

INTERNATIONAL STANDARD



**Universal serial bus interfaces for data and power –
Part 1-2: Common components – USB Power Delivery specification**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.220; 33.120; 35.200

ISBN 978-2-8322-4457-9

Warning! Make sure that you obtained this publication from an authorized distributor.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

UNIVERSAL SERIAL BUS INTERFACES FOR DATA AND POWER –

Part 1-2: Common components – USB Power Delivery specification

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62680-1-2 has been prepared by technical area 14: Interfaces and methods of measurement for personal computing equipment, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This second edition cancels and replaces the first edition published in 2016 and constitutes a technical revision.

The text of this standard was prepared by the USB Implementers Forum (USB-IF). The structure and editorial rules used in this publication reflect the practice of the organization which submitted it.

The text of this standard is based on the following documents:

CDV	Report on voting
100/2820/CDV	100/2906/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The IEC 62680 series is based on a series of specifications that were originally developed by the USB Implementers Forum (USB-IF). These specifications were submitted to the IEC under the auspices of a special agreement between the IEC and the USB-IF.

This standard is the USB-IF publication USB Power Delivery Specification Revision 3.0 V.1.0a and ECNs as of 2 August 2016.

The USB Implementers Forum, Inc.(USB-IF) is a non-profit corporation founded by the group of companies that developed the Universal Serial Bus specification. The USB-IF was formed to provide a support organization and forum for the advancement and adoption of Universal Serial Bus technology. The Forum facilitates the development of high-quality compatible USB peripherals (devices), and promotes the benefits of USB and the quality of products that have passed compliance testing.

ANY USB SPECIFICATIONS ARE PROVIDED TO YOU "AS IS, "WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NON-INFRINGEMENT, OR FITNESS FOR ANY PARTICULAR PURPOSE. THE USB IMPLEMENTERS FORUM AND THE AUTHORS OF ANY USB SPECIFICATIONS DISCLAIM ALL LIABILITY, INCLUDING LIABILITY FOR INFRINGEMENT OF ANY PROPRIETARY RIGHTS, RELATING TO USE OR IMPLEMENTATION OR INFORMATION IN THIS SPECIFICATION.

THE PROVISION OF ANY USB SPECIFICATIONS TO YOU DOES NOT PROVIDE YOU WITH ANY LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS.

Entering into USB Adopters Agreements may, however, allow a signing company to participate in a reciprocal, RAND-Z licensing arrangement for compliant products. For more information, please see:

<http://www.usb.org/developers/docs/>

http://www.usb.org/developers/devclass_docs#approved

IEC DOES NOT TAKE ANY POSITION AS TO WHETHER IT IS ADVISABLE FOR YOU TO ENTER INTO ANY USB ADOPTERS AGREEMENTS OR TO PARTICIPATE IN THE USB IMPLEMENTERS FORUM.”

Universal Serial Bus Power Delivery Specification

Revision 3.0, V1.0a. 25 March 2016 + ECNs 2 August 2016

Editors

Bob Dunstan	Intel Corporation
Richard Petrie	DisplayLink

Contributors

Charles Wang	ACON, Advanced-Connectek, Inc.
Conrad Choy	ACON, Advanced-Connectek, Inc.
Steve Sedio	ACON, Advanced-Connectek, Inc.
Vicky Chuang	ACON, Advanced-Connectek, Inc.
Joseph Scanlon	Advanced Micro Devices
Howard Chang	Allion Labs, Inc.
Greg Stewart	Analogix Semiconductor, Inc.
Mehran Badii	Analogix Semiconductor, Inc.
Bill Cornelius	Apple
Colin Whitby-Strevens	Apple
Corey Axelowitz	Apple
Corey Lange	Apple
Dave Conroy	Apple
David Sekowski	Apple
Girault Jones	Apple
James Orr	Apple
Jason Chung	Apple
Jennifer Tsai	Apple
Karl Bowers	Apple
Keith Porthouse	Apple
Matt Mora	Apple
Paul Baker	Apple
Reese Schreiber	Apple
Sameer Kelkar	Apple
Sasha Tietz	Apple
Sree Raman	Apple
William Ferry	Apple
Zaki Moussaoui	Apple
Bernard Shyu	Bizlink Technology, Inc.
Eric Wu	Bizlink Technology, Inc.
Morphy Hsieh	Bizlink Technology, Inc.
Shawn Meng	Bizlink Technology Inc.
Tiffany Hsiao	Bizlink Technology, Inc.
Weichung Ooi	Bizlink Technology, Inc.
Michal Staworko	Cadence Design Systems, Inc.
Alessandro Ingrassia	Canova Tech
Andrea Colognese	Canova Tech
Davide Ghedin	Canova Tech
Matteo Casalin	Canova Tech
Nicola Scantamburlo	Canova Tech

Yi-Feng Lin	Canyon Semiconductor	
Anup Nayak	Cypress Semiconductor	
Jagadeesan Raj	Cypress Semiconductor	
Pradeep Bajpai	Cypress Semiconductor	
Rushil Kadakia	Cypress Semiconductor	
Steven Wong	Cypress Semiconductor	
Subu Sankaran	Cypress Semiconductor	
Sumeet Gupta	Cypress Semiconductor	
Adolfo Montero	Dell Inc.	
Bruce Montag	Dell Inc.	
Gary Verdun	Dell Inc.	
Merle Wood	Dell Inc.	
Mohammed Hijazi	Dell Inc.	
Siddhartha Reddy	Dell Inc.	
Dan Ellis	DisplayLink	
Jason Young	DisplayLink	
Peter Burgers	DisplayLink	
Richard Petrie	DisplayLink	
Abel Astley	Ellisys	PD Chair/Device Policy Lead
Chuck Trefts	Ellisys	
Emmanuel Durin	Ellisys	
Mario Pasquali	Ellisys	
Chien-Cheng Kuo	Etron Technology, Inc.	
Jack Yang	Etron Technology, Inc.	
Richard Crisp	Etron Technology, Inc.	
Shyanjia Chen	Etron Technology, Inc.	
TsungTa Lu	Etron Technology, Inc.	
Christian Klein	Fairchild Semiconductor	
Oscar Freitas	Fairchild Semiconductor	
Souhib Harb	Fairchild Semiconductor	
AJ Yang	Foxconn / Hon Hai	
Fred Fons	Foxconn / Hon Hai	
Steve Sedio	Foxconn / Hon Hai	
Terry Little	Foxconn / Hon Hai	
Bob McVay	Fresco Logic Inc.	
Christopher Meyers	Fresco Logic Inc.	
Tom Burton	Fresco Logic Inc.	
Dian Kurniawan	Fresco Logic Inc.	
Adam Rodriguez	Google Inc.	
Alec Berg	Google Inc.	
David Schneider	Google Inc.	
Jim Guerin	Google Inc.	
Juan Fantin	Google Inc.	
Ken Wu	Google Inc.	

Mark Hayter	Google Inc.	
Nithya Jagannathan	Google Inc.	
Todd Broch	Google Inc.	
Vincent Palatin	Google Inc.	
Mike Engbretson	Granite River Labs	
Rajaraman V	Granite River Labs	
Alan Berkema	Hewlett Packard	
Lee Atkinson	Hewlett Packard	
Rahul Lakdawala	Hewlett Packard	
Robin Castell	Hewlett Packard	
Roger Benson	Hewlett Packard	
Ron Schooley	Hewlett Packard	
Vaibhav Malik	Hewlett Packard	
Walter Fry	Hewlett Packard	
Bob Dunstan	Intel Corporation	PD Chair/Protocol WG Lead
Brad Saunders	Intel Corporation	
Chee Lim Nge	Intel Corporation	
Christine Krause	Intel Corporation	
Dan Froelich	Intel Corporation	
David Harriman	Intel Corporation	
David Hines	Intel Corporation	
David Thompson	Intel Corporation	
Guobin Liu	Intel Corporation	
Harry Skinner	Intel Corporation	
Henrik Leegaard	Intel Corporation	
Jervis Lin	Intel Corporation	
John Howard	Intel Corporation	
Karthi Vadivelu	Intel Corporation	
Leo Heiland	Intel Corporation	
Maarit Harkonen	Intel Corporation	
Nge Chee Lim	Intel Corporation	
Paul Durley	Intel Corporation	
Rahman Ismail	Intel Corporation	System Policy Lead
Ronald Swartz	Intel Corporation	
Sarah Sharp	Intel Corporation	
Scott Brenden	Intel Corporation	
Sridharan Ranganathan	Intel Corporation	
Steve McGowan	Intel Corporation	
Tim McKee	Intel Corporation	PD Chair/Compliance Lead
Toby Opferman	Intel Corporation	
Kenta Minejima	Japan Aviation Electronics Industry Ltd. (JAE)	
Mark Saubert	Japan Aviation Electronics Industry Ltd. (JAE)	
Toshio Shimoyama	Japan Aviation Electronics Industry Ltd. (JAE)	
Brian Fetz	Keysight Technologies Inc.	

