FlexRay Physical Layer Eye-diagram Mask Testing

Application note

Introduction

Eye-diagram mask testing is one of the most important physical layer measurements that you can use to test the overall signal integrity of your FlexRay system. Agilent provides seven different FlexRay mask files based on FlexRay physical layer standards/ specifications for use with InfiniiVision 3000X, 4000X, 6000, and 7000 Series oscilloscopes (DSO or MSO) from Agilent. Which particular mask file you use is determined by the baud rate of your system, the test plane where testing will be performed (receiver input or transmitter output), and the type of output device that may be under test (Bus Driver or Active Star).

Eye-diagram testing is used in a broad range of today's higher speed serial bus applications including FlexRay. An eye-diagram is basically an overlay of digitized bits that shows when bits are valid (high or low). This provides a composite picture of the quality of a system's physical layer characteristics, which includes amplitude variations due to transmission line affects, reflections, over-shoot, ringing, signal edge placement, and jitter.

Agilent scopes are the only scopes that can perform hardware-based FlexRay eye-diagram mask testing. With hardware-based mask testing, up to 200,000 waveforms can be tested per second. This enables you to test more bits faster to insure reliable operation of your FlexRay system.

This application note will first provide you with an overview of the various types of FlexRay eye-diagram mask testing that can be performed. We will then provide you with simple step-by-step instructions on how to set up eye-diagram mask tests on an Agilent InfiniiVision series oscilloscope.

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A basic understanding of FlexRay eye-diagram mask testing

Using FlexRay mask test files only requires that your InfiniiVision series scope be equipped with the latest FlexRay option. The following FlexRay mask test files are available to download from Agilent's website at no charge.

√ FlexRay 10Mbs TP4 Mask.msk

√ FlexRay 5Mbs TP4 Mask.msk

√ FlexRay 2,5Mbs TP4 Mask.msk

√ FlexRay 10Mbs TP1 Mask.msk

√ FlexRay 10Mbs TP1-Incr V Mask.msk

√ FlexRay 10Mbs TP11 Mask.msk

√ FlexRay 10Mbs TP11-Incr V Mask.msk

Receiver Input Mask Testing

The three different TP4 mask files are for testing signals at the input of any FlexRay receiver. You should select the one that matches the baud rate of your FlexRay system.
TP4 mask testing is the most common eye-diagram mask test for evaluating the overall quality of your synchronous multi-node FlexRay system.

The scope's differential probe should be connected as close as possible to the BP and BM inputs of the receiving node that is under test as shown in Figure 1. To test all receiving nodes in the system, multiple TP4 mask tests must be performed with the probe re-connected to each receiving node's BP and BM test points.

Figure 2 shows an example of a FlexRay eye-diagram mask test based on a TP4-10 Mbps standard. The triggering reference for the TP4 mask test is each Byte Start Sequence (BSS) event. This is the same reference signal that FlexRay receivers use to re-synchronize and recover clocks for sampling received data. The Agilent InfiniiVision series oscilloscopes utilize a unique repetitive hardware clock recovery technique to capture and overlay each bit of every byte in the system. We will discuss later how you can "filter" testing on specific frame IDs.
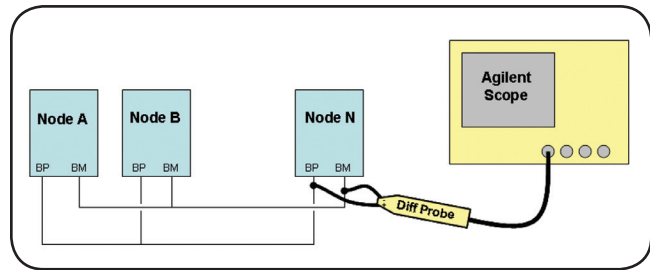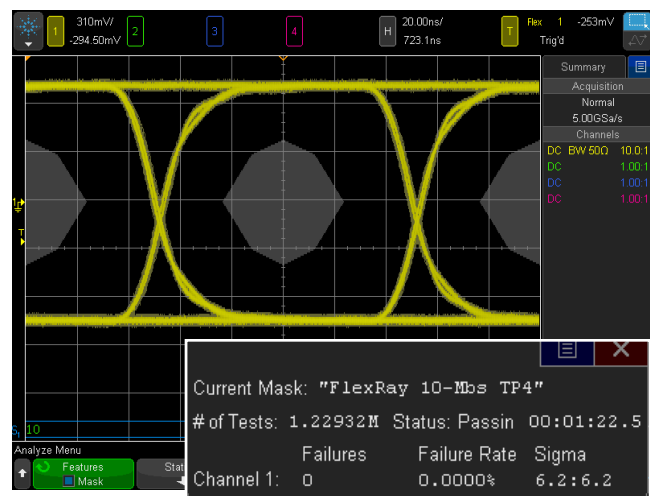

Figure 1: TP4 mask test setup.

