140 W HFB+PAG2S Solution Board (REF_140W_HFB_PAG2S) user guide

About this document

Scope and purpose

This document provides information about the 140 W USB PD reference board using a EZ-PD™ CYPAS213 for USB PD Extended Power Range (EPR) control, an XDPS2221 digital power controller for power factor correction (PFC) with hybrid flyback (HFB), and a CoolGaN™ IGLD60R190D1 MOSFET as a main switch. The document includes a quick start guide for EZ-PD™ CYPAS213 and XDPS2221 controller-based adapter solutions (REF_140W_HFB_PAG2S).

Intended audience

This document is primarily intended for anyone using the 140 W PFC+ HFB USB PD + synchronous-rectification (SR) high-power density charger adapter solution with highly integrated Infineon XDP™ and EZ-PD™ devices.

Important notice

“Evaluation Boards and Reference Boards” shall mean products embedded on a printed circuit board (PCB) for demonstration and/or evaluation purposes, which include, without limitation, demonstration, reference and evaluation boards, kits and design (collectively referred to as “Reference Board”).

Environmental conditions have been considered in the design of the Evaluation Boards and Reference Boards provided by Infineon Technologies. The design of the Evaluation Boards and Reference Boards has been tested by Infineon Technologies only as described in this document. The design is not qualified in terms of safety requirements, manufacturing and operation over the entire operating temperature range or lifetime.

The Evaluation Boards and Reference Boards provided by Infineon Technologies are subject to functional testing only under typical load conditions. Evaluation Boards and Reference Boards are not subject to the same procedures as regular products regarding returned material analysis (RMA), process change notification (PCN) and product discontinuation (PD).

Evaluation Boards and Reference Boards are not commercialized products, and are solely intended for evaluation and testing purposes. In particular, they shall not be used for reliability testing or production. The Evaluation Boards and Reference Boards may therefore not comply with CE or similar standards (including but not limited to the EMC Directive 2004/EC/108 and the EMC Act) and may not fulfill other requirements of the country in which they are operated by the customer. The customer shall ensure that all Evaluation Boards and Reference Boards will be handled in a way which is compliant with the relevant requirements and standards of the country in which they are operated.

The Evaluation Boards and Reference Boards as well as the information provided in this document are addressed only to qualified and skilled technical staff, for laboratory usage, and shall be used and managed according to the terms and conditions set forth in this document and in other related documentation supplied with the respective Evaluation Board or Reference Board.

It is the responsibility of the customer’s technical departments to evaluate the suitability of the Evaluation Boards and Reference Boards for the intended application, and to evaluate the completeness and correctness of the information provided in this document with respect to such application.

The customer is obliged to ensure that the use of the Evaluation Boards and Reference Boards does not cause any harm to persons or third party property.
The Evaluation Boards and Reference Boards and any information in this document is provided "as is" and Infineon Technologies disclaims any warranties, express or implied, including but not limited to warranties of non-infringement of third party rights and implied warranties of fitness for any purpose, or for merchantability.

Infineon Technologies shall not be responsible for any damages resulting from the use of the Evaluation Boards and Reference Boards and/or from any information provided in this document. The customer is obliged to defend, indemnify and hold Infineon Technologies harmless from and against any claims or damages arising out of or resulting from any use thereof.

Infineon Technologies reserves the right to modify this document and/or any information provided herein at any time without further notice.

Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	**Warning:** *The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning***: The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	**Warning:** *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	**Warning:** *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
	**Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	**Caution:** *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	**Caution:** *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	**Caution:** *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	**Caution:** *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

Table of contents

Table of contents

About this document **1**
Important notice **2**
Safety precautions **3**
Table of contents **4**
1 Introduction **5**
2 Specification **7**
3 Board overview **8**
4 Procedure to program EZ-PD™ CYPAS213-based board **11**
4.1 Programming interface and settings 11
4.1.1 Using the CY8CKIT-005 MiniProg4 Program and Debug Kit 11
4.1.2 Using the CY4532 EZ-PD™ Program and Evaluation Kit 12
4.2 .dP vision programming interface and settings 13
5 Test setup **14**
5.1 Test equipment 14
5.2 Power adapter tester (PAT) 14
6 Quick steps to demo **16**
References **17**
Revision history **18**
Disclaimer **19**

1 Introduction

As portable electronic devices such as smartphones, tablets, and laptops require faster charging, the Power Delivery (PD) technology is designed to provide the fastest charging possible through a USB Type-C (USB-C) cable. The REF_140W_HFB_PAG2S board delivers power up to 140 W with the help of USB PD Standard Power Range (SPR) and EPR standards through a USB-C connector. In addition, this board provides a single USB-C port (see Figure 1) on the universal AC-DC adapters that can charge a wide range of devices, such as smartphones, gaming laptops, and power tools.

