ACT5101-101-REF01 USB PD3.0+PPS Reference Design User's Guide

Description

This document describes the characteristics and operation of the active-semi **ACT5101-101-REF01** reference design. This design features a 39W car charger reference design with a 27W USB-C output and a 12W USB-A output. The document provides setup and operation instructions, schematic, layout, BOM, and test data. This Reference Design demonstrates the ACT5101QI101 power management IC plus Cypress CYPD1275-24LQXQT USB PD3.0 controller.

This reference design is a good starting point for designs requiring slight variations from the base design. The base design is suitable as-is for many different power profiles. The "Certifications" paragraph in this User's Guide shows the design's existing certifications. Many derivative requirements are easily achievable with only firmware modifications to the Cypress controller. This design has been certified for 45W on the USB-C output

This design is a joint design with active-semi and Cypress. Cypress provides additional documentation on their website here: http://www.cypress.com/documentation/reference-designs/ez-pd-ccg3pa-usb-c-pps-39w-dual-port-car-charger-power-adapter

Features

This Reference Design features a 2-output car charger application. Three major components in the design are active-semi's ACT5101 Integrated Buck-Boost Converter, active-semi's ACT4527 Integrated Buck Converter, and Cypress' CCG3PA (CYPD3175-24LQXQ) USB PD controller. The CCG3PA communicates with the downstream device to negotiate required power levels. It then communicates with the ACT5101 and ACT4527 to program them to meet the required power levels.

- Input Voltage = 4V to 22V

- USB-C Output up to 45W

- USB-A Output up to 27W

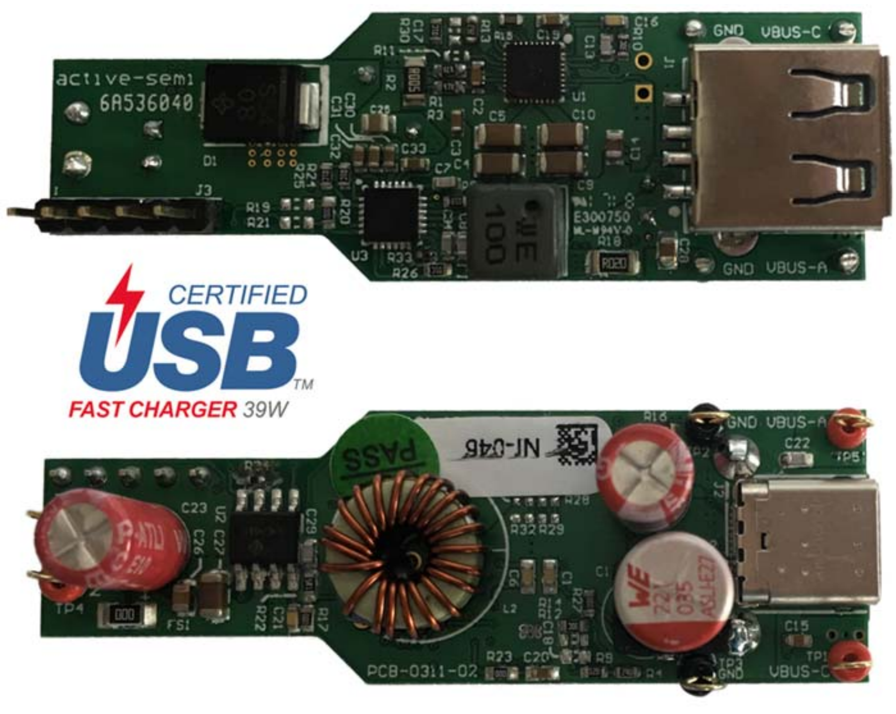


Figure 1 – Reference Design

Reference Design Contents

The ACT5101-101-REF01 reference design ships with the PCB only. All cables and test equipment must be user supplied.

Certifications

This reference design is tested to, and certified for several different power profiles. Each power profile below passed on the same hardware design. A firmware change is the only difference between the different designs. Each profile was tested to the USB_IF Test Procedure for USB Power Brick products. The TID details are available on the USB Organization website at http://www.usb.org/kcompliance/view/CertifiedUSBPowerBricks.pdf. active-semi certified the 39W (TID 1080029) design. All other designs were certified by other companies using the active-semi hardware and modified Cypress firmware.

39W: 27W USB-C PD3.0 + PPS and 12W USB-A PD3.0 (TID 1080029)

Name: 27W Buck-Boost Converter with Integrated FETs – ACT5101-101-REF01

- USB-C Output: 27W USB-C output is powered by the ACT5101 and controlled by the CYPD3175. It supports USB PD 3.0 + PPS protocol. It supports the power profiles listed below.
  - USB-PD power contract negotiation as provider
    - Source PDO 5V @ 3A
    - Source PDO 9V @ 3A
    - Source APDO: 3.3V-5.9V@3A
    - Source APDO: 3.3V-11V@3A
  - Legacy Charging
    - BC1.2 DCP
- USB-A Output: 12W USB-A output is powered by the ACT4527 and controlled by the CYPD3175. It supports the power profiles listed below.
  - Legacy Charging
    - Source PDO 5V @ 2.4A
    - Source PDO 9V @ 1.3A
    - Source PDO 12V @ 1A
    - BC1.2 DCP
    - Apple Charging 2.4A
    - QC 2.0 and AFC

45W USB-C PD3.0 with (TID 1080022)

Name: Mobileconn 45W PD3.0+PPS Car Charger – ACLEG45_02

- USB-C Output: 45W USB-C output is powered by the ACT5101 and controlled by the CYPD3175. It supports USB PD 3.0 + PPS protocol. It supports the power profiles listed below.
  - USB-PD power contract negotiation as provider
    - Source PDO 5V @ 3A
    - Source PDO 9V @ 3A
    - Source PDO 15V @ 3A

- USB-A Output: This certification does not use the USB-A output.

27W USB-C PD3.0 (TID 1080011)

Name: Xentris Wireless 27W Power Delivery 3.0 - PPS Charger - VPC27WPPSTYPEC-M

- USB-C Output - 27W USB-C output is powered by the ACT5101 and controlled by the CYPD3175. It supports USB PD 3.0 + PPS protocol. It supports the power profiles listed below.
  - USB-PD power contract negotiation as provider
    - Source PDO 5V @ 3A
    - Source PDO 9V @ 3A
    - Source APDO: 3.3V-5.9V@3A
    - Source APDO: 3.3V-11V@3A
  - Legacy Charging
    - BC1.2 DCP
- USB-A Output: This certification does not use the USB-A output.

Architecture

USB-C output power is provided by the ACT5101 buck-boost converter with integrated FETs. It converts input power to a regulated output voltage at the USB-C connector. The CCG3PA monitors the USB-C connector for communication via CC1/CC2 or DP1/DM1. The CCG3PA decodes the communication and programs the ACT5101 output voltage to any requested voltage in 20mV steps. It also programs the current limit. The CCG3PA monitors the output current for the PPS protocol. The ACT5101 can monitor the output current for all other protocols.

USB-A output power is provided by the ACT4527 buck converter. It converts input power to a regulated output voltage at the USB-C connector. The CCG3PA monitors the USB-A connector for communication via DP2/DM2. The CCG3PA decodes the communication and programs the ACT4527 output voltage to 5V, 9V, or 12V. Current limit is provided by the ACT4527.