Figure 2: FlexRay 10Mbs TP4 mask test on "all" frames at the receiver input of a specific node.

A basic understanding of FlexRay eye-diagram mask testing (continue)

Transmitter Output Mask Testing

The TP1 mask files are for testing the output of either a standard-voltage or increased-voltage Bus Driver (BD) device. The TP11 mask files are for testing the output of either a standard-voltage or increased-voltage Active Star (AS) device.

The differential output characteristics of these devices should be tested using a pulse/pattern generator as a source that drives the single-ended inputs of the device under test. The generator should be setup to output a continuous 1-0-1-0... serial pattern at 10 Mbs (5 MHz square wave) with a near-perfect 100 ns bit time and gated by TxEn-low as shown in Figure 3.

The output of the device under test (bus driver or active star) should be terminated with a 40-Ω resistor in parallel with a 100-pF capacitor across BP (bus plus output) and BM (bus minus output). The scope's differential probe should be connected to BP and BM as close as possible to the output of the device under test.

Figure 4 shows an example of a FlexRay mask test based on a "TP1-Standard V" mask file. TP1 and TP11 mask tests are based on the scope triggering on alternate rising and falling edges of the output differential signal.

Note that 5Mbs and 2.5 Mbs masks do not exist for testing the output characteristics of bus drivers and active stars at TP1 and TP11. Even if these devices will be used in 5 Mbs or 2.5 Mbs FlexRay systems, they should be tested to the 10Mbs standard.

Although the TP1 and TP11 mask files are intended for testing output devices using a signal/pattern generator as the device input source, these mask files can also be used to test actual 10 Mbs FlexRay output traffic generated by a FlexRay Communication Controller within "closed" ECU systems. However, it is critical that the network under test be carefully controlled and the test results should be carefully interpreted.

To test the output characteristics of a particular node within a synchronous system, such as a single ECU along with a second "buddy" node, first of all make sure that the length of the transmission line network is minimized and is tightly controlled. Secondly, be aware that the results of a TP1 or TP11 eye-diagram mask test on this type of 2-node system
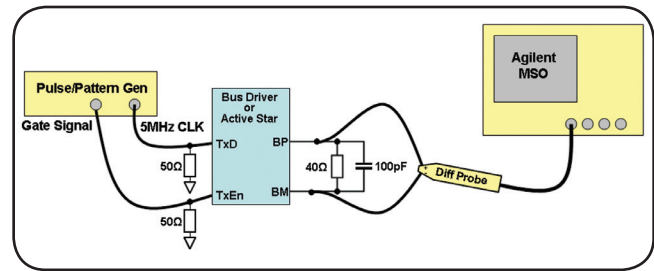

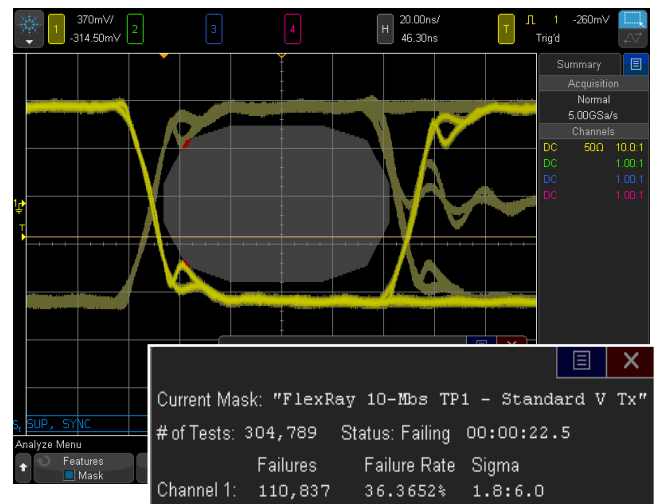*Figure 3: TP1 and TP11 mask test setup.*

Figure 4: TP1-Std V mask test at the output of a Bus Driver device.

will actually consist of both transmitted and received signals (signals generated from the "buddy" node). If the test passes when testing signals generated by both nodes, then you can be confident that the output characteristics of the particular transmitting node that is under test meets required output device specifications. But if the test fails, then this could be due to testing the "received" signals from the "buddy" node. There is no way to isolate TP1 and TP11 eye-diagram testing on particular frame IDs as there is with TP4 eye-diagram mask testing (receiver input testing).

