

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

EESTI STANDARDI EESSÕNA

NATIONAL FOREWORD

See Eesti standard EVS-EN IEC 62680-1-2:2022 sisaldab Euroopa standardi EN IEC 62680-1-2:2022 ingliskeelset teksti.	This Estonian standard EVS-EN IEC 62680-1-2:2022 consists of the English text of the European standard EN IEC 62680-1-2:2022.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation and Accreditation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 14.10.2022.	Date of Availability of the European standard is 14.10.2022.
Standard on kättesaadav Eesti Standardimis-ja Akrediteerimiskeskusest.	The standard is available from the Estonian Centre for Standardisation and Accreditation.

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 29.220, 33.120, 35.200

Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardimis- ja Akrediteerimiskeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardimis-ja Akrediteerimiskeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardimis-ja Akrediteerimiskeskusega: Koduleht www.evs.ee; telefon 605 5050; e-post info@evs.ee

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation and Accreditation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation and Accreditation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation and Accreditation:

Homepage www.evs.ee; phone +372 605 5050; e-mail info@evs.ee

English Version

Universal serial bus interfaces for data and power - Part 1-2:
Common components - USB Power Delivery specification
(IEC 62680-1-2:2022)

Interfaces de bus universel en série pour les données et
l'alimentation électrique - Partie 1-2: Composants communs
- Spécification de l'alimentation électrique par port USB
(IEC 62680-1-2:2022)

Schnittstellen des Universellen Seriellen Busses für Daten
und Energie - Teil 1-2: Gemeinsame Komponenten -
Festlegung für die USB-Stromversorgung
(IEC 62680-1-2:2022)

This European Standard was approved by CENELEC on 2022-10-10. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 100/3716/CDV, future edition 6 of IEC 62680-1-2, prepared by IEC/TC 100 "Audio, video and multimedia systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62680-1-2:2022.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2023-07-10
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2025-10-10

This document supersedes EN IEC 62680-1-2:2021 and all of its amendments and corrigenda (if any).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 62680-1-2:2022 was approved by CENELEC as a European Standard without any modification.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Interfaces de bus universel en série pour les données et l'alimentation
électrique –
Partie 1-2: Composants communs – Spécification de l'alimentation électrique
par port USB**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2022 USB-IF

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from IEC, or USB-IF at the respective address given below. Any questions about USB-IF copyright should be addressed to the USB-IF. Enquiries about obtaining additional rights to this publication and other information requests should be addressed to the IEC or your local IEC member National Committee.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

USB Implementers Forum, Inc.
3855 S.W. 153rd Drive
Beaverton, OR 97003
United States of America
Tel. +1 503-619-0426
Admin@usb.org
www.usb.org

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



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

**Interfaces de bus universel en série pour les données et l'alimentation
électrique –
Partie 1-2: Composants communs – Spécification de l'alimentation électrique
par port USB**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.220; 33.120; 35.200

ISBN 978-2-8322-5288-8

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

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 18: Multimedia home systems and applications for end-user networks, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

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 International Standard is based on the following documents:

Draft	Report on voting
100/3716/CDV	100/3763/RVC

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

A list of all parts in the IEC 62680 series, published under the general title *Universal serial bus interfaces for data and power*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

IMPORTANT – The "colour inside" logo on the cover page of this document 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 Universal Serial Bus Power Delivery Specification Revision 3.1, Version 1.1.

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:

<https://www.usb.org/documents>

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."

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
2.0	1.2	Including errata through 25-March-2016	25 March 2016
2.0	1.3	Including errata through 11-January-2017	11 January 2017
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	1.1	Including errata through 12-January-2016	12 January 2017
3.0	1.2	Including errata through 21-June-2018	21 June 2018
3.0	2.0	Including errata through 29-August-2019	29 August 2019
3.1	1.0	Including errata through May 2021	May 2021
3.1	1.1	Including errata through July 2021	July 2021

Table of Contents

INTELLECTUAL PROPERTY DISCLAIMER	6
Chairs	7
Editors	7
Contributors	7
Revision History	14
Table of Contents	15
List of Tables	35
List of Figures	42
1. Introduction	51
1.1 Overview	51
1.2 Purpose	52
1.3 Scope	52
1.4 Conventions	53
1.4.1 Precedence	53
1.4.2 Keywords	53
1.4.2.1 Conditional Normative	53
1.4.2.2 Deprecated	53
1.4.2.3 Discarded	53
1.4.2.4 Ignored	53
1.4.2.5 Invalid	53
1.4.2.6 May	53
1.4.2.7 May Not	53
1.4.2.8 N/A	53
1.4.2.9 Optional/Optionally/Optional Normative	54
1.4.2.10 Reserved	54
1.4.2.11 Shall/Normative	54
1.4.2.12 Shall Not	54
1.4.2.13 Should	54
1.4.2.14 Should Not	54
1.4.2.15 Valid	54
1.4.3 Numbering	54
1.5 Related Documents	54
1.6 Terms and Abbreviations	55
1.7 Parameter Values	63
1.8 Changes from Revision 3.0	64
1.9 Compatibility with Revision 2.0	64
2. Overview	64
2.1 Introduction	64
2.2 Section Overview	65
2.3 Compatibility with Revision 2.0	66
2.4 USB Power Delivery Capable Devices	66
2.5 SOP* Communication	67
2.5.1 Introduction	67
2.5.2 SOP* Collision Avoidance	67

2.5.3	SOP Communication.....	67
2.5.4	SOP'/SOP'' Communication with Cable Plugs	67
2.6	Operational Overview	69
2.6.1	Source Operation	69
2.6.2	Sink Operation.....	72
2.6.3	Cable Plugs	74
2.7	Architectural Overview	75
2.7.1	Policy	77
2.7.1.1	System Policy Manager.....	77
2.7.1.2	Device Policy Manager.....	78
2.7.1.3	Policy Engine	78
2.7.2	Message Formation and Transmission.....	78
2.7.2.1	Protocol Layer.....	78
2.7.2.2	PHY Layer	78
2.7.3	Collision Avoidance	78
2.7.3.1	Policy Engine	78
2.7.3.2	Protocol Layer.....	78
2.7.3.3	PHY Layer	79
2.7.4	Power supply	79
2.7.4.1	Source	79
2.7.4.2	Sink	79
2.7.4.3	Dual-Role Power Ports.....	79
2.7.4.4	Dead Battery or Lost Power Detection.....	79
2.7.4.5	VCONN Source.....	79
2.7.5	DFP/UFP	79
2.7.5.1	Downstream Facing Port (DFP).....	79
2.7.5.2	Upstream Facing Port (UFP)	79
2.7.5.3	Dual-Role Data Ports	80
2.7.6	Cable and Connectors	80
2.7.6.1	USB-C Port Control.....	80
2.7.7	Interactions between Non-PD, BC and PD devices	80
2.7.8	Power Rules	80
2.8	Extended Power Range (EPR) Operation	80
2.9	Charging Models	82
2.9.1	Fixed Voltage Charging Models	82
2.9.2	Programmable Power Supply (PPS) Charging Models	83
2.9.3	Adjustable Voltage Supply (AVS) Charging Models.....	83
3.	USB Type-A and USB Type-B Cable Assemblies and Connectors	83
4.	Electrical Requirements.....	83
4.1	Interoperability with other USB Specifications	83
4.2	Dead Battery Detection / Unpowered Port Detection.....	84
4.3	Cable IR Ground Drop (IR Drop)	84
4.4	Cable Type Detection	84
5.	Physical Layer	84
5.1	Physical Layer Overview	84
5.2	Physical Layer Functions.....	84
5.3	Symbol Encoding	86
5.4	Ordered Sets.....	87
5.5	Transmitted Bit Ordering	88

5.6	Packet Format	89
5.6.1	Packet Framing	89
5.6.1.1	Preamble	89
5.6.1.2	Start of Packet Sequences	89
5.6.1.2.1	Start of Packet Sequence (SOP)	89
5.6.1.2.2	Start of Packet Sequence Prime (SOP')	90
5.6.1.2.3	Start of Packet Sequence Double Prime (SOP'')	90
5.6.1.2.4	Start of Packet Sequence Prime Debug (SOP'_Debug)	90
5.6.1.2.5	Start of Packet Sequence Double Prime Debug (SOP''_Debug)	91
5.6.1.3	Packet Payload	91
5.6.1.4	CRC	91
5.6.1.5	End of Packet (EOP)	91
5.6.2	CRC	91
5.6.3	Packet Detection Errors	93
5.6.4	Hard Reset	93
5.6.5	Cable Reset	94
5.7	Collision Avoidance	94
5.8	Biphase Mark Coding (BMC) Signaling Scheme	95
5.8.1	Encoding and signaling	95
5.8.2	Transmit and Receive Masks	98
5.8.2.1	Transmit Masks	98
5.8.2.2	Receive Masks	100
5.8.3	Transmitter Load Model	104
5.8.4	BMC Common specifications	105
5.8.4.1	BMC Common Parameters	106
5.8.5	BMC Transmitter Specifications	106
5.8.5.1	Capacitance when not transmitting	107
5.8.5.2	Source Output Impedance	107
5.8.5.3	Bit Rate Drift	107
5.8.5.4	Inter-Frame Gap	108
5.8.5.5	Shorting of Transmitter Output	108
5.8.5.6	Fast Role Swap Transmission	108
5.8.6	BMC Receiver Specifications	109
5.8.6.1	Definition of Idle	109
5.8.6.2	Multi-Drop	110
5.8.6.3	Fast Role Swap Detection	110
5.9	Built in Self-Test (BIST)	112
5.9.1	BIST Carrier Mode	112
5.9.2	BIST Test Data	112
6.	Protocol Layer	112
6.1	Overview	112
6.2	Messages	112
6.2.1	Message Construction	113
6.2.1.1	Message Header	114
6.2.1.1.1	Extended	114
6.2.1.1.2	Number of Data Objects	114
6.2.1.1.3	MessageID	114

6.2.1.1.4	Port Power Role.....	115
6.2.1.1.5	Specification Revision.....	115
6.2.1.1.6	Port Data Role	117
6.2.1.1.7	Cable Plug	117
6.2.1.1.8	Message Type	117
6.2.1.2	Extended Message Header	118
6.2.1.2.1	Chunked	118
6.2.1.2.2	Chunk Number	119
6.2.1.2.3	Request Chunk	119
6.2.1.2.4	Data Size	119
6.2.1.2.5	Extended Message Examples	119
6.3	Control Message	124
6.3.1	GoodCRC Message	125
6.3.2	GotoMin Message.....	125
6.3.3	Accept Message	125
6.3.4	Reject Message.....	126
6.3.5	Ping Message.....	126
6.3.6	PS_RDY Message	126
6.3.7	Get_Source_Cap Message	126
6.3.8	Get_Sink_Cap Message	126
6.3.9	DR_Swap Message	127
6.3.10	PR_Swap Message.....	127
6.3.11	VCONN_Swap Message	128
6.3.12	Wait Message.....	128
6.3.12.1	Wait in response to a Request Message	129
6.3.12.2	Wait in response to a PR_Swap Message	129
6.3.12.3	Wait in response to a DR_Swap Message	129
6.3.12.4	Wait in response to a VCONN_Swap Message.....	129
6.3.13	Soft Reset Message	130
6.3.14	Data_Reset Message.....	130
6.3.15	Data_Reset_Complete Message	131
6.3.16	Not_Supported Message	131
6.3.17	Get_Source_Cap_Extended Message.....	131
6.3.18	Get_Status Message	131
6.3.19	FR_Swap Message.....	131
6.3.20	Get_PPS_Status.....	132
6.3.21	Get_Country_Codes	132
6.3.22	Get_Sink_Cap_Extended Message	132
6.3.23	Get_Source_Info Message.....	132
6.3.24	Get_Revision Message	132
6.4	Data Message	132
6.4.1	Capabilities Message.....	133
6.4.1.1	Use of the Capabilities Message	135
6.4.1.1.1	Use by Sources	135
6.4.1.1.2	Use by Sinks.....	135
6.4.1.1.3	Use by Dual-Role Power devices	135
6.4.1.2	Source_Capabilities Message	135
6.4.1.2.1	Management of the Power Reserve	136
6.4.1.2.2	Fixed Supply Power Data Object.....	137

