmable 3-in-1 NFC reference antenna.

Figure 3. Sniffing out NFC communication between a mobile phone (poller) and a tag (listener) using an NFC calibration coil.

CASE 1: Obverse Polarity Encoding with Similar Poller and Listener Logic Thresholds

We will begin with the simplest example where both poller (request) and listener (response) communications are based on Manchester encoding with "obverse" polarity. Obverse simply means "normal" polarity. In addition, both poller and listener modulation have similar logic threshold levels for this particular measurement example. In other words, poller modulation and listener modulation are both "within" the amplitude of the non-modulated carrier. Listener modulation can often be above the non-modulated carrier amplitude. We will address the case of dissimilar thresholds when we cover CASE 2.

After the two devices have been paired and are communicating with each other repetitively, you should begin setting up the oscilloscope with the scope's trigger condition based on random edge transitions while using the **Auto** trigger mode (not **Normal**). Next, scale the repetitively captured waveform for approximately seven divisions peak-to-peak deflection. Assuming your InfiniiVision oscilloscope is also licensed with the NFC trigger option, select to trigger on **SENSF_REQ** for NFC-F (212 kbps) or NFC-F (424 kbps) and then set the trigger level near the mid-point of poller modulation, which will be near the top of the waveform. Now change the trigger mode from **Auto** to **Normal**, and adjust the timebase so you can observe modulation as shown in Figure 4. Here we can see the initial SENSF_REQ modulation from the poller, followed by SENSF_RES modulation from the listener, followed by ATRF_REQ modulation from the poller. This is what we will set up the InfiniiVision oscilloscope to decode.
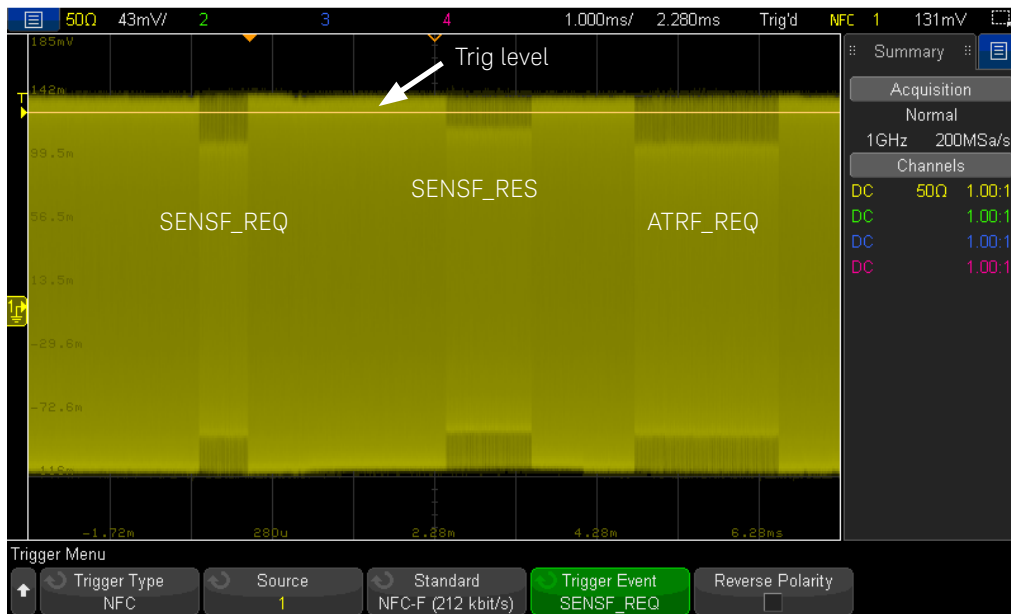

Figure 4. Establishing initial vertical and horizontal scaling and triggering.

CASE 1: Obverse Polarity Encoding with Similar Poller and Listener Logic Thresholds (Continued)

Before we can set up Manchester decoding on the oscilloscope, we must change the trigger condition because explicit NFC triggering can't be used with Manchester decoding. But that's okay. We will ultimately establish a more specific NFC trigger condition using Manchester triggering once we get Manchester decoding set up and working. For NFC-F (212 kbps), select the pulse-width trigger type based on a low pulse condition for > 1.5 µs but < 3.0 µs as shown in Figure 5. But if the NFC-F signal you are capturing is operating at 424 kbps, set the time-qualification to > 0.5 µs but < 1.5 µs. The trigger level should be set near the mid-point of modulation.

