Application Note

Dynamic Output Voltage Control Using TPSM63610 for USB Type-C Applications

Jimmy Hua

ABSTRACT

USB Type-C® is a popular interface that integrates signal data and power and is a specification for a symmetrical and reversible plug-in receptacle for USB devices. This application note details the design process to configure the TPSM63610 for a 5-V to 20-V dynamic output voltage design that is commonly used in USB applications.

Table of Contents

List of Figures

List of Tables

Trademarks

USB Type-C® is a registered trademark of USB Implementers Forum.
All trademarks are the property of their respective owners.

1 USB Type-C Specifications

For most USB applications, the USB port is used to charge personal electronic devices. With the demand for more processing power comes the need for more power in a highly efficient and thermally cool design. To meet the ever-growing trend of increased maximum power for USB applications, the system end equipment must be designed to accommodate the newly specified USB Type-C 1.2 (15 W) and USB PD 3.0 (100 W) power specifications detailed in Table 1-1 and illustrated in Figure 1-1.

Table 1-1. USB Specification and Maximum Voltage, Current, and Power

Specification	Maximum voltage	Maximum Current	Maximum Power
USB 2.0	5 V	500 mA	2.5 W
USB 3.0 and USB 3.1	5 V	900 mA	4.5 W
USB BC 1.2	5 V	1.5 A	7.5 W
USB Type-C 1.2	5 V	3 A	15 W
USB PD 3.0	20 V	5 A	100 W

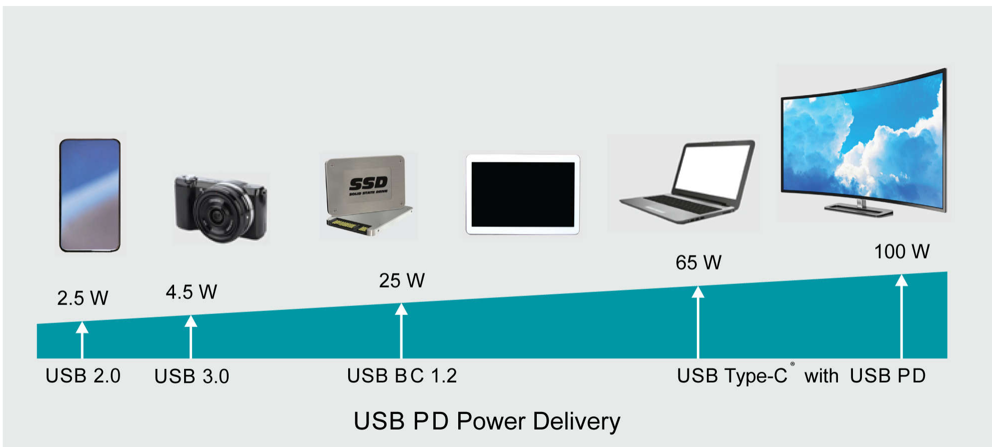

Figure 1-1. USB Source Power Demand Progression

The USB Type-C application is then further segmented into different power and data roles as shown in Figure 1-2. This application note focuses on a no data/source only USB Type-C end equipment with the use of a high-efficiency switching DC/DC power module as the intermediary buck design for a well-regulated output voltage rail.