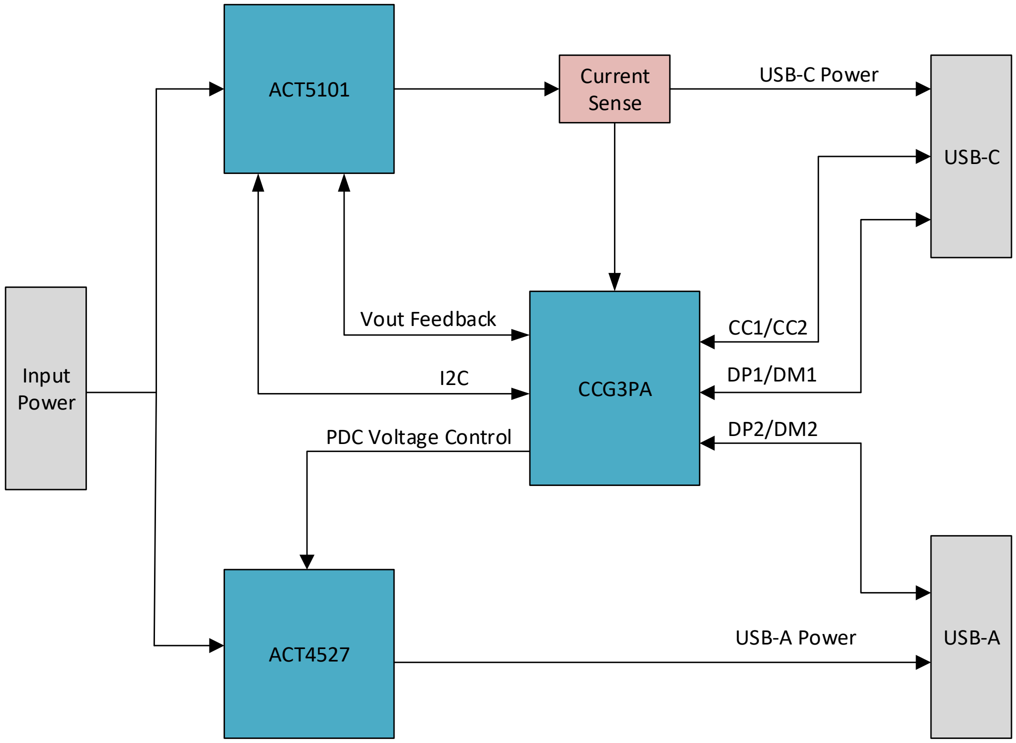


Figure 2 – Reference Design Block Diagram

Modifications

This reference design is highly flexible and supports multiple power profiles and communication protocols. The design is shipped with the default firmware and supports the protocols and power levels described in the 39W certification above. This configuration was certified by the USB organization. In addition, firmware changes allow the design to support USB PD 3.0, PPS, QC 4.0/4.0 +, QC 3.0/2.0, AFC, Apple charging and BC 1.2 on the USB-C connector. It also supports QC 2.0, Apple charging and BC 1.2 on the USB-A port. Each output can be used independently or at the same time. Firmware changes also allows the design to support different combinations of output power profiles. Contact active-semi at sales@active-semi.com for hardware and firmware modification support. Cypress Semiconductor also provides detailed firmware modification instructions on their website.

Required Equipment

ACT5101-101-REF01 Reference Design board

PowerZ-KM001C USB TypeC meter/tool.

Power supply → 4~22V @ 6A for full power operation

E-Load→3V-20V,3A output.

Oscilloscope →100MHz, 4 channels

Digital Multi-meters (DMM)

PC installed with PowerZ-KM001C USB TypeC meter/tool GUI.

Hardware Setup

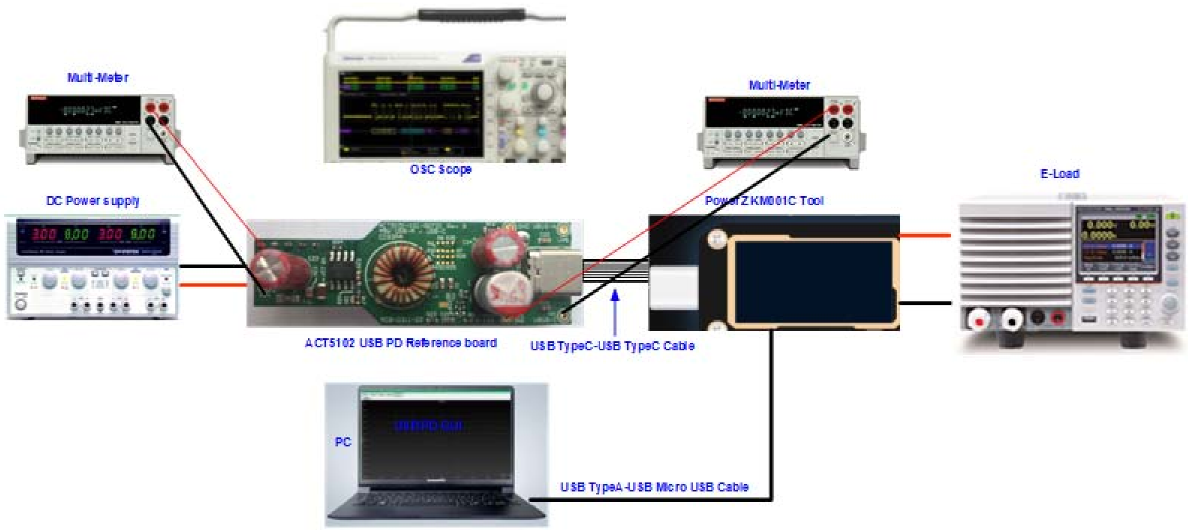


Figure 3 – Reference Design Setup

1. Connect a DC power supply to TP4 and TP6. Ensure that the power is applied to TP4 and ground is applied to TP6
2. Connect PowerZ KM001C USB TypeC PD meter/Tool to J1 (USB-C connector).
3. Connect the PC to the PowerZ KM001C USB TypeC PD meter/Tool with a USB-A micro USB cable.
4. Connect E-load to the output of PowerZ KM001C USB TypeC PD meter/Tool.

Recommended Operating Conditions

The ACT5101-101-REF01 is designed for an 8V-23V input voltage. The ACT5101 powering the USB-C output is a buck-boost converter that provides a regulated output voltage regardless of the input and output voltage ratio. The ACT4527 powering the USB-A output is a buck converter, so the input voltage must stay above the desired output voltage to stay in regulation.

Table 1. Recommended Operating Conditions

Parameter	Description	Min	Typ	Max	Unit
Vin	Input voltage range	8	-	23	V
Vout	Output voltage range	3	-	20	V
I_{out_max}	Maximum output current		3		A

Operation

Basic operation can be evaluated by simply applying an input voltage and connecting a load to the USB-A and USB-C output connectors. More thorough evaluation of USB protocols and different output voltages is achieved by using the PowerZ KM001C USB TypeC PD meter/Tool. Refer to this tool's operating instructions for details. Cypress Semiconductor also provides detailed evaluation instructions on their website.

