Keysight Technologies
NFC Device Turn-on and Debug
Using Keysight InfiniiVision X-Series Oscilloscopes

Application Note
Characterizing near field communication (NFC) signals for proper timing and amplitude modulation is important to insure reliable communication between polling (initiator) and listening (target) devices. Although there are a variety of available test tools today that can perform automated testing of NFC devices, during the R&D turn-on and debug phase of development it is often necessary to perform these measurements manually on the bench. The ideal tool for viewing and testing RF analog signal quality, including NFC, is an oscilloscope. As opposed to dedicated one-box NFC testers that only provide statically captured/digitized waveforms with pass/fail information, oscilloscopes provide repetitively updated waveforms. This is important because it gives the hardware designer the ability to monitor waveforms for intermittent signal anomalies, as well as the ability to make quick qualitative judgements about overall system operation. Once things are up and running, only then is it time to consider automated design verification testing, which can also be performed using a Keysight oscilloscope-based NFC test system.

This application note focuses on showing you how to use a Keysight InfiniiVision X-Series oscilloscope to trigger on NFC communication, how to demodulate the captured RF waveform, and then how to perform various parametric measurements on the demodulated waveform to verify system performance.
Sniffing Out NFC Communication

Although electrical signals captured by an oscilloscope are typically probed using either a standard 10:1 passive probe or an active probe, capturing NFC communication between a polling and listening device requires that the RF signal be "sniffed" out of the air. The easiest way to do this is with a passive NFC calibration coil/antenna placed in the vicinity of paired NFC devices (poller & listener) as shown in Figure 1. In this example a tag (listener) has been placed onto the calibration coil and then a mobile phone (poller) has been placed approximately 5 mm above the tag using a non-conductive spacer (yellow sticky note pad in this case). The output of the calibration coil is connected to the scope's channel-1 input 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 monitor modulated pulse wave shapes and timing between poller request and listener response communications.

Figure 1. Sniffing out NFC communication between a mobile phone (poller) and a tag (listener) using an NFC calibration coil.
Sniffing Out NFC Communication (Continued)

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 as shown in Figure 2. This uncalibrated loop is sufficient for sniffing out NFC communication and then making timing and qualitative measurements.

Figure 2. Creating an uncalibrated NFC RF “sniffer” using a standard 10:1 passive probe.
Triggering on NFC Communication

Often the biggest challenge when testing NFC communication on the R&D bench is establishing proper trigger conditions to provide a stable display of waveforms. Many engineers simply use the scope’s default edge trigger mode and then continually press SINGLE until they see what they are looking for. Unfortunately, this creates a “hit or miss” situation (usually miss), and we are back to a non-updated display of waveforms when using this single-shot acquisition technique.

Unless your scope has built-in NFC triggering capability, your best bet is to use the scope’s pulse-width trigger mode with time-qualification. You can begin with the Auto trigger mode while setting up vertical scaling and trigger level. But you should then switch to the Normal trigger mode (sometimes called “sweep” mode). NFC communication cycle times are likely to be relatively slow meaning that the scope could generate random and asynchronous automatic triggers if using the Auto trigger mode, which is typically undesirable.

Figure 3 shows an example of triggering at the beginning of an NFC-A SENS_REQ (sense request) by specifying to trigger only on low pulses > 1 µs but < 3 µs with the trigger level set within the positive half of poller modulated RF pulses. This method does not guarantee that the scope will always trigger on the first modulated pulse sent by the poller. Nor does it guarantee that the scope will always trigger on the initial set of communication (SENS_REQ or ALL_REQ). The scope could trigger on any modulated pulse within the first or second set (SDD_REQ) of communication from the poller. Another suggestion is to try different values of trigger holdoff time to help stabilize triggering. Note that to trigger on NFC-B, NFC-F (212 kbps), and NFC-F (424 kbps) will each require different time qualifications for pulse-width triggering.

Figure 3. Triggering on NFC-A communication using the scope’s pulse-width trigger mode.
Triggering on NFC Communication (Continued)

The most reliable method for triggering on NFC signals is to use a scope with an NFC triggering option, which is available on some of Keysight’s InfiniiVision X-Series oscilloscopes. You can quickly set up these scopes to trigger on any NFC signaling standard (NFC-A, NFC-B, NFC-F (212), or NFC-F (424)). You can also select to trigger on specific poller events such as SENS_REQ, ALL_REQ, or SDD_REQ. Figure 4 shows an example of the scope triggering on either SENS_REQ or ALL_REQ poller communication from a mobile phone to an NFC-A tag.

