TI Designs: TIDA-01451
Power Switching Reference Design For Set-Top Box

Description

This reference design emulates the power distribution of set-top boxes (STBs). By using integrated load switches to control the power rails, each rail can be turned on or off depending on the needs and wants of the user. Turning off rails that are not being used reduces power loss and helps to meet energy compliance standards, such as ENERGY STAR®. An eFuse placed at the input manages hot plug transients and protect the downstream DC/DC converters from an input voltage that is too high or too low, which reduces the end-equipment return rate.

Resources

TIDA-01451	Design Folder
TPS22918	Product Folder
TPS22976	Product Folder
TPS22945	Product Folder
TPS2065D	Product Folder
TPS2595x	Product Folder

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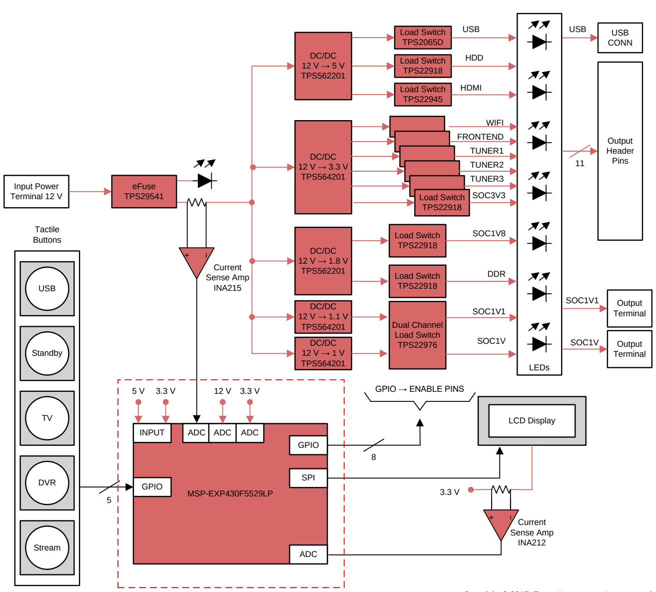
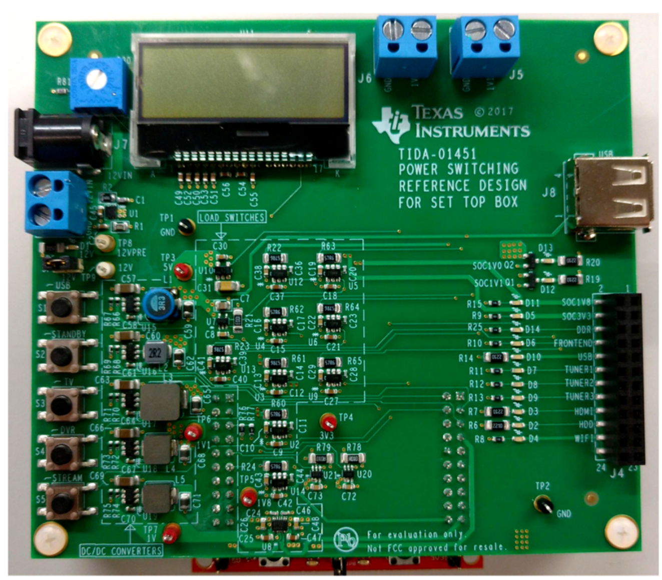
Features

- Fully-Featured Power Tree for Common Loads in STB Allows for Appropriate Selection of Load Switches and DC/DCs in System Design
- Current Limiting on HDMI Port Provides Necessary Protection for 5-V Rail
- Switching OFF Unused Loads Results in Higher System Efficiency and Lower Standby Current for Meeting Requirements Such as ENERGY STAR
- Load Switches Offer Smaller Solution Size and Lower Component Count as Compared to Discrete MOSFET Solution

Applications

- Set-Top Box (STB)
- Digital Video Recorder (DVR)





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1 System Description

This reference design showcases a power distribution and energy saving solution for set-top boxes (STBs). This design incorporates 12 load switches for 13 output rails that meet the specifications for various STB power rails including: high-definition multimedia interface (HDMI), hard disk drive (HDD), processor rails, front-end liquid-crystal displays (LCDs), USB, double data rate (DDR), and tuner blocks. The push-buttons control which “mode” the design is in and are responsible for turning the respective load switches ON or OFF. An eFuse at the input manages hot plug transients and protect downstream DC/DC converters from an input voltage that is too high or too low.

Power information displays on the LCD to verify energy savings in real time. A current sense amplifier is placed at the input of the design to monitor the total system current intake. A second current sense amplifier is placed before the LCD backlight to allow the microcontroller (MCU) to remove the impact of the LCD from the system power. The MCU is placed in low-power mode unless it is updating the LCD or it registers an input from the push-buttons.

All load switches have their output pin tied to a light-emitting diode (LED), for visual confirmation that the rail is ON, and an output pin on either a header block or a terminal connector. This configuration allows the user to attach real or electronic loads to each load switch for testing and verification. The USB load switch output is also tied to a USB-A female connector to allow connectivity to a USB device and charging when the load switch is enabled.

1.1 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
VISUAL		
LED current	—	15 mA
Typical LED forward voltage	$V_{FWD,RED}$	1.7 V
DC/DC – TPS562201		
Input voltage range	V_{IN}	6 V to 17 V
Output voltages	V_{OUT}	5.0 V, 1.8 V
Max current	I_{OUT}	2 A
DC/DC – TPS564201		
Input voltage range	V_{IN}	6 V to 17 V
Output voltages	V_{OUT}	3.3 V, 1.1 V, 1 V
Max current	I_{OUT}	4 A
eFuse – TPS259541		
Input voltage range	V_{IN}	2.7 V to 18 V
Max current	I_{OUT}	4 A
On resistance	R_{ON}	34 mΩ
Features of interest	Overvoltage protection (OVP), adjustable current limit, undervoltage lock out (UVLO), adjustable slew rate, thermal shutdown	
LOAD SWITCH – TPS22918		
Input voltage range	V_{IN}	1.0 V to 5.5 V
Max current	I_{OUT}	2 A
On resistance	R_{ON}	52 mΩ
Shutdown current	I_{SD}	0.5 µA
Features of interest	Quick output discharge (QOD), adjustable rise time	
LOAD SWITCH – TPS22976		
Input voltage range	V_{IN}	0.6 V to 5.7 V
Max current	I_{OUT}	6 A per channel
On resistance	R_{ON}	14 mΩ
Shutdown current	I_{SD}	1.375 µA

Table 1. Key System Specifications (continued)

PARAMETER	SPECIFICATIONS	DETAILS
Features of interest	Dual channel, adjustable rise time, thermal shutdown, quick output discharge (QOD)	
LOAD SWITCH – TPS22945		
Input voltage range	V_{IN}	1.62 V to 5.5 V
Max current	I_{OUT}	100 mA
On resistance	R_{ON}	0.4 Ω
Shutdown current	I_{SD}	1 µA
Features of interest	Current limit, UVLO, thermal shutdown, fault blanking, auto restart	
LOAD SWITCH – TPS2065D		
Input voltage range	V_{IN}	4.5 V to 5.5 V
Max current	I_{OUT}	1 A
On resistance	R_{ON}	96 mΩ
Shutdown current	I_{SD}	0.5 µA
Features of interest	Current Limit, deglitched fault reporting, output discharge, fixed soft start, reverse current blocking (RCB)	
CURRENT SENSE AMPLIFIER – INA212		
Common-mode range	V_{CM}	–0.3 V to 26 V
Gain	G	1000 V/V
CURRENT SENSE AMPLIFIER – INA215		
Common-mode range	V_{CM}	–0.3 V to 26 V
Gain	G	75 V/V
LCD – NHD-C128321Z		
Resolution	—	128 pixels x 32 pixels
Backlight voltage	V_{LED}	2.8 V to 3.3V
Backlight current	I_{LED}	10 mA to 26 mA
Communication protocol	—	SPI
MICROCONTROLLER – MSP-EXP430F5529LP		
ADC voltage	—	3.3 V
GPIO voltage	—	3.3 V