Schematic

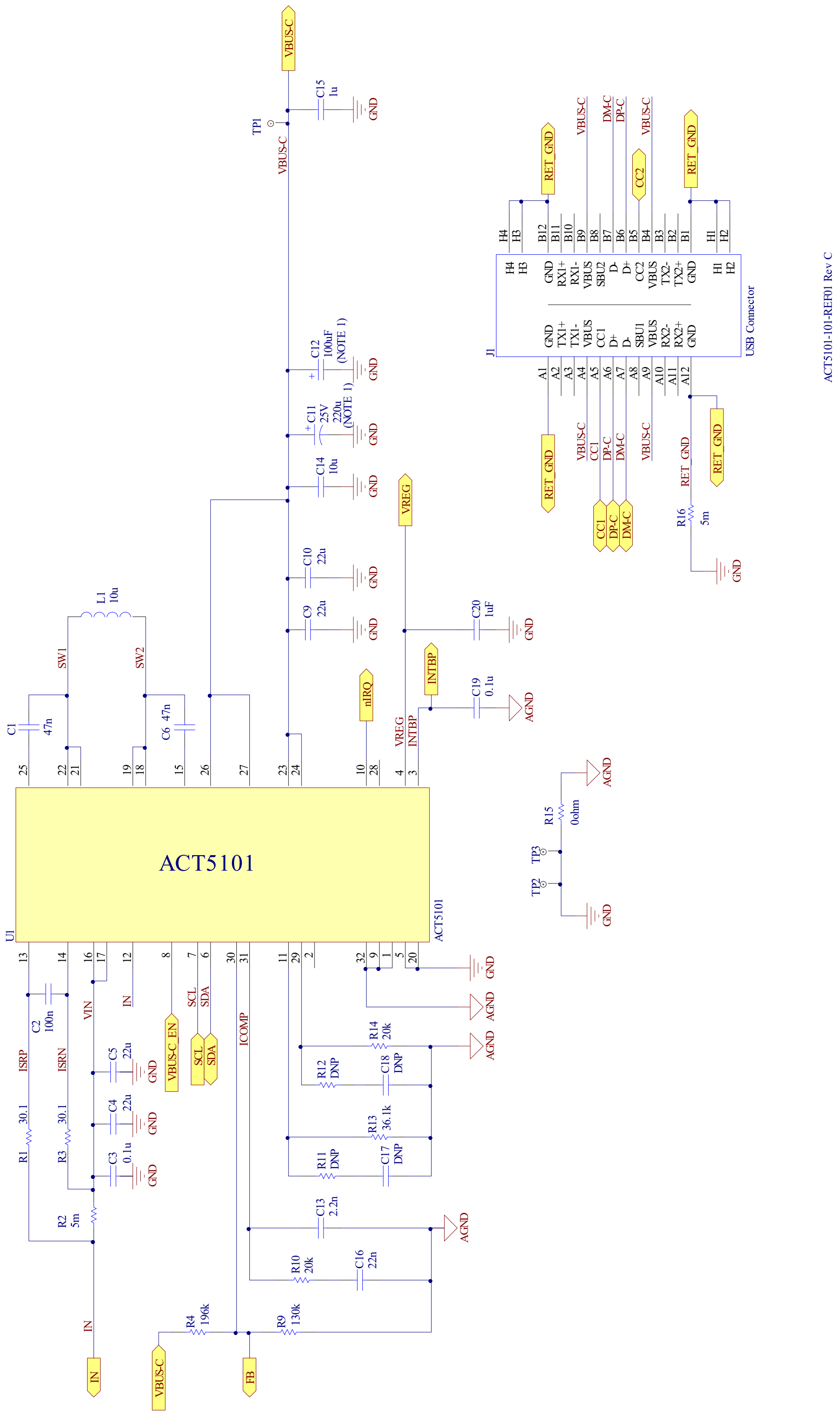


Figure 4 – Schematic Page 1

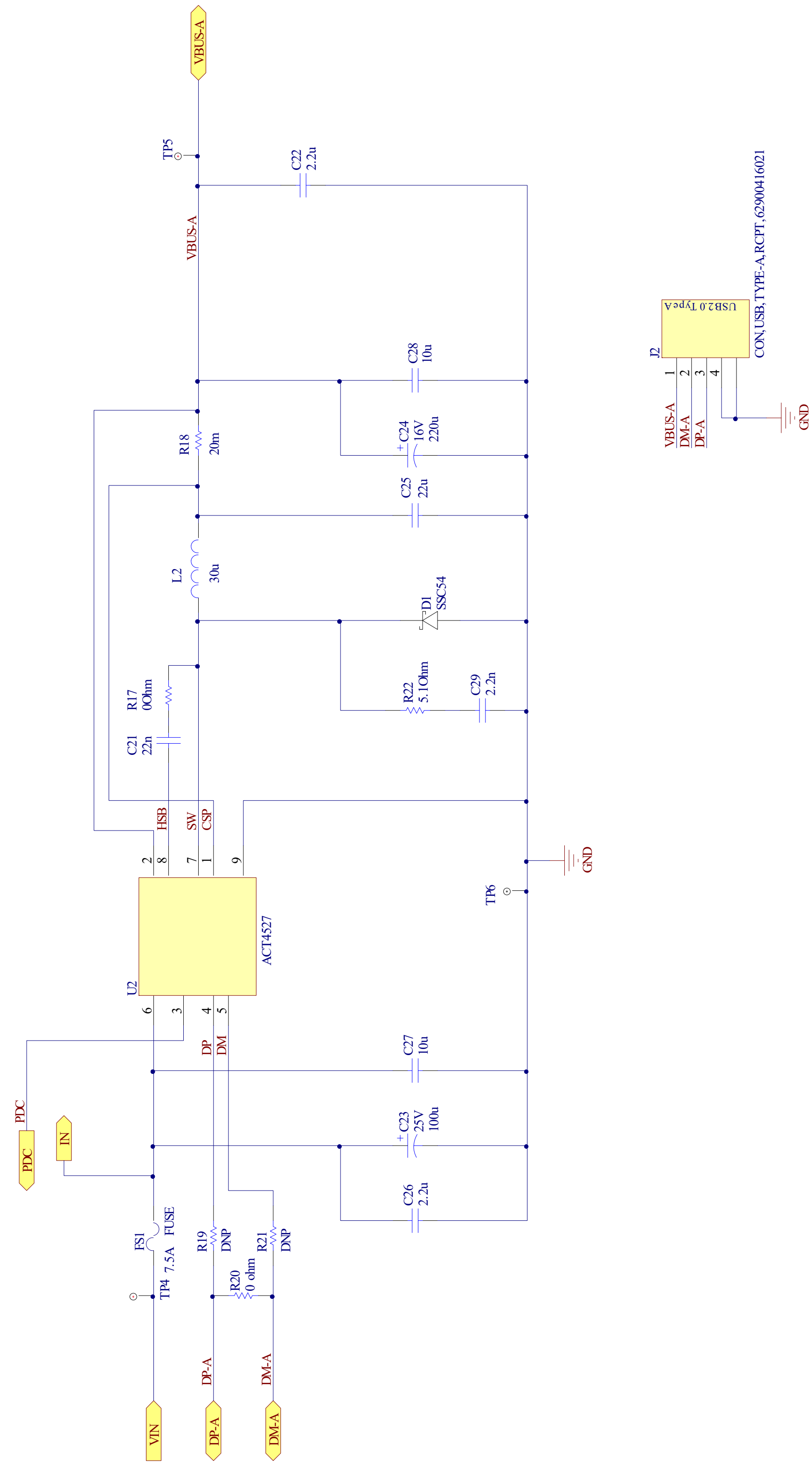


Figure 5 – Schematic Page 2

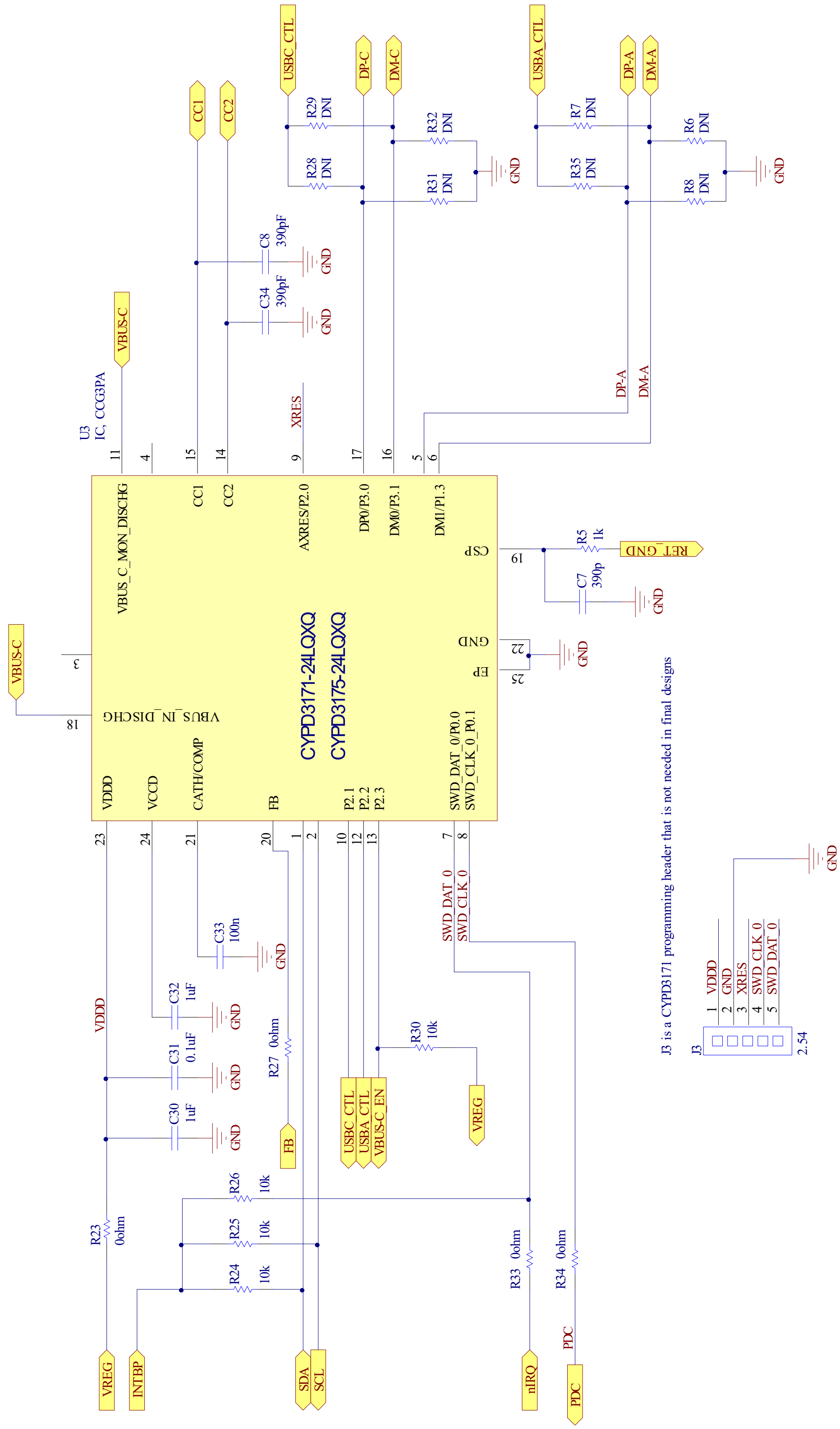


Figure 6 – Schematic Page 3

Layout

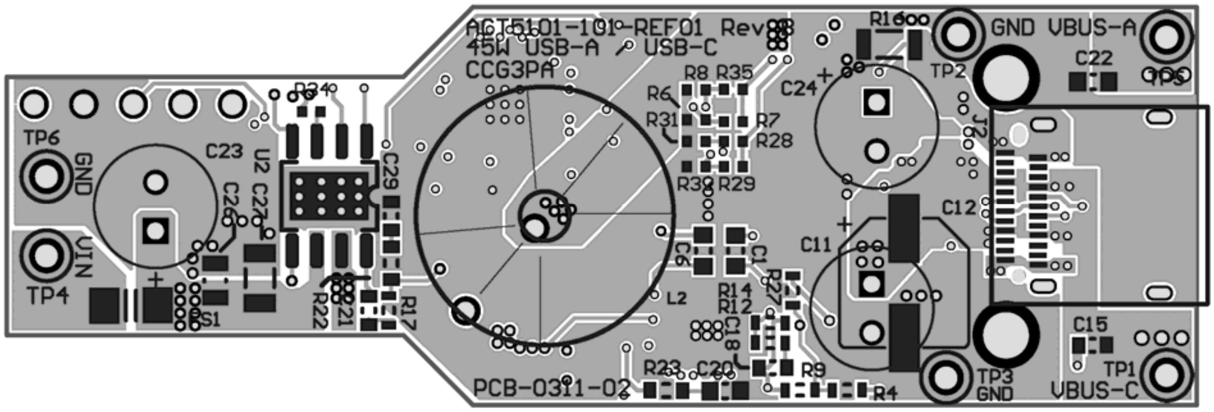


Figure 7 – Layout Top Assembly

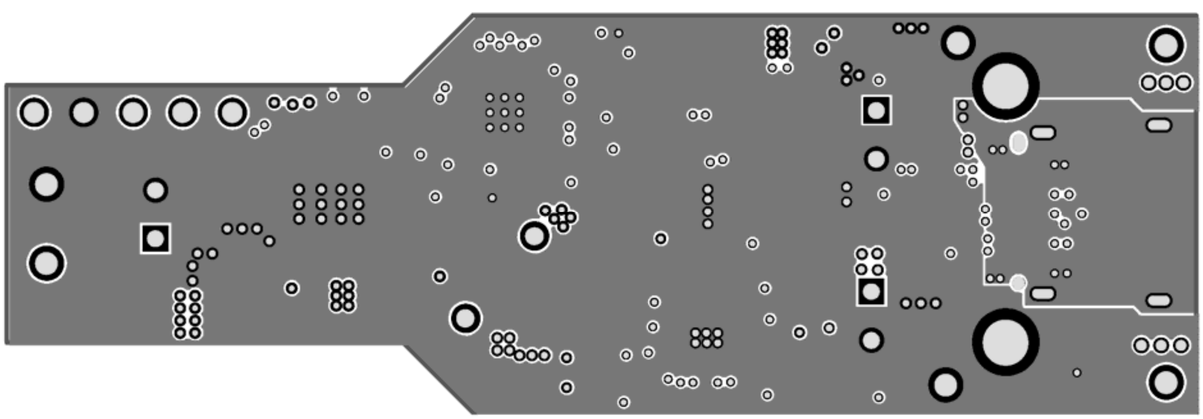


Figure 8 – Layout Layer 2

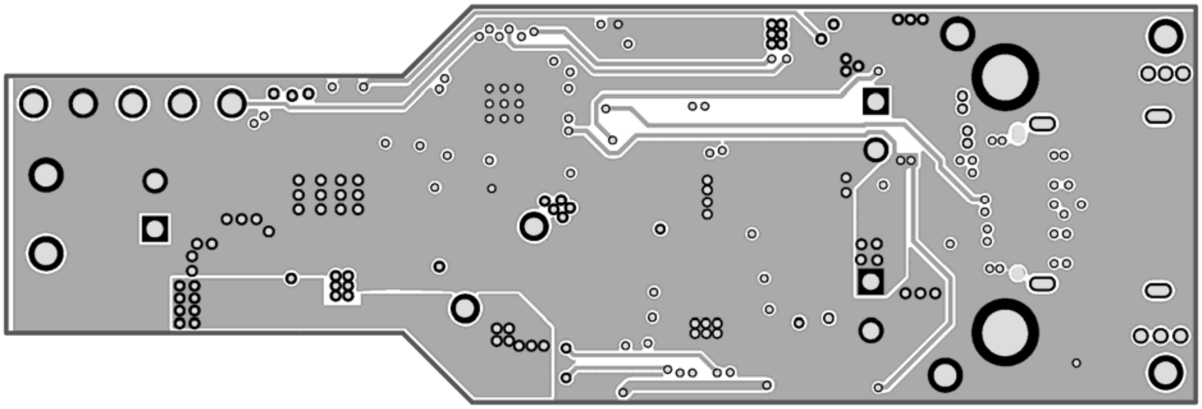


Figure 9 – Layout Layer 3

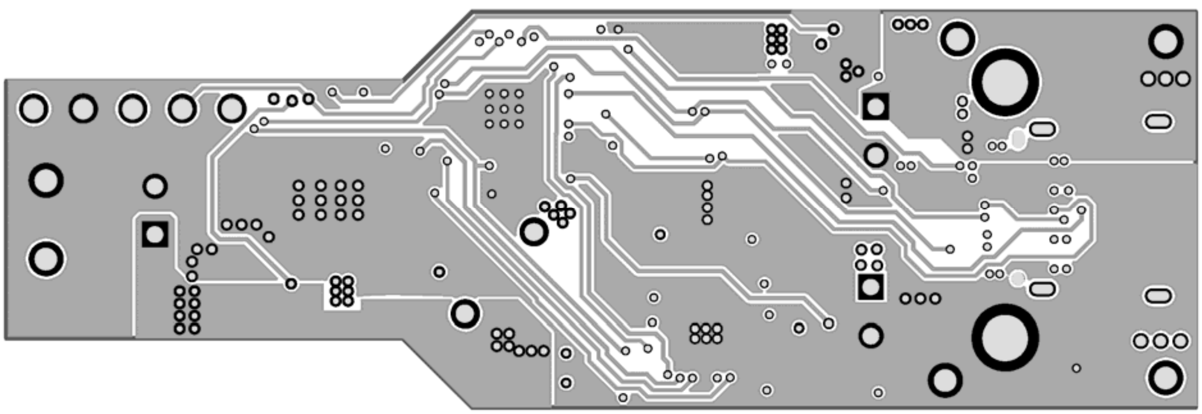


Figure 10 – Layout Layer 4

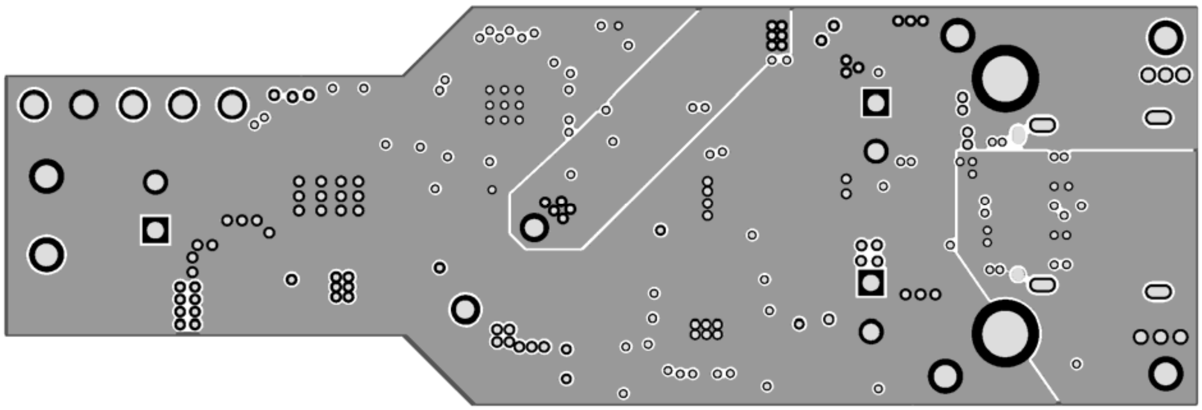


Figure 11 – Layout Bottom Layer

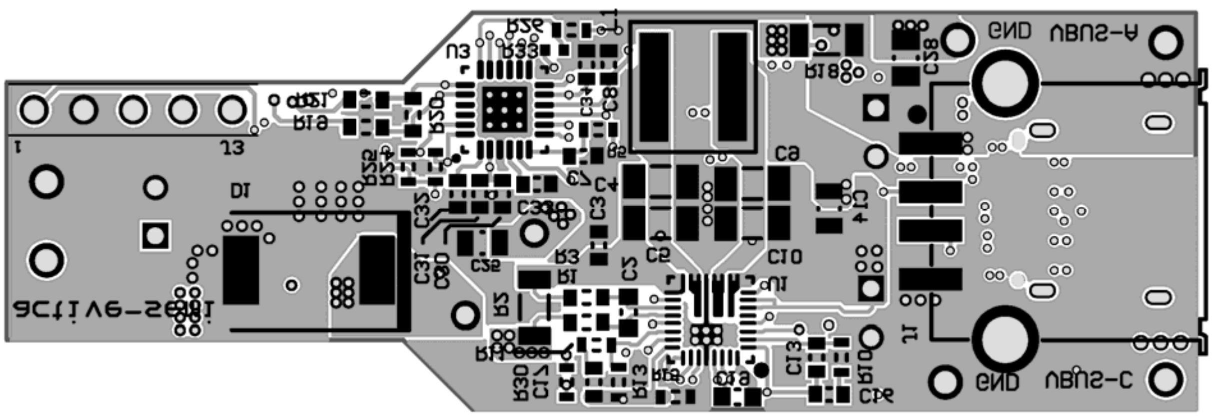


Figure 12 – Layout Bottom Assembly

Bill of Materials

Table 2. BOM

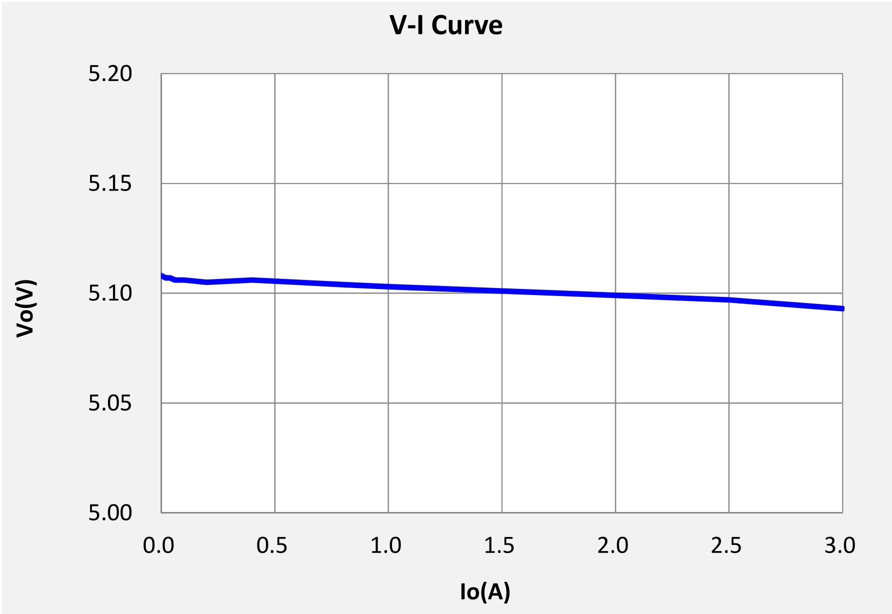
Item	Qty	Designator	Description	Package	Manufacture	Manufacture Part Number
1	2	C1, C6	Cap, Ceramic, 47nF, 25V, X5R, 10%	0603	Wurth	885012206069
2	5	C2, C3, C19, C31, C33	Cap, Ceramic, 0.1uF, 35V, X5R, 10%	0603	Wurth	885012206020
3	4	C4, C5, C9, C10	Cap, Ceramic, 22uF, 35V, 10%, X7R	1206	TDK	C3216X5R1V226M160AC
4	3	C8, C7, C34	Cap, Ceramic, 390pF, 6.3V, X5R, 10%	0603	Standard	std
5	1	C11	Cap, Aluminum, 220uF, 25V, 20%, WCAP-ATG8	6.3mm x 12.5mm	Wurth	860010473011
6	0	C12	Cap, Aluminum, 100uF, Aluminum, 25V, 20%, WCAP-ASLI	6.3mm x 5.5mm	Wurth	865080445010
