USB Eye Diagram Trimming (TPS65950/930/920/921)

ABSTRACT

The USB high-speed (HS) eye diagram is sometimes difficult to achieve. The TPS65950, TPS65930, TPS65921, and TPS65920 devices have trimming features that allow a slight correction of the eye opening. This document explains the use of these features through programming models, a description of the adjustment procedure, and eye pattern examples.

Topic **Page**

1 Introduction

The TPS65950 family devices have adjustment capabilities to help achieve the USB high-speed (HS) eye diagram. This document explains how to use these capabilities.

2 USB Connectivity

2.1 USB Transceiver Connectivity

The USB 2.0 standard defines an HS transfer rate of 480 Mb/s. The transmission is done from a transmitter to a receiver through a differential data line. To limit data reflection, the following must match:

- Transmitter output impedance
- Line characteristic impedance
- Receiver input impedance

The USB 2.0 standard defines a cable with a 90-Ω ± 10% differential impedance and 45-Ω single-ended impedance. Therefore, the USB cable characteristic impedance (ZTERM) is 45 Ω ± 10%. Eye patterns define the quality of the transmitted signal and the sensitivity of the input receiver. USB compliancy tests check these parameters

Figure 1 shows the USB transceiver connectivity.

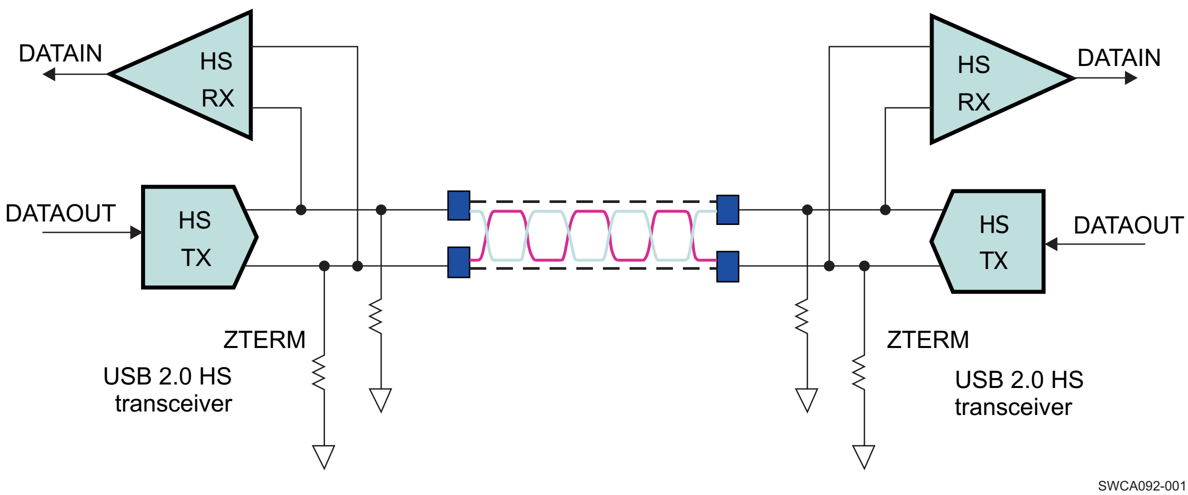

Figure 1. USB Transceiver Connectivity

2.2 USB Connection Simplified Model

Figure 2 shows a simplified model of the driver TX path.

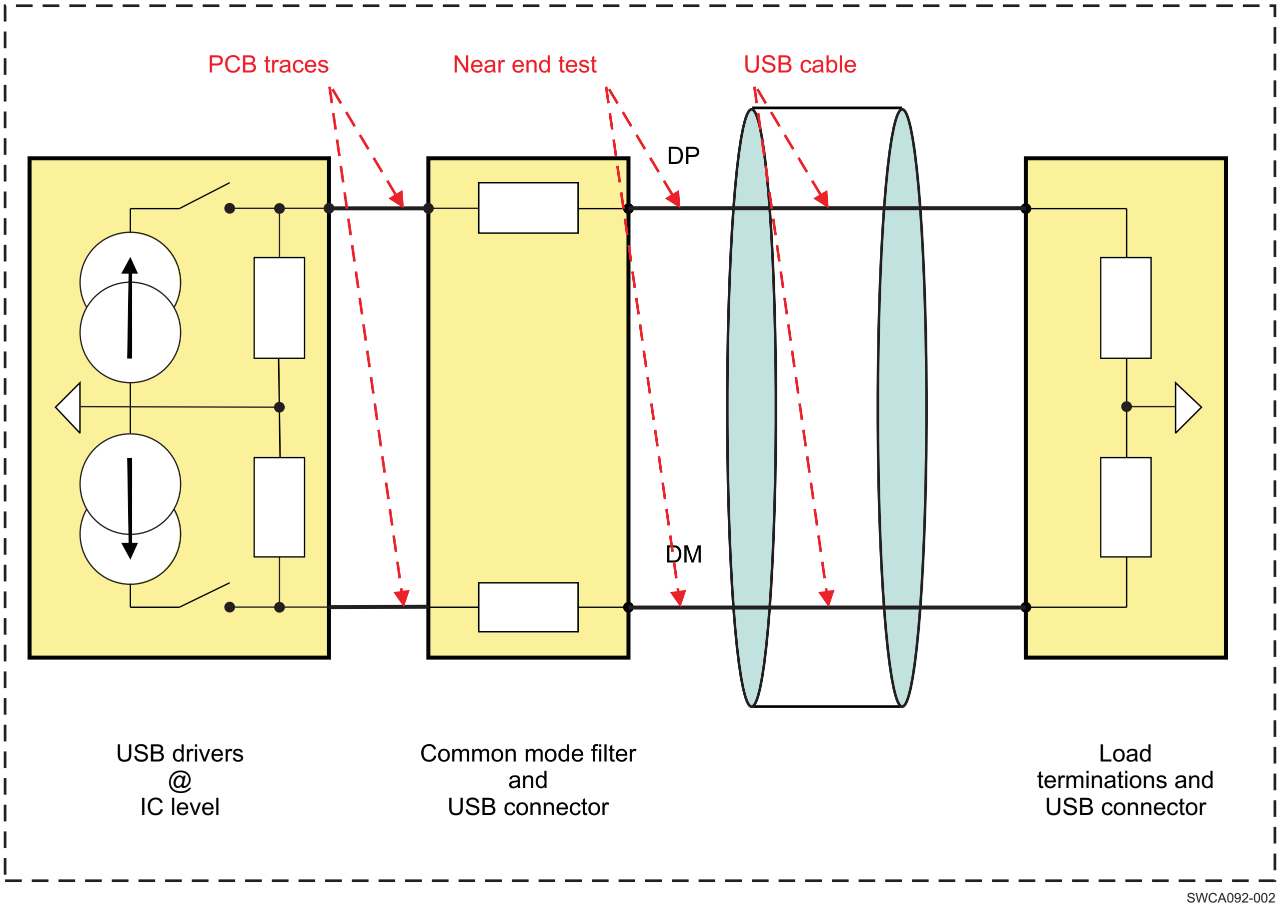

Figure 2. Driver TX Path Simplified Model

2.3 Adjustable Parameters

2.3.1 USB Driver and Connection Simplified Model

Figure 3 shows the simplified model of the USB driver and connection.