You should be cautioned to never test an actual in-car multi-node system consisting of a long and complex transmission line network (or a simulated in-car network) using either the TP1 or TP11 eye-diagram mask files.

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Step-by-step instructions on how to begin executing a FlexRay eye-diagram mask test

After downloading, unzipping, and storing the various FlexRay eye-diagram mask files onto a USB memory stick, insert the memory stick into the scope's USB port on the scope's front panel and then follow these simple steps:

1. Turn **OFF** all channels of the oscilloscope except for the channel that the differential probe is connected to. If you plan to use channel-1, it is recommended that you begin by pressing the **[Default Setup]** front panel key.

2. Press the **[Save/Recall]** front panel key.

3. Press the **Recall** menu softkey.

4. Press the **Recall: XXX** softkey (left-most menu key), and then select **Mask** as the file type to recall using the **selection knob**.

5. Press the **Location** softkey key, and then select the specific mask file to recall from the "/usb0" drive using the selection knob (shown in Figure 5).

6. Press the **Press to Recall** softkey.

When the mask file is loaded, in addition to recalling the pass/fail mask, the scope automatically detects which channel of the scope is turned on, sets the probe attenuation factor and input coupling, optimizes the V/div setting, sets the trigger level, and sets up the timebase to display two bits centered on-screen. In addition, the scope will perform a one-time time-skew calibration in order to place the mask in its proper location relative to the trigger event. The scope will then begin running the mask test sequence.

When the mask test sequence is running repetitively, you cannot change the scope's timebase settings (s/div and delay). Although you have the ability to re-scale the vertical settings of the scope after the mask test sequence begins, after making any vertical scale changes (V/div and/or offset) or trigger level changes, you should press the **[Run/Stop]** front panel key two times. The first time you press the **[Run/Stop]** key, mask testing will pause. The second time you press the **[Run/Stop]** key, the scope will perform a new time-skew calibration based on the new vertical and trigger level settings, and then begin repetitive mask testing again.

To exit a FlexRay mask test sequence, select either **Clear Mask** or **Mask Test = OFF** in the mask test menu. The scope will then restore most setup conditions to the state they were in prior to beginning the FlexRay eye-diagram mask test
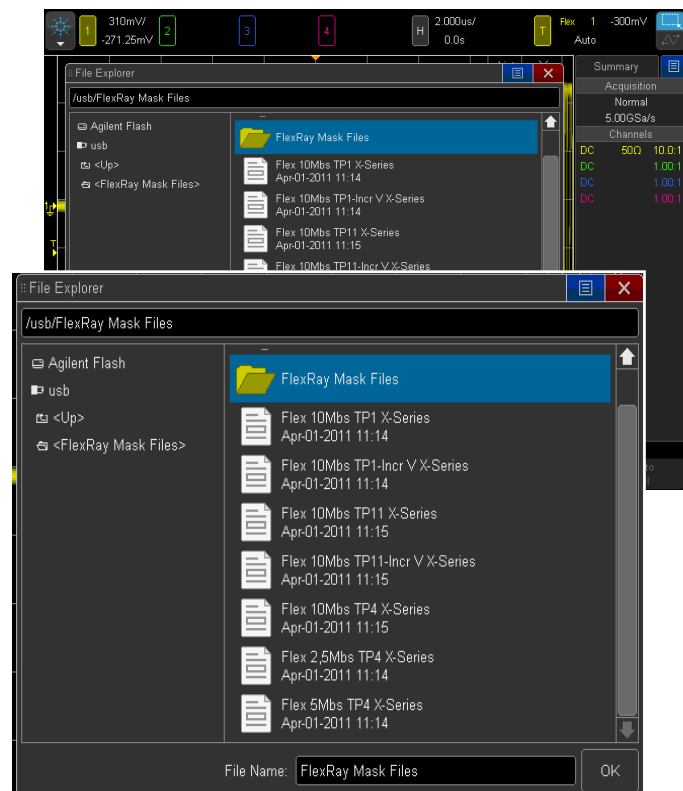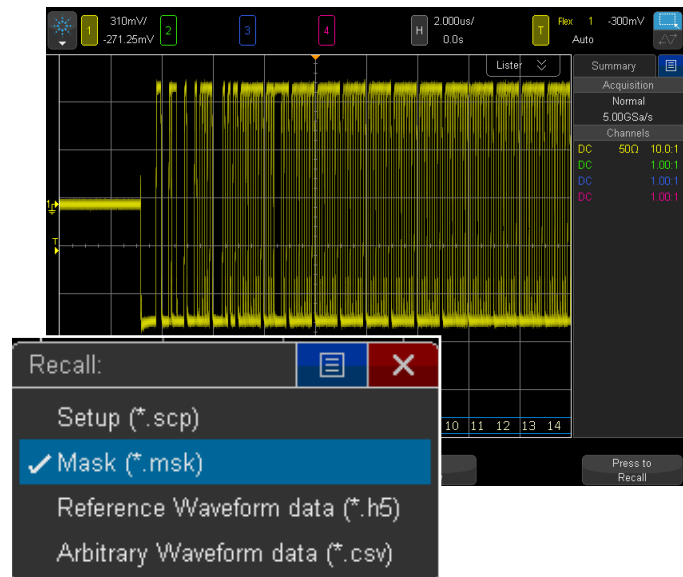