7	3	C13, C22, 29	Cap, Ceramic, 2.2nF, 25V, X5R, 10%	0603	Wurth	885012206061
8	2	C14, C28	Cap, Ceramic, 10uF, 25V, X5R, 10%	0805	Standard	std
9	4	C15, C20, C30, C32	Cap, Ceramic, 1uF, 25V, X5R, 10%	0603	Wurth	885012206026
10	2	C16, C21	Cap, Ceramic, 22nF, 25V, X5R, 10%	0603	Wurth	885012206067
11	0	C17	Cap, Ceramic, -uF, 25V, X5R, 10%	0603	Standard	std
12	0	C18	Cap, Ceramic, -uF, 25V, X5R, 10%	0603	Standard	std
13	1	C23	Cap, Aluminum, 100uF, 25V, 20%, WCAP-ATG8	6.3mm x 12.5mm	Wurth	860010473007
14	1	C24	Cap, Aluminum, 220uF, 16V, 20%, WCAP-ATG8	6.3mm x 12.5mm	Wurth	860010373010
15	1	C25	Cap, Ceramic, 22uF, 16V, X5R, 20%	0805	Standard	Standard
16	1	C26	Cap, Ceramic, 2.2uF, 25V, X5R, 10%	0805	Wurth	885012207079
17	1	C27	Cap, Ceramic, 10uF, 35V, X5R, 10%	1206	Standard	Standard
18	1	D1	Diode, Schottky, 40V, 5A	SMC	Vishay	SSC54
19	1	FS1	Fuse, 32V, 7A	1206	Standard	std
20	1	J1	Con, Recept, USB-C, 24POS, Surface Mount	na	Amphenol	12401598E4#2A
21	1	J2	Con, Recept, USB-A, Surface Mount	na	Wurth	62900416021
22	1	J3	Header, Unshrouded , 2.54, Male, 5P	na	Wurth	6130511121
23	1	L1	Inductor, 10uH, 5A, 26.5mohm	6mmx6mmx6mm	Wurth	74439346100
24	1	L2	Inductor, Toroid, 30uH, 4.5A, 32mohm	13.2mm x 6.5mm	E & E Magnetic Products	831-03915F