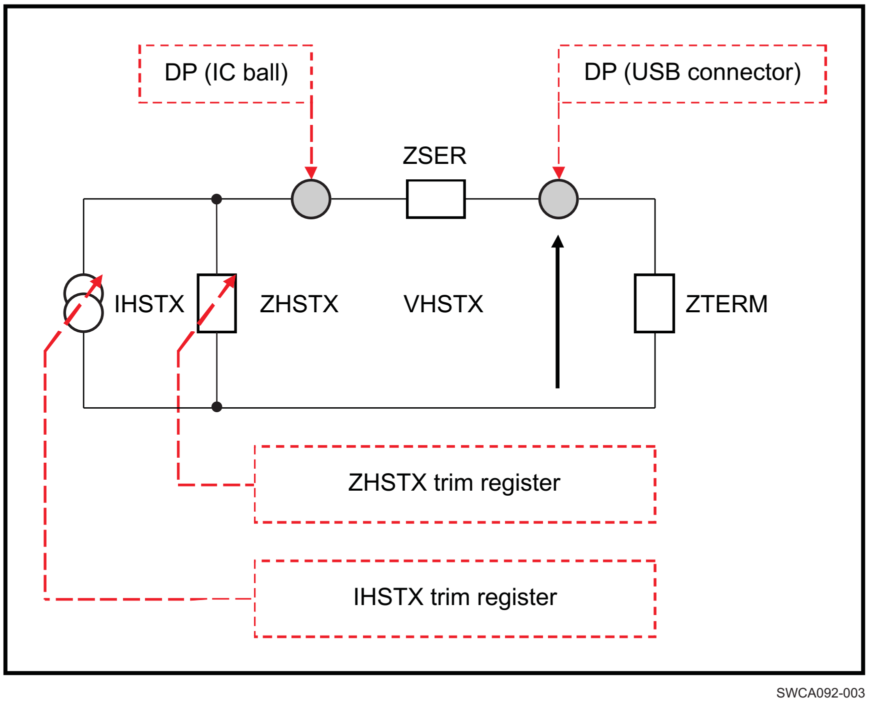

Figure 3. Half USB Driver Model

- IHSTX is a current source that sets the driver strength.
- ZHSTX is a resistor that sets the driver output impedance.
- ZSER is a resistor. It models the resistive path from DP, (DM) IC balls to DP, (DM) connector pin where the near-end measurements are made. The main contributor is the common mode filter.
- ZTERM is the USB cable characteristic impedance.

3 Programming Models

3.1 *TPS65950, TPS65930, and TPS65920*

Two registers control the eye tuning:

- VBUS_EN_TEST: Controls the driver output impedance ZHSTX
- ID_EN_TEST: Controls the driver strength and AC boost feature

3.1.1 Procedure to Access Registers

The VRUSB_3V1, VRUSB_1V8, and VRUSB_1V5 USB regulators must be set to on to start the configuration.

These registers are read/write protected. It is mandatory to:

1. Write: 0xB6 at address 0x97, I^2C address 0x49
2. Update: VBUS_EN_TEST and/or ID_EN_TEST
3. Write: 0x00 at address 0x97, I^2C address 0x49

3.1.2 Driver Output Impedance Adjustment

3.1.2.1 VBUS_EN_TEST Register

This register controls the HS driver output impedance.

Table 1. TPS65950-930-920 VBUS_EN_TEST

I2C Address	0x48		
Physical Address	0xF4	**Instance**	USB
Description	Test enable register – VUSB		
Type	RW		

7	6	5	4	3	2	1	0
RESERVED				COMP_VBUS_EN_BIT3	COMP_VBUS_EN_BIT2	COMP_VBUS_EN_BIT1	RESERVED

Bits	Field Name	Description	Type	Reset
7:4	RESERVED		R	0
3	COMP_VBUS_EN_BIT3	HS 45-Ω data line termination (ZHSDRV) output impedance programming. See Table 2 for details.	RW	0
2	COMP_VBUS_EN_BIT2		RW	1
1	COMP_VBUS_EN_BIT1		RW	0
0	RESERVED		RW	0

3.1.2.2 Output Impedance Programming

Table 2. Output Impedance Programming

COMP_VBUS_EN			ZHSDRV (Ω)
[3]	[2]	[1]	
0	1	0	45
0	1	1	44
1	0	0	43
1	0	1	42

3.1.3 Driver Strength Adjustment

3.1.3.1 ID_EN_TEST Register

This register controls the driver output strength.

Table 3. TPS65950-930-920 ID_EN_TEST

I2C Address	0x48		
Physical Address	0xF5	**Instance**	USB
Description	Test enable register – ID		
Type	RW		

7	6	5	4	3	2	1	0
RESERVED			COMP_ID_EN_BIT4	COMP_ID_EN_BIT3	COMP_ID_EN_BIT2	COMP_ID_EN_BIT1	RESERVED

Bits	Field Name	Description	Type	Reset
7:5	RESERVED		R	0
4	COMP_ID_EN_BIT4	HS differential output voltage (VHSOH) programming. See Table 4 for bit decoding.	RW	0
3	COMP_ID_EN_BIT3		RW	1
2	COMP_ID_EN_BIT2		RW	0
1	COMP_ID_EN_BIT1	HS differential output voltage AC boost enabling 0: Disabled (default) 1: Enabled	RW	0
0	RESERVED	Test mode: (OTG). Keep this bit set to 0.	RW	0

3.1.3.2 Driver Strength Programming

Table 4. TPS65950-930-920 USB Driver Strength Programming

COMP_ID_EN[4:2]			IHSDRV (mA)
[4]	[3]	[2]	
0	0	0	18.091
0	0	1	18.472
0	1	0	18.853
0	1	1	19.234

Table 4. TPS65950-930-920 USB Driver Strength Programming (continued)

COMP_ID_EN[4:2]			IHSDRV (mA)
1	0	0	19.615
1	0	1	19.996
1	1	0	20.377
1	1	1	20.758

3.2 TPS65921

Driver output impedance and driver strength are tuned in the same way as the TP65950 family. The programming model, however, differs. One register holds the entire feature. The register is not write protected.

The USB driver adjustment register is OTHER_FUNC_CTRL2 (see Table 5).

3.2.1 Driver Adjustment

Table 5. TPS65921 OTHER_FUNC_CTRL2

I2C Address	0x48		
Physical Address	0xB8	**Instance**	USB
Description	USB eye diagram trim register. Access is possible only through the I^2C.		
Type	RW		

7	6	5	4	3	2	1	0
ZHSTX		IHSTX				RESERVED	VBAT_TIMER_EN

Bits	Field Name	Description	Type	Reset
7:6	ZHSTX	HS output impedance configuration for eye diagram tuning: 00: 45.455 Ω 01: 43.779 Ω 10: 42.793 Ω 11: 42.411 Ω	RW	0x0
5:2	IHSTX	HS output drive strength configuration for eye diagram tuning: 0000: 17.928 mA 0001: 18.117 mA 0010: 18.306 mA 0011: 18.495 mA 0100: 18.683 mA 0101: 18.872 mA 0110: 19.061 mA 0111: 19.249 mA 1000: 19.438 mA 1001: 19.627 mA 1010: 19.816 mA	RW	0x1

Bits	Field Name	Description	Type	Reset
		1011: 20.004 mA 1100: 20.193 mA 1101: 20.382 mA 1110: 20.570 mA 1111: 20.759 mA IHSTX[0] is also the AC Boost enable. IHSTX[0] = 0: AC Boost is disabled. IHSTX[0] = 1: AC Boost is enabled.		
1	RESERVED	Charge pump enable	RO	0
0	VBAT_TIMER_EN	Enable the VBAT function for BCI.	RW	0

3.2.2 Driver Output Impedance Adjustment

The OTHER_FUNC_CTRL2[7:6] ZHSTX bit field controls the output impedance. Table 6 summarizes the behavior.