Babu Mailachalam	Lattice Semiconductor Corp
Gianluca Mariani	Lattice Semiconductor Corp
Joel Coplen	Lattice Semiconductor Corp
Thomas Watza	Lattice Semiconductor Corp
Vesa Lauri	Lattice Semiconductor Corp
Daniel H Jacobs	LeCroy Corporation
Jake Jacobs	LeCroy Corporation
Kimberley McKay	LeCroy Corporation
Mike Micheletti	LeCroy Corporation
Roy Chestnut	LeCroy Corporation
Phil Jakes	Lenovo
Dave Thompson	LSI Corporation
Alan Kinningham	Luxshare-ICT
Daniel Chen	Luxshare-ICT
Josue Castillo	Luxshare-ICT
Chris Yokum	MCCI Corporation
Geert Knapen	MCCI Corporation
Terry Moore	MCCI Corporation
Velmurugan Selvaraj	MCCI Corporation
Brian Marley	Microchip Technology Inc.
Dave Perchlik	Microchip Technology Inc.
Don Perkins	Microchip Technology Inc.
John Sisto	Microchip Technology Inc.
Josh Averyt	Microchip Technology Inc.
Kiet Tran	Microchip Technology Inc.
Mark Bohm	Microchip Technology Inc.
Matthew Kalibat	Microchip Technology Inc.
Mick Davis	Microchip Technology Inc.
Rich Wahler	Microchip Technology Inc.
Ronald Kunin	Microchip Technology Inc.
Shannon Cash	Microchip Technology Inc.
Anthony Chen	Microsoft Corporation
Dave Perchlik	Microsoft Corporation
David Voth	Microsoft Corporation
Geoff Shew	Microsoft Corporation
Jayson Kastens	Microsoft Corporation
Kai Inha	Microsoft Corporation
Marwan Kadado	Microsoft Corporation
Rahul Ramadas	Microsoft Corporation
Randy Aull	Microsoft Corporation
Shiu Ng	Microsoft Corporation
Timo Toivola	Microsoft Corporation
Toby Nixon	Microsoft Corporation
Vivek Gupta	Microsoft Corporation

Yang You	Microsoft Corporation	
Dan Wagner	Motorola Mobility Inc.	
Ben Crowe	MQP Electronics Ltd.	
Pat Crowe	MQP Electronics Ltd.	
Sten Carlsen	MQP Electronics Ltd.	
Frank Borngräber	Nokia Corporation	
Kai Inha	Nokia Corporation	
Pekka Leinonen	Nokia Corporation	
Richard Petrie	Nokia Corporation	PD Vice-Chair/Device Policy Lead
Sten Carlsen	Nokia Corporation	Physical Layer WG Lead
Abhijeet Kulkarni	NXP Semiconductors	
Ahmad Yazdi	NXP Semiconductors	
Bart Vertenten	NXP Semiconductors	
Dong Nguyen	NXP Semiconductors	
Guru Prasad	NXP Semiconductors	
Ken Jaramillo	NXP Semiconductors	
Krishnan TN	NXP Semiconductors	
Michael Joehren	NXP Semiconductors	
Robert de Nie	NXP Semiconductors	
Rod Whitby	NXP Semiconductors	
Vijendra Kuroodi	NXP Semiconductors	
Robert Heaton	Obsidian Technology	
Bryan McCoy	ON Semiconductor	
Cor Voorwinden	ON Semiconductor	
Edward Berrios	ON Semiconductor	Power Supply WG Lead
Tom Duffy	ON Semiconductor	
Craig Wiley	Parade Technologies Inc.	
Ricardo Pregiteer	Power Integrations	
Chris Sporck	Qualcomm, Inc.	
Craig Aiken	Qualcomm, Inc.	
George Paparrizos	Qualcomm, Inc.	
Giovanni Garcea	Qualcomm, Inc.	
James Goel	Qualcomm, Inc.	
Joshua Warner	Qualcomm, Inc.	
Narendra Mehta	Qualcomm, Inc.	
Terry Remple	Qualcomm, Inc.	
Yoram Rimoni	Qualcomm, Inc.	
Atsushi Mitamura	Renesas Electronics Corp.	
Dan Aoki	Renesas Electronics Corp.	
Kiichi Muto	Renesas Electronics Corp.	
Masami Katagiri	Renesas Electronics Corp.	
Nobuo Furuya	Renesas Electronics Corp.	
Patrick Yu	Renesas Electronics Corp.	
Peter Teng	Renesas Electronics Corp.	
Philip Leung	Renesas Electronics Corp.	
Steve Roux	Renesas Electronics Corp.	

Tetsu Sato	Renesas Electronics Corp.	
Heinz Wei	Richtek Technology Corporation	
Tatsuya Irisawa	Ricoh Company Ltd.	
Akihiro Ono	Rohm Co. Ltd.	
Chris Lin	Rohm Co. Ltd.	
Hidegori Nishimoto	Rohm Co. Ltd.	
Kris Bahar	Rohm Co. Ltd.	
Manabu Miyata	Rohm Co. Ltd.	
Ruben Balbuena	Rohm Co. Ltd.	
Takashi Sato	Rohm Co. Ltd.	
Vijendra Kuroodi	Rohm Co. Ltd.	
Yusuke Kondo	Rohm Co. Ltd.	
Matti Kulmala	Salcomp Plc	
Toni Lehimo	Salcomp Plc	
Tong Kim	Samsung Electronics Co. Ltd.	
Alvin Cox	Seagate Technology LLC	Cab Con WG Lead
John Hein	Seagate Technology LLC	
Marc Noblitt	Seagate Technology LLC	
Ronald Rueckert	Seagate Technology LLC	
Tony Priborsky	Seagate Technology LLC	
John Sisto	SMSC	
Ken Gay	SMSC	
Mark Bohm	SMSC	
Richard Wahler	SMSC	
Shannon Cash	SMSC	
Tim Knowlton	SMSC	
William Chiechi	SMSC	
Fabien Friess	ST-Ericsson	
Giuseppe Platania	ST-Ericsson	
Jean-Francois Gatto	ST-Ericsson	
Milan Stamenkovic	ST-Ericsson	
Nicolas Florenchie	ST-Ericsson	
Patrizia Milazzo	ST-Ericsson	
Christophe Lorin	ST-Microelectronics	
John Bloomfield	ST-Microelectronics	
Massimo Panzica	ST-Microelectronics	
Meriem Mersel	ST-Microelectronics	
Nathalie Ballot	ST-Microelectronics	
Pascal Legrand	ST-Microelectronics	
Patrizia Milazzo	ST-Microelectronics	
Zongyao Wen	Synopsys, Inc.	
Joan Marrinan	Tektronix	
Kimberley McKay	Teledyne-LeCroy	
Matthew Dunn	Teledyne-LeCroy	

Tony Minchell	Teledyne-LeCroy	
Anand Dabak	Texas Instruments	
Bill Waters	Texas Instruments	
Deric Waters	Texas Instruments	Physical Layer WG Lead
Grant Ley	Texas Instruments	
Ingolf Frank	Texas Instruments	
Ivo Huber	Texas Instruments	
Javed Ahmad	Texas Instruments	
Jean Picard	Texas Instruments	
Martin Patoka	Texas Instruments	
Scott Jackson	Texas Instruments	
Srinath Hosur	Texas Instruments	
Steven Tom	Texas Instruments	
Dydron Lin	VIA Technologies, Inc.	
Fong-Jim Wang	VIA Technologies, Inc.	
Jay Tseng	VIA Technologies, Inc.	
Rex Chang	VIA Technologies, Inc.	
Terrance Shih	VIA Technologies, Inc.	
Charles Neumann	Western Digital Technologies, Inc.	
Curtis Stevens	Western Digital Technologies, Inc.	
John Maroney	Western Digital Technologies, Inc.	

