

Using the LM61460-Q1 and LM61495-Q1 in USB Type-C Applications



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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 report details the increasing power trends in USB Type-C applications and highlights two design examples using the LM61460-Q1 and LM61495-Q1 buck converters for sourcing high-power USB applications and devices.

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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 solution. In order 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 requirements 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

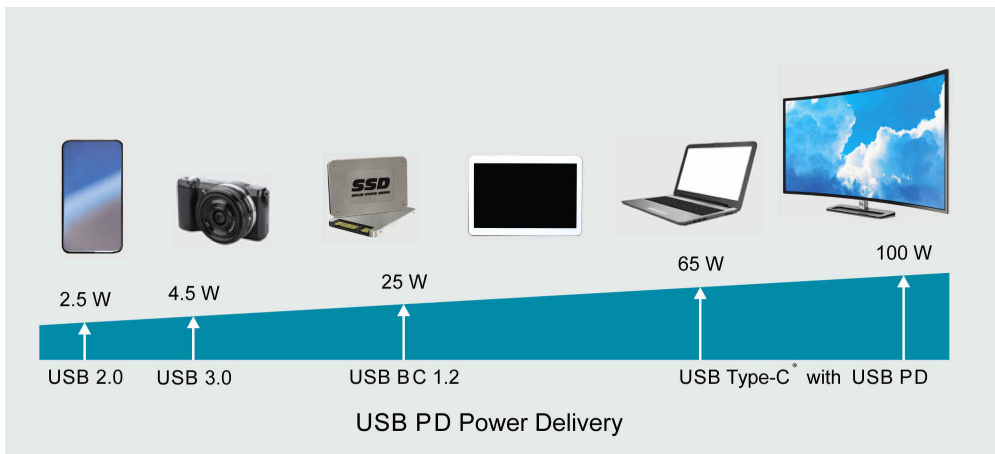


Figure 1-1. USB Source Power Demand Progression

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 buck converter as the intermediary DC/DC conversion for a well-regulated output voltage rail.

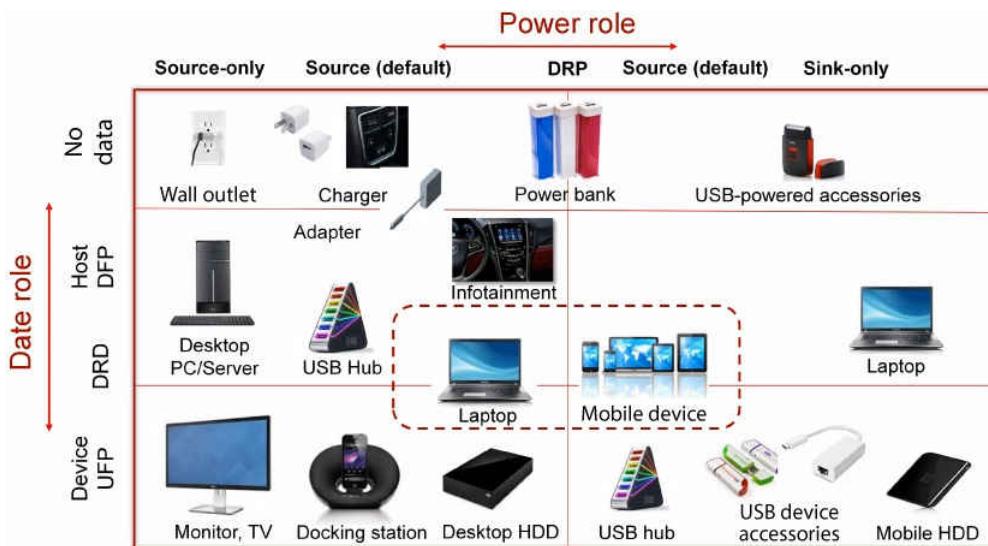


Figure 1-2. USB Type-C Application Examples

2 Popular AC Adapter Design

Popular designs for source-only AC/DC adapter takes the input AC voltage through an EMI filter and bridge rectifier. The EMI filter is used to ensure noise is not introduced to the input and the bridge rectifier provides a DC voltage to the quasi-resonant flyback (QRF) power stage. The QRF converter then provides a large step down secondary output voltage of ~21V while meeting isolated safety requirement. Since the secondary output of the flyback is loosely regulated using an auxiliary winding to provide voltage information reflected back to the primary side, an intermediary and well-regulated buck converter takes the flyback output voltage and provides another step down voltage to power the downstream personal electronic devices. The system is well-isolated from the input AC source because of the bridge and diode rectification and the output voltage is well-regulated because of the step down buck converter. Typical output voltages in USB Type-C applications are: 3.3 V, 5 V, 9 V, 15 V, and 20 V. [Figure 2-1](#) shows a typical system block diagram for a dual-port AC/DC adapter.