Figure 5. Recalling a FlexRay eye-diagram mask test file.

Performing FlexRay Eye-diagram Mask Tests on Specific Frame IDs

The TP4 mask files provided by Agilent will capture and perform mask testing on all bits of all bytes of all frames in the system. But in order to isolate signal integrity issues down to specific transmitting nodes, it may be desirable to perform TP4 mask testing on user-specified frame IDs. If you are using an Agilent 3000 and 4000 X-Series oscilloscope, select the scope's **[Trigger]** front panel key, and then change from triggering on BSS events from **All** frames to a specific frame ID value.

If you are using an Agilent 7000 Series oscilloscope, triggering on BSS events can be accomplished by editing a single parameter within the TP4 mask file on your PC using a standard text editor, such as Windows NotePad. First, open the TP4 mask file using a common text editor on your PC. Then scroll down to the second to last line of this text file (Figure 6) and modify the "ALL" text that is within the mask test sequence SCPI command **(:MTES:TSEQ:FLEX:TP4 1000000, ALL)** to the frame ID number (decimal format) that you want to test. In other words, if you want to perform an eye-diagram mask test on just frame ID:33, then change "ALL" to "33" **(:MTES:TSEQ:FLEX:TP4 1000000, 33)**.

Note that although not required, you may also want to modify the "mask test label" in this file in order to indicate which frame is being tested. The "mask test label" is specified on the 2nd line near the top of this text file. The default label is, "FlexRay 10-Mbs TP4". This label will appear in the scope's mask test menu after the file in recalled.

When you have finished editing the TP4 mask file, save this file as a text file using a ".msk" extension. It is also recommended to give this edited mask file a new file name in order to preserve the original "all" mask test file. Next, re-insert your memory stick into the scope's USB front-panel port and recall this edited mask file to begin performing TP4 mask testing on a specific frame ID.

Note that it is not generally necessary to test every frame ID generated by each node. The purpose of TP4 mask testing is

```
:CHAN%d:SCAL 500E-03
:CHAN%d:OFFS 0
:CHAN%d:BWL ON
:TRIGger:FLEXray:SOUR CHAN%d
:SBUS:MODE FLEX
:SBUS:DISP 1
:ACQ:MODE RTIM
:ACQ:TYPE NORM
:RUN
:MTES:TSEQ:FLEX:TP4 10000000, ALL
end_setup
```

Figure 6: Editing a TP4 mask file in order to test specific frame IDs.

to test the quality of signals generated from a specific node over the FlexRay network. Signals of different frame IDs that are generated from the same node (same transmitter) will all have similar analog signal quality characteristics, which are usually determined by the network; not the specific frame ID or transmitter. For this reason it is usually only necessary to test one frame ID from each transmitting node in the system in order the test the network from a specific transmitter to a specific receiver test plane.

Figure 7a shows an example of testing a multi-node synchronous FlexRay system at a specific receiver's TP4 input test plane using the mask file's default "all" mask test sequence command. From this test we can see that various transmitting nodes are generating signals that exhibit different characteristics at our particular TP4 test plane. And we can also see that one or more transmitting nodes are producing mask violations due to insufficient signal amplitude. When testing the entire system (all frames), the mask failure rate is approximately 0.5%.

