TIDA-00194

TI Design: Skylake Power Delivery

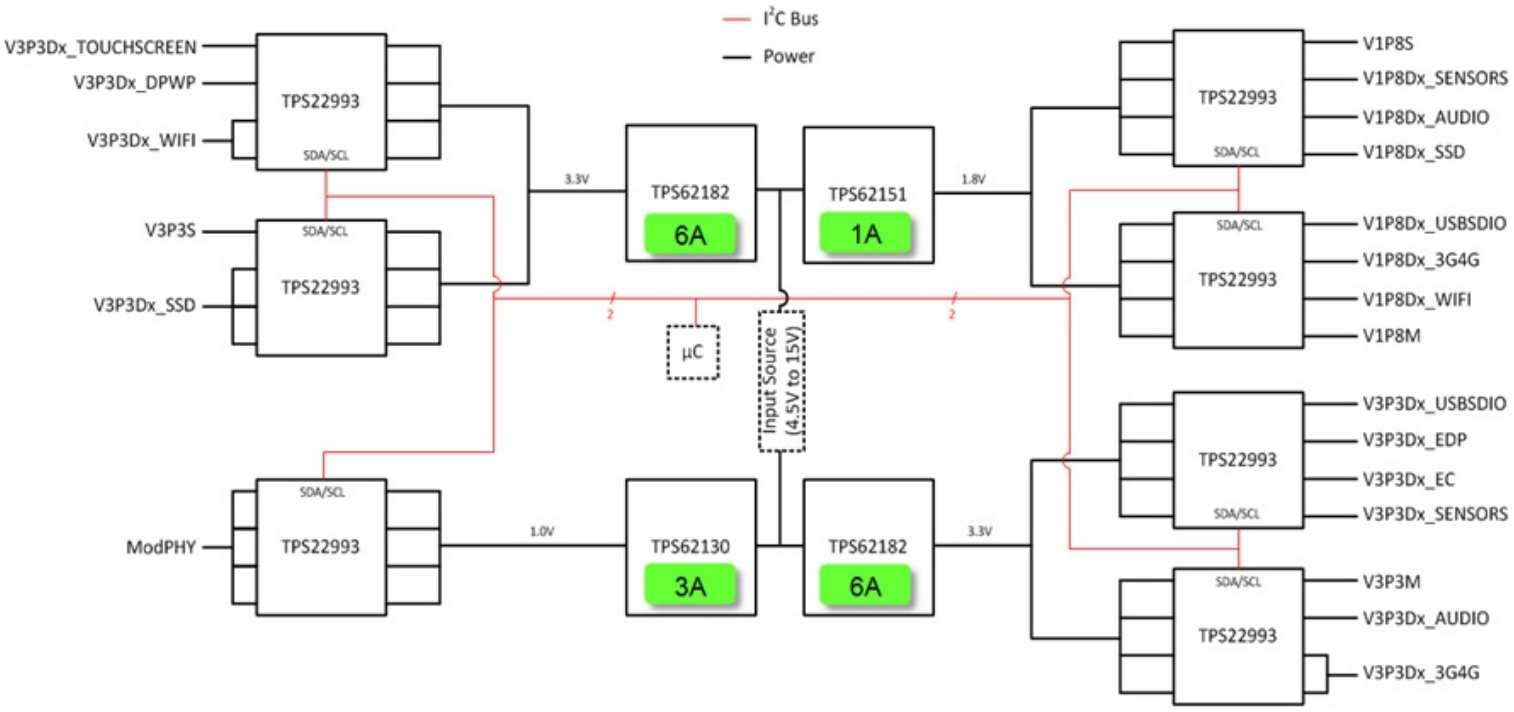
Test Report

Texas Instruments

1. Description

TI Design: Skylake Power Delivery contains four DC-DC converters & seven TPS22993 load switches. The DC-DC converters used in the design are TPS62151 (x1), TPS62182 (x2), and TPS62130 (x1). TPS22993 is a quad channel load switch with each switch capable of supporting 1.2A of load current. Support for higher load currents is made possible by combining two or more channels together as is demonstrated in the design. The TPS22993 load switches are I2C programmable (ON_delay, Rise Time, Discharge Resistance) and can be controlled by either I2C or GPIO. A PC based GUI was developed to communicate with the board via the USB2ANY which generates the I2C and GPIO control signals. The board is rated to operate with input supply voltages from 4.5V to 15V to emulate 2S & 3S battery topologies. LEDs are used to indicate the ON state of the DC-DC convertors (Blue) and 21 voltage rails (Green). A total of 21 rails can be switched using this design with load currents varying from 0.01A to 2.5A. Sense test points were used for taking the voltage measurements.

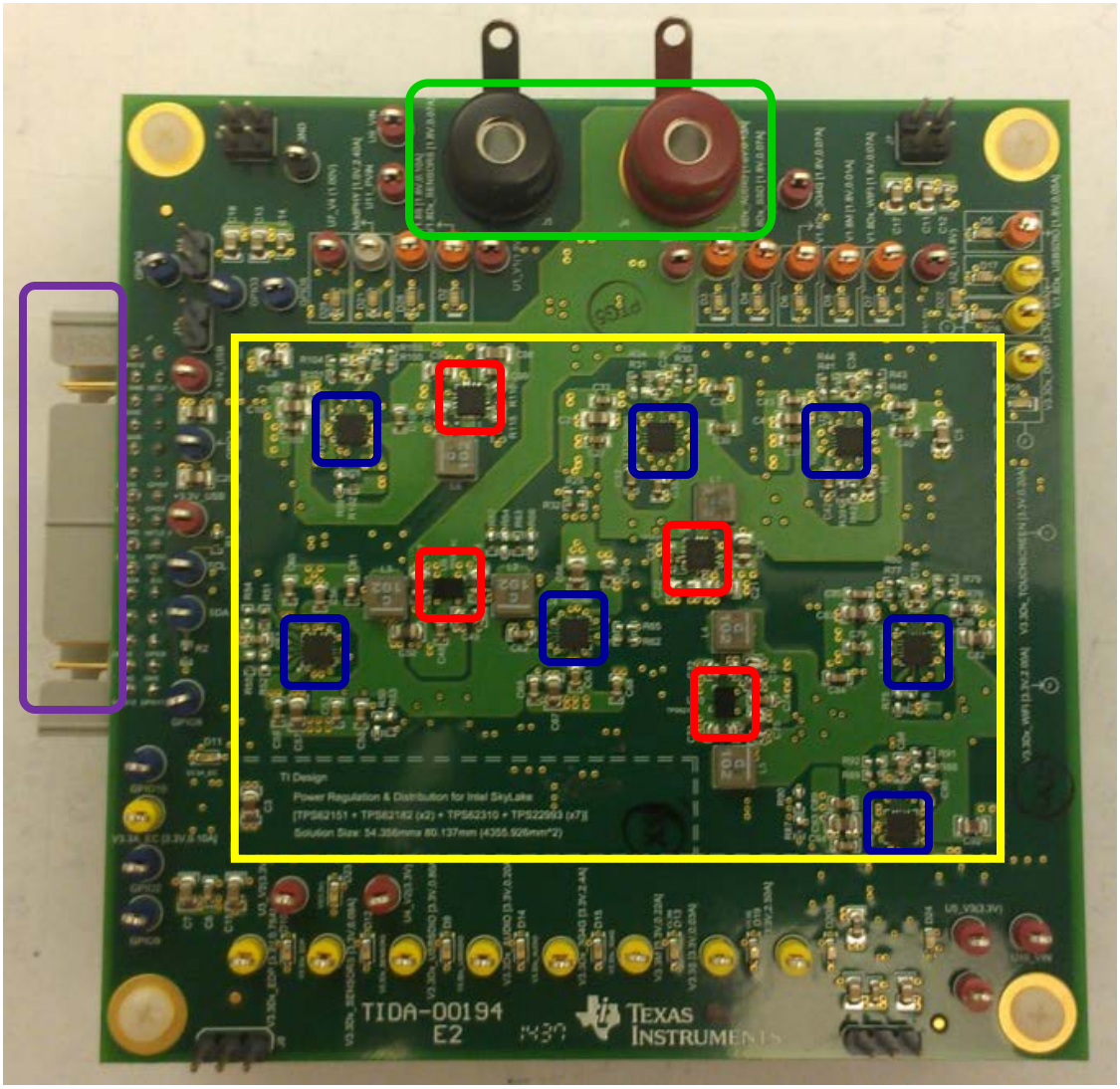
2. System Block diagram



3. TI Design Voltage Rails

DC-DC Part #	Rail Voltage	DC-DC Load	Ultrabook Rail Name	TPS22993 LS Channel	LS Load
U8_TPS62151	1.8V	0.57A	V1.8S	U1_CH1	0.10A
			V1.8Dx_SENSORS	U1_CH2	0.07A
			V1.8Dx_AUDIO	U1_CH3	0.13A
			V1.8Dx_SSD	U1_CH4	0.07A
			V1.8Dx_USBSDIO	U2_CH1	0.05A
			V1.8Dx_3G4G	U2_CH2	0.07A
			V1.8Dx_WIFI	U2_CH3	0.07A
			V1.8M	U2_CH4	0.01A
U9_TPS62182	3.3V	4.56A	V3.3Dx_USBSDIO	U3_CH1	0.80A
			V3.3Dx_EDP	U3_CH2	0.75A
			V3.3A_EC	U3_CH3	0.10A
			V3.3Dx_SENSORS	U3_CH4	0.05A
			V3.3M	U4_CH1	0.22A
			V3.3Dx_AUDIO	U4_CH2	0.20A
			V3.3Dx_3G4G	U4_CH3	2.4A
				U4_CH4	
U10_TPS62182	3.3V	5.23A	V3.3Dx_TOUCHSCREEN	U5_CH1	0.20A
			V3.3Dx_DPWP	U5_CH2	0.50A
			V3.3Dx_WIFI	U5_CH3	2.00A
				U5_CH4	
			V3.3S	U6_CH1	0.03A
			V3.3Dx_SSD	U6_CH2	2.50A
				U6_CH3	
				U6_CH4	
U11_TPS62130	1V	2.4A	ModPHY	U7_CH1	2.4A
				U7_CH2	
				U7_CH3	
				U7_CH4	

4. *TI Design: Skylake Power Delivery* – Board Overview



= DC-DC converter

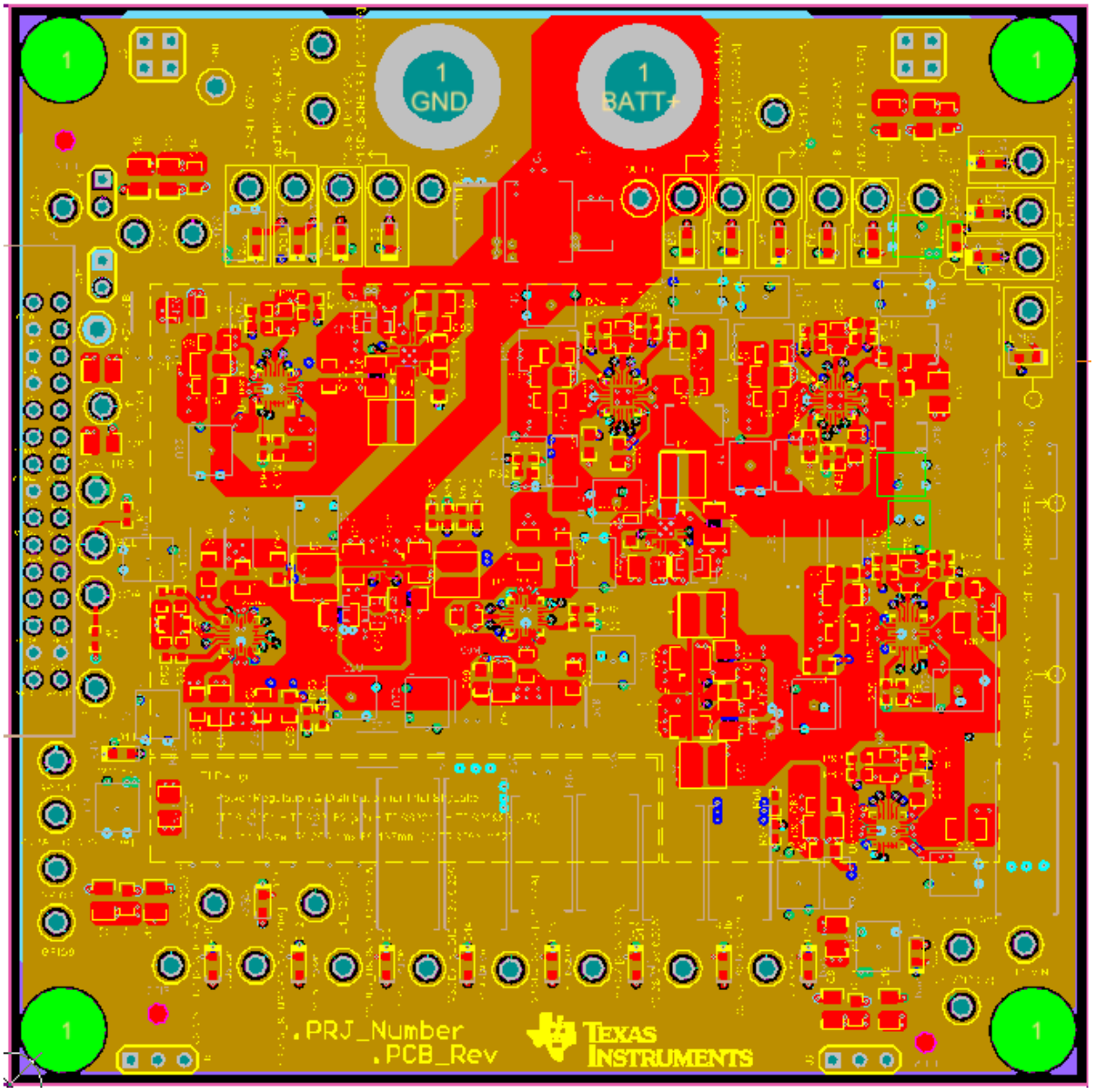
= TPS22993 Load Switch

= USB2ANY Connector

= PWR & GND connections of the board

= Solution size (excluding debug circuitry)

5. PC Board Layout

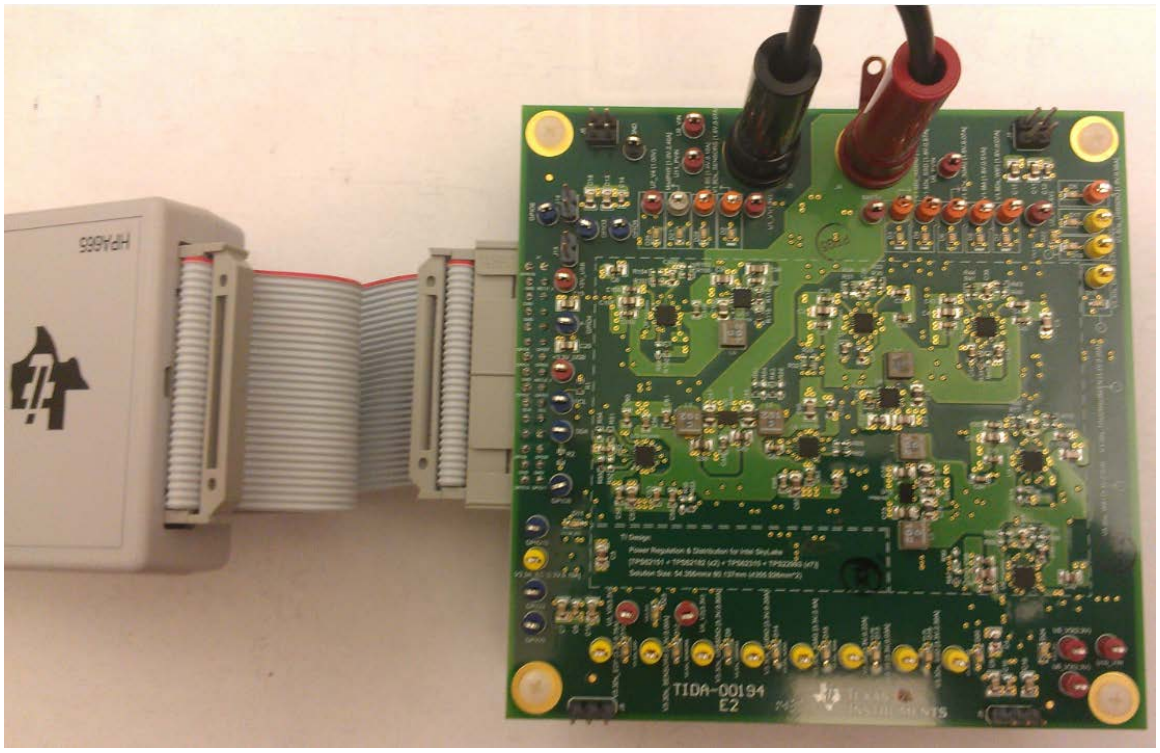


6. Important Thermal Notice

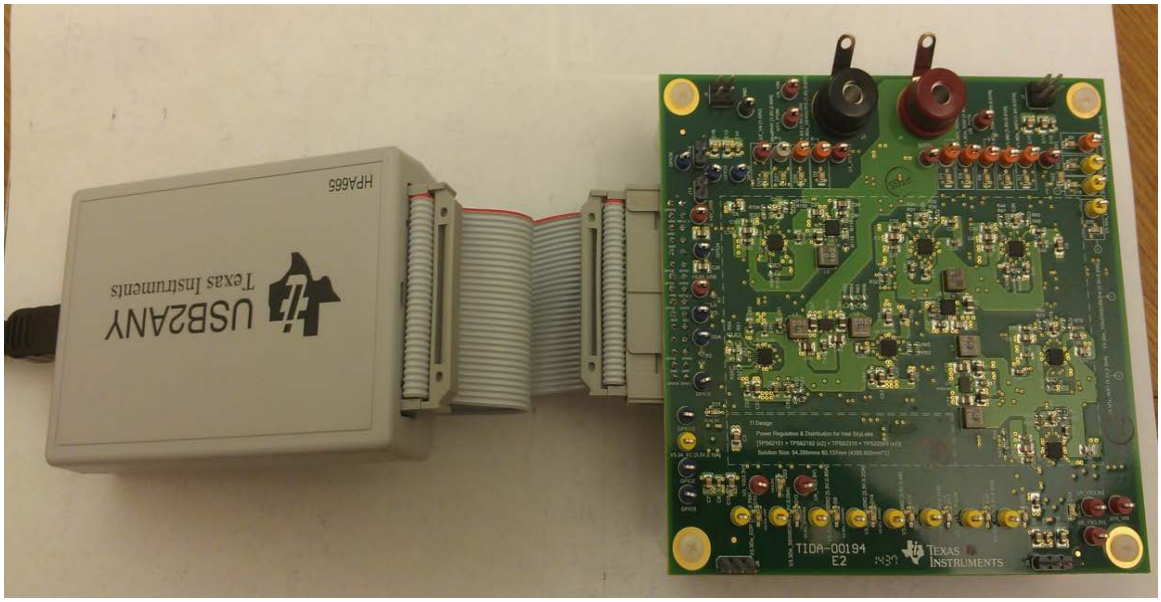
This board is not optimized for thermal performance.

7. Bench Set Up

PWR & GND are delivered to the board as shown below.

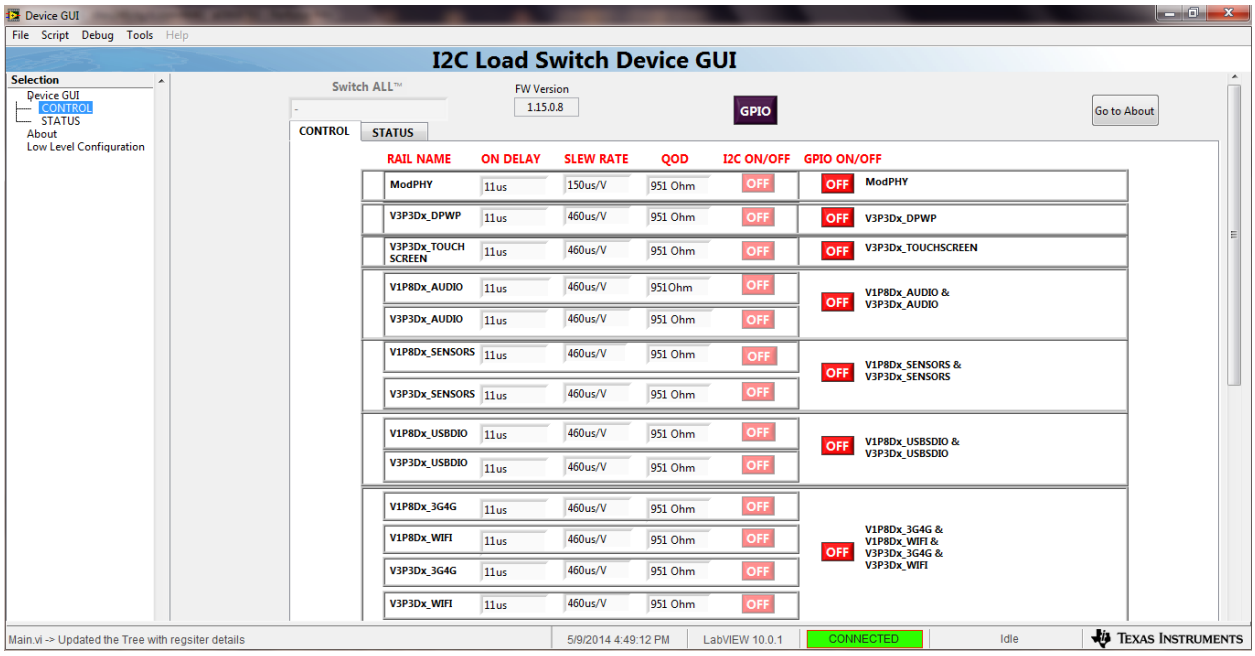


The USB2ANY is connected to the board as shown in the below picture.