This trigger condition will be used temporarily and will provide a relatively stable trigger condition while setting up Manchester decoding.
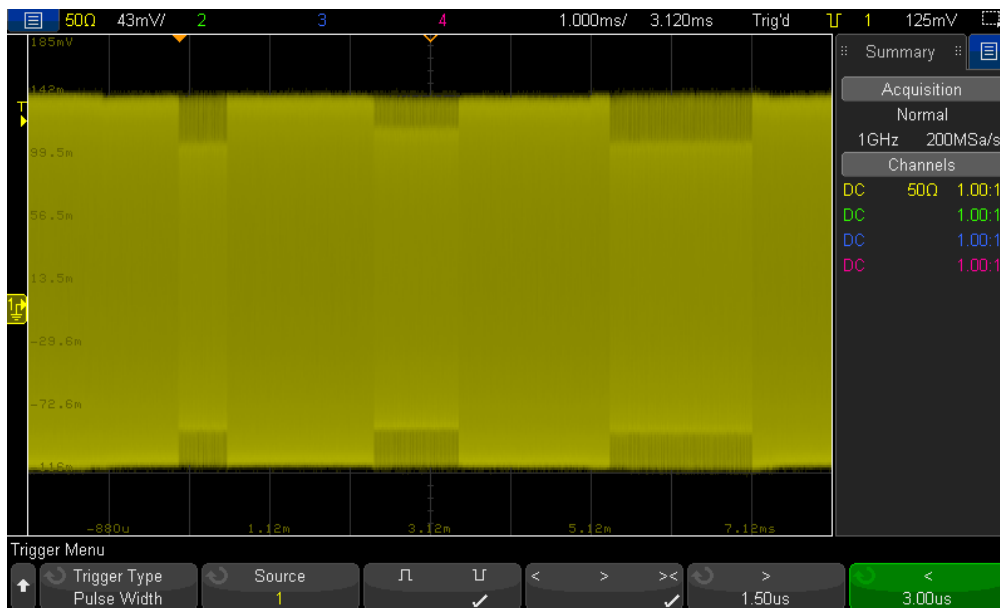

Figure 5. Setting up a temporary pulse-width trigger condition.

To set up Manchester decoding, first select the **Serial (S1)** decode menu and then select the **Manchester** mode as shown in Figure 6.
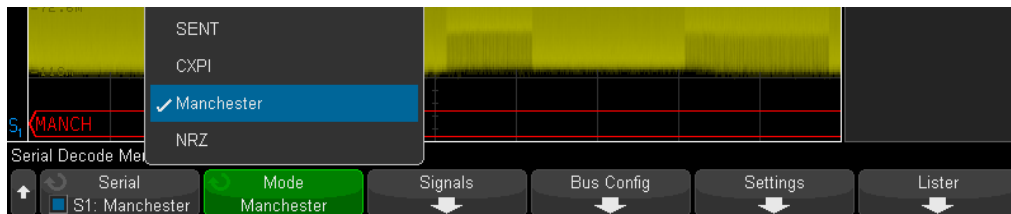

Figure 6. The Manchester decode menu.

CASE 1: Obverse Polarity Encoding with Similar Poller and Listener Logic Thresholds (Continued)

The InfiniiVision oscilloscope's user-definable Manchester decoder was created to address a broad range of serial bus applications — not just NFC-F. There are many parameters that must be established in the oscilloscope's Manchester decode setup menus to define the NFC-F protocol. These user-definable parameters are set in the **Signals, Bus Config,** and **Settings** sub-menus shown in Figure 6. But before proceeding with setting up Manchester decoding, it's best to have a basic understanding of the NFC-F frame format, which is shown in Figure 7.