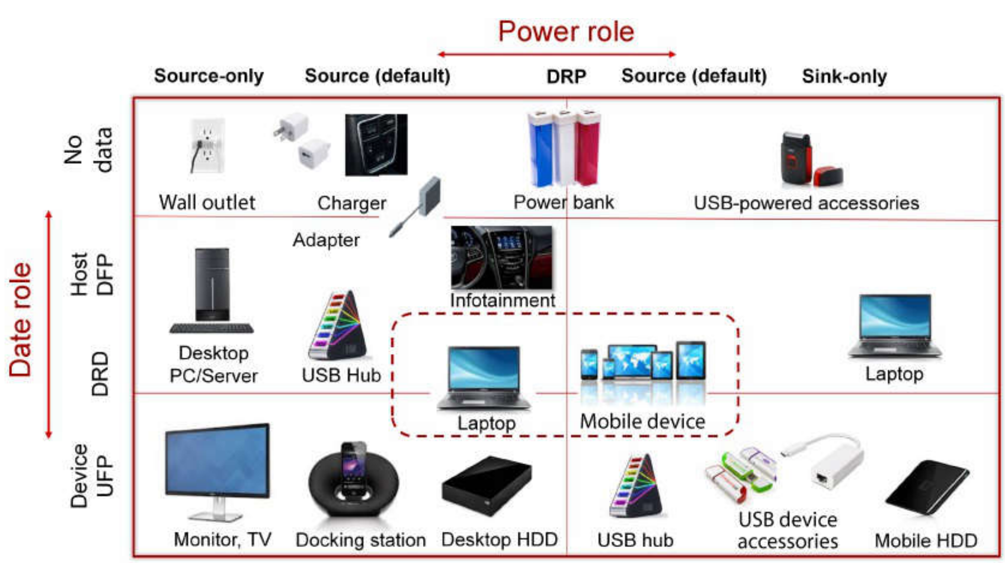

Figure 1-2. USB Type-C Application Examples

2 Avionics USB Type-C PD Design

Since USB Type-C application designs are trending and becoming more popular, below is an example of a source only USB Type-C power delivery (PD) design in an avionics system. The common output voltages for USB Type-C applications are: 5-V, 9-V, 15-V, and 20-V. The regulated input voltage is sourced from a 24-V aircraft battery that is commonly made from lead acid. When fully charged from the alternator, the input voltage rail can be as high as 28-V. In this application design the block diagram details a system that allows for charging of passenger devices (eg. cellular phone, tablet, laptop) and/or display video from the passenger devices.

Power modules become more impactful in designs that have limited board space or projecst that have limited engineering resources. The TPSM63610 buck power module is selected to meet the following design requirements for USB Type-C applications based on the list of benefits below:

- Small form factor and ease of design in applicaiton
- Dynamic output voltage scalability with simple external feedback control circuitry
- High output current capability with good thermal performance to achieve up to 5 A/100 W design for PD specification