Revision History

Revision	Version	Comments	Issue Date
1.0	1.0	Initial release Revision 1.0	5 July, 2012
1.0	1.1	Including errata through 31-October-2012	31 October 2012
1.0	1.2	Including errata through 26-June-2013	26 June, 2013
1.0	1.3	Including errata through 11-March-2014	11 March 2014
2.0	1.0	Initial release Revision 2.0	11 August 2014
2.0	1.1	Including errata through 7-May 2015	7 May 2015
3.0	1.0	Initial release Revision 3.0	11 December 2015
3.0	1.0a	Including errata through 25-March-2016	25 March 2016
3.0	1.0a + ECNs	This markup contains the following ECNs applied to the Revision 3.0 V1.0a specification text: • Applicability of Messages • DRP and DRD bits in Capabilities Messages • Wait Timing • iCapChange Removal • vSafe5V Voltage Range Clarification • Wait Timing • NoResponseTimer • Specification Revision Interoperability	2 August 2016

Revision	Version	Comments	Issue Date
		• tProtErrHardReset • VDM Language • bcdDevice	

INTELLECTUAL PROPERTY DISCLAIMER

THIS SPECIFICATION IS PROVIDED TO YOU “AS IS” WITH NO WARRANTIES WHATSOEVER, INCLUDING ANY WARRANTY OF MERCHANTABILITY, NON-INFRINGEMENT, OR FITNESS FOR ANY PARTICULAR PURPOSE. THE AUTHORS OF THIS SPECIFICATION DISCLAIM ALL LIABILITY, INCLUDING LIABILITY FOR INFRINGEMENT OF ANY PROPRIETARY RIGHTS, RELATING TO USE OR IMPLEMENTATION OF INFORMATION IN THIS SPECIFICATION. THE PROVISION OF THIS SPECIFICATION TO YOU DOES NOT PROVIDE YOU WITH ANY LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS.

Please send comments via electronic mail to techsup@usb.org

For industry information, refer to the USB Implementers Forum web page at <http://www.usb.org>

All product names are trademarks, registered trademarks, or service marks of their respective owners.

Copyright © 2010-2016 Hewlett-Packard Company, Intel Corporation, Microsoft Corporation, Renesas, STMicroelectronics, and Texas Instruments

All rights reserved.

Table of Contents

Contributors	6
Revision History	12
Table of Contents	15
List of Tables	22
List of Figures	27
1. Introduction	34
1.1 Overview	34
1.2 Purpose	35
1.3 Scope	35
1.4 Conventions	35
1.4.1 Precedence	35
1.4.2 Keywords	35
1.4.3 Numbering	36
1.5 Related Documents	37
1.6 Terms and Abbreviations	37
1.7 Parameter Values	44
1.8 Changes From Revision 2.0	45
1.9 Compatibility with Revision 2.0	45
2. Overview	45
2.1 Introduction	45
2.2 Section Overview	47
2.3 Revision 2.0 Changes and Compatibility	48
2.3.1 Changes From Revision 2.0	48
2.3.2 Compatibility with Revision 2.0	48
2.4 USB Power Delivery Capable Devices	49
2.5 SOP* Communication	50
2.5.1 Introduction	50
2.5.2 SOP* Collision Avoidance	50
2.5.3 SOP Communication	50
2.5.4 SOP*/SOP'' Communication with Cable Plugs	50
2.6 Operational Overview	52
2.6.1 Source Operation	52
2.6.2 Sink Operation	55
2.6.3 Cable Plugs	57
2.7 Architectural Overview	58
2.7.1 Policy	60
2.7.2 Message Formation and Transmission	61
2.7.3 Collision Avoidance	61
2.7.4 Power supply	62
2.7.5 DFP/UFP	62
2.7.6 VCONN Source	62

2.7.7	Cable and Connectors	62
2.7.8	Interactions between Non-PD, BC and PD devices	63
2.7.9	Power Rules	63
3.	USB Type-A and USB Type-B Cable Assemblies and Connectors	63
4.	Electrical Requirements	63
4.1	Interoperability with other USB Specifications	63
4.2	Dead Battery Detection / Unpowered Port Detection	63
4.3	Cable IR Ground Drop (IR Drop)	63
4.4	Cable Type Detection	64
5.	Physical Layer	64
5.1	Physical Layer Overview	64
5.2	Physical Layer Functions	64
5.3	Symbol Encoding	65
5.4	Ordered Sets	66
5.5	Transmitted Bit Ordering	67
5.6	Packet Format	68
5.6.1	Packet Framing	68
5.6.2	CRC	70
5.6.3	Packet Detection Errors	72
5.6.4	Hard Reset	72
5.6.5	Cable Reset	73
5.7	Collision Avoidance	73
5.8	Biphase Mark Coding (BMC) Signaling Scheme	74
5.8.1	Encoding and signaling	74
5.8.2	Transmit and Receive Masks	77
5.8.3	Transmitter Load Model	83
5.8.4	BMC Common specifications	84
5.8.5	BMC Transmitter Specifications	85
5.8.6	BMC Receiver Specifications	87
5.9	Built in Self-Test (BIST)	91
5.9.1	BIST Carrier Mode	91
5.9.2	BIST Test Data	91
6.	Protocol Layer	91
6.1	Overview	91
6.2	Messages	91
6.2.1	Message Construction	92
6.3	Control Message	102
6.3.1	GoodCRC Message	103
6.3.2	GotoMin Message	103
6.3.3	Accept Message	103
6.3.4	Reject Message	104
6.3.5	Ping Message	104
6.3.6	PS_RDY Message	104
6.3.7	Get_Source_Cap Message	104
6.3.8	Get_Sink_Cap Message	104

6.3.9	DR_Swap Message	104
6.3.10	PR_Swap Message	105
6.3.11	VCONN_Swap Message	106
6.3.12	Wait Message	106
6.3.13	Soft Reset Message	107
6.3.14	Not_Supported Message	108
6.3.15	Get_Source_Cap_Extended Message	108
6.3.16	Get_Status Message	108
6.3.17	FR_Swap Message	108
6.4	Data Message	109
6.4.1	Capabilities Message	109
6.4.2	Request Message	117
6.4.3	BIST Message	121
6.4.4	Vendor Defined Message	122
6.4.5	Battery_Status Message	143
6.4.6	Alert Message	144
6.5	Extended Message	145
6.5.1	Source_Capabilities_Extended Message	146
6.5.2	Status Message	150
6.5.3	Get_Battery_Cap Message	151
6.5.4	Get_Battery_Status Message	151
6.5.5	Battery_Capabilities Message	152
6.5.6	Get_Manufacturer_Info Message	153
6.5.7	Manufacturer_Info Message	153
6.5.8	Security Messages	154
6.5.9	Firmware Update Messages	155
6.6	Timers	155
6.6.1	CRCReceiveTimer	155
6.6.2	SenderResponseTimer	156
6.6.3	Capability Timers	156
6.6.4	Wait Timers and Times	157
6.6.5	Power Supply Timers	157
6.6.6	NoResponseTimer	158
6.6.7	BIST Timers	159
6.6.8	Power Role Swap Timers	159
6.6.9	Soft Reset Timers	159
6.6.10	Hard Reset Timers	160
6.6.11	Structured VDM Timers	160
6.6.12	VCONN Timers	161
6.6.13	tCableMessage	162
6.6.14	DiscoverIdentityTimer	162
6.6.15	Collision Avoidance Timers	162
6.6.16	tFRSwapInit	162
6.6.17	Time Values and Timers	162

6.7	Counters	165
6.7.1	MessageID Counter	165
6.7.2	Retry Counter	165
6.7.3	Hard Reset Counter	166
6.7.4	Capabilities Counter	166
6.7.5	Discover Identity Counter	166
6.7.6	VDMBusyCounter	166
6.7.7	Counter Values and Counters	166
6.8	Reset	167
6.8.1	Soft Reset and Protocol Error	167
6.8.2	Hard Reset	168
6.8.3	Cable Reset	168
6.9	Collision Avoidance	168
6.10	Message Discarding	169
6.11	State behavior	170
6.11.1	Introduction to state diagrams used in Chapter 6	170
6.11.2	State Operation	170
6.11.3	List of Protocol Layer States	182
6.12	Message Applicability	183
6.12.1	Applicability of Control Messages	184
6.12.2	Applicability of Data Messages	185
6.12.3	Applicability of Extended Messages	185
6.12.4	Applicability of Structured VDM Commands	186
6.12.5	Applicability of Reset Signaling	187
6.12.6	Applicability of Fast Role Swap signal	187
6.13	Value Parameters	188
7.	Power Supply	188
7.1	Source Requirements	188
7.1.1	Behavioral Aspects	188
7.1.2	Source Bulk Capacitance	188
7.1.3	Types of Sources	189
7.1.4	Positive Voltage Transitions	189
7.1.5	Negative Voltage Transitions	190
7.1.6	Response to Hard Resets	191
7.1.7	Changing the Output Power Capability	192
7.1.8	Robust Source Operation	192
7.1.9	Output Voltage Tolerance and Range	193
7.1.10	Charging and Discharging the Bulk Capacitance on V_{BUS}	194
7.1.11	Swap Standby for Sources	194
7.1.12	Source Peak Current Operation	194
7.1.13	Source Capabilities Extended Parameters	196
7.1.14	Fast Role Swap	197
7.2	Sink Requirements	199
7.2.1	Behavioral Aspects	199
7.2.2	Sink Bulk Capacitance	199