Table 6. TPS65921 USB Driver Output Impedance Programming

OTHER_FUNC_CTRL2		ZHSTX (Ω)
[7]	[6]	
0	0	45.455
0	1	43.779
1	0	42.793
1	1	42.411

3.2.3 Driver Strength Adjustment

The OTHER_FUNC_CTRL2[5:2] IHSTX bit field controls the driver current and the AC boost feature. The OTHER_FUNC_CTRL2[5:3] bits set the current source magnitude, while the OTHER_FUNC_CTRL2[2] bit enables the AC_BOOST feature. This function decreases DP (DM) rise and fall time; it keeps the eye amplitude unchanged.

In Table 7, to improve readability, the field corresponding to the OTHER_FUNC_CTRL2[5:2] bit field is named IHSTX. Therefore, IHSTX[0] is OTHER_FUNC_CTRL2[2]. It sets the AC_BOOST feature. IHSTX[3:1] are OTHER_FUNC_CTRL2[5:3]; they set the driver strength.

3.2.3.1 How to Read the IHSTX Current Table

The IHSTX table is split over AC_BOOST to improve readability of the document.

3.2.3.2 No AC Boost

AC boost is disabled when IHSTX[0] = 0; IHSTX[3:1] bits set the magnitude.

Table 7. TPS65921 USB Driver Strength Programming – No AC Boost

No AC Boost (IHSTX[0] = 0)			
IHSTX[3]	IHSTX[2]	IHSTX[1]	Drive Strength (mA)
0	0	0	17.928
0	0	1	18.306
0	1	0	18.653
0	1	1	19.061
1	0	0	19.438
1	0	1	19.816
1	1	0	20.193

Table 7. TPS65921 USB Driver Strength Programming – No AC Boost (continued)

No AC Boost (IHSTX[0] = 0)			
1	1	1	20.570

3.2.3.3 AC Boost Enabled

AC boost is enabled when IHSTX[0] =1; the IHSTX[3:1] bits set the current magnitude.

Table 8. TPS65921 USB Driver Strength Programming – AC Boost

With AC Boost (IHSTX[0] = 1)			
IHSTX[3]	**IHSTX[2]**	**IHSTX[1]**	**Drive Strength (mA)**
0	0	0	18.117
0	0	1	18.495
0	1	0	18.872
0	1	1	19.249
1	0	0	19.627
1	0	1	20.004
1	1	0	20.382
1	1	1	20.759

4 Adjustment Procedure

To adjust the eye diagram:

1. Adjust the driver impedance (ZDRV) to ensure correct impedance matching between the device and the PCB. Remember that only the DC resistances of the routed paths and components can be compensated.
2. Adjust the driver strength to achieve the correct eye amplitude.

5 Conclusion

TPS65950/930/920/921 have USB eye diagram capability. This document explains how to exercise it.

Appendix A Measurements and Examples

A.1 Measurements Setup

Figure 4 shows the USB eye diagram setup.

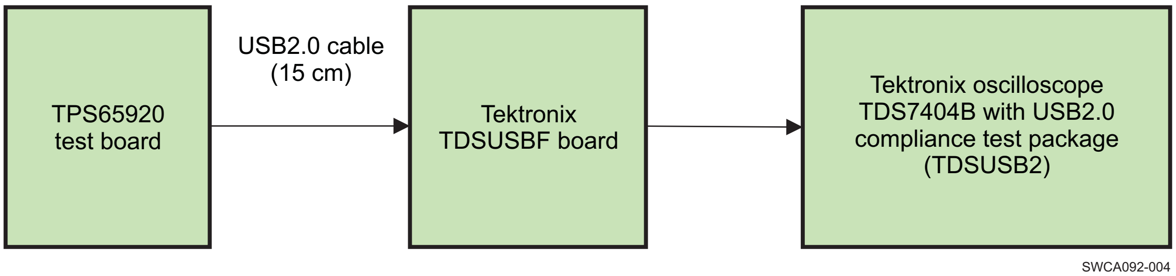

Figure 4. USB Eye Diagram Setup

A.2 Eye Pattern Examples (TPS65920)

The plots in Figure 5 through Figure 14 are related to the TPS65920. Other devices of the family behave in the same way.

