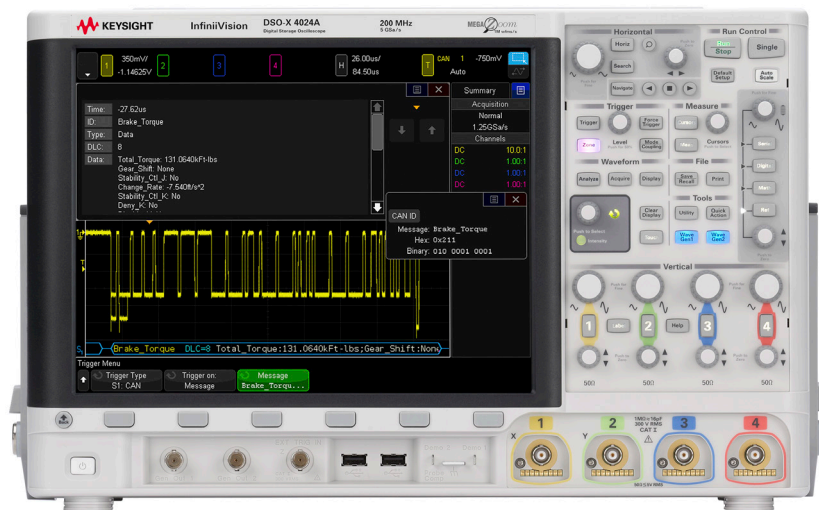# Keysight Technologies
Debug Automotive Designs Faster with CAN-dbc Symbolic Trigger and Decode

For Keysight InfiniiVision
4000 and 6000 X-Series Oscilloscopes

Application Note

KEYSIGHT
TECHNOLOGIES

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 CANanalyzer, 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. 4000 and 6000 X-Series oscilloscope. CAN-dbc symbolic triggering and decode is standard with the DSOX4AUTO and DSOX6AUTO CAN/LIN options.

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 InfiniiVision 2000, 3000, 4000, and 6000 X-Series oscilloscopes, have the ability to trigger on and decode the CAN bus in a hexadecimal format. This type of measurement capability is an option on InfiniiVision X-Series oscilloscopes.

Figure 1 shows a Keysight InfiniiVision X-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 upper 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 $0x201_{HEX}$, which correlates to $010\ 000\ 0001_{Binary}$. The 8-byte data field of this particular frame (0x201) shows "0B A8 00 00 27 10 00 00." But what does $0x201_{HEX}$ mean? And what does that long data string of hexadecimal characters mean?

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 4000 and 6000 X-Series oscilloscopes (CAN-dbc not available on Keysight's 2000 and 3000 X-Series). Figure 2 shows the 4000 X-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?
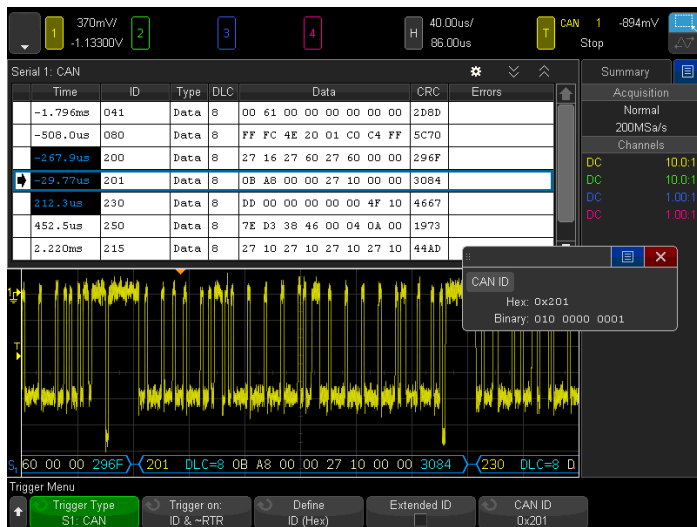

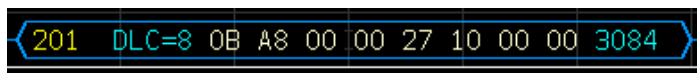Figure 1a. Triggering on and decoding frame 0x201.

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

Figure 1b. Expanded view of hexadecimal decode trace.

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 $2{,}190{,}911{,}837_{Decimal}$ 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 to 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 4000 and 6000 X-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 front panel USB ports.
2. Press the [Save/Recall] front panel key.
3. Select CAN Symbolic Data (*.dbc) as the type of file to recall into the oscilloscope.
4. Press the Load to: softkey, and then select to load the .dbc file into either S1 (Serial Bus #1) or S2 (Serial Bus #2). Note that the 4000 and 6000 X-Series oscilloscopes have two independent serial bus decoders.
5. Using the oscilloscope's touch screen, navigate to the .dbc that you want to load.
6. Press the Press to Recall softkey to load the .dbc file.