7.2.3	Sink Standby	199
7.2.4	Suspend Power Consumption	199
7.2.5	Zero Negotiated Current	200
7.2.6	Transient Load Behavior	200
7.2.7	Swap Standby for Sinks	200
7.2.8	Sink Peak Current Operation	200
7.2.9	Robust Sink Operation	200
7.2.10	Fast Role Swap	201
7.3	Transitions	203
7.3.1	Increasing the Current	204
7.3.2	Increasing the Voltage	206
7.3.3	Increasing the Voltage and Current	208
7.3.4	Increasing the Voltage and Decreasing the Current	210
7.3.5	Decreasing the Voltage and Increasing the Current	212
7.3.6	Decreasing the Current	214
7.3.7	Decreasing the Voltage	216
7.3.8	Decreasing the Voltage and the Current	218
7.3.9	Sink Requested Power Role Swap	220
7.3.10	Source Requested Power Role Swap	223
7.3.11	GotoMin Current Decrease	226
7.3.12	Source Initiated Hard Reset	228
7.3.13	Sink Initiated Hard Reset	230
7.3.14	No change in Current or Voltage	232
7.3.15	Fast Role Swap	234
7.4	Electrical Parameters	236
7.4.1	Source Electrical Parameters	236
7.4.2	Sink Electrical Parameters	238
7.4.3	Common Electrical Parameters	239
8.	Device Policy	239
8.1	Overview	239
8.2	Device Policy Manager	239
8.2.1	Capabilities	241
8.2.2	System Policy	241
8.2.3	Control of Source/Sink	241
8.2.4	Cable Detection	241
8.2.5	Managing Power Requirements	242
8.2.6	Use of “Externally Powered” bit with Batteries and AC supplies	243
8.2.7	Interface to the Policy Engine	245
8.3	Policy Engine	245
8.3.1	Introduction	245
8.3.2	Atomic Message Sequence Diagrams	246
8.3.3	State Diagrams	368
9.	States and Status Reporting	441
9.1	Overview	441

9.1.1	PDUSB Device and Hub Requirements	443
9.1.2	Mapping to USB Device States	443
9.1.3	PD Software Stack	446
9.1.4	PDUSB Device Enumeration	446
9.2	PD Class Specific Descriptors	448
9.2.1	USB Power Delivery Capability Descriptor	448
9.2.2	Battery Info Capability Descriptor	449
9.2.3	PD Consumer Port Capability Descriptor	450
9.2.4	PD Provider Port Capability Descriptor	451
9.3	PD Class Specific Requests and Events	453
9.3.1	Class-specific Requests	453
9.4	PDUSB Hub and PDUSB Peripheral Device Requests	454
9.4.1	GetBatteryStatus	454
9.4.2	SetPDFeature	455
10.	Power Rules	457
10.1	Introduction	457
10.2	Source Power Rules	457
10.2.1	Source Power Rule Considerations	457
10.2.2	Normative Voltages and Currents	458
10.2.3	Optional Voltages/Currents	460
10.2.4	Power sharing between ports	461
10.3	Sink Power Rules	461
10.3.1	Sink Power Rule Considerations	461
10.3.2	Normative Sink Rules	461
A.	CRC calculation	461
A.1	C code example	461
A.2	Table showing the full calculation over one Message	463
B.	PD Message Sequence Examples	464
B.1	External power is supplied downstream	464
B.2	External power is supplied upstream	468
B.3	Giving back power	475
C.	VDM Command Examples	485
C.1	Discover Identity Example	485
C.1.1	Discover Identity Command request	485
C.1.2	Discover Identity Command response – Active Cable	486
C.1.3	Discover Identity Command response – Hub	487
C.2	Discover SVIDs Example	489
C.2.1	Discover SVIDs Command request	489
C.2.1	Discover SVIDs Command response	489
C.3	Discover Modes Example	491
C.3.1	Discover Modes Command request	491
C.3.2	Discover Modes Command response	491
C.4	Enter Mode Example	493
C.4.1	Enter Mode Command request	493
C.4.2	Enter Mode Command response	493

C.4.1	Enter Mode Command request with additional VDO	494
C.5	Exit Mode Example.....	495
C.5.1	Exit Mode Command request.....	495
C.5.2	Exit Mode Command response	495
C.6	Attention Example	497
C.6.1	Attention Command request	497
C.6.2	Attention Command request with additional VDO	497

List of Tables

Table 1-1 Terms and Abbreviations	37
Table 5-1 4b5b Symbol Encoding Table	65
Table 5-2 Ordered Sets	66
Table 5-3 Validation of Ordered Sets	66
Table 5-4 Data Size	67
Table 5-5 SOP ordered set	68
Table 5-6 SOP' ordered set	69
Table 5-7 SOP'' ordered set.....	69
Table 5-8 SOP'_Debug ordered set	70
Table 5-9 SOP''_Debug ordered set.....	70
Table 5-10 CRC-32 Mapping.....	71
Table 5-11 Hard Reset ordered set	72
Table 5-12 Cable Reset ordered set	73
Table 5-13 Rp values used for Collision Avoidance.....	74
Table 5-14 BMC Tx Mask Definition, X Values	79
Table 5-15 BMC Tx Mask Definition, Y Values	79
Table 5-16 BMC Rx Mask Definition.....	83
Table 5-17 BMC Common Normative Requirements.....	85
Table 5-18 BMC Transmitter Normative Requirements.....	85
Table 5-19 BMC Receiver Normative Requirements.....	88
Table 6-1 Message Header	93
Table 6-2 Revision Interoperability during an Explicit Contract.....	95
Table 6-3 Extended Message Header	96
Table 6-4 Use of Unchunked Message Supported bit	98
Table 6-5 Control Message Types.....	102
Table 6-6 Data Message Types	109
Table 6-7 Power Data Object	110
Table 6-8 Fixed Supply PDO - Source	112
Table 6-9 Fixed Power Source Peak Current Capability	114
Table 6-10 Variable Supply (non-Battery) PDO - Source	114
Table 6-11 Battery Supply PDO - Source	114
Table 6-12 Fixed Supply PDO - Sink.....	115
Table 6-13 Variable Supply (non-Battery) PDO - Sink	116
Table 6-14 Battery Supply PDO - Sink	117
Table 6-15 Fixed and Variable Request Data Object.....	117
Table 6-16 Fixed and Variable Request Data Object with GiveBack Support.....	117
Table 6-17 Battery Request Data Object.....	118
Table 6-18 Battery Request Data Object with GiveBack Support.....	118
Table 6-19 BIST Data Object	121

Table 6-20 Unstructured VDM Header	123
Table 6-21 Structured VDM Header	124
Table 6-22 Structured VDM Commands	124
Table 6-23 SVID Values.....	125
Table 6-24 Commands and Responses.....	127
Table 6-25 ID Header VDO	128
Table 6-26 Product Types (UFP).....	129
Table 6-27 Product Types (Cable Plug)	129
Table 6-28 Product Types (DFP).....	129
Table 6-29 Cert Stat VDO	130
Table 6-30 Product VDO	130
Table 6-31 Passive Cable VDO.....	131
Table 6-32 Active Cable VDO	132
Table 6-33 AMA VDO	134
Table 6-34 Discover SVIDs Responder VDO.....	135
Table 6-35 Battery Status Data Object (BSDO).....	143
Table 6-36 Alert Data Object.....	144
Table 6-37 Extended Message Types	145
Table 6-38 Source Capabilities Extended Data Block (SCEDB).....	146
Table 6-39 Status Data Block (SSDB).....	150
Table 6-40 Get Battery Cap Data Block (GBCDB)	151
Table 6-41 Get Battery Status Data Block (GBSDB).....	152
Table 6-42 Battery Capability Data Block (BCDB)	152
Table 6-43 Get Manufacturer Info Data Block (GMIDB).....	153
Table 6-44 Manufacturer Info Data Block (MIDB)	154
Table 6-45 Time Values	163
Table 6-46 Timers.....	164
Table 6-47 Counter parameters	166
Table 6-48 Counters	167
Table 6-49 Message discarding	169
Table 6-50 Protocol Layer States	182
Table 6-51 Applicability of Control Messages.....	184
Table 6-52 Applicability of Data Messages.....	185
Table 6-53 Applicability of Extended Messages	185
Table 6-54 Applicability of Structured VDM Commands.....	186
Table 6-55 Applicability of Reset Signaling	187
Table 6-56 Applicability of Fast Role Swap signal	187
Table 6-57 Value Parameters	188
Table 7-1 Sequence Description for Increasing the Current	205

