Table of Contents

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Chapter 1. Introduction

The growing popularity of standard USB PD3.1 chargers for mobile phones and notebook PCs spurs the demand for leveraging standard PD3.1 chargers to replace purposely and individually built chargers for battery-power electronic devices, reducing E-Waste.

The AP33771C Evaluation Board (EVB) is intended to be used as an evaluation vehicle for charging applications between a Type-C Connector-equipped Device (**TCD**, Energy Sink) and a Type-C Connector-equipped PD Charger or Adaptor (**PDC**, Energy Source) through a Type-C to Type-C cable.

Figure 1 illustrates a TCD embedded with a PD3.1 sink controller IC (i.e. AP33771C). This is physically connected to a PDC, embedded with a USB PD3.1 source controller (e.g. AP43771) through a suitable Type-C to Type-C cable. Based on the USB PD3.1 compliance protocol, the AP33771C may go through the USB PD3.1 standard negotiation process with the AP43771, and then the TCD will retrieve power from the PDC.

USB PDC

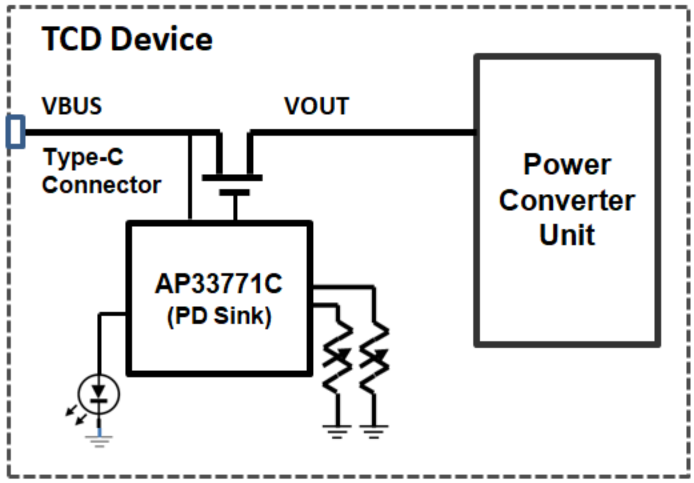

Figure 1 – A typical TCD with the AP33771C PD3.1 Sink Controller requesting power from a USB PDC

To improve the AP33771C's user experience as a USB sink controller in TCDs, the AP33771C has built-in firmware to deal with automatic cable voltage drop compensation, as well as legacy Type-A charging through a Type-A to Type-C cable.

The AP33771C's Evaluation Board (EVB) User Guide explains a simple resistor-setting arrangement to request desired input voltage and current for a typical TCD. The grant voltage and current back from a PDC, for a successful match with source capability, can cover the power request.

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Chapter 2. AP33771C Sink Controller

2.1 Package Pinout

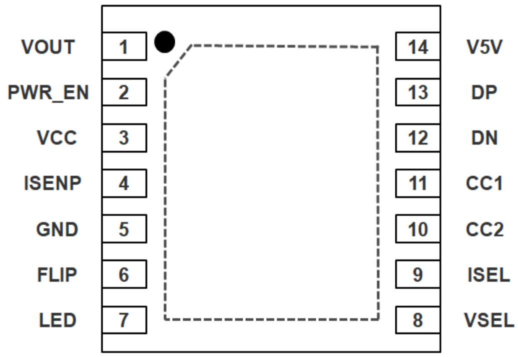

Figure 2 – Package Pinout

2.2 Pin Descriptions

Pin No.	Pin Name	**Type** (Notes)	Pin Function
1	**VOUT**	**AHV**	Terminal for VOUT monitoring.
2	**PWR_EN**	**AHV**	To control external VOUT. Connected to external NMOS switch, ON (High) or OFF (Low).
3	**VCC**	**AHV**	The power supply of the AP33771C. A 1µF cap is required to connect this pin to GND pin.
4	**ISENP**	**AHV**	Current sense positive node.
5	**GND**	**GND**	Ground
6	**FLIP**	**DO**	Flip indicator of Type-C plug. Is low if CC is connected to CC1 and high if connected to CC2.
7	**LED**	**DO**	LED indicator of the system status
8	**VSEL**	**AI**	Voltage selection pin, connect resistance to ground to set Voltage.
9	**ISEL**	**AI**	Current selection pin, connect resistance to ground to set Current.
10	**CC2**	**AIO**	Type-C configuration channel 2
11	**CC1**	**AIO**	Type-C configuration channel 1
12	**DN**	**AIO**	USB 2.0 data negative node
13	**DP**	**AIO**	USB 2.0 data positive node
14	**V5V**	**AP**	5V LDO output if VCC is on. A 1µF cap is required to connect this pin to GND.
-	**EPAD**	**GND**	Exposed pad is suggested to connect to Ground

Table 1 – Pin Descriptions of the AP33771C PD Sink Controller

Notes:
AHV – Analog High-Voltage pin
AP – Power for Analog Circuit and Analog Input/Output pins, 5.0V operation
AI – Analog Input pin
AIO – Analog Input/Output pin; DP/DN & CC1/CC2 are 3.3V operation
DO – Digital Output pin; all are 5.0V operation.