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 4 shows a Keysight 4000 X-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 "tools" icon selection, you can select to turn on the live "packet viewer" 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.
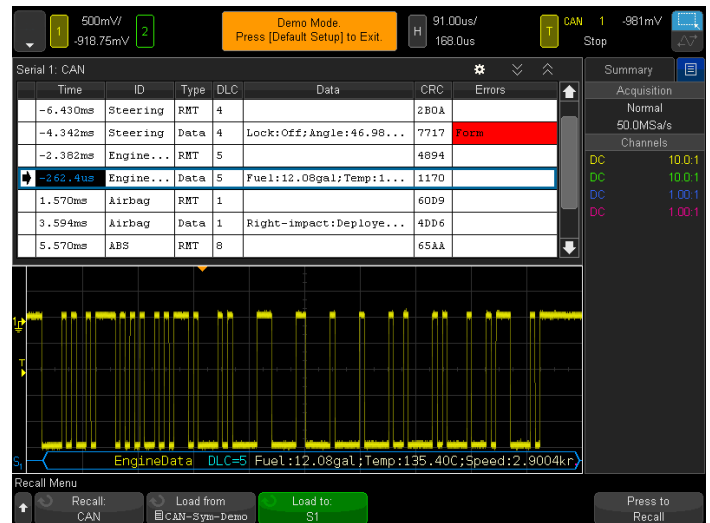

Figure 4a. Recalling the .dbc into the oscilloscope in order to trigger and decode symbolically.

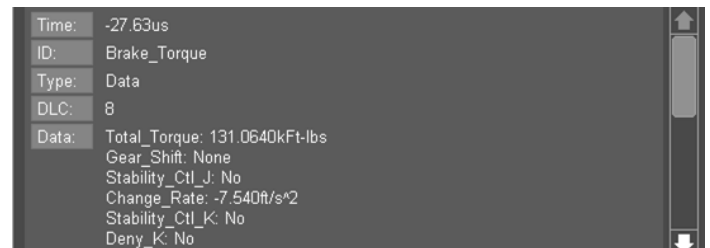Figure 4b. Expanded view of symbolic decode trace.

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

Decoding the CAN Bus in Symbolic and Hexadecimal Format Simultaneously

The Keysight InfiniiVision 4000 and 6000 X-Series oscilloscopes have two independent serial bus decoders, which are typically used to decode two different serial buses simultaneously. However, you can also use these two serial bus decoders to decode the same CAN bus in both symbolic format and hexadecimal format simultaneously as shown in Figure 6. The upper time-correlated decode trace shows this CAN bus being decoded symbolically, while the lower time-correlated decode trace shows this same CAN bus being decoded in hexadecimal format. This can be useful when it is necessary to correlate raw bits with CAN-dbc symbolic decoding.

.dbc File Security

Most automotive .dbc files that define a particular vehicle are propriety. Since Keysight's InfiniiVision 4000 and 6000 X-Series oscilloscopes are based on an embedded operating system, there is no interface for retrieving the file to get it back out of the oscilloscope after it has been loaded. Even when connected to the Internet via the oscilloscope's LAN port, users can't access the internal CPU flash memory system. In addition, you can easily erase the file using the oscilloscope's standard Secure-Erase feature, which is required by many of Keysight's aerospace and defense customers. Since most .dbc files are protected and propriety, this is a critical security tool for the automotive industry as well. When the Secure-Erase feature is executed, there are no residuals of the .dbc file left in the oscilloscope.
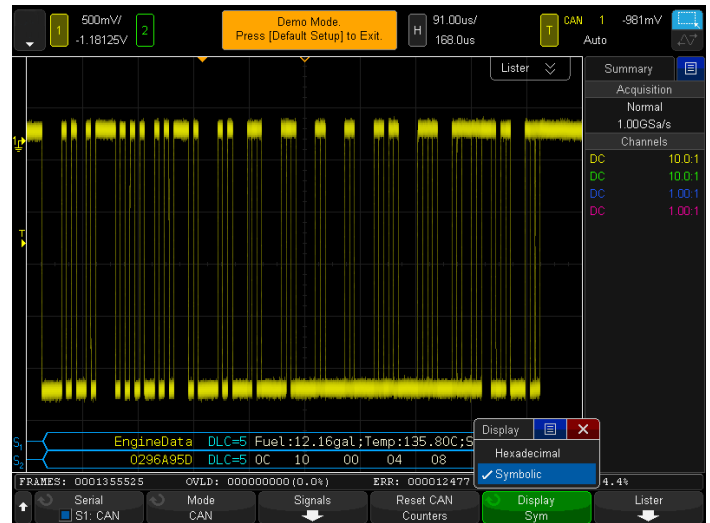

Figure 6a. Decoding a CAN bus symbolically and in hexadecimal format simultaneously.