It is challenging for the converter topologies used until now to deliver higher power and quicker charging. Therefore, considering factors such as electromagnetic compatibility, power factor correction, standby power, and average efficiency ensures that the chargers and adapters are effective and efficient.

The size or power density of the charger and the adapter becomes a critical factor for the design engineers and the users. The power efficiency of the USB-C chargers and the adapters is crucial in determining their power density. Therefore, converter topology, usage model, integration, and flexibility of the controller functionalities are key factors to consider when selecting the right adapter architecture.

Figure 1 shows a high-level block diagram of the XDPS2221 and EZ-PD™ CYPAS213 adapter and charger solutions. The front-end AC-DC converter produces the required output voltage while ensuring the PFC at the front-end for requesting power level. On the other hand, the USB-C PD controller ensures that the defined USB-C PD specifications and performance are achieved.

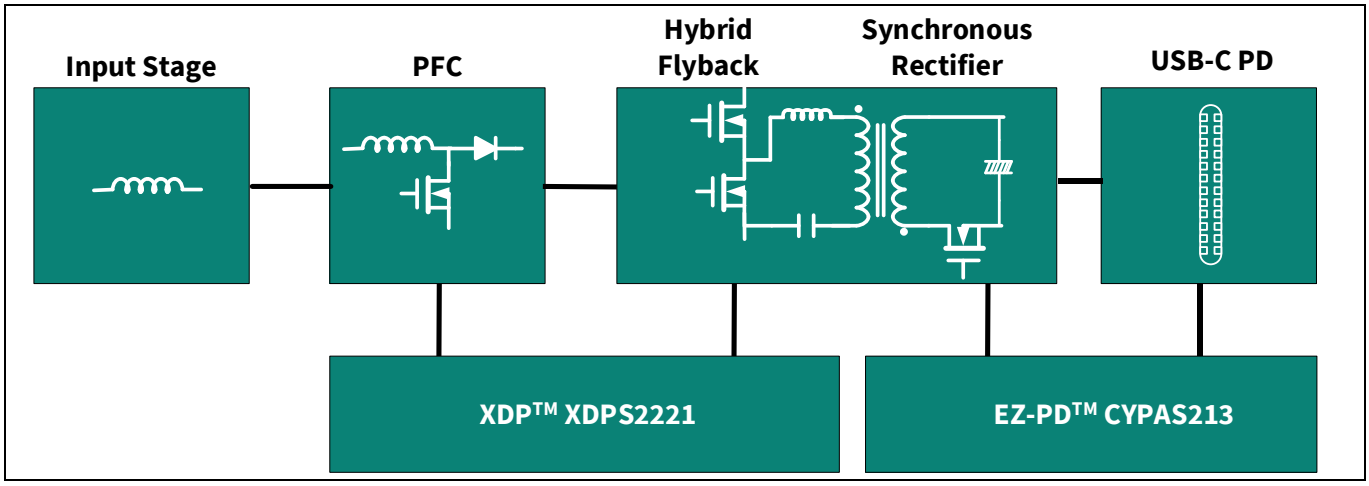

Figure 1 High-level block diagram of a USB PD adapter

Infineon's XDPS2221 solution offers a PFC and HFB combo design that enables high power density designs and system efficiency, meeting international regulatory standards on power efficiency (such as EU CoC Version 5 Tier 2 and DoE Level VI), as well as an effective control of the adaptive wide output voltage range for the latest USB PD EPR standard V3.1.

It is well suited for drive GaN-based devices, such as CoolGaN™ switches, along with the EZ-PD™ PAG2S-based USB-C PD with synchronous rectifier (SR) controller, which has compatibility with USB PD/programmable power supply (PPS) standards. The EZ-PD™ PAG2S supports a single PD/PPS port capable of controlling SR, which makes it an ideal choice for the adaptive output USB-C PD charger/adapter applications.

Introduction

Table 2 Critical components bill of materials (BOM)

