TIDA-00194

TI Design: Skylake Power Delivery

Test Report
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

<table>
<thead>
<tr>
<th>DC-DC Part#</th>
<th>Rail Voltage</th>
<th>DC-DC Load</th>
<th>Ultrabook Rail Name</th>
<th>TPS22993 LS Channel</th>
<th>LS Load</th>
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<td>VDD1.83</td>
<td>U1_C1H1</td>
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<td></td>
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<td>2.4A</td>
<td>ModPHY</td>
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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 = 212\,\mu s, \ t_{ON} = 475.8\,\mu s, \ t_R = 505.1\,\mu s

![Graph showing timing measurements](image-url)
**V1P8S** turn-off & fall time

\[ t_{\text{OFF}} = 2.366\mu s, \ t_f = 3.4\mu s \]

**V1P8Dx_SENSORS** delay time, turn-on time & rise time

\[ t_D = 224\mu s, \ t_{\text{ON}} = 448.6\mu s, \ t_R = 571.7\mu s \]
V1P8Dx_SENSORS turn-off & fall time

\[ t_{\text{off}} = 2.966 \mu s, \quad t_f = 5.1 \mu s \]

V1P8Dx_AUDIO delay time, turn-on time & rise time

\[ t_D = 224 \mu s, \quad t_{\text{on}} = 466.6 \mu s, \quad t_R = 566.1 \mu s \]
**V1P8Dx_AUDIO** turn-off & fall time

\[ t_{\text{OFF}} = 2.22\,\mu\text{s}, \ t_{\text{F}} = 2.54\,\mu\text{s} \]

**V1P8Dx_SSD** delay time, turn-on time & rise time

\[ t_{\text{D}} = 224\,\mu\text{s}, \ t_{\text{ON}} = 451.4\,\mu\text{s}, \ t_{\text{R}} = 562.8\,\mu\text{s} \]
V1P8Dx_SSD turn-off & fall time

$t_{\text{off}} = 2.857\mu s$, $t_f = 5.073\mu s$

V3P3Dx_3G4G delay time, turn-on time & rise time

$t_D = 356\mu s$, $t_{\text{on}} = 793.4\mu s$, $t_R = 923.2\mu s$
**V3P3Dx_3G4G** turn-off & fall time

\[ t_{\text{off}} = 2.32\text{us}, \quad t_{\text{f}} = 2.5\text{us} \]

**V3P3Dx_AUDIO** delay time, turn-on time & rise time

\[ t_{\Delta} = 300\text{us}, \quad t_{\text{on}} = 649.6\text{us}, \quad t_{\text{r}} = 846.7\text{us} \]
V3P3Dx_AUDIO turn-off & fall time

\[ t_{\text{off}} = 2.6\mu\text{s}, \quad t_F = 3.4\mu\text{s} \]

V3P3Dx_SSD delay time, turn-on time & rise time

\[ t_D = 356\mu\text{s}, \quad t_{\text{ON}} = 771.4\mu\text{s}, \quad t_R = 962.7\mu\text{s} \]
V3P3Dx_SSD turn-off & fall time

t\(_{OFF} = 7.2\,\text{us},\ t_F = 17.5\,\text{us}\)

V3P3Dx_WIFI delay time, turn-on time & rise time

t\(_D = 356\,\text{us},\ t_{ON} = 770\,\text{us},\ t_R = 941\,\text{us}\)
V3P3Dx_WIFI turn-off & fall time

t_{\text{OFF}} = 2.5\text{us}, t_{\text{F}} = 3.3\text{us}

V3P3M delay time, turn-on time & rise time

t_{\text{D}} = 296\text{us}, t_{\text{ON}} = 693\text{us}, t_{\text{R}} = 895\text{us}
**V3P3M** turn-off & fall time

\[ t_{\text{OFF}} = 2.4\,\mu s, \quad t_{F} = 3.04\,\mu s \]

**ModPHY** delay time, turn-on time & rise time

\[ t_{D} = 8.7\,\mu s, \quad t_{\text{ON}} = 9.1\,\mu s, \quad t_{R} = 0.97\,\mu s \]
ModPHY turn-off & fall time

t_{OFF} = 1.56\mu s, t_F = 0.32\mu s

<table>
<thead>
<tr>
<th>Rail name</th>
<th>( t_D ) (\mu s)</th>
<th>( t_{ON} ) (\mu s)</th>
<th>( t_R ) (\mu s)</th>
<th>( t_{OFF} ) (\mu s)</th>
<th>( t_F ) (\mu s)</th>
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</table>
9.1.2 $R_{ON}$ measurements:

**Setup:** \[ R_{ON} = \frac{(V_{IN} - V_{OUT})}{I_{load}} \]

<table>
<thead>
<tr>
<th>Rail name</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
<th>$V_{IN} - V_{OUT}$ (mV)</th>
<th>$R_{ON}$ (mohm)</th>
<th>Pout (W)</th>
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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)
9.2.2 Output Ripple

No load Ripple

U8_TPS62151 (1.8V) & U11_TPS62130 (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)
9.2.3 Load step Response

V1P8Dx_AUDIO
V3P3Dx_EDP

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V3P3Dx_WIFI
ModPHY

Tek Stop

U11_1p0V

ModPHY

Tek PreVu

U11_1p0V

ModPHY
9.2.4 Efficiency

Efficiency vs. Load - U8_TPS62151

VIN=12V
VIN=7.2V

Efficiency vs. Load - U9_TPS62182

VIN=12V
VIN=7.2V
Efficiency vs. Load - U10_TPS62182

- Efficiency (%)
- Load current (mA)
- VIN=12V
- VIN=7.2V
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