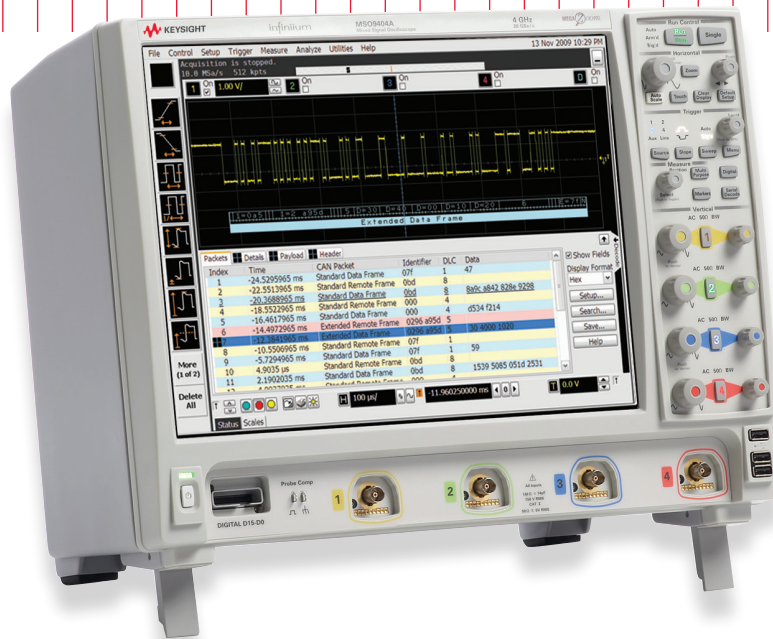


# Keysight Technologies

## Debug Automotive Designs Faster with CAN-dbc Symbolic Trigger and Decode For Keysight Infiniium Oscilloscopes

### Application Note





## Introduction

The differential Controller Area Network (CAN) bus is used extensively in all of today's automobiles for drive-train and body control. This protocol was developed by Bosch more than 30 years ago, and it is still considered the "workhorse" serial control bus of the automobile. The CAN bus has also been heavily adopted for industrial and medical equipment control applications.

The oscilloscope is the primary measurement tool used today to test and debug the physical layer of this serial bus. Although CAN bus protocol analyzers, such as Vector's CANalyzer, are also commonly used for testing and debugging at a higher-abstraction application level, the advantage of an oscilloscope is that it provides you with the ability to monitor the analog quality (signal integrity) of the physical layer of the CAN bus. The electrical environment in automobiles is naturally harsh with lots of noise and often unexpected transients. The core competence of an oscilloscope is that it can capture and show you details of those infrequent automotive transients and noise that could be producing CAN bus errors.

This application note will begin by showing the difference between oscilloscope hexadecimal triggering and decode versus CAN-dbc symbolic triggering and decode of a CAN differential bus. We will then provide some background on the core element required to symbolically decode the CAN bus, which is an industry-standard .dbc file. In addition, we will provide step-by-step instructions on how to perform CAN symbolic-level triggering and decode using a Keysight Technologies, Inc. Infiniium oscilloscope. CAN-dbc symbolic triggering and decode is standard with the N8803A or N8803B CAN/LIN/FlexRay option.

## Triggering on and Decoding the CAN Bus

To assist in synchronizing on and identifying specific CAN frames to test and debug, most of today’s mid-range and high performance oscilloscopes, including Keysight’s Infiniium 9000 Series oscilloscopes, have the ability to trigger on and decode the CAN bus in a hexadecimal format.

Figure 1 shows a Keysight 9000 Series oscilloscope triggering on and decoding the CAN bus in a hexadecimal format. Note that with the oscilloscope’s analog capture capability, we can see noise as well as various pulse amplitudes in this measurement example. Below each captured frame is the time-correlated decode trace telling you what the contents are of that particular frame. In the lower half of the oscilloscope’s display is the protocol lister that shows the contents of all captured frames in a tabular format, which is more similar to a traditional protocol analyzer’s display.

In this particular measurement example, the oscilloscope had been set up to trigger on frame ID 0x201<sub>HEX</sub>, which correlates to 010 000 0001<sub>Binary</sub>. The 8-byte data field of this particular frame (0x201) shows “0B A8 00 00 27 10 00 00.” But what does 0x201<sub>HEX</sub> mean? And what does that long data string of hexadecimal characters mean?