SoS (sync)				SoF		SoD	Data				EoD	
								Payload				
S1	S2	....	S47	S48	B2	4D	LEN	Byte 1	Byte 2	.....	Byte n	CRC_F1	CRC_F2

48-bit Sync Field   2-byte SoF (always B24Dh)   1-byte Length Code (Payload +1)   n-byte Payload   2-byte CRC
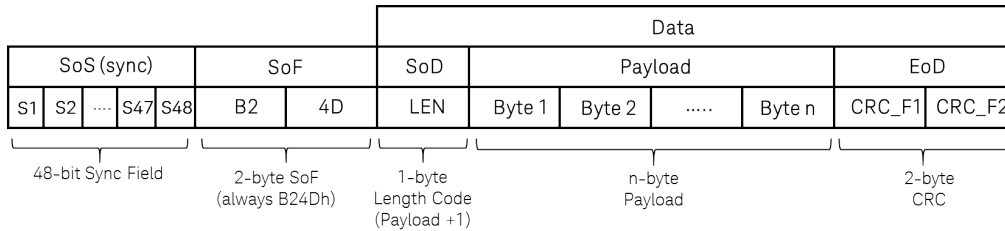
Figure 7. NFC-F frame format, including the 48-bit SoS (start-of-sequence) synchronization field.

Let's now define the SoS (start-of-sequence), SoF (start-of-frame), and data fields in the oscilloscope's Manchester decoder setup sub-menus to effectively duplicate the NFC-F frame format shown in Figure 7. In the **Signals** sub-menu, define the following parameters as shown in Figure 8.

– Source = 1 (if using channel-1 as the input source for NFC-F)
– Threshold = near mid-point of the high side of modulation
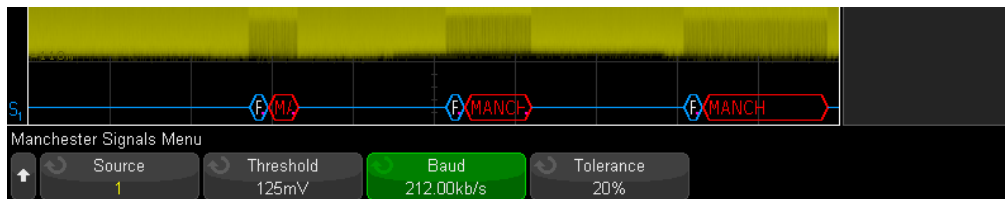– Baud = 212 kbps or 424 kbps
– Tolerance = 20%

Figure 8. Establishing Manchester signal parameters.

CASE 1: Obverse Polarity Encoding with Similar Poller and Listener Logic Thresholds (Continued)

If you are unsure of the baud rate of the NFC-F signal you are testing, you can zoom-in to view the sync bits near the beginning of either poller or listener modulation and then measure the period of one cycle using the oscilloscope's timing cursors to determine the appropriate baud rate setting as shown in Figure 9. Note that using the oscilloscope's Peak-detect acquisition mode may be helpful.
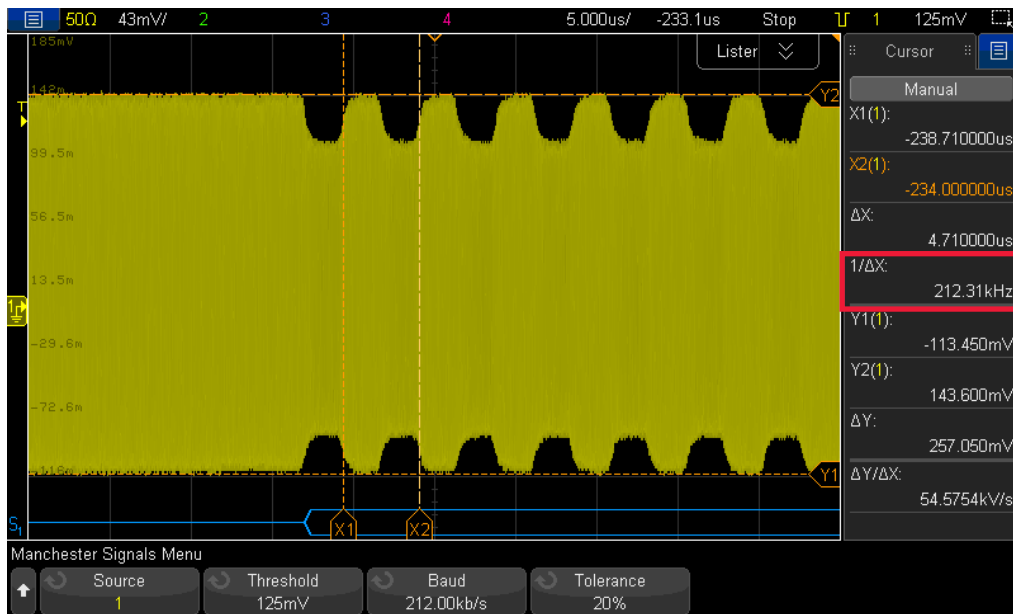