6.4.1.2.3	Variable Supply (non-Battery) Power Data Object.....	139
6.4.1.2.4	Battery Supply Power Data Object.....	139
6.4.1.2.5	Augmented Power Data Object (APDO)	140
6.4.1.3	Sink Capabilities Message	141
6.4.1.3.1	Sink Fixed Supply Power Data Object.....	141
6.4.1.3.2	Variable Supply (non-Battery) Power Data Object.....	143
6.4.1.3.3	Battery Supply Power Data Object	143
6.4.1.3.4	Programmable Power Supply Augmented Power Data Object	143
6.4.2	Request Message	144
6.4.2.1	Object Position.....	146
6.4.2.2	GiveBack Flag.....	146
6.4.2.3	Capability Mismatch	146
6.4.2.4	USB Communications Capable	147
6.4.2.5	No USB Suspend	147
6.4.2.6	Unchunked Extended Messages Supported	147
6.4.2.7	EPR Mode Capable.....	147
6.4.2.8	Operating Current	148
6.4.2.9	Maximum Operating Current	148
6.4.2.10	Minimum Operating Current	148
6.4.2.11	Operating Power	149
6.4.2.12	Maximum Operating Power	149
6.4.2.13	Minimum Operating Power	149
6.4.2.14	Output Voltage.....	149
6.4.3	BIST Message	149
6.4.3.1	BIST Carrier Mode	151
6.4.3.2	BIST Test Data	151
6.4.3.3	BIST Shared Capacity Test Mode	151
6.4.3.3.1	BIST Shared Test Mode Entry.....	151
6.4.3.3.2	BIST Shared Test Mode Exit.....	151
6.4.4	Vendor Defined Message.....	152
6.4.4.1	Unstructured VDM.....	153
6.4.4.1.1	USB Vendor ID	153
6.4.4.1.2	VDM Type.....	153
6.4.4.2	Structured VDM	153
6.4.4.2.1	SVID	155
6.4.4.2.2	VDM Type.....	155
6.4.4.2.3	Structured VDM Version	155
6.4.4.2.4	Object Position	155
6.4.4.2.5	Command Type	156
6.4.4.2.6	Command	156
6.4.4.3	Use of Commands.....	157
6.4.4.3.1	Discover Identity	157
6.4.4.3.2	Discover SVIDs.....	172
6.4.4.3.3	Discover Modes	173
6.4.4.3.4	Enter Mode Command	174
6.4.4.3.5	Exit Mode Command.....	176
6.4.4.3.6	Attention	177

6.4.4.4	Command Processes	177
6.4.4.4.1	Discovery Process	178
6.4.4.4.2	Enter Vendor Mode / Exit Vendor Mode Processes	179
6.4.4.5	VDM Message Timing and Normal PD Messages	180
6.4.5	Battery_Status Message	180
6.4.5.1	Battery Present Capacity	181
6.4.5.2	Battery Info	181
6.4.5.2.1	Invalid Battery Reference	181
6.4.5.2.2	Battery is Present	181
6.4.5.2.3	Battery Charging Status	181
6.4.6	Alert Message	181
6.4.6.1	Type of Alert	182
6.4.6.1.1	Battery Status Change	182
6.4.6.1.2	Over-Current Protection Event	182
6.4.6.1.3	Over-Temperature Protection Event	182
6.4.6.1.4	Operating Condition Change	182
6.4.6.1.5	Source Input Change Event	182
6.4.6.1.6	Over-Voltage Protection Event	183
6.4.6.1.7	Extended Alert Event	183
6.4.6.2	Fixed Batteries	183
6.4.6.3	Hot Swappable Batteries	183
6.4.6.4	Extended Alert Event Types	183
6.4.6.4.1	Power State Change	183
6.4.6.4.2	Power Button Press	183
6.4.6.4.3	Power Button Release	183
6.4.6.4.4	Controller initiated wake	183
6.4.7	Get_Country_Info Message	183
6.4.8	Enter_USB Message	184
6.4.8.1	USB Mode Field	185
6.4.8.2	USB4 DRD Field	185
6.4.8.3	USB3 DRD Field	185
6.4.8.4	Cable Speed Field	185
6.4.8.5	Cable Type Field	185
6.4.8.6	Cable Current Field	185
6.4.8.7	PCIe Support Field	186
6.4.8.8	DP Support Field	186
6.4.8.9	TBT Support Field	186
6.4.8.10	Host Present Field	186
6.4.9	EPR_Request Message	186
6.4.10	EPR_Mode Message	186
6.4.10.1	Process to enter EPR Mode	187
6.4.10.2	Operation in EPR Mode	190
6.4.10.3	Exiting EPR Mode	190
6.4.10.3.1	Commanded Exit	190
6.4.10.3.2	Implicit Exit	190
6.4.10.3.3	Exits due to errors	191
6.4.11	Source_Info Message	191
6.4.11.1	Port Type Field	191

6.4.11.2	Port Maximum PDP Field	191
6.4.11.3	Port Present PDP Field	192
6.4.11.4	Port Reported PDP Field	192
6.4.12	Revision Message	192
6.5	Extended Message	192
6.5.1	Source_Capabilities_Extended Message	193
6.5.1.1	Vendor ID (VID) Field	195
6.5.1.2	Product ID (PID) Field	196
6.5.1.3	XID Field	196
6.5.1.4	Firmware Version Field	196
6.5.1.5	Hardware Version Field	196
6.5.1.6	Voltage Regulation Field	196
6.5.1.6.1	Load Step Slew Rate	196
6.5.1.6.2	Load Step Magnitude	196
6.5.1.7	Holdup Time Field	196
6.5.1.8	Compliance Field	196
6.5.1.9	Touch Current Field	196
6.5.1.10	Peak Current Field	197
6.5.1.11	Touch Temp Field	197
6.5.1.12	Source Inputs Field	197
6.5.1.13	Number of Batteries/Battery Slots Field	197
6.5.1.14	SPR Source PDP Rating Field	198
6.5.1.15	EPR Source PDP Rating Field	198
6.5.2	Status Message	198
6.5.2.1	SOP Status Message	198
6.5.2.1.1	Internal Temp Field	200
6.5.2.1.2	Present Input Field	200
6.5.2.1.3	Present Battery Input Field	200
6.5.2.1.4	Event Flags Field	200
6.5.2.1.5	Temperature Status Field	201
6.5.2.1.6	Power Status Field	201
6.5.2.1.7	Power state change	201
6.5.2.2	SOP'/SOP'' Status Message	201
6.5.2.2.1	Internal Temp Field	202
6.5.2.2.2	Thermal Shutdown Field	202
6.5.3	Get_Battery_Cap Message	202
6.5.4	Get_Battery_Status Message	203
6.5.5	Battery_Capabilities Message	203
6.5.5.1	Battery Design Capacity Field	204
6.5.5.2	Battery Last Full Charge Capacity Field	204
6.5.5.3	Battery Type Field	204
6.5.5.3.1	Invalid Battery Reference	204
6.5.6	Get_Manufacturer_Info Message	204
6.5.7	Manufacturer_Info Message	205
6.5.7.1	Vendor ID (VID)	205
6.5.7.2	Product ID (PID)	205
6.5.7.3	Manufacturer String	206
6.5.8	Security Messages	206
6.5.8.1	Security_Request	206

6.5.8.2	Security_Response	206
6.5.9	Firmware Update Messages	207
6.5.9.1	Firmware_Update_Request	207
6.5.9.2	Firmware_Update_Response	207
6.5.10	PPS_Status Message	207
6.5.10.1	Output Voltage Field	208
6.5.10.2	Output Current Field	208
6.5.10.3	Real Time Flags Field	208
6.5.11	Country_Codes Message	208
6.5.11.1	Country Code Field	209
6.5.12	Country_Info Message	209
6.5.12.1	Country Code Field	209
6.5.12.2	Country Specific Data Field	209
6.5.13	Sink_Capabilities_Extended Message	210
6.5.13.1	Vendor ID (VID) Field	212
6.5.13.2	Product ID (PID) Field	212
6.5.13.3	XID Field	212
6.5.13.4	Firmware Version Field	212
6.5.13.5	Hardware Version Field	212
6.5.13.6	SKEDB Version Field	212
6.5.13.7	Load Step Field	212
6.5.13.8	Sink Load Characteristics Field	212
6.5.13.9	Compliance Field	212
6.5.13.10	Touch Temp	212
6.5.13.11	Battery Info	212
6.5.13.12	Sink Modes	213
6.5.13.13	Sink Minimum PDP	213
6.5.13.14	Sink Operational PDP	213
6.5.13.15	Sink Maximum PDP	213
6.5.13.16	EPR Sink Minimum PDP	213
6.5.13.17	EPR Sink Operational PDP	213
6.5.13.18	EPR Sink Maximum PDP	214
6.5.14	Extended_Control Message	214
6.5.14.1	EPR_Get_Source_Cap Message	214
6.5.14.2	EPR_Get_Sink_Cap Message	215
6.5.14.3	EPR_KeepAlive Message	215
6.5.14.4	EPR_KeepAlive_Ack Message	215
6.5.15	EPR Capabilities Message	215
6.5.15.1	EPR Capabilities Message Construction	215
6.5.15.2	EPR_Source_Capabilities Message	216
6.5.15.3	EPR_Sink_Capabilities Message	216
6.5.16	Vendor_Defined_Extended Message	216
6.6	Timers	217
6.6.1	CRCReceiveTimer	217
6.6.2	SenderResponseTimer	218
6.6.3	Capability Timers	218
6.6.3.1	SourceCapabilityTimer	218
6.6.3.2	SinkWaitCapTimer	218
6.6.3.3	tFirstSourceCap	219