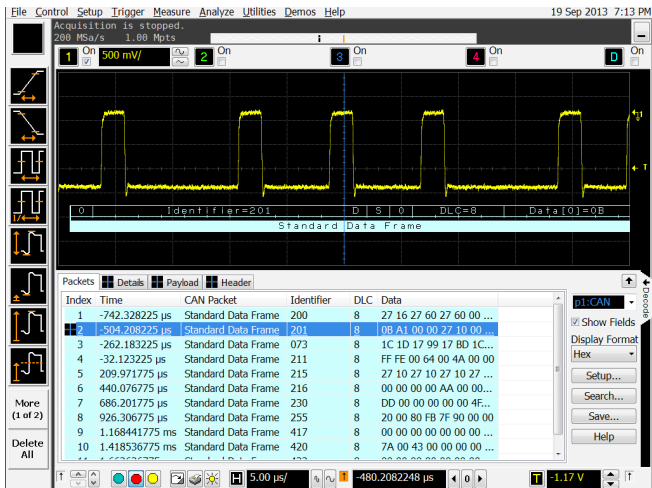


Figure 1a. Triggering on and decoding frame 0x201.



Figure 1b. Expanded view of hexadecimal decode trace.

## Symbolically Decoding the CAN Bus

As mentioned earlier, one of the advantages of a CAN protocol analyzer is that it can display results at a higher-abstraction application level. In other words, it translates captured data into human language such as “Speed = 852.52 rpm” – not just cryptic bits. CAN-dbc symbolic triggering and decode can also be achieved on Keysight’s 9000 Series oscilloscopes. Figure 2 shows the 9000 Series oscilloscope now triggering on and decoding the bus symbolically.

In this measurement example, the oscilloscope was set up to trigger on message “Brake\_Torque,” which directly relates to a specific frame ID (0x211). Instead of a long string of hexadecimal characters representing the data field in this frame/message, the oscilloscope now displays “signal” names with signed values, units, and/or encoded states such as “On,” “Off,” “Reverse,” etc. In symbolic CAN language, note that a “signal” is not an electrical input to the oscilloscope’s BNCs. A “signal” typically represents a physical parameter or condition such as “Total\_Torque: 131.0640k ft/lbs” as shown in this example. So how does the oscilloscope translate raw bits into symbolic code?

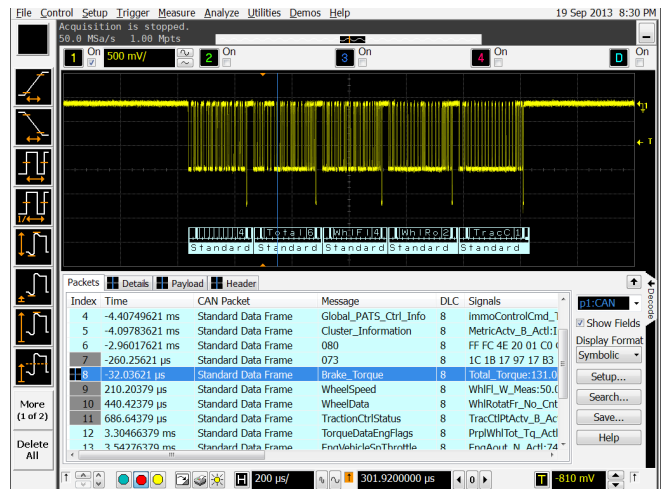


Figure 2a. Symbolically triggering on and decoding the CAN bus.



Figure 2b. Expanded view of symbolic decode trace.

## Understanding .dbc Files

All vehicles have associated with each CAN bus and for each particular vehicle a .dbc file, which stands for “data base CAN.” A .dbc file is an ASCII formatted file with a .dbc extension that defines the CAN network. Figure 3 shows a portion of a simple .dbc file created by Keysight. This particular .dbc file defines a CAN demonstration signal often used by Keysight for oscilloscope training purposes.

“Messages” are simply labels that represent specific frame IDs. For instance, frame ID 2,190,911,837<sub>Decimal</sub> has been defined to be Message: EngineData in this .dbc file. “Signals” are a bit more complex. Within Message: EngineData, which consists of 5 bytes of data (DLC = 5), we have defined three signals labeled “Fuel,” “Temp,” and “Speed.” Each signal has a specified start-bit and length. For example, “Temp” begins at bit #24 and has a length of 8 bits. Also associated with each defined signal are variable conversion factors, units, min and max warning values, and a big Endian/little Endian indicator.