2 System Overview

2.1 Block Diagram

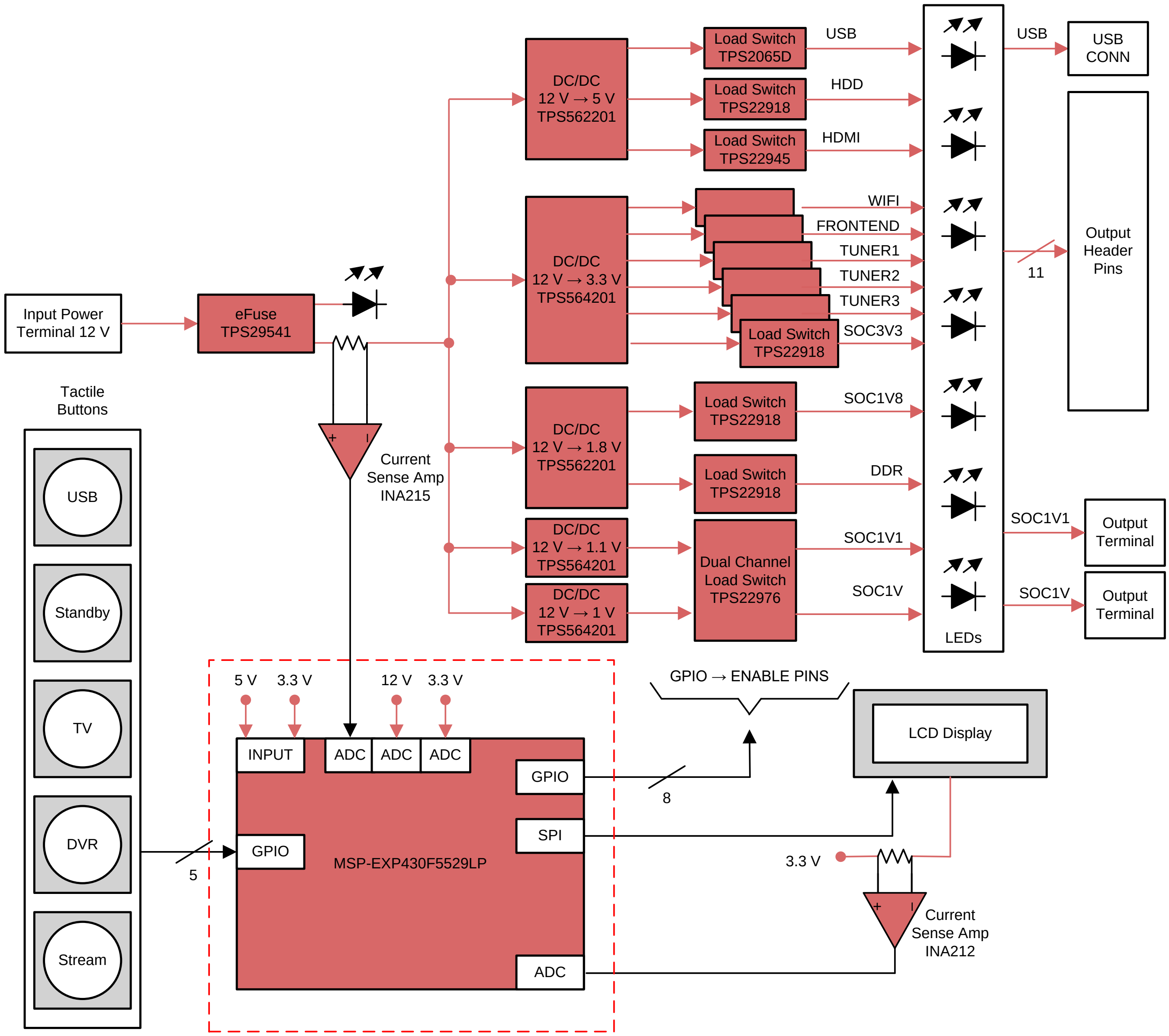

Figure 1. TIDA-01451 Block Diagram

2.2 Design Considerations

2.2.1 Total Solution Size

STBs, digital video recorders (DVRs), and other media or streaming devices are continually getting smaller and sleeker, which requires a more space-conscious layout. The aim of this reference design is to keep the load switch solution size as compact and space efficient as possible. In the center of the board is a dashed box with a silkscreen title labeled “LOAD SWITCHES” (see Figure 2).

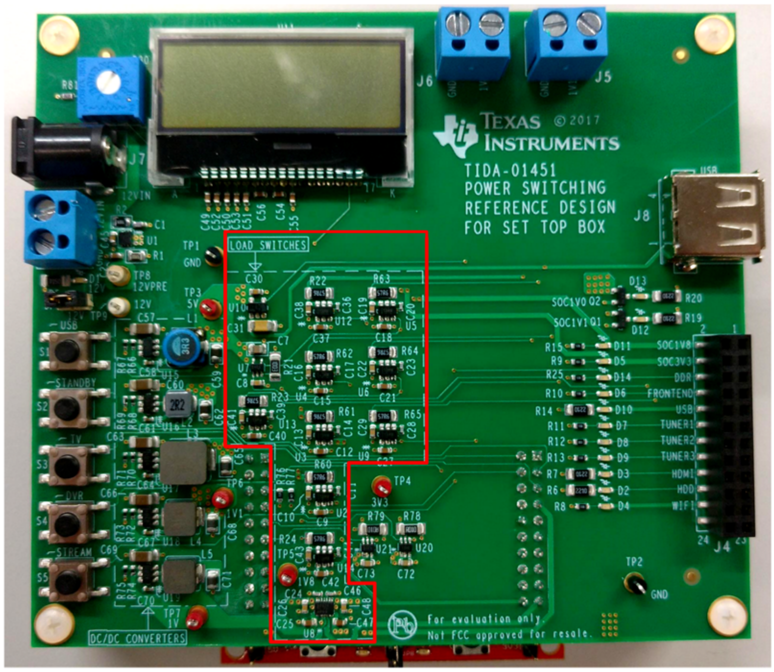

Figure 2. "LOAD SWITCHES" Area

This boxed-off area includes 12 load switches, which provide the 13 output rails for the reference design. All load switches include a controlled rise time and the additional features listed in Table 1.

The total solution size for all the load switches, their passive components, and board layout spacing is 1290 mm^2. The load switches and passive components alone add up to 187.4 mm^2. The ratio between the board layout and integrated circuit (IC) + passive sizes is approximately 6.9 times, which is a ratio used in later calculations.

Selecting a Load Switch to Replace a Discrete Solution (SLVA887) provides a comparison between discrete and integrated load switches, which includes the features present in the load switches used for this design (see Table 2). This document serves as a reference for calculating a discrete implementation solution size for comparison to the reference design’s integrated solution size (see Table 3).