A.2.1 Driver Strength (IHSTX) Trim Impact

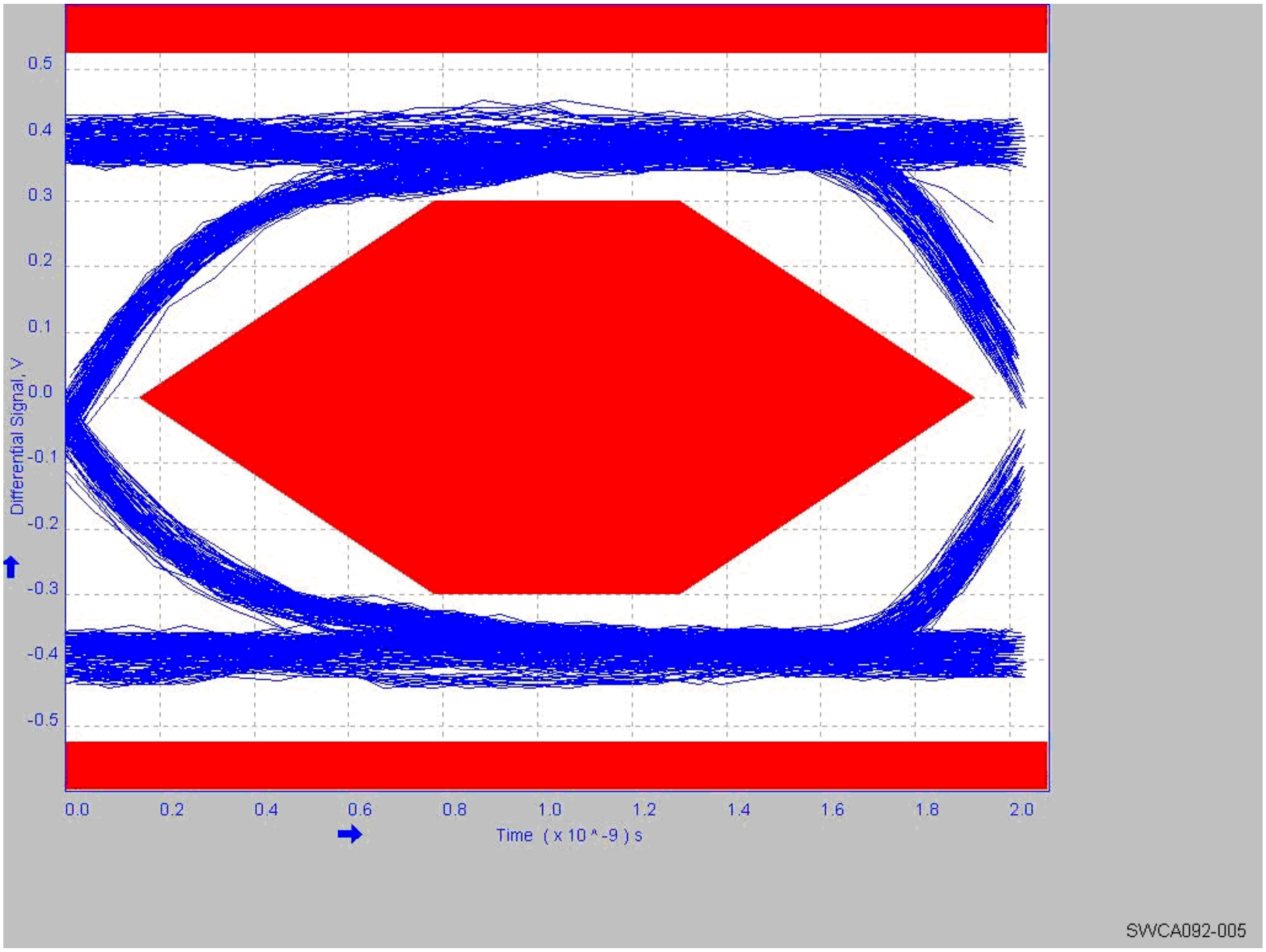

Figure 5. TPS65920 – COMP_ID_EN[4:2] = 0b000

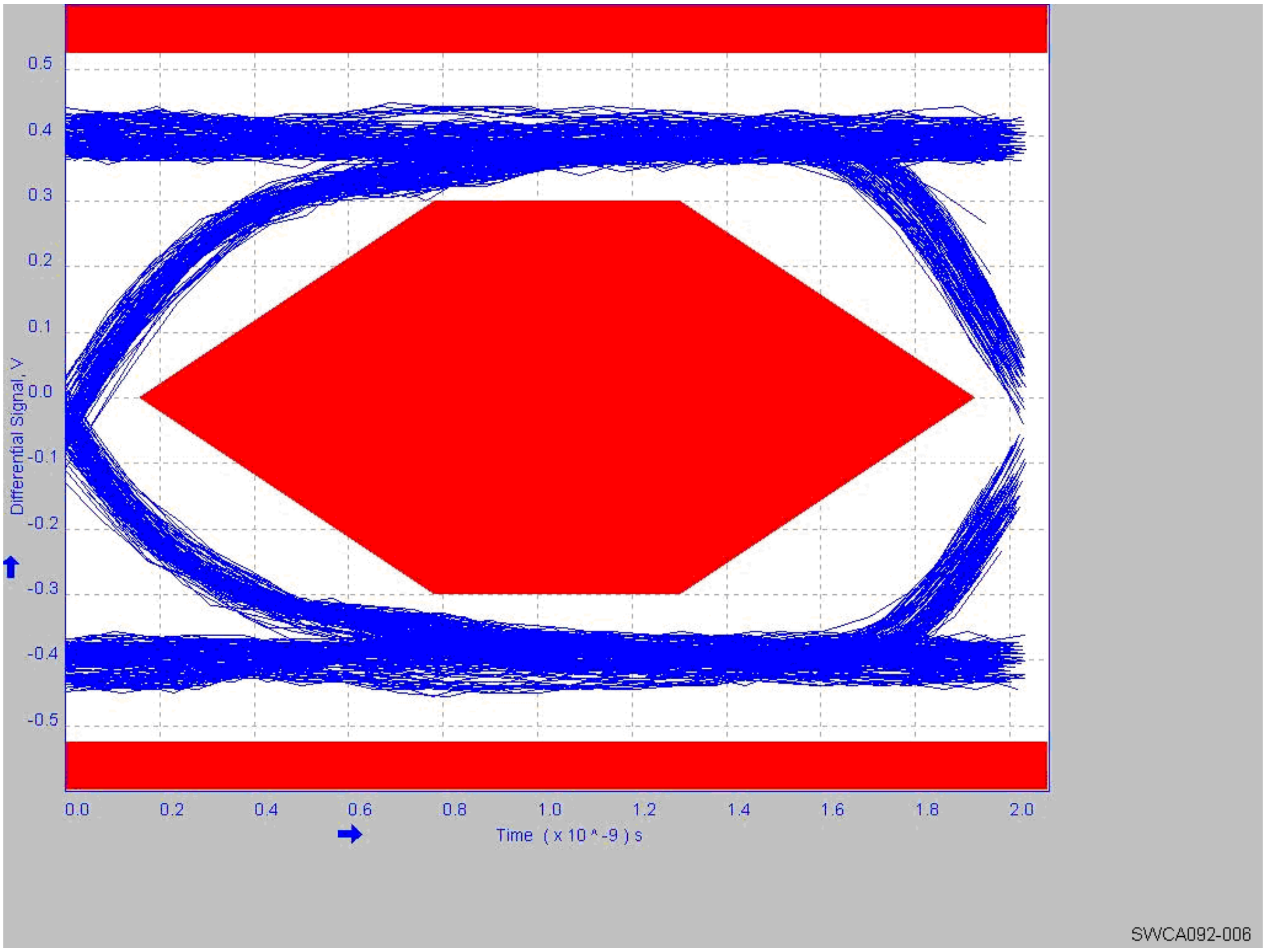