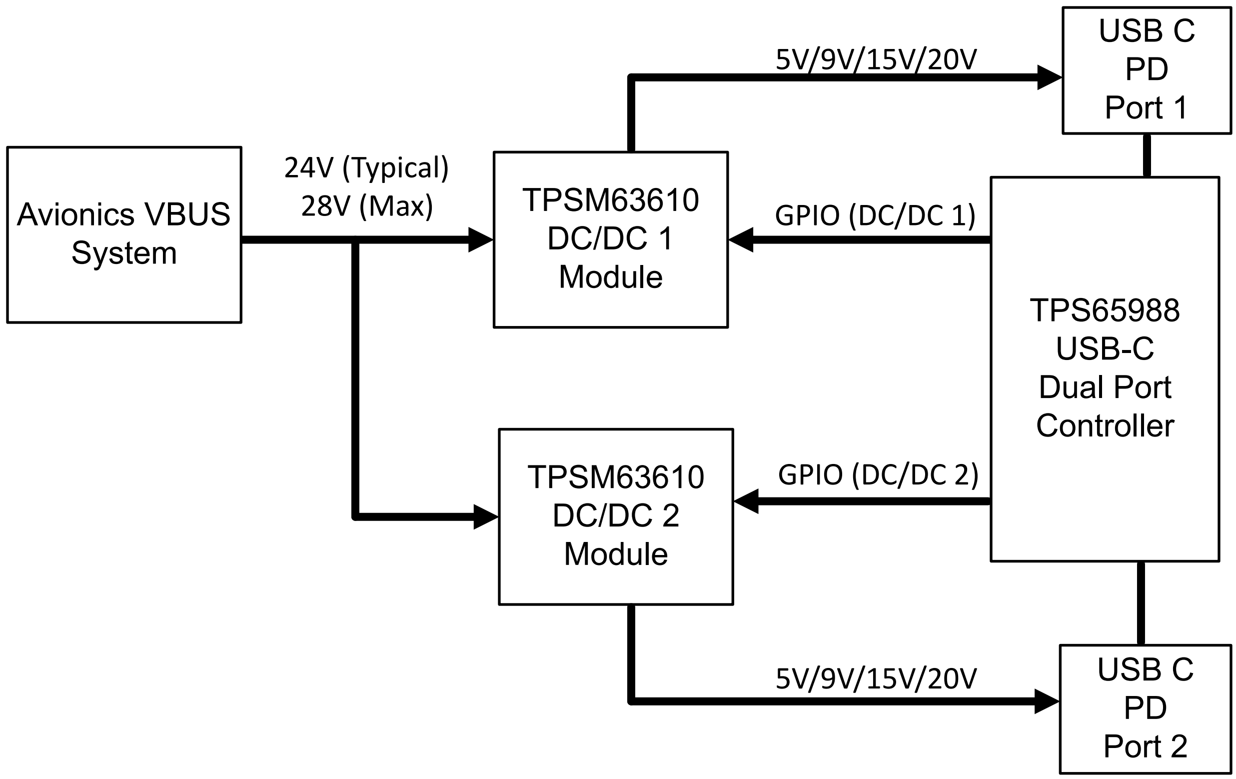

Figure 2-1. Dual-Port USB Type-C Power/Data Source

3 Dynamic Output Voltage Control Method

Figure 3-1 presents a simple approach to dynamically control the output voltage of a DC/DC step down buck converter through multiple parallel lower feedback resistors and switches. Controlling the switch can place the external lower resistors in parallel with R_{BOT} to dynamically change the output voltage regulation point. Refer to Equation 1 for details on calculating the new output voltage. Though easy to implement, this control method has several drawbacks as listed below:

- Abrupt resistor switching to adjust V_{OUT} from the lowest voltage to the highest voltage can cause the feedback node voltage to spike instantaneously
- The component design for multiple output voltages increase due to the additional lower feedback resistors and switches required to dynamically adjust V_{OUT}. One way to minimize the switch components is to use a TS5A3359 (3:1, 1-channel analog multiplexer).
- Additionally, if the system application requires slew rate control, refer to Section 9.1.6 of the voltage transition requirements section from the TPS25740B data sheet for more details on the additional slew rate control circuitry during negotiation of output voltage transitions. The design example in this app note does not cover this additional circuitry.

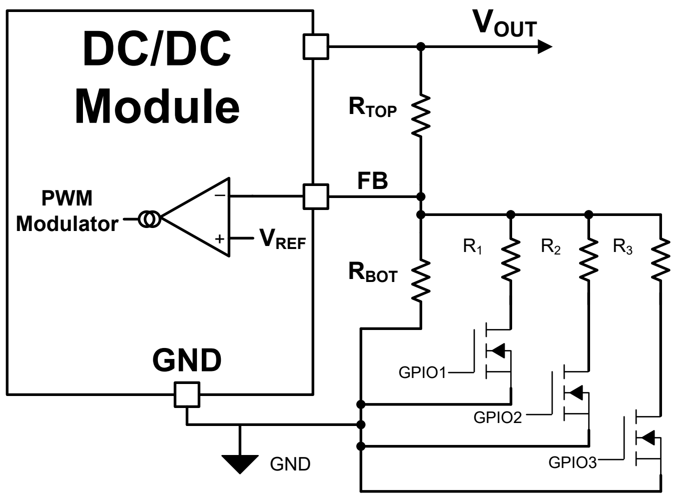

Figure 3-1. Feedback Resistor Switch Network Control Scheme

$$V_{OUT} = V_{FB} \times \left(1 + \frac{R_{TOP}}{\frac{R_{BOT} \times R_i}{R_{BOT} + R_i}}\right) \quad (1)$$

Note

R_i represents the external lower resistor (R_1, R_2, or R_3) that is placed in parallel with R_{BOT} through control of the individual MOSFET switches.

For a TI USB Type-C dual buck reference design example using this feedback resistor switch network control method, refer to PMP22416.