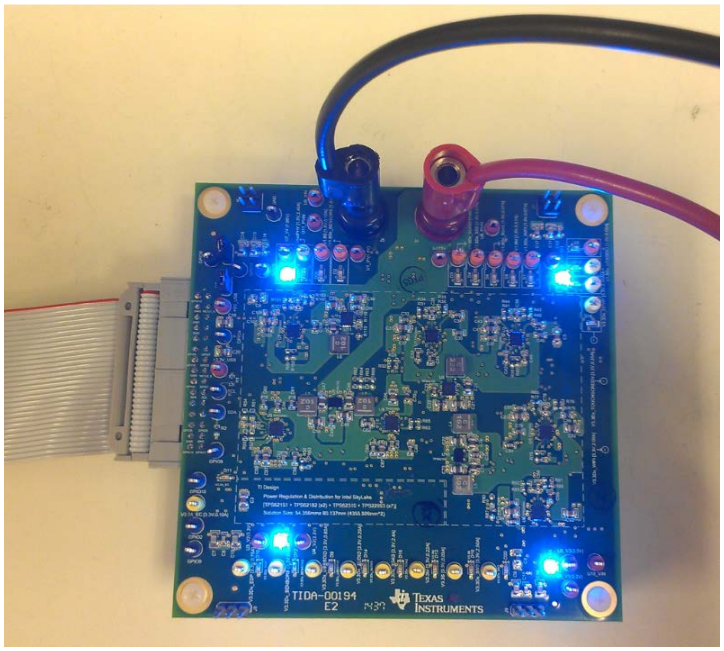


A USB cable is connected from USB2ANY to the computer with installed GUI software.

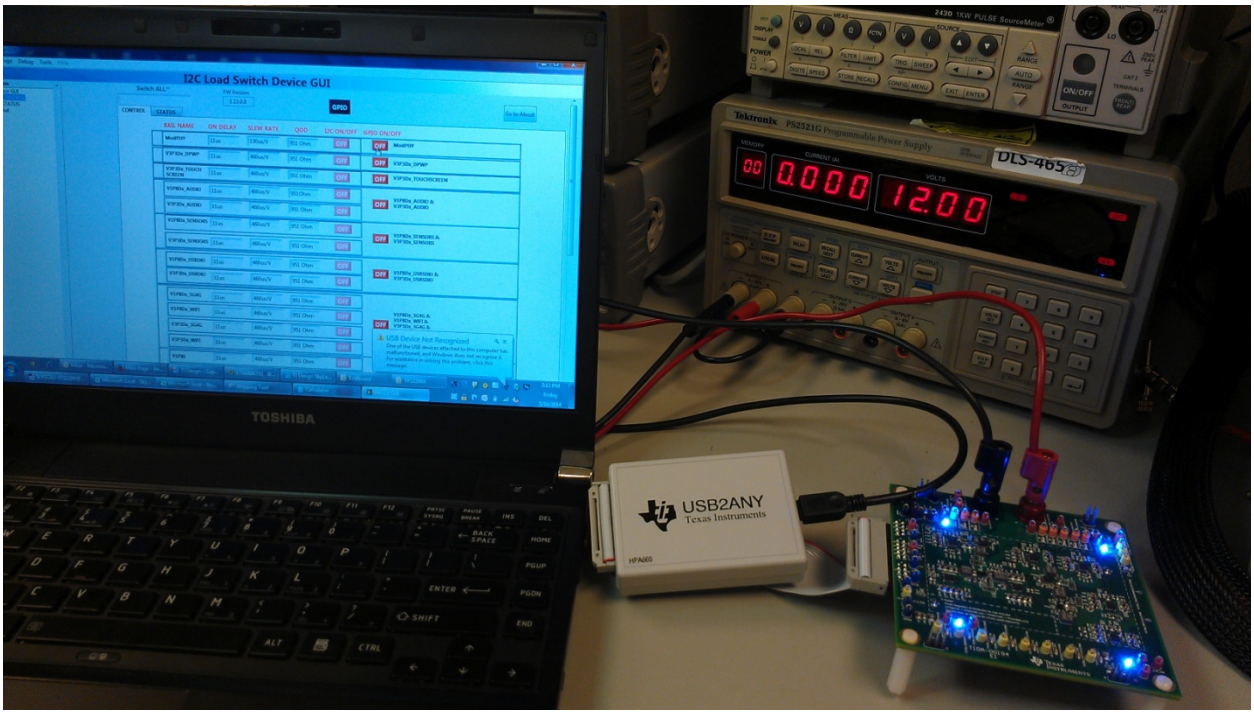
The GUI CONTROL tab is used to program and control the 7 load switches.



DC-DC power good is indicated by the Blue LED's turning on as shown in below picture.



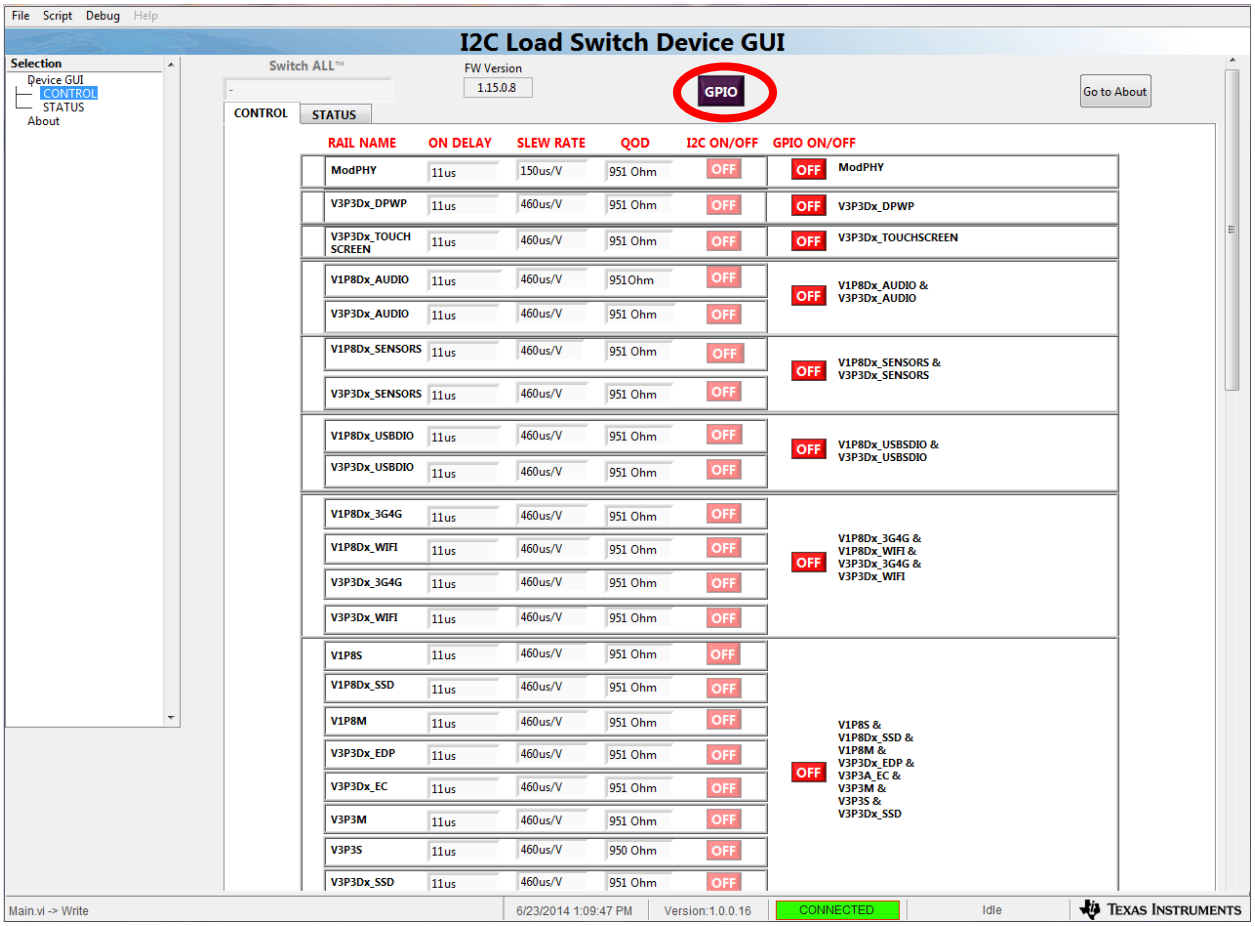
21 Unique rails can be turned ON/OFF using I2C, GPIO and SWITCHALL™ commands.



8. Graphical User Interface

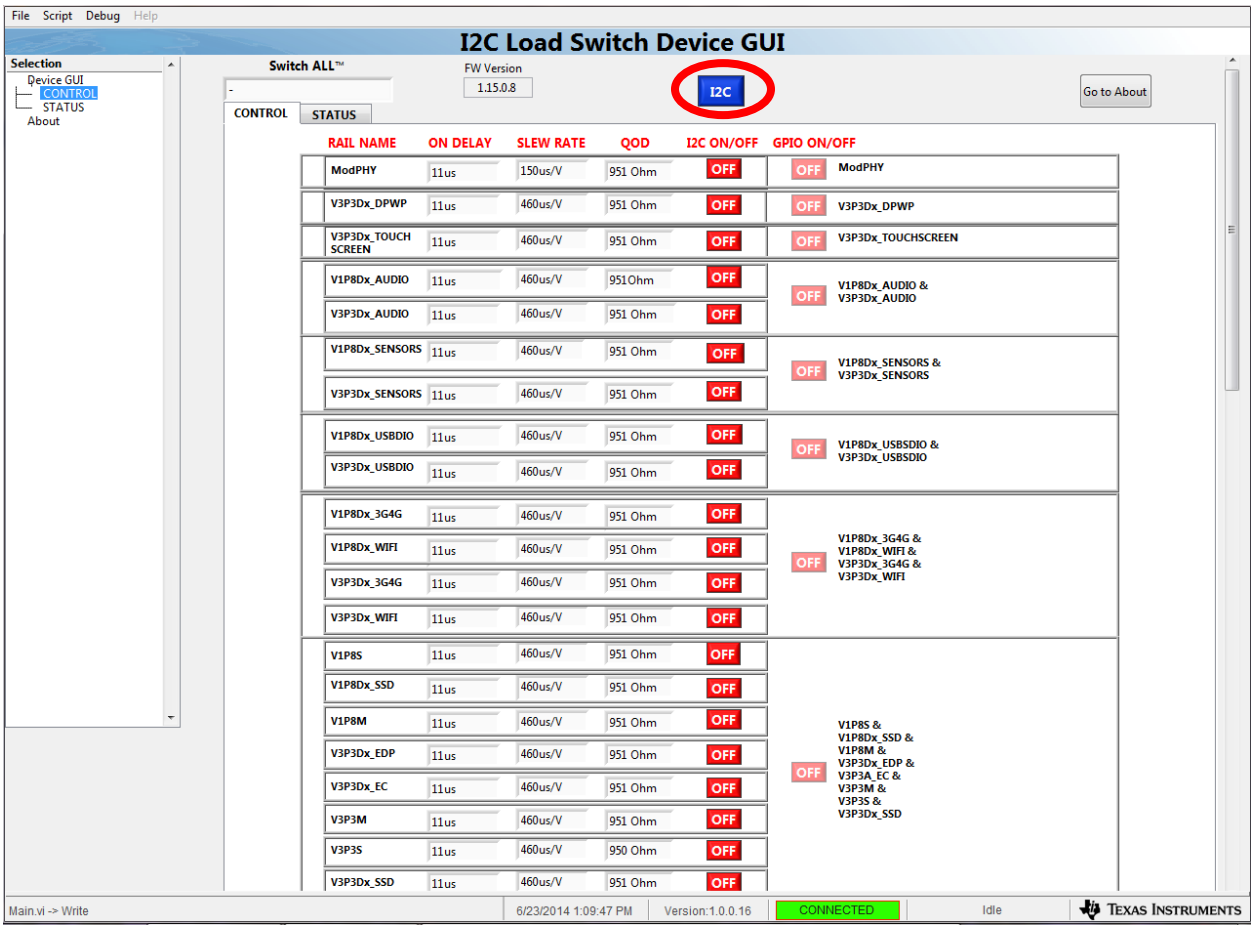
The GUI contains two main tabs, CONTROL & STATUS. The CONTROL tab has buttons to turn on/off different channels in I2C or GPIO modes. The CONTROL tab also has drop down selection options to change ON DELAY, SLEW RATE, and Quick Output Discharge (QOD) resistance for each individual rail. Navigate to the desired page just by clicking on the CONTROL or STATUS tabs.

In the below picture, the CONTROL tab is shown in GPIO mode. Please note that I2C ON/OFF buttons are grayed out indicating that the board is in GPIO mode.



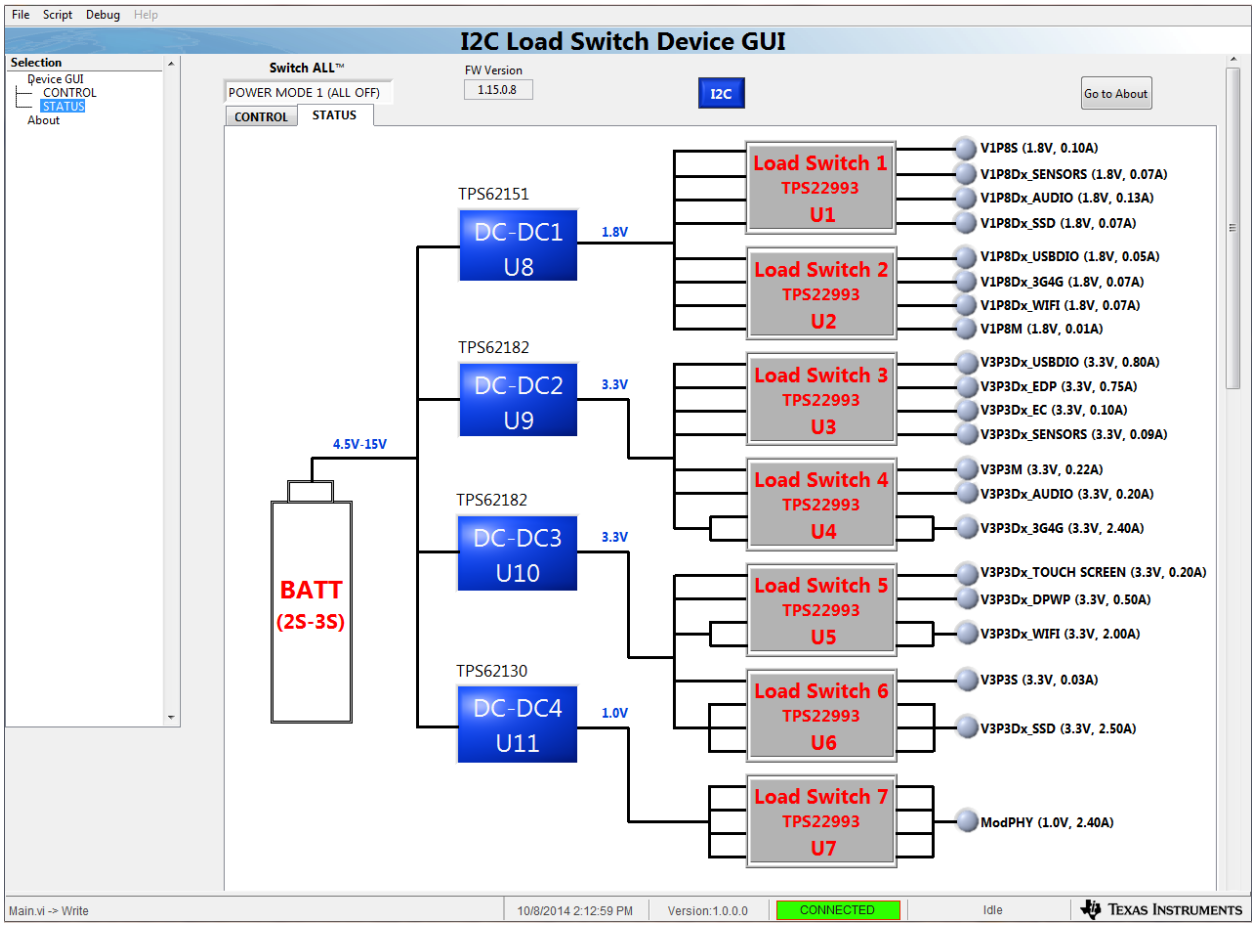
Switch to I2C mode by clicking on GPIO button on the top (highlighted in red oval).

Below picture shows the CONTROL page with the mode changed to I2C (highlighted in red oval). The GPIO ON/OFF buttons are *grayed out* to indicate that the board is in GPIO mode.

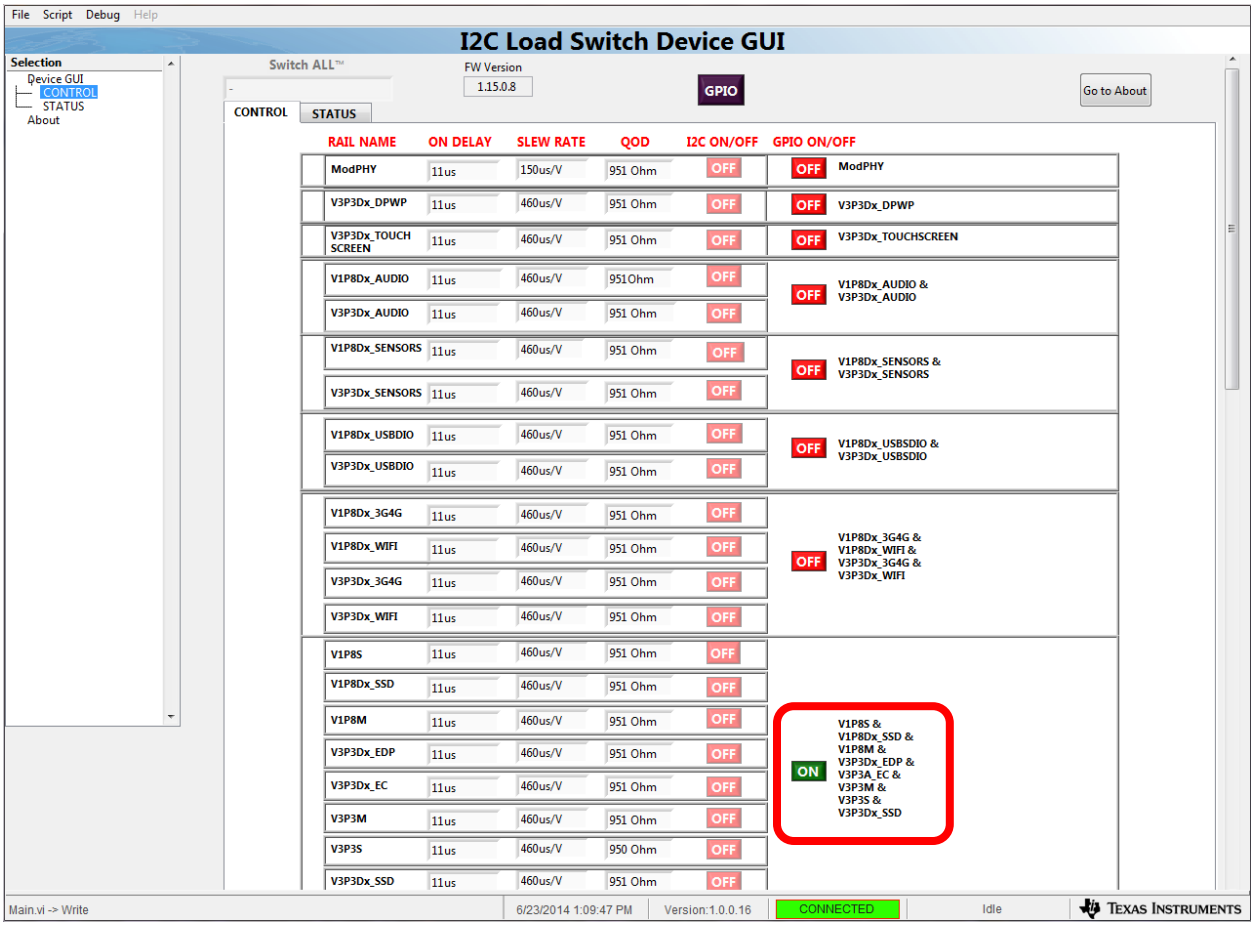


In each mode different rails or group of rails (GPIO) can be turned on/off by clicking on the ON/OFF button. GPIO control or I2C control is selectable on a per rail basis.

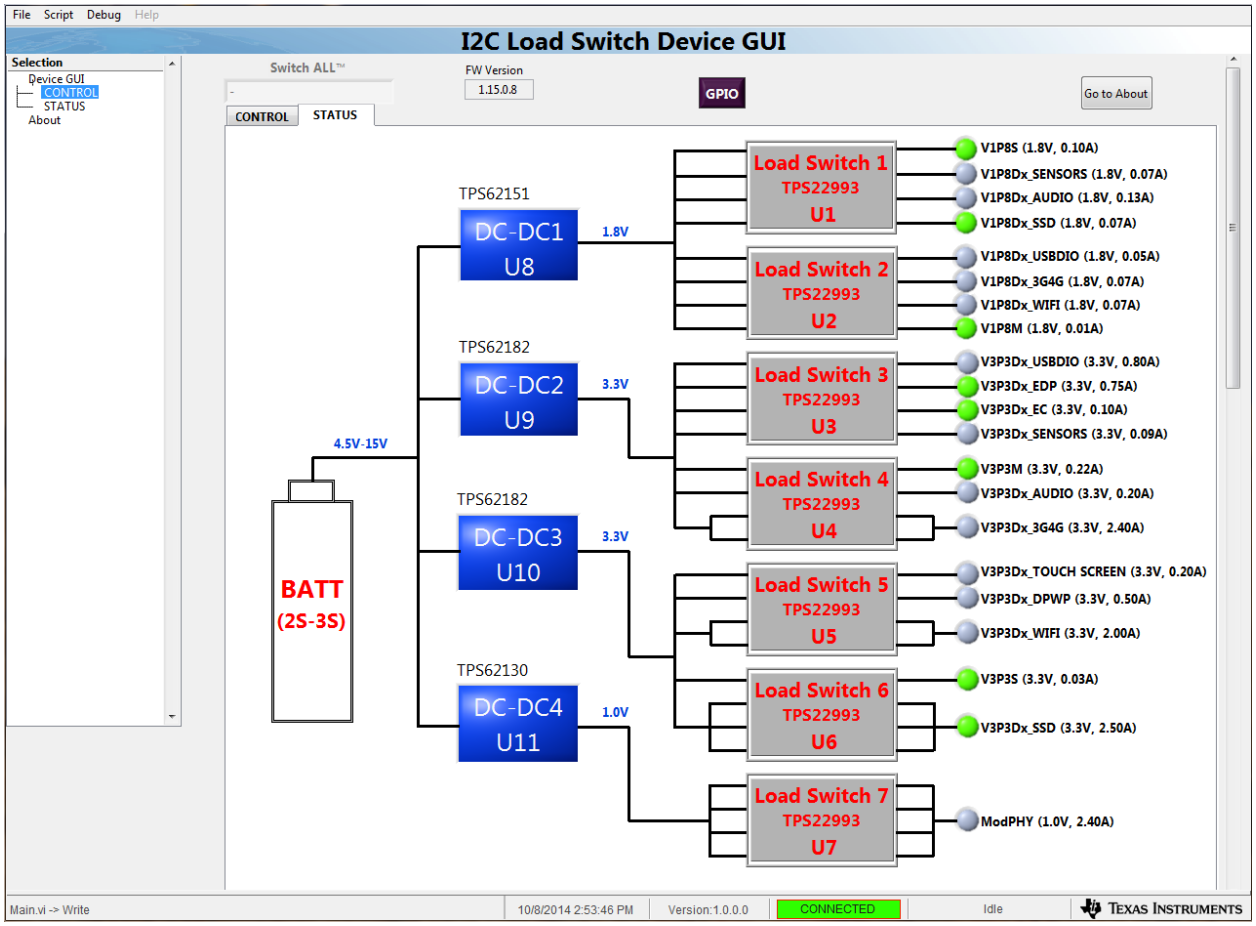
Below graphic shows the GUI STATUS tab with indicators for each of 21 power rails.