Table 7-2 Sequence Description for Increasing the Voltage	207
Table 7-3 Sequence Diagram for Increasing the Voltage and Current	209
Table 7-4 Sequence Description for Increasing the Voltage and Decreasing the Current.....	211
Table 7-5 Sequence Description for Decreasing the Voltage and Increasing the Current.....	213
Table 7-6 Sequence Description for Decreasing the Current	215
Table 7-7 Sequence Description for Decreasing the Voltage	217
Table 7-8 Sequence Description for Decreasing the Voltage and the Current.....	219
Table 7-9 Sequence Description for a Sink Requested Power Role Swap	221
Table 7-10 Sequence Description for a Source Requested Power Role Swap	224
Table 7-11 Sequence Description for a GotoMin Current Decrease	227
Table 7-12 Sequence Description for a Source Initiated Hard Reset	229
Table 7-13 Sequence Description for a Sink Initiated Hard Reset	231
Table 7-14 Sequence Description for no change in Current or Voltage.....	233
Table 7-15 Sequence Description for Fast Role Swap.....	234
Table 7-16 Source Electrical Parameters	236
Table 7-17 Sink Electrical Parameters	238
Table 7-18 Common Source/Sink Electrical Parameters.....	239
Table 8-1 Basic Message Flow	246
Table 8-2 Potential issues in Basic Message Flow	247
Table 8-3 Basic Message Flow with CRC failure	249
Table 8-4 Interruptible and Non-interruptible AMS	249
Table 8-5 Steps for a successful Power Negotiation.....	252
Table 8-6 Steps for a GotoMin Negotiation	255
Table 8-7 Steps for a Soft Reset	257
Table 8-8 Steps for Source initiated Hard Reset	260
Table 8-9 Steps for Sink initiated Hard Reset.....	263
Table 8-10 Steps for Source initiated Hard Reset – Sink long reset	266
Table 8-11 Steps for a Successful Source Initiated Power Role Swap Sequence	270
Table 8-12 Steps for a Successful Sink Initiated Power Role Swap Sequence	275
Table 8-13 Steps for a Successful Fast Role Swap Sequence.....	280
Table 8-14 Steps for Data Role Swap, UFP operating as Sink initiates	284
Table 8-15 Steps for Data Role Swap, UFP operating as Source initiates	286
Table 8-16 Steps for Data Role Swap, DFP operating as Source initiates	290
Table 8-17 Steps for Data Role Swap, DFP operating as Sink initiates	292
Table 8-18 Steps for Source to Sink VCONN Source Swap.....	296
Table 8-19 Steps for Sink to Source VCONN Source Swap.....	299
Table 8-20 Steps for Source Alert to Sink	301
Table 8-21 Steps for Sink Alert to Source	303
Table 8-22 Steps for a Sink getting Source status Sequence	305
Table 8-23 Steps for a Source getting Sink status Sequence	307

Table 8-24 Steps for a Sink getting Source capabilities Sequence	309
Table 8-25 Steps for a Dual-Role Source getting Dual-Role Sink's capabilities as a Source Sequence	311
Table 8-26 Steps for a Source getting Sink capabilities Sequence	313
Table 8-27 Steps for a Dual-Role Sink getting Dual-Role Source capabilities as a Sink Sequence	315
Table 8-28 Steps for a Sink getting Source extended capabilities Sequence	317
Table 8-29 Steps for a Dual-Role Source getting Dual-Role Sink extended capabilities Sequence	319
Table 8-30 Steps for a Sink getting Source Battery capabilities Sequence	321
Table 8-31 Steps for a Source getting Sink Battery capabilities Sequence	323
Table 8-32 Steps for a Source getting Sink's Port Manufacturer information Sequence	325
Table 8-33 Steps for a Source getting Sink's Port Manufacturer information Sequence	327
Table 8-34 Steps for a Source getting Sink's Battery Manufacturer information Sequence ..	329
Table 8-35 Steps for a Source getting Sink's Battery Manufacturer information Sequence ..	331
Table 8-36 Steps for a Source getting Sink's Port Manufacturer information Sequence	333
Table 8-37 Steps for a Source requesting a security exchange with a Sink Sequence	335
Table 8-38 Steps for a Sink requesting a security exchange with a Source Sequence	337
Table 8-39 Steps for a Vconn Source requesting a security exchange with a Cable Plug Sequence	339
Table 8-40 Steps for a Source requesting a firmware update exchange with a Sink Sequence	341
Table 8-41 Steps for a Sink requesting a firmware update exchange with a Source Sequence	343
Table 8-42 Steps for a Vconn Source requesting a firmware update exchange with a Cable Plug Sequence	345
Table 8-43 Steps for DFP to UFP Discover Identity	347
Table 8-44 Steps for Source Port to Cable Plug Discover Identity	349
Table 8-45 Steps for DFP to Cable Plug Discover Identity	351
Table 8-46 Steps for DFP to UFP Enter Mode	354
Table 8-47 Steps for DFP to UFP Exit Mode	357
Table 8-48 Steps for DFP to Cable Plug Enter Mode	360
Table 8-49 Steps for DFP to Cable Plug Exit Mode	362
Table 8-50 Steps for UFP to DFP Attention	364
Table 8-51 Steps for BIST Eye Pattern Test	367
Table 8-52 Policy Engine States	436
Table 9-1 USB Power Delivery Type Codes	448
Table 9-2 USB Power Delivery Capability Descriptor	448
Table 9-3 Battery Info Capability Descriptor	450
Table 9-4 PD Consumer Port Descriptor	451
Table 9-5 PD Provider Port Descriptor	452

Table 9-6 PD Class Requests	453
Table 9-7 PD Class Request Codes	453
Table 9-8 PD Class Feature Selectors	453
Table 9-9 Battery Status Structure	454
Table 9-10 Battery Wake Mask	456
Table 9-11 Charging Policy Encoding	456
Table 10-1 Considerations for Sources	457
Table 10-2 Normative Voltages and Currents	458
Table 10-3 Fixed Supply PDO – Source 5V	459
Table 10-4 Fixed Supply PDO – Source 9V	460
Table 10-5 Fixed Supply PDO – Source 15V	460
Table 10-6 Fixed Supply PDO – Source 20V	460
Table B-1 External power is supplied downstream	465
Table B-2 External power is supplied upstream	468
Table B-3 Giving back power	475
Table C-1 Discover Identity Command request from Initiator Example	486
Table C-2 Discover Identity Command response from Active Cable Responder Example	486
Table C-3 Discover Identity Command response from Hub Responder Example	488
Table C-4 Discover SVIDs Command request from Initiator Example	489
Table C-5 Discover SVIDs Command response from Responder Example	489
Table C-6 Discover Modes Command request from Initiator Example	491
Table C-7 Discover Modes Command response from Responder Example	491
Table C-8 Enter Mode Command request from Initiator Example	493
Table C-9 Enter Mode Command response from Responder Example	493
Table C-10 Enter Mode Command request from Initiator Example	494
Table C-11 Exit Mode Command request from Initiator Example	495
Table C-12 Exit Mode Command response from Responder Example	495
Table C-13 Attention Command request from Initiator Example	497
Table C-14 Attention Command request from Initiator with additional VDO Example	497

List of Figures

Figure 2-1 Logical Structure of USB Power Delivery Capable Devices	49
Figure 2-2 Example SOP' Communication between VCONN Source and Cable Plug(s)	51
Figure 2-3 USB Power Delivery Communications Stack	58
Figure 2-4 USB Power Delivery Communication Over USB	59
Figure 2-5 High Level Architecture View	60
Figure 5-1 Interpretation of ordered sets	66
Figure 5-2 Transmit Order for Various Sizes of Data	67
Figure 5-3 USB Power Delivery Packet Format	68
Figure 5-4 CRC 32 generation	71
Figure 5-5 Line format of Hard Reset	73
Figure 5-6 Line format of Cable Reset	73
Figure 5-7 BMC Example	74
Figure 5-8 BMC Transmitter Block Diagram	75
Figure 5-9 BMC Receiver Block Diagram	75
Figure 5-10 BMC Encoded Start of Preamble	76
Figure 5-11 Transmitting or Receiving BMC Encoded Frame Terminated by Zero with High-to-Low Last Transition	76
Figure 5-12 Transmitting or Receiving BMC Encoded Frame Terminated by One with High-to-Low Last Transition	76
Figure 5-13 Transmitting or Receiving BMC Encoded Frame Terminated by Zero with Low to High Last Transition	77
Figure 5-14 Transmitting or Receiving BMC Encoded Frame Terminated by One with Low to High Last Transition	77
Figure 5-15 BMC Tx 'ONE' Mask	78
Figure 5-16 BMC Tx 'ZERO' Mask	78
Figure 5-17 BMC Rx 'ONE' Mask when Sourcing Power	80
Figure 5-18 BMC Rx 'ZERO' Mask when Sourcing Power	81
Figure 5-19 BMC Rx 'ONE' Mask when Power neutral	81
Figure 5-20 BMC Rx 'ZERO' Mask when Power neutral	82
Figure 5-21 BMC Rx 'ONE' Mask when Sinking Power	82
Figure 5-22 BMC Rx 'ZERO' Mask when Sinking Power	83
Figure 5-23 Transmitter Load Model for BMC Tx from a Source	84
Figure 5-24 Transmitter Load Model for BMC Tx from a Sink	84
Figure 5-25 Transmitter diagram illustrating zDriver	86
Figure 5-26 Inter-Frame Gap Timings	87
Figure 5-27 Example Multi-Drop Configuration showing two DRPs	89
Figure 5-28 Example Multi-Drop Configuration showing a DFP and UFP	89
Figure 5-29 Test Data Frame	91
Figure 6-1 USB Power Delivery Packet Format including Control Message Payload	92