The buck converter is selected to meet the following design requirements for USB Type-C applications listed below:

- Small form factor and thermally efficient solution
- Dynamic output voltage scalability
- High output current capability with good thermal performance to achieve up to 5A to meet USB PD 3.0 specifications

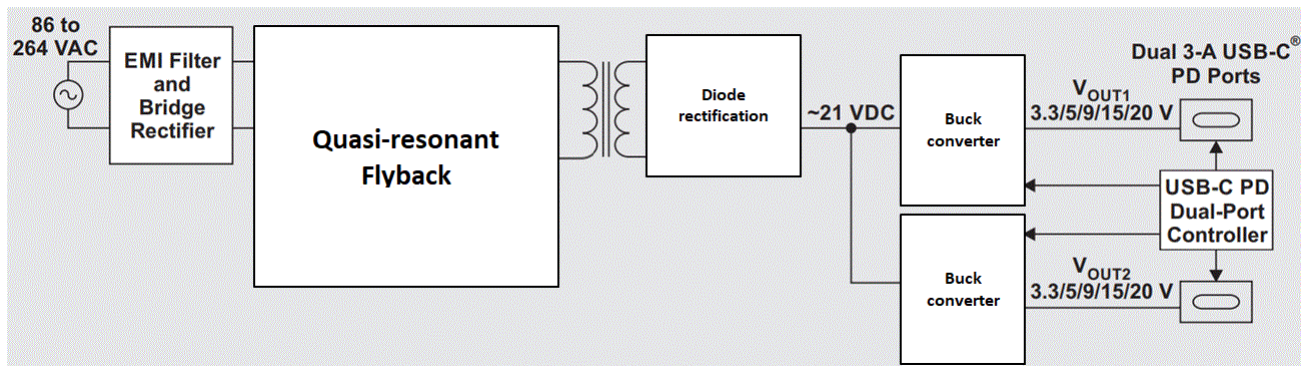


Figure 2-1. Dual-Port USB Type-C Power Brick

3 Dynamic Output Voltage Control Methods

3.1 Method 1: Feedback Resistor Switch Network

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 will 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 and may trigger a false overvoltage protection (OVP) fault or PGOOD trigger low. The application design will need to be validated to ensure this does not occur.
- The component solution 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).
- For DC/DC step down buck converters utilizing a transconductance type error amplifier, the system is slightly difficult to properly compensate. This is because the lower feedback resistors directly impacts the gain of the system throughout the entire frequency range, which in turn impacts the crossover frequency of the system across different V_{OUT} points and consequently affects the phase margin of the system. Refer to [Figure 3-2](#) for the simulated LM61460-Q1 small signal loop response for the lowest output voltage of 5 V and the highest output voltage of 20 V. Note that the gain loop crosses 0 dB for at different crossover frequencies for different V_{OUT} voltages and will have an impact on the system transient performance. Depending on the specific buck converter used, the output capacitance may need to be modified accordingly to create a stable design that is applicable across the entire V_{OUT} voltage range.

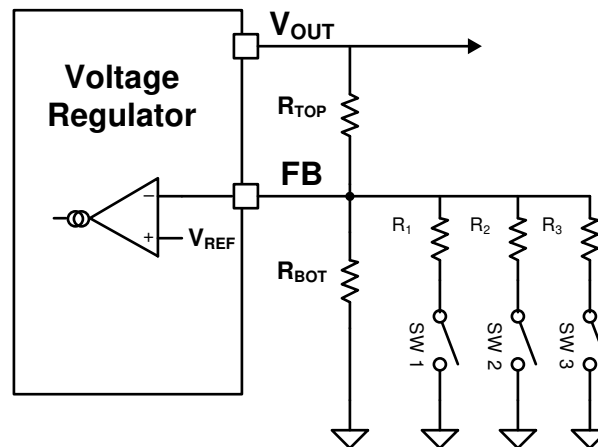


Figure 3-1. Feedback Resistor Switch Network Control Scheme

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

Note

R_i is the external lower resistor placed in parallel with R_{BOT} through control of the respective switch.