Table 2. Load Switch Features

DEVICE	FEATURES			
	QUICK OUTPUT DISCHARGE	REVERSE CURRENT BLOCKING	CURRENT LIMITING	UNDERVOLTAGE LOCK OUT
TPS22918	Yes	—	—	—
TPS22976	Yes	—	—	—
TPS2065D	Yes	Yes	Yes	—
TPS22945	—	—	Yes	Yes

Table 3. Discrete Implementation Size Comparison

DEVICE	BASIC DISCRETE SWITCH (mm²)	SIZE OF IMPLEMENTING FEATURE DISCRETELY (mm²)				TOTAL SPACE (mm²)	NO OF DEVICES	TOTAL SIZE (mm²)
		QUICK OUTPUT DISCHARGE	REVERSE CURRENT BLOCKING	CURRENT LIMITING	UNDERVOLTAGE LOCK OUT			
TPS22918	17.24	8.62	—	—	—	25.86	9	232.74
TPS22976	34.48	17.64	—	—	—	51.72	1	51.72
TPS2065D	17.24	8.62	8.12	6.02	—	40	1	40
TPS22945	17.24	—	—	6.02	12.04	35.3	1	35.3
							TOTAL	**359.76**

Note that the calculation in Table 3 for the discrete implementation does not include thermal shutdown, which is present in the TPS22976 and TPS22945, or fault reporting, which is present in the TPS2065D.

Assuming the same 6.9 times ratio between the total board space and IC + passive sizes, the total solution size for a discrete implementation is approximately 2490 mm², or about 93% larger than the integrated solution.

2.2.2 Minimize Standby Power Consumption

STBs, DVRs, and other media or streaming devices can receive certifications based on their power consumption in different operating modes, one of which is Deep Sleep Mode in Version 5.0 of ENERGY STAR, which requires less than or equal to 1 W. This reference design aims to reduce the power consumption of non always-on rails by disconnecting the loads from the DC/DC converters when they are not in use (see Figure 2).

Always-on rails are required by critical components in the system and must remain on throughout all operational modes. The power supplied through these rails is part of the bottom-line power consumption of the product. Non always-on rails are used only in certain operating modes and can be turned off when idle to save power.

The required voltage level for always-on rails varies from system to system, which is why all five DC/DC converters in this reference design are left enabled (see Figure 3). The 13 output rails are considered non always-on rails and therefore have a load switch to disconnect the rail to save power. The eFuse is always enabled to allow the five DC/DC converters to continue to operate in case an always-on rail is required.

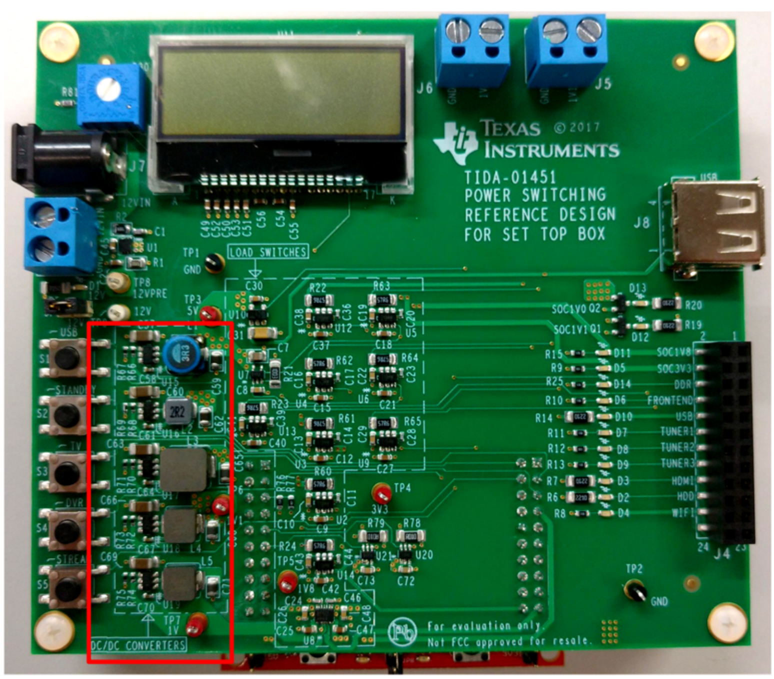

Figure 3. eFuse and DC/DCs

This reference design keeps the standby mode power consumption at or below 50 mW by disabling all of the load switches but leaving the DC/DC converters enabled.

Achieve further power savings by placing the always-on DC/DC converters in a separate power tree from the eFuse, then disabling the eFuse on the non always-on power tree (see Figure 4). This change replaces the quiescent current of the five DC/DC converters (1.9 mA) with the shutdown current of the eFuse (1 µA).

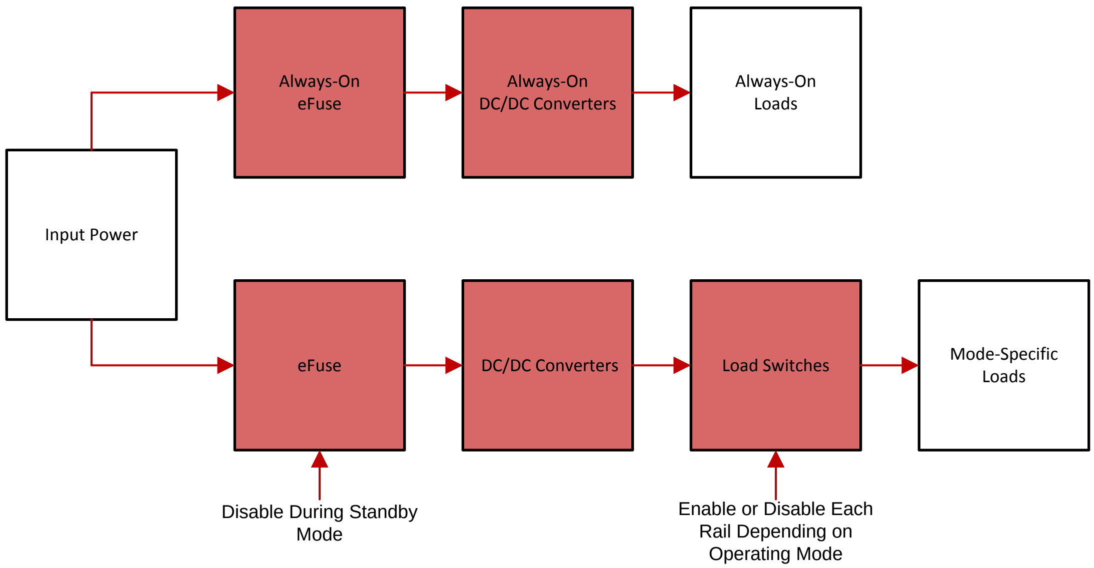

Figure 4. Separate Always-On Power Tree for Additional Power Savings

2.3 Highlighted Products

2.3.1 TPS259541

The TPS2595x family of eFuses is a highly-integrated circuit protection and power management solution in a small package. The devices use few external components and provide multiple protection modes. They are a robust defense against overloads, short circuits, voltage surges, and excessive inrush current. Current limit level can be set with a single external resistor. Overvoltage events are limited by internal clamping circuits to a safe fixed maximum, with no external components required. Applications with particular inrush current requirements can set the output slew rate with a single external capacitor.

2.3.2 TPS22918

The TPS22918 is a 5.5-V, 2-A load switch in a six-pin SOT-23 package. To reduce voltage drop for low-voltage and high-current rails, the device implements a low-resistance N-channel MOSFET, which reduces the dropout voltage across the device. The device has a configurable slew rate that reduces or eliminates power supply droop due to large inrush currents. The device also features a quick output discharge (QOD) pin, which allows for the configuration of the discharge rate of V_{OUT}. QOD occurs when the switch is disabled. The device has very-low leakage currents during shutdown, which also helps mitigate leakage for downstream modules during standby. The integrated control logic, driver, charge pump, and output discharge field-effect transistor (FET) eliminates the requirement for any external components, which reduces solution size and bill of materials (BOM) count.

2.3.3 TPS22976

The TPS22976 is a dual-channel load switch with controlled turnon. The device contains two N-channel MOSFETs that can operate over an input voltage range of 0.6 V to 5.7 V, and can support a maximum continuous current of 6 A per channel. Each switch is independently controlled by an ON and OFF input (ON1 and ON2), which can interface directly with low-voltage control signals. The TPS22976 is capable of thermal shutdown when the junction temperature is above the threshold, turning the switch OFF. The switch turns ON again when the junction temperature stabilizes to a safe range. The TPS22976 also offers an optional integrated 230-Ω on-chip load resistor for QOD when the switch is turned OFF.