Designator	Description	Manufacturer	Part number
U1	EZ-PD™ PAG2S SR and USB PD IC	Infineon Technologies	CYPAS213-32LQXQ
U200	PFC and HFB combo IC	Infineon Technologies	XDPS2221-PG-DSO-14
Q2	N-channel 40 V 19 A (Ta), 40 A (Tc) - Surface mount PG-TDSON-8 FL	Infineon Technologies	BSZ018N04LS
Q100, Q300, Q301	600 V CoolGaN™ enhancement-mode power transistor/ PG-LSON-8-1	Infineon Technologies	IGLD60R190D1 CoolGaN™
Q400, Q401	OptiMOS™ 5 power-transistor, 100 V	Infineon Technologies	BSC070N10NS5 OptiMOS™
C106	Electrolytic capacitor 82 µF/450 V/20%/18.0 mm × 25.0 mm	UCC	82 µF 450 V 18 mm x 25 mm
C216, C219, C221	Electrolytic capacitor, 330 µF/35 V/20%/8.00 mm × 16.00 mm	KEMET	330 µF/35 V/W 8.0 mm × L 16.0 mm
T100	PFC choke, L: 190 µH, Np: Na = 46:9, RM10	Sumida	PS22-110
T200	HFB transformer, Np: Ns: Na1: Na2 = 21: 3: 1: 2, RM10, Lp: 230 µH, Llk: 2.8 µH, RM10	Sumida	PS22-109
LC100	CMC, L: 12 mH/2.36 A/0.1 Ω, 0.15 mm x 1.0 mm/36T, Dimension: 22.00 mm × 12.50 mm × 20.00 mm	ItaCoil	SCF1515050
LD100	Inductor, 300 µH/2.5 A/150 mΩ/ 21.00 mm × 11.2 mm	Würth Elektronik	7447060

2 Specification

Table 3 Test specifications

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input voltage	Vin(limit)		90		264	Vac
Operating voltage	Vin			115/230		Vac
Input frequency	Freq		47	50/60	63	Hz
Inrush current	I_{INRUSH}	264 Vac cold start			70	A
Input current	Iin	Vin = 100 Vac		2000		mA
Total power output	Pout			140		W
Turn on time		<1 sec @90 Vac, full load			1	s
Overvoltage protection		120 ~ 150% of output rated load, hiccup mode	120		150	%
Output voltage	Vo	Rated load = Io	5		28	V
Output current	Io		0		5	A
Full load (140 W) efficiency	η	@90 Vac		92		%
Full load (140 W) efficiency	η	@230 Vac		94.5		%
Standby power	Pstandby	CoC compliant (No load) unattached			75	mW
Light load power consumption (ErP/EuP Lot6)	EuP	Pout = 250 mW @15 V, 20 V, 28 V @115 Vac and 230 Vac			480	mW
Voltage ripple	Vripple	Vo			5	%
Load regulation		Vo			5	%
Holdup time	Tholdup	Vin = 90 Vac, full load	5			ms
Current ripple	Iripple	Io			5	%
Current protection	Ilimit	Limit set at 10% of Io, hiccup mode, auto recovery	10		12	%
Overload capability		As per USB PD Rev3.1 v1.1 spec. in % IOC			200	%
Leakage current	Ileak				0.02	mA
Switching frequency range	FNL	Indicatory only. Does not reflect the operating mode.	15		250	kHz
Temperature	tstorage	Storage temperature	-40		85	°C
	toperating	Operating temperature	0		50	°C
		Component temperature (MOSFET at 50°C ambient)			115	°C
		Component temperature (Transformer at 50°C ambient)			105	°C
Board dimensions	LxWxH	Height		24		mm
		Width		38.5		mm
		Length		117.5		mm

3 Board overview

The EZ-PD™ CYPAS213 + XDPS2221-based EPR 140 W USB PD charger and adapter solution (REF_140W_HFB_PAG2S) is designed to meet the specifications as shown in Table 3.

Figure 2 shows the schematic diagram for the XDPS2221 PFC hybrid flyback in the converter stage and the EZ-PD™ PAG2S-based single-port USB-C PD output. In this solution, the EZ-PD™ PAG2S operates at varying frequencies depending on the control mode of the hybrid flyback (HFB) and the configurable parameter settings.

The EZ-PD™ PAG2S IC is integrated with a synchronous rectifier (SR) and USB PD power management feature that regulates the output voltage and current and negotiates with the connected device to provide the required power and voltage levels.