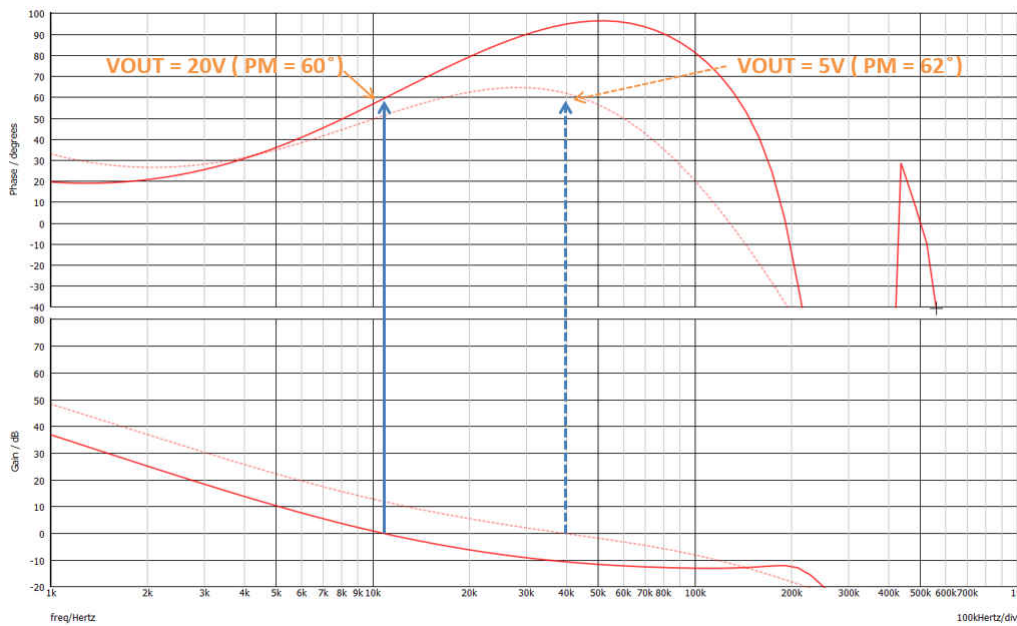


Figure 3-2. Feedback Resistor Switch Network Control Scheme Bode Plot

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

3.2 Method 2: Feedback Current Injection Network

This method controls the output voltage by an external current injection into the feedback node of the DC/DC buck converter as shown in [Figure 3-3](#). In this control configuration, the system is:

- Easier to compensate since there is a fixed output voltage setpoint. The injected current lowers the voltage regulation point of the DC/DC buck converter from high to low.
- Smaller solution size since there is no need for additional bottom resistors to configure V_{OUT} .
- The DC gain of the system loop remains constant throughout the entire typical USB Type-C V_{OUT} range since the bottom resistor is set and fixed to a single component value. Refer to [Figure 3-4](#) for the simulated LM61460-Q1 small signal loop response for the lowest output voltage of 5 V and the highest output voltage of 20 V using this control method. Note that the loop gain response crosses 0 dB at the same frequency for different V_{OUT} voltages so the transient loop response is expected to be similar for all output voltage settings.

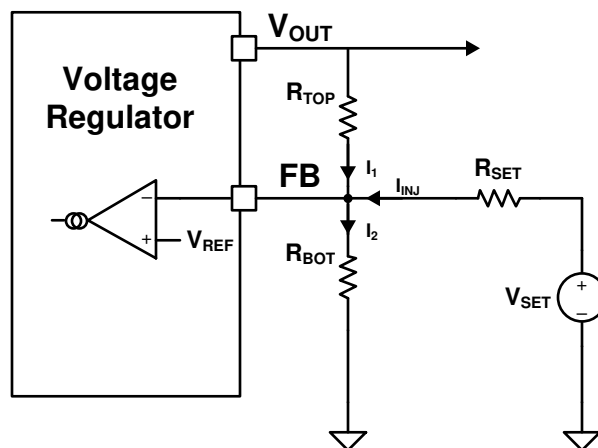


Figure 3-3. Feedback Current Injection Network Control Scheme

$$V_{OUT} = V_{FB} \left(1 + \frac{R_{TOP}}{R_{BOT}} \right) - \left(\frac{V_{SET} - V_{REF}}{R_{SET}} \right) \cdot R_{TOP} \quad (2)$$