2.3.4 TPS22945

The TPS22945 load switches provide protection to systems and loads in high-current conditions. The TPS22945 contain a 0.4-Ω current-limited P-channel MOSFET that can operate over an input voltage range of 1.62 V to 5.5 V. Current is prevented from flowing when the MOSFET is OFF. The switch is controlled by an ON and OFF input (ON), which is capable of interfacing directly with low-voltage control signals. The TPS22945 includes thermal shutdown protection which prevents damage to the device when a continuous overcurrent condition causes excessive heating by turning off the switch. These devices provide an integrated, robust solution to provide current limiting the output current to a safe level by switching into a constant-current mode when the output load exceeds the current-limit threshold. The OC logic output asserts low during overcurrent, undervoltage, or overtemperature conditions. These additional features make the TPS22945 an ideal solution for applications where current limiting is necessary.

2.3.5 TPS2065D

The TPS2065D power-distribution switch family is intended for applications such as USB where heavy capacitive loads and short circuits are likely to be encountered. The device can continuously deliver up to 1-A output current. The TPS2065D limits the output current to a safe level by operating in a constant-current mode when the output load exceeds the current limit threshold. This provides a predictable fault current under all conditions. The fast overload response time eases the burden on the main 5-V supply to provide regulated power when the output is shorted. The power-switch rise and fall times are controlled to minimize current surges during turnon and turnoff.

2.3.6 TPS564201

The TPS564201 is a simple, easy-to-use, 4-A synchronous step-down converter in SOT-23 package. The device is optimized to operate with minimum external component count and also optimized to achieve low standby current. These switch-mode power supply (SMPS) devices employ D-CAP2™ mode control, provide a fast transient response, and support both low-equivalent series resistance (ESR) output capacitors such as specialty polymer and ultra-low ESR ceramic capacitors with no external compensation components.

2.3.7 TPS562201

The TPS562201 and TPS562208 are simple, easy-to-use, 2-A synchronous step-down converters in SOT-23 package. The devices are optimized to operate with minimum external component counts and also optimized to achieve low standby current. These switch mode power supply (SMPS) devices employ D-CAP2™ mode control, provide a fast transient response, and support both low equivalent series resistance (ESR) output capacitors such as specialty polymer and ultra-low ESR ceramic capacitors with no external compensation components.

2.3.8 INA21x

The INA21x are voltage-output, current-shunt monitors (also called current-sense amplifiers) that are commonly used for overcurrent protection, precision-current measurement for system optimization, or in closed-loop feedback circuits. This series of devices can sense drops across shunts at common-mode voltages from –0.3 V to 26 V, independent of the supply voltage. Six fixed gains are available: 50 V/V, 75 V/V, 100 V/V, 200 V/V, 500 V/V, or 1000 V/V. The low offset of the zero-drift architecture enables current sensing with maximum drops across the shunt as low as 10-mV full-scale.

2.3.9 MSP-EXP430F5529LP

The MSP-EXP430F5529LP LaunchPad™ Development Kit is an inexpensive, simple MCU development kit for the MSP430F5529 USB MCU. This product offers an easy way to start developing on the MSP430™ MCU, with an onboard emulation for programming and debugging, as well as buttons and LEDs for a simple user interface. Rapid prototyping is quick and easy due to 40-pin BoosterPack™ expansion headers, as well as a wide range of available BoosterPack plug-in development board modules. The designer can quickly add features like wireless, displays, sensors, and much more. The MSP-EXP430F5529LP LaunchPad includes the MSP430F5529 16-bit MCU with 128-KB flash, 8-KB RAM, up to 25-MHz CPU speed, integrated USB 2.0 PHY, 12-bit ADC, timers, serial communication (universal asynchronous receiver/transmitter (UART), I^2C, serial peripheral interface (SPI), and more.

3 Getting Started Hardware and Software

3.1 Software Install

This reference design board uses an MSP-EXP430F5529LP device. See the setup and flashing instructions for the LaunchPad in the user's guide: *Sharp® LCD BoosterPack (430BOOST-SHARP96) for the LaunchPad* (SLAU553).

See the TIDA-01451 product folder for the available software for this reference design.

The software uses the input from the tactile buttons and controls the load switches through general purpose input/output (GPIO) signals according to the state machine. Two current sense amplifiers are connected to the ADCs of the MSP430 to provide real-time power measurements of the system, which the LCD shows.

3.2 System Setup

After installing the software, disconnect the MSP430 LaunchPad from the computer and remove all the MSP430 jumpers highlighted in Figure 5.

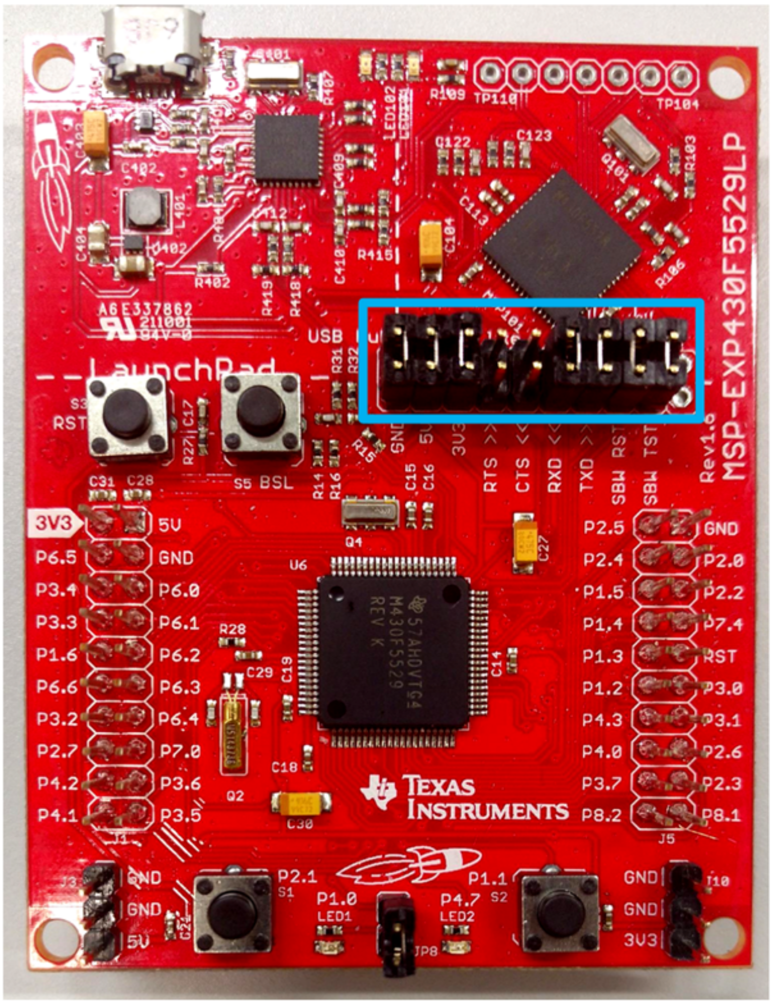

Figure 5. MSP430™ LaunchPad™ Jumpers to Remove

After removing the jumpers, attach the MSP430 GPIO pins to the headers on the backside of the TIDA-01451 board (see Figure 6). Using either the terminal connector or the barrel jack connector, apply a 12-V input to the TIDA-01451 board. Table 4 notes the test points, which should be at their designated voltage after supplying the 12-V input.