Board overview

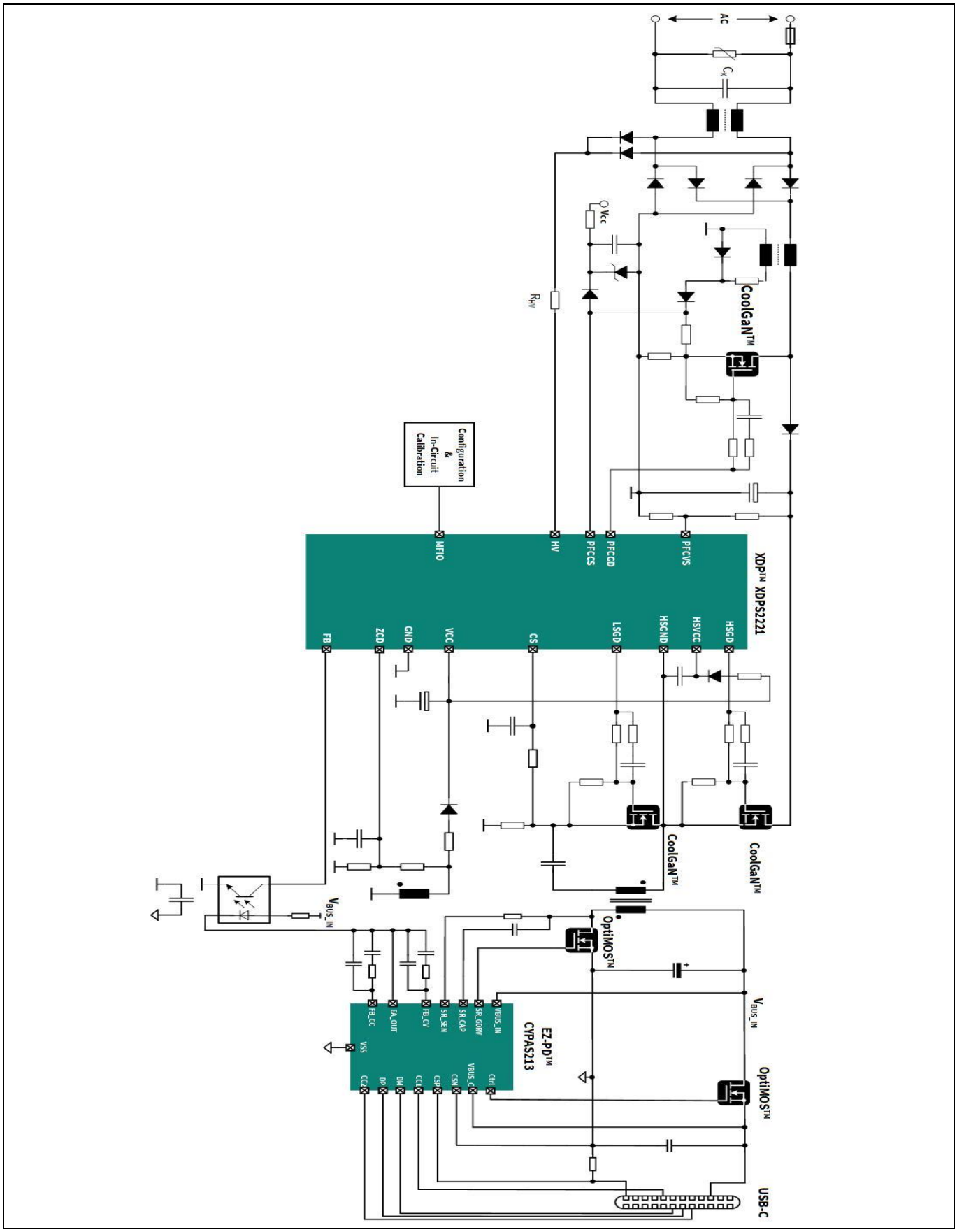

Figure 2 Schematic diagram of EZ-PD™ PAG2S + XDPS2221-based design

Board overview

The waveform shown in Figure 3 illustrates the constant voltage (CV) and constant current (CC) modes of performance of the 140 W USB-C PD converter. This solution attains a power factor exceeding 0.9 for the entire input voltage range at a 140 W load while surpassing 0.98 for an input voltage of 115 Vac and a 140 W load.

