TI Designs

Multi-Rail, Low-I_Q Power Reference Design for Wearable Applications

Design Overview

Wearable applications such as smart wristbands use two main power rails to supply the wireless MCU, sensors, and display. The design of these devices is tiny and therefore requires the smallest solution size possible. This reference design offers a complete wearable solution based on the TPS62770 multi-rail DC-DC converter including the CC2650 and PMOLED display.

Design Resources

PMP9792	Design Folder
TPS62770	Product Folder
CC2650	Product Folder

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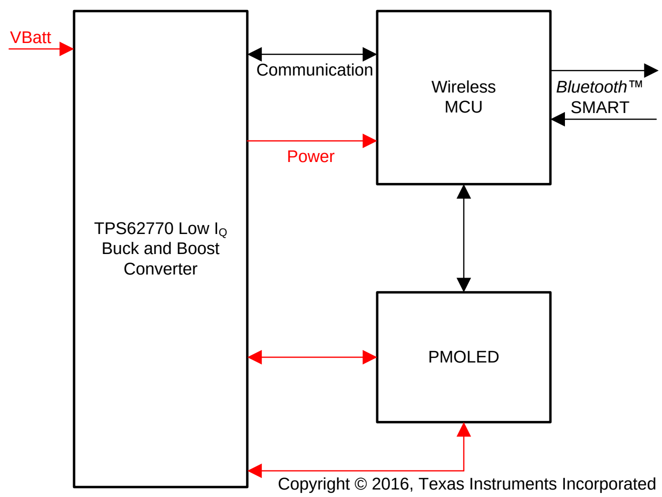
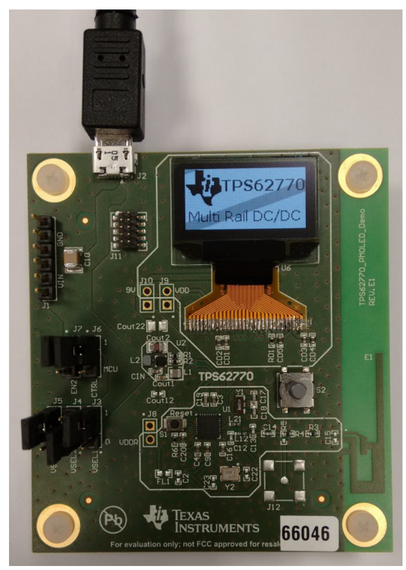
Design Features

- TPS62770: Fully Adjustable V_{OUT}
  - Buck Conversion From 1 V to 3 V
  - Boost Conversion up to 15 V
- Optimized Battery Lifetime From Ultra-Low I_Q
- *Bluetooth* Smart Interface for Smartphone Interaction
- Visualization Through PMOLED

Featured Applications

- Smart Wristbands
- Smart Watch
- Wireless Sensor
- Wearable Electronics





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1 Key System Specifications

The PMP9792 TI Design features the following devices:

- TPS62770
- CC2650
- 128x64-pixel screen DD-12864WE-4A

2 System Description

The PMP9792 has been designed for wearable applications with small displays and low power consumption. This subsection addresses the main design elements, such as the power management, wireless microcontroller (MCU), and display.

3 Block Diagram

Figure 1 shows a detailed block diagram of the PMP9792 TI Design. The red lines show the power connections and the blue lines represent control signals. The input voltage (established either by USB plug or pin contact) connects to the TPS62770 device, which supplies the display and the CC2650 device.

The wireless MCU controls the display and sends the data to be displayed. The MCU controls the DC-DC converter, as well.