25	2	R1, R3	Res, 30.1ohm, 1%	0603	Standard	Standard
26	2	R2,R16	Res, 5mohm, 1%	1206	SART	
27	1	R4	Res, 196kohm, 1%	0603	Standard	Standard
28	1	R5	Res, 1kohm, 1%	0603	Standard	Standard
29	0	R6, R7, R8, R28, R29, R31, R32, R35	Res, -kohm, 1%	0402	Standard	Standard
30	1	R9	Res, 130kohm, 1%	0603	Standard	Standard

31	2	R10, R14	Res, 20.0kohm, 1%	0603	Standard	Standard
32	0	R11, R12, R19, R21	Res, -kohm, 1%	0603	Standard	Standard
33	1	R13	Res, 36.1kohm, 1%	0603	Standard	Standard
34	5	R15, R17, R20, R23, R27	Res, 0ohm, 1%	0603	Standard	Standard
35	1	R18	Res, 20mohm, 1%	1206	SART	Standard
36	1	R22	Res, 5.1ohm, 5%	0603	Standard	Standard
37	4	R24, R25, R26, R30	Res, 10.0kohm, 1%	0603	Standard	Standard
38	2	R33, R34	Res, 0ohm, 1%	0402	Standard	Standard
39	3	TP1, TP4, TP5	TEST POINT PC MINI .040"D RED	na	5000	Keystone
40	3	TP2, TP3, TP6	TEST POINT PC MINI .040"D BLK	na	5001	Keystone
41	1	U1	IC, ACT5101, Integrated Buck-Boost	QFN32-4x4	active-semi	ACT5101QI102
42	1	U2	IC, ACT4527, 40V, 3A, Buck	SOP-8EP	active-semi	ACT4527YH
43	1	U3	IC, CCG3PA, USB-C Con-troller with Power Delivery	QFN24-4X4	Cypress	CYPD3175-24LQXQ
44	1	-	Firmware, Cypress	na	Cypress	CCG3PA_USB-C-PPS-39W_Dual_PortCar Charger_Reference_De-sign_Rev0
45	1	-	PCB, ACT5101-101-REF01, Rev B	n/a	Standard	PCB-0311-02