Figure 6b. Expanded view of symbolic decode trace.

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 "$0x0296A95D_{HEX}$."

Oscilloscopes with CAN-dbc symbolic trigger and decode, such as Keysight's InfiniiVision 4000 and 6000 X-Series oscilloscopes, 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 DSOX4AUTO/DSOX6AUTO options (CAN/LIN) licensed on a Keysight InfiniiVision 4000 or 6000 X-Series oscilloscope.

Related Literature

Publication title	Publication type	Publication number
InfiniiVision 4000 X-Series Oscilloscopes	Data sheet	5991-1103EN
InfiniiVision 6000 X-Series Oscilloscopes	Data sheet	5991-4087EN
Serial Bus Options for InfiniiVision X-Series Oscilloscopes	Data sheet	5990-6677EN
InfiniiVision Oscilloscope Probes and Accessories	Data sheet	5968-8153EN
Oscilloscope Measurement Tools to Help Debug Automotive Serial Buses Faster	Application note	5991-0512EN
Characterizing CAN Bus Arbitration	Application note	5991-4166EN
CAN Eye-diagram Mask Testing	Application note	5991-0484EN
Using Segmented Memory for Serial Bus Applications	Application note	5990-5817EN

Product web site

For the most up-to-date and complete application and product information, please visit our product Web site at:
www.keysight.com/find/dsox4auto
www.keysight.com/find/dsox6auto
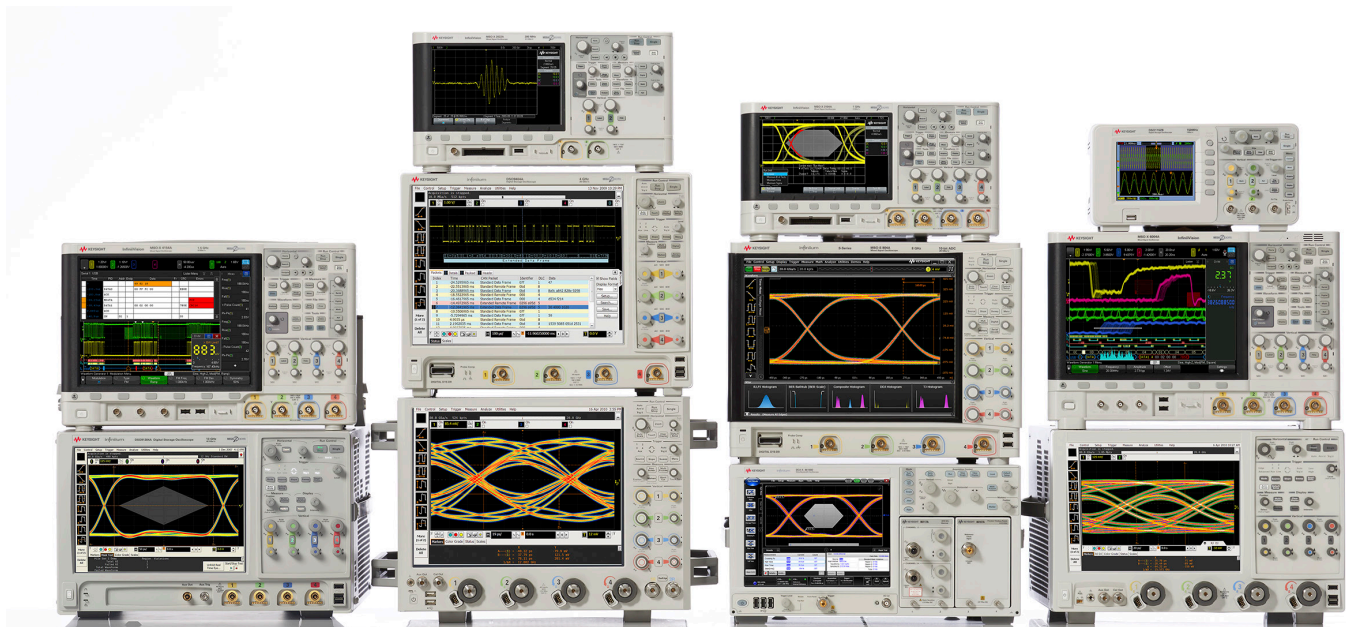
Keysight Oscilloscopes

Multiple form factors from 20 MHz to > 90 GHz | Industry-leading specs | Powerful applications

myKeysight

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

www.keysight.com/go/quality
Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2008
Quality Management System

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/scope

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	1 800 112 929
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-09-23-14)

KEYSIGHT
TECHNOLOGIES