Figure 6-2 USB Power Delivery Packet Format including Data Message Payload	92
Figure 6-3 USB Power Delivery Packet Format including an Extended Message Header and Payload.....	92
Figure 6-4 Example Security_Request sequence Unchunked (Chunked bit = 0)	98
Figure 6-5 Example byte transmission for Security_Request Message of Data Size 7 (Chunked bit is set to 0).....	98
Figure 6-6 Example byte transmission for Security_Response Message of Data Size 7 (Chunked bit is set to 0).....	99
Figure 6-7 Example Security_Request sequence Chunked (Chunked bit = 1).....	100
Figure 6-8 Example Security_Request Message of Data Size 7 (Chunked bit set to 1).....	101
Figure 6-9 Example Chunk 0 of Security_Response Message of Data Size 30 (Chunked bit set to 1)	101
Figure 6-10 Example byte transmission for a Security_Request Message Chunk request (Chunked bit is set to 1).....	101
Figure 6-11 Example Chunk 1 of Security_Response Message of Data Size 30 (Chunked bit set to 1)	102
Figure 6-12 Example Capabilities Message with 2 Power Data Objects.....	110
Figure 6-13 BIST Message	121
Figure 6-14 Vendor Defined Message	122
Figure 6-15 Discover Identity Command response	127
Figure 6-16 Example Discover SVIDs response with 3 SVIDs	135
Figure 6-17 Example Discover SVIDs response with 4 SVIDs	135
Figure 6-18 Example Discover SVIDs response with 12 SVIDs followed by an empty response.....	135
Figure 6-19 Example Discover Modes response for a given SVID with 3 Modes.....	136
Figure 6-20 Successful Enter Mode sequence	137
Figure 6-21 Enter Mode sequence Interrupted by Source Capabilities and then Re-run	138
Figure 6-22 Unsuccessful Enter Mode sequence due to NAK.....	138
Figure 6-23 Exit Mode sequence.....	139
Figure 6-24 Attention Command request/response sequence.....	140
Figure 6-25 Command request/response sequence.....	140
Figure 6-26 Enter/Exit Mode Process.....	142
Figure 6-27 Battery_Status Message	143
Figure 6-28 Alert Message.....	144
Figure 6-29 Source_Capabilities_Extended Message.....	146
Figure 6-30 Status Message	150
Figure 6-31 Get_Battery_Cap Message	151
Figure 6-32 Get_Battery_Status Message.....	152
Figure 6-33 Battery_Capabilities Message	152
Figure 6-34 Get_Manufacturer_Info Message	153
Figure 6-35 Manufacturer_Info Message.....	153
Figure 6-36 Security_Request Message.....	154

Figure 6-37 Security_Response Message	155
Figure 6-38 Firmware_Update_Request Message	155
Figure 6-39 Firmware_Update_Response Message	155
Figure 6-40 Outline of States	170
Figure 6-41 References to states	170
Figure 6-42 Common Protocol Layer Message transmission State Diagram	171
Figure 6-43 Source Protocol Layer Message transmission State Diagram	174
Figure 6-44 Sink Protocol Layer Message transmission State Diagram	175
Figure 6-45 Protocol layer Message reception	177
Figure 6-46 Hard/Cable Reset	179
Figure 7-1 Placement of Source Bulk Capacitance	189
Figure 7-2 Transition Envelope for Positive Voltage Transitions	190
Figure 7-3 Transition Envelope for Negative Voltage Transitions	191
Figure 7-4 Source V_{BUS} Response to Hard Reset	192
Figure 7-5 Application of vSrcNew and vSrcValid limits after tSrcReady	194
Figure 7-6 Source Peak Current Overload	195
Figure 7-7 Holdup Time Measurement	197
Figure 7-8 V_{BUS} Power during Fast Role Swap	198
Figure 7-9 V_{BUS} detection and timing during Fast Role Swap.....	198
Figure 7-10 Placement of Sink Bulk Capacitance	199
Figure 7-11 Transition Diagram for Increasing the Current	204
Figure 7-12 Transition Diagram for Increasing the Voltage	206
Figure 7-13 Transition Diagram for Increasing the Voltage and Current	208
Figure 7-14 Transition Diagram for Increasing the Voltage and Decreasing the Current	210
Figure 7-15 Transition Diagram for Decreasing the Voltage and Increasing the Current	212
Figure 7-16 Transition Diagram for Decreasing the Current	214
Figure 7-17 Transition Diagram for Decreasing the Voltage	216
Figure 7-18 Transition Diagram for Decreasing the Voltage and the Current	218
Figure 7-19 Transition Diagram for a Sink Requested Power Role Swap.....	220
Figure 7-20 Transition Diagram for a Source Requested Power Role Swap.....	223
Figure 7-21 Transition Diagram for a GotoMin Current Decrease	226
Figure 7-22 Transition Diagram for a Source Initiated Hard Reset.....	228
Figure 7-23 Transition Diagram for a Sink Initiated Hard Reset	230
Figure 7-24 Transition Diagram for no change in Current or Voltage	232
Figure 7-25 Transition Diagram for Fast Role Swap	234
Figure 8-1 Example of daisy chained displays.....	244
Figure 8-2 Basic Message Exchange (Successful)	246
Figure 8-3 Basic Message flow indicating possible errors	247
Figure 8-4 Basic Message Flow with Bad CRC followed by a Retry.....	248

Figure 8-5 Successful Power Negotiation.....	251
Figure 8-6 Successful GotoMin operation.....	255
Figure 8-7 Soft Reset.....	257
Figure 8-8 Source initiated Hard Reset	259
Figure 8-9 Sink Initiated Hard Reset	262
Figure 8-10 Source initiated reset - Sink long reset.....	265
Figure 8-11 Successful Power Role Swap Sequence Initiated by the Source	269
Figure 8-12 Successful Power Role Swap Sequence Initiated by the Sink.....	274
Figure 8-13 Successful Fast Role Swap Sequence	279
Figure 8-14 Data Role Swap, UFP operating as Sink initiates	283
Figure 8-15 Data Role Swap, UFP operating as Source initiates	286
Figure 8-16 Data Role Swap, DFP operating as Source initiates	289
Figure 8-17 Data Role Swap, DFP operating as Sink initiates	292
Figure 8-18 Source to Sink VCONN Source Swap	295
Figure 8-19 Sink to Source VCONN Source Swap	298
Figure 8-20 Source Alert to Sink	301
Figure 8-21 Sink Alert to Source	303
Figure 8-22 Sink Gets Source Status	305
Figure 8-23 Source Gets Sink Status	307
Figure 8-24 Sink Gets Source's Capabilities	309
Figure 8-25 Dual-Role Source Gets Dual-Role Sink's Capabilities as a Source	311
Figure 8-26 Source Gets Sink's Capabilities	313
Figure 8-27 Dual-Role Sink Gets Dual-Role Source's Capabilities as a Sink	315
Figure 8-28 Sink Gets Source's Extended Capabilities.....	317
Figure 8-29 Dual-Role Source Gets Dual-Role Sink's Extended Capabilities.....	319
Figure 8-30 Sink Gets Source's Battery Capabilities	321
Figure 8-31 Source Gets Sink's Battery Capabilities	323
Figure 8-32 Source Gets Sink's Port Manufacturer Information	325
Figure 8-33 Sink Gets Source's Port Manufacturer Information	327
Figure 8-34 Source Gets Sink's Battery Manufacturer Information	329
Figure 8-35 Sink Gets Source's Battery Manufacturer Information	331
Figure 8-36 VCONN Source Gets Cable Plug's Manufacturer Information.....	333
Figure 8-37 Source requests security exchange with Sink.....	335
Figure 8-38 Sink requests security exchange with Source.....	337
Figure 8-39 Vconn Source requests security exchange with Cable Plug.....	339
Figure 8-40 Source requests firmware update exchange with Sink	341
Figure 8-41 Sink requests firmware update exchange with Source.....	343
Figure 8-42 Vconn Source requests firmware update exchange with Cable Plug	345
Figure 8-43 DFP to UFP Discover Identity.....	347
Figure 8-44 Source Port to Cable Plug Discover Identity.....	349