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Chapter 3. AP33771C EVB Descriptions

3.1 EVB Schematics

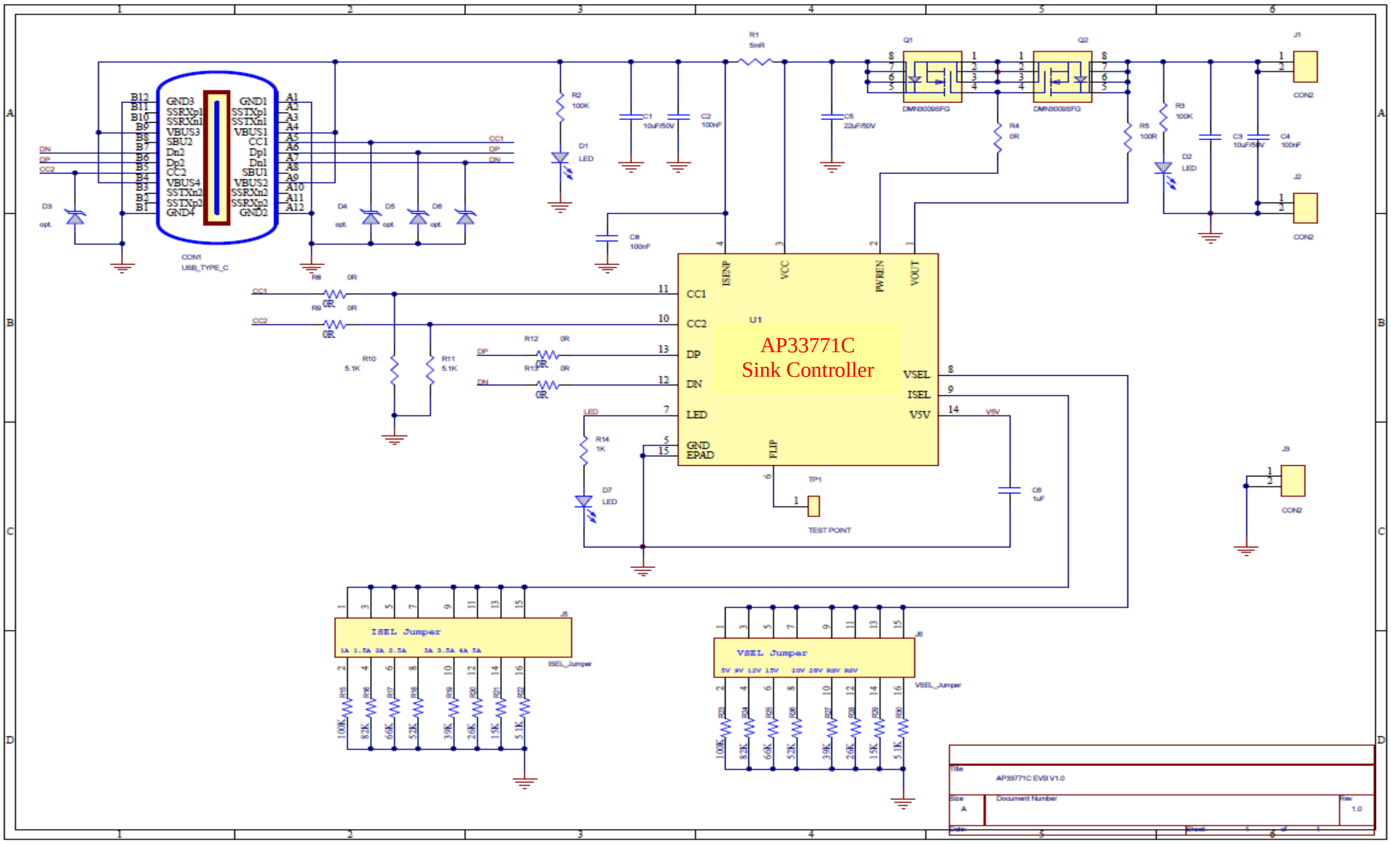

Figure 3 – Schematics of the AP33771C Evaluation Board

The AP33771C, a USB Type-C PD sink controller, is used to request power from an attached USB PD source adaptor through simple external resistor settings. The schematic of the AP33771C EVB is shown in Figure 3.

The voltage and current requests are expressed by appropriate resistors connected to the VSEL and ISEL pins, respectively. After initializing power-on, the AP33771C automatically evaluates all PDOs from the PD source capability and finds the matched PDO according to its internal matching criteria. If some of the PDO is matched, the MOS switch is turned on to connect VBUS to VOUT.