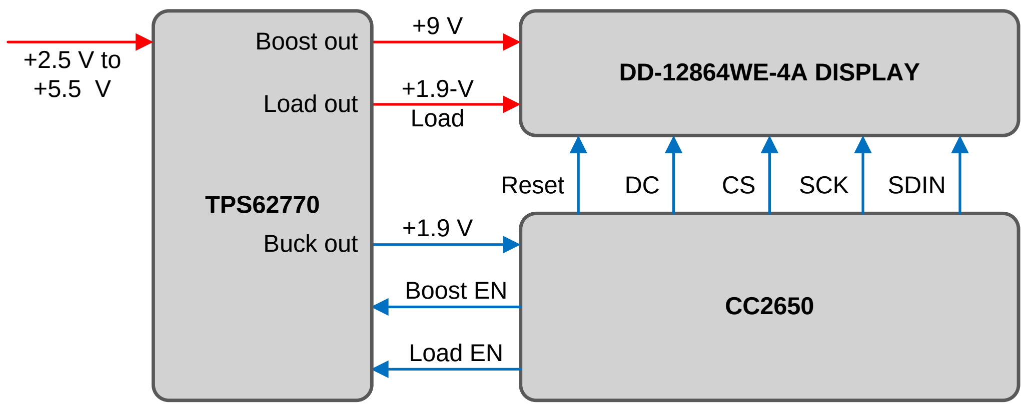

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Figure 1. PMP9792 Block Diagram

3.1 Highlighted Products

3.1.1 TPS62770

The TPS62770 is a tiny power solution for wearable applications (see Figure 2). The device includes a 360-nA ultra-low IQ step-down converter, a slew-rate-controlled load switch, and a dual-mode boost converter. The output voltage of the step down converter can be selected with three VSEL between 1.0 V, 1.05 V, 1.1 V, 1.2 V, 1.8 V, 1.9 V, 2.0 V, and 3.0 V. The output voltage can be changed during operation. In shutdown mode, the output of the step down converter is pulled to GND. The integrated load switch is internally connected to the output of the step down converter and features slew rate control during the turnon phase. After turning off, the output of the load switch connects to GND.

The dual-mode boost converter can generate a constant output voltage up to 15 V for applications such as a passive-matrix organic light-emitting diode (PMOLED) supply or a constant output current, which is used in LED back light supplies. The output voltage can be adjusted up to 15 V with external resistors or set to a fixed 12 V by connecting the FB pin to V_{IN}. The device features an internal overvoltage protection of 17 V in case the FB node has been left open or tight to GND. The TPS62770 also includes an internal rectifier and load disconnect function. When used as a constant output current driver, the device offers a pulse width modulation (PWM) to analog converter to scale down the reference voltage according to the duty cycle of the PWM signal.

The device is available in a small 16-pin, 0.4-mm pitch WCSP package.