Figure 6. TPS65920 – COMP_ID_EN[4:2] = 0b001

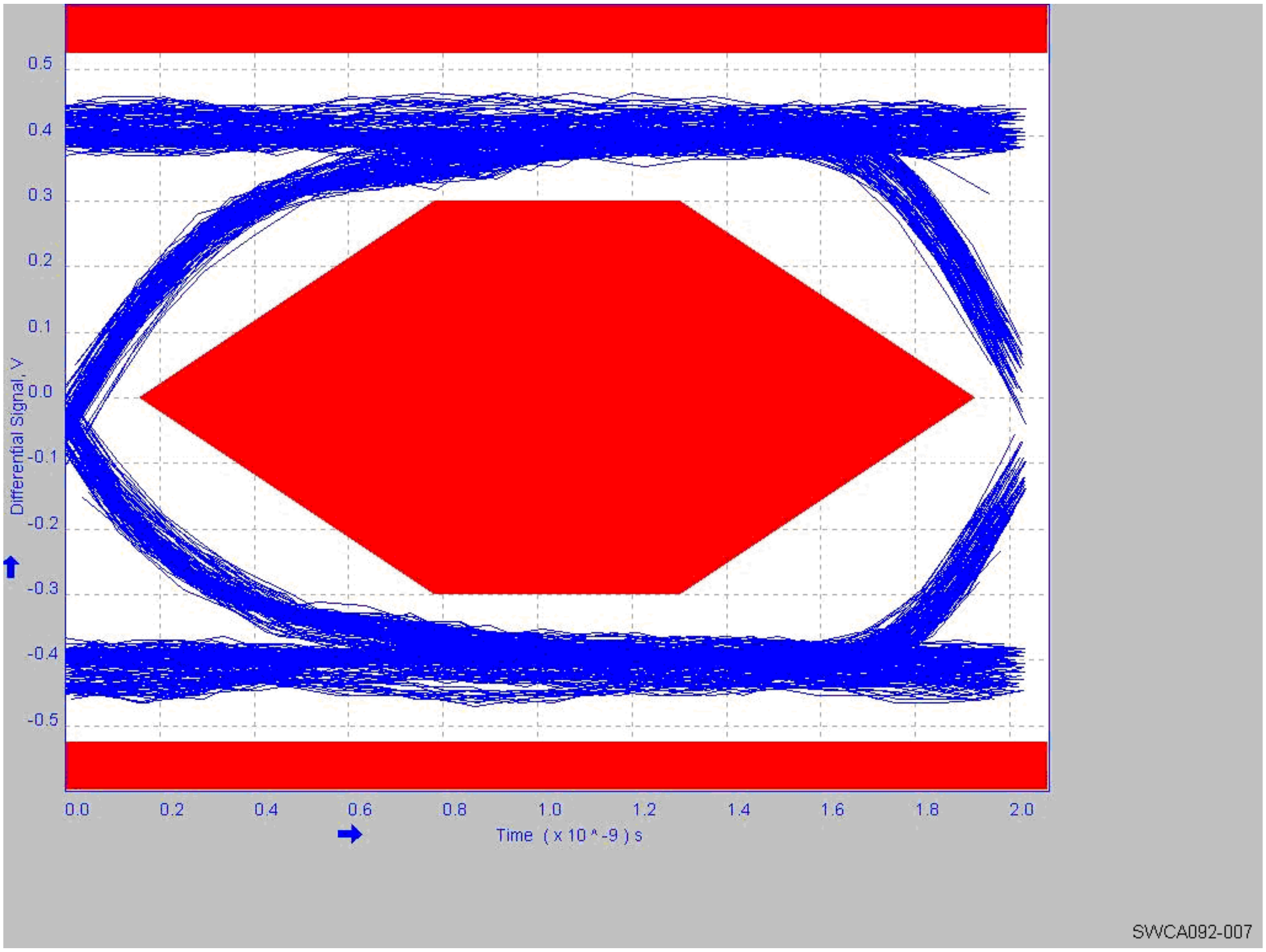

Figure 7. TPS65920 – COMP_ID_EN[4:2] = 0b010

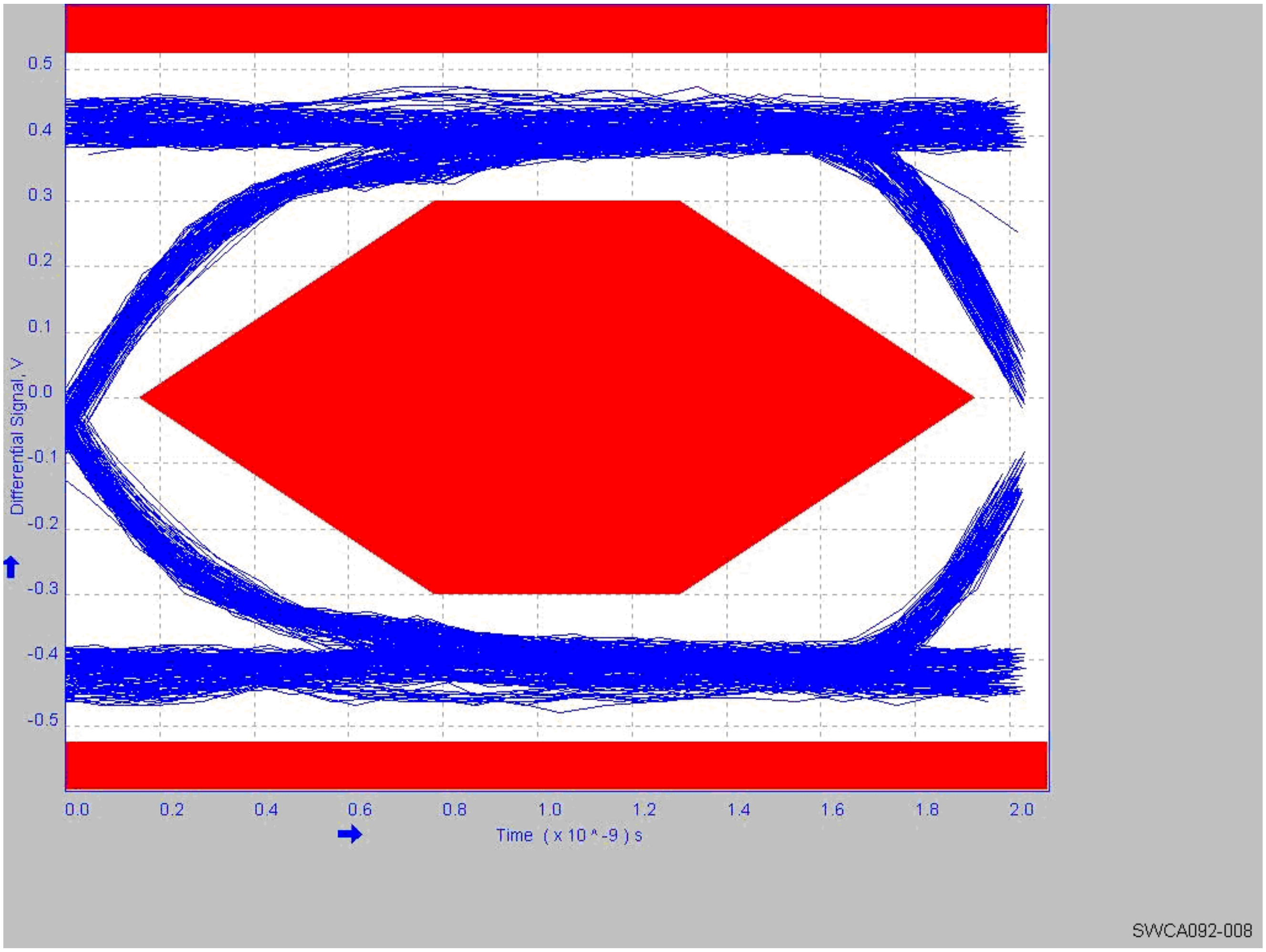

Figure 8. TPS65920 – COMP_ID_EN[4:2] = 0b011