6.6.4	Wait Timers and Times	219
6.6.4.1	SinkRequestTimer	219
6.6.4.2	tPRSwapWait	219
6.6.4.3	tDRSwapWait	219
6.6.4.4	tVconnSwapWait	219
6.6.5	Power Supply Timers	220
6.6.5.1	PSTransitionTimer	220
6.6.5.2	PSSourceOffTimer	220
6.6.5.2.1	Use during Power Role Swap	220
6.6.5.2.2	Use during Fast Role Swap	220
6.6.5.3	PSSourceOnTimer	221
6.6.5.3.1	Use during Power Role Swap	221
6.6.5.3.2	Use during Fast Role Swap	221
6.6.6	NoResponseTimer	221
6.6.7	BIST Timers	222
6.6.7.1	tBISTCarrierMode	222
6.6.7.2	BISTContModeTimer	222
6.6.7.3	tBISTSharedTestMode	222
6.6.8	Power Role Swap Timers	222
6.6.8.1	SwapSourceStartTimer	222
6.6.9	Soft Reset Timers	222
6.6.9.1	tSoftReset	222
6.6.9.2	tProtErrSoftReset	222
6.6.10	Data Reset Timers	222
6.6.10.1	VCONNDischargeTimer	222
6.6.10.2	tDataReset	223
6.6.10.3	DataResetFailTimer	223
6.6.11	Hard Reset Timers	223
6.6.11.1	HardResetCompleteTimer	223
6.6.11.2	PSHardResetTimer	223
6.6.11.3	tDRSwapHardReset	223
6.6.11.4	tProtErrHardReset	223
6.6.12	Structured VDM Timers	224
6.6.12.1	VDMResponseTimer	224
6.6.12.2	VDMModeEntryTimer	224
6.6.12.3	VDMModeExitTimer	224
6.6.12.4	tVDMBusy	225
6.6.13	VCONN Timers	225
6.6.13.1	VCONNOnTimer	225
6.6.13.2	tVCONNSourceOff	225
6.6.14	tCableMessage	225
6.6.15	DiscoverIdentityTimer	225
6.6.16	Collision Avoidance Timers	225
6.6.17	Fast Role Swap Timers	226
6.6.17.1	tFRSwap5V	226
6.6.17.2	tFRSwapComplete	226
6.6.17.3	tFRSwapInit	226
6.6.18	Chunking Timers	226
6.6.18.1	ChunkingNotSupportedTimer	226

6.6.18.2	ChunkSenderRequestTimer	226
6.6.18.3	ChunkSenderResponseTimer	226
6.6.19	Programmable Power Supply Timers	227
6.6.19.1	SinkPPSPeriodicTimer	227
6.6.19.2	SourcePPSCommTimer	227
6.6.20	tEnterUSB	227
6.6.21	EPR Timers	228
6.6.21.1	SinkEPREnterTimer Timer	228
6.6.21.2	SinkEPRKeepAlive Timer	228
6.6.21.3	SourceEPRKeepAlive Timer	228
6.6.22	Time Values and Timers	228
6.7	Counters	232
6.7.1	MessageID Counter	232
6.7.1.1	Transmitter Usage	232
6.7.1.2	Receiver Usage	232
6.7.2	Retry Counter	232
6.7.3	Hard Reset Counter	233
6.7.4	Capabilities Counter	233
6.7.5	Discover Identity Counter	233
6.7.6	VDMBusyCounter	233
6.7.7	Counter Values and Counters	233
6.8	Reset	234
6.8.1	Soft Reset and Protocol Error	234
6.8.2	Data Reset	236
6.8.3	Hard Reset	236
6.8.3.1	Cable Plugs and Hard Reset	237
6.8.3.2	Modal Operation and Hard Reset	237
6.8.4	Cable Reset	237
6.9	Collision Avoidance	237
6.10	Message Discarding	237
6.11	State behavior	239
6.11.1	Introduction to state diagrams used in Chapter 6	239
6.11.2	State Operation	239
6.11.2.1	Protocol Layer Chunking	240
6.11.2.1.1	Architecture of Device Including Chunking Layer	240
6.11.2.1.2	Chunked Rx State Diagram	242
6.11.2.1.3	Chunked Tx State Diagram	245
6.11.2.1.4	Chunked Message Router State Diagram	249
6.11.2.2	Protocol Layer Message Transmission	251
6.11.2.2.1	Common Protocol Layer Message Transmission State Diagram	251
6.11.2.2.2	Source Protocol Layer Message Transmission State Diagram	254
6.11.2.2.3	Sink Protocol Layer Message Transmission State Diagram	255
6.11.2.3	Protocol Layer Message Reception	256
6.11.2.3.1	PRL_Rx_Wait_for_PHY_Message state	257
6.11.2.3.2	PRL_Rx_Layer_Reset_for_Receive state	257
6.11.2.3.3	PRL_Rx_Send_GoodCRC state	258
6.11.2.3.4	PRL_Rx_Check_MessageID state	258

6.11.2.3.5	PRL_Rx_Store_MessageID state	258
6.11.2.4	Hard Reset operation	259
6.11.2.4.1	PRL_HR_Reset_Layer state	260
6.11.2.4.2	PRL_HR_Indicate_Hard_Reset state	260
6.11.2.4.3	PRL_HR_Request_Hard_Reset state	260
6.11.2.4.4	PRL_HR_Wait_for_PHY_Hard_Reset_Complete state	260
6.11.2.4.5	PRL_HR_PHY_Hard_Reset_Requested state	261
6.11.2.4.6	PRL_HR_Wait_for_PE_Hard_Reset_Complete state	261
6.11.2.4.7	PRL_HR_PE_Hard_Reset_Complete	261
6.11.3	List of Protocol Layer States	262
6.12	Message Applicability	264
6.12.1	Applicability of Control Messages	265
6.12.2	Applicability of Data Messages	266
6.12.3	Applicability of Extended Messages	267
6.12.4	Applicability of Extended Control Messages	269
6.12.5	Applicability of Structured VDM Commands	269
6.12.6	Applicability of Reset Signaling	270
6.12.7	Applicability of Fast Role Swap signal	270
6.13	Value Parameters	272
7.	Power Supply	272
7.1	Source Requirements	272
7.1.1	Behavioral Aspects	272
7.1.2	Source Bulk Capacitance	272
7.1.3	Types of Sources	273
7.1.4	Source Transitions	273
7.1.4.1	Fixed Supply	273
7.1.4.1.1	Fixed Supply Positive Voltage Transitions	273
7.1.4.1.2	Fixed Supply Negative Voltage Transitions	274
7.1.4.2	SPR Programmable Power Supply (PPS)	275
7.1.4.2.1	SPR Programmable Power Supply Voltage Transitions	275
7.1.4.2.2	SPR Programmable Power Supply Current Limit	277
7.1.4.2.3	SPR PPS Constant Power Mode	280
7.1.4.3	EPR Adjustable Voltage Supply (AVS)	281
7.1.4.3.1	EPR Adjustable Voltage Supply Voltage Transitions	281
7.1.4.3.2	EPR Adjustable Voltage Supply Current	283
7.1.5	Response to Hard Resets	283
7.1.6	Changing the Output Power Capability	284
7.1.7	Robust Source Operation	284
7.1.7.1	Output Over Current Protection	284
7.1.7.2	Over Temperature Protection	285
7.1.7.3	vSafe5V Externally Applied to Ports Supplying vSafe5V	285
7.1.7.4	Detach	285
7.1.7.5	Output Voltage Limit	285
7.1.8	Output Voltage Tolerance and Range	286
7.1.8.1	Programmable Power Supply Output Voltage Tolerance and Range	286

7.1.8.2	Adjustable Voltage Supply Output Voltage tolerance and Range	287
7.1.9	Charging and Discharging the Bulk Capacitance on V_{BUS}	287
7.1.10	Swap Standby for Sources	287
7.1.11	Source Peak Current Operation	287
7.1.12	Source Capabilities Extended Parameters	289
7.1.12.1	Voltage Regulation Field	289
7.1.12.1.1	Load Step Slew Rate	289
7.1.12.1.2	Load Step Magnitude	289
7.1.12.2	Holdup Time Field	289
7.1.12.3	Compliance Field	290
7.1.12.4	Peak Current	290
7.1.12.5	Source Inputs	290
7.1.12.6	Batteries	291
7.1.13	Fast Role Swap	291
7.1.14	Non-application of V_{BUS} Slew Rate Limits	292
7.1.15	VCONN Power Cycle	293
7.1.15.1	UFP VCONN Power Cycle	293
7.1.15.2	DFP VCONN Power Cycle	293
7.2	Sink Requirements	294
7.2.1	Behavioral Aspects	294
7.2.2	Sink Bulk Capacitance	294
7.2.3	Sink Standby	295
7.2.3.1	Programmable Power Supply Sink Standby	295
7.2.4	Suspend Power Consumption	295
7.2.5	Zero Negotiated Current	295
7.2.6	Transient Load Behavior	295
7.2.7	Swap Standby for Sinks	296
7.2.8	Sink Peak Current Operation	296
7.2.9	Robust Sink Operation	296
7.2.9.1	Sink Bulk Capacitance Discharge at Detach	296
7.2.9.2	Input Over Voltage Protection	297
7.2.9.3	Over Temperature Protection	297
7.2.9.4	Over Current Protection	297
7.2.10	Fast Role Swap	298
7.3	Transitions	299
7.3.1	Increasing the Current	300
7.3.2	Increasing the Voltage	302
7.3.3	Increasing the Voltage and Current	304
7.3.4	Increasing the Voltage and Decreasing the Current	306
7.3.5	Decreasing the Voltage and Increasing the Current	308
7.3.6	Decreasing the Current	310
7.3.7	Decreasing the Voltage	312
7.3.8	Decreasing the Voltage and the Current	314
7.3.9	Sink Requested Power Role Swap	316
7.3.10	Source Requested Power Role Swap	318
7.3.11	GotoMin Current Decrease	320
7.3.12	Source Initiated Hard Reset	322
7.3.13	Sink Initiated Hard Reset	324

7.3.14	No change in Current or Voltage	326
7.3.15	Fast Role Swap	328
7.3.16	Increasing the Programmable Power Supply (PPS) Voltage	330
7.3.17	Decreasing the Programmable Power Supply (PPS) Voltage	332
7.3.18	Increasing the Adjustable Voltage Supply (AVS) Voltage	334
7.3.19	Decreasing the Adjustable Voltage Supply (AVS) Voltage	336
7.3.20	Changing the Source PDO or APDO	338
7.3.21	Increasing the Programmable Power Supply Current	340
7.3.22	Decreasing the Programmable Power Supply Current	342
7.3.23	Same Request Programmable Power Supply	344
7.4	Electrical Parameters	345
7.4.1	Source Electrical Parameters	345
7.4.2	Sink Electrical Parameters	351
7.4.3	Common Electrical Parameters	352
8.	Device Policy	353
8.1	Overview	353
8.2	Device Policy Manager	353
8.2.1	Capabilities	355
8.2.2	System Policy	355
8.2.3	Control of Source/Sink	355
8.2.4	Cable Detection	355
8.2.4.1	Device Policy Manager in a Provider	355
8.2.4.2	Device Policy Manager in a Consumer	356
8.2.4.3	Device Policy Manager in a Consumer/Provider	356
8.2.4.4	Device Policy Manager in a Provider/Consumer	356
8.2.5	Managing Power Requirements	356
8.2.5.1	Managing the Power Reserve	356
8.2.5.2	Power Capability Mismatch	357
8.2.5.2.1	Local device handling of mismatch	357
8.2.5.2.2	Device Policy Manager Communication with System Policy	357
8.2.6	Use of “Unconstrained Power” bit with Batteries and AC supplies	358
8.2.6.1	AC Supplies	358
8.2.6.2	Battery Supplies	359
8.2.7	Interface to the Policy Engine	360
8.2.7.1	Device Policy Manager in a Provider	360
8.2.7.2	Device Policy Manager in a Consumer	360
8.2.7.3	Device Policy Manager in a Dual-Role Power Device	360
8.2.7.4	Device Policy Manager in a Dual-Role Power Device Dead Battery handling	360
8.3	Policy Engine	361
8.3.1	Introduction	361
8.3.2	Atomic Message Sequence Diagrams	361
8.3.2.1	Introduction	361
8.3.2.1.1	Basic Message Exchange	361
8.3.2.1.2	Errors in Basic Message flow	362
8.3.2.1.3	Interruptible and Non-Interruptible Atomic Message Sequences	366
8.3.2.2	Power Negotiation	367