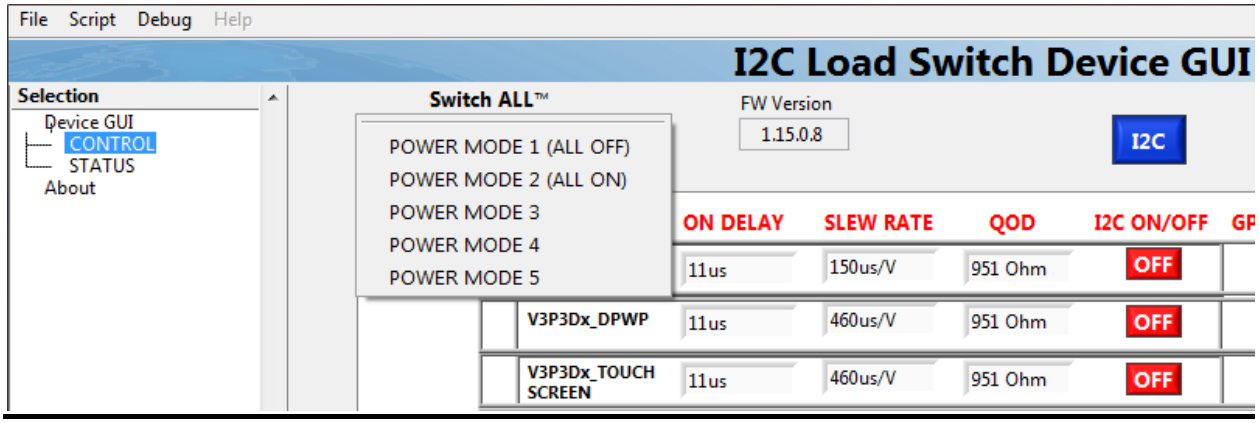
Below shows CONTROL tab when several grouped rails are turned ON when in GPIO mode.



Below shows STATUS tab when several grouped rails are turned ON when in GPIO mode.



Groups of rails can be also be controlled with a single I2C command when using the TPS22993 Switch ALL™ feature.



9. Test Data

9.1 TPS22993 Load Switches

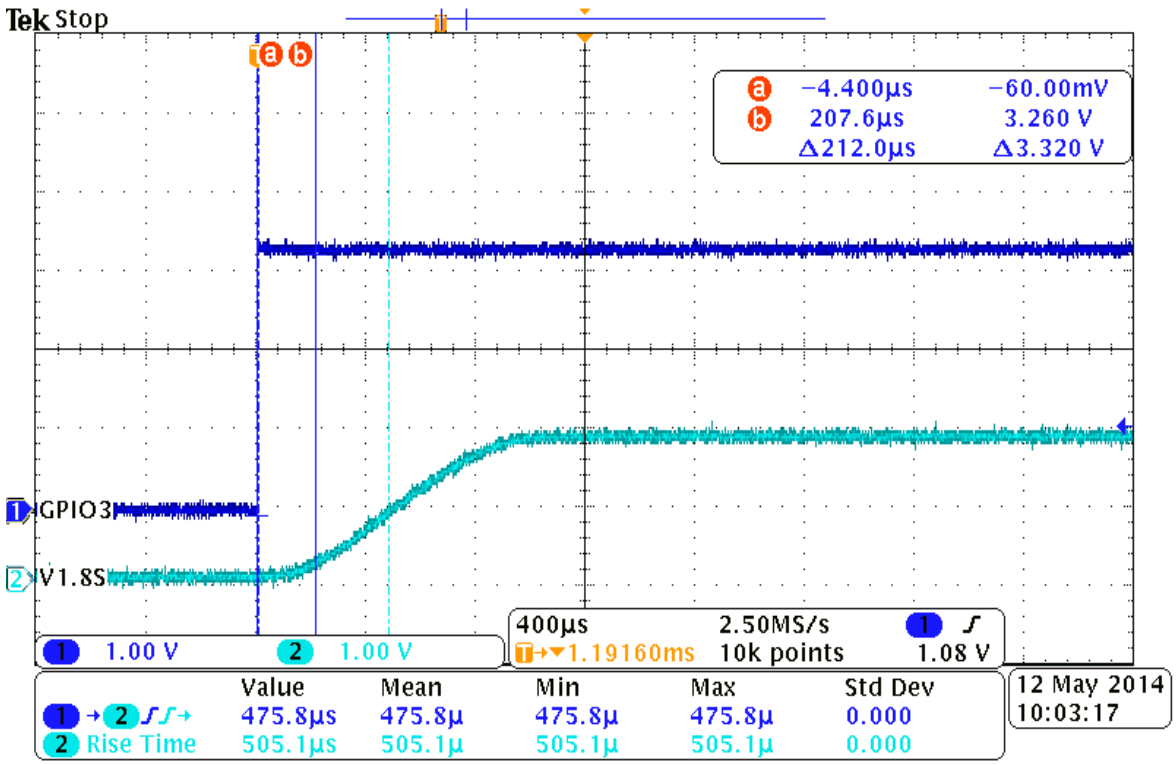
9.1.1 Timing measurements

VOUT x ON delay time = t_D, VOUT x turn-on time = t_{ON}, VOUT x turn-off time = t_{OFF},

VOUT x rise time = t_R, VOUT x fall time = t_F,

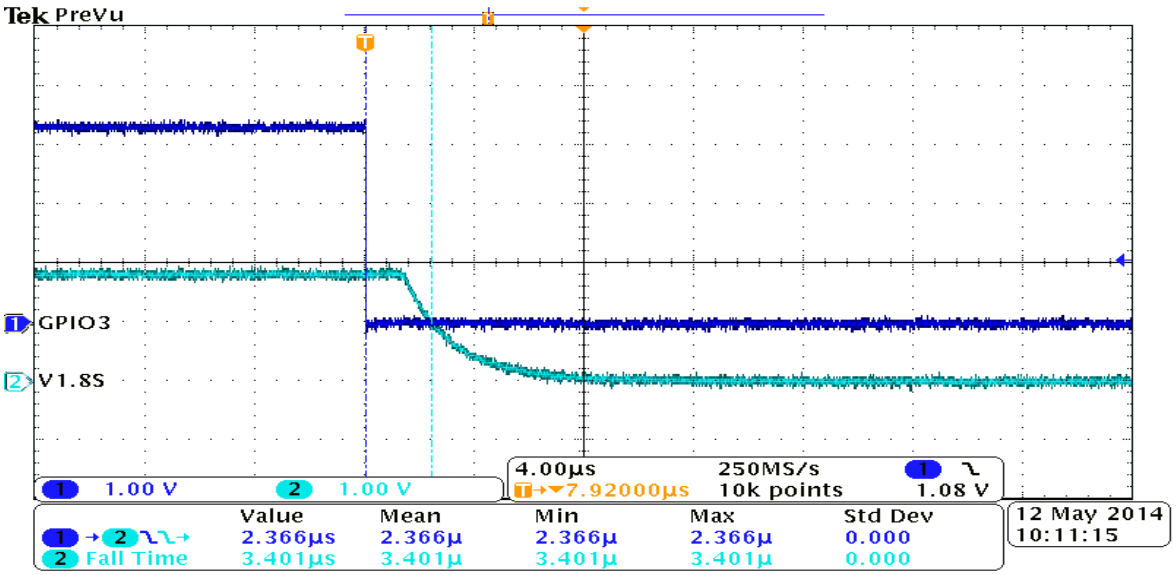
V1P8S delay time, turn-on time & rise time

t_D = 212us, t_{ON} = 475.8us, t_R = 505.1us



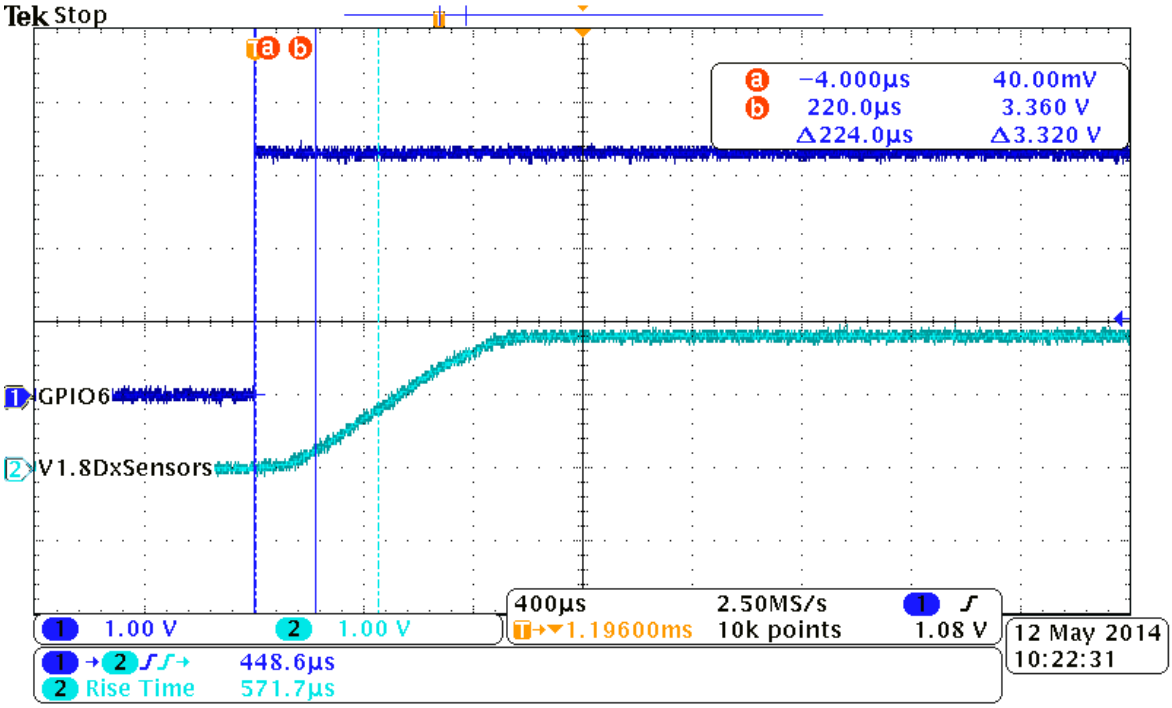
V1P8S turn-off & fall time

t_{OFF} = 2.366us, t_F = 3.4us



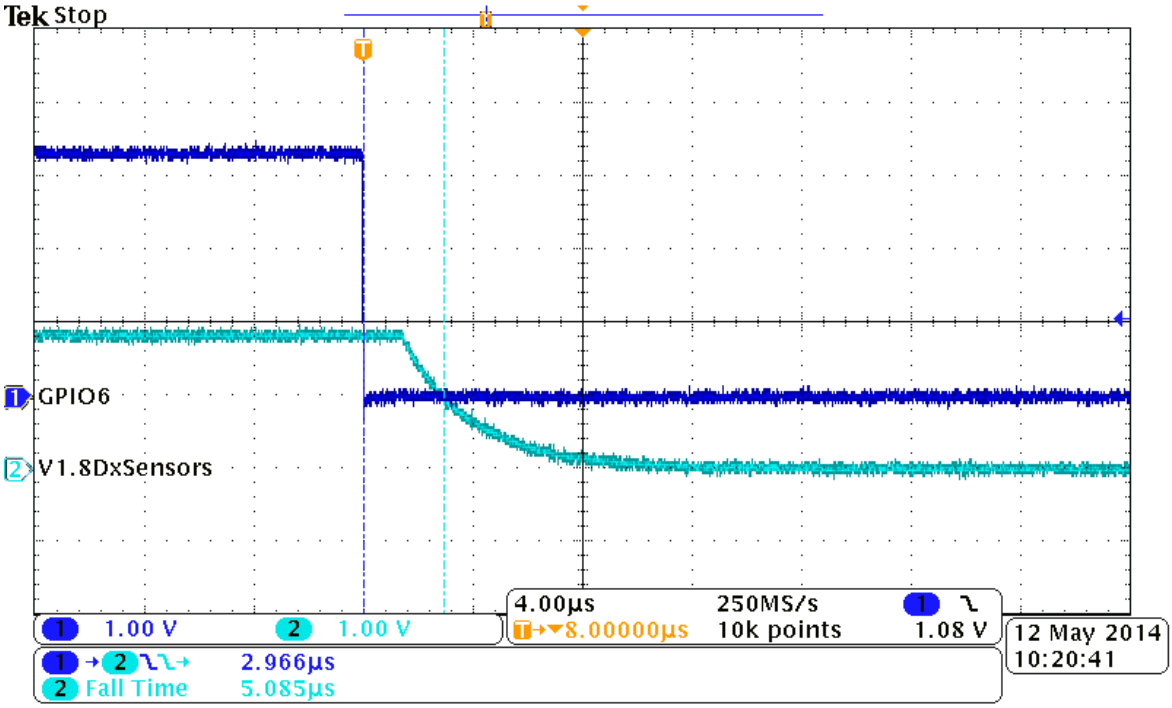
V1P8Dx_SENSORS delay time, turn-on time & rise time

t_D = 224us, t_{ON} = 448.6us, t_R = 571.7us



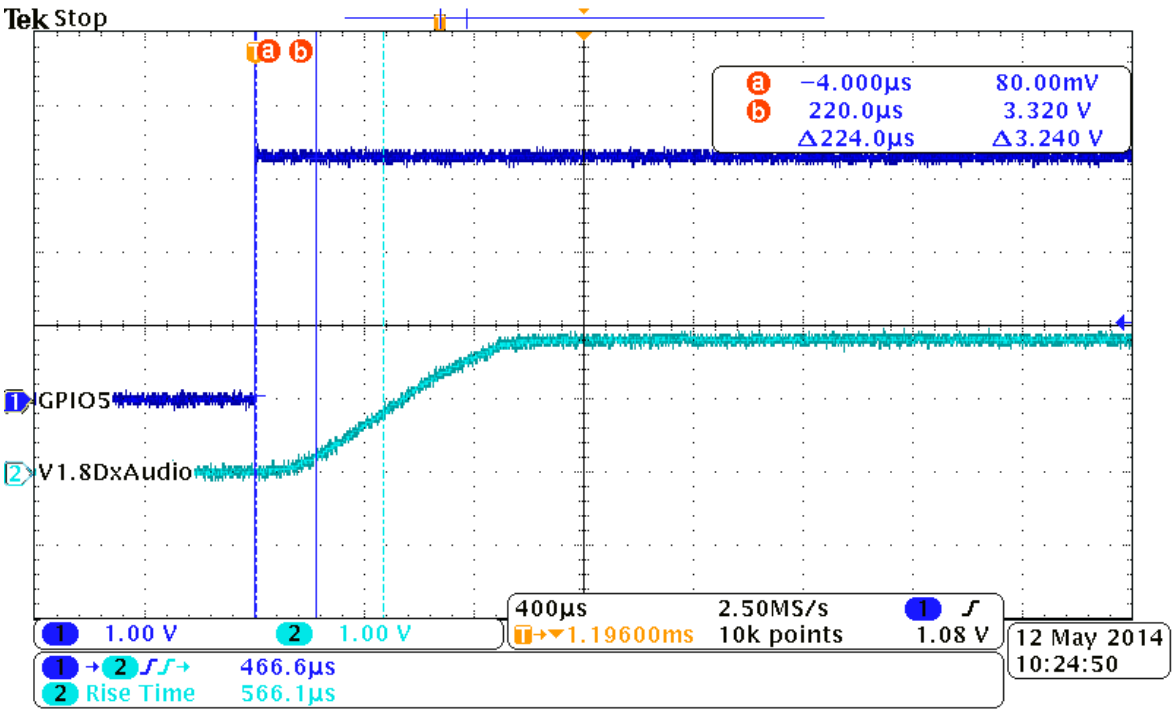
V1P8Dx_SENSORS turn-off & fall time

t_{OFF} = 2.966us, t_F = 5.1us



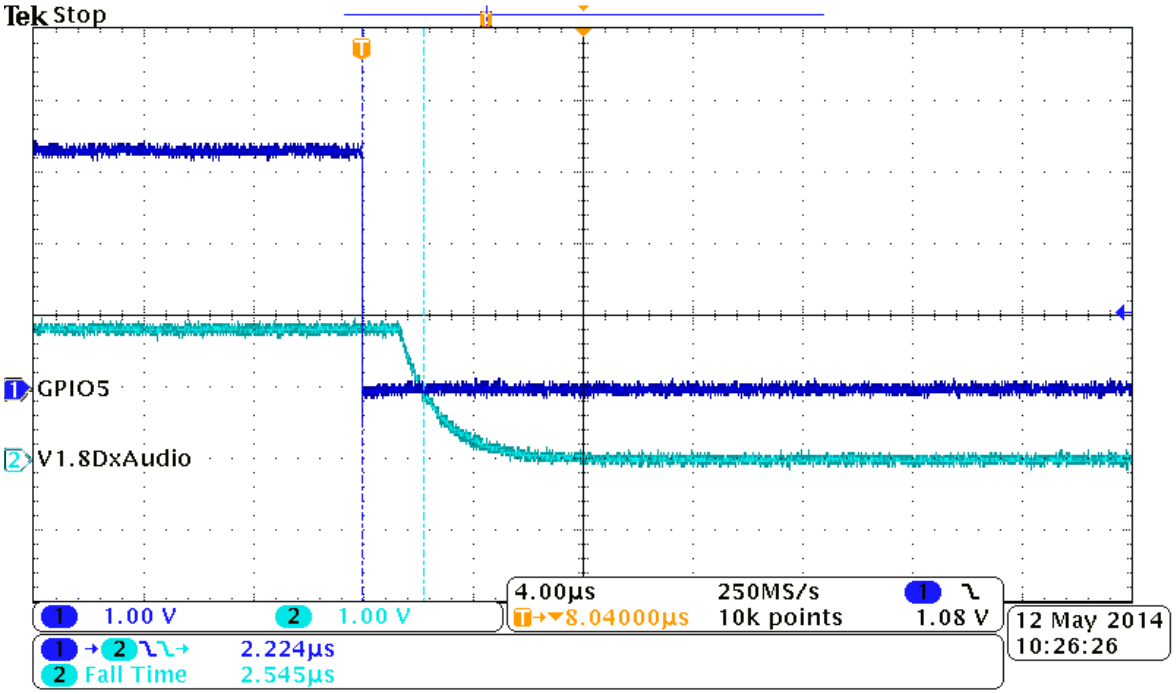
V1P8Dx_AUDIO delay time, turn-on time & rise time

t_D = 224us, t_{ON} = 466.6us, t_R = 566.1us



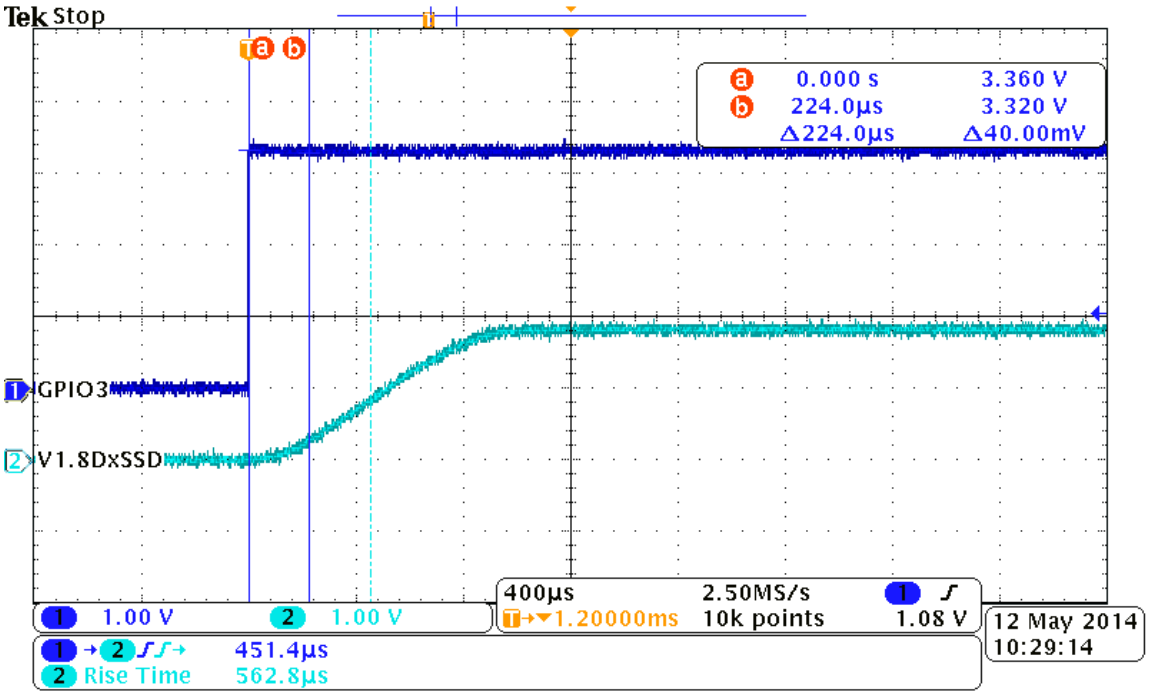
V1P8Dx_AUDIO turn-off & fall time

t_{OFF} = 2.22us, t_F = 2.54us



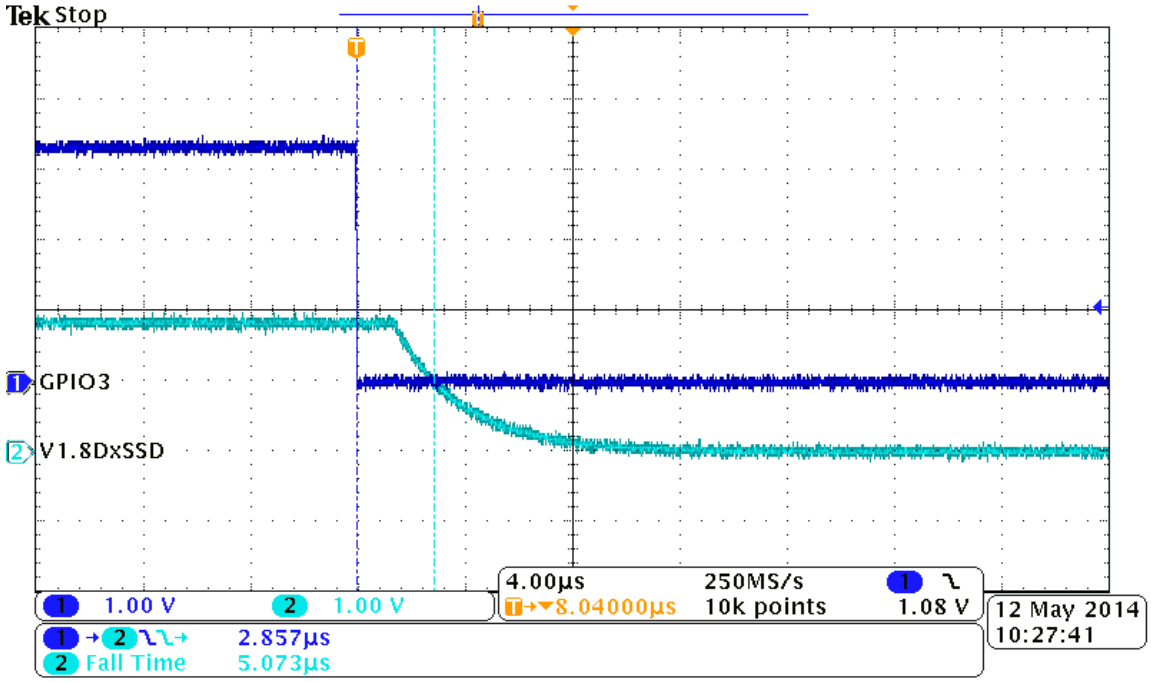
V1P8Dx_SSD delay time, turn-on time & rise time