4 Schematic

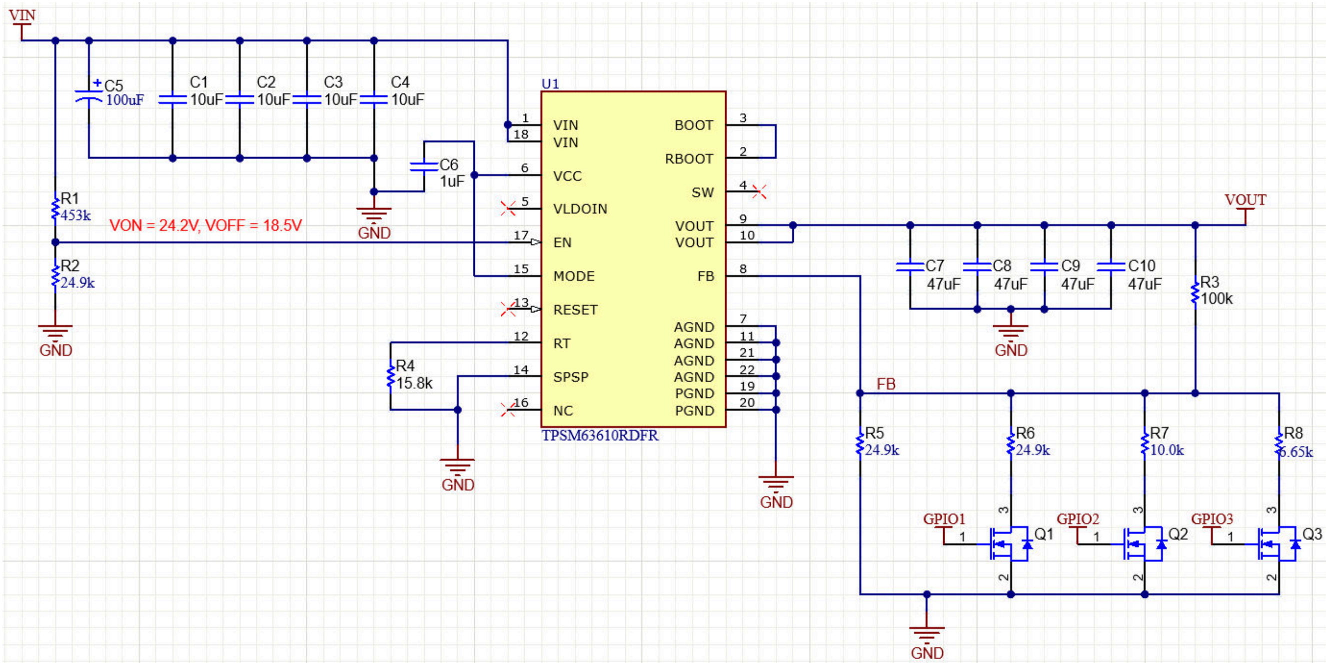

Figure 4-1. USB Type-C Schematic Using the TPSM63610 Power Module with Feedback Resistor Network Control

Table 4-1. GPIO Parallel Feedback Resistor Network Truth Table

GPIO1	GPIO2	GPIO3	FB Top (kΩ)	FB Bot (kΩ)	Vout (V)
0	0	0	100	24.9	5.016
1	0	0	100	12.45	9.032
0	1	0	100	7.135	15.016
0	0	1	100	5.248	20.054

Note

1. Vout calculation is based off nominal top and bottom feedback resistor and does not account for part tolerance and variation.
2. GPIO entry are logic level values where "1" means voltage applied and "0" means no voltage applied.

5 Lab Measurements

Below are the efficiency and infrared (IR) top case IC thermal measurements of the TPSM63610 configured for the different USB Type C PD output voltage applications: 5-V, 9-V, 15-V, and 20-V at the full 5-A load current. Unless otherwise indicated, V_{IN} = 28-V, I_{OUT} = 5-A, and F_{SW} = 1 MHz.