The AP33771C supports dead-battery functionality and can be woken up as soon as an active PD adaptor is plugged in the TCD Type-C receptacle. After the power link is set up between the source and sink, OVP, UVP, and OCP protections are enabled to monitor the power-charging status. In addition, moisture detection between DP and DN is implemented during the cable insertion. In case power protection is triggered, the AP33771C shuts down the VOUT enable NMOS switch and discharges the VOUT voltage. Meanwhile, the AP33771C provides an LED indication for the system's operating status and supports FLIP indication of the Type-C attachment.

3.2 EVB TOP View

The AP33771C EVB is illustrated in Figure 4 using 50mm x 25mm dimensions, with key portions listed below:

- VOUT connection
- Voltage and current selection
- LED indications for system status
- CC flip indication pin
- LED indication of VBUS and VOUT

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

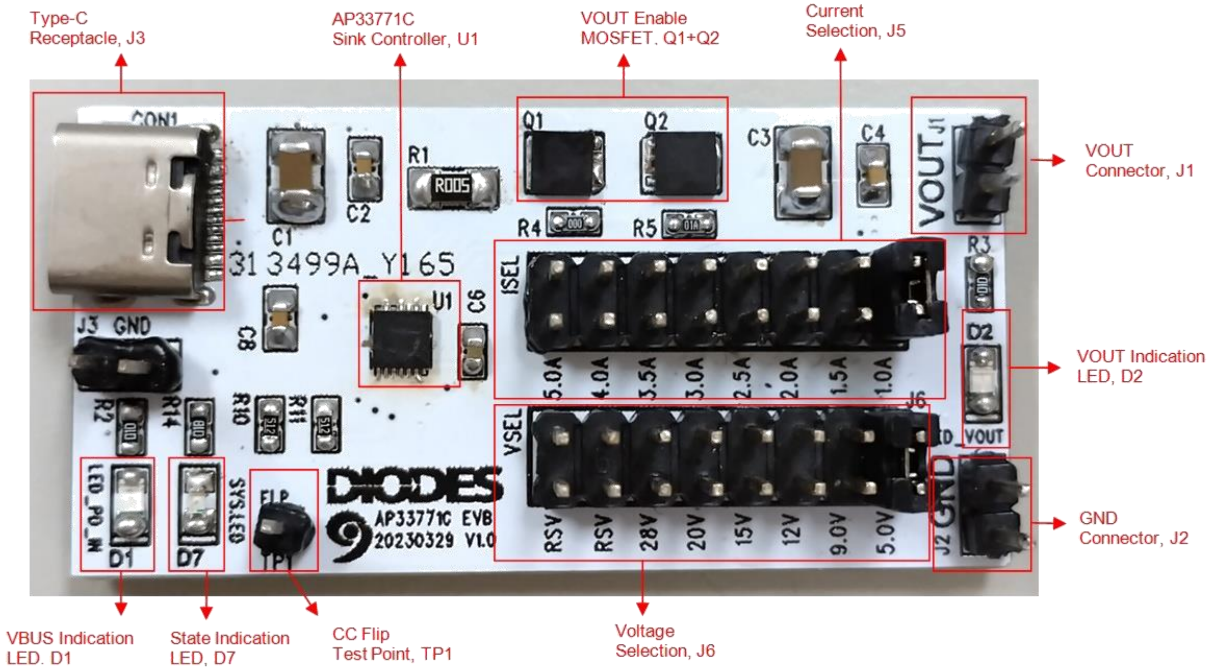

Figure 4 – AP33771C Evaluation Board top view and its key portions

3.3 EVB Quick Setup

Steps for quick setup are shown in Figure 6.

Step 1: Connect resistor-setting jumpers (J6); for example, setting up 20V2A
Step 2: Connect J1/J2 to a load
Step 3: Connect the Type-C connector to a USB PD adaptor (PDC), and power on EVB with the USB PD adaptor (D2/D7 will be illuminated)

The AP33771C Evaluation Board will output the requested voltage and current on the load after the above steps.