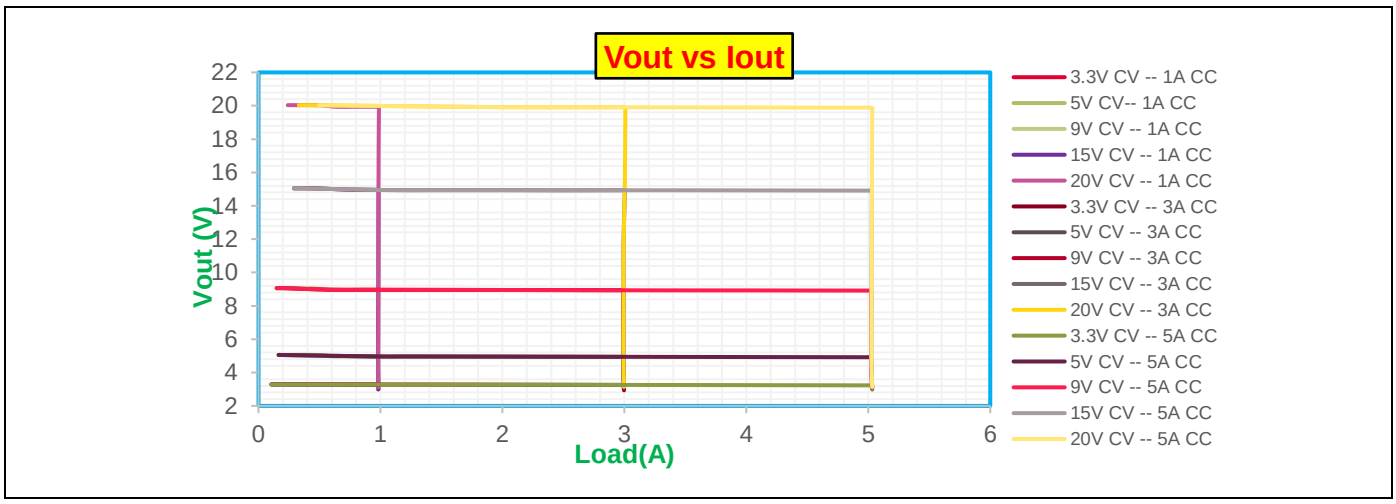

Figure 3 USB PD CV and CC performance at 115 Vac

4 Procedure to program EZ-PD™ CYPAS213-based board

EZ-PD™ PAG2S supports the PSoC™ MiniProg4 (CY8CKIT-005) as a programmer to program the EZ-PD™ controllers. The EZ-PD™ CYPAS213-based main board can be programmed using a PSoC™ MiniProg4 five-pin connection.

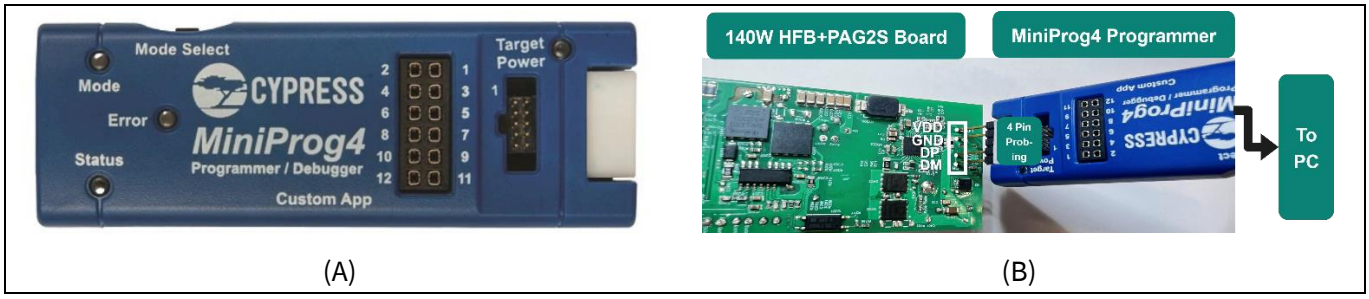

Figure 4 (A) PSoC™ MiniProg4 (CY8CKIT-005) Programmer Kit and (B) Programmer Kit connection with provision jumper

4.1 Programming interface and settings

There are two ways to program the firmware file on an EZ-PD™ CYPAS213-based main board:

1. Using the CY8CKIT-005 MiniProg4 Program and Debug Kit
2. Using the CY4532 EZ-PD™ Program and Evaluation Kit

4.1.1 Using the CY8CKIT-005 MiniProg4 Program and Debug Kit

Prior to starting CYPAS213 firmware burning, a provision jumper connection between the Programmer Kit and CYPAS213 IC pin signals (VDDD, GND, DP, and DM) is required, as shown in Figure 4(B).