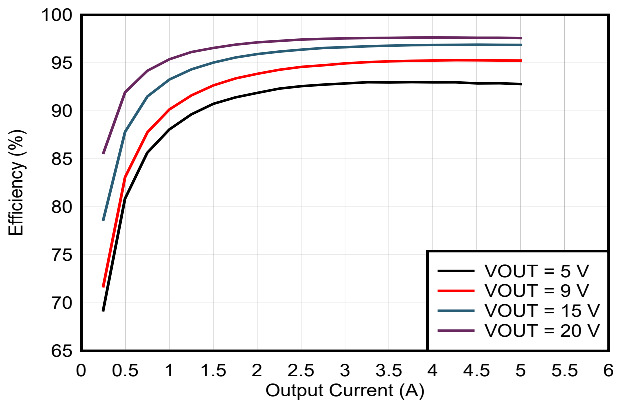

Figure 5-1. Efficiency Measurement for V_{IN} = 24-V

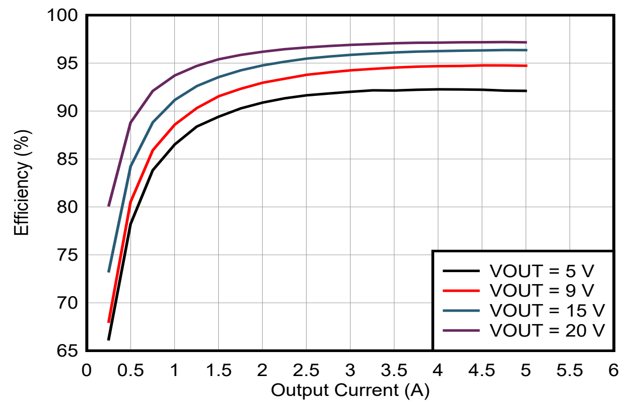

Figure 5-2. Efficiency Measurement for V_{IN} = 28-V

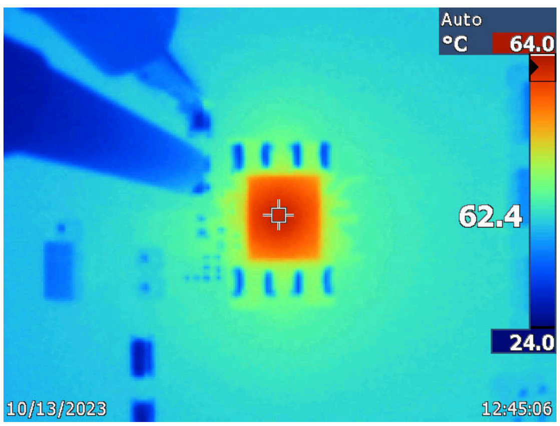

Figure 5-3. Thermal Measurement for V_{OUT} = 5-V

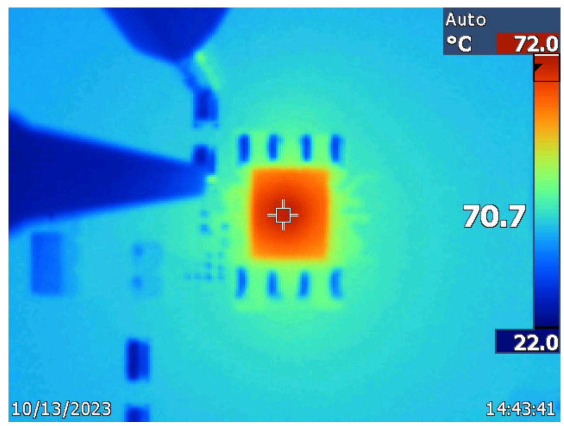

Figure 5-4. Thermal Measurement for V_{OUT} = 9-V

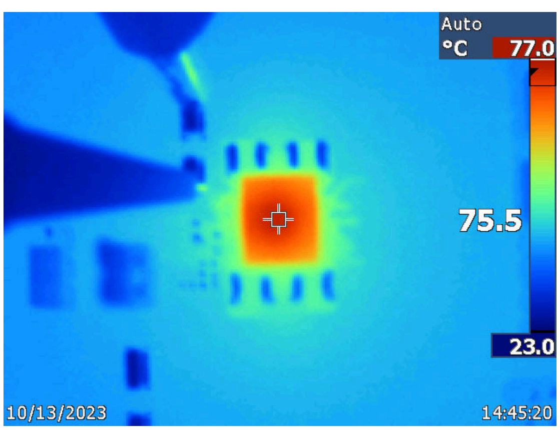

Figure 5-5. Thermal Measurement for V_{OUT} = 15-V

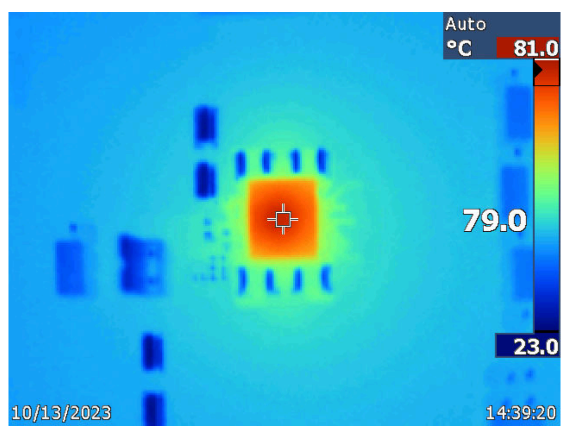

Figure 5-6. Thermal Measurement for V_{OUT} = 20-V

6 Summary

Power modules become more impactful in designs that have limited board space or projects that have limited engineering resources. Such requirements can be simply achieved with the TPSM63610 power module regulator that integrates the switching MOSFETs and inductor with internal compensation. By adding an external resistor feedback control network onto the feedback node the power module can be configured for systems that require dynamic output voltage controlled such as in USB Type-C applications. The modified EVM schematic, efficiency curve, and top case thermal image details the expected performance from the TPSM63610EVM used in a generic avionics application with input voltage range between 24-V and 28-V and output voltage range following the USB Type-C PD specifications of 5-V, 9-V, 15-V, and 20-V at 5-A max output load.

7 References

1. Texas Instruments, *A Primer on USB Type-C® and USB Power Delivery Applications and Requirements* white paper.
2. Texas Instruments, *PMP22416 - USB Type-C® dual-buck reference design* reference design.
3. Texas Instruments, *Introduction to USB Type-C and Power Delivery* training and videos.
4. Texas Instruments, *How to Dynamically Adjust Power Module Output Voltage* application note.