t_D = 224us, t_{ON} = 451.4us, t_R = 562.8us



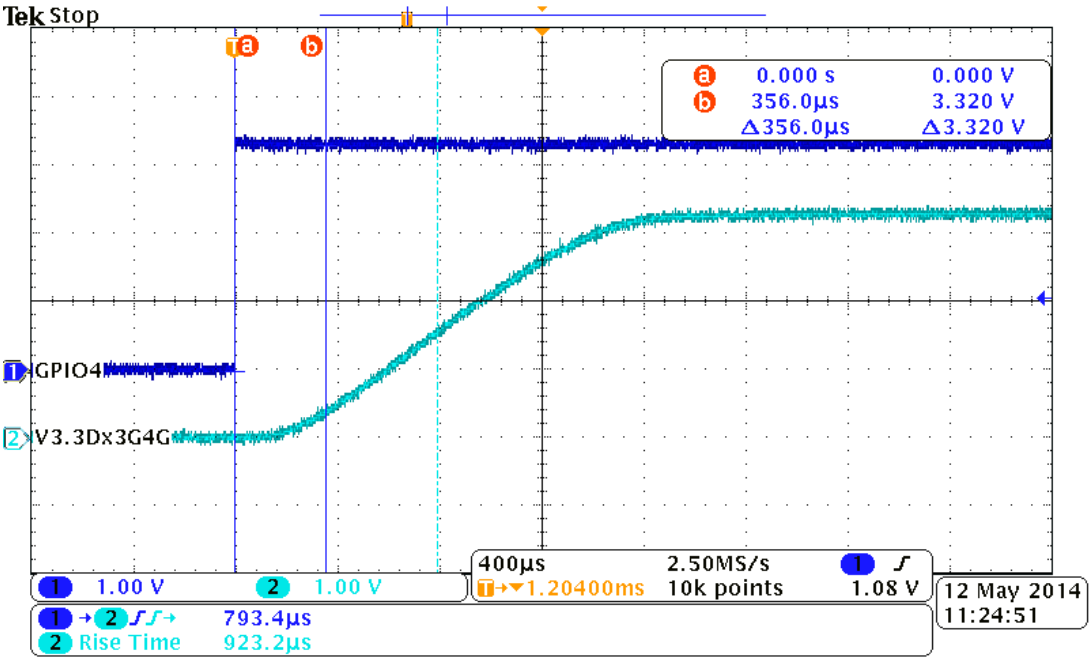
V1P8Dx_SSD turn-off & fall time

t_{OFF} = 2.857us, t_F = 5.073us



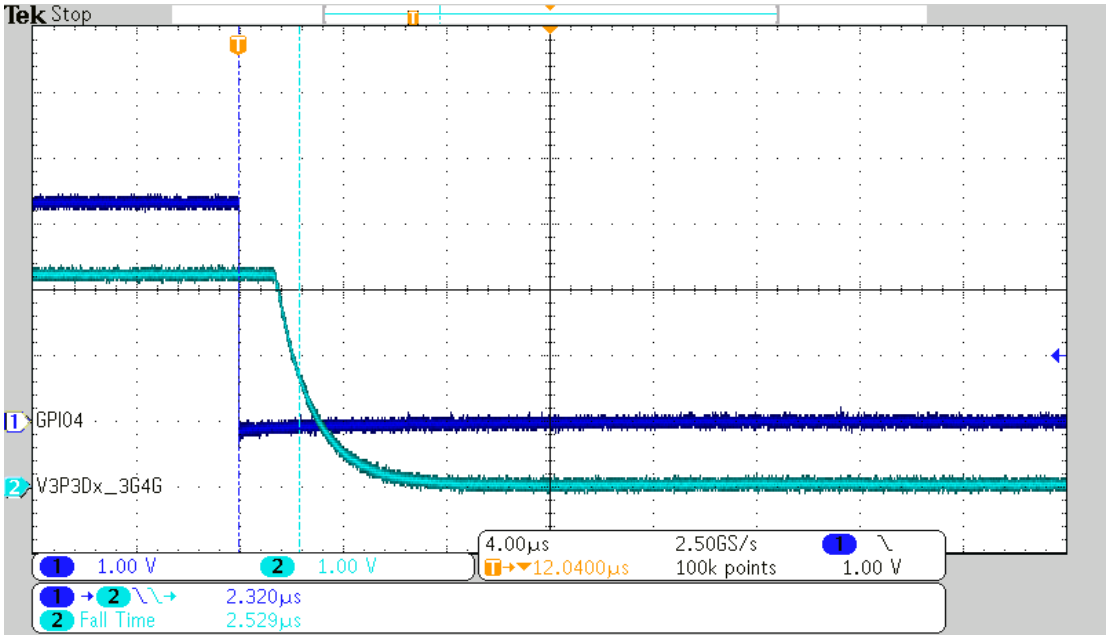
V3P3Dx_3G4G delay time, turn-on time & rise time

t_D = 356us, t_{ON} = 793.4us, t_R = 923.2us



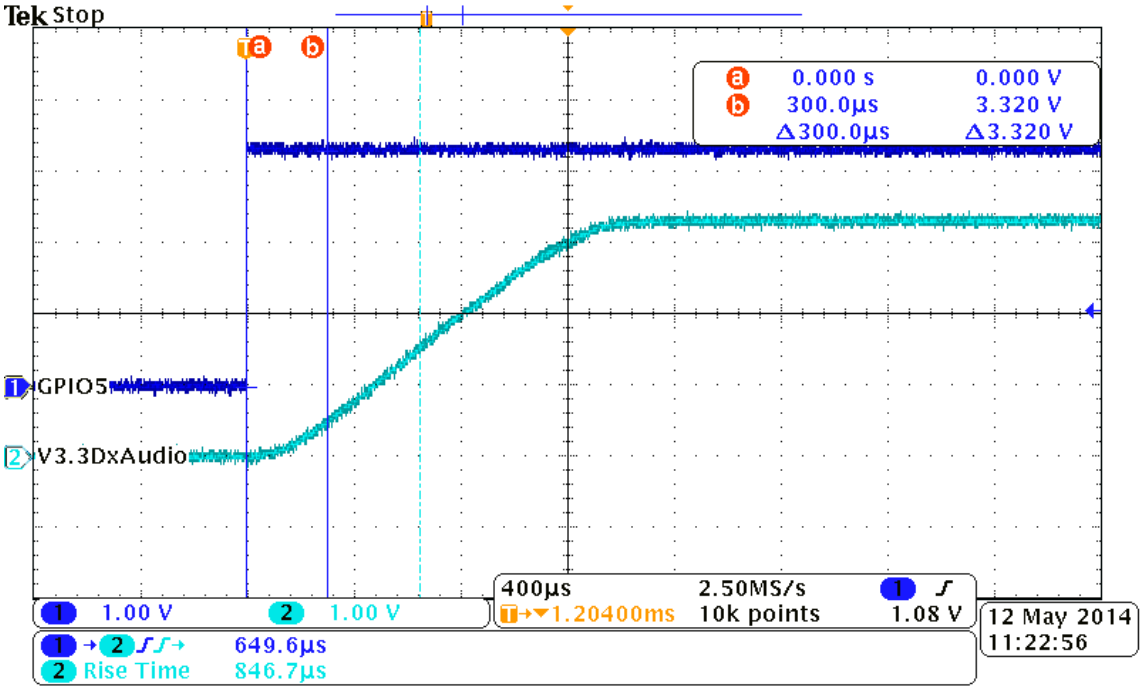
V3P3Dx_3G4G turn-off & fall time

t_{OFF} = 2.32us, t_F = 2.5us



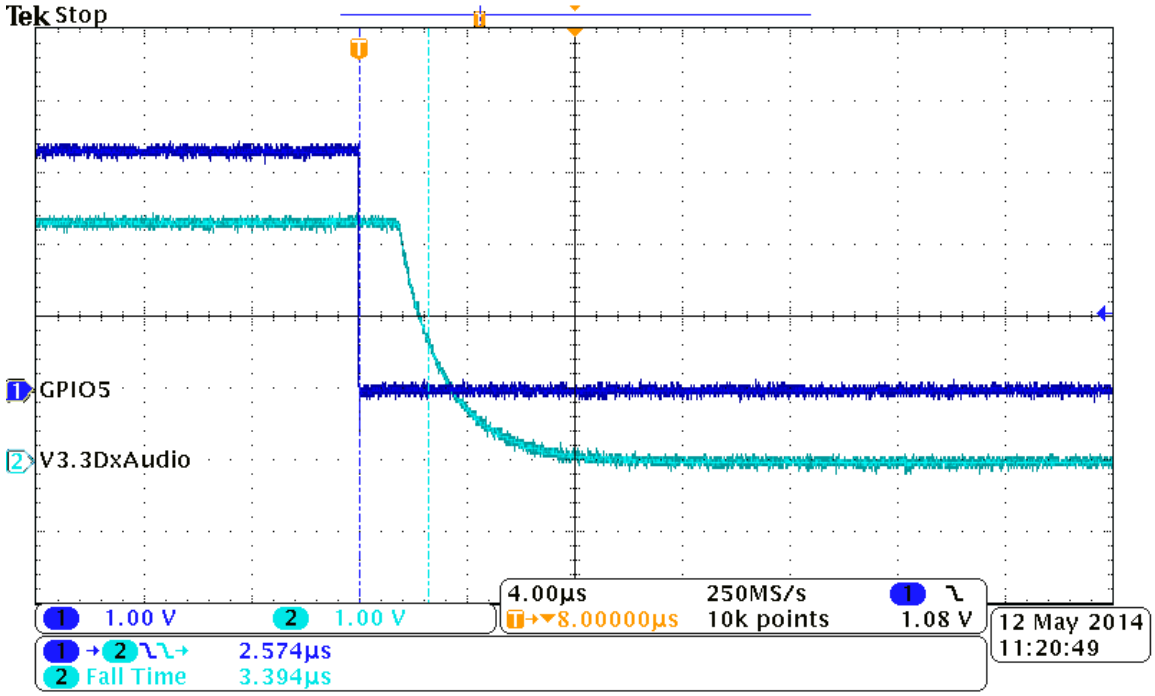
V3P3Dx_AUDIO delay time, turn-on time & rise time

t_D = 300us, t_{ON} = 649.6us, t_R = 846.7us



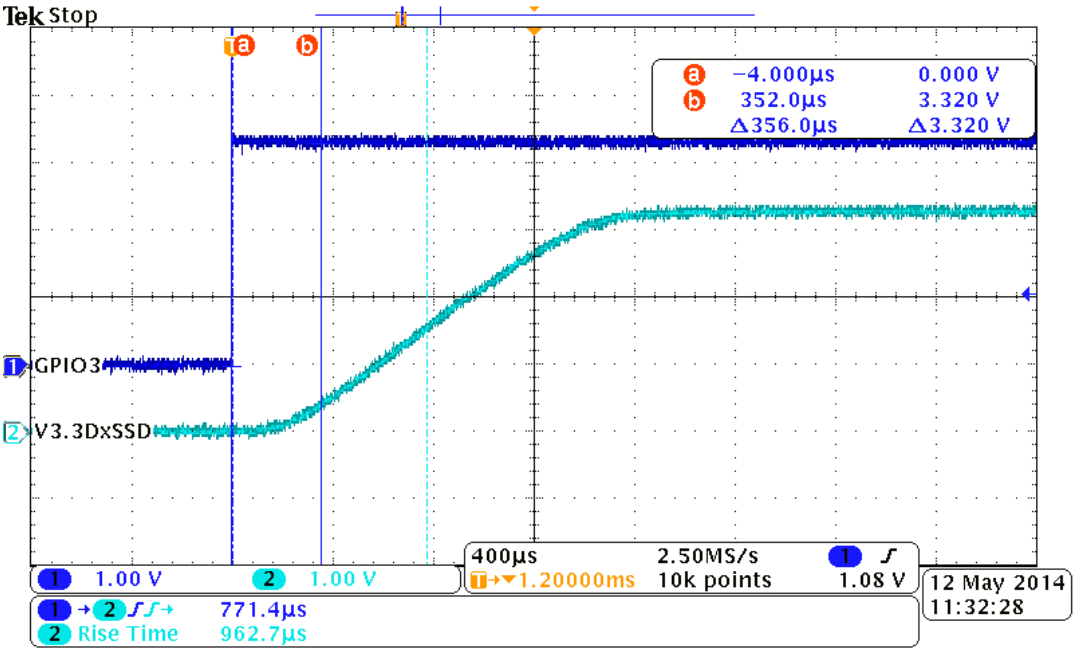
V3P3Dx_AUDIO turn-off & fall time

t_{OFF} = 2.6us, t_F = 3.4us



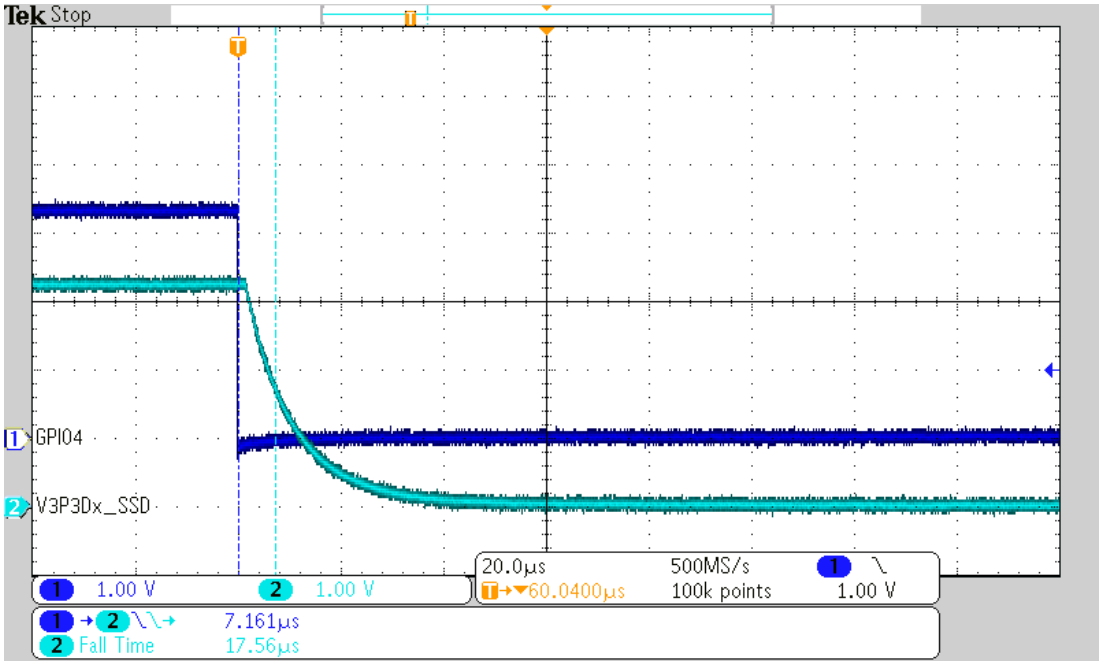
V3P3Dx_SSD delay time, turn-on time & rise time

t_D = 356us, t_{ON} = 771.4us, t_R = 962.7us



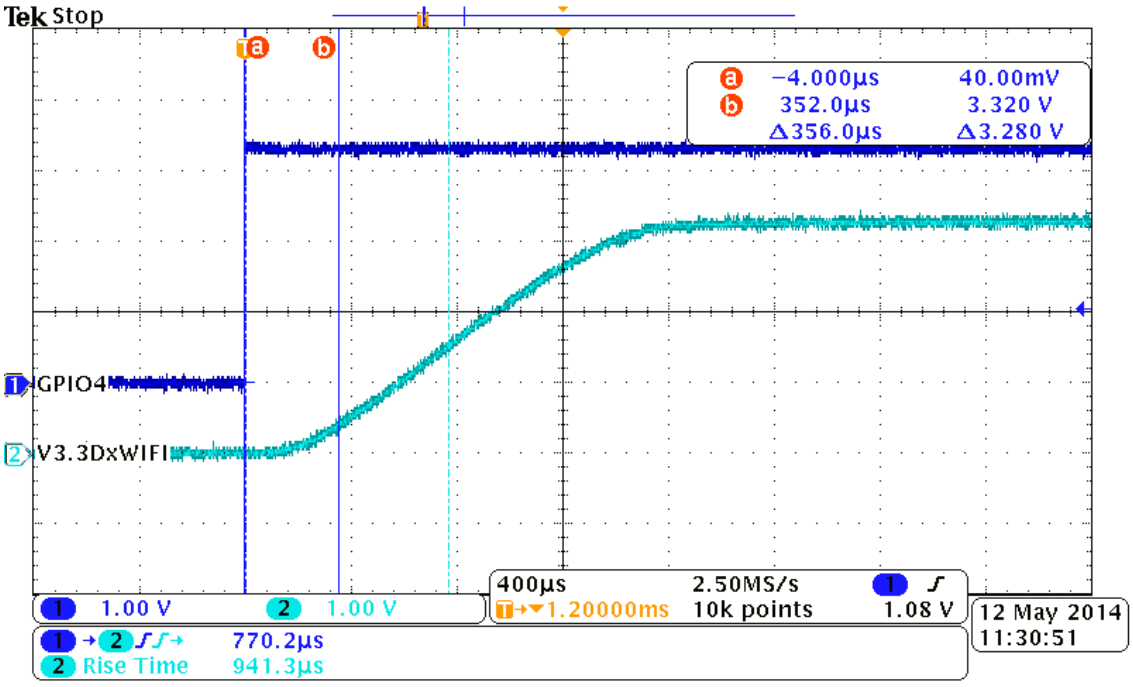
V3P3Dx_SSD turn-off & fall time

t_{OFF} = 7.2us, t_F = 17.5us



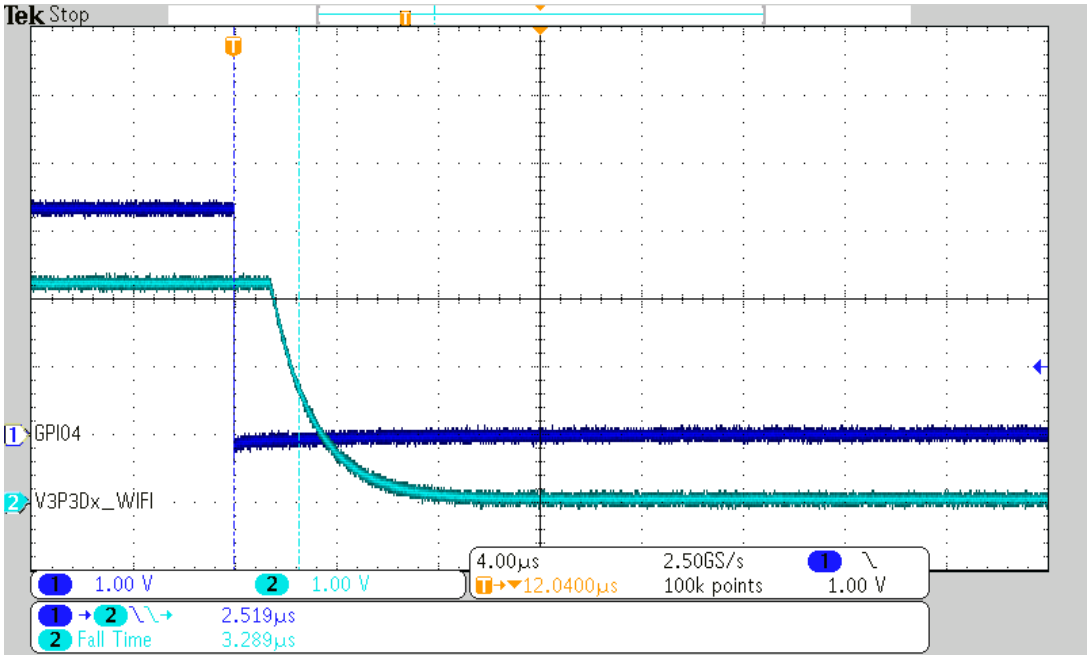
V3P3Dx_WIFI delay time, turn-on time & rise time