Once stable triggering has been established, you can then easily identify specific frames of poller and listener modulation and then use the scope’s timing cursors to measure frame delay time (FTD) from request-to-response frames and from response-to-request frames.

Figure 4. Triggering NFC communication using the scope’s NFC optional triggering.
Demodulating NFC Waveforms

Using the scope’s automatic parametric timing measurements to characterize critical modulated pulse shape parameters such as $t_1$, $t_2$, $t_3$, $t_4$, and $t_5$, requires the creation of a demodulated waveform for which the pulse parameter measurements can be performed on. A demodulated waveform can be created using one or more of the scope’s waveform math functions. Figure 5 shows an example of using the scope’s envelope waveform math function to create a demodulated waveform (purple trace). The scope’s envelope math function is based on a frequency-domain Hilbert transform. You can also apply waveform math filtering to the envelope waveform to further reduce uncertainty/noise of the demodulated waveform if desired.

Figure 5. Demodulating the captured NFC waveform using the scope’s envelope waveform math function.
Characterizing Pulse Wave Shapes of NFC Modulation

Once you have established stable triggering and created a demodulated waveform using the scope’s envelope waveform math function, it is fairly easy to perform various pulse parameter measurements on either poller modulation or listener response load modulation. Depending on the NFC standard (A, B, or F), different parametric measurements are required. For NFC-A poller modulation, the key test parameters include the following:

- Modulation index
- Data rate
- \( t_1, t_2, t_3, t_4, t_5 \)
- Overshoot

Modulation index \( (m_i) \) is defined as:

\[
m_i = \frac{[A(t)_{\text{MAX}} - A(t)_{\text{MIN}}]}{[A(t)_{\text{MAX}} + A(t)_{\text{MIN}}]},
\]

where \( A(t)_{\text{MAX}} \) is the steady-state non-modulated amplitude of the RF carrier, and

where \( A(t)_{\text{MIN}} \) is the steady-state amplitude during the depth of modulation.

Unfortunately, modulation index is not one of the available automatic measurements on most oscilloscopes (maybe none), but it can be measured indirectly. \( A(t)_{\text{MAX}} \) can be directly measured on the demodulated waveform math function (purple trace) using the scope’s “Top” measurement, and \( A(t)_{\text{MIN}} \) can be directly measured using the scope’s “Base” measurement as shown in Figure 6. We can then easily calculate the modulation index by taking the difference, the sum, and the ratio as modulation index is defined in the above formula. For the example shown in Figure 6, we measured \( A(t)_{\text{MAX}} \) at 865 mV (Top) and \( A(t)_{\text{MIN}} \) at 12.2 mV (Base). Therefore, the modulation index computes to be 97.2%, which is well within specification (≥ 90%).

Figure 6. Measuring modulation index and data rate on NFC-A poller modulation.
Because NFC-A poller modulation is based on modified Miller encoding, we can directly confirm the data rate by simply measuring the frequency of the narrowest set of demodulated pulses. This is also shown in Figure 6, where we measured 105.9 kHz. Again, this is well within the NFC-A poller specification of ≥ 104.5 kbps but ≤ 107.5 kbps. If we were performing this measurement on NFC-B poller modulation, the data rate would be twice the measured frequency because NFC-poller modulation is based on NRZ encoding.

The $t_1$, $t_2$, $t_3$, $t_4$, and $t_5$ parameters are transition and pulse duration times of NFC-A poller modulation based on various threshold levels as shown in Figure 7. For sake of brevity, this application note will only show how to measure $t_2$ and $t_4$. Performing the other timing parameters ($t_1$, $t_3$, and $t_5$) can be accomplished using similar measurement techniques.

![Figure 7. NFC-A poller modulation pulse wave shape parameters.](image)
Characterizing Pulse Wave Shapes of NFC Modulation (Continued)

The $t_2$ timing parameter is the duration of time that modulation is below 5%. For this we can use a negative pulse width measurement (-Width). The scope’s default measurement threshold levels for pulse width measurements is to measure from 50% on the leading edge of a pulse to 50% on the trailing edge of the same pulse. But measurement threshold levels can be customized on most of today’s oscilloscopes. Figure 8 shows the required $t_2$ measurement on the scope using a custom measurement threshold of 5%. At 2.29 µs, this barely meets the maximum $t_2$ specification of 2.30 µs.