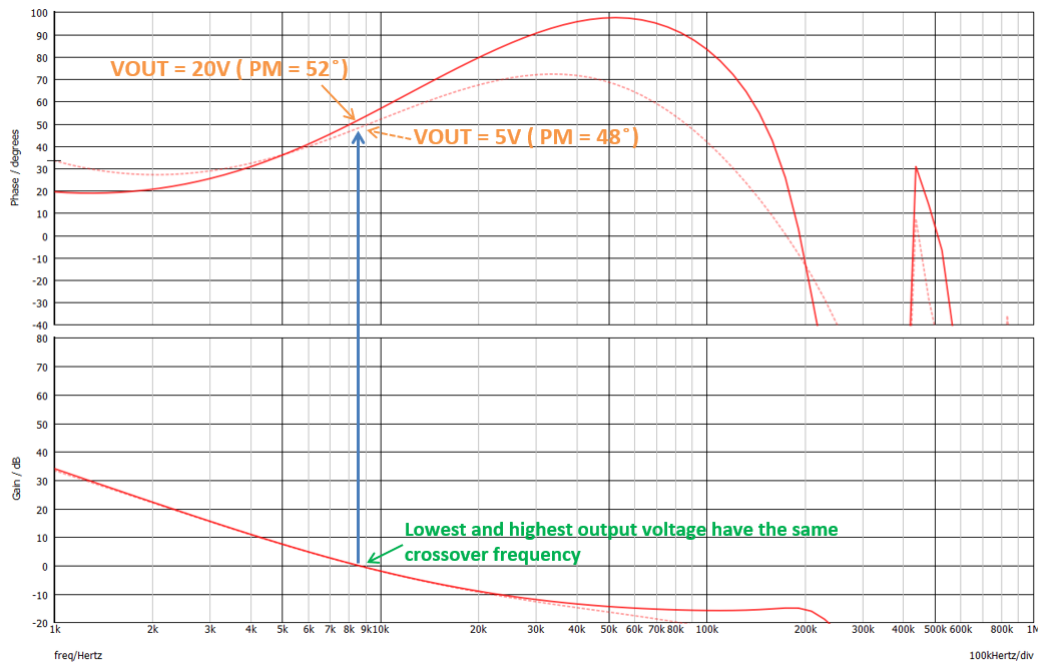


Figure 3-4. Feedback Current Injection Network Control Scheme Bode Plot

For this application note, the current injection control method is used to demonstrate how the LM61460-Q1 and LM61495-Q1 design examples can be used in an USB Type-C applications. Refer to [SLVA861](#) for additional reading material using the [LM10011](#) current DAC as the external current injection source.

Design Procedure for Method 2

- Set the feedback network to regulate at the highest V_{OUT} . For USB PD 3.0, the highest V_{OUT} is 20 V. Note that setting the top and bottom resistors to output the highest V_{OUT} enables a significantly reduced output capacitance solution that reduces overall solution size and solution cost.
- Set V_{SET} equal to the feedback reference voltage for zero injection current at the highest V_{OUT} setting. For the LM61460-Q1 and LM61495-Q1, V_{SET} is set to 1 V since both DC/DC step down buck converter has an internal reference voltage (V_{REF}) equal to 1 V.
- Calculate the required V_{SET} for the desired output voltage regulation point from the equation shown in [Equation 2](#).
- If a PWM signal followed by an RC filter is used to produce the DC bias voltage for the external injection current, it is important to have sufficient attenuation to remove unwanted ripple. It is recommended to have the corner frequency of RC filter at least two decade that of the PWM signal to get a 40 dB attenuation and prevent noise from coupling into the feedback node.

4 Schematic

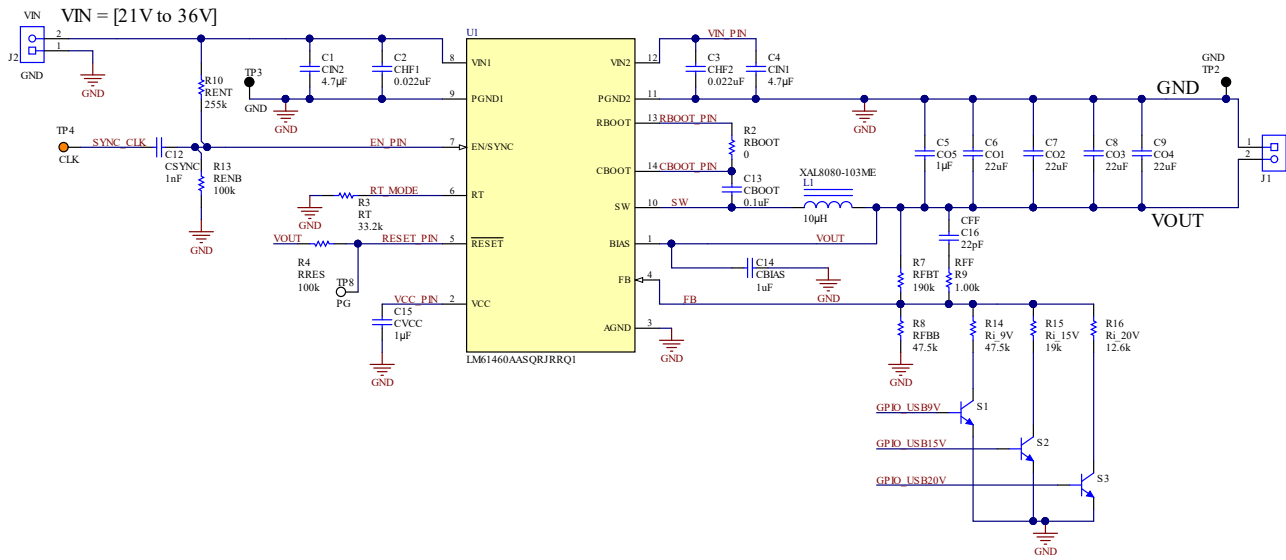


Figure 4-1. USB Type-C Schematic using the LM61460-Q1 6-A Buck Converter (Resistor Switch Network Control)