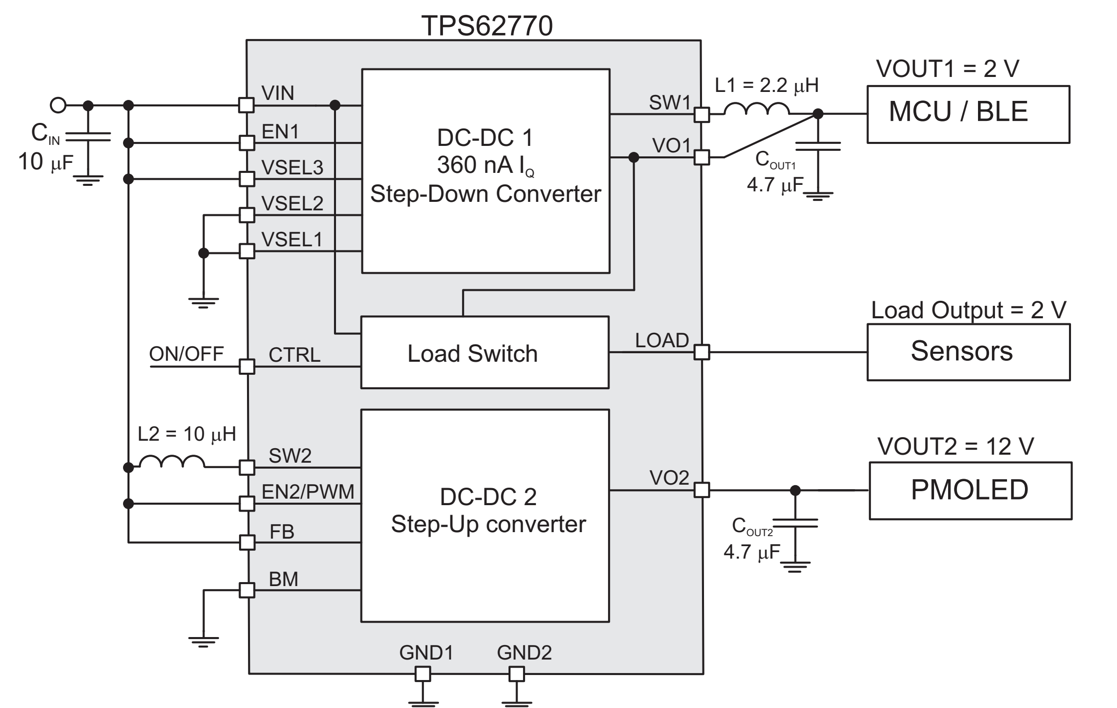

Figure 2. TPS62770 Internal Block Diagram

3.1.2 CC2650

The CC2650 is a wireless MCU targeting *Bluetooth* Smart, ZigBee® and 6LoWPAN, and ZigBee RF4CE remote control applications (see Figure 3).

The device is a member of the CC26xx family of cost-effective, ultra-low power, 2.4-GHz radio frequency (RF) devices. A very-low, active RF and MCU current and low-power mode current consumption provides excellent battery lifetime and allows operation on small coin cell batteries and in energy-harvesting applications.

The CC2650 contains a 32-bit ARM® Cortex®-M3 running at 48-MHz as the main processor and a rich peripheral feature set, including a unique ultra-low power sensor controller, which is ideal for interfacing external sensors or collecting analog and digital data autonomously while the rest of the system is in sleep mode.

These features make the CC2650 ideal for applications within a whole range of products including industrial, consumer electronics, and medical.

The *Bluetooth*® low energy controller and the IEEE 802.15.4 MAC are embedded into ROM and partly run on a separate ARM® Cortex®-M0 processor. This architecture improves overall system performance and power consumption and frees up flash memory for the application. The Bluetooth Smart and ZigBee stacks are available free of charge from www.ti.com.

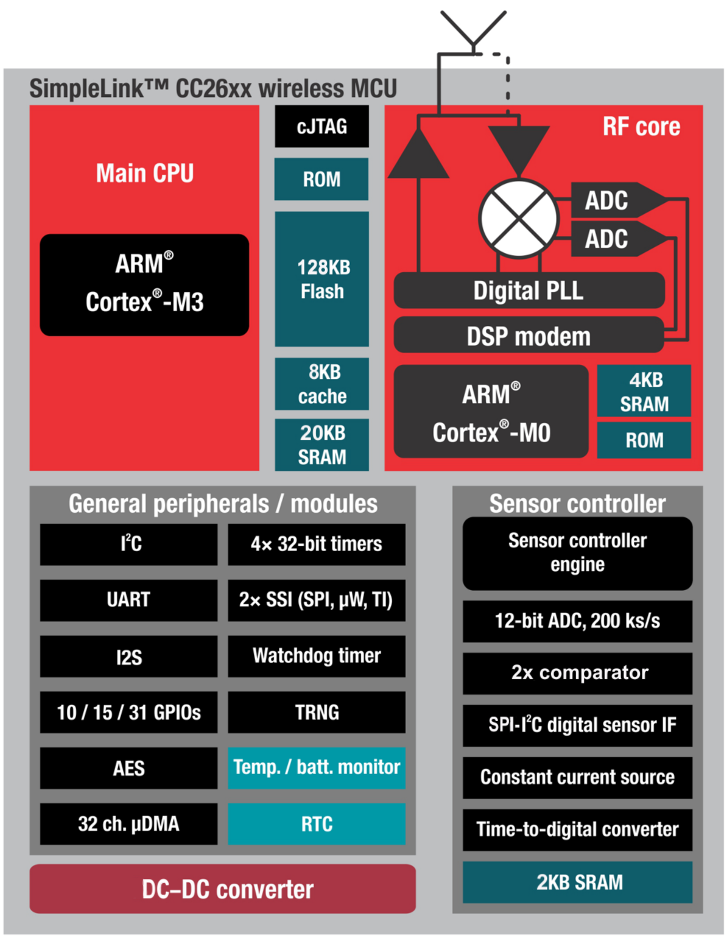

Figure 3. CC2650 Internal Block Diagram

3.1.3 Densitron Display DD-12864WE-4A

The DD-12864WE-4A display from Densitron Technologies is a 128x64-pixel PMOLED display (see Figure 4). The overall dimensions are 26.70 mm × 19.26 mm × 1.45 mm. The screen uses an integrated SSD1306 driver.