Figure 9. Measuring the period of sync bits to determine proper baud rate setting.

After establishing appropriate parameters in the **Signals** sub-menu, press the **Back** key to return to 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 10.

- Display format = word
- Sync size = 48 (SoS)
- Header size = 16 (SoF = 2 bytes)
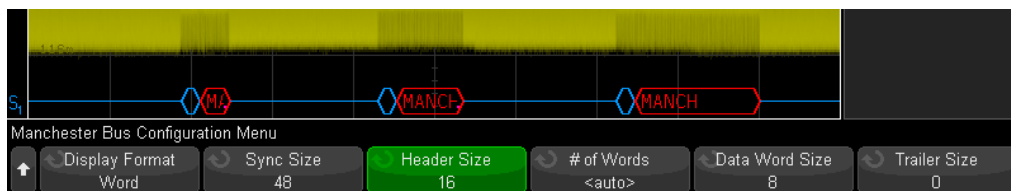- # of words = <auto> (data field)
- Data word size = 8
- Trailer size = 0

Figure 10. Establishing Manchester bus configuration parameters.

CASE 1: Obverse Polarity Encoding with Similar Poller and Listener Logic Thresholds (Continued)

Note that since each burst of poller and listener modulation can have various lengths, it is important to use <auto> for the **# of Words** to define the data field. However, when <auto> is used, the **Trailer Size** must be set to 0, which is the default setting. This means that the CRC will be included as the last few decoded bytes of the data field.

Press the **Back** key to return to the main **Manchester** decode menu, then select the **Settings** sub-menu. Define the following parameters in the **Settings** sub-menu as shown in Figure 11.

  – Start edge # = 2
  – Polarity - falling edge = logic 1 (obverse/normal polarity)
  – Bit order = MSB
  – Idle bits = 1.50
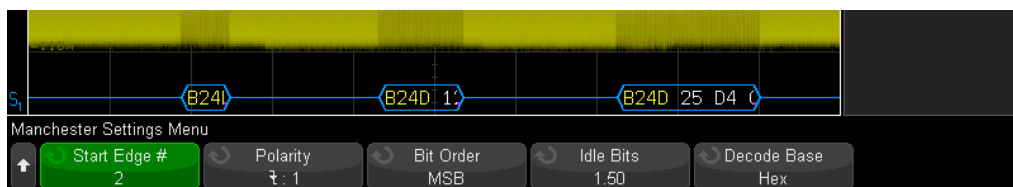 – Decode base = hex

Figure 11. Establishing Manchester settings parameters.

Determining the correct setting for **Start Edge #** and **Polarity** are critical and often the most difficult to determine, especially if you are unsure of the polarity of encoding (obverse or reverse). The correct setting for **Start Edge #** will either be "1" or "2" and depends on the polarity of encoding and whether modulation occurs within the carrier or above the carrier. But the easiest method of setting the start edge # is to simply start with a setting (either "1" or "2") and observe the decode trace below the waveform. If you observe Manchester errors (MANCH) in the decode trace, as shown in Figure 10, then if the **Start Edge #** is initially set to "1", change it to "2". Or if it is initially set to "2", change it to "1".

Once the **Start Edge #** has been set correctly, you can then set **Polarity**. If you know the polarity of encoding, then for "obverse" polarity a falling edge is a logic 1. If encoding is based on "reverse" polarity, then a rising edge is a logic 1. But if you are unsure of the **Polarity** of encoding, then it is relatively easy to empirically determine the correct setting. If the header byte (SoF) in the decode trace below the waveform is decoded as B24Dh, as shown in Figure 11, then the **Polarity** is set correctly. But if the header byte is decoded as 4DB2h, change the **Polarity** setting.