Figure 8-45 DFP to Cable Plug Discover Identity	351
Figure 8-46 DFP to UFP Enter Mode.....	354
Figure 8-47 DFP to UFP Exit Mode	356
Figure 8-48 DFP to Cable Plug Enter Mode	359
Figure 8-49 DFP to Cable Plug Exit Mode	362
Figure 8-50 UFP to DFP Attention.....	364
Figure 8-51 BIST Carrier Mode Test	366
Figure 8-52 Outline of States	368
Figure 8-53 References to states	368
Figure 8-54 Example of state reference with conditions	368
Figure 8-55 Example of state reference with the same entry and exit.....	369
Figure 8-56 Source Port Policy Engine state diagram	370
Figure 8-57 Sink Port state diagram.....	376
Figure 8-58 Source Port Soft Reset and Protocol Error State Diagram	380
Figure 8-59 Sink Port Soft Reset and Protocol Error Diagram	381
Figure 8-60 Source Port Not Supported Message State Diagram	382
Figure 8-61 Sink Port Not Supported Message State Diagram	383
Figure 8-62 Source Port Ping State Diagram	383
Figure 8-63 Source Port Source Alert State Diagram	384
Figure 8-64 Sink Port Source Alert State Diagram	384
Figure 8-65 Sink Port Sink Alert State Diagram.....	384
Figure 8-66 Source Port Sink Alert State Diagram	385
Figure 8-67 Sink Port Get Source Capabilities Extended state diagram	385
Figure 8-68 Source Give Source Capabilities Extended state diagram	386
Figure 8-69 Sink Port Get Source Status state diagram	386
Figure 8-70 Source Give Source Status state diagram	387
Figure 8-71 Source Port Get Sink Status state diagram	387
Figure 8-72 Sink Give Sink Status state diagram	387
Figure 8-73 Get Battery Capabilities state diagram	388
Figure 8-74 Give Battery Capabilities state diagram.....	388
Figure 8-75 Get Battery Status state diagram	389
Figure 8-76 Give Battery Status state diagram.....	389
Figure 8-77 Get Manufacturer Information state diagram	390
Figure 8-78 Give Manufacturer Information state diagram.....	390
Figure 8-79 Send security request state diagram	391
Figure 8-80 Send security response state diagram.....	391
Figure 8-81 Security response received state diagram.....	392
Figure 8-82 Send firmware update request state diagram	393
Figure 8-83 Send firmware update response state diagram.....	393

Figure 8-84 Firmware update response received state diagram.....	394
Figure 8-85: DFP to UFP Data Role Swap State Diagram	395
Figure 8-86: UFP to DFP Data Role Swap State Diagram	397
Figure 8-87: Dual-Role Port in Source to Sink Power Role Swap State Diagram	399
Figure 8-88: Dual-role Port in Sink to Source Power Role Swap State Diagram	402
Figure 8-89: Dual-Role Port in Source to Sink Fast Role Swap State Diagram	405
Figure 8-90: Dual-role Port in Sink to Source Fast Role Swap State Diagram	408
Figure 8-91 Dual-Role (Source) Get Source Capabilities diagram	410
Figure 8-92 Dual-Role (Source) Give Sink Capabilities diagram	410
Figure 8-93 Dual-Role (Sink) Get Sink Capabilities State Diagram	411
Figure 8-94 Dual-Role (Sink) Give Source Capabilities State Diagram	411
Figure 8-95 Dual-Role (Source) Get Source Capabilities Extended state diagram	412
Figure 8-96 Dual-Role (Source) Give Sink Capabilities diagram	412
Figure 8-97 VCONN Swap State Diagram	413
Figure 8-98 Initiator to Port VDM Discover Identity State Diagram	415
Figure 8-99 Initiator VDM Discover SVIDs State Diagram	416
Figure 8-100 Initiator VDM Discover Modes State Diagram	417
Figure 8-101 Initiator VDM Attention State Diagram	418
Figure 8-102 Responder Structured VDM Discover Identity State Diagram.....	419
Figure 8-103 Responder Structured VDM Discover SVIDs State Diagram	420
Figure 8-104 Responder Structured VDM Discover Modes State Diagram.....	420
Figure 8-105 Receiving a Structured VDM Attention State Diagram	421
Figure 8-106 DFP VDM Mode Entry State Diagram	422
Figure 8-107 DFP VDM Mode Exit State Diagram	423
Figure 8-108 UFP Structured VDM Enter Mode State Diagram.....	424
Figure 8-109 UFP Structured VDM Exit Mode State Diagram	425
Figure 8-110 Cable Ready VDM State Diagram	426
Figure 8-111 Cable Plug Soft Reset State Diagram.....	426
Figure 8-112 Cable Plug Hard Reset State Diagram	427
Figure 8-113 DFP Soft Reset or Cable Reset of a Cable Plug State Diagram.....	428
Figure 8-114 UFP Source Soft Reset of a Cable Plug State Diagram	429
Figure 8-115 Source Startup Structured VDM Discover Identity State Diagram	430
Figure 8-116 Cable Plug Structured VDM Enter Mode State Diagram	431
Figure 8-117 Cable Plug Structured VDM Exit Mode State Diagram	432
Figure 8-118 BIST Carrier Mode State Diagram	434
Figure 9-1 Example PD Topology.....	442
Figure 9-2 Mapping of PD Topology to USB	443
Figure 9-3 USB Attached to USB Powered State Transition	444
Figure 9-4 Any USB State to USB Attached State Transition (When operating as a Consumer).....	445

Figure 9-5 Any USB State to USB Attached State Transition (When operating as a Provider).....	445
Figure 9-6 Any USB State to USB Attached State Transition (After a USB Type-C Data Role Swap)	446
Figure 9-7 Software stack on a PD aware OS	446
Figure 9-8 Enumeration of a PDUSB Device	447
Figure 10-1 Source Power Rule Illustration	458
Figure 10-2 Source Power Rule Example.....	459
Figure B-1 External Power supplied downstream	464
Figure B-2 External Power supplied upstream.....	468
Figure B-3 Giving Back Power	475

1 Introduction

USB has evolved from a data interface capable of supplying limited power to a primary provider of power with a data interface. Today many devices charge or get their power from USB ports contained in laptops, cars, aircraft or even wall sockets. USB has become a ubiquitous power socket for many small devices such as cell phones, MP3 players and other hand-held devices. Users need USB to fulfill their requirements not only in terms of data but also to provide power to, or charge, their devices simply, often without the need to load a driver, in order to carry out “traditional” USB functions.

There are however, still many devices which either require an additional power connection to the wall, or exceed the USB rated current in order to operate. Increasingly, international regulations require better energy management due to ecological and practical concerns relating to the availability of power. Regulations limit the amount of power available from the wall which has led to a pressing need to optimize power usage. The USB Power Delivery Specification has the potential to minimize waste as it becomes a standard for charging devices that are not satisfied by [\[USBBC 1.2\]](#).

Wider usage of wireless solutions is an attempt to remove data cabling but the need for “tethered” charging remains. In addition, industrial design requirements drive wired connectivity to do much more over the same connector.

USB Power Delivery is designed to enable the maximum functionality of USB by providing more flexible power delivery along with data over a single cable. Its aim is to operate with and build on the existing USB ecosystem; increasing power levels from existing USB standards, for example Battery Charging, enabling new higher power use cases such as USB powered Hard Disk Drives (HDDs) and printers.

With USB Power Delivery the power direction is no longer fixed. This enables the product with the power (Host or Peripheral) to provide the power. For example, a display with a supply from the wall can power, or charge, a laptop. Alternatively, USB power bricks or chargers are able to supply power to laptops and other battery powered devices through their, traditionally power providing, USB ports.

USB Power Delivery enables hubs to become the means to optimize power management across multiple peripherals by allowing each device to take only the power it requires, and to get more power when required for a given application. For example battery powered devices can get increased charging current and then give it back temporarily when the user’s HDD requires spinning up. *Optionally* the hubs can communicate with the PC to enable even more intelligent and flexible management of power either automatically or with some level of user intervention.

USB Power Delivery allows Low Power cases such as headsets to negotiate for only the power they require. This provides a simple solution that enables USB devices to operate at their optimal power levels.