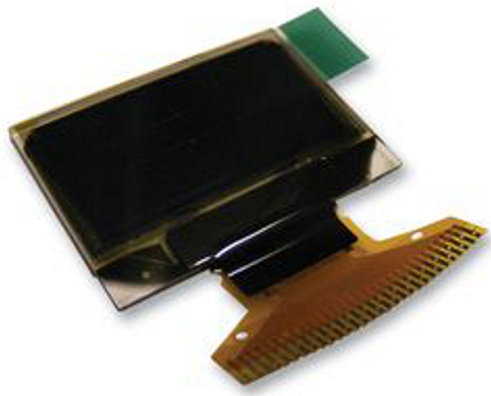

Figure 4. PMOLED Display Image

The display enables different types of communications like 68xx-series microprocessor (MPU) parallel interface, 8080 series MPU parallel interface, serial peripheral interface (SPI) with three or four wires, and I^2C. The application for this design uses the four-wire SPI communication between the display and CC2650 device.

The display is a bicolor display, which means that the color is white when a pixel is on and the color is black when a pixel is off.

4 Software Architecture

The PMP9792 TI Design uses a loaded firmware for testing and demonstration purposes. Figure 5 shows the functionality of the firmware.

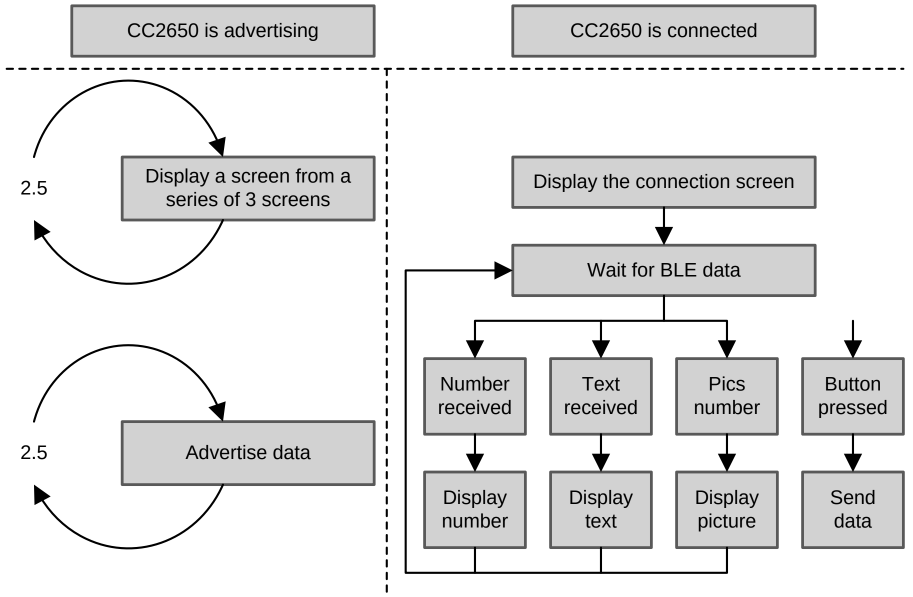

Figure 5. Software Functional Chart

5 Getting Started Hardware

This section provides an overview of the PCB with the applicable settings through jumpers.