8.3.2.2.1	SPR.....	367
8.3.2.2.2	EPR.....	375
8.3.2.3	Soft Reset.....	394
8.3.2.4	Data Reset.....	396
8.3.2.4.1	DFP Initiated Data Reset where the DFP is the VCONN Source.....	396
8.3.2.4.2	DFP Receives Data Reset where the DFP is the VCONN Source.....	398
8.3.2.4.3	DFP Initiated Data Reset where the UFP is the VCONN Source.....	401
8.3.2.4.4	DFP Receives Data Reset where the UFP is the VCONN Source.....	405
8.3.2.5	Hard Reset.....	409
8.3.2.5.1	Source Initiated Hard Reset.....	409
8.3.2.5.2	Sink Initiated Hard Reset.....	412
8.3.2.5.3	Source Initiated Hard Reset – Sink Long Reset.....	415
8.3.2.6	Power Role Swap.....	419
8.3.2.6.1	Source Initiated Power Role Swap without subsequent Power Negotiation.....	419
8.3.2.6.2	Sink Initiated Power Role Swap without subsequent Power Negotiation.....	424
8.3.2.7	Fast Role Swap.....	429
8.3.2.8	Data Role Swap.....	434
8.3.2.8.1	Data Role Swap, Initiated by UFP Operating as Sink.....	434
8.3.2.8.2	Data Role Swap, Initiated by UFP Operating as Source.....	436
8.3.2.8.3	Data Role Swap, Initiated by DFP Operating as Source.....	438
8.3.2.8.4	Data Role Swap, Initiated by DFP Operating as Sink.....	440
8.3.2.9	VCONN Swap.....	442
8.3.2.9.1	Source to Sink VCONN Source Swap.....	442
8.3.2.9.2	Sink to Source VCONN Source Swap.....	445
8.3.2.10	Additional Capabilities, Status and Information.....	448
8.3.2.10.1	Alert.....	448
8.3.2.10.2	Status.....	451
8.3.2.10.3	Source/Sink Capabilities.....	457
8.3.2.10.4	Extended Capabilities.....	465
8.3.2.10.5	Battery Capabilities and Status.....	469
8.3.2.10.6	Manufacturer Information.....	477
8.3.2.10.7	Country Codes.....	487
8.3.2.10.8	Country Information.....	493
8.3.2.11	Security.....	499
8.3.2.11.1	Source requests security exchange with Sink.....	499
8.3.2.11.2	Sink requests security exchange with Source.....	501
8.3.2.11.3	VCONN Source requests security exchange with Cable Plug.....	503
8.3.2.12	Firmware Update.....	505
8.3.2.12.1	Source requests firmware update exchange with Sink.....	505

8.3.2.12.2	Sink requests firmware update exchange with Source	507
8.3.2.12.3	VCONN Source requests firmware update exchange with Cable Plug	509
8.3.2.13	Structured VDM	511
8.3.2.13.1	DFP to UFP Discover Identity	511
8.3.2.13.2	Source Port to Cable Plug Discover Identity	512
8.3.2.13.3	DFP to Cable Plug Discover Identity	515
8.3.2.13.4	DFP to UFP Enter Mode	517
8.3.2.13.5	DFP to UFP Exit Mode	519
8.3.2.13.6	DFP to Cable Plug Enter Mode	521
8.3.2.13.7	DFP to Cable Plug Exit Mode	523
8.3.2.13.8	UFP to DFP Attention	525
8.3.2.14	Built in Self-Test (BIST)	526
8.3.2.14.1	BIST Carrier Mode	526
8.3.2.14.2	BIST Test Data	527
8.3.2.15	Enter USB	531
8.3.2.15.1	UFP Entering USB4TM Mode (Valid)	531
8.3.2.15.2	Cable Plug Entering USB4 Mode (Valid)	533
8.3.2.15.3	UFP Entering USB4 Mode (Invalid)	534
8.3.2.15.4	Cable Plug Entering USB4 Mode (Invalid)	536
8.3.2.16	Unstructured Vendor Defined Messages	538
8.3.2.16.1	Unstructured VDM	538
8.3.2.16.2	Unstructured VDEM	540
8.3.3	State Diagrams	542
8.3.3.1	Introduction to state diagrams used in Chapter 8	542
8.3.3.2	Policy Engine Source Port State Diagram	544
8.3.3.2.1	PE_SRC_Startup State	546
8.3.3.2.2	PE_SRC_Discovery State	546
8.3.3.2.3	PE_SRC_Send_Capabilities State	547
8.3.3.2.4	PE_SRC_Negotiate_Capability State	548
8.3.3.2.5	PE_SRC_Transition_Supply State	548
8.3.3.2.6	PE_SRC_Ready State	548
8.3.3.2.7	PE_SRC_Disabled State	549
8.3.3.2.8	PE_SRC_Capability_Response State	549
8.3.3.2.9	PE_SRC_Hard_Reset State	550
8.3.3.2.10	PE_SRC_Hard_Reset_Received State	550
8.3.3.2.11	PE_SRC_Transition_to_default State	550
8.3.3.2.12	PE_SRC_Get_Sink_Cap State	551
8.3.3.2.13	PE_SRC_Wait_New_Capabilities State	551
8.3.3.2.14	PE_SRC_EPR_Keep_Alive State	551
8.3.3.2.15	PE_SRC_Give_Source_Cap State	551
8.3.3.3	Policy Engine Sink Port State Diagram	553
8.3.3.3.1	PE_SNK_Startup State	554
8.3.3.3.2	PE_SNK_Discovery State	554
8.3.3.3.3	PE_SNK_Wait_for_Capabilities State	554
8.3.3.3.4	PE_SNK_Evaluate_Capability State	554
8.3.3.3.5	PE_SNK_Select_Capability State	555
8.3.3.3.6	PE_SNK_Transition_Sink State	555

8.3.3.3.7	PE_SNK_Ready State	555
8.3.3.3.8	PE_SNK_Hard_Reset State	556
8.3.3.3.9	PE_SNK_Transition_to_default State	557
8.3.3.3.10	PE_SNK_Give_Sink_Cap State	557
8.3.3.3.11	PE_SNK_EPR_Keep_Alive	557
8.3.3.3.12	PE_SNK_Get_Source_Cap State	557
8.3.3.4	SOP Soft Reset and Protocol Error State Diagrams	558
8.3.3.4.1	Source Port Soft Reset and Protocol Error State Diagram	558
8.3.3.4.2	SOP Sink Port Soft Reset and Protocol Error State Diagram	560
8.3.3.5	Data Reset State Diagrams	561
8.3.3.5.1	DFP Data_Reset Message State Diagrams	561
8.3.3.5.2	UFP Data_Reset Message State Diagrams	563
8.3.3.6	Not Supported Message State Diagrams	565
8.3.3.6.1	Source Port Not Supported Message State Diagram	565
8.3.3.6.2	Sink Port Not Supported Message State Diagram	567
8.3.3.7	Source Port Ping State Diagram	568
8.3.3.7.1	PE_SRC_Ping State	568
8.3.3.8	Source Alert State Diagrams	568
8.3.3.8.1	Source Port Source Alert State Diagram	568
8.3.3.8.2	Sink Port Source Alert State Diagram	568
8.3.3.8.3	Sink Port Sink Alert State Diagram	569
8.3.3.8.4	Source Port Sink Alert State Diagram	569
8.3.3.9	Source Capabilities Extended State Diagrams	570
8.3.3.9.1	Sink Port Get Source Capabilities Extended State Diagram	570
8.3.3.9.2	Source Give Source Capabilities Extended State Diagram	570
8.3.3.10	Status State Diagrams	571
8.3.3.10.1	Sink Port Get Source Status State Diagram	571
8.3.3.10.2	Source Give Source Status State Diagram	571
8.3.3.10.3	Source Port Get Sink Status State Diagram	572
8.3.3.10.4	Sink Give Sink Status State Diagram	572
8.3.3.10.5	Sink Port Get Source PPS Status State Diagram	572
8.3.3.10.6	Source Give Source PPS Status State Diagram	573
8.3.3.11	Battery Capabilities State Diagrams	573
8.3.3.11.1	Get Battery Capabilities State Diagram	573
8.3.3.11.2	Give Battery Capabilities State Diagram	574
8.3.3.12	Battery Status State Diagrams	574
8.3.3.12.1	Get Battery Status State Diagram	574
8.3.3.12.2	Give Battery Status State Diagram	575
8.3.3.13	Manufacturer Information State Diagrams	575
8.3.3.13.1	Get Manufacturer Information State Diagram	575
8.3.3.13.2	Give Manufacturer Information State Diagram	576
8.3.3.14	Country Codes and Information State Diagrams	577
8.3.3.14.1	Get Country Codes State Diagram	577
8.3.3.14.2	Give Country Codes State Diagram	577

8.3.3.14.3	Get Country Information State Diagram	578
8.3.3.14.4	Give Country Information State Diagram	578
8.3.3.15	Enter_USB Message State Diagrams	579
8.3.3.15.1	DFP Enter_USB Message State Diagrams	579
8.3.3.15.2	UFP or Cable Plug Enter_USB Message State Diagrams	579
8.3.3.16	Security State Diagrams.....	580
8.3.3.16.1	Send Security Request State Diagram	580
8.3.3.16.2	Send Security Response State Diagram.....	580
8.3.3.16.3	Security Response Received State Diagram	581
8.3.3.17	Firmware Update State Diagrams.....	581
8.3.3.17.1	Send Firmware Update Request State Diagram	581
8.3.3.17.2	Send Firmware Update Response State Diagram.....	581
8.3.3.17.3	Firmware Update Response Received State Diagram.....	582
8.3.3.18	Dual-Role Port State Diagrams	582
8.3.3.18.1	DFP to UFP Data Role Swap State Diagram	583
8.3.3.18.2	UFP to DFP Data Role Swap State Diagram	585
8.3.3.18.3	Policy Engine in Source to Sink Power Role Swap State Diagram	587
8.3.3.18.4	Policy Engine in Sink to Source Power Role Swap State Diagram	589
8.3.3.18.5	Policy Engine in Source to Sink Fast Role Swap State Diagram.....	592
8.3.3.18.6	Policy Engine in Sink to Source Fast Role Swap State Diagram.....	594
8.3.3.18.7	Source Port Get Source Capabilities State Diagram.....	597
8.3.3.18.8	Dual-Role (Source Port) Give Sink Capabilities State Diagram.....	598
8.3.3.18.9	Dual-Role (Sink Port) Get Sink Capabilities State Diagram.....	598
8.3.3.18.10	Dual-Role (Sink Port) Give Source Capabilities State Diagram.....	599
8.3.3.18.11	Dual-Role (Source Port) Get Source Capabilities Extended State Diagram	599
8.3.3.18.12	Dual-Role (Sink Port) Give Source Capabilities Extended State Diagram	600
8.3.3.19	VCONN Swap State Diagram	600
8.3.3.19.1	PE_VCS_Send_Swap State	601
8.3.3.19.2	PE_VCS_Evaluate_Swap State	602
8.3.3.19.3	PE_VCS_Accept_Swap State	602
8.3.3.19.4	PE_VCS_Reject_Swap State	602
8.3.3.19.5	PE_VCS_UFP_Wait_for_VCONN State.....	603
8.3.3.19.6	PE_VCS_Turn_Off_VCONN State.....	603
8.3.3.19.7	PE_VCS_Turn_On_VCONN State.....	603
8.3.3.19.8	PE_VCS_Send_PS_Rdy State	603
8.3.3.19.9	PE_VCS_Force_VCONN State	603
8.3.3.20	Initiator Structured VDM State Diagrams	603
8.3.3.20.1	Initiator Structured VDM Discover Identity State Diagram.....	603