Figure 7b shows a mask test at the same input test plane, but the mask file was edited in order to test just frame ID:13. Now we can see that the mask failure rate is over 30% and we have isolated our mask testing down to the troublesome transmitting node and its associated transmission line network.
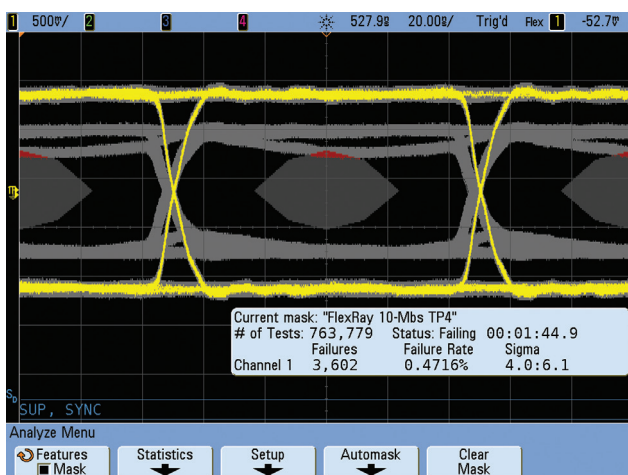

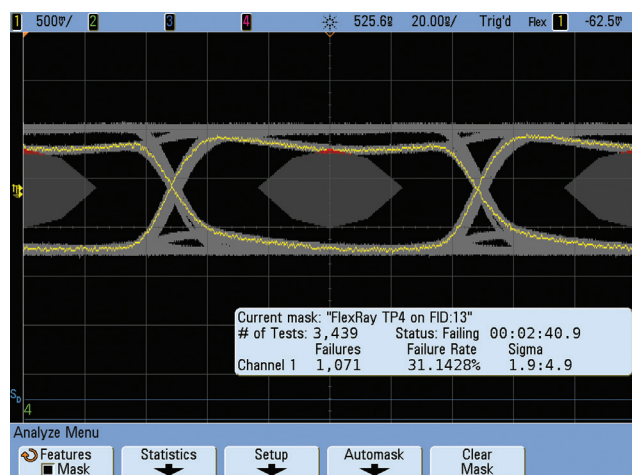*Figure 7a. TP4 mask test on ALL frames.*

Figure 7b. TP4 mask test on frame ID:13.

System Requirements

To perform FlexRay eye-diagram mask testing on a 3000 or 4000 X-Series oscilloscope, your scope must be licensed with the FlexRay triggering and decode option (DSOX3FLEX or DSOX4FLEX), as well as the mask test option (DSOX3MASK or DSOX4MASK). In addition, your 3000 X-Series oscilloscope must be running on firmware revision 2.0 or later.

To perform FlexRay eye-diagram mask testing on a 6000 or 7000 Series oscilloscope, your scope must be licensed with the FlexRay triggering and decode option (Option FLX or N5432C). Although the mask test option is also required, this option (Option LMT) comes standard with the FlexRay option. In addition, your 6000 or 7000 Series oscilloscope must be running on firmware revision 6.0 or later. If your 6000 or 7000 Series oscilloscope is licensed with a previous version of the FlexRay option (Option FRS) that utilizes the VPT1000 FlexRay acquisition module, contact Agilent about upgrading to the latest FlexRay option (Option FLX).
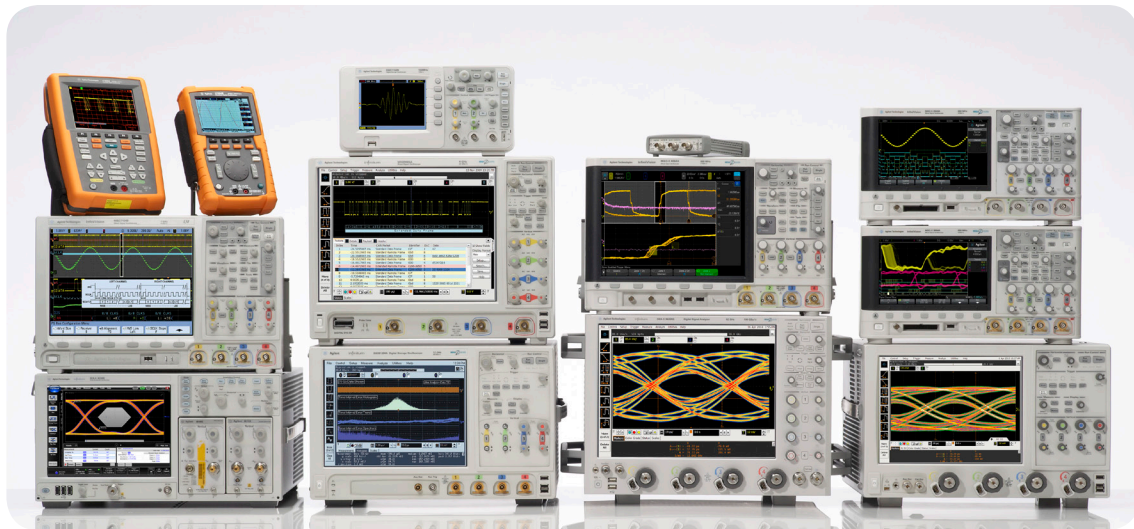
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