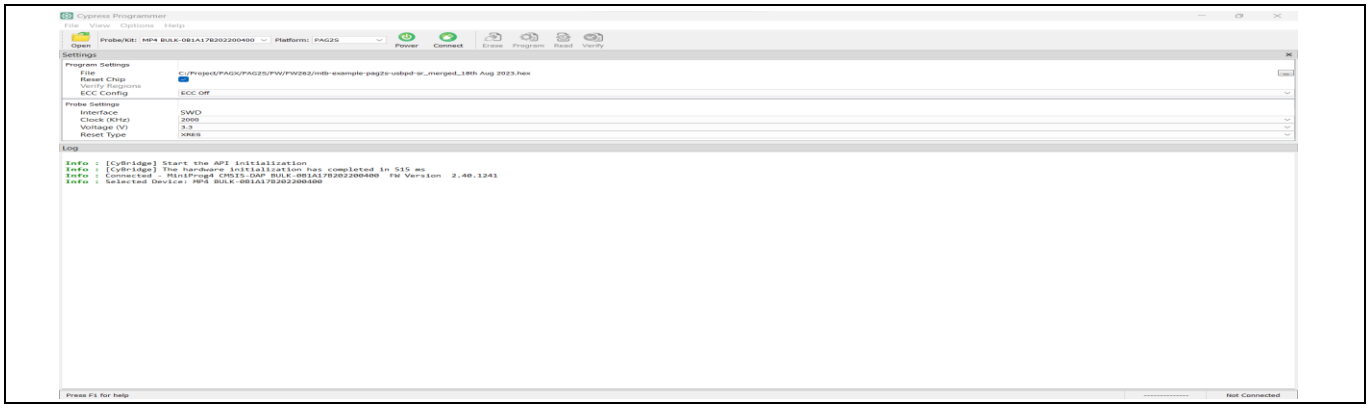

Figure 5 Programming interface to program EZ-PD™ PAG2S

1. On the programmer window, click **Open** to select the firmware (.hex) file from the folder as shown in Figure 5.
2. Select the **PAG2S** option from the drop-down for Platform.
3. Click **Power** to power the programmer cable.

If successful, it is indicated at the bottom right of the window as “Powered”.

4. Click **Connect** after you see “Powered”.

Procedure to program EZ-PD™ CYPAS213-based board

After successful toggling between the PAG2S IC and programmer, the “Connected” message is shown at the bottom right of the window.

5. Click **Program** after you see the “Connected” message.

If the program is successful, a “Successfully programmed” message is shown at the bottom of the window.

The second way to program the CYPAS213 IC firmware is shown in the next section.

4.1.2 Using the CY4532 EZ-PD™ Program and Evaluation Kit

CYPAS213 supports another method for firmware programming that uses the CY4532 EZ-PD™ Program and Evaluation Kit, as shown in Figure 6. The proceed CYPAS213 firmware programming CY4532 kit is to be connected to the CYPAS213-based board via a USB Type-C connector, and a +5 V is to be supplied to VBUS_IN at the CYPAS213-based board. The procedures for programming are:

1. In the EZ-PD™ Configuration Utility programmer window, click the firmware update icon, as shown in Figure 6(B).
2. In the Firmware Update pop-up window, click **…** to select the firmware file for **Firmware path**, as shown in Figure 6(C).
3. Click **UFP-Unknown** to connect to the CYPAS213-based board.

If toggling between CYPAS213 and the Programmer Kit is successful, the “DR Swap Successful” message is shown at the bottom left of the window.

4. Click **Program** to start the firmware file update.

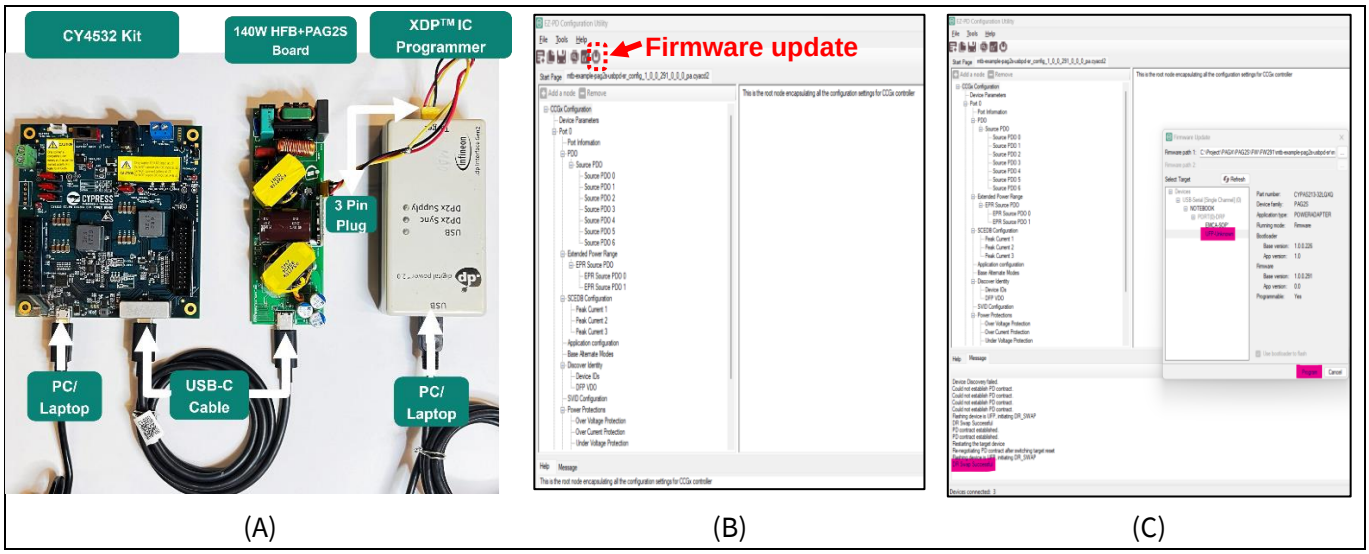

Figure 6 CYPAS213 programming using (A) CY4532 EZ-PD™ Program Kit (left side kit) via USB Type-C connector and XDP™ IC .dP vision programming interface (right side kit), (B) EZ-PD™ Configuration Utility, and (C) Programming file selection and Program window

Procedure to program EZ-PD™ CYPAS213-based board

4.2 .dP vision programming interface and settings

To communicate with the control IC and burn the configurable parameters, the .dp interface board Gen 2 is required. The interface board requires firmware version 2.5 (dpIfGen2_V2.5.0_2017_6_27) or later to establish communication with the control IC XDPS2221.