8.3.3.20.2	Initiator Structured VDM Discover SVIDs State Diagram.....	605
8.3.3.20.3	Initiator Structured VDM Discover Modes State Diagram.....	606
8.3.3.20.4	Initiator Structured VDM Attention State Diagram.....	607
8.3.3.21	Responder Structured VDM State Diagrams.....	608
8.3.3.21.1	Responder Structured VDM Discover Identity State Diagram.....	608
8.3.3.21.2	Responder Structured VDM Discover SVIDs State Diagram.....	608
8.3.3.21.3	Responder Structured VDM Discover Modes State Diagram.....	609
8.3.3.21.4	Receiving a Structured VDM Attention State Diagram.....	610
8.3.3.22	DFP Structured VDM State Diagrams.....	611
8.3.3.22.1	DFP Structured VDM Mode Entry State Diagram	611
8.3.3.22.2	DFP Structured VDM Mode Exit State Diagram.....	612
8.3.3.23	UFP Structured VDM State Diagrams.....	613
8.3.3.23.1	UFP Structured VDM Enter Mode State Diagram	614
8.3.3.23.2	UFP Structured VDM Exit Mode State Diagram.....	615
8.3.3.24	Cable Plug Specific State Diagrams.....	616
8.3.3.24.1	Cable Plug Cable Ready State Diagram.....	616
8.3.3.24.2	Soft/Hard/Cable Reset	616
8.3.3.24.3	Source Startup Structured VDM Discover Identity of a Cable Plug State Diagram	620
8.3.3.24.4	Cable Plug Mode Entry/Exit	621
8.3.3.25	EPR Mode State Diagrams.....	624
8.3.3.25.1	Source EPR Mode Entry State Diagram	624
8.3.3.25.2	Sink EPR Mode Entry State Diagram	626
8.3.3.25.3	Source EPR Mode Exit State Diagram	627
8.3.3.25.4	Sink EPR Mode Exit State Diagram	628
8.3.3.26	BIST State diagrams.....	628
8.3.3.26.1	BIST Carrier Mode State Diagram.....	628
8.3.3.27	USB Type-C Referenced States	629
8.3.3.27.1	ErrorRecovery state.....	629
8.3.3.28	Policy Engine States	630
9.	States and Status Reporting	636
9.1	Overview.....	636
9.1.1	PDUSB Device and Hub Requirements	638
9.1.2	Mapping to USB Device States	638
9.1.3	PD Software Stack.....	641
9.1.4	PDUSB Device Enumeration.....	641
9.2	PD Specific Descriptors.....	643
9.2.1	USB Power Delivery Capability Descriptor	643
9.2.2	Battery Info Capability Descriptor	644
9.2.3	PD Consumer Port Capability Descriptor	645
9.2.4	PD Provider Port Capability Descriptor	645
9.3	PD Specific Requests and Events	646
9.3.1	PD Specific Requests	646
9.4	PDUSB Hub and PDUSB Peripheral Device Requests.....	647

9.4.1	GetBatteryStatus	647
9.4.2	SetPDFeature	648
9.4.2.1	BATTERY_WAKE_MASK Feature Selector	648
9.4.2.2	CHARGING_POLICY Feature Selector	649
10.	Power Rules	650
10.1	Introduction	650
10.2	Source Power Rules	650
10.2.1	Source Power Rule Considerations	650
10.2.2	Normative Voltages and Currents	651
10.2.3	Optional Voltages/Currents	654
10.2.3.1	Optional Normative Fixed, Variable and Battery Supply	654
10.2.3.2	Optional Normative SPR Programmable Power Supply	654
10.2.3.2.1	SPR Programmable Power Supply Voltage Ranges	655
10.2.3.2.2	Examples of the use of SPR Programmable Power Supplies	655
10.2.3.3	Optional Normative Extended Power Range (EPR)	656
10.2.3.3.1	EPR Adjustable Voltage Supply (AVS) Voltage Ranges	659
10.2.4	Power sharing between ports	660
10.3	Sink Power Rules	660
10.3.1	Sink Power Rule Considerations	660
10.3.2	Normative Sink Rules	660
A.	CRC calculation	661
A.1	C code example	661
A.2	Table showing the full calculation over one Message	663
B.	PD Message Sequence Examples	664
B.1	External power is supplied downstream	664
B.2	External power is supplied upstream	667
B.3	Giving back power	674
C.	VDM Command Examples	684
C.1	Discover Identity Example	684
C.1.1	Discover Identity Command request	684
C.1.2	Discover Identity Command response – Active Cable	684
C.1.3	Discover Identity Command response – Hub	686
C.2	Discover SVIDs Example	687
C.2.1	Discover SVIDs Command request	687
C.2.2	Discover SVIDs Command response	687
C.3	Discover Modes Example	689
C.3.1	Discover Modes Command request	689
C.3.2	Discover Modes Command response	689
C.4	Enter Mode Example	691
C.4.1	Enter Mode Command request	691
C.4.2	Enter Mode Command response	691
C.4.3	Enter Mode Command request with additional VDO	692
C.5	Exit Mode Example	693
C.5.1	Exit Mode Command request	693
C.5.2	Exit Mode Command response	693
C.6	Attention Example	694

C.6.1	Attention Command request.....	694
C.6.2	Attention Command request with additional VDO.....	694
D.	BMC Receiver Design Examples	695
D.1	Finite Difference Scheme	695
D.1.1	Sample Circuitry	695
D.1.2	Theory	695
D.1.3	Data Recovery	698
D.1.4	Noise Zone and Detection Zone.....	698
D.2	Subtraction Scheme	699
D.2.1	Sample Circuitry	699
D.2.2	Output of Each Circuit Block	699
D.2.3	Subtractor Output at Power Source and Power Sink	700
D.2.4	Noise Zone and Detection Zone.....	701
E.	FRS System Level Example.....	701
E.1	Overview.....	701
E.2	FRS Initial Setup	703
E.3	FRS Process	705

This document is a preview generated by EVS

List of Tables

Table 1-1 Terms and Abbreviations.....	55
Table 2-1 Fixed Voltage Power Ranges	82
Table 2-2 PPS Voltage Power Ranges	83
Table 2-3 EPR Adjustable Voltage Supply Voltage Ranges	83
Table 5-1 4b5b Symbol Encoding Table	86
Table 5-2 Ordered Sets.	87
Table 5-3 Validation of Ordered Sets	87
Table 5-4 Data Size	88
Table 5-5 SOP ordered set.	89
Table 5-6 SOP' ordered set.	90
Table 5-7 SOP'' ordered set.....	90
Table 5-8 SOP'_Debug ordered set.	91
Table 5-9 SOP''_Debug ordered set.....	91
Table 5-10 CRC-32 Mapping.....	92
Table 5-11 Hard Reset ordered set.	93
Table 5-12 Cable Reset ordered set.....	94
Table 5-13 Rp values used for Collision Avoidance.....	95
Table 5-14 BMC Tx Mask Definition, X Values	99
Table 5-15 BMC Tx Mask Definition, Y Values	100
Table 5-16 BMC Rx Mask Definition.....	104
Table 5-17 BMC Common Normative Requirements.....	106
Table 5-18 BMC Transmitter Normative Requirements.....	106
Table 5-19 BMC Receiver Normative Requirements.....	109
Table 6-1 Message Header	114
Table 6-2 Revision Interoperability during an Explicit Contract.....	117
Table 6-3 Extended Message Header	118
Table 6-4 Use of Unchunked Message Supported bit	120
Table 6-5 Control Message Types.....	124
Table 6-6 Data Message Types.....	133
Table 6-7 Power Data Object	134
Table 6-8 Augmented Power Data Object	135
Table 6-9 Fixed Supply PDO - Source.....	137
Table 6-10 Fixed Power Source Peak Current Capability	139
Table 6-11 Variable Supply (non-Battery) PDO - Source	139
Table 6-12 Battery Supply PDO - Source	140
Table 6-13 SPR Programmable Power Supply APDO - Source.....	140
Table 6-14 EPR Adjustable Voltage Supply APDO – Source	141
Table 6-15 Fixed Supply PDO - Sink.....	141
Table 6-16 Variable Supply (non-Battery) PDO - Sink	143
Table 6-17 Battery Supply PDO - Sink	143
Table 6-18 Programmable Power Supply APDO - Sink.....	144
Table 6-19 EPR Adjustable Voltage Supply APDO - Sink	144

Table 6-20 Fixed and Variable Request Data Object	145
Table 6-21 Fixed and Variable Request Data Object with GiveBack Support	145
Table 6-22 Battery Request Data Object	145
Table 6-23 Battery Request Data Object with GiveBack Support	145
Table 6-24 Programmable Request Data Object	146
Table 6-25 AVS Request Data Object	146
Table 6-26 BIST Data Object	150
Table 6-27 Unstructured VDM Header	153
Table 6-28 Structured VDM Header	154
Table 6-29 Structured VDM Commands	155
Table 6-30 SVID Values	155
Table 6-31 Commands and Responses	157
Table 6-32 ID Header VDO	159
Table 6-33 Product Types (UFP)	160
Table 6-34 Product Types (Cable Plug/VPD)	160
Table 6-35 Product Types (DFP)	161
Table 6-36 Cert Stat VDO	161
Table 6-37 Product VDO	161
Table 6-38 UFP VDO	162
Table 6-39 DFP VDO	163
Table 6-40 Passive Cable VDO	164
Table 6-41 Active Cable VDO 1	166
Table 6-42 Active Cable VDO 2	169
Table 6-43 VPD VDO	171
Table 6-44 Discover SVIDs Responder VDO	172
Table 6-45 Battery Status Data Object (BSDO)	180
Table 6-46 Alert Data Object	181
Table 6-47 Country Code Data Object	184
Table 6-48 Enter_USB Data Object	184
Table 6-49 EPR Mode Data Object (EPRMDO)	187
Table 6-50 Source_Info Data Object	191
Table 6-51 Revision Data Object	192
Table 6-52 Extended Message Types	193
Table 6-53 Source Capabilities Extended Data Block (SCEDB)	194
Table 6-54 SOP Status Data Block (SDB)	198
Table 6-55 SOP'/SOP'' Status Data Block (SDB)	202
Table 6-56 Get Battery Cap Data Block (GBCDB)	202
Table 6-57 Get Battery Status Data Block (GBSDB)	203
Table 6-58 Battery Capability Data Block (BCDB)	203
Table 6-59 Get Manufacturer Info Data Block (GMIDB)	204
Table 6-60 Manufacturer Info Data Block (MIDB)	205
Table 6-61 PPS Status Data Block (PPSSDB)	207
Table 6-62 Country Codes Data Block (CCDB)	209