5.1 Hardware Overview

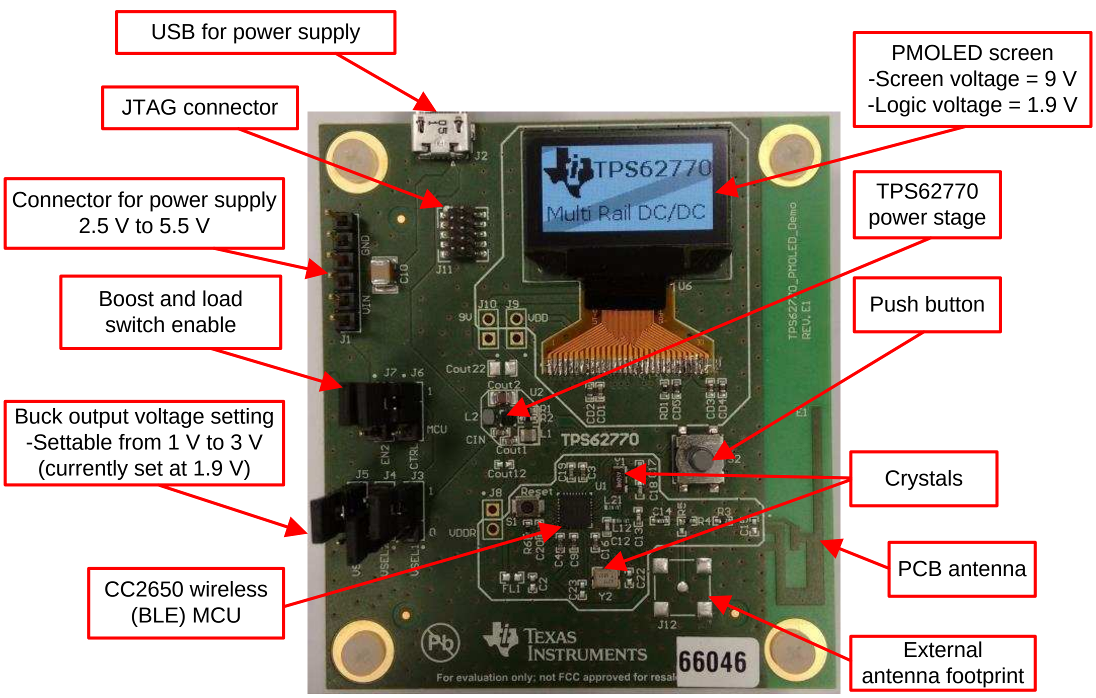

Figure 6. PMP9792 Overview

5.2 Multi-Rail Power Solution

The power solution occupies a very small footprint on the PCB because of the tiny 16-pin, 1.62×1.62-mm WCSP package (0.4-mm pitch) and the required passive components (see Figure 7).

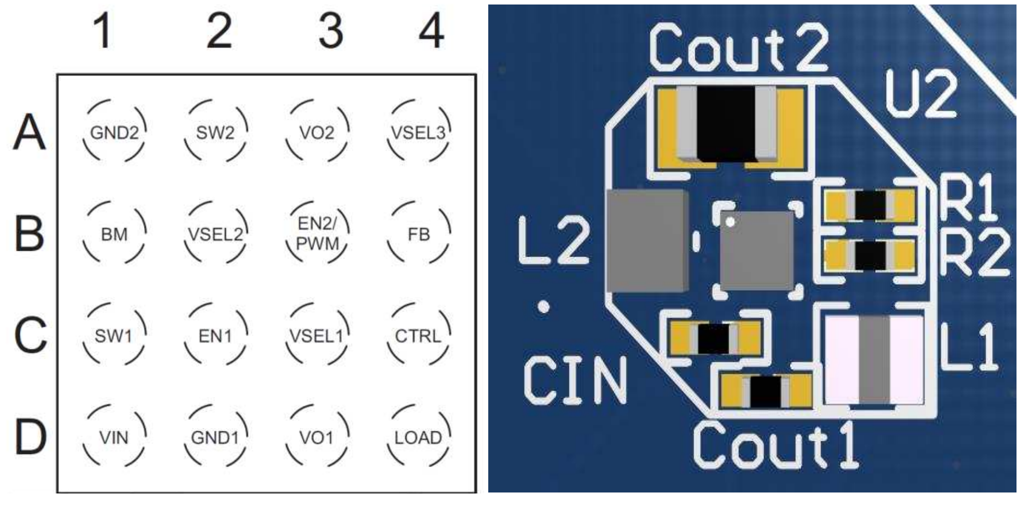

Figure 7. TPS62770 Device Pinout and Layout

5.3 Voltage Setting

The board enables the option to set the buck output voltage through the J3, J4, and J5 jumpers (see Figure 8). The user can then choose the CC2650 voltage by moving these three jumpers. The initial configuration of the buck output voltage has been set to 1.8 V.

The board also has an option to force the enable for the boost (EN2, J7) and the enable for the load switch (CTRL, J6) by setting the jumpers to logic 1. The user also has the option to put the jumpers on the MCU setting, after which the user may set the enable pins directly from the CC2650 device.