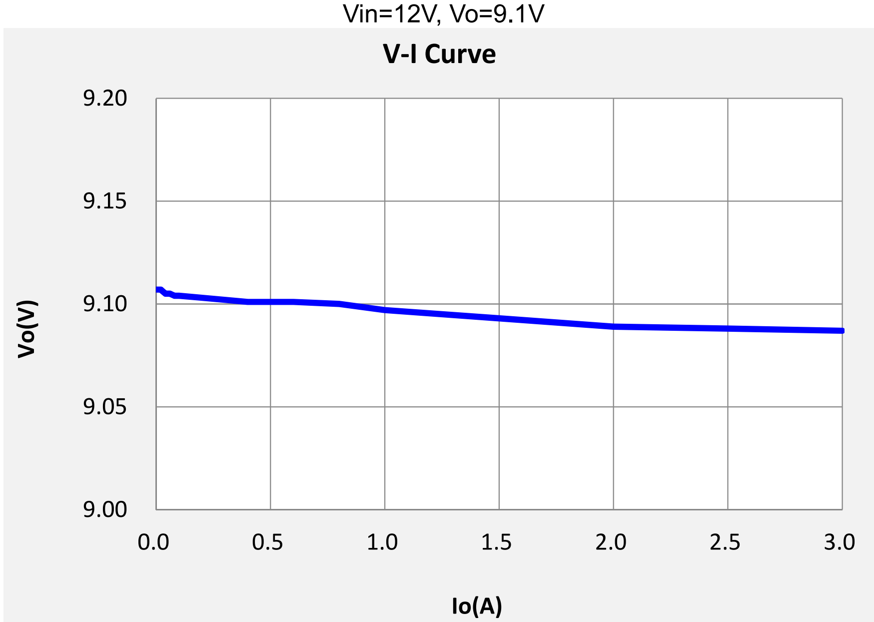
Test Results

Output Regulation (on PCB board)