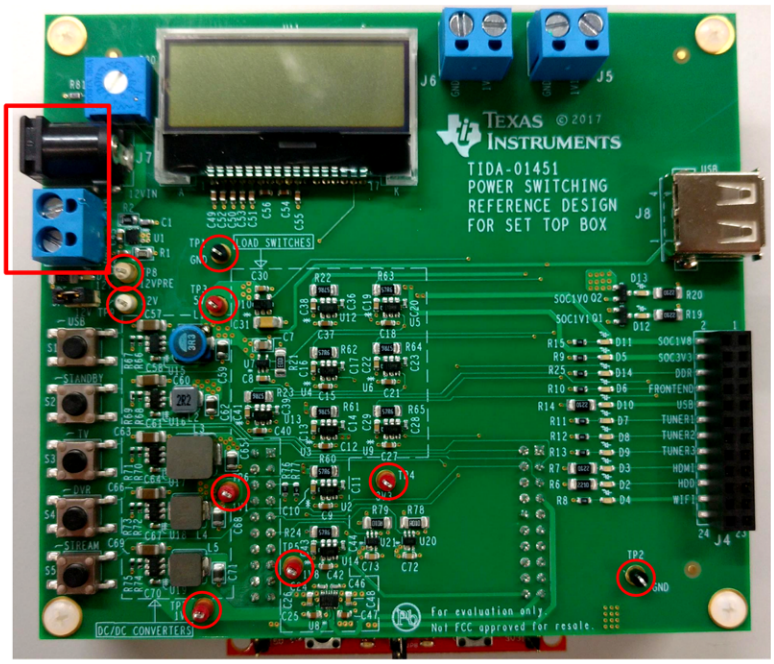

Figure 6. Board Image With TP Highlighted and Items Relevant to Setup

Table 4. Test Points

TEST POINT	FUNCTION
TP1 and TP2	Ground
TP3	5-V rail; before any load switch
TP4	3.3-V rail; before any load switch
TP5	1.8-V rail; before any load switch
TP6	1.1-V rail; before any load switch
TP7	1-V rail; before any load switch
TP8	12-V rail; after TPS259541, before input current sense amplifier
TP9	12-V rail; after input current sense amplifier

3.3 Button and Knob Functions

The bottom-left side of the TIDA-01451 board contains five push-buttons. These buttons are used to enable and disable the load switches to simulate various operating modes of STBs and DVRs. Table 5 describes how each button functions and controls the load switches.

A potentiometer is available in the top-left corner of the TIDA-01451 board (see Figure 7). This potentiometer functions to increase or decrease the brightness of the LCD screen, which is located on the top side of the board.

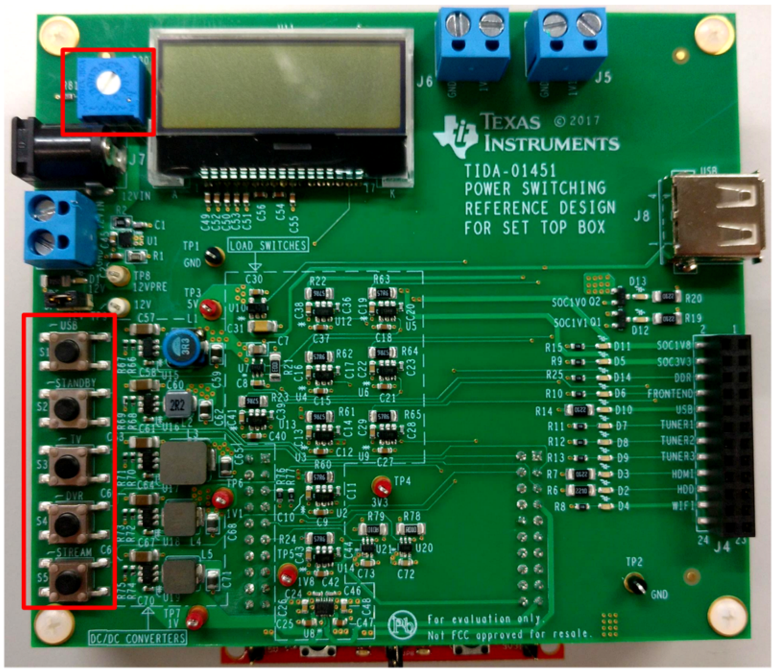

Figure 7. Board Image With Buttons and Potentiometer Highlighted

Table 5. Button and Knob Functions

BUTTON OR KNOB	FUNCTIONS
USB	Toggles the TPS2065D-USB load switch (U10)
	This function is independent of the other operation modes in the TI Design
	The USB female connector (J8) power rail is toggled as a result of the USB load switch
Standby	The TI Design goes into Standby Mode and turns off all load switches except for the USB load switch
TV	When pressed the TI Design goes into TV Mode
	Toggles the TPS22918-Tuner1 load switch (U5)
	Toggles the TPS22945-HDMI load switch (U7)
DVR	When pressed the TI Design goes into DVR Mode
	Toggles the TPS22918-Tuner2 load switch (U6)
	Toggles the TPS22918-HDD load switch (U13)
Stream	When pressed the TI Design goes into Stream Mode
	Toggles the TPS22918-Tuner3 load switch (U9)
	Toggles the TPS22918-WIFI load switch (U12)
Potentiometer knob	Controls the brightness of the LCD backlight

4 Testing and Results

4.1 *Functionality*

4.1.1 Step 1—Apply Power to Board

The top-left corner of the TIDA-01451 reference design board has a barrel jack connector and a phoenix terminal connector. These two connectors are for power input at 12 V. *Use only one power input at any given time*. After applying the power to the board, the 12-V_{IN} LED and the LCD screen turn ON (see Figure 8 and Figure 9). If the jumper JP1 is removed the 12-V_{IN} LED does not turn ON.

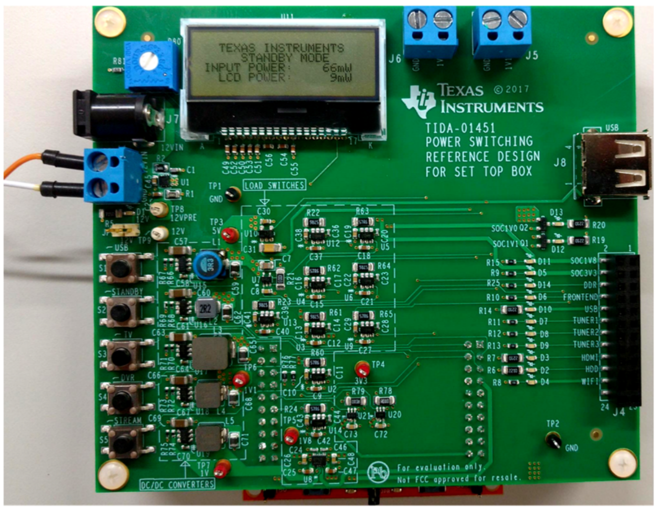

Figure 8. Full Board 12 V_{IN} With LCD ON

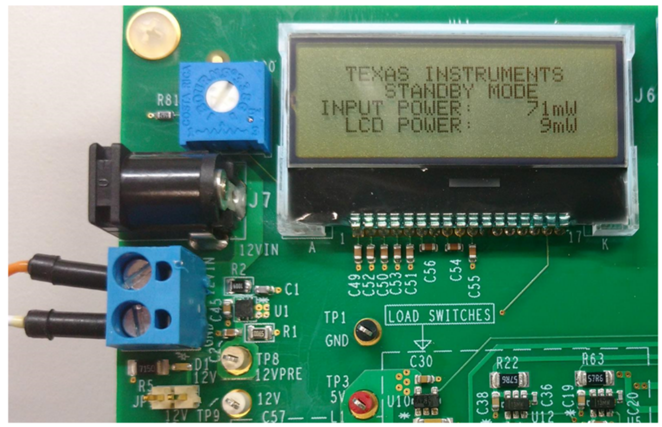

Figure 9. LCD With Power Measurements

4.1.2 Step 2—Test Buttons and Potentiometer

Along the left side of the TIDA-01451 reference design board are five tactile buttons and a potentiometer. The five buttons are labeled: USB, STANDBY, TV, DVR, and STREAM. These buttons pull a GPIO on the MSP430 LaunchPad low to trigger an interrupt. The potentiometer controls the brightness of the LCD backlight by voltage dividing the 3.3-V rail that is connected to the LCD.