Table 6-63 Country Info Data Block (CIDB).....	209
Table 6-64 Sink Capabilities Extended Data Block (SKEDB)	210
Table 6-65 Extended Control Data Block (SDB)	214
Table 6-66 Extended Control Message Types	214
Table 6-67 Time Values	229
Table 6-68 Timers.....	230
Table 6-69 Counter parameters	233
Table 6-70 Counters	234
Table 6-71 Response to an incoming Message (except VDM)	235
Table 6-72 Response to an incoming VDM.....	236
Table 6-73 Message discarding	238
Table 6-74 Protocol Layer States	262
Table 6-75 Applicability of Control Messages	265
Table 6-76 Applicability of Data Messages.....	266
Table 6-77 Applicability of Extended Messages	267
Table 6-78 Applicability of Extended Control Messages	269
Table 6-79 Applicability of Structured VDM Commands.....	269
Table 6-80 Applicability of Reset Signaling	270
Table 6-81 Applicability of Fast Role Swap signal	271
Table 6-82 Value Parameters	272
Table 7-1 Sequence Description for Increasing the Current.....	301
Table 7-2 Sequence Description for Increasing the Voltage	303
Table 7-3 Sequence Diagram for Increasing the Voltage and Current	305
Table 7-4 Sequence Description for Increasing the Voltage and Decreasing the Current.....	307
Table 7-5 Sequence Description for Decreasing the Voltage and Increasing the Current.....	309
Table 7-6 Sequence Description for Decreasing the Current.....	311
Table 7-7 Sequence Description for Decreasing the Voltage.....	313
Table 7-8 Sequence Description for Decreasing the Voltage and the Current.....	315
Table 7-9 Sequence Description for a Sink Requested Power Role Swap	317
Table 7-10 Sequence Description for a Source Requested Power Role Swap	319
Table 7-11 Sequence Description for a GotoMin Current Decrease.....	321
Table 7-12 Sequence Description for a Source Initiated Hard Reset	323
Table 7-13 Sequence Description for a Sink Initiated Hard Reset.....	325
Table 7-14 Sequence Description for no change in Current or Voltage.....	327
Table 7-15 Sequence Description for Fast Role Swap.....	328
Table 7-16 Sequence Description for Increasing the Programmable Power Supply Voltage	330
Table 7-17 Sequence Description for Decreasing the Programmable Power Supply Voltage	332
Table 7-18 Sequence Description for Increasing the Adjustable Voltage Supply Voltage.....	334
Table 7-19 Sequence Description for Decreasing the Adjustable Voltage Supply Voltage	336
Table 7-20 Sequence Description for Changing the Source PDO or APDO	338
Table 7-21 Sequence Description for increasing the Current in PPS mode.....	340

Table 7-22 Sequence Description for decreasing the Current in PPS mode.....	342
Table 7-23 Sequence Description for no change in Current or Voltage in PPS mode.....	344
Table 7-24 Source Electrical Parameters	345
Table 7-25 Sink Electrical Parameters	351
Table 7-26 Common Source/Sink Electrical Parameters.....	352
Table 8-1 Basic Message Flow	362
Table 8-2 Potential issues in Basic Message Flow	363
Table 8-3 Basic Message Flow with CRC failure	364
Table 8-4 Interruptible and Non-interruptible AMS.....	366
Table 8-5 Steps for a successful Power Negotiation.....	368
Table 8-6 Steps for a GotoMin Negotiation.....	371
Table 8-7 Steps for SPR PPS Keep Alive.....	373
Table 8-8 Steps for Entering EPR Mode (Success)	377
Table 8-9 Steps for Entering EPR Mode (Failure due to non-EPR cable).....	380
Table 8-10 Steps for Entering EPR Mode (Failure of VCONN Swap).....	382
Table 8-11 Steps for a successful EPR Power Negotiation.....	385
Table 8-12 Steps for EPR Keep Alive.....	388
Table 8-13 Steps for Exiting EPR Mode (Sink Initiated).....	390
Table 8-14 Steps for Exiting EPR Mode (Source Initiated)	392
Table 8-15 Steps for a Soft Reset	394
Table 8-16 Steps for a DFP Initiated Data Reset where the DFP is the VCONN Source	397
Table 8-17 Steps for a DFP Receiving a Data Reset where the DFP is the VCONN Source	399
Table 8-18 Steps for a DFP Initiated Data Reset where the UFP is the VCONN Source	403
Table 8-19 Steps for a DFP Receiving a Data Reset where the UFP is the VCONN Source	407
Table 8-20 Steps for Source initiated Hard Reset.....	411
Table 8-21 Steps for Sink initiated Hard Reset.....	414
Table 8-22 Steps for Source initiated Hard Reset – Sink long reset	416
Table 8-23 Steps for a Successful Source Initiated Power Role Swap Sequence	421
Table 8-24 Steps for a Successful Sink Initiated Power Role Swap Sequence	426
Table 8-25 Steps for a Successful Fast Role Swap Sequence.....	431
Table 8-26 Steps for Data Role Swap, UFP operating as Sink initiates	434
Table 8-27 Steps for Data Role Swap, UFP operating as Source initiates	436
Table 8-28 Steps for Data Role Swap, DFP operating as Source initiates	438
Table 8-29 Steps for Data Role Swap, DFP operating as Sink initiates	440
Table 8-30 Steps for Source to Sink VCONN Source Swap.....	443
Table 8-31 Steps for Sink to Source VCONN Source Swap.....	446
Table 8-32 Steps for Source Alert to Sink	449
Table 8-33 Steps for Sink Alert to Source	450
Table 8-34 Steps for a Sink getting Source Status Sequence.....	451
Table 8-35 Steps for a Source getting Sink Status Sequence.....	453
Table 8-36 Steps for a Sink getting Source PPS status Sequence	455
Table 8-37 Steps for a Sink getting Source Capabilities Sequence	457

Table 8-38 Steps for a Dual-Role Source getting Dual-Role Sink's capabilities as a Source Sequence	459
Table 8-39 Steps for a Source getting Sink Capabilities Sequence	461
Table 8-40 Steps for a Dual-Role Sink getting Dual-Role Source capabilities as a Sink Sequence	463
Table 8-41 Steps for a Sink getting Source extended capabilities Sequence	465
Table 8-42 Steps for a Dual-Role Source getting Dual-Role Sink extended capabilities Sequence	467
Table 8-43 Steps for a Sink getting Source Battery capabilities Sequence	469
Table 8-44 Steps for a Source getting Sink Battery capabilities Sequence	471
Table 8-45 Steps for a Sink getting Source Battery status Sequence	473
Table 8-46 Steps for a Source getting Sink Battery status Sequence	475
Table 8-47 Steps for a Source getting Sink's Port Manufacturer Information Sequence	477
Table 8-48 Steps for a Source getting Sink's Port Manufacturer Information Sequence	479
Table 8-49 Steps for a Source getting Sink's Battery Manufacturer Information Sequence	481
Table 8-50 Steps for a Source getting Sink's Battery Manufacturer Information Sequence	483
Table 8-51 Steps for a VCONN Source getting Sink's Port Manufacturer Information Sequence	485
Table 8-52 Steps for a Source getting Country Codes Sequence	487
Table 8-53 Steps for a Source getting Sink's Country Codes Sequence	489
Table 8-54 Steps for a VCONN Source getting Sink's Country Codes Sequence	491
Table 8-55 Steps for a Source getting Country Information Sequence	493
Table 8-56 Steps for a Source getting Sink's Country Information Sequence	495
Table 8-57 Steps for a VCONN Source getting Sink's Country Information Sequence	497
Table 8-58 Steps for a Source requesting a security exchange with a Sink Sequence	499
Table 8-59 Steps for a Sink requesting a security exchange with a Source Sequence	501
Table 8-60 Steps for a VCONN Source requesting a security exchange with a Cable Plug Sequence	503
Table 8-61 Steps for a Source requesting a firmware update exchange with a Sink Sequence	505
Table 8-62 Steps for a Sink requesting a firmware update exchange with a Source Sequence	507
Table 8-63 Steps for a VCONN Source requesting a firmware update exchange with a Cable Plug Sequence	509
Table 8-64 Steps for DFP to UFP Discover Identity	511
Table 8-65 Steps for Source Port to Cable Plug Discover Identity	513
Table 8-66 Steps for DFP to Cable Plug Discover Identity	515
Table 8-67 Steps for DFP to UFP Enter Mode	517
Table 8-68 Steps for DFP to UFP Exit Mode	519
Table 8-69 Steps for DFP to Cable Plug Enter Mode	521
Table 8-70 Steps for DFP to Cable Plug Exit Mode	523
Table 8-71 Steps for UFP to DFP Attention	525
Table 8-72 Steps for BIST Carrier Mode Test	527
Table 8-73 Steps for BIST Test Data Test	529

Table 8-74 Steps for UFP USB4 Mode Entry (Valid).....	531
Table 8-75 Steps for Cable Plug USB4 Mode Entry (Valid)	533
Table 8-76 Steps for UFP USB4 Mode Entry (Invalid)	535
Table 8-77 Steps for Cable Plug USB4 Mode Entry (Invalid)	537
Table 8-78 Steps for Unstructured VDM Message Sequence	539
Table 8-79 Steps for Unstructured VDEM Message Sequence	541
Table 8-80 Policy Engine States	630
Table 9-1 USB Power Delivery Type Codes	643
Table 9-2 USB Power Delivery Capability Descriptor	643
Table 9-3 Battery Info Capability Descriptor	644
Table 9-4 PD Consumer Port Descriptor	645
Table 9-5 PD Provider Port Descriptor	646
Table 9-6 PD Requests	646
Table 9-7 PD Request Codes.....	646
Table 9-8 PD Feature Selectors.....	647
Table 9-9 Battery Status Structure	647
Table 9-10 Battery Wake Mask	649
Table 9-11 Charging Policy Encoding	649
Table 10-1 Considerations for Sources	650
Table 10-2 SPR Normative Voltages and Minimum Currents	651
Table 10-3 Fixed Supply PDO – Source 5V	653
Table 10-4 Fixed Supply PDO – Source 9V	653
Table 10-5 Fixed Supply PDO – Source 15V.....	653
Table 10-6 Fixed Supply PDO – Source 20V.....	653
Table 10-7 SPR Programmable Power Supply PDOs and APDOs based on the PDP	654
Table 10-8 SPR Programmable Power Supply Voltage Ranges.....	655
Table 10-9 EPR Source Capabilities based in the Port's PDP	657
Table 10-10 EPR Source Capabilities based on a Shared Port's Equivalent PDP	658
Table 10-11 EPR Source Equivalent PDP Examples	659
Table 10-12 EPR Adjustable Voltage Supply (AVS) Voltage Ranges	660
Table B-1 External power is supplied downstream	665
Table B-2 External power is supplied upstream.....	668
Table B-3 Giving back power.	674
Table C-1 Discover Identity Command request from Initiator Example.	684
Table C-2 Discover Identity Command response from Active Cable Responder Example	685
Table C-3 Discover Identity Command response from Hub Responder Example	686
Table C-4 Discover SVIDs Command request from Initiator Example.	687
Table C-5 Discover SVIDs Command response from Responder Example.	687
Table C-6 Discover Modes Command request from Initiator Example.	689
Table C-7 Discover Modes Command response from Responder Example.....	689
Table C-8 Enter Mode Command request from Initiator Example.	691
Table C-9 Enter Mode Command response from Responder Example.....	691