The .dp interface board is connected to a computer through a mini-B USB port at the left end of the board. Upon successful communication with the computer, the LED USB turns ON. At the right end of the interface board, an 8-pin connector is available for communication with the control IC XDPS2221, where the pins VCC, Comm, and GND must be connected to the IC VCC, MFIO, and ground pins, respectively.

Figure 7 .dp vision interface board Programmer Kit

Figure 7 shows the GUI of the programming software that provides (.ahex) firmware file programming protocol for the XDPS2221 controller.

1. Click **Browse** to select the (.ahex) file.
2. After connecting the .dp vision programmer, click the **Power Device On…** button to power up the .dp vision programmer, as shown in Figure 8.

A green light at the left bottom corner of the window will indicate that the programmer is powered.

3. Click **Burn OTP** to start firmware programming after 3 green LEDs light up on the .dp vision programmer.
4. Disconnect the .dp vision programmer from the 140 W USB PD board.

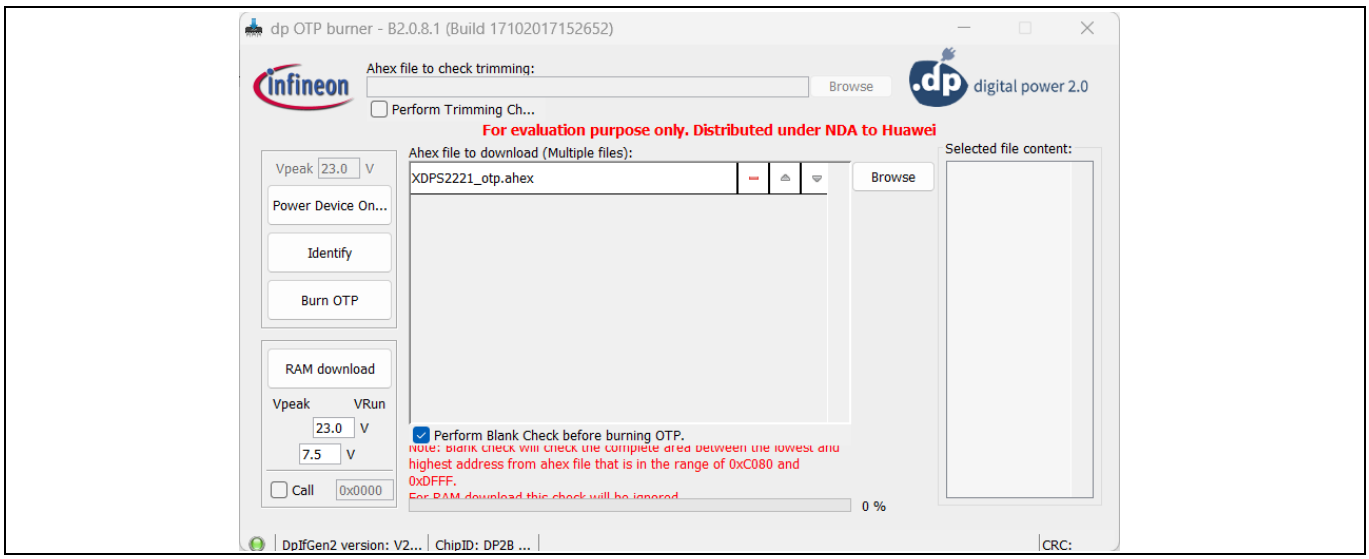

Figure 8 .dp vision programming interface to XDPS2221

5 Test setup

Figure 9 shows the optimal test setup to capture the electrical data of the DUT and calculate the efficiency. The setup captures the following data:

- Input power using a power meter
- Output power using high resolution output multimeters