t_D = 356us, t_{ON} = 770us, t_R = 941us



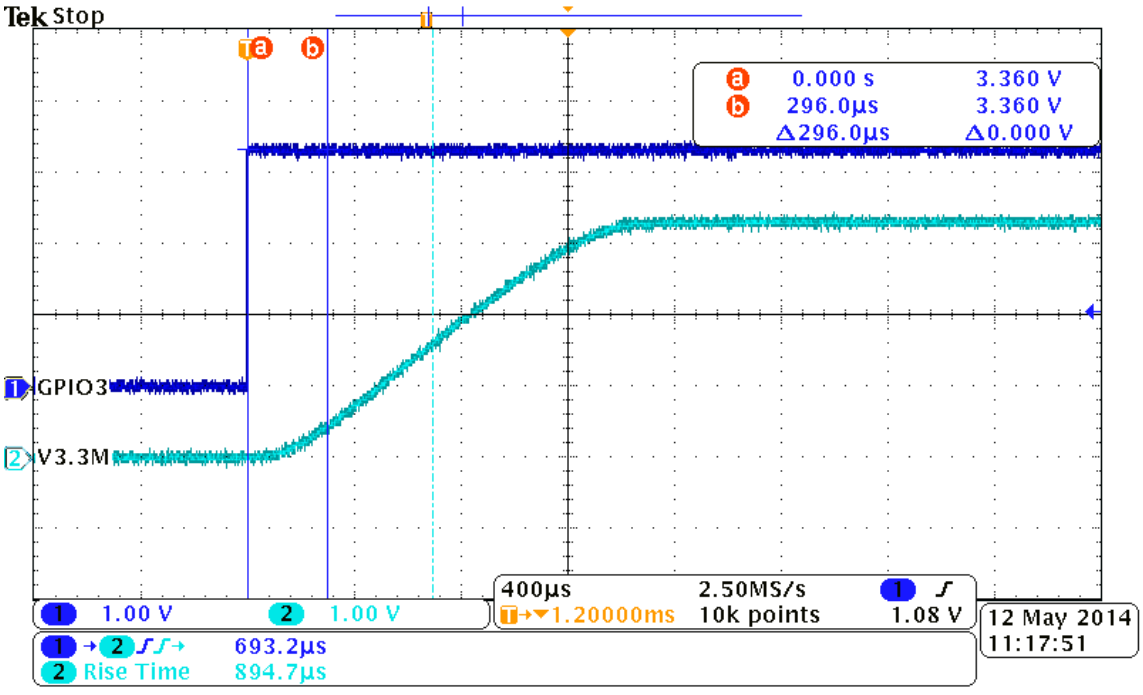
V3P3Dx_WIFI turn-off & fall time

t_{OFF} = 2.5us, t_F = 3.3us



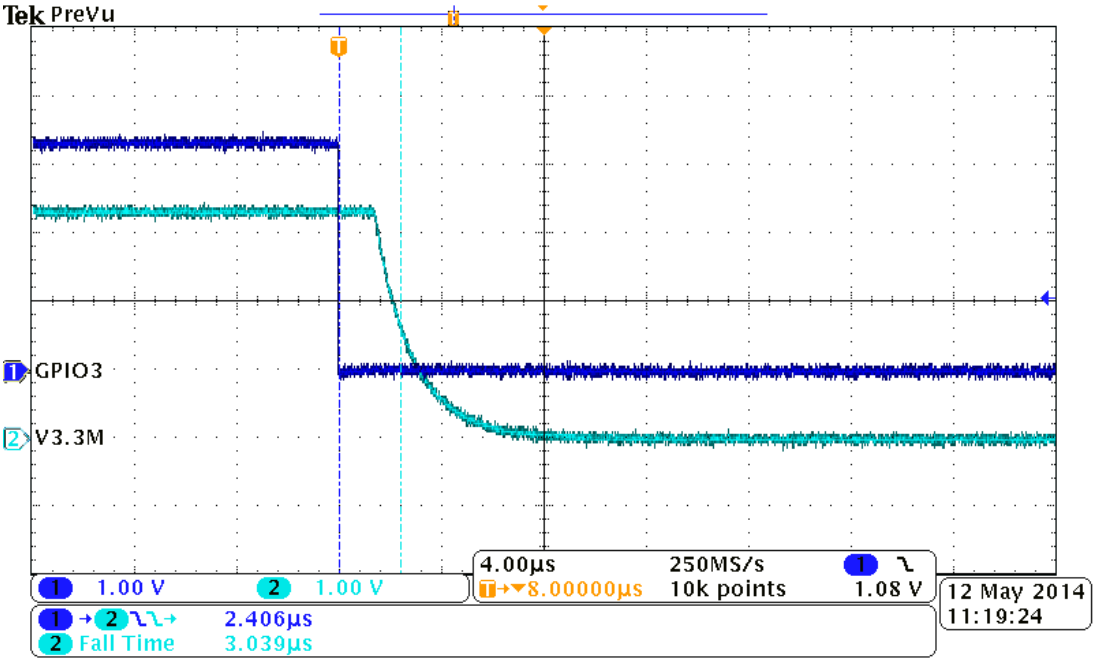
V3P3M delay time, turn-on time & rise time

t_D = 296us, t_{ON} = 693us, t_R = 895us



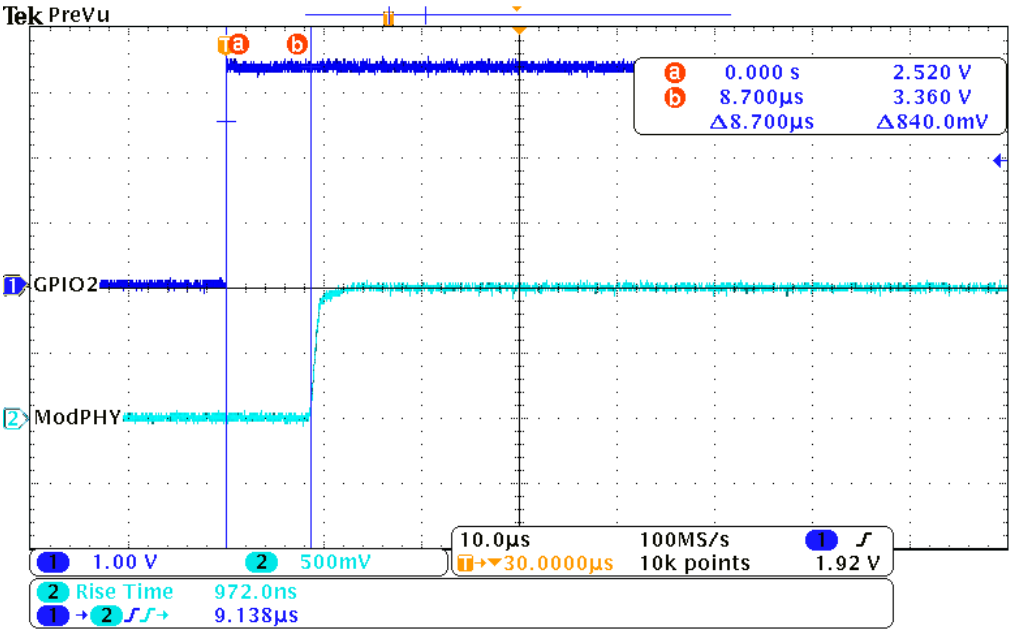
V3P3M turn-off & fall time

t_{OFF}= 2.4us, t_F = 3.04us



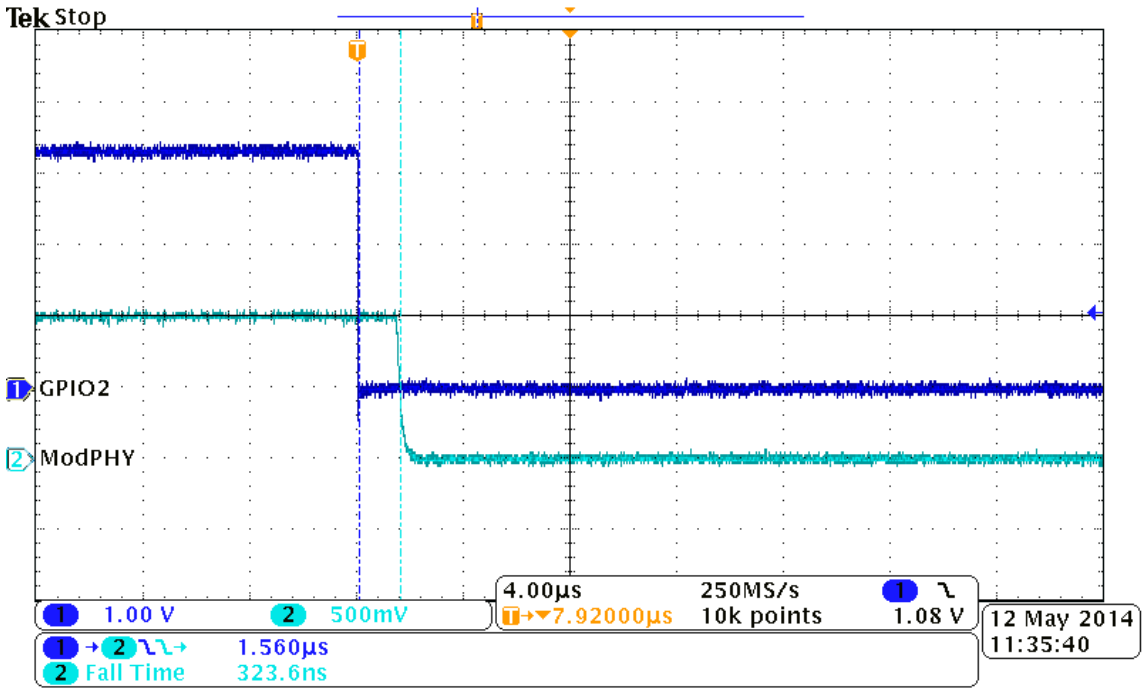
ModPHY delay time, turn-on time & rise time

t_D = 8.7us, t_{ON} = 9.1us, t_R = 0.97us



ModPHY turn-off & fall time

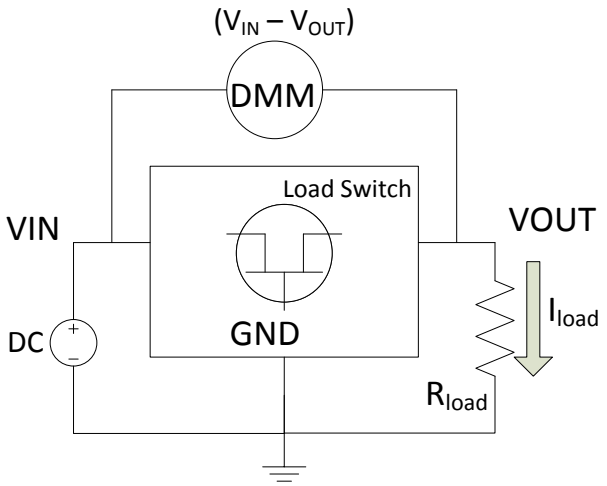
t_{OFF} = 1.56us, t_F = 0.32us



Rail name	t_D (µs)	t_{ON} (µs)	t_R (µs)	t_{OFF} (µs)	t_F (µs)
V1P8S	212	475.8	505.1	2.37	3.4
V1P8Dx_SENSORS	224	448.6	571.7	2.97	5.1
V1P8Dx_AUDIO	224	466.6	566.1	2.22	2.5
V1P8Dx_SSD	224	451.4	562.8	2.86	5.1
V3P3M	296	693	895	2.4	3.0
V3P3Dx_AUDIO	300	649.6	846.7	2.6	3.4
V3P3Dx_3G4G	356	793.4	923.2	2.32	2.5
V3P3Dx_WIFI	356	770	941	2.5	3.3
V3P3Dx_SSD	356	771.4	962.7	7.2	17.5
ModPHY	8.7	9.1	0.97	1.56	0.32

9.1.2 R_{ON} measurements:

Setup: $R_{ON} = (V_{IN} - V_{OUT})/I_{load}$



Rail name	Voltage (V)	Current (mA)	V_{IN}-V_{OUT} (mV)	R_{ON} (mohm)	Pout (W)
V1P8S	1.8	100	2.27	22.7	0.180
V1P8Dx_SENSORS	1.8	70.6	1.38	19.5	0.127
V1P8Dx_AUDIO	1.8	131.4	2.49	18.9	0.237
V1P8Dx_SSD	1.8	70.6	1.34	19.0	0.127
V1P8Dx_USBSDIO	1.8	50	0.94	18.8	0.090
V1P8Dx_3G4G	1.8	70.6	1.32	18.7	0.127
V1P8Dx_WIFI	1.8	70.6	1.38	19.5	0.127
V1P8M	1.8	10	0.19	19.0	0.018
V3P3Dx_USBSDIO	3.3	750	15.55	20.7	2.475
V3P3Dx_EDP	3.3	750	15.36	20.5	2.475
V3P3A_EC	3.3	100	1.9	19.0	0.330
V3P3Dx_SENSORS	3.3	90.4	2.04	22.6	0.298
V3P3M	3.3	220	4.36	19.8	0.726
V3P3Dx_AUDIO	3.3	200	4.55	22.8	0.660
V3P3Dx_3G4G	3.3	2292	26.02	11.4	7.564
V3P3Dx_TOUCHSCREEN	3.3	200	4.98	24.9	0.660
V3P3Dx_DPWP	3.3	500	12.5	25.0	1.650
V3P3Dx_WIFI	3.3	1964	24.27	12.4	6.481
V3P3S	3.3	30	0.72	24.0	0.099
V3P3Dx_SSD	3.3	2500	22.02	8.8	8.250
ModPHY	1.0	2381	12.13	5.1	2.381

Total combined Output Power = 35W

Note: This board is not optimized for thermal performance.

9.1.3 System Quiescent and Shutdown Current

Quiescent Current (I_Q):

I_Q on BATT at 12V = 215uA

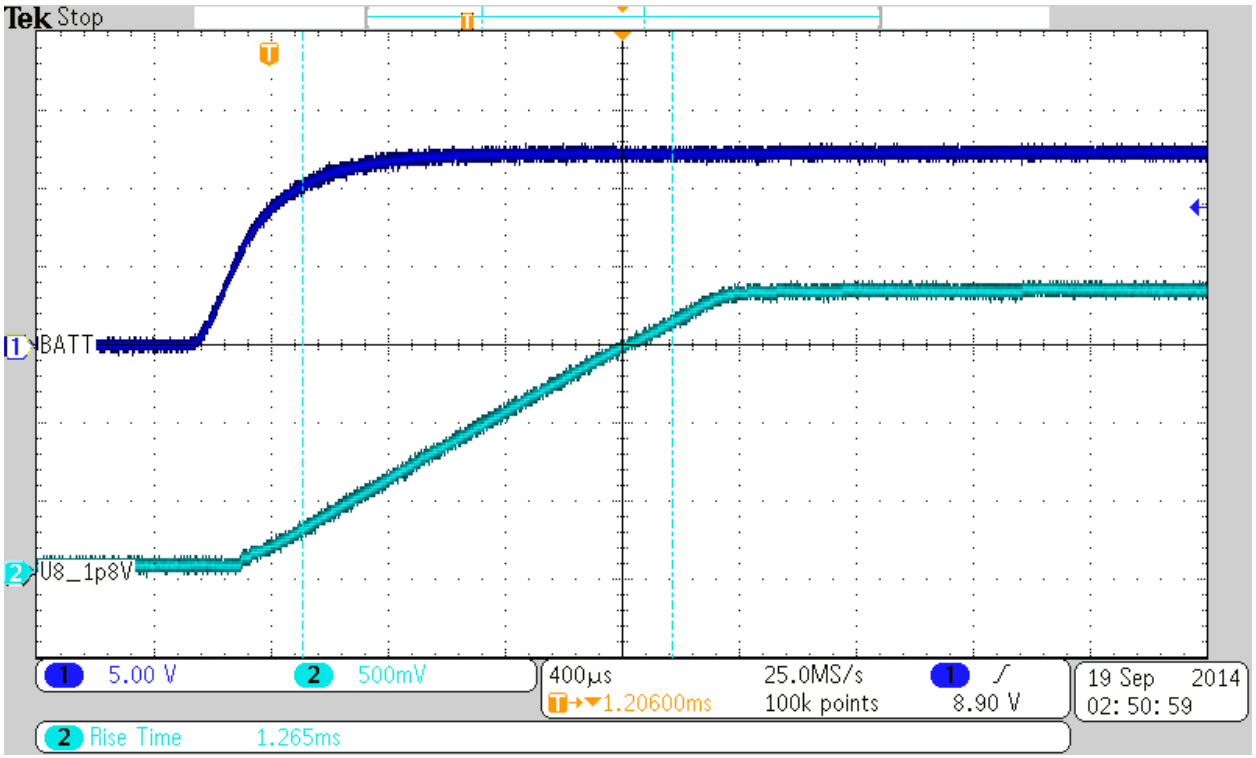
Shutdown Current (I_{SD}):

I_{SD} on BATT at 12V = 49.2uA

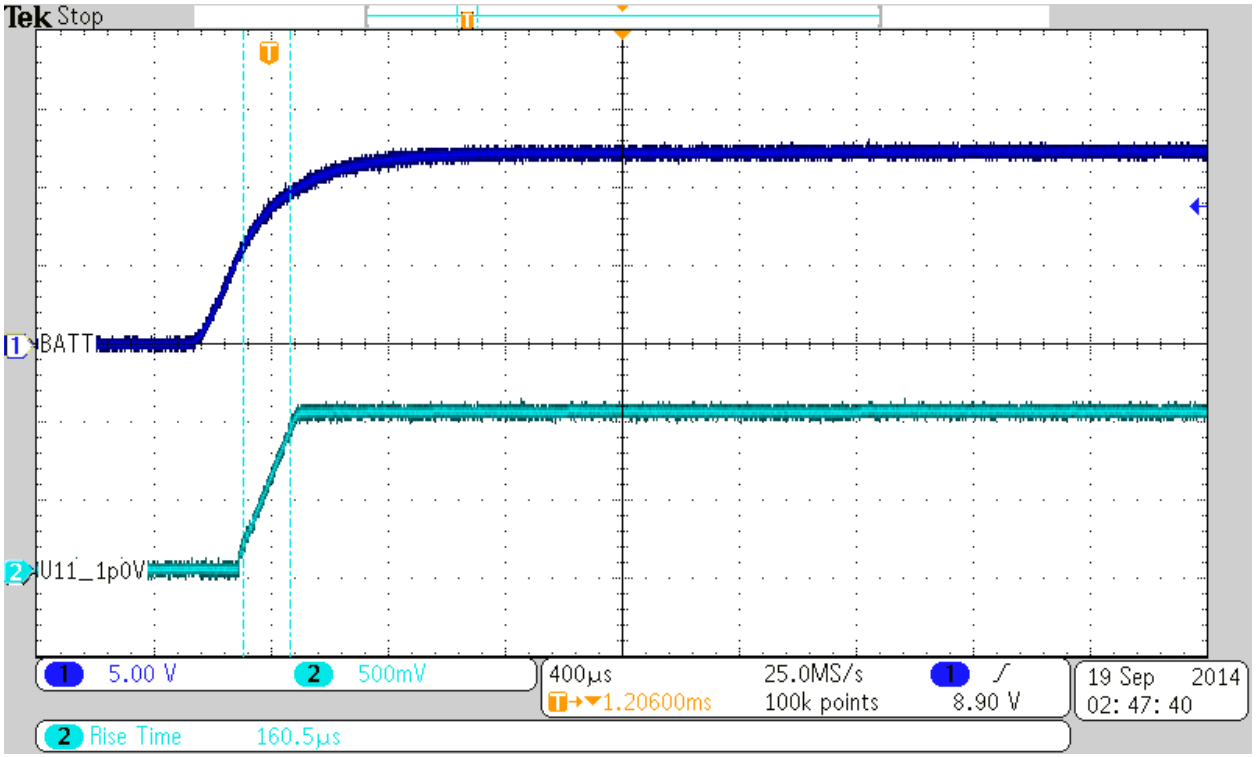
9.2 TPS621xx DC-DC converters

9.2.1 Start-up waveforms

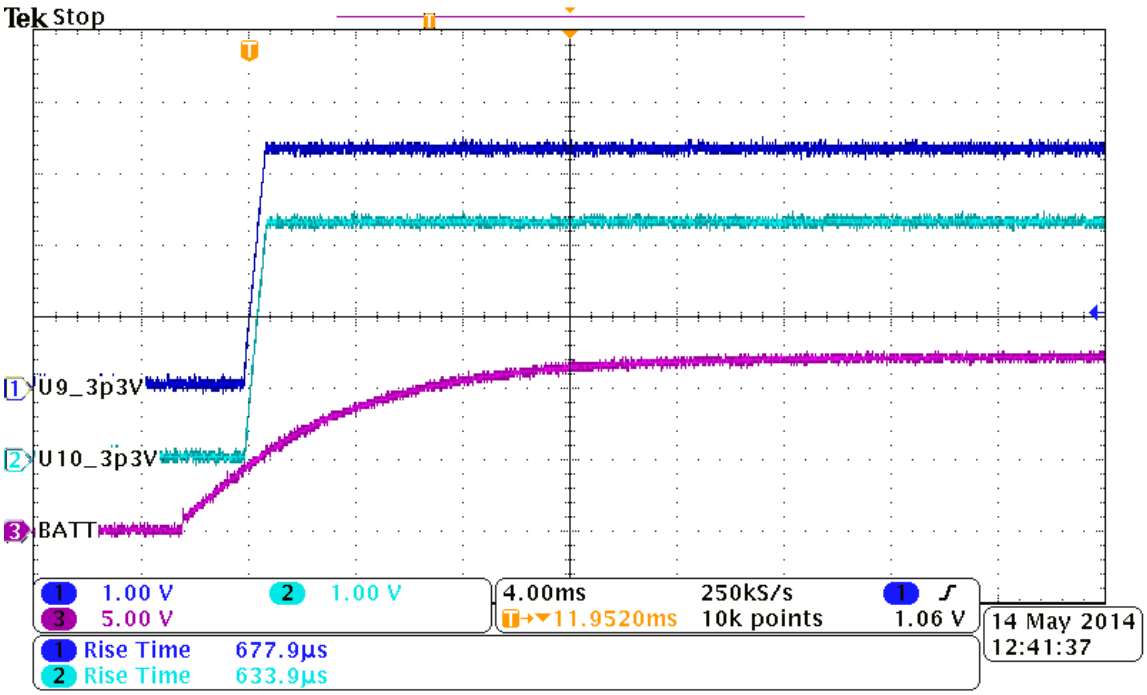
U8_TPS62151 (1.8V)



U11_TPS62130 (1.0V)