Using Manchester Triggering to Trigger on Specific NFC-F Commands

At this point, the oscilloscope should be decoding NFC-F communication between these two devices correctly, but we probably don't have a very reliable trigger condition since we are still using a pulse-width trigger condition. We can establish a more stable trigger condition if we now use Manchester triggering. The following table shows hex codes for various NFC-F poller request and listener response commands.

Command	Request (initiator)	Response (target)
Sense	SENS_REQ: B24D XX 00XX ...	SENS_RES: B24D XX 01XX ...
Attribute	ATR_REQ: B24D XX D400 ...	ATR_RES: B24D XX D501 ...
Parameter selection	PSL_REQ: B24D XX D404 ...	PSL_RES: B24D XX D505 ...
Data exchange protocol	DEP_REQ: B24D XX D406 ...	DEP_RES: B24D XX D507 ...
Deselect	DSL_REQ: B24D XX D408 ...	DSL_RES: B24D XX D509 ...
Release	RSL_REQ: B24D XX D40A ...	RSL_RES: B24D XX D50B ...

"B24D" is the 2-byte start-of-frame (SoF) code for all frames. The next byte, shown as "XX" in the above table, is the 1-byte length code, which can have various values. The next two bytes (00XX, 01XX, D400, D501, etc.) determine the specific request or response command. Let's now set up the scope to trigger on SENS_REQ.

Select the **Trigger** menu and then select the **S1: Manchester** trigger type. Change the trigger condition from the default **SOF** to **Value**. Next, set **#Bits** to 40. To specify one of these commands as our trigger condition on the InfiniiVision oscilloscope, we must enter the value in a binary format. If we want to establish more stable triggering on SENS_REQ (B24D XX 00XX ...), we will need to enter the following 40-bit binary value:

B	2	4	D	X	X	0	0	X	X
1011	0010	0100	1101	XXXX	XXXX	0000	0000	XXXX	XXXX

SoF   LEN   SENSF_REQ

Using Manchester Triggering to Trigger on Specific NFC-F Commands (Continued)

Figure 12. Triggering on SENS_REQ using Manchester triggering.

Figure 12 shows the oscilloscope triggering on SENS_REQ along with the protocol lister decode display turned on and shown in the upper half of the scope's display.

Note that with Manchester triggering, the oscilloscope is not limited to triggering on just the first 40 bits of the frame, which encompasses the command set. You can also set up the scope to trigger on specific payload contents by entering additional bits to trigger on.

CASE 2: Reverse Polarity with Dissimilar Poller and Listener Logic Thresholds

If poller and listener modulation have dissimilar logic thresholds (poller modulation within the carrier — listener modulation above the carrier), or if poller and listener modulation have opposite polarity encoding, then the NFC-F communication signal must be captured using two channels of the oscilloscope along with the use of two separate Manchester decoders. InfiniiVision oscilloscopes support dual-bus decoding utilizing two separate protocol decoders. However, it is easiest to begin with a single oscilloscope channel to trigger on and decode just poller communication and then expand into a two-channel measurement utilizing two separate decoders.