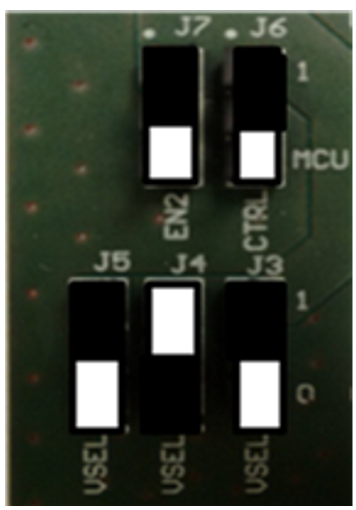

Figure 8. VSEL Jumper Image

Table 1 lists the jumper positions required to set the buck output voltage. The recommended supply for VDDS and VDDR is 1.7 V to 1.95 V.

Table 1. Buck Converter Output Voltage by Jumper Settings

V_{BUCK_OUT} (V)	VSEL3 (J5)	VSEL2 (J4)	VSEL1 (J3)
1	0	0	0
1.05	0	0	1
1.1	0	1	0
1.2	0	1	1
1.8	1	0	0
1.9	1	0	1
2	1	1	0
3*	1	1	1

Table 2. Color Mapping For Table 1

(blue)	Recommended values of the buck output voltage for the CC2650.
(yellow)	Not recommend values of the buck output voltage for the CC2650. Does not cause damage but the CC2650 does not work.
(red)	Do not use this voltage per risk of destroying the CC2650.

CAUTION

The absolute maximum voltage for VDDS and VDDR for the CC2650 device is 2.25 V.

6 Test Data and Measurements

This section shows several measurements from the PMP9792 board. The following subsection provides DC measurements that show the overall current consumption. Section 6.2 shows the behavior of the display and the boost converter output during display refreshment for several pictures.

6.1 DC Current Measurements

In this measurement, the system is in advertising mode and displays the welcome screen (see Figure 9). The system is supplied with an adjustable DC voltage and the input current is measured. The boost output is at 9 V (display supply) while the buck output is set to 1.8 V (CC2650 supply).

The blue curve shows the overall current consumption at the input of the TPS62770 device. The green curve represents the boost converter output current, which supplies the PMOLED display. The red trace shows the buck converter output current, which powers the CC2650 in advertising mode.

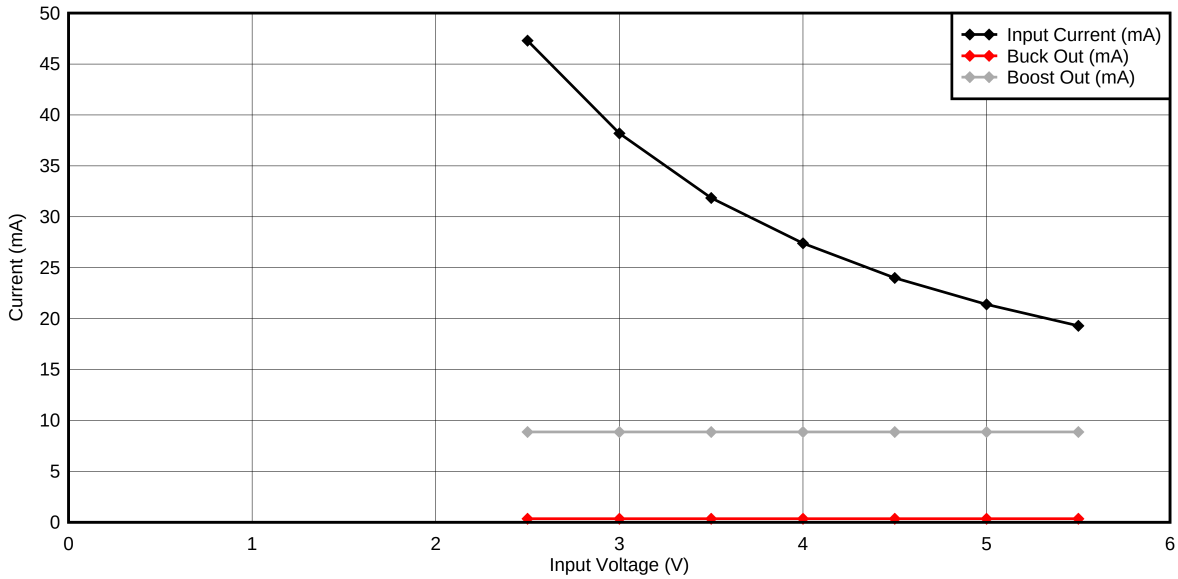

Figure 9. Current Consumption Measurements

6.2 Display Measurements

The following measurements in Figure 10 show the boost converter output voltage and current. The dynamic current consumption varies over time and depends on the picture that the display is currently showing.