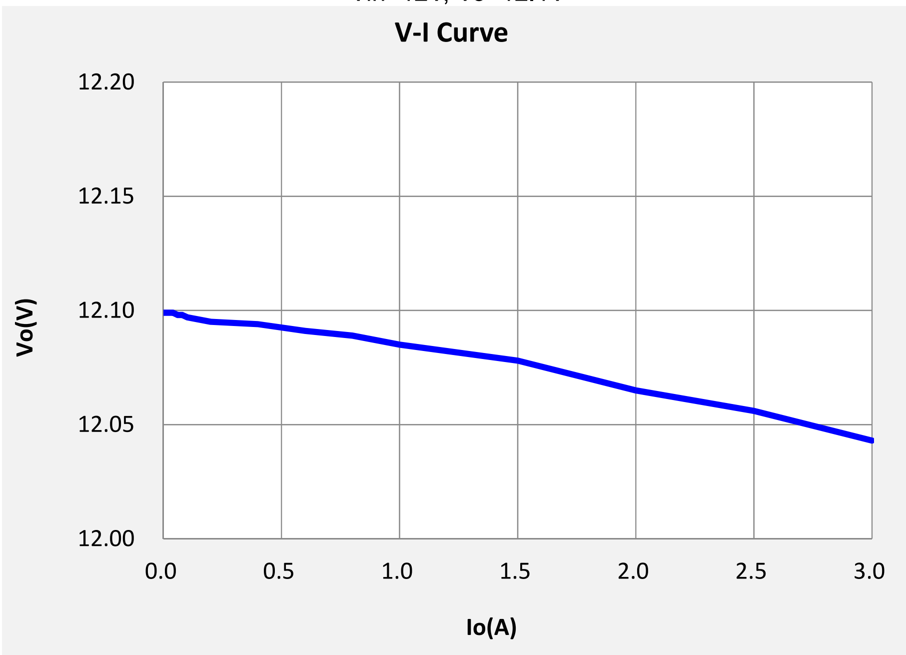
Vin=12V, Vo=5.1V



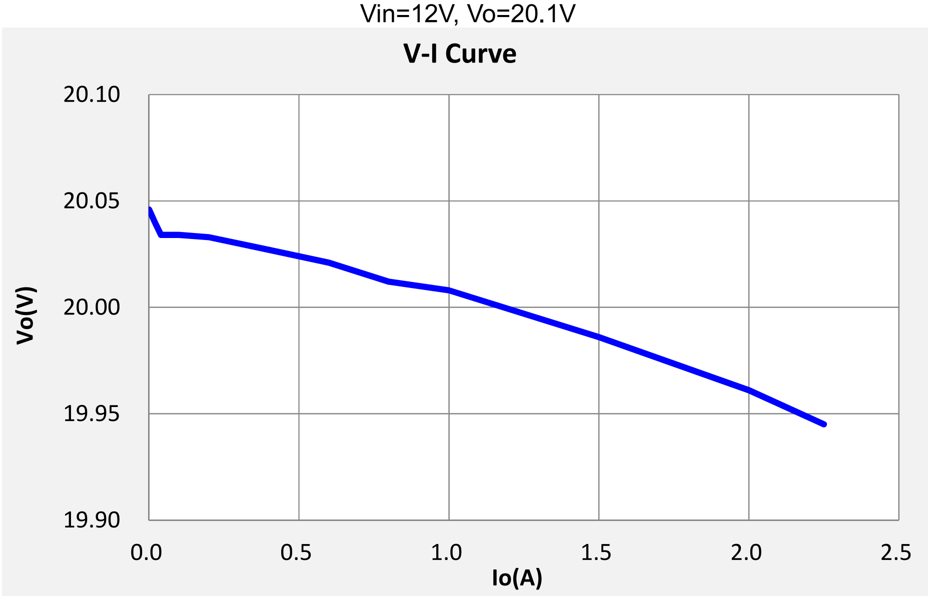
Vin=12V, Vo=9.1V



Vin=12V, Vo=12.1V



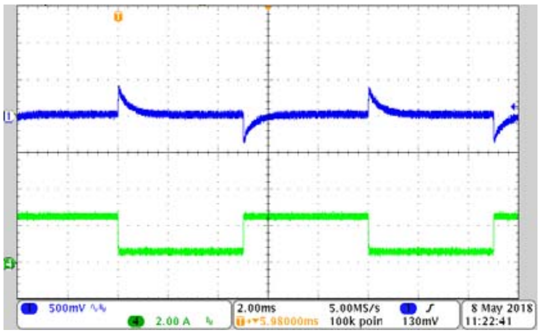
Vin=12V, Vo=20.1V



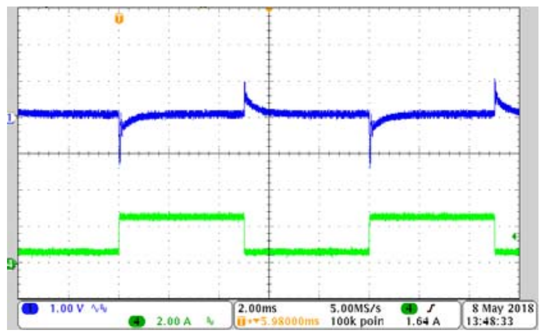
Load transient

Test condition: Vin=12V, Io=0.5A-2.5A-0.5A
CH1: Vo (ac)   CH4: Io

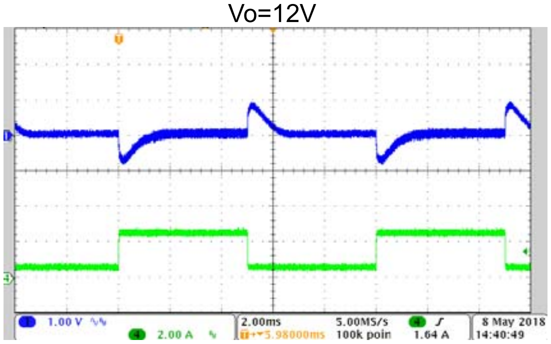
Vo=5.1V



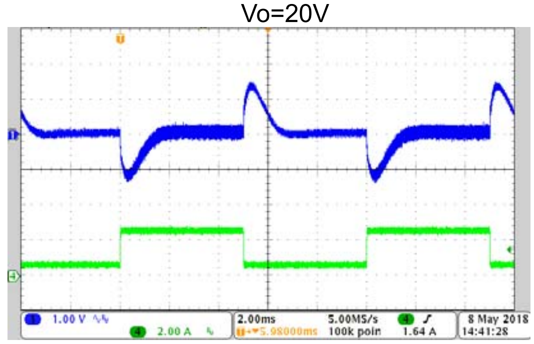
Vo=9.1V



Vo=12V



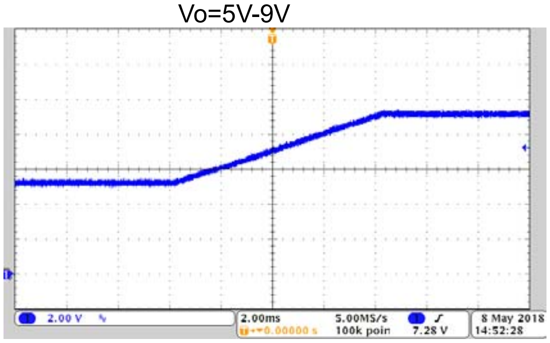
Vo=20V



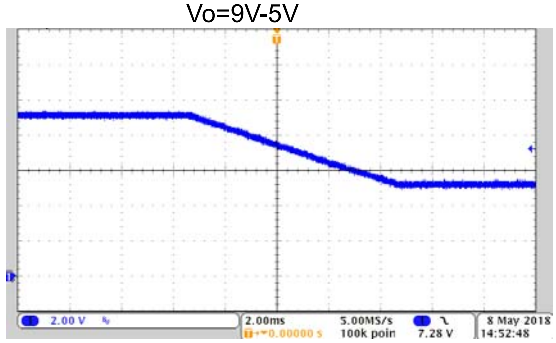
Vo Dynamic Voltage Scaling

Test condition: Vin=12V, Io=2A

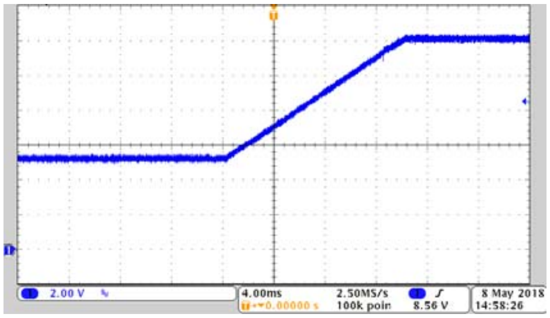
Vo=5V-9V



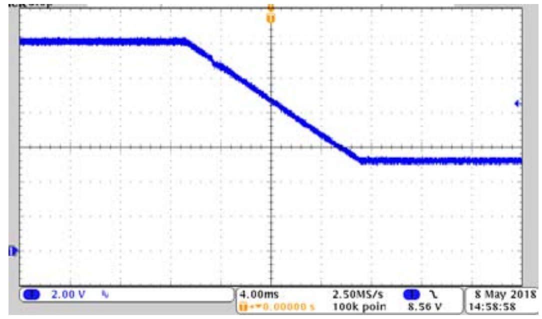
Vo=9V-5V



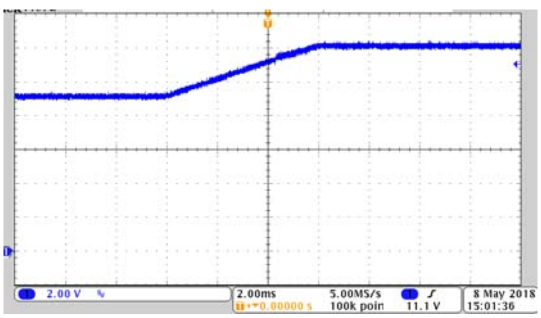
Vo=5V-12V



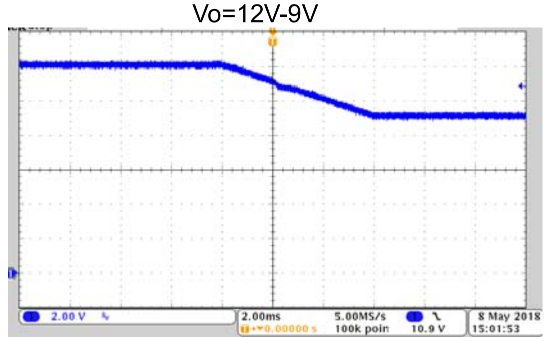
Vo=12V-5V



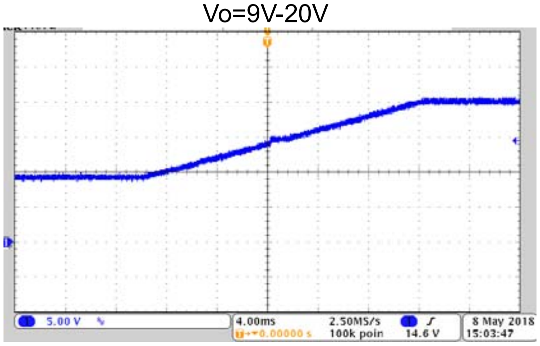
Vo=9V-12V



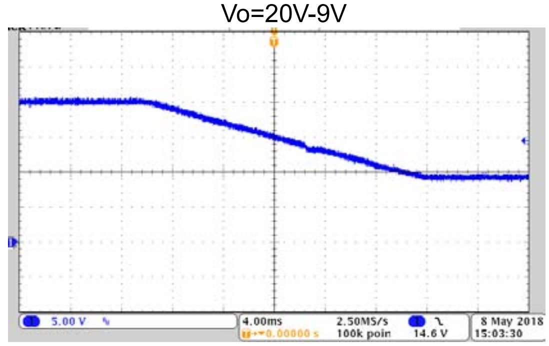
Vo=12V-9V



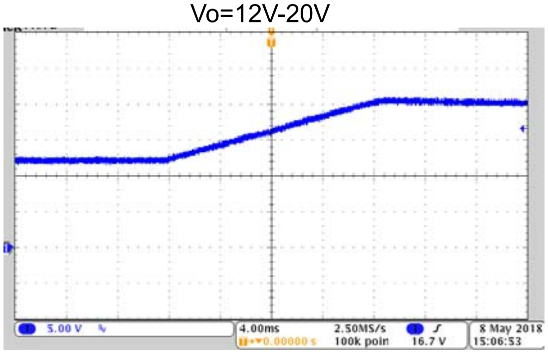
Vo=9V-20V



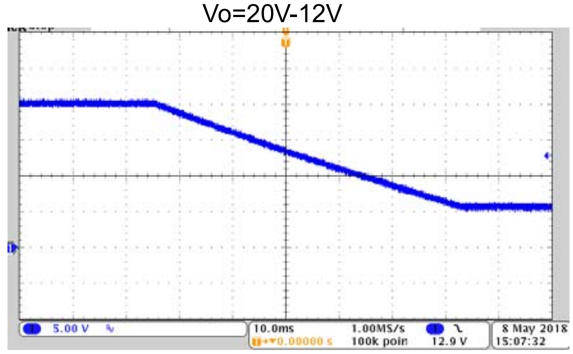
Vo=20V-9V