In this measurement example NFC-F communication is based on a baud rate of 424 kbps with reverse polarity modulation. Figure 13 shows the oscilloscope's timebase set to view SENSF_REQ and SENSF_RES. Here you can see that poller modulation (SENSF_REQ) is "within" the non-modulated carrier amplitude, and listener load modulation (SENSF_RES) is above (or outside of) the non-modulated carrier amplitude. Decoding both (poller modulation and listener modulation) will require capturing the waveform on two oscilloscope channels and setting up two separate Manchester decoders.
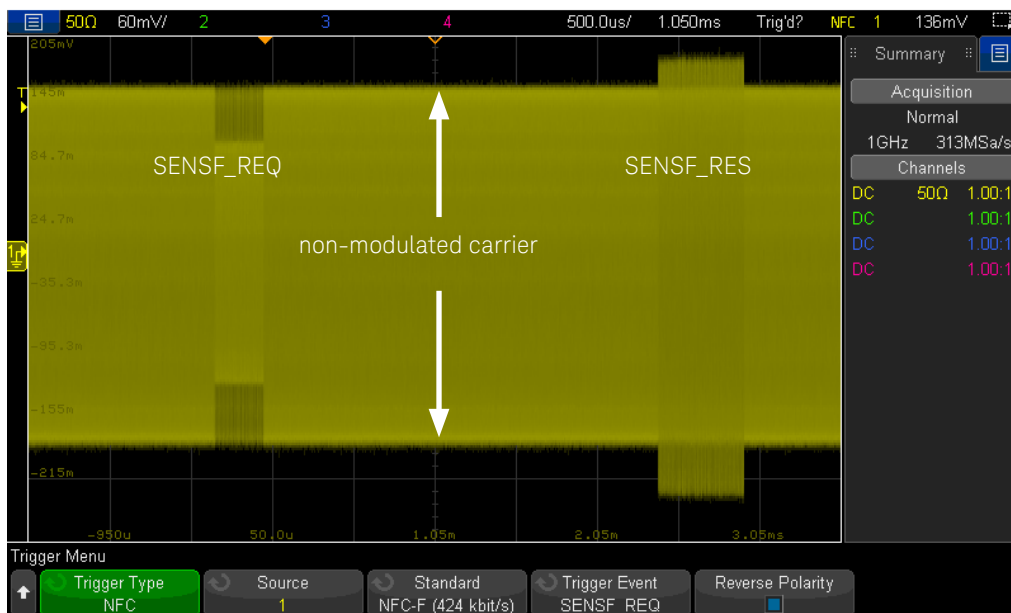

Figure 13. Example of poller and listener modulation with dissimilar logic thresholds.

CASE 2: Reverse Polarity with Dissimilar Poller and Listener Logic Thresholds (Continued)

To decode the poller communication and to trigger on SENS_REQ, as shown in Figure 14, set up the oscilloscope like it was for CASE 1 with the following differences:

– Baud rate = 424 kbps (or 212 kbps if appropriate)
– Start edge # = 1 (reverse polarity)
– Polarity – Rising edge = logic 1 (reverse polarity)

If you aren't sure if encoding is based on reverse or obverse polarity, follow the procedure previously described by first setting the **Start Edge #** to either "1" or "2" until decoded MANCH errors are eliminated, and then set polarity until the SoF header is decoded as "B24D".
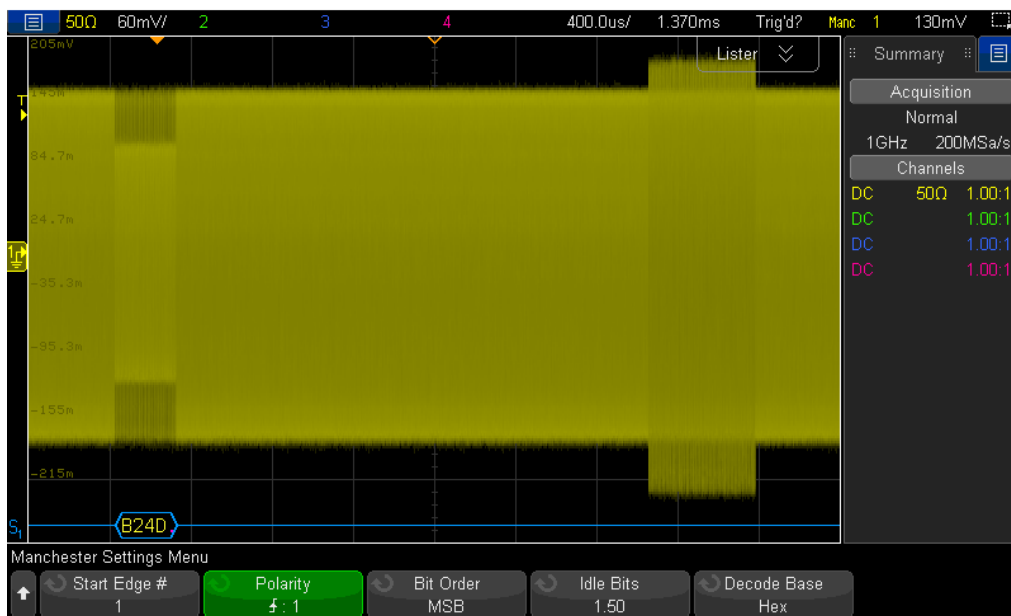

Figure 14. Decoding NFC-F (424) reverse polarity poller modulation.