![Figure 8. Measuring $t_2$ using the scope’s custom measurement threshold levels.](image)

The $t_4$ timing parameter is a transition time measurement from 5% to 60% on the trailing edge of modulation. For this measurement we can use the scope’s rise time measurement with custom measurement thresholds. The scope’s default measurement threshold settings for rise and fall time measurements are 10% and 90%, but this can be easily modified as shown in Figure 9. This measurement of $t_4$ at 390 ns meets the $t_4$ specification of < 440 ns.

![Figure 9. Measuring $t_4$ using the scope’s custom measurement threshold levels.](image)
Summary

During the turn-on and debug phase of development of NFC-enabled devices, visually monitoring and verifying timing parameters are typically performed manually on the R&D test bench using an oscilloscope prior to performing any type of automated verification testing. Using an oscilloscope with NFC triggering and the "envelope" waveform math function along with automatic parametric measurements can speed up the turn-on and debug process.

Although not covered in this application note, the measurements discussed in this document — along with many others — can be fully automated using Keysight’s NFC automated test software along with the N2116A programmable 3-in-1 NFC reference antenna (poller-3 equivalent coil, listener-3 equivalent coil, and resonant frequency test coil). Refer to the data sheet on this product solution listed at the end of this document for additional information about this automated test solution.

To learn how to perform frequency-domain sideband measurements on NFC-A and NFC-B listener load modulation, refer to the application note titled, “NFC-A and -B Sideband Measurements” listed at the end of this document.

Related Products

For full/complete NFC conformance testing, Keysight recommends the T3111S.

- Supports analog RF and digital protocol parts of NFC, EMV™ and ISO test specifications
- Platform supports R&D, pre-conformance and conformance testing
- Fully qualified by NFC Forum certification program
- Qualified for EMV Level 1 test including PICC/Mobile and PCD
- Software-upgradeable, integrated, automated, extensible test platform
- Available with automatic positions robots for accurate antenna location
- Easy-to-use test manager for execution and results analysis
Related Literature

<table>
<thead>
<tr>
<th>Publication title</th>
<th>Publication number</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSOXT3NFC/DSOX4NFC Automated NFC Test Software, N2116A/N2134A/N2135A</td>
<td>5992-1593EN</td>
</tr>
<tr>
<td>Programmable NFC 3-in-1 Antenna - Data Sheet</td>
<td></td>
</tr>
<tr>
<td>InfiniVision 3000T X-Series Oscilloscopes - Data Sheet</td>
<td>5992-0140EN</td>
</tr>
<tr>
<td>InfiniVision 4000 X-Series Oscilloscopes - Data Sheet</td>
<td>5991-1103EN</td>
</tr>
<tr>
<td>T3100S Series NFC Test Systems - Technical Overview</td>
<td>5992-0188EN</td>
</tr>
<tr>
<td>NFC-A and -B Sideband Measurements - Application Note</td>
<td>5992-2067EN</td>
</tr>
<tr>
<td>NFC Testing Using an Oscilloscope – Part 1: R&amp;D benchtop testing</td>
<td>Youtube.com</td>
</tr>
<tr>
<td>NFC Testing Using an Oscilloscope – Part 2: Automated testing</td>
<td>Youtube.com</td>
</tr>
</tbody>
</table>

www.axiestandard.org
AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. The business that became Keysight was a founding member of the AXIe consortium. ATCA®, AdvancedTCA®, and the ATCA logo are registered US trademarks of the PCI Industrial Computer Manufacturers Group.

www.lxistandard.org
LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. The business that became Keysight was a founding member of the LXI consortium.

www.pxisa.org
PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.
Evolving Since 1939

Our unique combination of hardware, software, services, and people can help you reach your next breakthrough. We are unlocking the future of technology. From Hewlett-Packard to Agilent to Keysight.

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

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 SERVICES

Accelerate Technology Adoption. Lower costs.

Keysight Services
www.keysight.com/find/service
Keysight Services can help from acquisition to renewal across your instrument’s lifecycle. Our comprehensive service offerings—one-stop calibration, repair, asset management, technology refresh, consulting, training and more—helps you improve product quality and lower costs.

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.

EMV™ is a trademark owned by EMVCo.

www.keysight.com/find/scopes-nfc
www.keysight.com/find/infinivision

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 1 800 888 844
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 5093286
Spain 800 000154
Sweden 0200 682255
Switzerland 0800 805363
Opt. 1 (DE)
Opt. 2 (FR)
Opt. 3 (IT)
United Kingdom 0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus (BP-9-7-17)

DEKRA Certified
ISO 9001 Quality Management System

www.keysight.com/go/quality

Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2015
Quality Management System

This information is subject to change without notice.
© Keysight Technologies, 2017
Published in USA, December 1, 2017
5992-2068EN
www.keysight.com