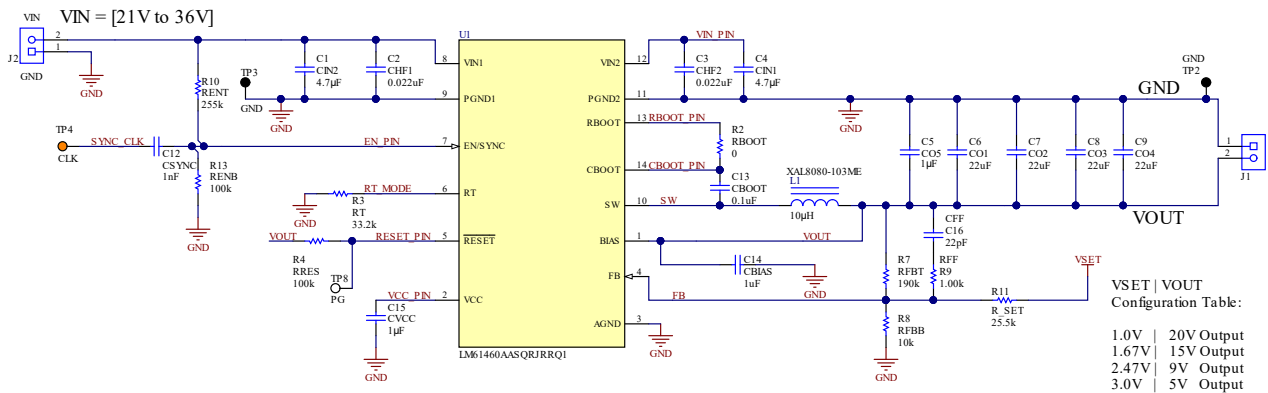


Figure 4-2. USB Type-C Schematic using the LM61460-Q1 6-A Buck Converter (Current Injection Control)

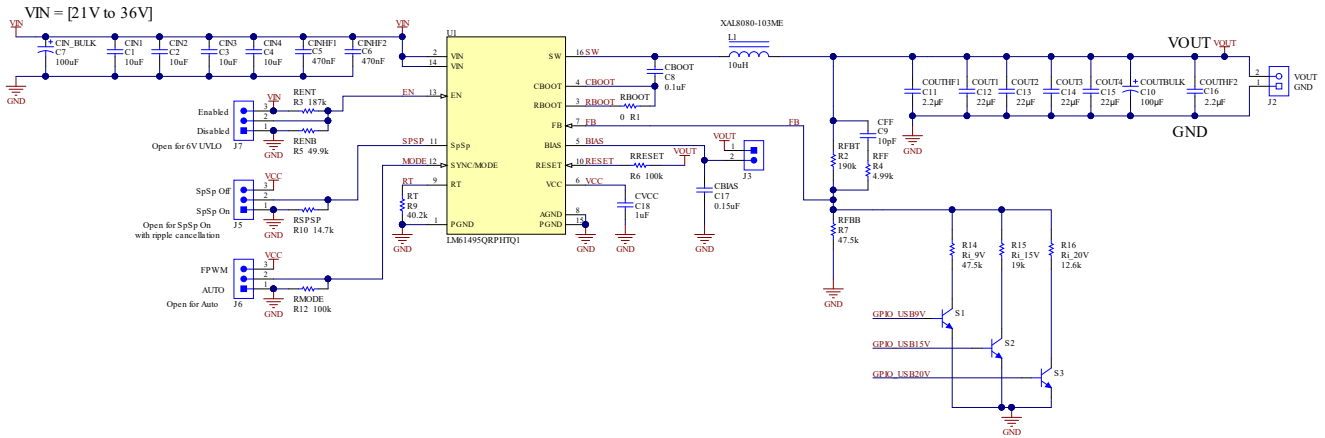


Figure 4-3. USB Type-C Schematic using the LM61495-Q1 10-A Buck Converter (Resistor Switch Network Control)

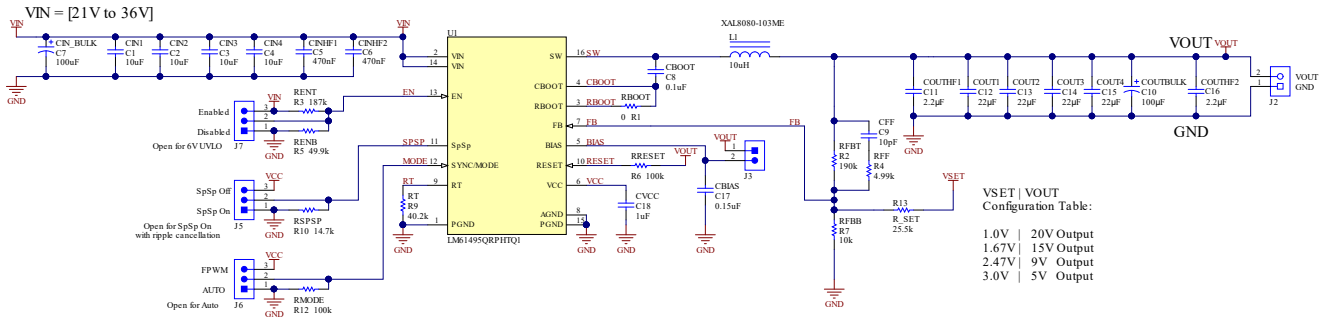


Figure 4-4. USB Type-C Schematic using the LM61495-Q1 10-A Buck Converter (Current Injection Control)

5 Lab Measurements

Following are the efficiency comparison and side by side thermal image comparison between LM61460-Q1 and LM61495-Q1 device in USB Type-C application for 5 V, 9 V, 15 V, and 20 V.