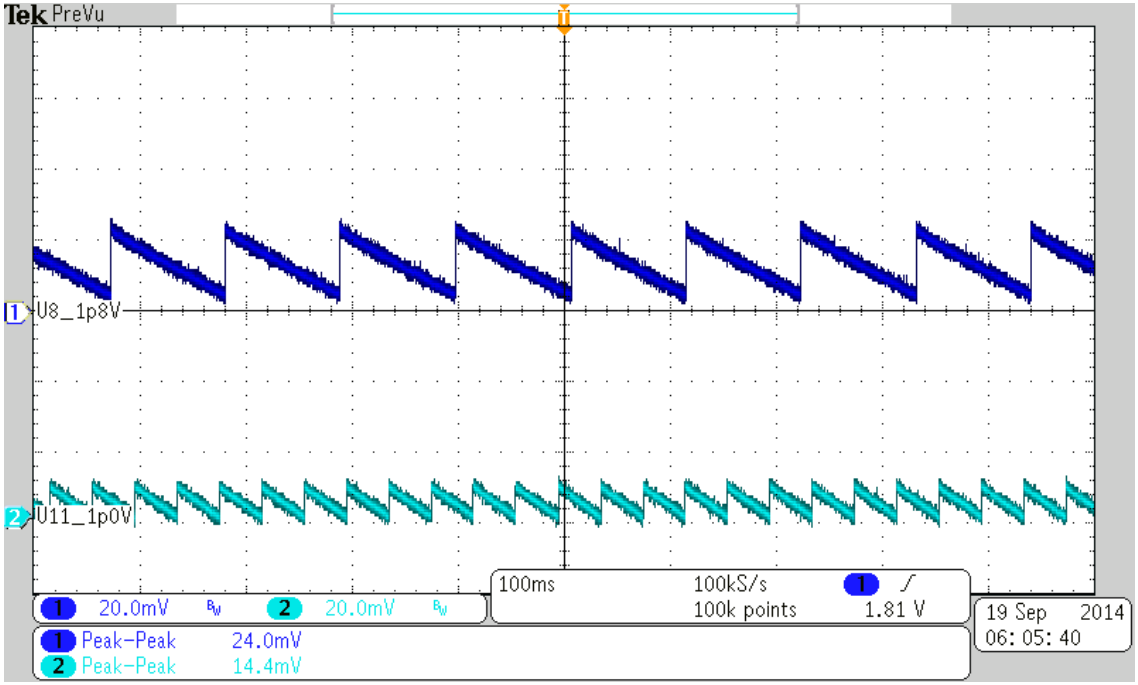
U9_TPS62182 (3.3V) & U10_TPS62182 (3.3V)



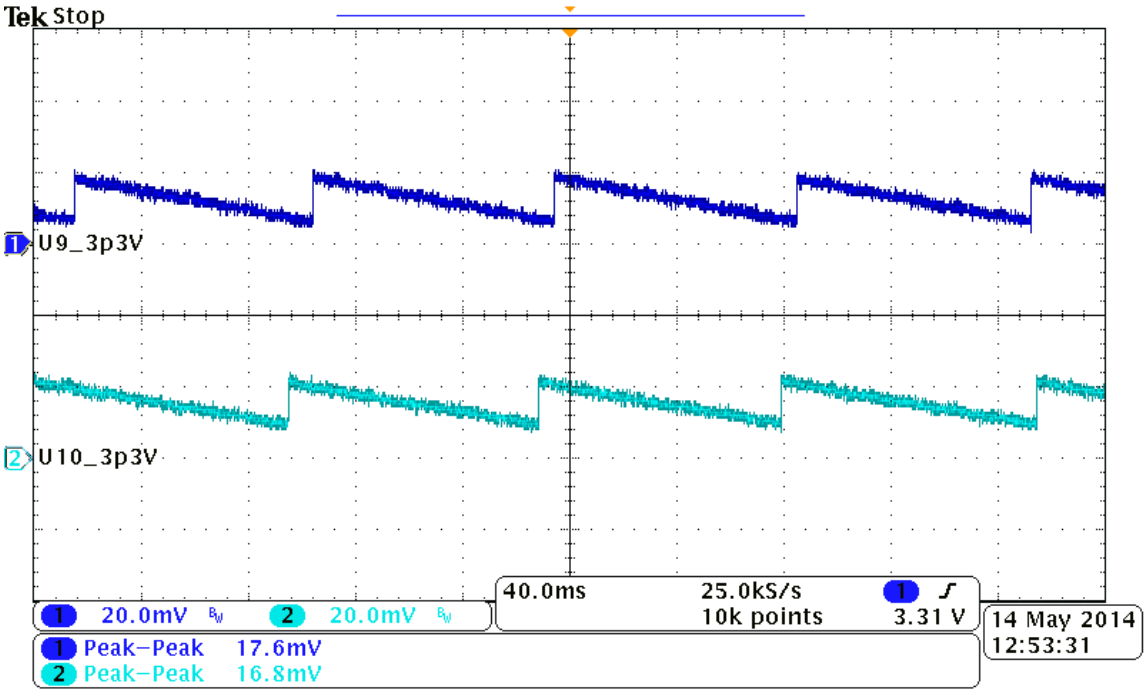
9.2.2 Output Ripple

No load Ripple

U8_TPS62151 (1.8V) & U11TPS62130 (1.0V)

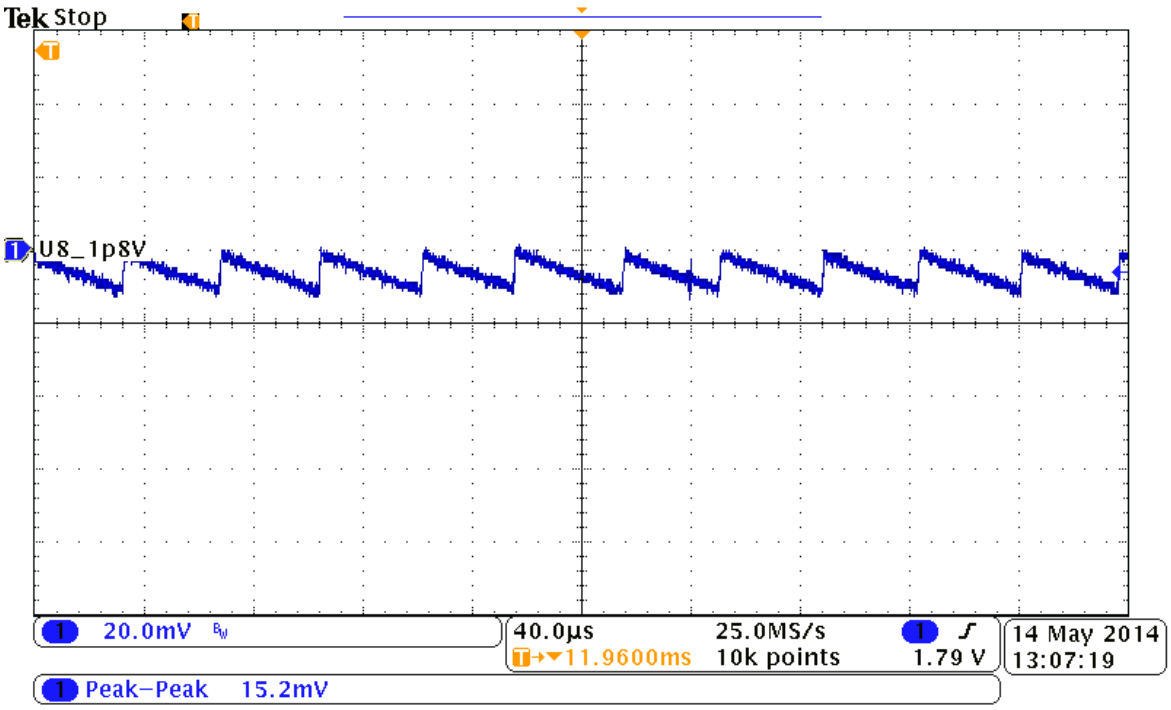


U9_TPS62182 (3.3V) & U10_TPS62182 (3.3V)

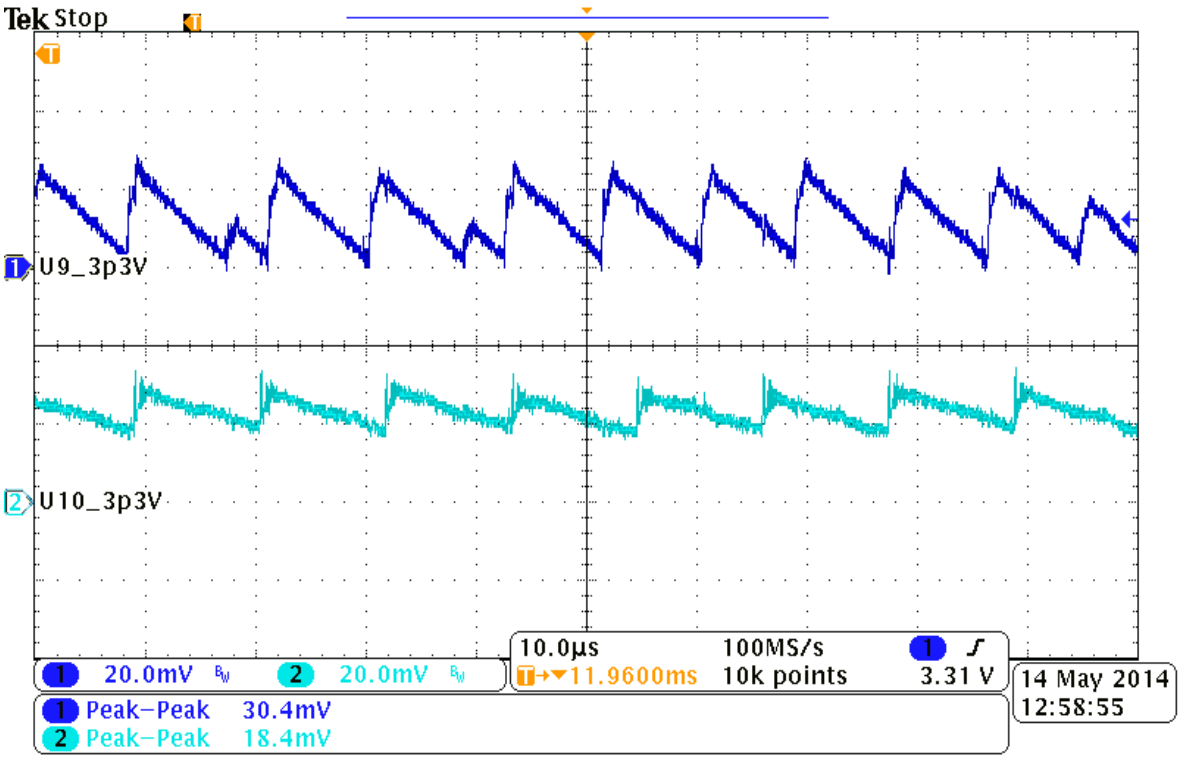


Light load Ripple

U8_TPS62151 (1.8V) V1P8M ON

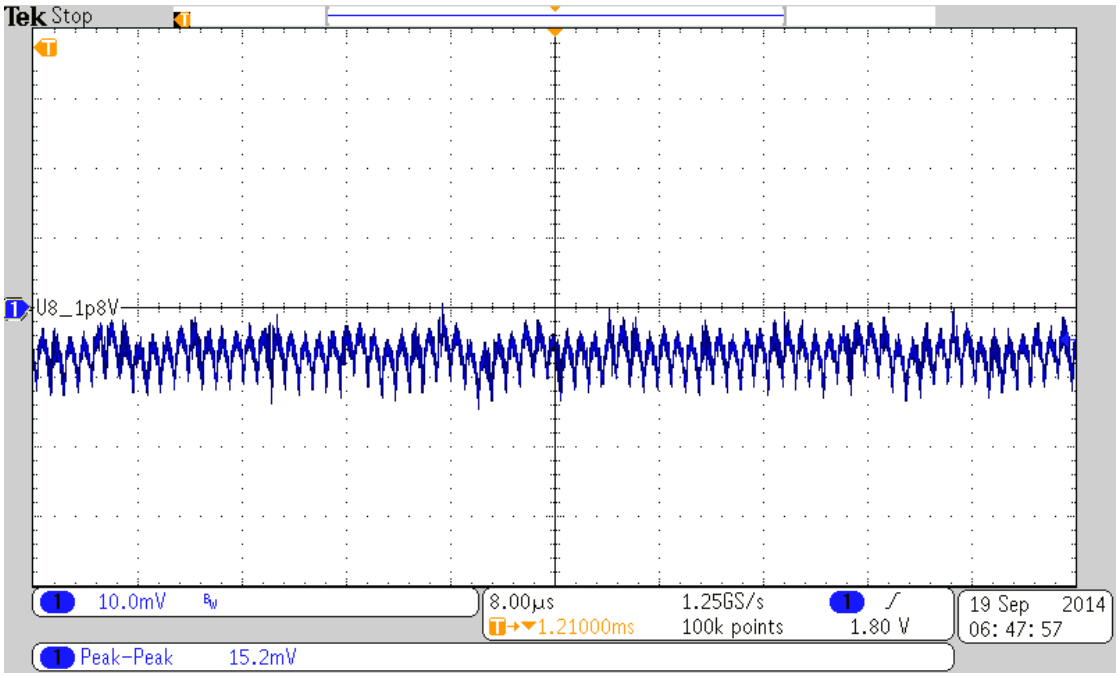


U9_TPS62182 (3.3V) EC ON & U10_TPS62182 (3.3V) V3P3S ON

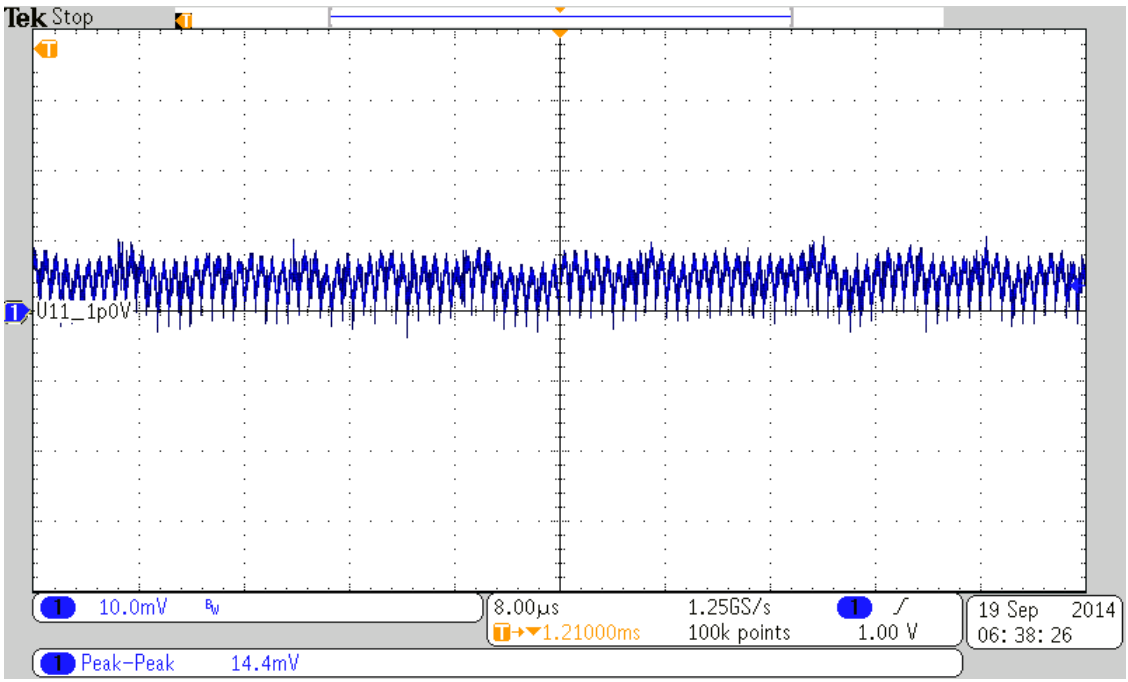


Full load Ripple

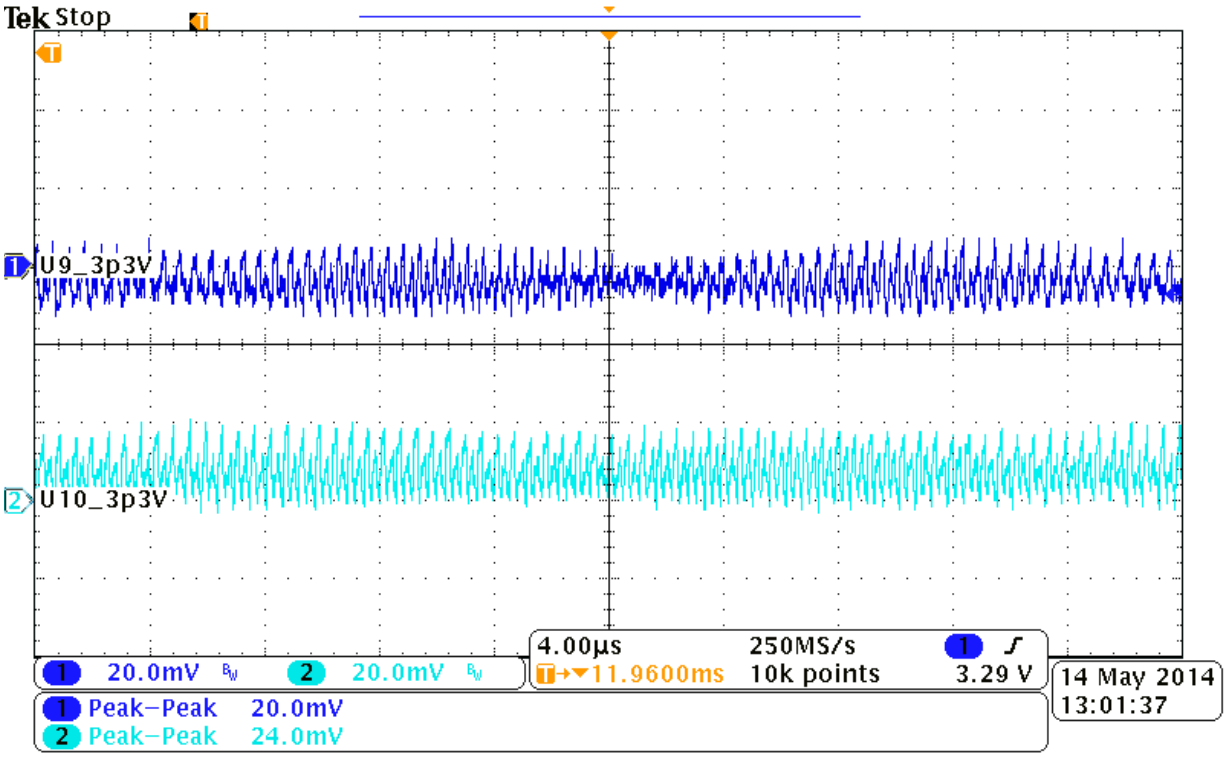
U8_TPS62151 (1.8V)



U11TPS62130 (1.0V)

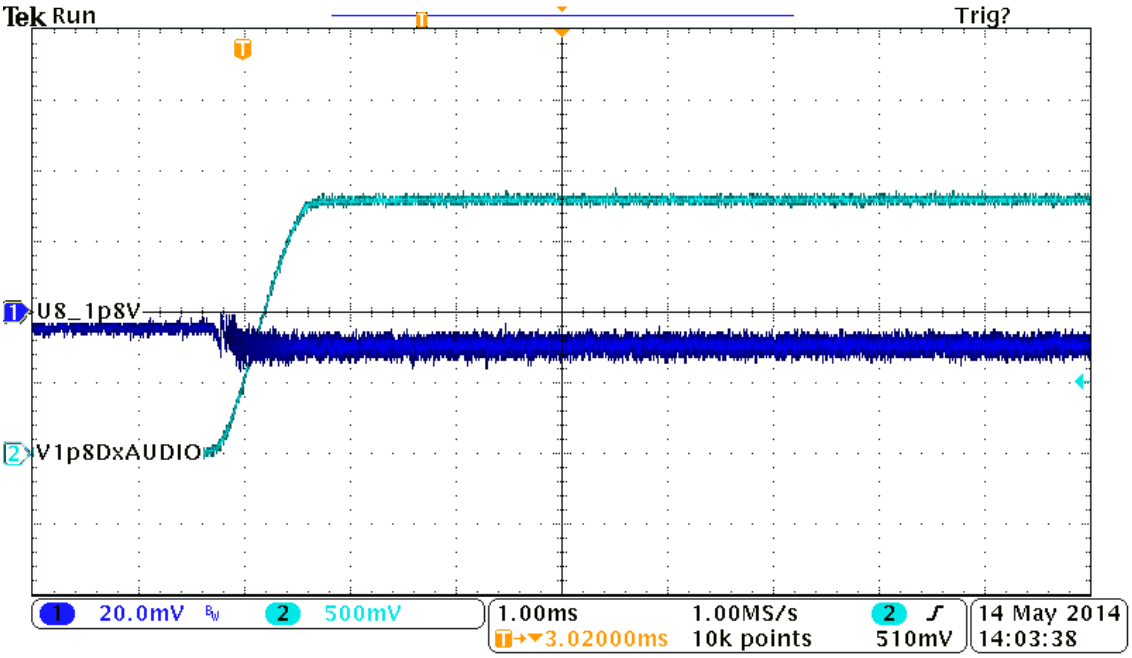


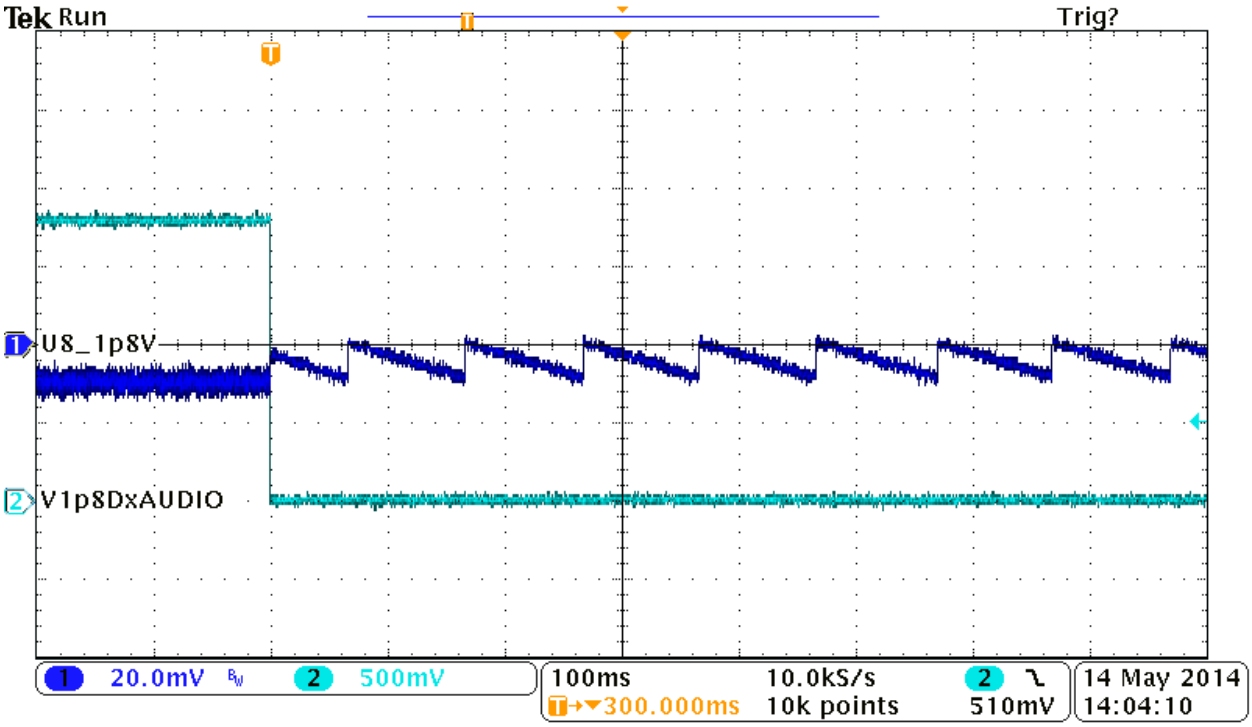
U9_TPS62182 (3.3V) & U10_TPS62182 (3.3V)