Table C-10 Enter Mode Command request from Initiator Example.	692
Table C-11 Exit Mode Command request from Initiator Example.	693
Table C-12 Exit Mode Command response from Responder Example.	693
Table C-13 Attention Command request from Initiator Example.....	694
Table C-14 Attention Command request from Initiator with additional VDO Example	695
Table E-1 Sequence Table for setup of a Fast Role Swap (Hub connected to Power Adapter first).....	703
Table E-2 Sequence Table for setup of a Fast Role Swap (Hub connected to Notebook before Power Adapter)	704
Table E-3 Sequence Table for slow Vbus discharge (it discharges after FR_Swap message is sent).....	706
Table E-4 Vbus discharges quickly after adapter disconnected.	708

List of Figures

Figure 2-1 Logical Structure of USB Power Delivery Capable Devices	66
Figure 2-2 Example SOP' Communication between VCONN Source and Cable Plug(s)	68
Figure 2-3 USB Power Delivery Communications Stack	75
Figure 2-4 USB Power Delivery Communication Over USB	76
Figure 2-5 High Level Architecture View	77
Figure 2-6 Example of a Normal EPR Mode Operational Flow	82
Figure 5-1 Interpretation of ordered sets	87
Figure 5-2 Transmit Order for Various Sizes of Data	88
Figure 5-3 USB Power Delivery Packet Format	89
Figure 5-4 CRC 32 generation	92
Figure 5-5 Line format of Hard Reset	94
Figure 5-6 Line format of Cable Reset	94
Figure 5-7 BMC Example	95
Figure 5-8 BMC Transmitter Block Diagram	96
Figure 5-9 BMC Receiver Block Diagram	96
Figure 5-10 BMC Encoded Start of Preamble	96
Figure 5-11 Transmitting or Receiving BMC Encoded Frame Terminated by Zero with High-to-Low Last Transition	97
Figure 5-12 Transmitting or Receiving BMC Encoded Frame Terminated by One with High-to-Low Last Transition	97
Figure 5-13 Transmitting or Receiving BMC Encoded Frame Terminated by Zero with Low to High Last Transition	98
Figure 5-14 Transmitting or Receiving BMC Encoded Frame Terminated by One with Low to High Last Transition	98
Figure 5-15 BMC Tx 'ONE' Mask	99
Figure 5-16 BMC Tx 'ZERO' Mask	99
Figure 5-17 BMC Rx 'ONE' Mask when Sourcing Power	101
Figure 5-18 BMC Rx 'ZERO' Mask when Sourcing Power	102
Figure 5-19 BMC Rx 'ONE' Mask when Power neutral	102
Figure 5-20 BMC Rx 'ZERO' Mask when Power neutral	103
Figure 5-21 BMC Rx 'ONE' Mask when Sinking Power	103
Figure 5-22 BMC Rx 'ZERO' Mask when Sinking Power	104
Figure 5-23 Transmitter Load Model for BMC Tx from a Source	105
Figure 5-24 Transmitter Load Model for BMC Tx from a Sink	105
Figure 5-25 Transmitter diagram illustrating zDriver	107
Figure 5-26 Inter-Frame Gap Timings	108
Figure 5-27 Example Multi-Drop Configuration showing two DRPs	110
Figure 5-28 Example Multi-Drop Configuration showing a DFP and UFP	110
Figure 5-29 Test Data Frame	112
Figure 6-1 USB Power Delivery Packet Format including Control Message Payload	113
Figure 6-2 USB Power Delivery Packet Format including Data Message Payload	113
Figure 6-3 USB Power Delivery Packet Format including an Extended Message Header and Payload	114

Figure 6-4 Example Security_Request sequence Unchunked (Chunked bit = 0)	120
Figure 6-5 Example byte transmission for Security_Request Message of Data Size 7 (Chunked bit is set to 0)	120
Figure 6-6 Example byte transmission for Security_Response Message of Data Size 7 (Chunked bit is set to 0)	121
Figure 6-7 Example Security_Request sequence Chunked (Chunked bit = 1)	122
Figure 6-8 Example Security_Request Message of Data Size 7 (Chunked bit set to 1)	122
Figure 6-9 Example Chunk 0 of Security_Response Message of Data Size 30 (Chunked bit set to 1)	123
Figure 6-10 Example byte transmission for a Security_Response Message Chunk request (Chunked bit is set to 1)	123
Figure 6-11 Example Chunk 1 of Security_Response Message of Data Size 30 (Chunked bit set to 1)	124
Figure 6-12 Example Capabilities Message with 2 Power Data Objects	134
Figure 6-13 BIST Message	149
Figure 6-14 Vendor Defined Message	152
Figure 6-15 Discover Identity Command response	158
Figure 6-16 Discover Identity Command response for a DRD	158
Figure 6-17 Example Discover SVIDs response with 3 SVIDs	173
Figure 6-18 Example Discover SVIDs response with 4 SVIDs	173
Figure 6-19 Example Discover SVIDs response with 12 SVIDs followed by an empty response	173
Figure 6-20 Example Discover Modes response for a given SVID with 3 Modes	174
Figure 6-21 Successful Enter Mode sequence	175
Figure 6-22 Enter Mode sequence Interrupted by Source Capabilities and then Re-run	175
Figure 6-23 Unsuccessful Enter Mode sequence due to NAK	176
Figure 6-24 Exit Mode sequence	177
Figure 6-25 Attention Command request/response sequence	177
Figure 6-26 Command request/response sequence	178
Figure 6-27 Enter/Exit Mode Process	179
Figure 6-28 Battery_Status Message	180
Figure 6-29 Alert Message	181
Figure 6-30 Get_Country_Info Message	184
Figure 6-31 Enter_USB Message	184
Figure 6-32 EPR_Request Message	186
Figure 6-33 EPR Mode DO Message	187
Figure 6-34 Illustration of process to enter EPR Mode	188
Figure 6-35 Source_Info Message	191
Figure 6-36 Revision Message Data Object	192
Figure 6-37 Source_Capabilities_Extended Message	194
Figure 6-38 SOP Status Message	198
Figure 6-39 SOP'/SOP'' Status Message	202
Figure 6-40 Get_Battery_Cap Message	202
Figure 6-41 Get_Battery_Status Message	203
Figure 6-42 Battery_Capabilities Message	203

Figure 6-43 Get_Manufacturer_Info Message	204
Figure 6-44 Manufacturer_Info Message	205
Figure 6-45 Security_Request Message	206
Figure 6-46 Security_Response Message	206
Figure 6-47 Firmware_Update_Request Message	207
Figure 6-48 Firmware_Update_Response Message	207
Figure 6-49 PPS_Status Message	207
Figure 6-50 Country_Codes Message	209
Figure 6-51 Country_Info Message	209
Figure 6-52 Sink_Capabilities_Extended Message	210
Figure 6-53 Extended_Control Message	214
Figure 6-54 Mapping SPR Capabilities to EPR Capabilities	215
Figure 6-55 Vendor_Defined_Extended Message	217
Figure 6-56 Outline of States	239
Figure 6-57 References to states	239
Figure 6-58 Chunking architecture Showing Message and Control Flow	240
Figure 6-59 Chunked Rx State Diagram	242
Figure 6-60 Chunked Tx State Diagram	245
Figure 6-61 Chunked Message Router State Diagram	249
Figure 6-62 Common Protocol Layer Message Transmission State Diagram	251
Figure 6-63 Source Protocol Layer Message Transmission State Diagram	254
Figure 6-64 Sink Protocol Layer Message Transmission State Diagram	255
Figure 6-65 Protocol layer Message reception	257
Figure 6-66 Hard/Cable Reset	259
Figure 7-1 Placement of Source Bulk Capacitance	273
Figure 7-2 Transition Envelope for Positive Voltage Transitions	274
Figure 7-3 Transition Envelope for Negative Voltage Transitions	275
Figure 7-4 PPS Positive Voltage Transitions	276
Figure 7-5 PPS Negative Voltage Transitions	277
Figure 7-6 Expected PPS Ripple Relative to an LSB	277
Figure 7-7 SPR PPS Programmable Voltage and Current Limit	279
Figure 7-8 iPpsCLOperatingDetail	280
Figure 7-9 SPR PPS Programmable Voltage and Current Limit	281
Figure 7-10 AVS Positive Voltage Transitions	282
Figure 7-11 AVS Negative Voltage Transitions	282
Figure 7-12 Expected AVS Ripple Relative to an LSB	283
Figure 7-13 Source V _{BUS} and V _{CONN} Response to Hard Reset	284
Figure 7-14 Application of vSrcNew and vSrcValid limits after tSrcReady	286
Figure 7-15 Source Peak Current Overload	288
Figure 7-16 Holdup Time Measurement	290
Figure 7-17 V _{BUS} Power during Fast Role Swap	291
Figure 7-18 V _{BUS} detection and timing during Fast Role Swap, initial V _{BUS} (at new source) > vSafe5V (min).	292

Figure 7-19 V_{BUS} detection and timing during Fast Role Swap, initial V_{BUS} (at new source) < v_{Safe5V} (min).	292
Figure 7-20 Data Reset UFP VCONN Power Cycle	293
Figure 7-21 Data Reset DFP VCONN Power Cycle	294
Figure 7-22 Placement of Sink Bulk Capacitance	295
Figure 7-23 Transition Diagram for Increasing the Current	300
Figure 7-24 Transition Diagram for Increasing the Voltage	302
Figure 7-25 Transition Diagram for Increasing the Voltage and Current	304
Figure 7-26 Transition Diagram for Increasing the Voltage and Decreasing the Current	306
Figure 7-27 Transition Diagram for Decreasing the Voltage and Increasing the Current	308
Figure 7-28 Transition Diagram for Decreasing the Current	310
Figure 7-29 Transition Diagram for Decreasing the Voltage	312
Figure 7-30 Transition Diagram for Decreasing the Voltage and the Current	314
Figure 7-31 Transition Diagram for a Sink Requested Power Role Swap	316
Figure 7-32 Transition Diagram for a Source Requested Power Role Swap	318
Figure 7-33 Transition Diagram for a GotoMin Current Decrease	320
Figure 7-34 Transition Diagram for a Source Initiated Hard Reset	322
Figure 7-35 Transition Diagram for a Sink Initiated Hard Reset	324
Figure 7-36 Transition Diagram for no change in Current or Voltage	326
Figure 7-37 Transition Diagram for Fast Role Swap	328
Figure 7-38 Transition Diagram for Increasing the Programmable Power Supply Voltage	330
Figure 7-39 Transition Diagram for Decreasing the Programmable Power Supply Voltage	332
Figure 7-40 Transition Diagram for Increasing the Programmable Power Supply Voltage	334
Figure 7-41 Transition Diagram for Decreasing the Adjustable Voltage Supply Voltage	336
Figure 7-42 Transition Diagram for Changing the Source PDO or APDO	338
Figure 7-43 Transition Diagram for increasing the Current in PPS mode	340
Figure 7-44 Transition Diagram for decreasing the Current in PPS mode	342
Figure 7-45 Transition Diagram for no change in Current or Voltage in PPS mode	344
Figure 8-1 Example of daisy chained displays	359
Figure 8-2 Basic Message Exchange (Successful)	362
Figure 8-3 Basic Message flow indicating possible errors	363
Figure 8-4 Basic Message Flow with Bad CRC followed by a Retry	364
Figure 8-5 Successful Fixed, Variable or Battery SPR Power Negotiation	368
Figure 8-6 Successful GotoMin operation	371
Figure 8-7 SPR PPS Keep Alive	373
Figure 8-8 Entering EPR Mode (Success)	376
Figure 8-9 Entering EPR Mode (Failure due to non-EPR cable)	379
Figure 8-10 Entering EPR Mode (Failure of VCONN Swap)	382
Figure 8-11 Successful Fixed EPR Power Negotiation	385
Figure 8-12 EPR Keep Alive	388
Figure 8-13 Exiting EPR Mode (Sink Initiated)	390