5.1 Bench Measurement (V_{OUT} = 5 V)

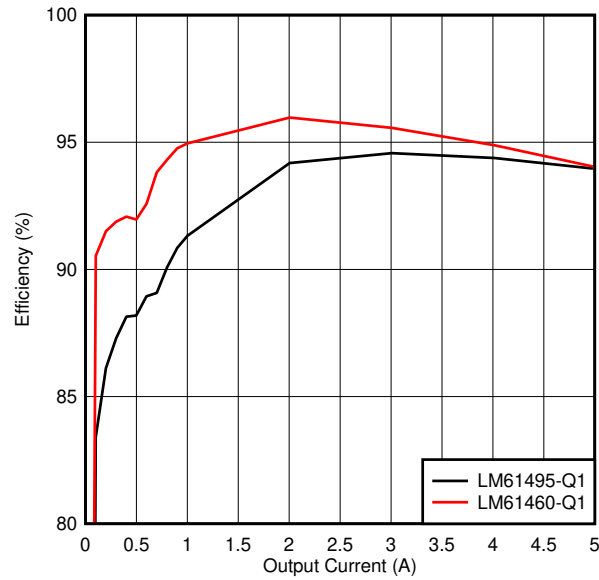


Figure 5-1. Efficiency (V_{IN}= 21 V ; V_{OUT}= 5 V)

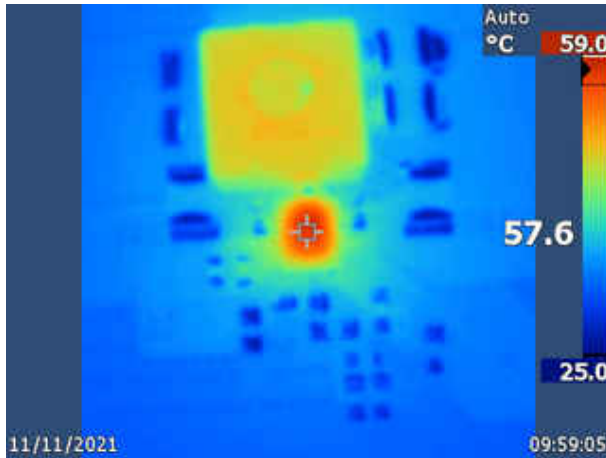


Figure 5-2. LM61460-Q1 IR Thermal (V_{IN}= 21 V ; V_{OUT}= 5 V)

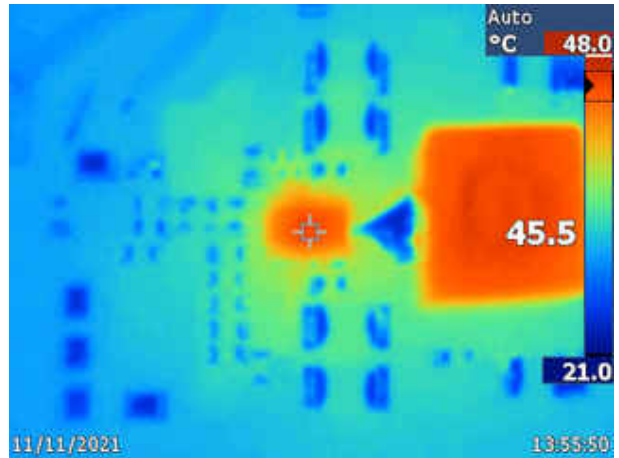


Figure 5-3. LM61495-Q1 IR Thermal (V_{IN}= 21 V ; V_{OUT}= 5 V)

5.2 Bench Measurement ($V_{OUT} = 9\text{ V}$)

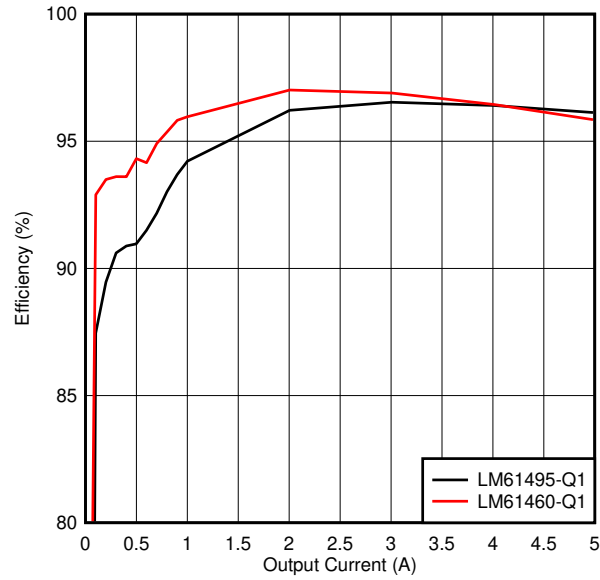


Figure 5-4. Efficiency ($V_{IN} = 21\text{ V}$; $V_{OUT} = 9\text{ V}$)