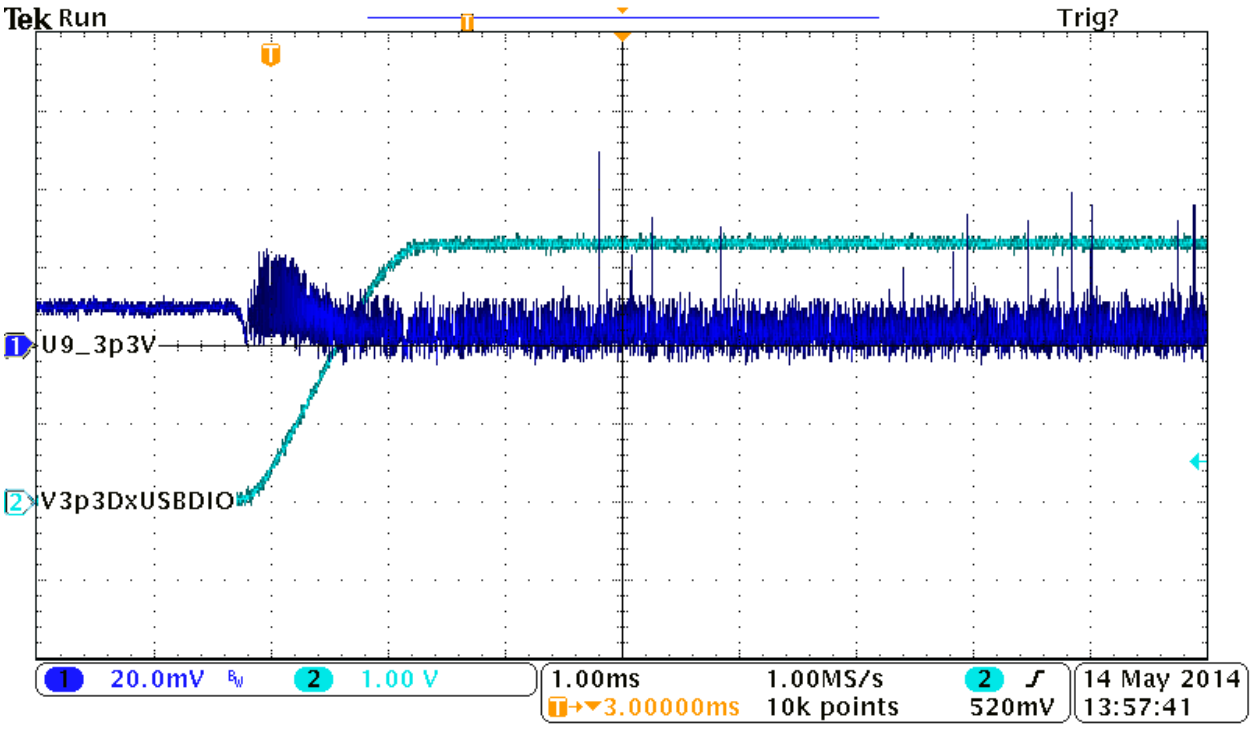
9.2.3 Load step Response

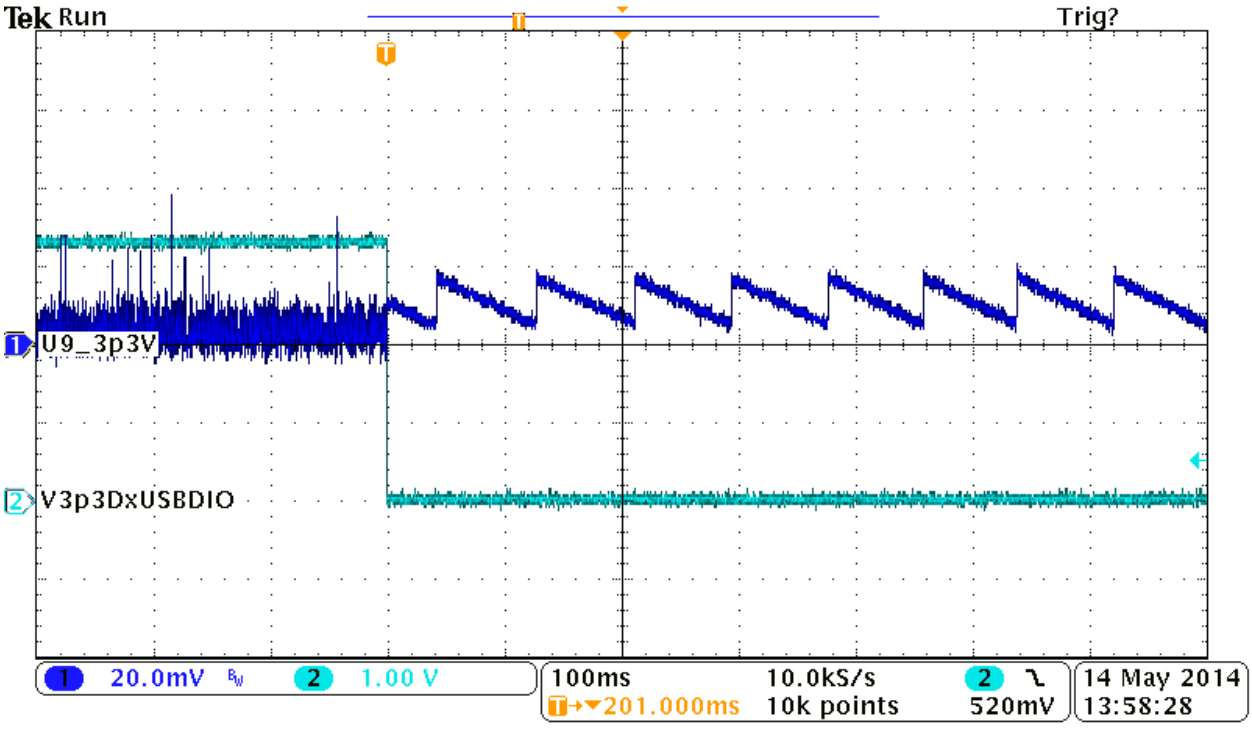
V1P8Dx_AUDIO



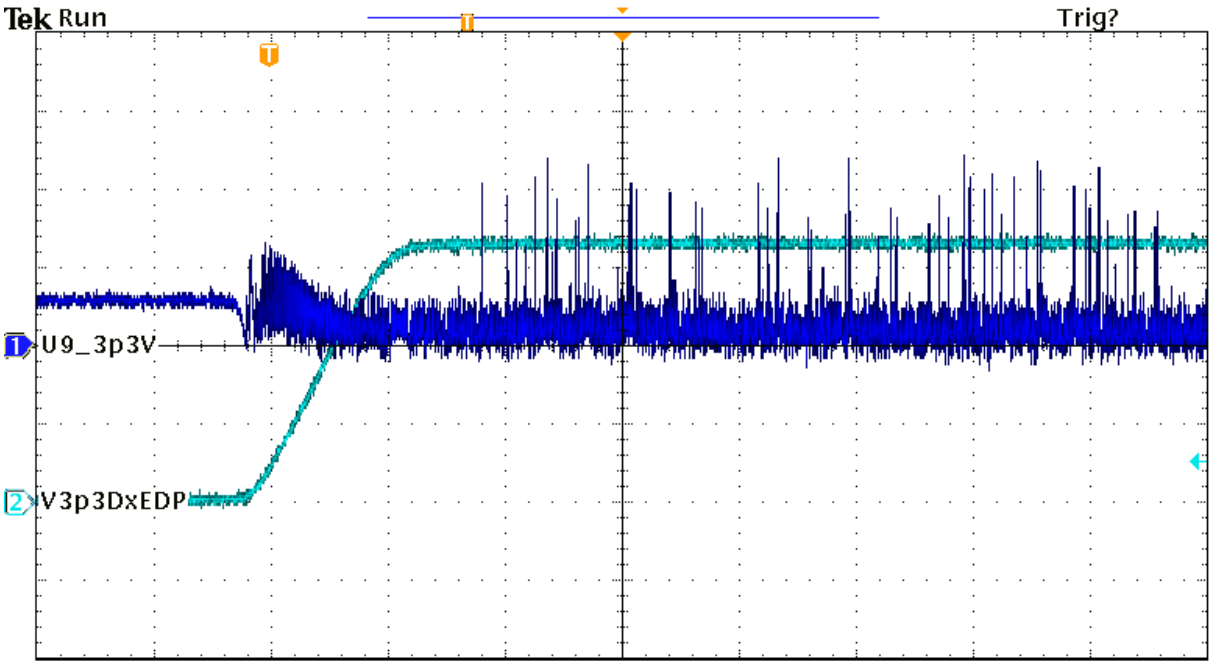


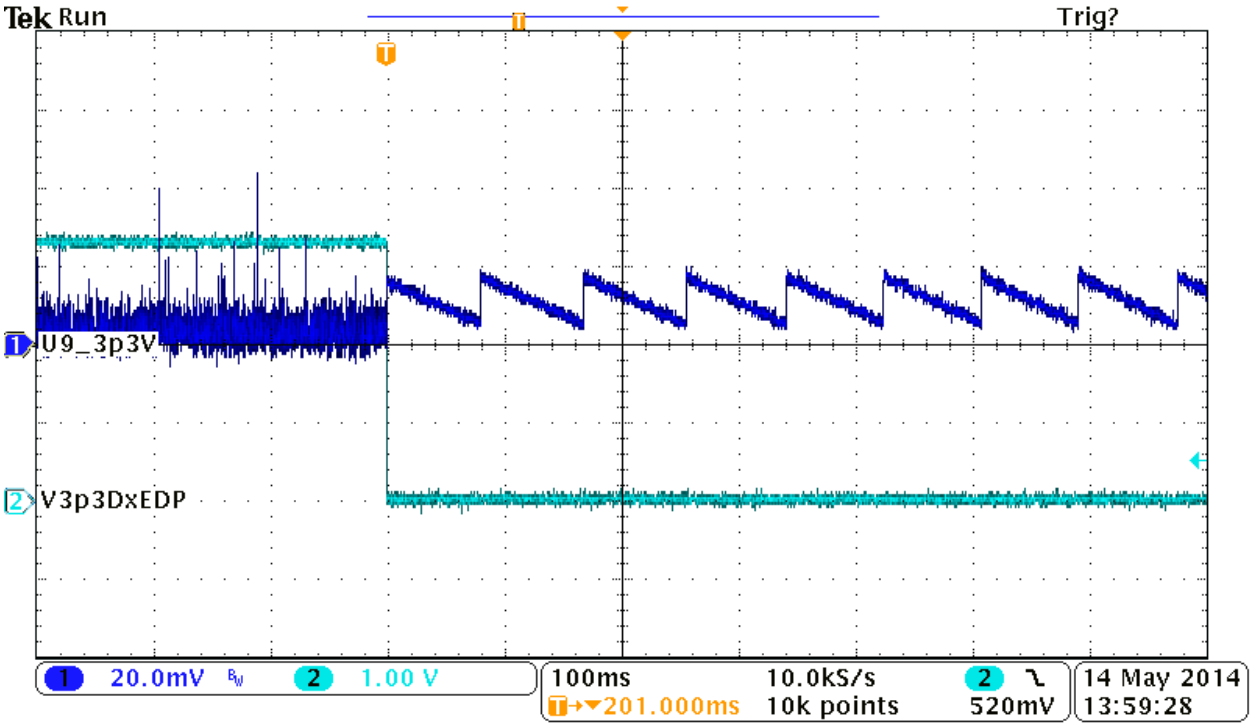
V3P3Dx_USBDIO



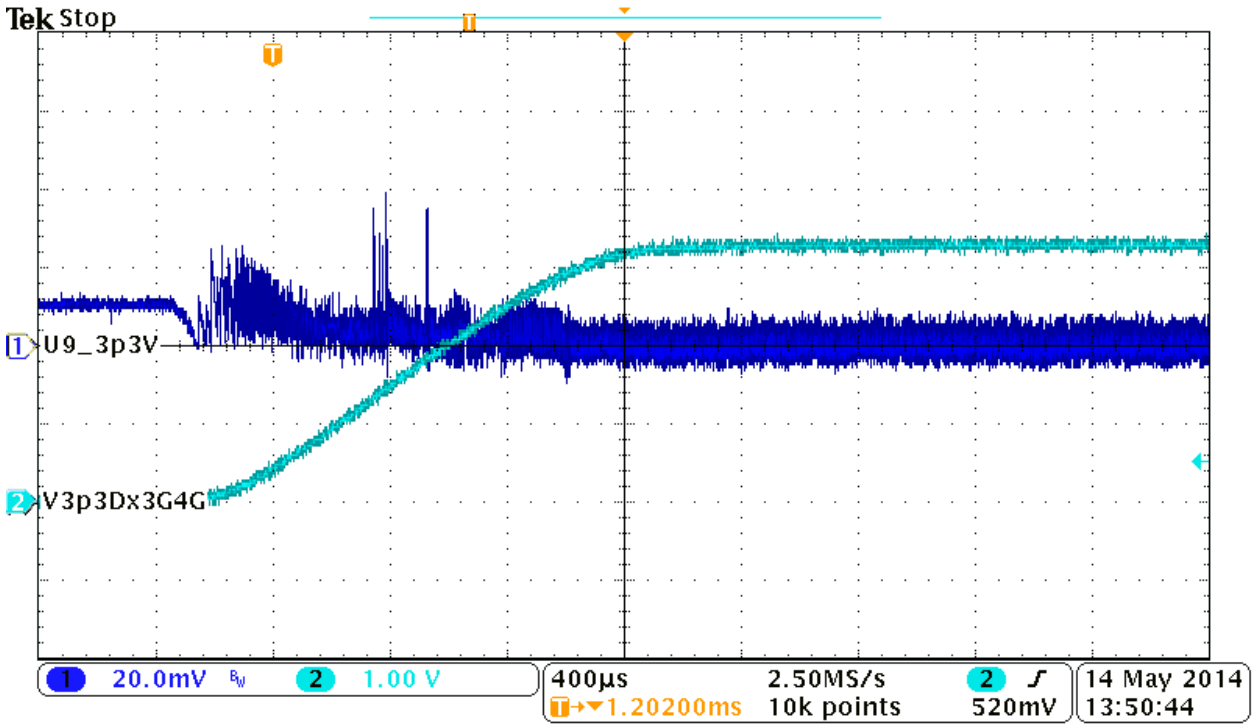


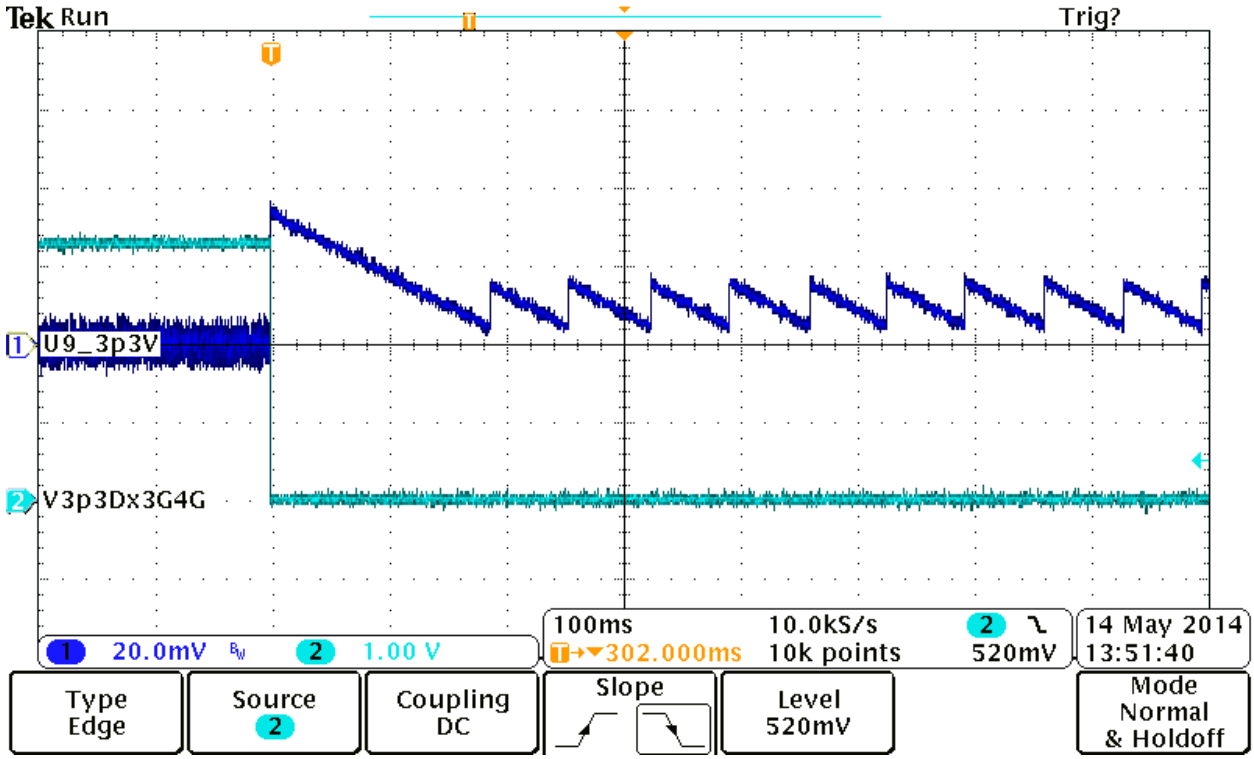
V3P3Dx_EDP


Tek Run
Trig?
U9_3p3V
V3p3DxEDP

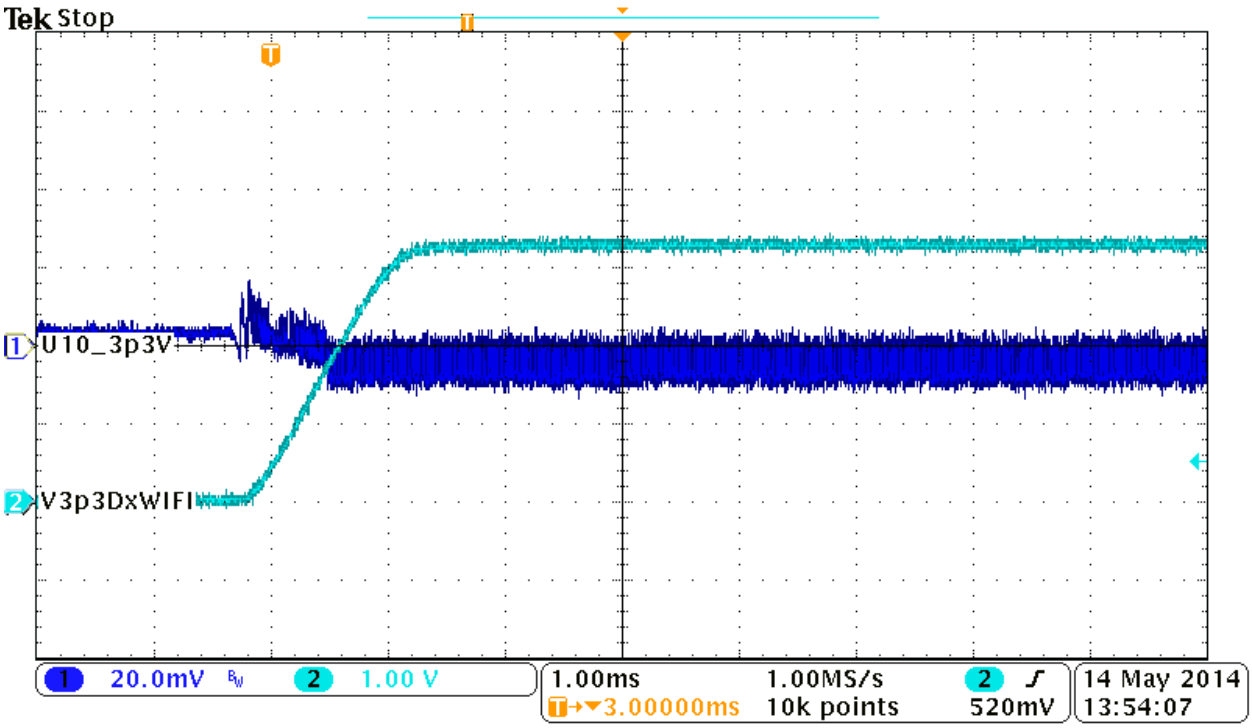

Tek Run
Trig?
U9_3p3V
V3p3DxEDP
1 20.0mV Bw
2 1.00 V
100ms
10.0kS/s
201.000ms
10k points
2
520mV
14 May 2014
13:59:28