The blue trace shows the AC behavior (9-V DC offset) of the boost converter output as a reaction to the dynamic current change. The magenta trace shows the current consumption of the display.

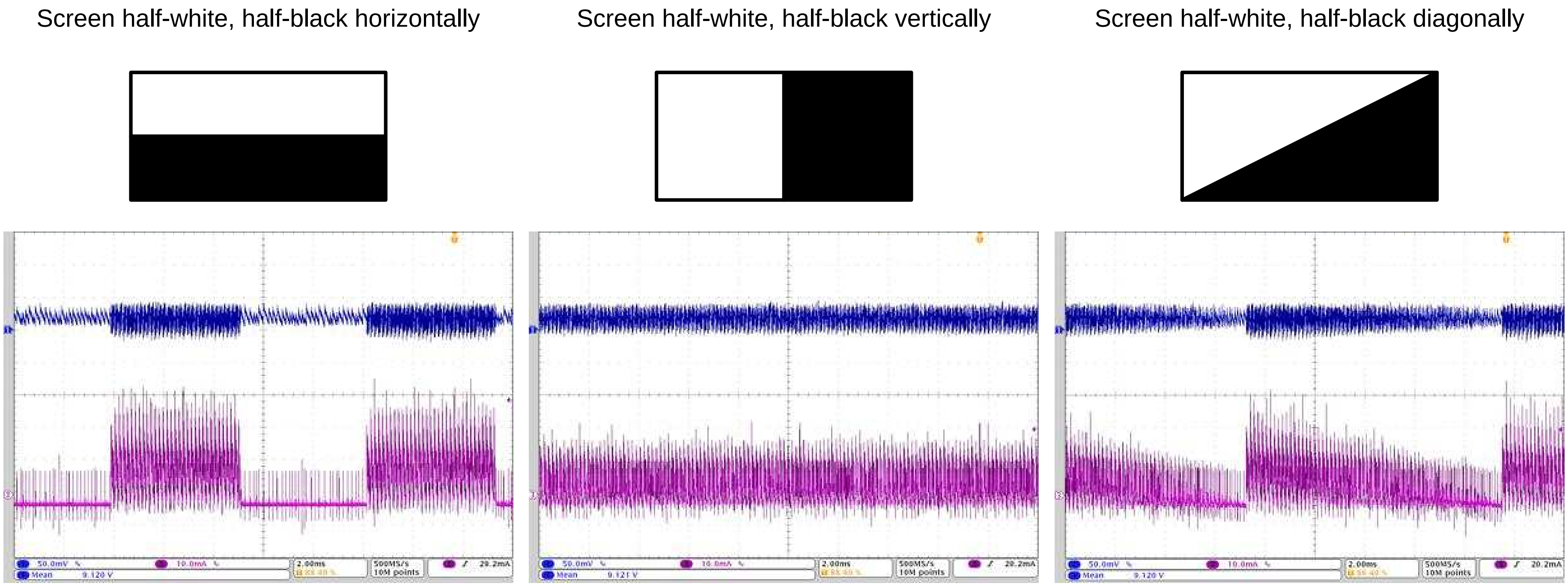

Figure 10. Supply Measurements—Dynamic PMOLED Display

7 Design Files

7.1 Schematics

To download the schematics, see the design files at PMP9792.

7.2 Bill of Materials

To download the bill of materials (BOM), see the design files at PMP9792.

7.3 Layout Prints

To download the layer plots, see the design files at PMP9792.

7.4 Altium Project

To download the Altium project files, see the design files at PMP9792.

7.5 Gerber Files

To download the Gerber files, see the design files at PMP9792.

7.6 Assembly Drawings

To download the assembly drawings, see the design files at PMP9792.

8 Software Files

To download the software files, see the design files at PMP9792.

9 References

1. Texas Instruments, *CC2650 SimpleLink™ Multistandard Wireless MCU*, CC2650 Datasheet (SWRS158)
2. Texas Instruments, *TPS62770 Multi-Rail DC/DC Converter For Wearable Applications*, TPS62770 Datasheet (SLVSCX0)

10 About the Author

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