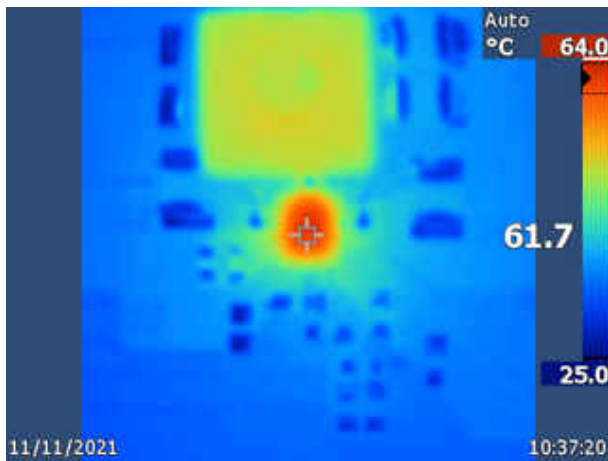


Figure 5-5. LM61460-Q1 IR Thermal ($V_{IN} = 21\text{ V}$; $V_{OUT} = 9\text{ V}$)

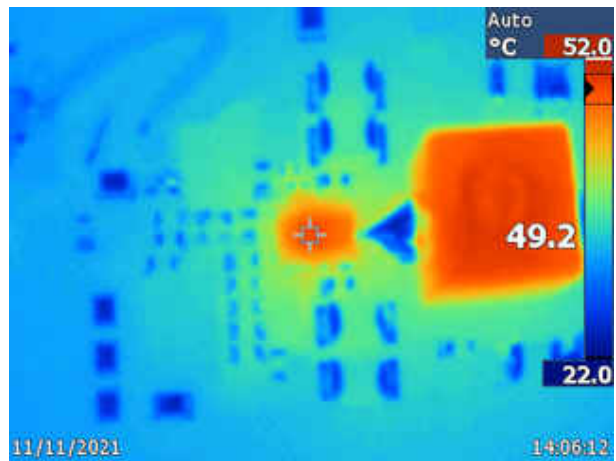


Figure 5-6. LM61495-Q1 IR Thermal ($V_{IN} = 21\text{ V}$; $V_{OUT} = 9\text{ V}$)

5.3 Bench Measurement (V_{OUT} = 15 V)

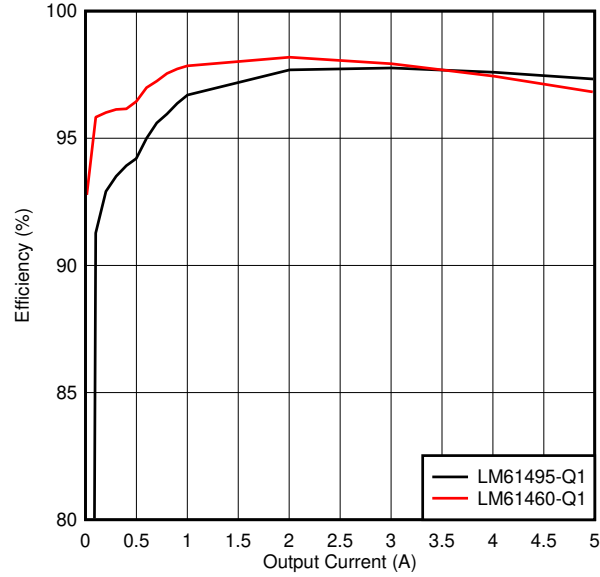


Figure 5-7. Efficiency (V_{IN} = 21 V ; V_{OUT} = 15 V)

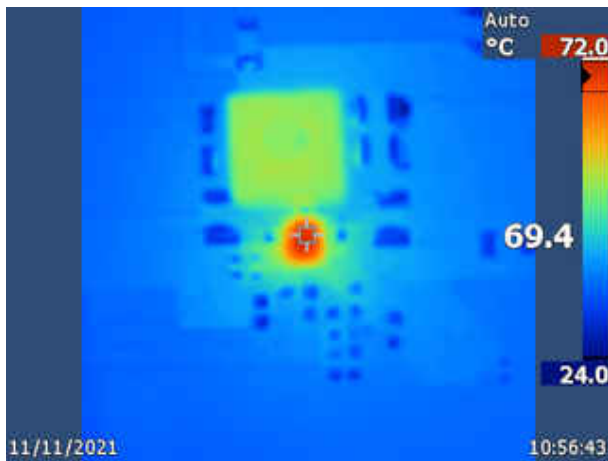


Figure 5-8. LM61460-Q1 IR Thermal (V_{IN} = 21 V ; V_{OUT} = 15 V)