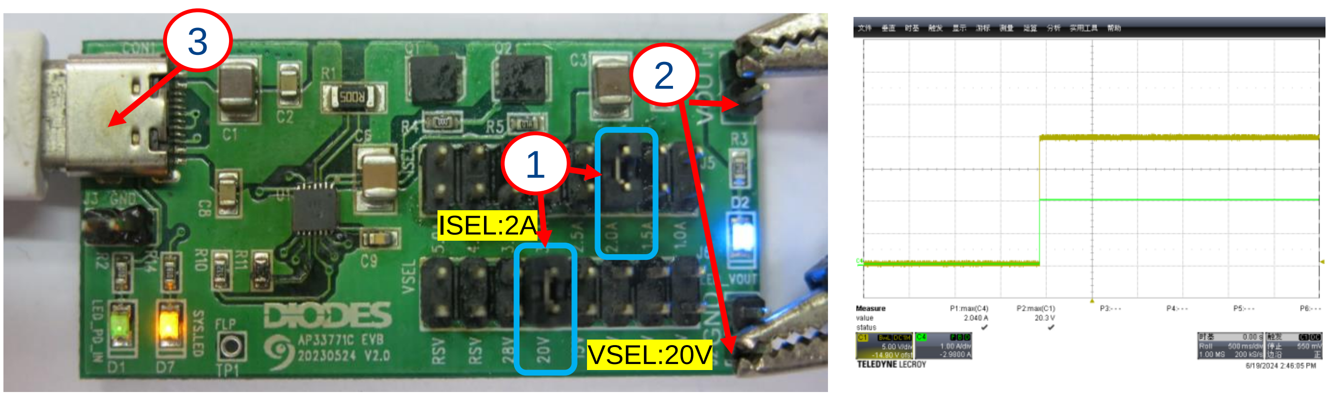

Figure 5 – AP33771C EVB setup sequence

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

3.4 EVB Function Description

Jumper Locations

The AP33771C EVB provides users a simple resistor-setting through jumpers, which enable USB PD negotiation between the TCD device and an external PDC. If the negotiation is successful, the PDC delivers the requested voltage and current to the TCD device through VBUS in the Type-C cable. If negotiation is not successful, the PDC goes back to 5V PDO. During the evaluation, VOUT can be connected to a load to check the current negotiation result. The jumpers on the EVB are listed in Table 2 below.

Location	Function
J1	VOUT Connector for External Load
J5	Voltage Selection Jump
J6	Current Selection Jump

Table 2 – Jumpers and functions of the Evaluation Board

Voltage and Current Selections

VSEL and ISEL settings determine the selected voltage and current to negotiate with the power source. The mapping between the VSEL/ISEL's amplitudes and resistance values are illustrated in Table 3 below, where it is suggested to use the resistors with 1% accuracy.

Index	1	2	3	4	5	6	7	8
VSEL	5V	9V	12V	15V	20V	28V	Reserved	Reserved
ISEL	1A	1.5A	2A	2.5A	3A	3.5A	4A	5A
Resistance (KΩ, 1%)	100	82	66	52	39	26	15	5.1

Table 3 – Voltage selection and current selection versus J5 and J6 connector settings

During the AP33771C's voltage selection process, the Extended Power Range (EPR) has priority over the Standard Power Range (SPR). The Adjustable Voltage Supply (AVS) and Programmable Power Supply (PPS) PDOs also have priority over Fixed PDOs. This reminds system designers that if the current requirement is greater than 3A, a suitable e-Marker cable with over 3A current rating is necessary.

LED for System State Indication

The AP33771C's LED pin is used to reflect the system's states. Below, Table 4 summarizes the LED indications and VOUT ON/OFF for each corresponding state.

State	LED Indication	VOUT	Comments
INIT	NA	OFF	During VBUS/Rd attachment and AP33771C initialization
CHARGING	4-sec Breathing	ON	Successful negotiation or entering Non-PD Mode; charging start
MISMATCH	Full Light	OFF	Voltage or current mismatch
MOISTURE	2-sec Flicker	OFF	DP/DN abnormal impedance detected
FAULT	0.6-sec Flicker	OFF	OVP, OCP, or UVP occurrence

Table 4 – LED Indications of System States

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

CC Flip Test Point

The AP33771C uses the FLIP pin for CC flip indication, as shown in Table 5 below. If the CC is not flipped, the FLIP pin output is low. If the CC is flipped, the FLIP pin output is high.

CC Flip Indication		
CC Detection	CC1 Detected	CC2 Detected
FLIP Output	0 (Low)	1 (High)

Table 5 – CC Flip Indication

LEDs for VBUS and VOUT Indications

The AP33771C uses LEDs, D1 and D7, for VBUS and VOUT state indications respectively.

D1's on or off status indicates whether the USB PDC power is delivered to VBUS. D7's on or off status indicates if the VBUS power is switched to VOUT for load consumption.

3.5 EVB System BOM

The BOM list of the EVB schematic is shown in Table 6 below.

Item	Quantity	Reference	Part
1	1	C1	10µ/50V
2	1	C2	0.1µ/50V
3	1	C3	10µ/50V
4	1	C4	0.1µ/50V
5	1	C5	22µ/50V
6	1	C6	1µ/50V
7	1	C8	0.1µ/50V
8	3	D1, D2, D7	LED
9	2	Q1, Q2	DMN3009SFG
10	2	R10, R11	5.1K
11	5	R4,R8,R9, R12, R13	0R
12	1	R5	100R
13	1	R14	1K
14	2	R2, R3	100K
15	1	R1	5mR/1206
16	16	R15 ~R30	1% accuracy; selection for power capability
17	1	CON1	USB Type-C receptacle
18	1	U1	AP33771C-DFN14
19	3	J1~J3	VOUT and GND
20	1	TP1	CC flip output pin
21	4	D3~D6	Zener diode (optional)

Table 6 – BOM list of the AP33771C EVB's schematics

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Chapter 4. USB PD Source-to-Sink Application Examples

Figure 6 and usage cases 1-6 show the different scenarios and procedures of the TCD's power profile request from a PDC power source.