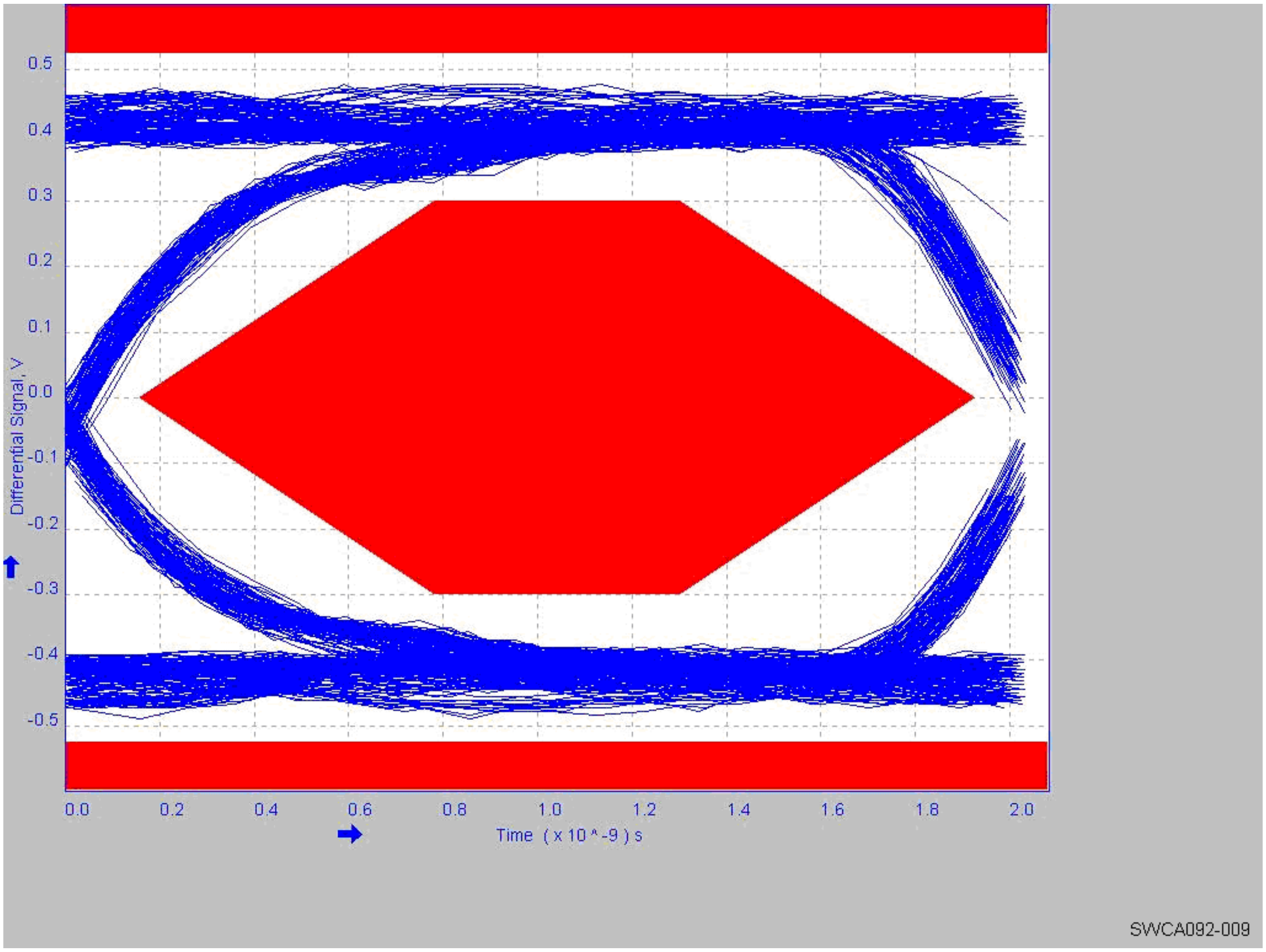

Figure 9. TPS65920 – COMP_ID_EN[4:2] = 0b100

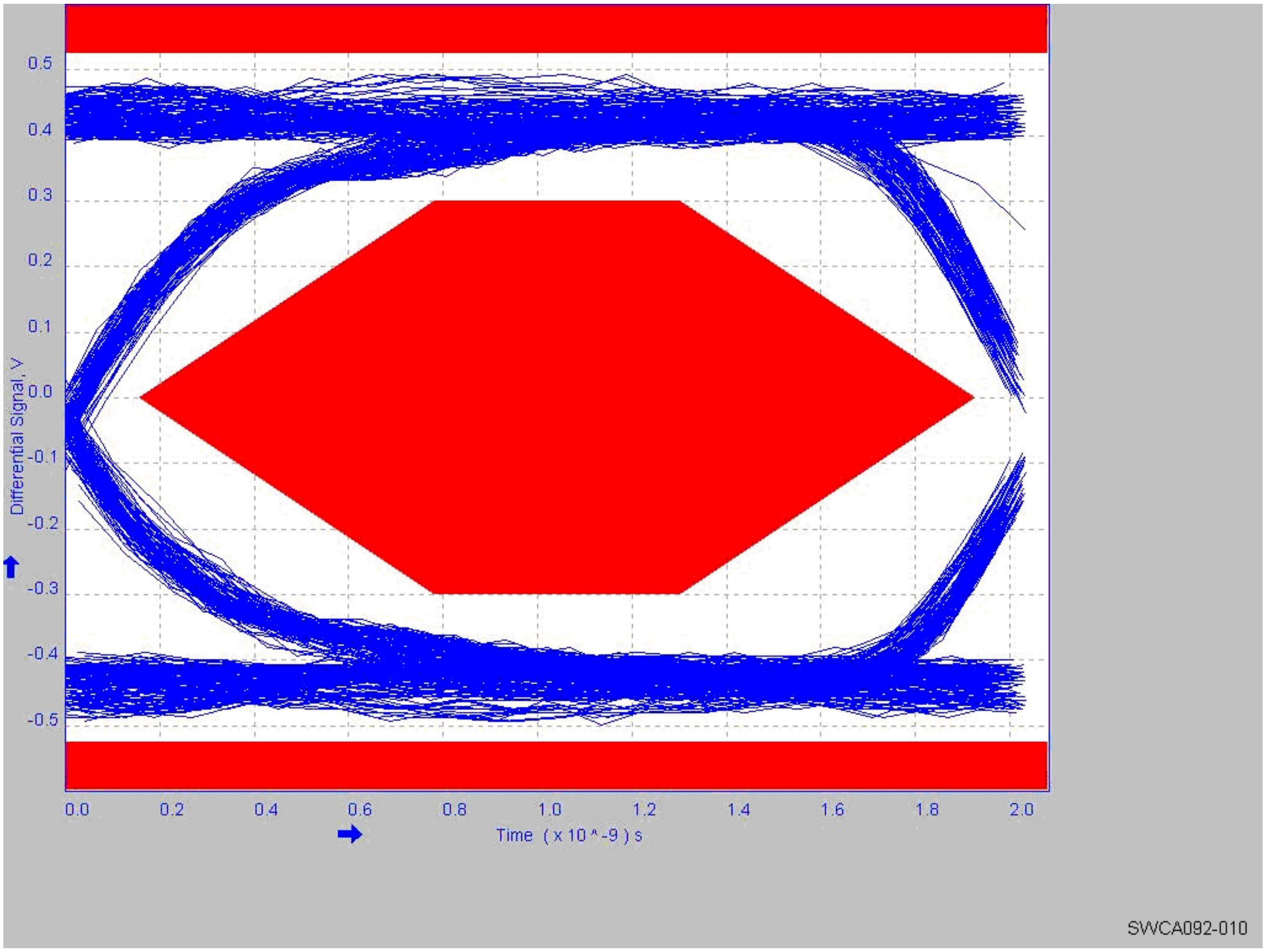

Figure 10. TPS65920 – COMP_ID_EN[4:2] = 0b101