Besides translating data into physical values/variables, signals can also be state-encoded. Referring to Message: ABS, signal “Frnt-R” begins at bit #7 and has a length of just 1 bit. This means it can only have a binary value of either 0 or 1. Near the bottom of the file, “Frnt-R” has also been defined to be an encoded state where, if the value of the signal is 0, the oscilloscope will display “unlocked.” If the value of this signal is 1, the oscilloscope will display “locked.”

The .dbc files that define CAN buses for specific vehicles are much more complex than the example .dbc created by Keysight and shown in Figure 3. Unfortunately, it is not possible to show a more complex .dbc file based on a real automobile in this document. Automotive vendors protect these files and consider them to be propriety and top secret. They don’t want their competitors to know how they have defined their networks. Refer the section sub-titled “.dbc File Security” later in this document for more information about this topic.

Although Keysight created the .dbc file shown in Figure 3 using a text editor, there are much more efficient ways to create .dbc files – especially when creating a .dbc file for more complex automotive CAN systems. The most common tool used today is Vector’s CANdb++ software tool. For more information about this software tool, contact Vector Informatik GmbH.

```
BO_ 2190911837 EngineData: 5 Engine
SG_ Fuel : 8|8@1+ (0.01,12) [0|21] "gal" Gateway
SG_ Temp : 24|8@1+ (0.2,135) [-50|150] "C" Gateway
SG_ Speed : 32|8@1+ (0.1,2900) [0|8000] "rpm" Gateway

BO_ 189 ABS: 8 Brakes
SG_ Frnt-R : 7|1@1+ (1,0) [0|1] "" Gateway
SG_ Frnt-L : 2|1@1+ (1,0) [0|1] "" Gateway
SG_ Rear-R : 11|1@1+ (1,0) [0|1] "" Gateway
SG_ Rear-L : 10|1@1+ (1,0) [0|1] "" Gateway
SG_ FR-Pressure : 40|8@1+ (.1,105) [0|200] "psi" Gateway
SG_ FL-Pressure : 32|8@1+ (.1,105) [0|200] "psi" Gateway
SG_ RR-Pressure : 56|8@1+ (.1,105) [0|200] "psi" Gateway
SG_ RL-Pressure : 48|8@1+ (.1,105) [0|200] "psi" Gateway

BO_ 127 Airbag: 1 Emergency
SG_ Frwd-impact : 7|1@1+ (1,0) [0|1] "" Gateway
SG_ Rear-impact : 6|1@1+ (1,0) [0|1] "" Gateway
SG_ Left-impact : 2|1@1+ (1,0) [0|1] "" Gateway
SG_ Right-impact : 0|1@1+ (1,0) [0|1] "" Gateway

BO_ 000 Steering: 4 Steering
SG_ Lock : 20|1@1+ (1,0) [0|1] "" Gateway
SG_ Angle : 24|8@1+ (0.03,45) [0|48] "deg" Gateway

CM_ "CAN communication matrix for power train electronics
*****
implemented: turn lights, warning lights, windows";

VAL_ 189 Frnt-R 0 "Unlocked" 1 "locked" ;
VAL_ 189 Frnt-L 0 "Unlocked" 1 "locked" ;
VAL_ 189 Rear-R 0 "Unlocked" 1 "locked" ;
VAL_ 189 Rear-L 0 "Unlocked" 1 "locked" ;
VAL_ 127 Frwd-impact 0 "Deployed" 1 "Armed" ;
VAL_ 127 Rear-impact 0 "Deployed" 1 "Armed" ;
VAL_ 127 Left-impact 0 "Deployed" 1 "Armed" ;
VAL_ 127 Right-impact 0 "Deployed" 1 "Armed" ;
VAL_ 000 Lock 0 "On" 1 "off" ;
```

Figure 3. Simple example of a .dbc file's contents.

## Enabling CAN-dbc Symbolic Trigger and Decode in the Oscilloscope

Once a .dbc file is available for the CAN network you want to test and debug, importing the .dbc file into the Keysight 9000 Series oscilloscope is very easy.

1. Store the .dbc file onto your USB flash drive and then insert it into one of the oscilloscope's USB ports.
2. Go to SETUP menu and select Protocol Decode.
3. Load CAN Symbolic Data (\*.dbc) as shown in Figure 4a.
4. Navigate to the .dbc that you want to load.