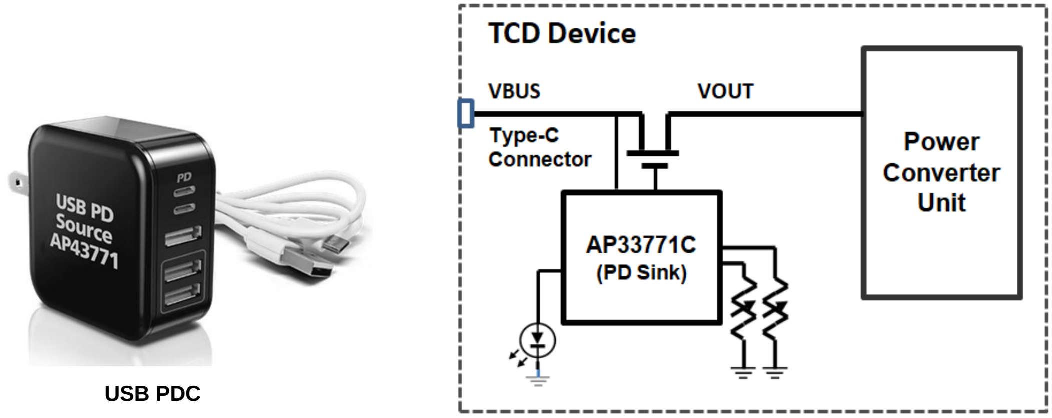

Figure 6 – The application scenarios are based on a typical TCD device requesting power profile from a USB PDC

Case 1:	**PDC=45W**		**TCD = 28V and 1.5A**
	PDO:	**APDO:**	
	5V/3A	**3.3V~21V/1A**	**VSEL= 28V RVSEL= 26KΩ VBUS = 28V**
	9V/3A	**15V~28V/45W**	**ISEL=1.5A RISEL= 82KΩ VOUT = 28V**
	12V/2.5A		
	15V/2A		
	20V/1.5A		
	28V/1.5A		

A TCD requests 28V and 1.5A from a given 45W PDC source with fixed PDOs: 5V/3A, 9V/3A, 12V/2.5A, 15V/2A, 20V/1.5A, 28V/1.5A, 3.3V~21V/1A, 15V~28V/45W.

Step 1: set VSEL to "26KΩ" to get 28V, set ISEL to "82KΩ" to get 1.5A.
Step 2: AP33771C starts to handshake with the powered PDC as soon as a Type-C cable is connected.
Step 3: according to Matching Mechanism, APDO 15V~28V/45W can match ISEL.
Step 4: VOUT = 28V, because VSEL and ISEL are all matched, then the MOS switches are enabled.

Case 2:	**PDC=56W**		**TCD = 28V and 2A**
	PDO:	**APDO:**	
	5V/3A	**3.3V~21V/1A**	**VSEL= 28V RVSEL= 26KΩ VBUS = 28V**
	9V/3A	**15V~28V/45W**	**ISEL= 2A RISEL= 66KΩ VOUT = 28V**
	12V/2.5A		
	15V/2A		
	20V/1.5A		
	28V/2A		

TCD requests 28V and 2A from a given 56W PDC source with fixed PDOs: 5V/3A, 9V/3A, 12V/2.5A, 15V/2A, 20V/1.5A, 28V/2A, 3.3V~21V/1A, 15V~28V/45W.

Step 1: set VSEL to "26KΩ" to get 28V, set ISEL to "66KΩ" to get 2A.
Step 2: AP33771C starts to handshake with the powered PDC as soon as a Type-C cable is connected.
Step 3: according to Matching Mechanism, APDO can't match ISEL, search Fixed PDOs.
Step 4: VOUT = 28V, because VSEL and ISEL are all matched, then the MOS switches are enabled.

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Case 3:	PDC=45W		TCD = 28V and 2A
	PDO:	APDO:	
	5V/3A	3.3V~21V/1A	VSEL= 28V R_{VSEL}= 26KΩ VBUS = 15V
	9V/3A	15V~28V/45W	ISEL= 2A R_{ISEL}= 66KΩ VOUT = 15V
	12V/2.5A		
	15V/2A		
	20V/1.5A		
	28V/1.5A		

TCD requests 28V and 2A from a given 45W PDC source with fixed PDOs: 5V/3A, 9V/3A, 12V/2.5A, 15V/2A, 20V/1.5A, 28V/1.5A, 3.3V~21V/1A, 15V~28V/45W.