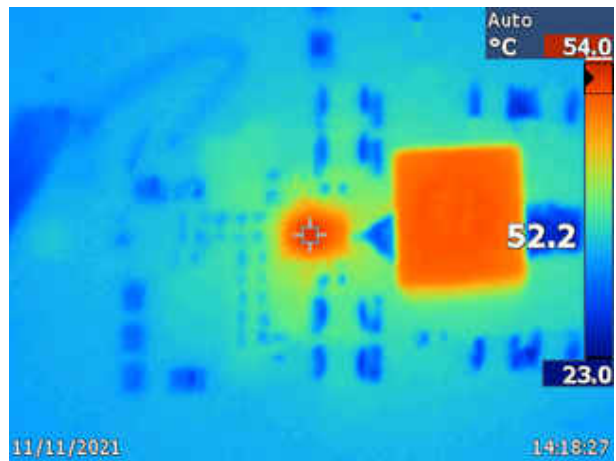


Figure 5-9. LM61495-Q1 IR Thermal (V_{IN} = 21 V ; V_{OUT} = 15 V)

5.4 Bench Measurement ($V_{OUT} = 20\text{ V}$)

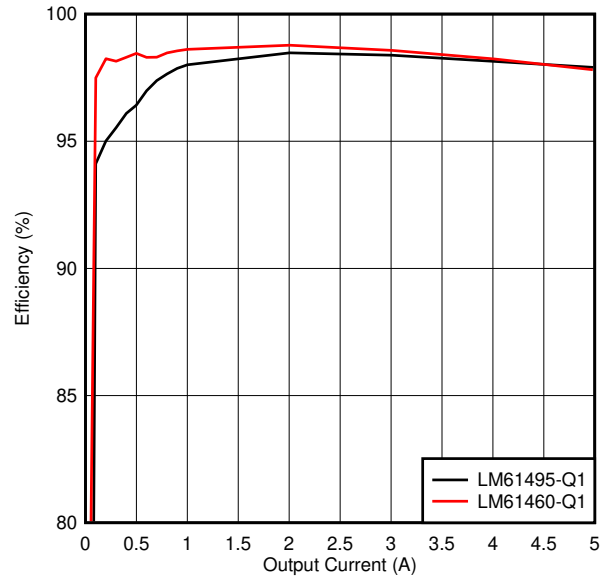


Figure 5-10. Efficiency ($V_{IN} = 21\text{ V}$; $V_{OUT} = 20\text{ V}$)

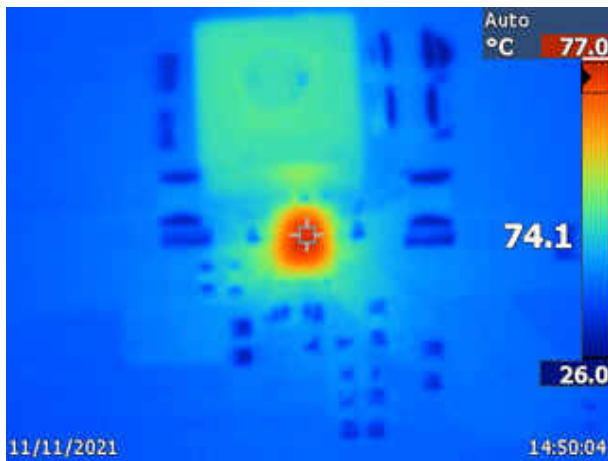


Figure 5-11. LM61460-Q1 IR Thermal ($V_{IN} = 21\text{ V}$; $V_{OUT} = 20\text{ V}$)

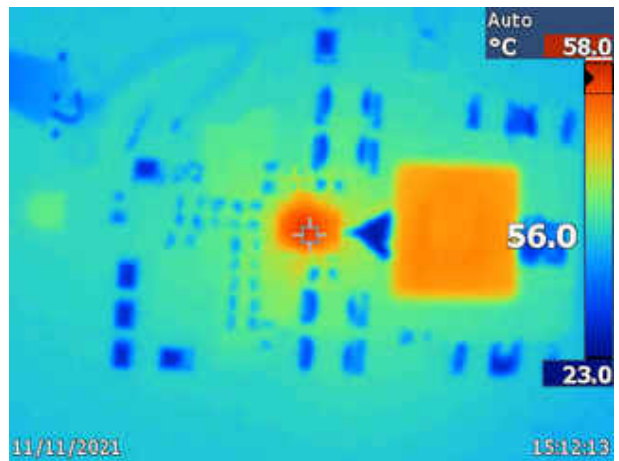


Figure 5-12. LM61495-Q1 IR Thermal ($V_{IN} = 21\text{ V}$; $V_{OUT} = 20\text{ V}$)

6 Summary

This application note details the design considerations when using a buck converter in an USB Type-C application. Two design examples using the highly efficient buck converters, the LM61460-Q1 and LM61495-Q1 buck converters, step down a typical 21 V input supply voltage to a lower dynamically controllable output voltage set between 5 V to 20 V following USB Type-C PD specifications. The modified EVM schematics, efficiency curve comparisons, and side-by-side thermal image comparisons of the two converters showcase the strengths of each device. While the LM61460-Q1 device optimized particularly for output currents lower than 5 A, the higher current rated LM61495-Q1 device is thermally cooler because of its larger package size and lower internal R_{DS-ON} .

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.

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