The Power Delivery Specification, in addition to providing mechanisms to negotiate power also can be used as a side-band channel for standard and vendor defined messaging. Power Delivery enables alternative modes of operation by providing the mechanisms to discover, enter and exit Alternate Modes. The specification also enables discovery of cable capabilities such as supported speeds and current levels.

1.1 Overview

This specification defines how USB Devices may negotiate for more current and/or higher or lower voltages over the USB cable (using the USB Type-C CC wire as the communications channel) than are defined in the [\[USB 2.0\]](#), [\[USB 3.1\]](#), [\[USB Type-C 1.2\]](#) or [\[USBBC 1.2\]](#) specifications. It allows Devices with greater power requirements than can be met with today’s specification to get the power they require to operate from V_{BUS} and negotiate with external power sources (e.g. Wall Warts). In addition, it allows a Source and Sink to swap power roles such that a Device could supply power to the Host. For example, a display could supply power to a notebook to charge its battery.

The USB Power Delivery Specification is guided by the following principles:

- a) Works seamlessly with legacy USB Devices
- b) Compatible with existing spec-compliant USB cables
- c) Minimizes potential damage from non-compliant cables (e.g. ‘Y’ cables etc.)

d) Optimized for low-cost implementations

This specification defines mechanisms to discover, enter and exit Modes defined either by a standard or by a particular vendor. These Modes can be supported either by the Port Partner or by a cable connecting the two Port Partners.

The specification defines mechanisms to discover the capabilities of cables which can communicate using Power Delivery.

This specification adds a mechanism to swap the data roles such that the upstream facing Port becomes the downstream facing Port and vice versa. It also enables a swap of the end supplying V_{CONN} to a powered cable.

1.2 Purpose

The USB Power Delivery specification defines a power delivery system covering all elements of a USB system including: Hosts, Devices, Hubs, Chargers and cable assemblies. This specification describes the architecture, protocols, power supply behavior, connectors and cabling necessary for managing power delivery over USB at up to 100W. This specification is intended to be fully compatible and extend the existing USB infrastructure. It is intended that this specification will allow system OEMs, power supply and peripheral developers adequate flexibility for product versatility and market differentiation without losing backwards compatibility.

USB Power Delivery is designed to operate independently of the existing USB bus defined mechanisms used to negotiate power which are:

- [\[USB 2.0\]](#), [\[USB 3.1\]](#) in band requests for high power interfaces.
- [\[USBBC 1.2\]](#) mechanisms for supplying higher power (not mandated by this specification).
- [\[USB Type-C 1.2\]](#) mechanisms for supplying higher power

Initial operating conditions remain the USB Default Operation as defined in [\[USB 2.0\]](#), [\[USB 3.1\]](#), [\[USB Type-C 1.2\]](#) or [\[USBBC 1.2\]](#).

- The DFP sources *vSafe5V* over V_{BUS} .
- The UFP consumes power from V_{BUS} .

1.3 Scope

This specification is intended as an extension to the existing [\[USB 2.0\]](#), [\[USB 3.1\]](#), [\[USB Type-C 1.2\]](#) and [\[USBBC 1.2\]](#) specifications. It addresses only the elements required to implement USB Power Delivery. It is targeted at power supply vendors, manufacturers of [\[USB 2.0\]](#), [\[USB 3.1\]](#), [\[USB Type-C 1.2\]](#) and [\[USBBC 1.2\]](#) Platforms, Devices and cable assemblies.

Normative information is provided to allow interoperability of components designed to this specification. Informative information, when provided, may illustrate possible design implementation.

1.4 Conventions

1.4.1 Precedence

If there is a conflict between text, figures, and tables, the precedence shall be tables, figures, and then text.

1.4.2 Keywords

The following keywords differentiate between the levels of requirements and options.

1.4.2.1 Conditional Normative

Conditional Normative is a keyword used to indicate a feature that is mandatory when another related feature has been implemented. Designers are mandated to implement all such requirements, when the dependent features have been implemented, to ensure interoperability with other compliant Devices.

1.4.2.2 Deprecated

Deprecated is a keyword used to indicate a feature, supported in previous releases of the specification, which is no longer supported.

1.4.2.3 Discarded

Discarded is a keyword indicating that a Packet when received shall be thrown away by the PHY Layer and not passed to the Protocol Layer for processing. No **GoodCRC** Message shall be sent in response to the Packet.

1.4.2.4 Ignored

Ignored is a keyword indicating Messages or Message fields which, when received, shall result in no action by the receiver, aside from returning a **GoodCRC** Message to acknowledge Message receipt.

1.4.2.5 Invalid

Invalid is a keyword when used in relation to a Message indicates that the Message's usage or fields fall outside of the defined specification usage. When **Invalid** is used in relation to an Explicit Contract it indicates that a previously established Explicit Contract which can no longer be maintained by the Source.

1.4.2.6 May

May is a keyword that indicates a choice with no implied preference.

1.4.2.7 N/A

N/A is a keyword that indicates that a field or value is not applicable and has no defined value and shall not be checked or used by the recipient.

1.4.2.8 Optional/Optionally/Optional Normative

Optional, **Optionally** and **Optional Normative** are equivalent keywords that describe features not mandated by this specification. However, if an **Optional** feature is implemented, the feature shall be implemented as defined by this specification.

1.4.2.9 Reserved

Reserved is a keyword indicating reserved bits, bytes, words, fields, and code values that are set-aside for future standardization. Their use and interpretation may be specified by future extensions to this specification and shall not be utilized or adapted by vendor implementation. A **Reserved** bit, byte, word, or field shall be set to zero by the sender and shall be **Ignored** by the receiver. **Reserved** field values shall not be sent by the sender and shall be **Ignored** by the receiver.

1.4.2.10 Shall/Normative

Shall and **Normative** are equivalent keywords indicating a mandatory requirement. Designers are mandated to implement all such requirements to ensure interoperability with other compliant Devices.

1.4.2.11 Should

Should is a keyword indicating flexibility of choice with a preferred alternative. Equivalent to the phrase "it is recommended that".

1.4.3 Numbering

Numbers that are immediately followed by a lowercase "b" (e.g., 01b) are binary values. Numbers that are immediately followed by an uppercase "B" are byte values. Numbers that are immediately followed by a lowercase "h" (e.g., 3Ah) or are preceded by "0x" (e.g. 0xFF00) are hexadecimal values. Numbers not immediately followed by either a "b", "B", or "h" are decimal values.

1.5 Related Documents

- **[USB 2.0]** – Universal Serial Bus Specification, Revision 2.0, plus ECN and Errata http://www.usb.org/developers/docs/usb20_docs/.
- **[USB 3.1]** – Universal Serial Bus 3.1 Specification, Revision 1 plus ECN and Errata (this includes the entire document release package including the OTG&EH v3.0 specification). www.usb.org/developers/docs.
- **[USBTypeCAuthentication 1.0]**, Universal Serial Bus Type-C Authentication Specification, Revision 1.0, March 25, 2016. www.usb.org/developers/docs.
- **[USBPDFirmwareUpdate 1.0]**, Universal Serial Bus Power Delivery Firmware Update Specification, Revision 1.0. www.usb.org/developers/docs. Expected publication date H2 2016.
- **[USBBC 1.2]** – Universal Serial Bus Battery Charging Specification, Revision 1.2 plus Errata (referred to in this document as the Battery Charging specification). www.usb.org/developers/devclass_docs#approved.
- **[USBBridge 1.0]** – Universal Serial Bus Type-C Bridge Specification, Revision 1.0, March 25, 2016. www.usb.org/developers/docs.
- **[USBTypeCBridge 1.0]** – Universal Serial Bus Type-C Bridge Specification, Revision 1.0, March 25, 2016. www.usb.org/developers/docs.
- **[USBD 2.0]** – Universal Serial Bus Power Delivery Specification, Revision 2, Version 1.2, March 25, 2016. www.usb.org/developers/docs.
- **[USBPDCompliance]** – USB Power Delivery Compliance Plan version 1.0 http://www.usb.org/developers/docs/devclass_docs/.
- **[USB Type-C 1.2]** – Universal Serial Bus Type-C Cable and Connector Specification, Revision 1.2, March 25, 2016. www.usb.org/developers/docs.
- **[IEC 60958-1]** IEC 60958-1 Digital Audio Interface Part:1 General Edition 3.0 2008-09 www.iec.ch
- **[IEC 60950-1]** IEC 60950-1:2005 Information technology equipment – Safety – Part 1: General requirements: Amendment 1:2009, Amendment 2:2013
- **[IEC 62368-1]** IEC 62368-1 Audio/Video, information and communication technology equipment – Part 1: Safety requirements
- **[IEC 63002]** Draft CD for IEC 63002 Identification and Communication Interoperability Method for External DC Power Supplies Used With Portable Computing Devices.