CASE 2: Reverse Polarity with Dissimilar Poller and Listener Logic Thresholds (Continued)

To decode listener modulation, we must create a real-time duplicate of this waveform on another channel of the oscilloscope. Using a BNC Tee and a short BNC cable, input the NFC-F signal from your pick-up antenna into two channels of the oscilloscope, as shown in Figure 15. The oscilloscope input channel at the "end-of-the-line" (channel-2 in this case) should be terminated into 50 Ω while the other channel should be terminated into 1 MΩ. The net termination impedance will still be 50 Ω. Next, turn on the second channel and set vertical scaling (V/div and offset) to the same settings as the input channel that was previously set up to decode poller modulation. With matched scaling, both waveforms (channel 1 and channel 2) should be overlaid on top of one another.
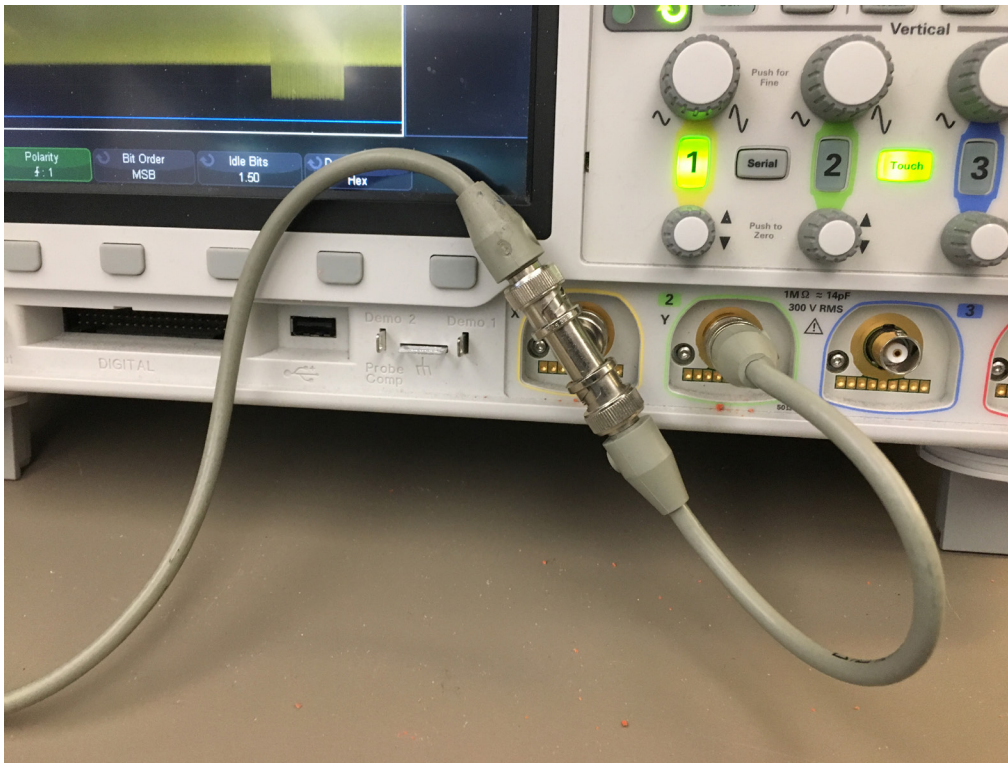

Figure 15. Splitting the signal into channel 1 and channel 2 of the oscilloscope.