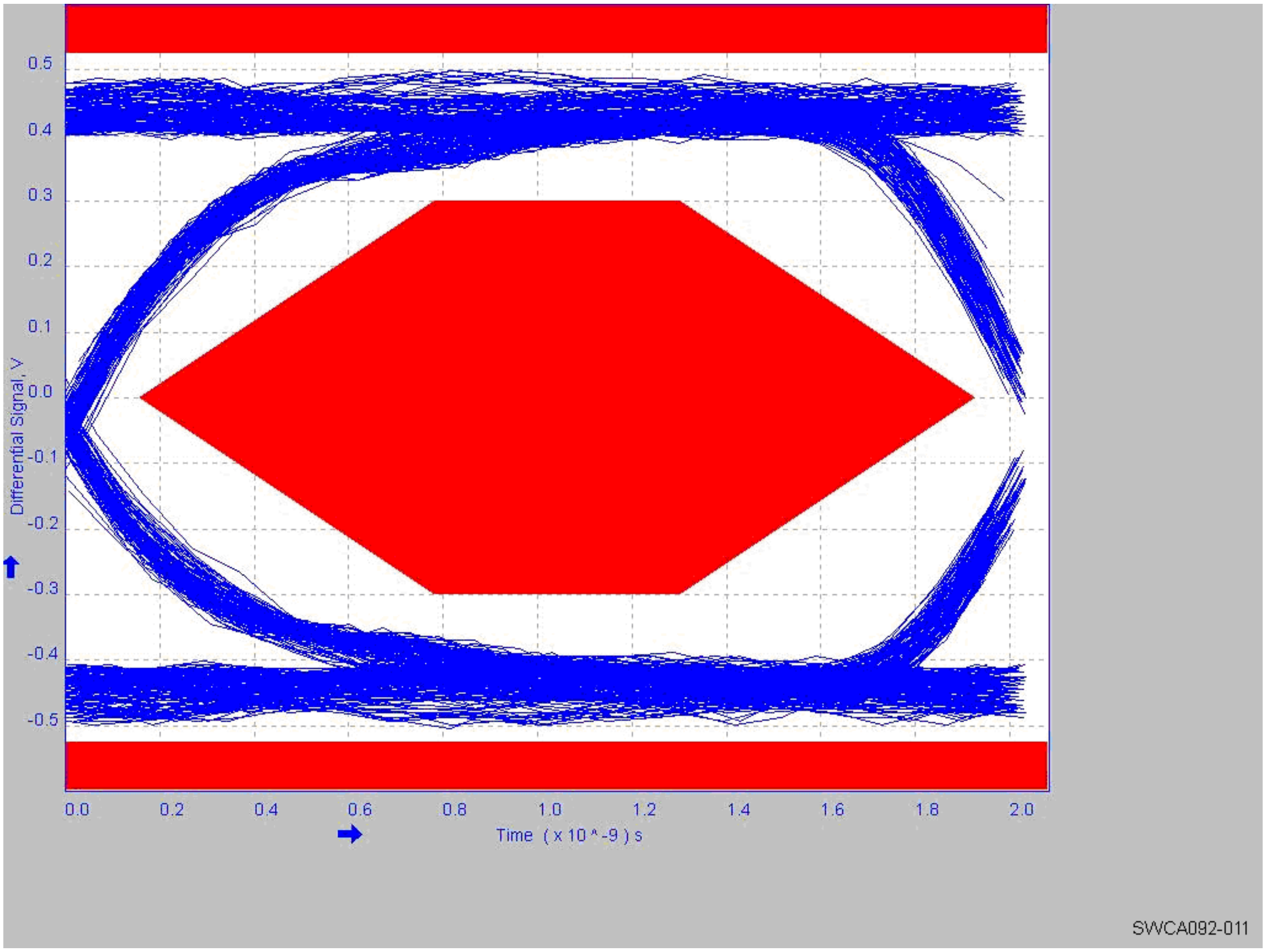

Figure 11. TPS65920 – COMP_ID_EN[4:2] = 0b110

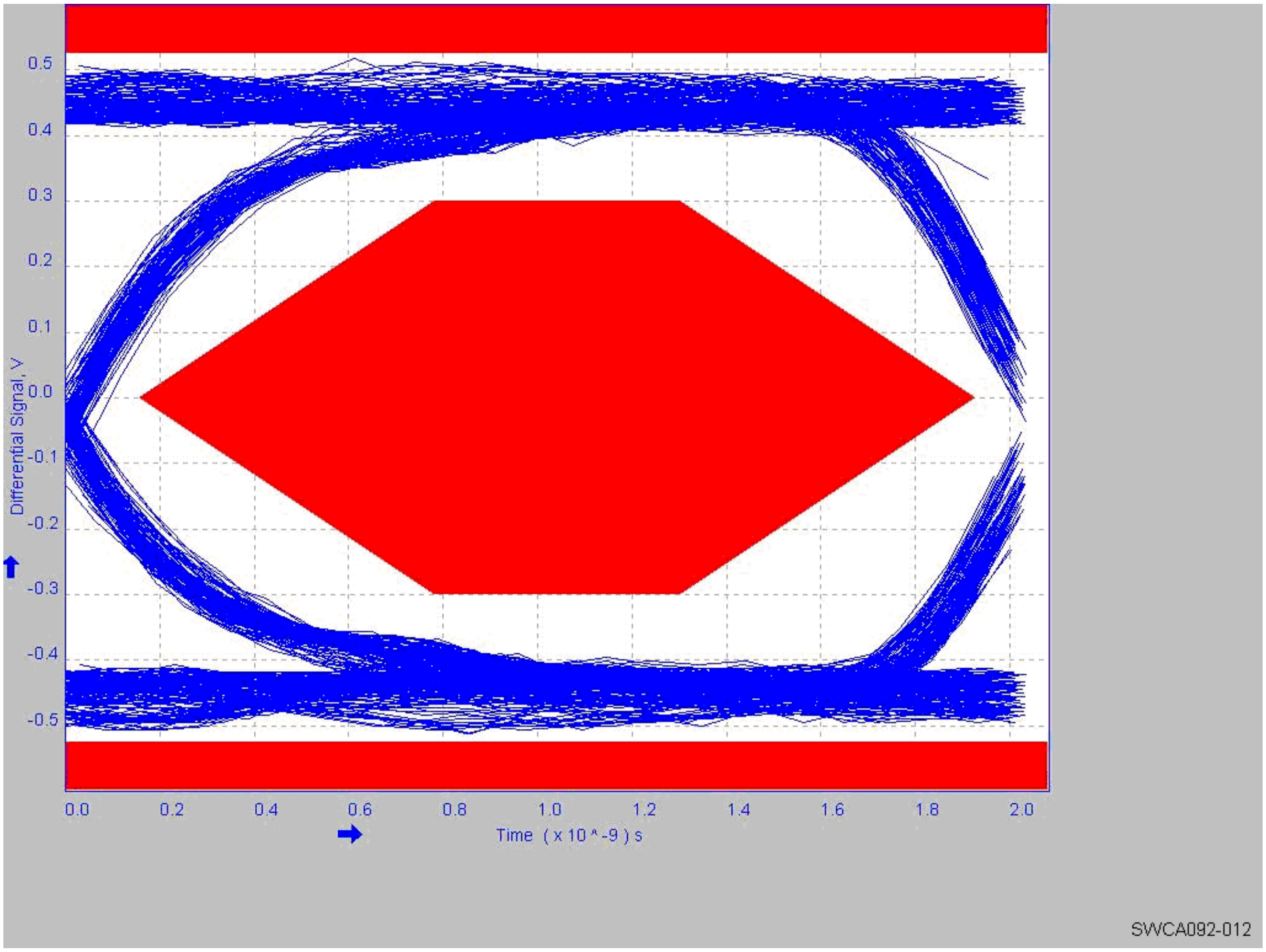

Figure 12. TPS65920 – IHSTX = 0b111

A.2.2 AC_Boost (TPS65920)