The oscilloscope will then parse the file and save all the important conversion parameters. The oscilloscope's CAN decode and trigger menus then provide options to turn on symbolic decode and give you the ability to trigger on messages and signals on a symbolic level.

Figure 4b shows a Keysight 9000 Series oscilloscope triggering on and decoding the built-in CAN training signal symbolically using the .dbc file referenced in Figure 3. Below the captured CAN frame is the time-correlated decode trace showing Message: EngineData with signals "Fuel," "Temp," and "Speed." In the top half of the oscilloscope's display is the protocol lister display showing all captured frames/messages decoded symbolically. In this example, we can easily read all three signals (Fuel, Temp, and Speed) and values within the time-correlated decode trace below the waveform. But this is typically not the case.

Real vehicle .dbc files often have long names for both messages and signals, and they also often include more than three signals per message. This makes it impossible to view all of the important data within a single message in either time-correlated decode trace or the protocol lister. But with the lister's details tab selection, you can select to display all signals updated within the message the oscilloscope is currently triggering on. Figure 5 shows an expanded view of the packet viewer from a message that includes several signals. To view the signals at the bottom of the list, simply use the scroll bar.

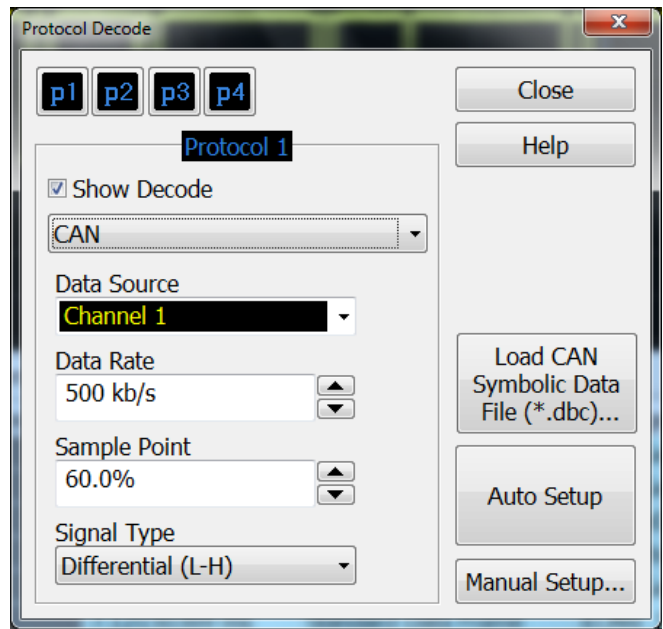


Figure 4a. Recalling the .dbc into the oscilloscope in order to trigger and decode symbolically.

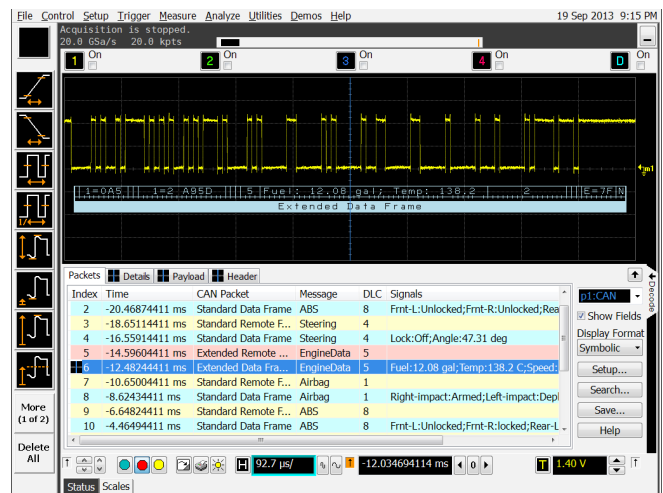


Figure 4b. View messages and signals in lister or on waveform area.

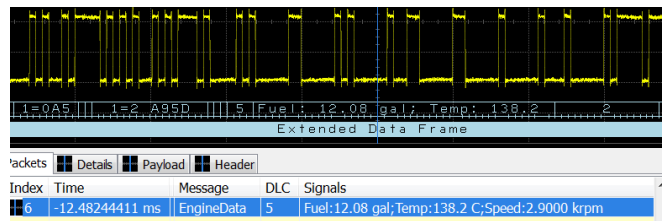


Figure 4c. Expanded view of symbolic decode trace.