CASE 2: Reverse Polarity with Dissimilar Poller and Listener Logic Thresholds (Continued)

To set up listener modulation decoding, turn on the Serial 2 decoder based on the following settings:

- S2 mode: Manchester
- Signals sub-menu:
  - Source = 2 (channel-2)
  - Threshold = Set within listener modular
  - Baud = 424 kbps
  - Tolerance = 20%
- Bus config sub-menu:
  - Display format = Word
  - Sync size = 48
  - Header size = 16
  - # of words = <auto>
  - Data word size = 8
  - Trailer size = 0
- Settings sub-menu:
  - Start edge # = 2
  - Polarity: rising = 1
  - Bit order = MSB
  - Idle bits = 1.50
  - Decode base = hex

Figure 16 shows decoding of poller and listener modulation using two separate decoders of the oscilloscope.
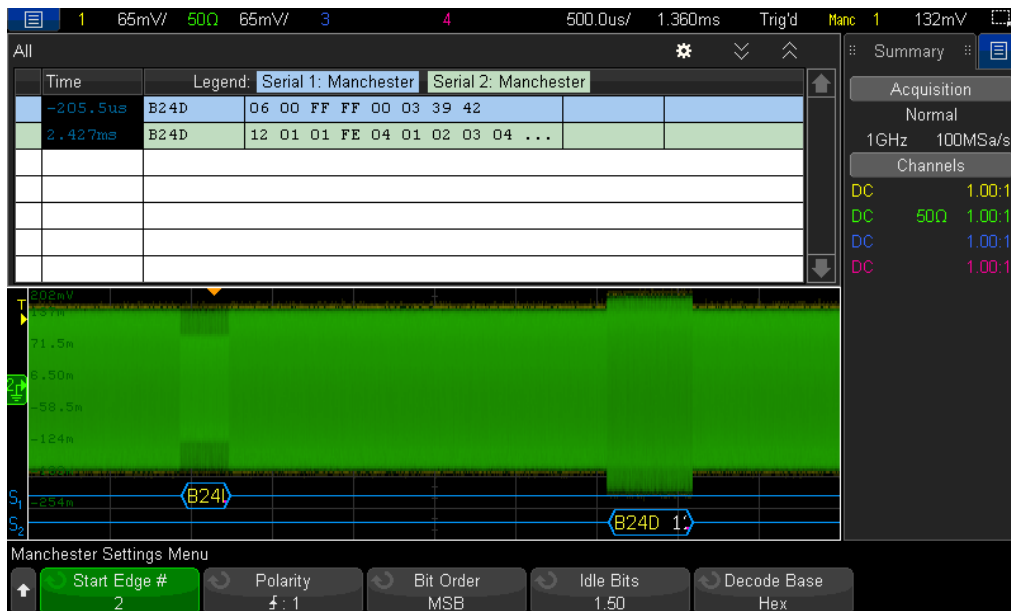

Figure 16. Setting up Serial 2 to decode listener modulation.

Summary

Using Keysight's user-definable Manchester/NRZ serial trigger and decode option on an InfiniiVision 3000T X- and 4000 X-Series oscilloscope can help you quickly test and debug NFC-F poller and listener protocol communication based on ASK-modulated Manchester-encoding. To learn more about testing NFC devices, refer to documents in **Related Literature** section below.

Related Literature

Publication title	Publication number
InfiniiVision 3000T X-Series Oscilloscopes - Data Sheet	5992-0140EN
InfiniiVision 4000 X-Series Oscilloscopes - Data Sheet	5991-1103EN
DSOXT3NFC/DSOX4NFC Automated NFC Test Software, N2116A/N2134A/ N2135A Programmable NFC 3-in-1 Antenna - Data Sheet	5992-1593EN
Serial Bus Options for InfiniiVision X-Series Oscilloscopes - Data Sheet	5990-6677EN
NFC Device Turn-on and Debug - Application Note	5992-2066EN
NFC-A and -B Sideband Measurements - Application Note	5992-2067EN

To download these documents directly, insert the publication number in the URL:
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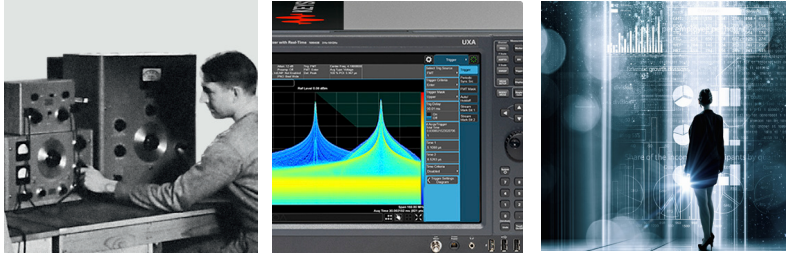www.keysight.com/find/software

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