4.1.2.1 USB Button

After pressing the "USB" button, the D10 LED along the right side of the board turns ON (see Figure 10). The output pin J4-10 ramps up to 5 V and supplies power to the loads connected to this pin. The USB connector also becomes active; if a phone is connected to the USB charger when a user turns on the USB rail, the phone charges (see Figure 11).

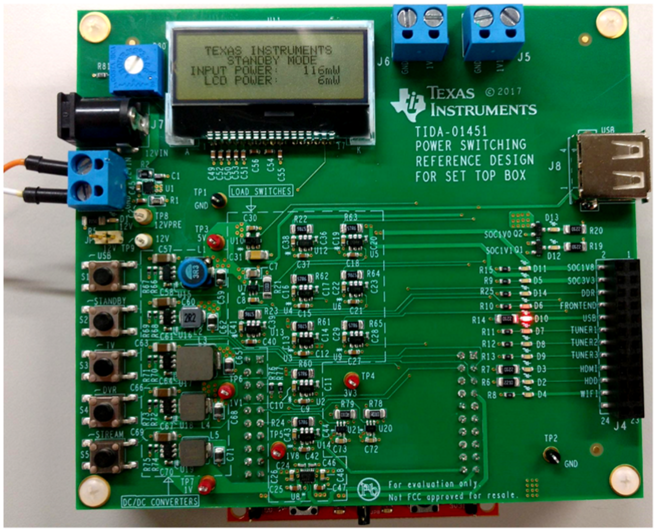

Figure 10. Image of USB LED

Figure 11. Phone Charging on Connector

4.1.2.2 TV, DVR, Stream, and Standby Buttons

The TV, DVR, stream, and standby buttons control the output rails specified in Table 5. Figure 12 through Figure 15 show how each button controls the output LEDs and output pins. Note that the TV, DVR, and stream modes of operation can be used in any combination.

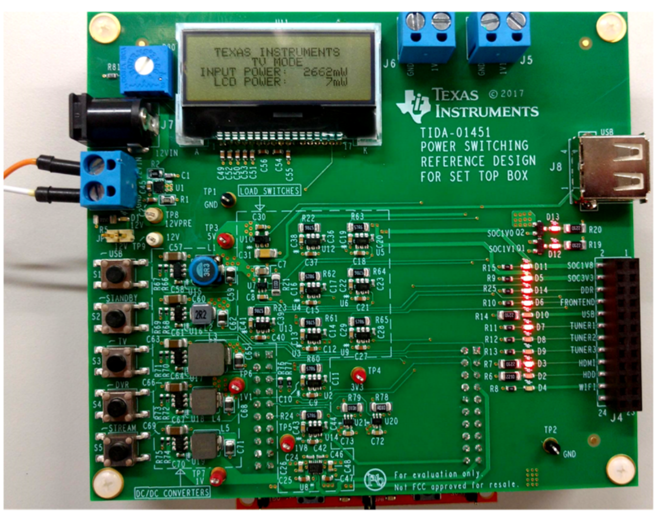

Figure 12. TV Button LEDs (HDMI, Tuner1, Front End, SOC+DDR)

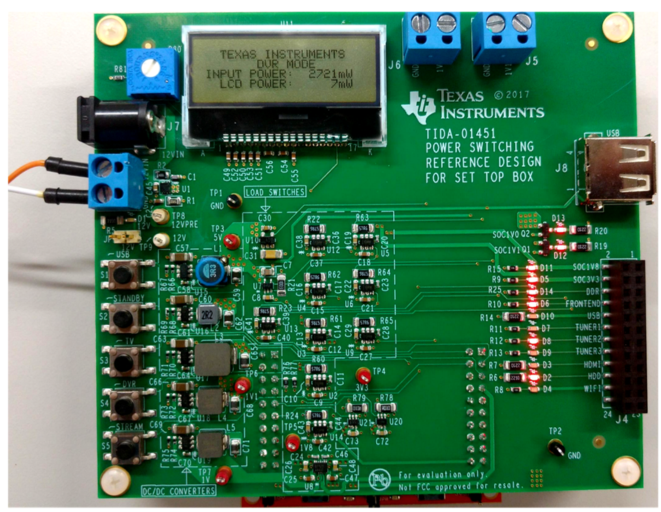

Figure 13. DVR Button LEDs (HDD, Tuner2, Front End, SOC+DDR)

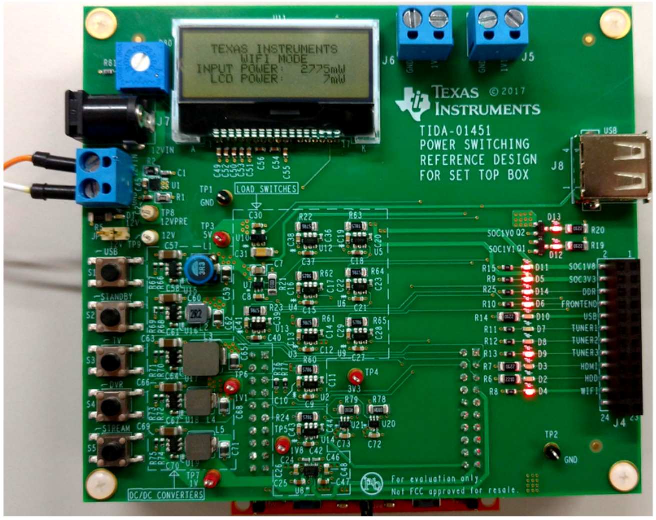

Figure 14. Stream Button LEDs (WIFI, Tuner3, Front End, SOC+DDR)

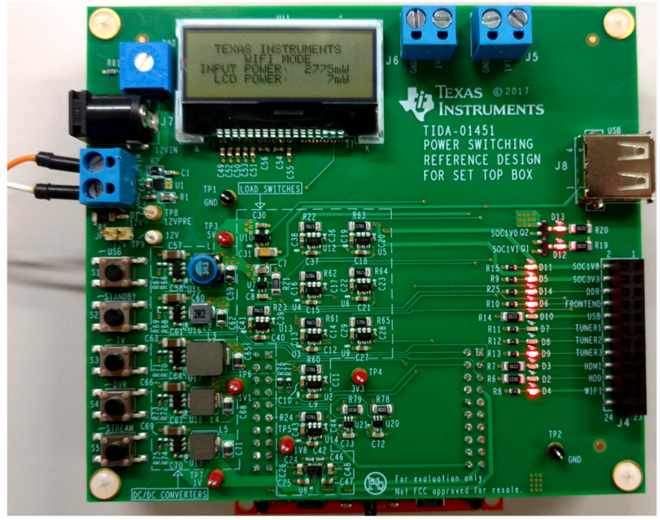

Figure 15. Standby Button LEDs (All LEDs OFF Except USB)

4.1.2.3 Potentiometer

The potentiometer supplies a voltage between 2.8 V and 3.3 V to the LCD. As the voltage increases so does the current to the LCD, thereby increasing the brightness (see Figure 16 and Figure 17). The current that the LCD draws is measured by a current sense amplifier and combined with a voltage measurement on that rail. The resulting power consumption of the LCD shows on the screen as “LCD POWER:”.