Step 1: set VSEL to “26KΩ” to get 28V, set ISEL to “66KΩ” to get 2A.
Step 2: AP33771C starts to handshake with the powered PDC as soon as a Type-C cable is connected.
Step 3: according to Matching Mechanism, 28V can’t match ISEL, search for PDOs below 28V.
Step 4: VOUT = 15V, because 15V/2A can match ISEL request, then the MOS switches are enabled.

Case 4:	PDC=45W		TCD = 28V and 2.5A
	PDO:	APDO:	
	5V/3A	3.3V~21V/1A	VSEL= 28V R_{VSEL}= 26KΩ VBUS = 12V
	9V/3A	15V~28V/45W	ISEL= 2.5A R_{ISEL}= 52KΩ VOUT = 12V
	12V/2.5A		
	15V/2A		
	20V/1.5A		
	28V/1.5A		

TCD requests 28V and 2.5A from a given 45W PDC source with fixed PDOs: 5V/3A, 9V/3A, 12V/2.5A, 15V/2A, 20V/1.5A, 28V/1.5A, 3.3V~21V/1A, 15V~28V/45W.

Step 1: set VSEL to “26KΩ” to get 28V, set ISEL to “52KΩ” to get 2.5A.
Step 2: AP33771C starts to handshake with the powered PDC as soon as a Type-C cable is connected.
Step 3: according to Matching Mechanism, 28V can’t match ISEL, search for PDOs below 28V.
Step 4: VOUT = 12V, because 12V/2.5A can match ISEL request, then the MOS switches are enabled.

Case 5:	PDC=45W		TCD = 28V and 3A
	PDO:	APDO:	
	5V/3A	3.3V~21V/1A	VSEL= 28V RVSEL= 26KΩ VBUS = 9V
	9V/3A	15V~28V/45W	ISEL= 3A RISEL= 39KΩ VOUT = 9V
	12V/2.5A		
	15V/2A		
	20V/1.5A		
	28V/1.5A		

TCD requests 28V and 3A from a given 45W PDC source with fixed PDOs: 5V/3A, 9V/3A, 12V/2.5A, 15V/2A, 20V/1.5A, 28V/1.5A, 3.3V~21V/1A, 15V~28V/45W.

Step 1: set VSEL to “26KΩ” to get 28V, set ISEL to “39KΩ” to get 3A.
Step 2: AP33771C starts to handshake with the powered PDC as soon as a Type-C cable is connected.
Step 3: according to Matching Mechanism, 28V can’t match ISEL, search for PDOs below 28V.
Step 4: VOUT = 9V, because 9V/3A can match ISEL request, then the MOS switches are enabled.

Case 6:	PDC=45W		TCD = 28V and 3.5A
	PDO:	APDO:	
	5V/3A	3.3V~21V/1A	VSEL= 28V RVSEL= 26KΩ VBUS = 5V
	9V/3A	15V~28V/45W	ISEL= 3.5A RISEL= 26KΩ VOUT = 0V
	12V/2.5A		
	15V/2A		
	20V/1.5A		
	28V/1.5A		

TCD requests 28V and 3.5A from a given 45W PDC source with fixed PDOs: 5V/3A, 9V/3A, 12V/2.5A, 15V/2A, 20V/1.5A, 28V/1.5A, 3.3V~21V/1A, 15V~28V/45W.

Step 1: set VSEL to “26KΩ” to get 28V, set ISEL to “26KΩ” to get 3.5A.
Step 2: AP33771C starts to handshake with the powered PDC as soon as a Type-C cable is connected.
Step 3: according to Matching Mechanism, 28V can’t match ISEL, search for PDOs below 28V.
Step 4: VOUT = 0V, because all PDOs can’t match ISEL, then the MOS switches are disabled.

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Chapter 5. Compliance test

The AP33771C EVB passes all test items in Ellisys USB-PD Compliance tester, as shown in Figure 7 below.