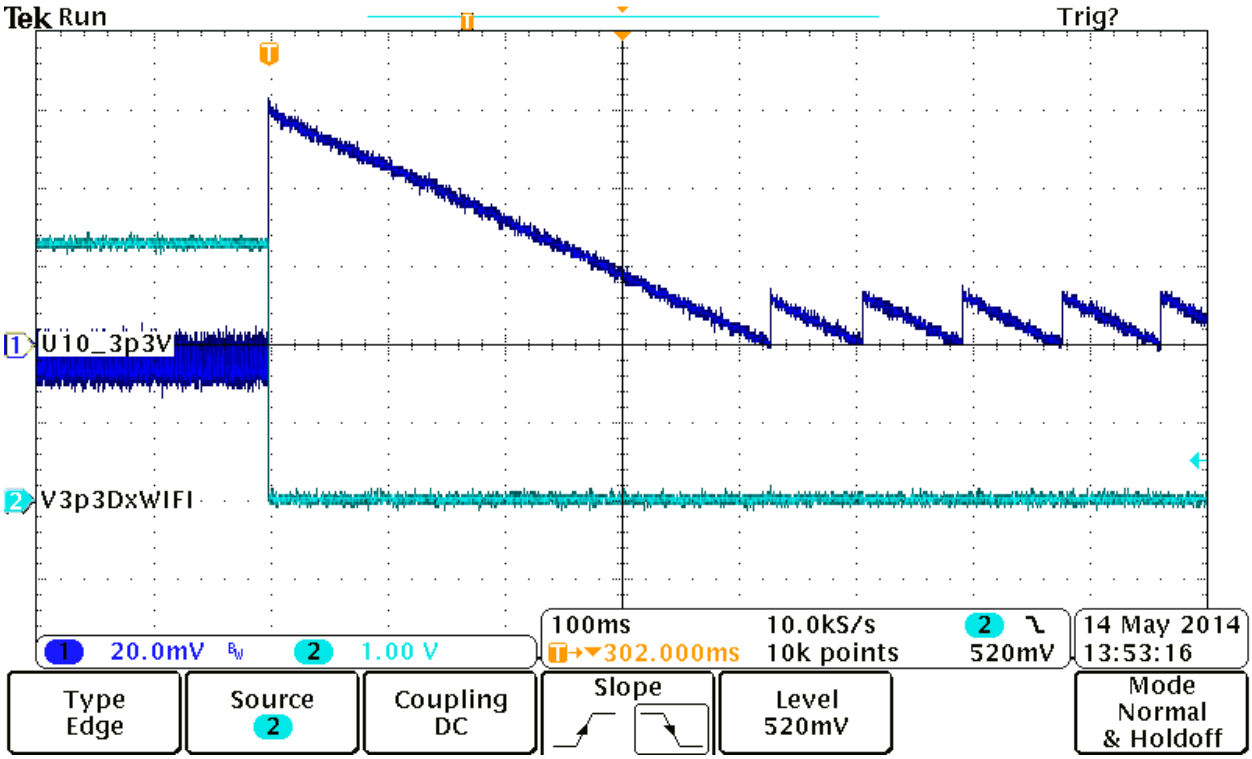
V3P3Dx_3G4G


Tek Stop
U9_3p3V
V3p3Dx3G4G
1 20.0mV BW 2 1.00 V
400µs 2.50MS/s
1.20200ms 10k points
2 520mV
14 May 2014
13:50:44

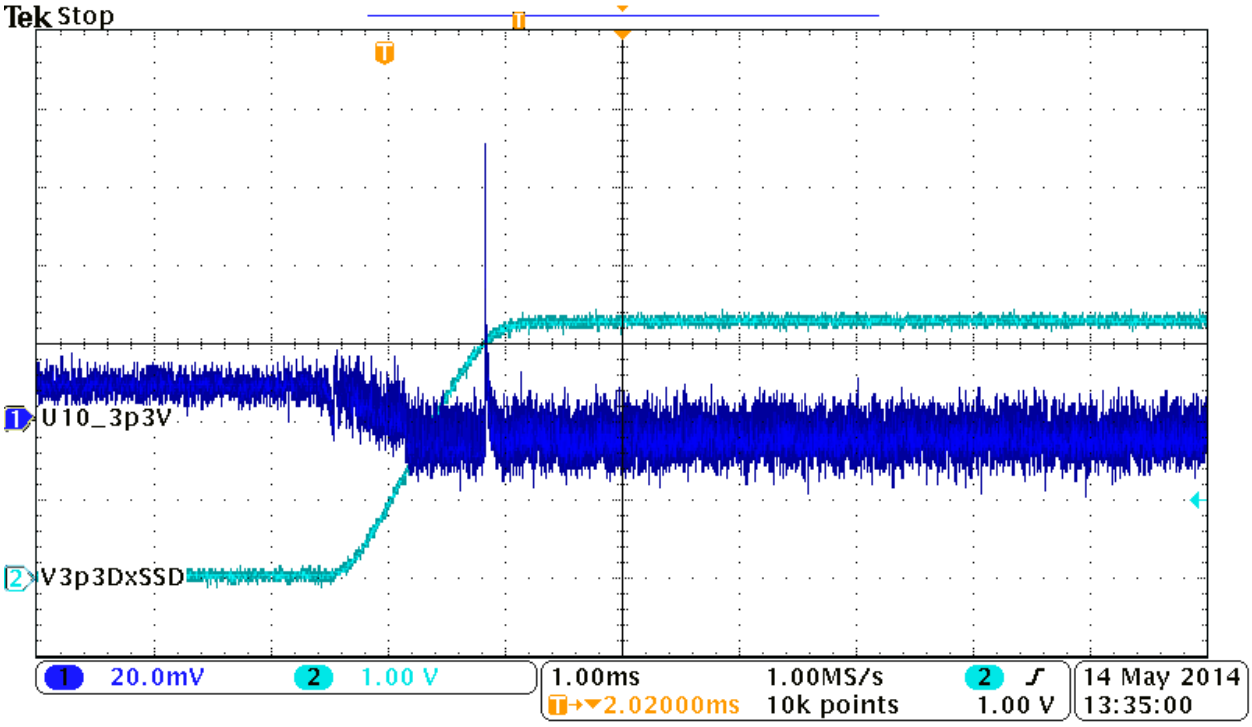

Tek Run
Trig?
U9_3p3V
V3p3Dx3G4G
1 20.0mV BW 2 1.00 V
100ms 10.0kS/s
302.000ms 10k points
2 520mV
14 May 2014
13:51:40
Type
Edge
Source
2
Coupling
DC
Slope
Level
520mV
Mode
Normal
& Holdoff

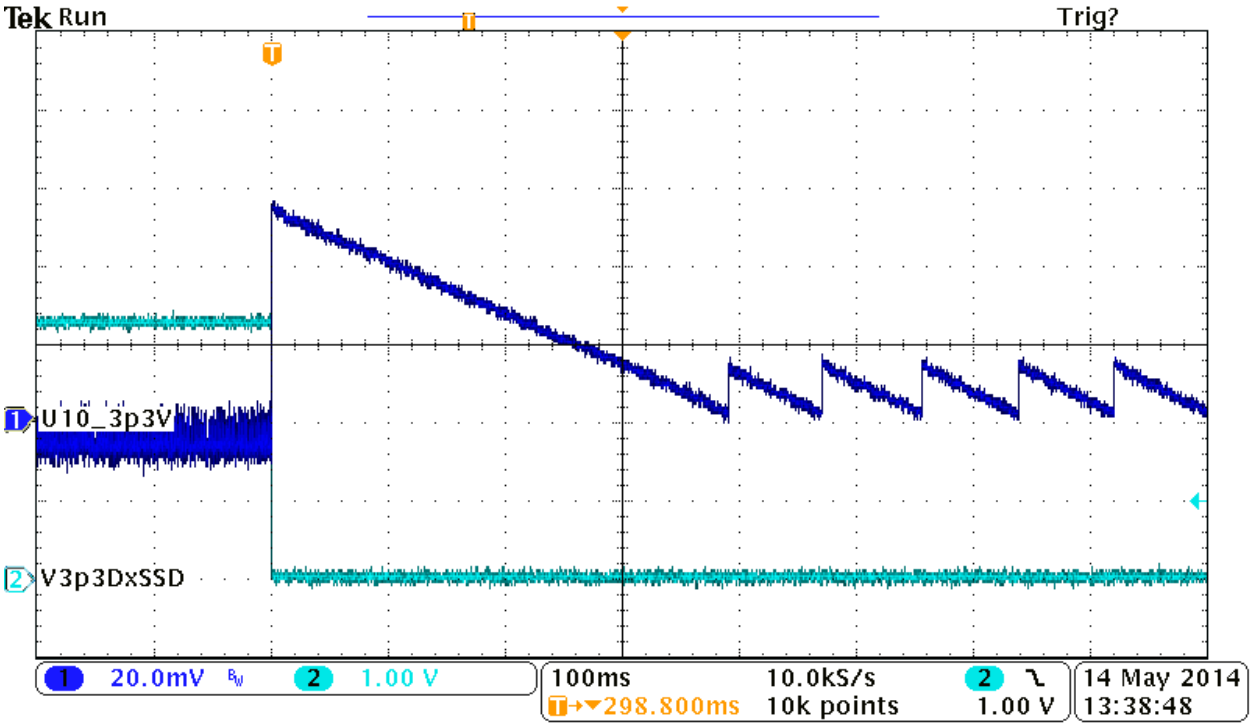
V3P3Dx_WIFI


Tek Stop
U10_3p3V
V3p3DxWIFI
20.0mV
1.00 V
1.00ms
1.00MS/s
3.00000ms
10k points
520mV
14 May 2014
13:54:07

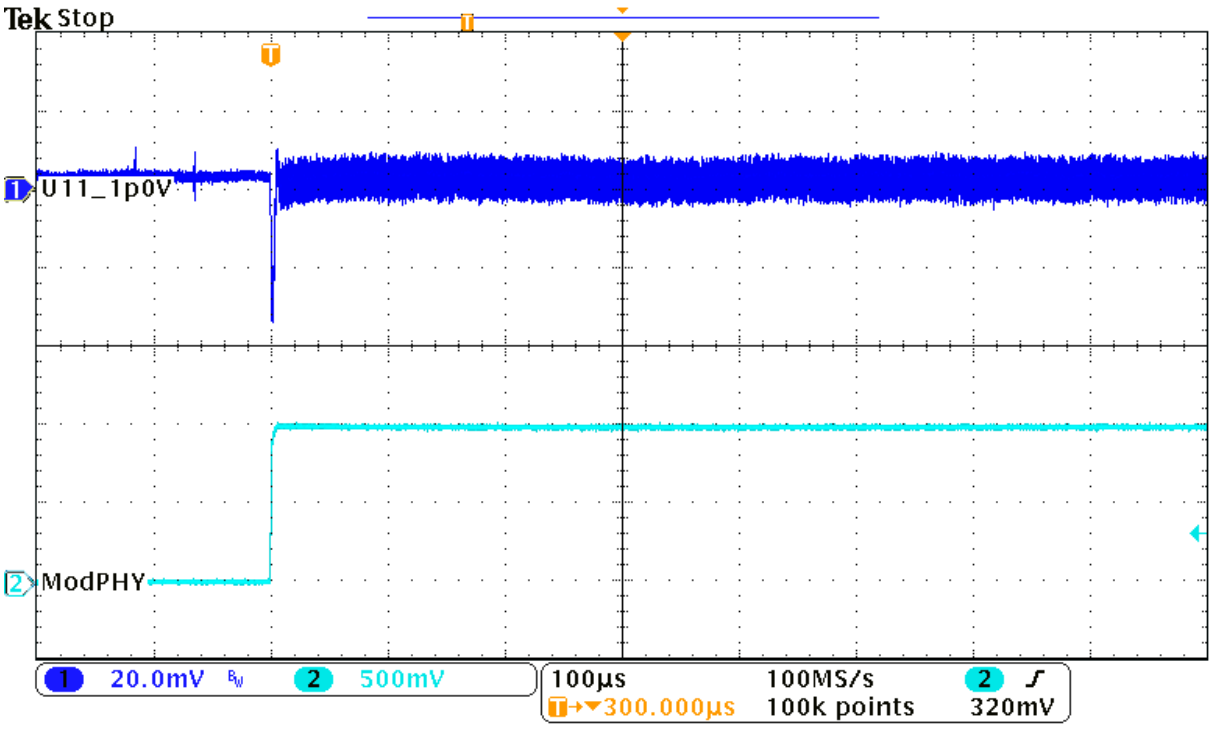

Tek Run
Trig?
U10_3p3V
V3p3DxWIFI
20.0mV
1.00 V
100ms
10.0kS/s
302.000ms
10k points
520mV
14 May 2014
13:53:16
Type
Edge
Source
2
Coupling
DC
Slope
Level
520mV
Mode
Normal
& Holdoff

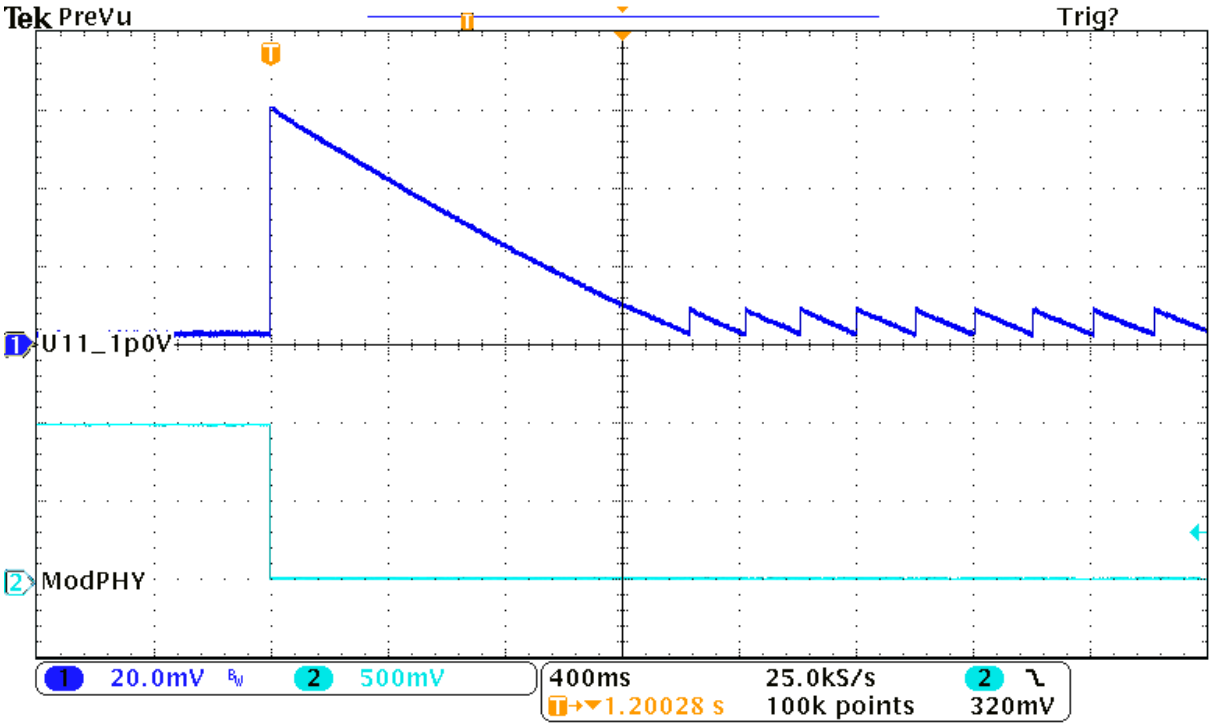
V3P3Dx_SSD


Tek Stop
U10_3p3V
V3p3DxSSD
1 20.0mV
2 1.00 V
1.00ms
1.00MS/s
2.02000ms
10k points
2 1.00 V
14 May 2014
13:35:00

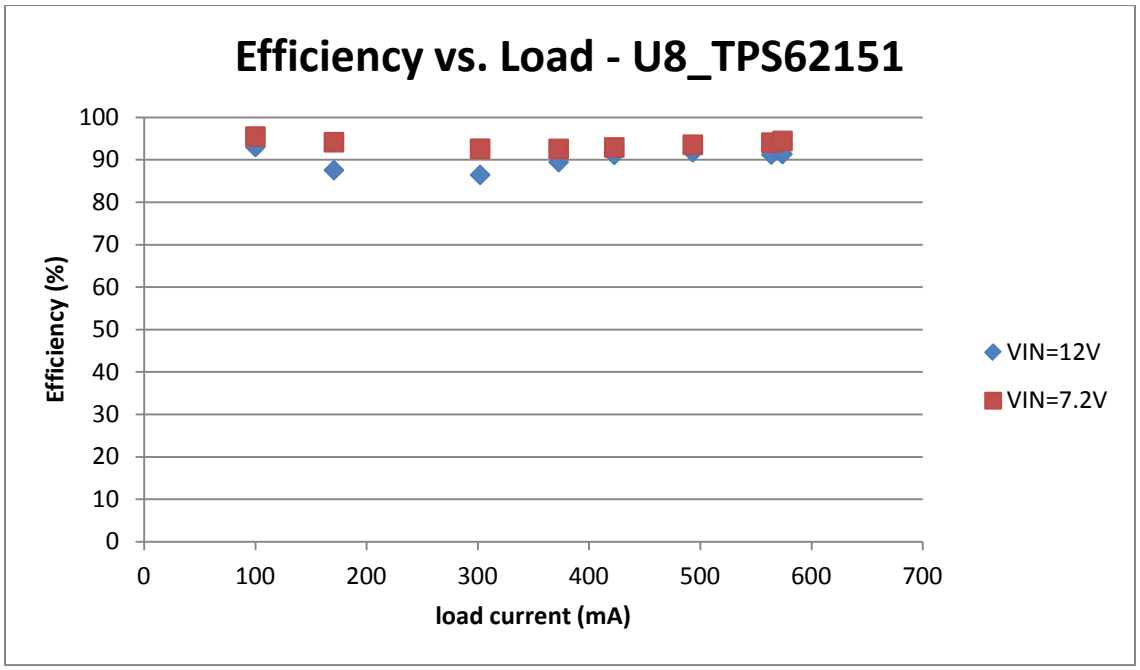

Tek Run
Trig?
U10_3p3V
V3p3DxSSD
1 20.0mV
2 1.00 V
100ms
10.0kS/s
298.800ms
10k points
2 1.00 V
14 May 2014
13:38:48

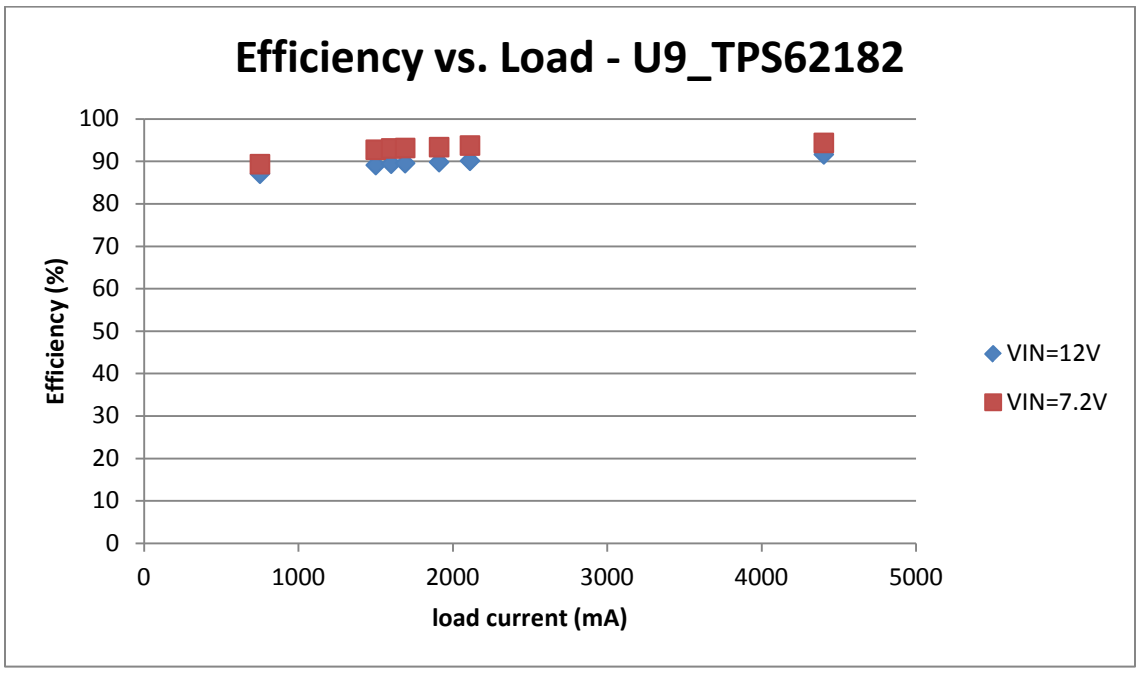
ModPHY

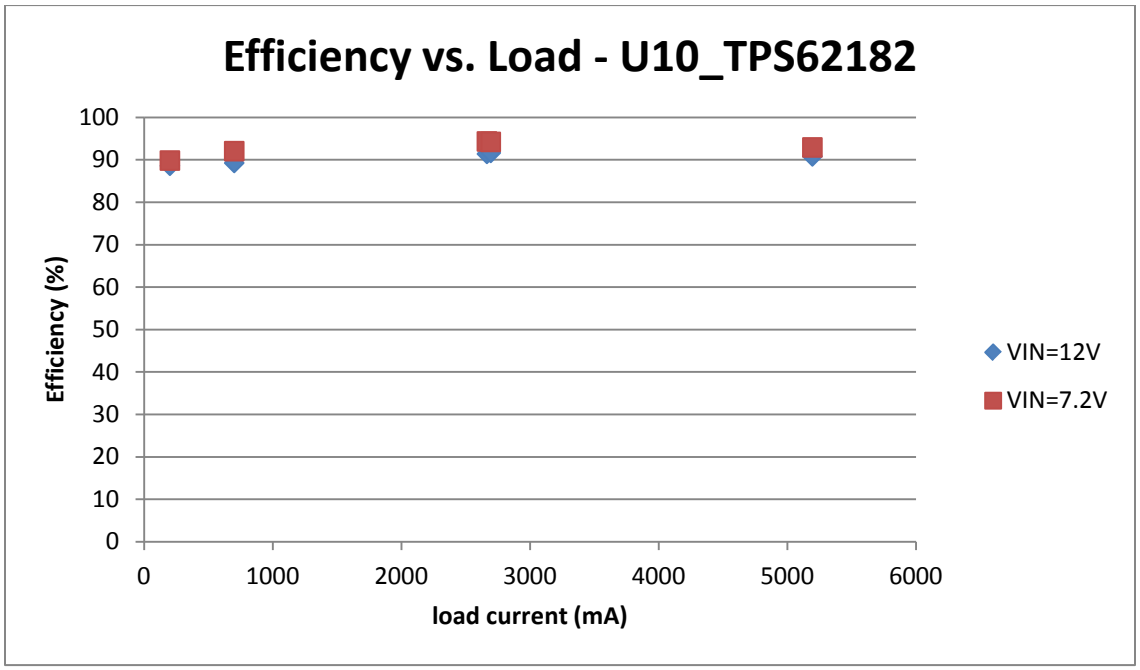

Tek Stop
U11_1p0V
ModPHY
1 20.0mV BW 2 500mV
100µs 100MS/s 2
300.000µs 100k points 320mV


Tek PreVu
Trig?
U11_1p0V
ModPHY
1 20.0mV BW 2 500mV
400ms 25.0kS/s 2
1.20028 s 100k points 320mV

9.2.4 Efficiency






Efficiency vs. Load - U10_TPS62182
Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
load current (mA)
VIN=12V
VIN=7.2V

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