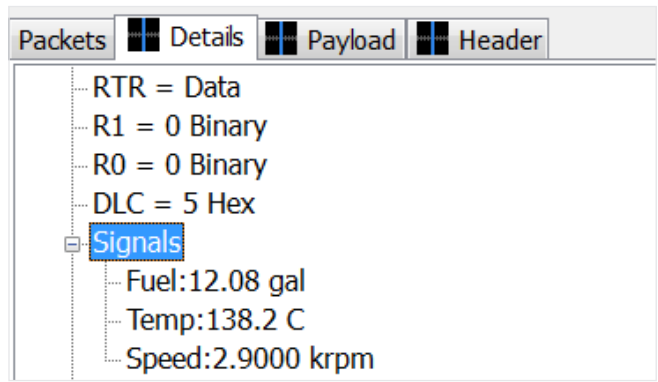


Figure 5. Viewing a message and all of its signals within the oscilloscope's packet detail tab.

## Decoding the CAN bus in Symbolic and Hexadecimal Format Simultaneously

Keysight Infiniium oscilloscopes have four independent serial bus decoders, which can be used to decode two or more different serial buses simultaneously. The upper time-correlated decode trace shows this CAN bus being decoded symbolically, while the lower time-correlated decode trace shows a time-correlated LIN bus. This can be useful when working with multiple buses.

When a .dbc file is loaded, both the oscilloscope trigger and the protocol search capabilities are enabled at the symbolic level. Figure 7 show an example when the oscilloscope is set to trigger on the message "Airbag" when the signal value is set to "Left-impact." Infiniium protocol options also feature a post-acquisition search capability. The user can search for a specified message or a signal state or value.

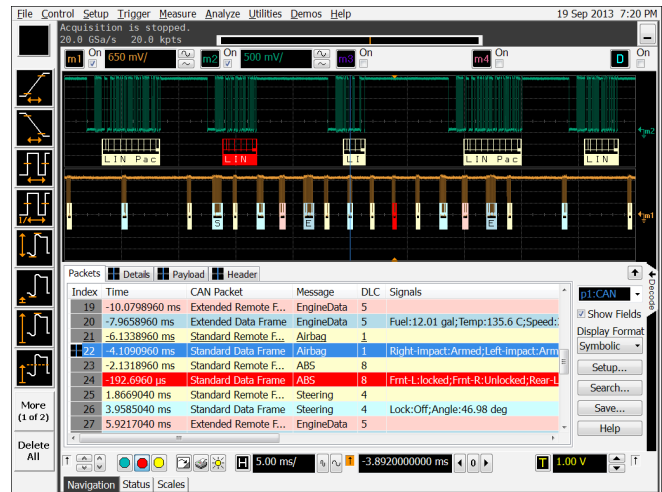


Figure 6. Decoding a CAN bus symbolically simultaneously with a LIN bus.

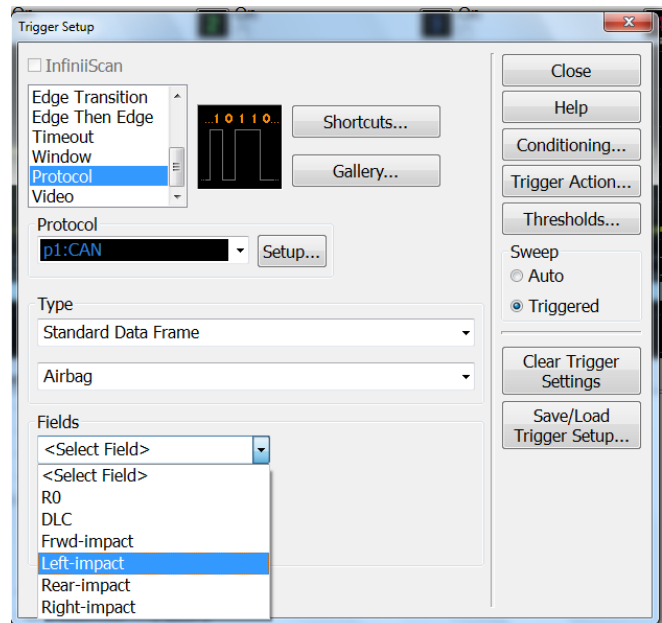


Figure 7. Setting the trigger at the message and signal symbolic here.