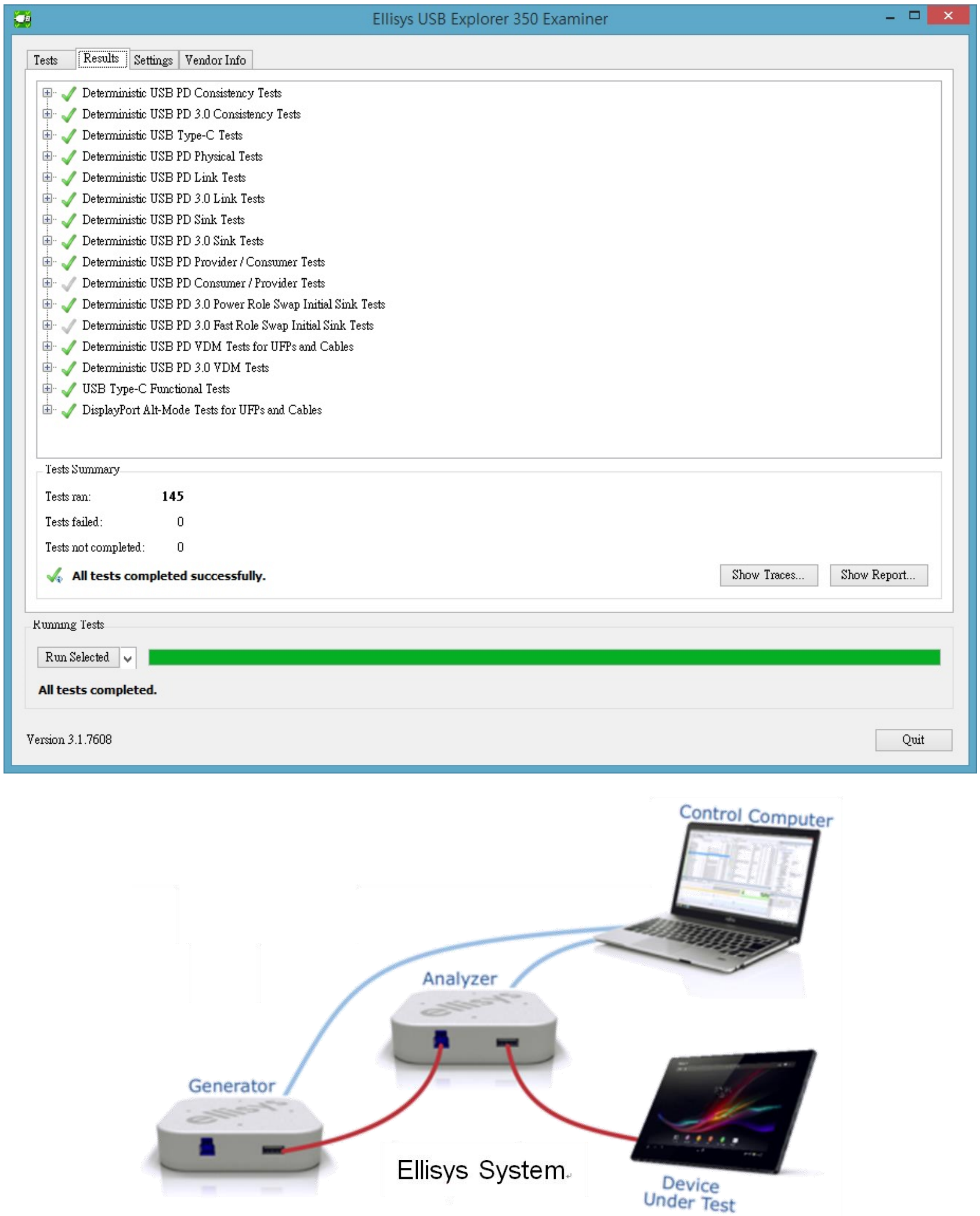

Figure 7 – Ellisys USB PD test environment and test item list

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

Chapter 6. Design Considerations

6.1 Termination of CC1/CC2 channels

Since the AP33771C has no internal Rd resistor embedded, the designer must place a 5.1K ohm resistor on both CC1 and CC2 to GND, as shown in Figure 8 below. A lack of any Rd will cause the AP33771C to misrecognize the direction of the CC, and will not enter into the PD negotiation process.