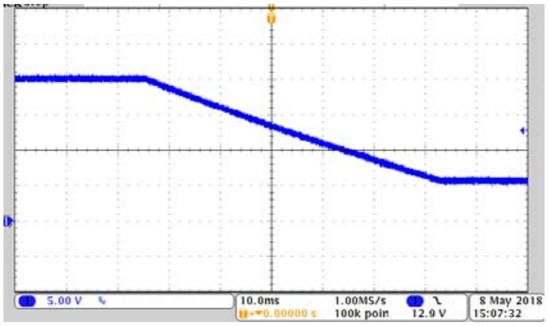
Vo=12V-20V



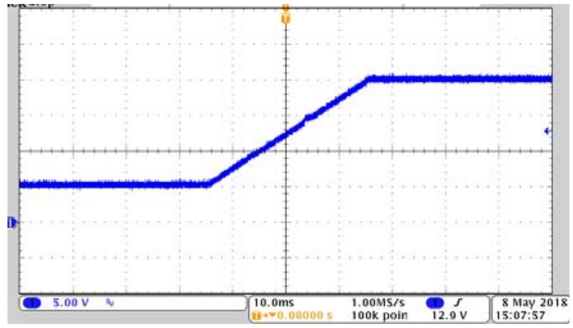
Vo=20V-12V



Vo=5V-20V



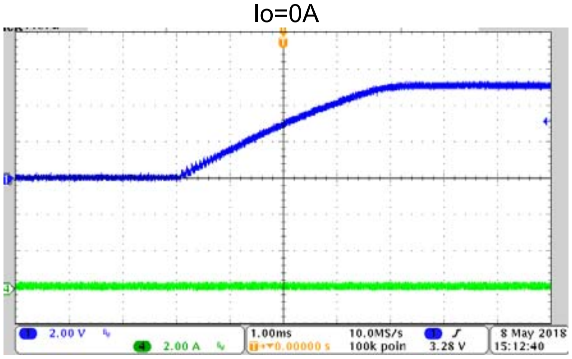
Vo=20V-5V



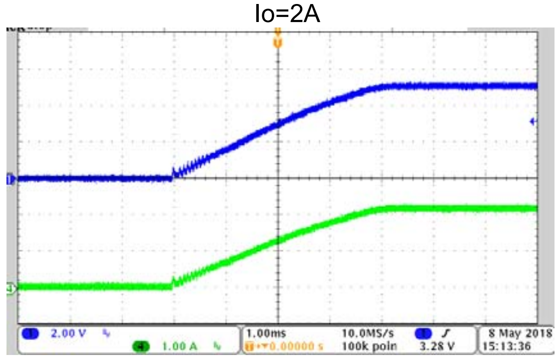
Start up waveform

Test condition: Vin=12V, power up by Vin
CH1:Vo CH4:Io

Io=0A



Io=2A

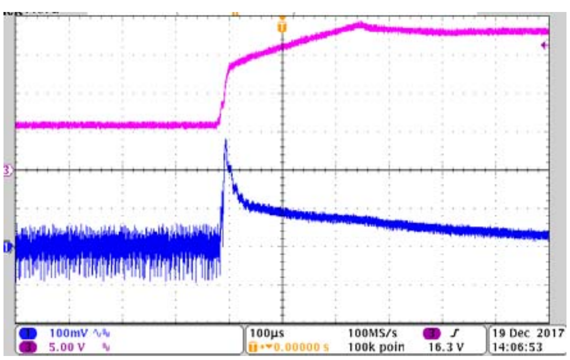


Line Transient

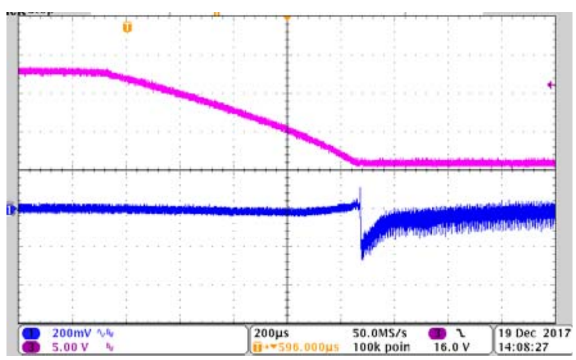
Test condition: Vin=18V-6V-18V, Io=2A

CH1:Vo(ac) CH3:Vin

Vin=6V-18V



Vin=18V-6V

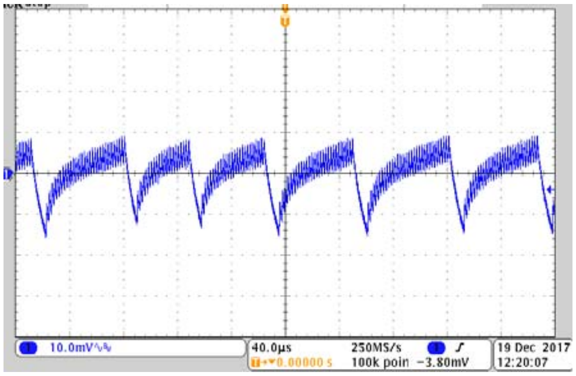


Output Voltage Ripple

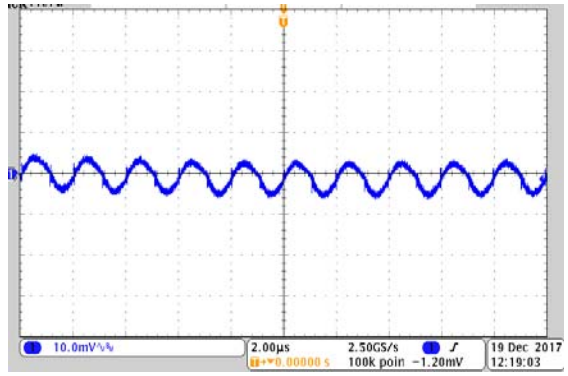
Test Condition: Vin =12V
CH1:Vo(ac)

Vo=5.1V

Io=80mA

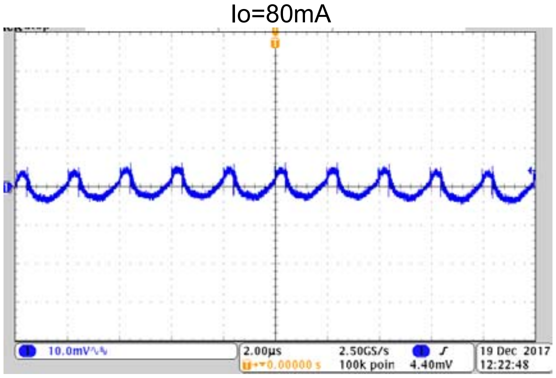


Io=3A

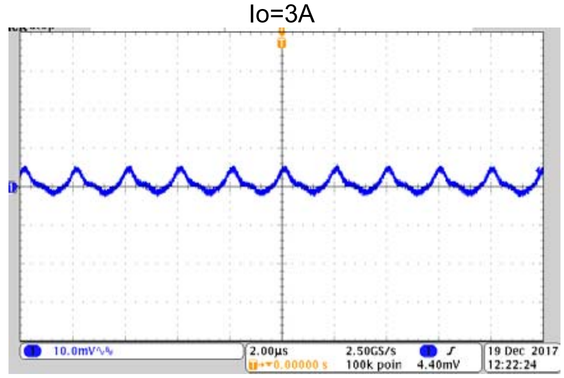


Vo=9.1V

Io=80mA

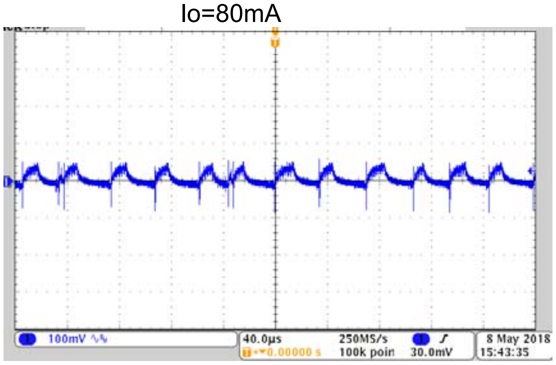


Io=3A

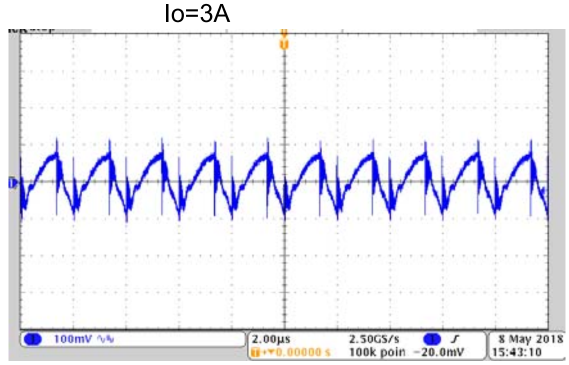


Vo=12.1V

Io=80mA

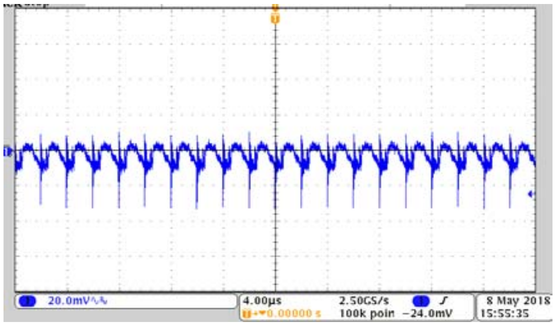


Io=3A

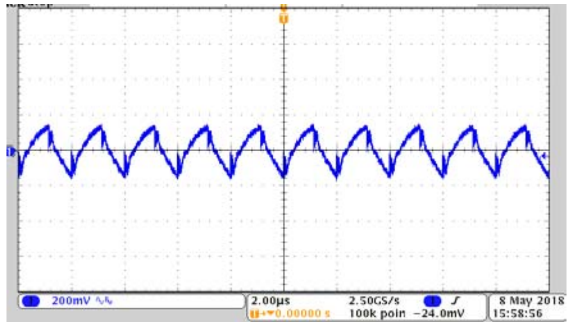


Vo=20.1V

Io=80mA



Io=2.25A



Efficiency

Test Condition: Vin =12V