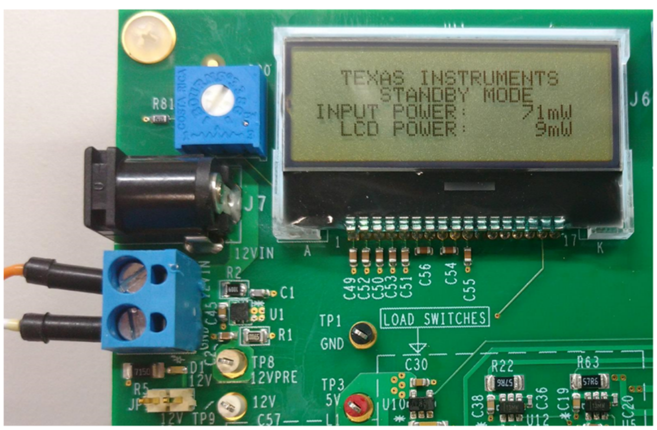

Figure 16. LCD at Lowest Brightness

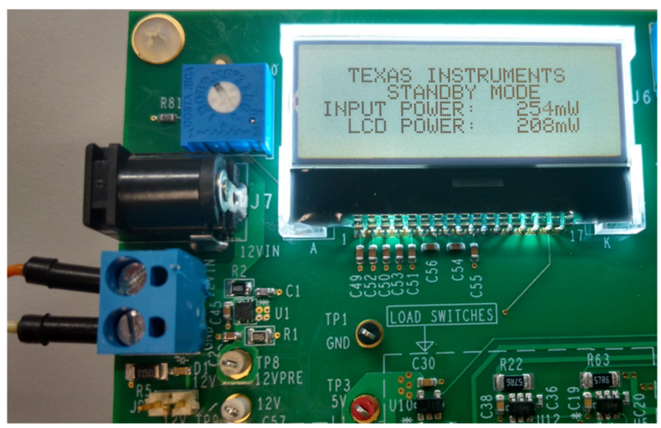

Figure 17. LCD at Highest Brightness

4.1.3 Test Point Voltages

The TIDA-01451 reference design board offers nine test points. TP1 and TP2 are ground test points. TP3 through TP9 correspond to the functions listed in Table 6. A voltage measurement at each test point has been averaged across the three boards, which the last column provides.

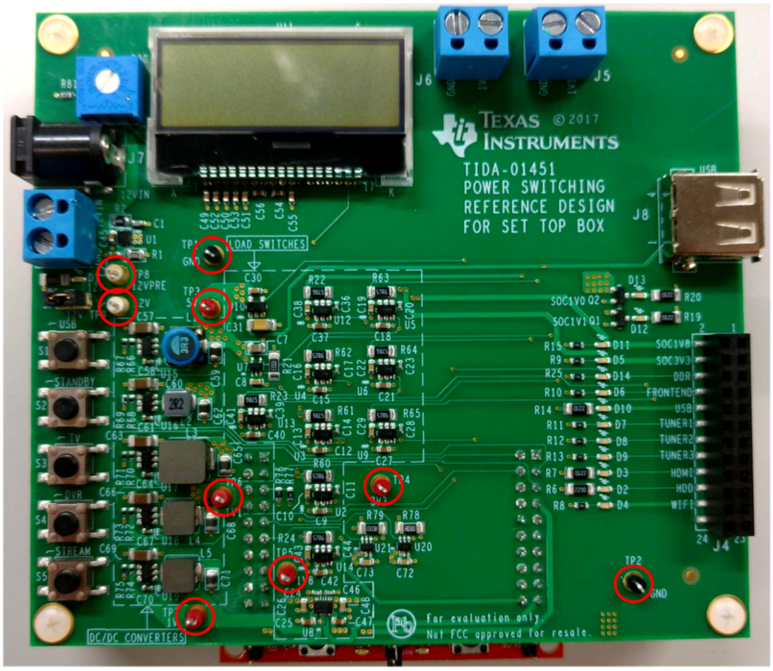

Figure 18. Board Image With Test Points Highlighted

Table 6. Measured Test Point Voltages

TEST POINT	FUNCTION	IDEAL VOLTAGE (V)	MEASURED VOLTAGE (V)
TP3	5-V rail; before any load switch	5	4.958
TP4	3.3-V rail; before any load switch	3.3	3.302
TP5	1.8-V rail; before any load switch	1.8	1.812
TP6	1.1-V rail; before any load switch	1.1	1.119
TP7	1-V rail; before any load switch	1	1.007
TP8	12-V rail; after TPS259541, before input current sense amplifier	12	11.998
TP9	12-V rail; after input current sense amplifier	12	11.997

4.1.4 Output Voltages

The TIDA-01451 reference design board has 13 output rails, Figure 19 shows. Table 7 lists the device-on resistance and output trace resistance for each output rail on the board. Table 8 shows the output voltages of each rail when pulling the maximum current for each rail. The trace resistance of a voltage rail in any system plays a large part in the efficiency of the system and the voltage tolerance of the rail.

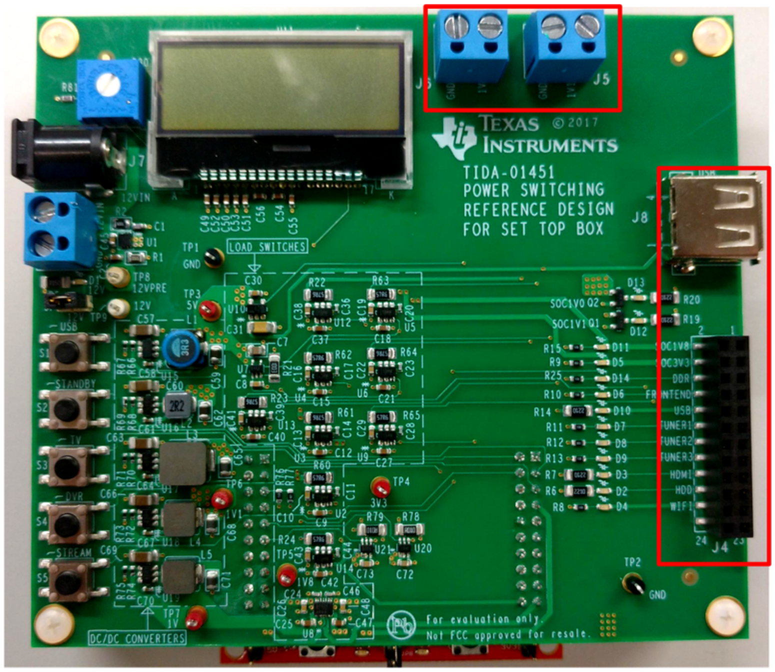

Figure 19. Board Image With Outputs Highlighted

Table 7. Output Rail Trace Resistance

OUTPUT PIN	FUNCTION	LOAD (A)	DEVICE ON-RESISTANCE (TYP)	TRACE RESISTANCE (AVG)
J6	SOC1V	4 A	14 mΩ	30 mΩ
J5	SOC1V1	4 A	14 mΩ	18 mΩ
J4-2	SOC1V8	0.5 A	52 mΩ	44 mΩ
J4-4	SOC3V3	0.5 A	52 mΩ	50 mΩ
J4-6	DDR	0.2 A	52 mΩ	186 mΩ
J4-8	Front End	0.5 A	52 mΩ	146 mΩ
J4-10	USB	1 A	96 mΩ	73 mΩ
J4-12	Tuner1	0.5 A	52 mΩ	142 mΩ
J4-14	Tuner2	0.5 A	52 mΩ	128 mΩ
J4-16	Tuner3	0.5 A	52 mΩ	113 mΩ
J4-18	HDMI	0.055 A	400 mΩ	165 mΩ
J4-20	HDD	0.8 A	52 mΩ	174 mΩ
J4-22	WIFI	1 A	52 mΩ	71 mΩ