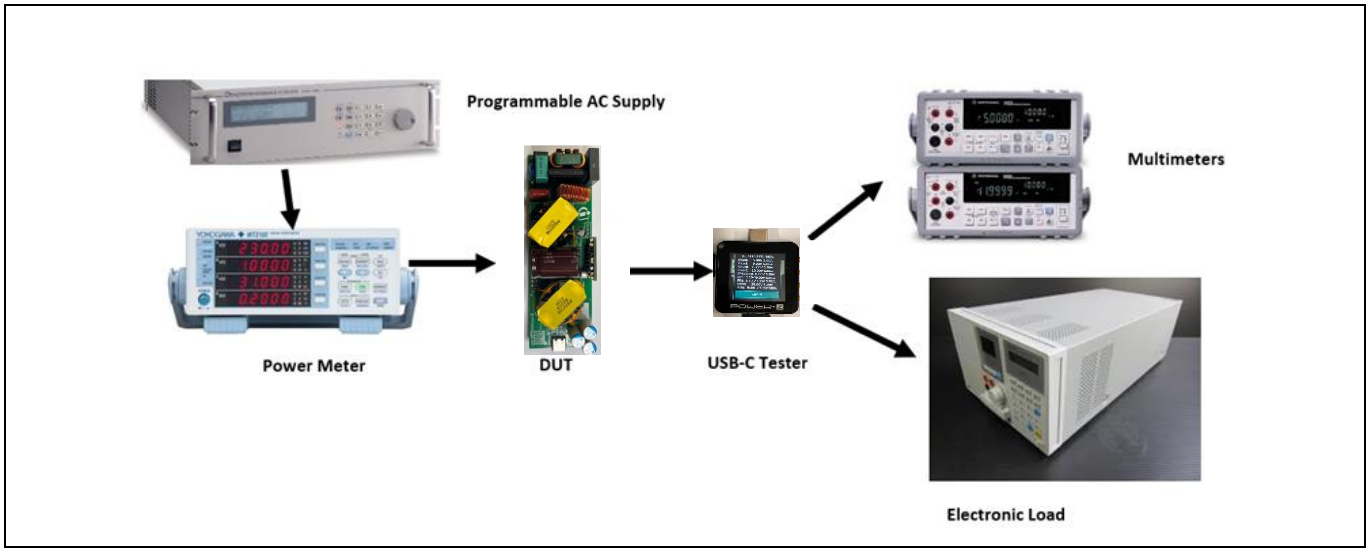

Figure 9 Test equipment connected to the standalone REF_140W_HFB_PAG2S Solution Board

5.1 Test equipment

Table 4 shows the test equipment used to measure performance parameters such as efficiency, ripple, regulation, and transient response.

Table 4 Test equipment details

Test setup	Description
Programmable AC source	Chroma 61501
AC power meter	Yokogawa WT310E
PAT tester	POWER-Z PAT
Electronic load	Chroma 63103A
Multimeters	Keysight 34465A

5.2 Power adapter tester (PAT)

Connect the DUT to a USB-C power adapter tester (PAT) using a USB Type-C cable. After the connection is established, the tester will do a PDO discovery and display the results.

The EZ-PD™ CYPAS213 + XDPS2221-based EPR 140 W USB PD charger/adapter solution is pre-configured with the following PDOs, PPS, and AVS:

- **Fixed PDOs**: 5.0 V / 5.0 A; 9.0 V / 5.0 A; 15.0 V / 5.0 A; 20.0 V / 5.0 A / 28.0 V / 5.0 A
- **PPS**: 3.3 V to 11.0 V, 5.0 A; 3.3 V to 16.0 V, 5.0 A; 3.3 V to 21.0 V, 5.0 A (PPS power limited)

Test setup

- **AVS**: 15.0 V-28.0 V 140 W

Choose a suitable pre-configured PDO or configure a new one using the EZ-PD™ Configuration Utility.

Figure 10 USB-C PD POWER-Z tester

6 Quick steps to demo

The following are the quick steps to set up and start the 140 W EPR USB PD Solution Board. This test uses pre-configured PDOs.

1. Connect the 140 W Solution Board input to the AC terminal of the power meter (which must be connected to the programmable AC supply beforehand), as shown in Figure 8.
2. Connect a USB PD tester or a power adapter tester (PAT) to the port and ensure that the USB PD tester gets a successful Power Delivery contact, as shown in Figure 9.
3. Connect the electronic load at the PAT tester load terminal, as shown in Figure 8.
4. Select the desired voltage on the PAT UI and ramp up the load on the electronic load.

References

Datasheets

[1] EZ-PD™ PAG2S, SR + USB-C PD IC

[2] XDPS2221 PFC + Hybrid-Flyback combo IC

[3] CoolGaN™ IGLD60R190D1 600V CoolGaN™ enhancement-mode Power Transistor

Revision history

Document revision	Date	Description of changes
**	2023-10-06	Initial release.
*A	2024-01-29	Updated user guide title and programming method.

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2024-01-29

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference

002-38685 Rev. *A

Warnings

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.