## Summary

There are many tools that automotive engineers use today to test and debug their CAN-based designs. The oscilloscope is the primary tool used to test and debug the physical layer of the differential CAN bus. Using an oscilloscope with a CAN trigger and decode option can speed up the debugging and testing process. And using oscilloscopes with the additional CAN-dbc symbolic trigger and decode capability will make isolating particular messages and signals for testing even faster and more intuitive. After all, “EngineData” makes a lot more sense than “0x0296A95D<sub>HEX</sub>”

Oscilloscopes with CAN-dbc symbolic trigger and decode, such as Keysight’s Infiniium 9000 Series, won’t replace a CAN protocol analyzer, and a CAN protocol analyzer will never replace an oscilloscope. Automotive engineers designing and testing CAN buses in their vehicles and ECUs will typically have both instruments at their disposal for optimum testing.

CAN-dbc symbolic triggering and decode comes standard with the N8803A or N8803B CAN, LIN, FlexRay option licensed on a Keysight Infiniium oscilloscopes.

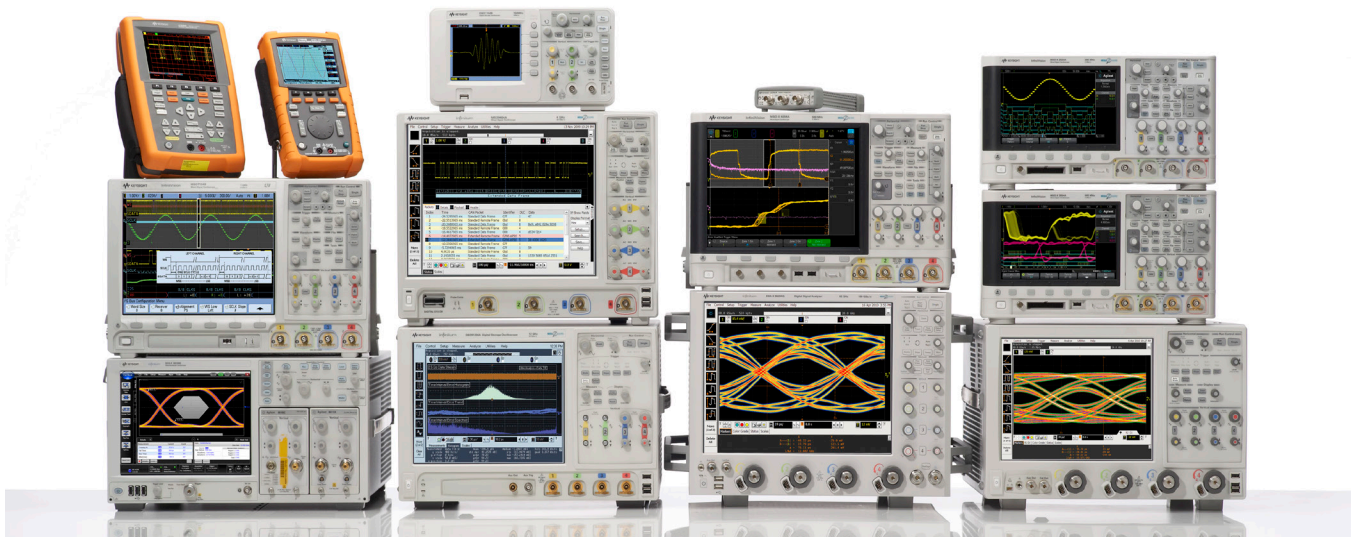
## Related Literature

Publication title	Publication type	Publication number
Keysight Infiniium 9000 Series Oscilloscopes	Data sheet	5990-3746EN
Infiniium Oscilloscope Probes and Accessories	Data sheet	5968-7141EN
Oscilloscope Measurement Tools to Help Debug Automotive Serial Buses Faster	Application note	5991-0512EN
CAN Eye-diagram Mask Testing	Application note	5991-0484EN
Using Segmented Memory for Serial Bus Applications	Application note	5990-5817EN
N8803B CAN, LIN, FlexRay Protocol Trigger and Decode for Infiniium 9000 Series	Data sheet	5990-5077EN
N8803A CAN, LIN, FlexRay Protocol Trigger and Decode for Infiniium 9000 Series	Data sheet	5990-4099EN

To download these documents, insert the publication number in the URL:  
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## Product Web site

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