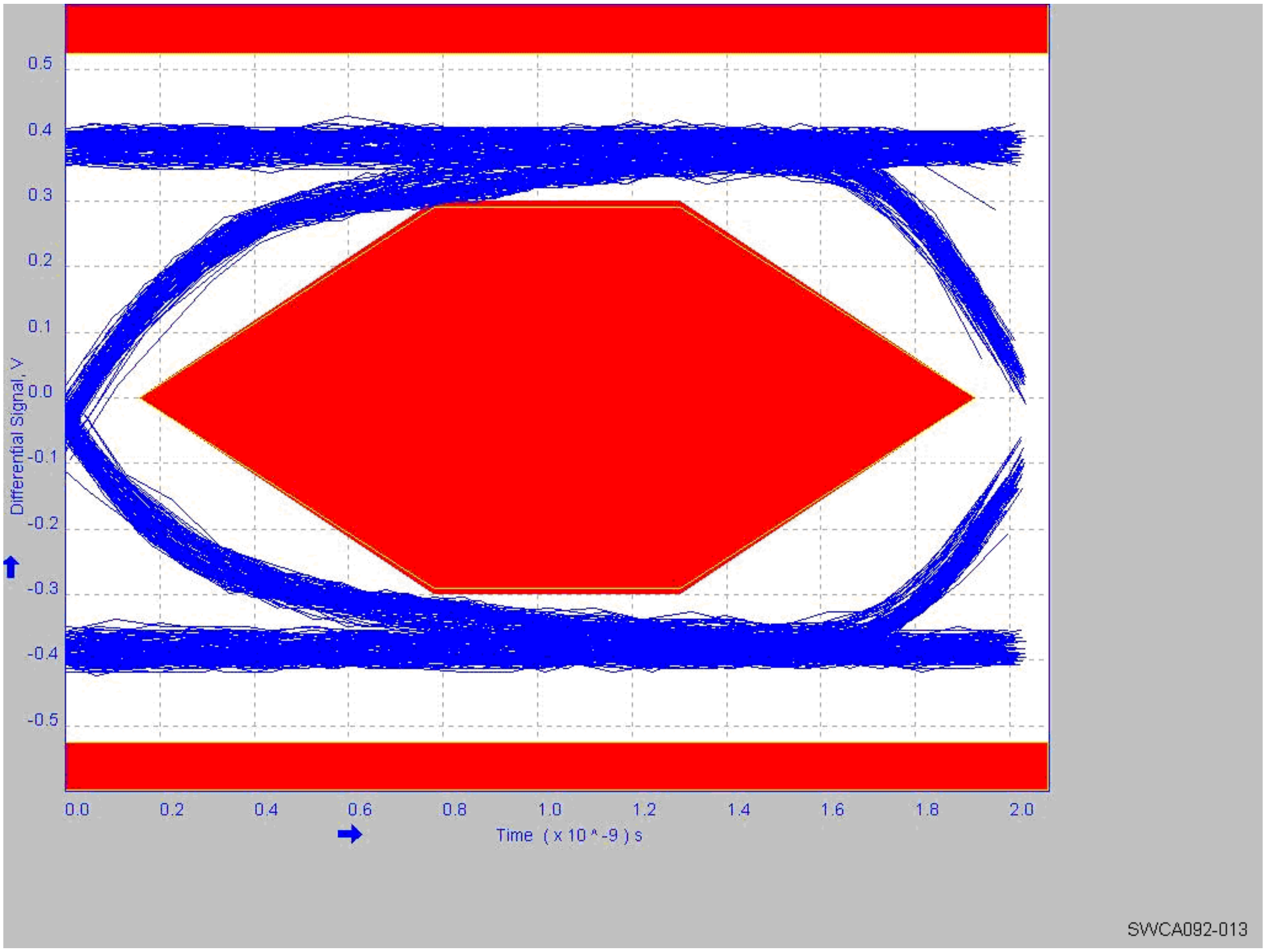

Figure 13. No Boost – COMP_ID_EN[4:2] = 0b010

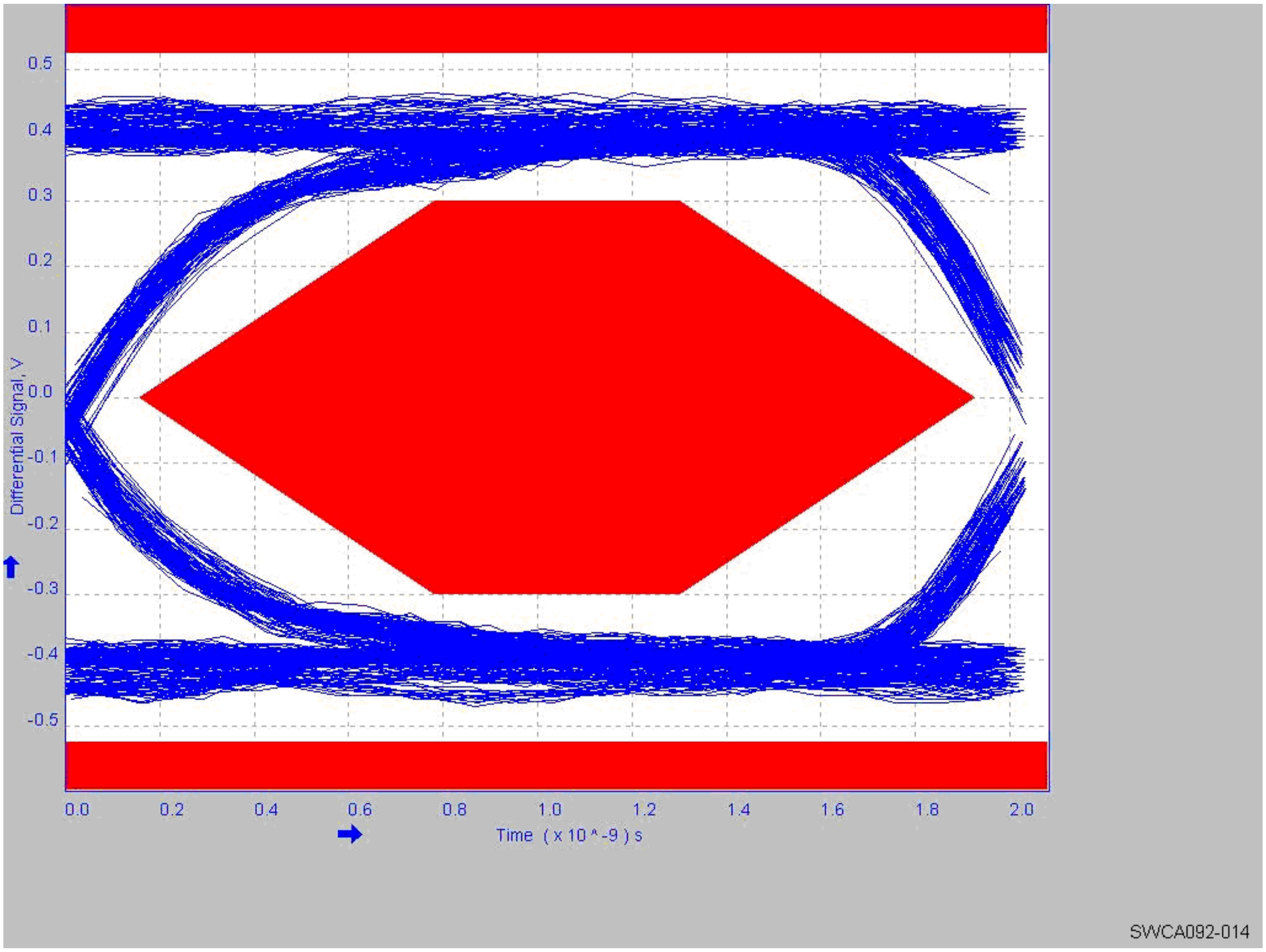

Figure 14. With Boost – COMP_ID_EN[4:2] = 0b010

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