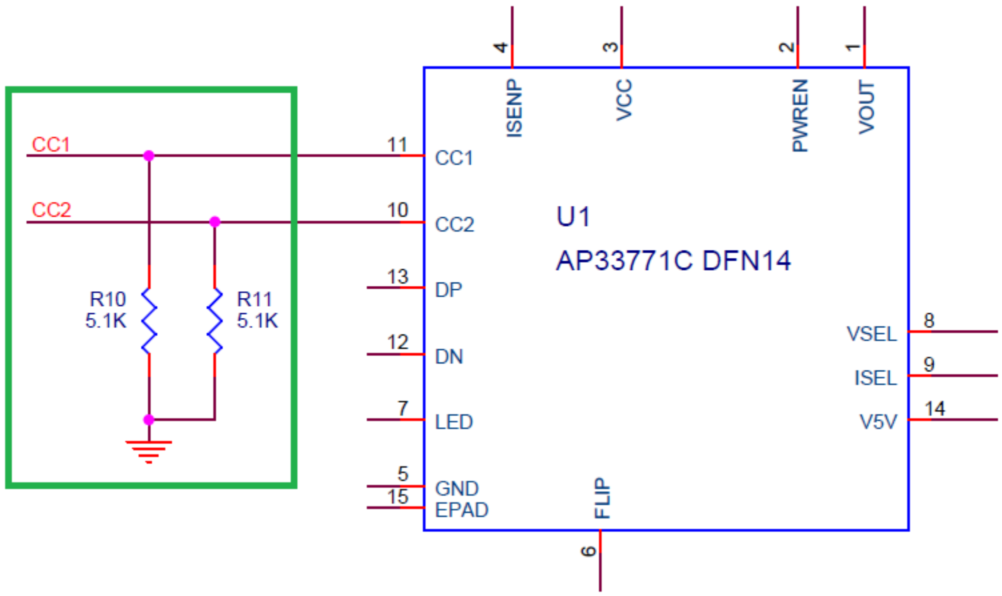

Figure 8 – Make sure the connection of external Rd resistors on CC1 and CC2

6.2 ESD Considerations

The AP33771C EVB is designed for functional evaluation without an ESD protection component on board. Do not use the AP33771C EVB to test ESD. For manufacturing, users must consider adding suitable ESD protection devices or optimize their PCB designs.

Chapter 7. Revision History

Revision	Issue Date	Comment
1.0	11/16/2023	Initial Release

© 2024 Copyright Diodes Incorporated. All Rights Reserved.

IMPORTANT NOTICE

1. DIODES INCORPORATED (Diodes) AND ITS SUBSIDIARIES MAKE NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARDS TO ANY INFORMATION CONTAINED IN THIS DOCUMENT, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION).

2. The Information contained herein is for informational purpose only and is provided only to illustrate the operation of Diodes' products described herein and application examples. Diodes does not assume any liability arising out of the application or use of this document or any product described herein. This document is intended for skilled and technically trained engineering customers and users who design with Diodes' products. Diodes' products may be used to facilitate safety-related applications; however, in all instances customers and users are responsible for (a) selecting the appropriate Diodes products for their applications, (b) evaluating the suitability of Diodes' products for their intended applications, (c) ensuring their applications, which incorporate Diodes' products, comply the applicable legal and regulatory requirements as well as safety and functional-safety related standards, and (d) ensuring they design with appropriate safeguards (including testing, validation, quality control techniques, redundancy, malfunction prevention, and appropriate treatment for aging degradation) to minimize the risks associated with their applications.

3. Diodes assumes no liability for any application-related information, support, assistance or feedback that may be provided by Diodes from time to time. Any customer or user of this document or products described herein will assume all risks and liabilities associated with such use, and will hold Diodes and all companies whose products are represented herein or on Diodes' websites, harmless against all damages and liabilities.

4. Products described herein may be covered by one or more United States, international or foreign patents and pending patent applications. Product names and markings noted herein may also be covered by one or more United States, international or foreign trademarks and trademark applications. Diodes does not convey any license under any of its intellectual property rights or the rights of any third parties (including third parties whose products and services may be described in this document or on Diodes' website) under this document.

5. Diodes' products are provided subject to Diodes' Standard Terms and Conditions of Sale (https://www.diodes.com/about/company/terms-and-conditions/terms-and-conditions-of-sales/) or other applicable terms. This document does not alter or expand the applicable warranties provided by Diodes. Diodes does not warrant or accept any liability whatsoever in respect of any products purchased through unauthorized sales channel.

6. Diodes' products and technology may not be used for or incorporated into any products or systems whose manufacture, use or sale is prohibited under any applicable laws and regulations. Should customers or users use Diodes' products in contravention of any applicable laws or regulations, or for any unintended or unauthorized application, customers and users will (a) be solely responsible for any damages, losses or penalties arising in connection therewith or as a result thereof, and (b) indemnify and hold Diodes and its representatives and agents harmless against any and all claims, damages, expenses, and attorney fees arising out of, directly or indirectly, any claim relating to any noncompliance with the applicable laws and regulations, as well as any unintended or unauthorized application.

7. While efforts have been made to ensure the information contained in this document is accurate, complete and current, it may contain technical inaccuracies, omissions and typographical errors. Diodes does not warrant that information contained in this document is error-free and Diodes is under no obligation to update or otherwise correct this information. Notwithstanding the foregoing, Diodes reserves the right to make modifications, enhancements, improvements, corrections or other changes without further notice to this document and any product described herein. This document is written in English but may be translated into multiple languages for reference. Only the English version of this document is the final and determinative format released by Diodes.

8. Any unauthorized copying, modification, distribution, transmission, display or other use of this document (or any portion hereof) is prohibited. Diodes assumes no responsibility for any losses incurred by the customers or users or any third parties arising from any such unauthorized use.

9. This Notice may be periodically updated with the most recent version available at https://www.diodes.com/about/company/terms-and-conditions/important-notice

The Diodes logo is a registered trademark of Diodes Incorporated in the United States and other countries.
All other trademarks are the property of their respective owners.
© 2024 Diodes Incorporated. All Rights Reserved.

www.diodes.com

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Diodes Incorporated:

AP33771C-EVB