Table 8. Output Rail Voltage Drop

OUTPUT PIN	FUNCTION	IDEAL VOLTAGE WITH NO LOAD (V)	MEASURED VOLTAGE WITH NO LOAD (V)	IDEAL VOLTAGE WITH LOAD (V)	MEASURE VOLTAGE WITH LOAD (V)
J6	SOC1V	1	0.977	0.824	0.863
J5	SOC1V1	1.1	1.078	0.972	0.955
J4-2	SOC1V8	1.8	1.794	1.752	1.742
J4-4	SOC3V3	3.3	3.278	3.249	3.223
J4-6	DDR	1.8	1.792	1.752	1.745
J4-8	Front End	3.3	3.277	3.201	3.172
J4-10	USB	5	4.995	4.831	4.796
J4-12	Tuner1	3.3	3.277	3.203	3.175
J4-14	Tuner2	3.3	3.277	3.210	3.184
J4-16	Tuner3	3.3	3.278	3.218	3.188
J4-18	HDMI	5	4.949	4.963	4.916
J4-20	HDD	5	4.954	4.819	4.777
J4-22	WIFI	3.3	3.278	3.177	3.148

4.2 System Standby Current

The system standby current measurement was taken when the TIDA-01451 reference design was in standby mode. Standby mode turns off all the load switches. The LCD was set to the lowest brightness. The current consumption of the board is limited to the quiescent current of the DC/DC converters, the eFuse, the MSP430, and the LCD. The eFuse and DC/DCs were left enabled for “always-on” rail considerations. For information on always-on versus non always-on rails, see the previous Section 2.2.2.

Table 9. Measured Shutdown Current

RAIL	LOAD SWITCHES ENABLED	EXPECTED INPUT CURRENT (TYP)	MEASURED INPUT CURRENT
System in standby	None	4.2 mA	4.16 mA
System in standby with USB switch ON	TPS2065D (U10)	10.5 mA	10.67 mA
System in standby withphone charging	TPS2065D (U10)	225 mA	225.6 mA

The standby power of the TIDA-01451 reference design board is approximately 50 mW.

4.3 Hot Plug

A hot plug event occurs when a user turns on a power source and then plugs this into the board. These events can cause overvoltage transients, a high inrush current into the board, or both. An eFuse is used on the TIDA-01451 reference design board to control inrush current and protect downstream components from input voltages that are too high or too low. Figure 20 shows a scope shot of the eFuse output after applying a live 12-V supply to the board. The eFuse ramps up the output linearly.

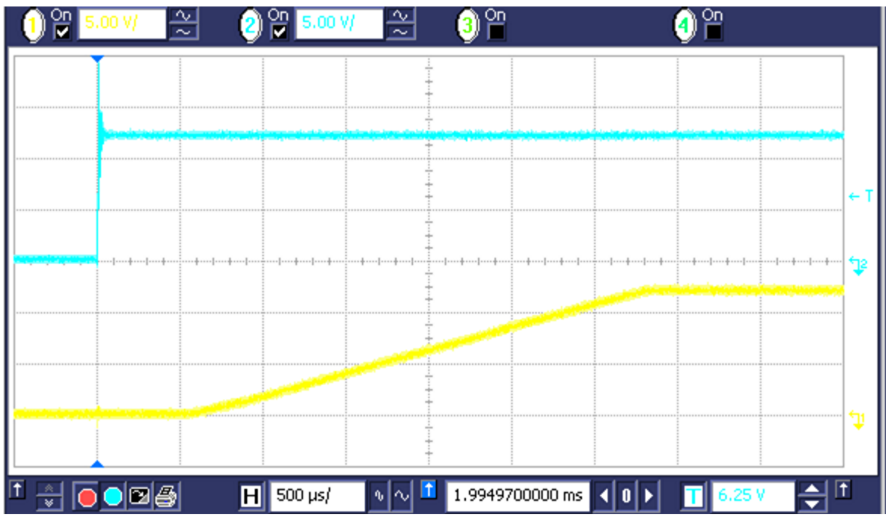

Figure 20. Hot Plug Event on eFuse

4.4 Current Sense and Power Measurement Accuracy

The board contains two current sense amplifiers: One amplifier measures the input current, the other measures the current to the LCD.

The input current measurement runs into issues with the switching DC/DC converters because they do not pull a constant current but rather a pulse of current. A buffer, averaging, and dampening are used within the software to control the variation of the current reading.

The LCD, which displays the input power, takes 5 s to 10 s to settle at a power value when the input current changes. The displayed input power rating may oscillate around ±30 mW at higher power readings. The power measurement accuracy for both readings is less than or equal to 5%. Figure 21 and Figure 22 show the power measurement accuracy plots from an example board.

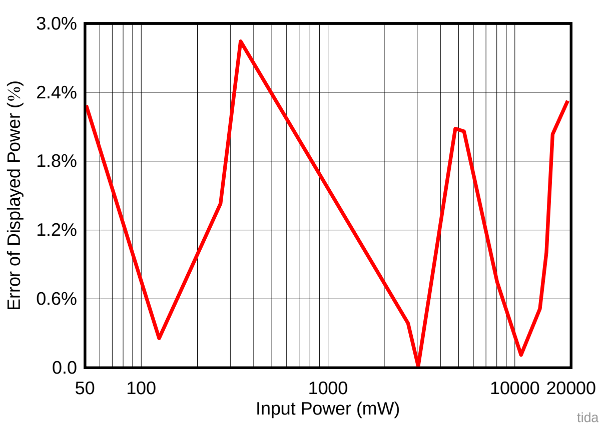

Figure 21. Input Power Accuracy

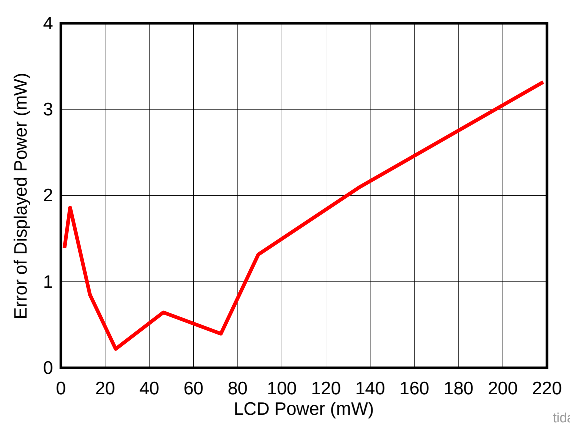

Figure 22. LCD Power Accuracy

5 Design Files

5.1 Schematics

To download the schematics, see the design files at http://www.ti.com/tool/TIDA-01451.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at http://www.ti.com/tool/TIDA-01451.

5.3 Layout Prints

To download the layer plots, see the design files at http://www.ti.com/tool/TIDA-01451.

5.4 CAD Files

To download the CAD files, see the design files at http://www.ti.com/tool/TIDA-01451.

5.5 Gerber Files

To download the Gerber files, see the design files at http://www.ti.com/tool/TIDA-01451.

5.6 Assembly Drawings

To download the assembly drawings, see the design files at http://www.ti.com/tool/TIDA-01451.

6 Software Files

To download the software files, see the design files at http://www.ti.com/tool/TIDA-01451.

7 Related Documentation

1. Texas Instruments, *Selecting a Load Switch to Replace a Discrete Solution*, Application Report (SLVA887)
2. Texas Instruments, *MSP430F5529 LaunchPad™ Development Kit*, User's Guide (SLAU533)

7.1 Trademarks

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8 Terminology

DVR— Digital video recorder

ESR— Equivalent series resistance

FET— Field-effect transistor

GPIO— General purpose input/output (pins or signals)

IC— Integrated circuit

MCU— Microcontroller

SMPS— Switch-mode power supply

SPI— Serial peripheral interface

STB— Set-top box

QOD— Quick output discharge

UART— Universal asynchronous receiver/transmitter

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