Figure 8-14 Exiting EPR Mode (Source Initiated)	392
Figure 8-15 Soft Reset.....	394
Figure 8-16 DFP Initiated Data Reset where the DFP is the VCONN Source.....	396
Figure 8-17 DFP Receives Data Reset where the DFP is the VCONN Source.....	399
Figure 8-18 DFP Initiated Data Reset where the UFP is the Vconn Source	402
Figure 8-19 DFP Receives a Data Reset where the UFP is the VCONN Source	406
Figure 8-20 Source initiated Hard Reset	410
Figure 8-21 Sink Initiated Hard Reset	413
Figure 8-22 Source initiated reset - Sink long reset.....	416
Figure 8-23 Successful Power Role Swap Sequence Initiated by the Source	420
Figure 8-24 Successful Power Role Swap Sequence Initiated by the Sink.....	425
Figure 8-25 Successful Fast Role Swap Sequence	430
Figure 8-26 Data Role Swap, UFP operating as Sink initiates	434
Figure 8-27 Data Role Swap, UFP operating as Source initiates	436
Figure 8-28 Data Role Swap, DFP operating as Source initiates	438
Figure 8-29 Data Role Swap, DFP operating as Sink initiates	440
Figure 8-30 Source to Sink VCONN Source Swap.....	442
Figure 8-31 Sink to Source VCONN Source Swap.....	445
Figure 8-32 Source Alert to Sink	448
Figure 8-33 Sink Alert to Source	450
Figure 8-34 Sink Gets Source Status	451
Figure 8-35 Source Gets Sink Status	453
Figure 8-36 Sink Gets Source PPS Status	455
Figure 8-37 Sink Gets Source's Capabilities	457
Figure 8-38 Dual-Role Source Gets Dual-Role Sink's Capabilities as a Source	459
Figure 8-39 Source Gets Sink's Capabilities	461
Figure 8-40 Dual-Role Sink Gets Dual-Role Source's Capabilities as a Sink	463
Figure 8-41 Sink Gets Source's Extended Capabilities.....	465
Figure 8-42 Dual-Role Source Gets Dual-Role Sink's Extended Capabilities	467
Figure 8-43 Sink Gets Source's Battery Capabilities	469
Figure 8-44 Source Gets Sink's Battery Capabilities	471
Figure 8-45 Sink Gets Source's Battery Status	473
Figure 8-46 Source Gets Sink's Battery Status	475
Figure 8-47 Source Gets Sink's Port Manufacturer Information	477
Figure 8-48 Sink Gets Source's Port Manufacturer Information	479
Figure 8-49 Source Gets Sink's Battery Manufacturer Information	481
Figure 8-50 Sink Gets Source's Battery Manufacturer Information	483
Figure 8-51 VCONN Source Gets Cable Plug's Manufacturer Information	485
Figure 8-52 Source Gets Sink's Country Codes	487
Figure 8-53 Sink Gets Source's Country Codes	489
Figure 8-54 VCONN Source Gets Cable Plug's Country Codes	491
Figure 8-55 Source Gets Sink's Country Information	493
Figure 8-56 Sink Gets Source's Country Information	495

Figure 8-57 VCONN Source Gets Cable Plug's Country Information	497
Figure 8-58 Source requests security exchange with Sink.....	499
Figure 8-59 Sink requests security exchange with Source.....	501
Figure 8-60 VCONN Source requests security exchange with Cable Plug	503
Figure 8-61 Source requests firmware update exchange with Sink.....	505
Figure 8-62 Sink requests firmware update exchange with Source.....	507
Figure 8-63 VCONN Source requests firmware update exchange with Cable Plug	509
Figure 8-64 DFP to UFP Discover Identity.....	511
Figure 8-65 Source Port to Cable Plug Discover Identity.....	513
Figure 8-66 DFP to Cable Plug Discover Identity	515
Figure 8-67 DFP to UFP Enter Mode.....	517
Figure 8-68 DFP to UFP Exit Mode	519
Figure 8-69 DFP to Cable Plug Enter Mode	521
Figure 8-70 DFP to Cable Plug Exit Mode.....	523
Figure 8-71 UFP to DFP Attention.....	525
Figure 8-72 BIST Carrier Mode Test	526
Figure 8-73 BIST Test Data Test.....	528
Figure 8-74 UFP Entering USB4 Mode (Valid).....	531
Figure 8-75 Cable Plug Entering USB4 Mode (Valid)	533
Figure 8-76 UFP Entering USB4 Mode (Invalid)	535
Figure 8-77 Cable Plug Entering USB4 Mode (Invalid)	537
Figure 8-78 Unstructured VDM Message Sequence	539
Figure 8-79 Unstructured VDEM Message Sequence.....	541
Figure 8-80 Outline of States	542
Figure 8-81 References to states	543
Figure 8-82 Example of state reference with conditions	543
Figure 8-83 Example of state reference with the same entry and exit.....	543
Figure 8-84 Source Port Policy Engine State Diagram	545
Figure 8-85 Sink Port State Diagram.....	553
Figure 8-86 Source Port Soft Reset and Protocol Error State Diagram.....	558
Figure 8-87 Sink Port Soft Reset and Protocol Error Diagram	560
Figure 8-88 DFP Data_Reset Message State Diagram.....	562
Figure 8-89 UFP Data_Reset Message State Diagram.....	564
Figure 8-90 Source Port Not Supported Message State Diagram	566
Figure 8-91 Sink Port Not Supported Message State Diagram	567
Figure 8-92 Source Port Ping State Diagram.....	568
Figure 8-93 Source Port Source Alert State Diagram	568
Figure 8-94 Sink Port Source Alert State Diagram	568
Figure 8-95 Sink Port Sink Alert State Diagram.....	569
Figure 8-96 Source Port Sink Alert State Diagram	569
Figure 8-97 Sink Port Get Source Capabilities Extended State Diagram	570
Figure 8-98 Source Give Source Capabilities Extended State Diagram	570
Figure 8-99 Sink Port Get Source Status State Diagram	571

Figure 8-100 Source Give Source Status State Diagram	571
Figure 8-101 Source Port Get Sink Status State Diagram	572
Figure 8-102 Sink Give Sink Status State Diagram	572
Figure 8-103 Sink Port Get Source PPS Status State Diagram.....	573
Figure 8-104 Source Give Source PPS Status State Diagram	573
Figure 8-105 Get Battery Capabilities State Diagram	574
Figure 8-106 Give Battery Capabilities State Diagram.....	574
Figure 8-107 Get Battery Status State Diagram	575
Figure 8-108 Give Battery Status State Diagram	575
Figure 8-109 Get Manufacturer Information State Diagram	576
Figure 8-110 Give Manufacturer Information State Diagram.....	576
Figure 8-111 Get Country Codes State Diagram	577
Figure 8-112 Give Country Codes State Diagram.....	577
Figure 8-113 Get Country Information State Diagram.....	578
Figure 8-114 Give Country Information State Diagram	578
Figure 8-115 DFP Enter_USB Message State Diagram	579
Figure 8-116 UFP Enter_USB Message State Diagram	579
Figure 8-117 Send security request State Diagram	580
Figure 8-118 Send security response State Diagram.....	580
Figure 8-119 Security response received State Diagram	581
Figure 8-120 Send firmware update request State Diagram	581
Figure 8-121 Send firmware update response State Diagram.....	582
Figure 8-122 Firmware update response received State Diagram.....	582
Figure 8-123: DFP to UFP Data Role Swap State Diagram	583
Figure 8-124: UFP to DFP Data Role Swap State Diagram	585
Figure 8-125: Dual-Role Port in Source to Sink Power Role Swap State Diagram	587
Figure 8-126: Dual-role Port in Sink to Source Power Role Swap State Diagram.....	590
Figure 8-127: Dual-Role Port in Source to Sink Fast Role Swap State Diagram	593
Figure 8-128: Dual-role Port in Sink to Source Fast Role Swap State Diagram	595
Figure 8-129 Dual-Role (Source) Get Source Capabilities diagram	597
Figure 8-130 Dual-Role (Source) Give Sink Capabilities diagram.....	598
Figure 8-131 Dual-Role (Sink) Get Sink Capabilities State Diagram	598
Figure 8-132 Dual-Role (Sink) Give Source Capabilities State Diagram	599
Figure 8-133 Dual-Role (Source) Get Source Capabilities Extended State Diagram.....	600
Figure 8-134 Dual-Role (Source) Give Sink Capabilities diagram.....	600
Figure 8-135 VCONN Swap State Diagram	601
Figure 8-136 Initiator to Port VDM Discover Identity State Diagram	604
Figure 8-137 Initiator VDM Discover SVIDs State Diagram	605
Figure 8-138 Initiator VDM Discover Modes State Diagram.....	606
Figure 8-139 Initiator VDM Attention State Diagram.....	607
Figure 8-140 Responder Structured VDM Discover Identity State Diagram.....	608
Figure 8-141 Responder Structured VDM Discover SVIDs State Diagram	609
Figure 8-142 Responder Structured VDM Discover Modes State Diagram.....	610

Figure 8-143 Receiving a Structured VDM Attention State Diagram	611
Figure 8-144 DFP VDM Mode Entry State Diagram	611
Figure 8-145 DFP VDM Mode Exit State Diagram	613
Figure 8-146 UFP Structured VDM Enter Mode State Diagram	614
Figure 8-147 UFP Structured VDM Exit Mode State Diagram	615
Figure 8-148 Cable Ready VDM State Diagram	616
Figure 8-149 Cable Plug Soft Reset State Diagram	616
Figure 8-150 Cable Plug Hard Reset State Diagram	617
Figure 8-151 DFP/VCONN Source Soft Reset or Cable Reset of a Cable Plug or VPD State Diagram	618
Figure 8-152 UFP/VCONN Source Soft Reset of a Cable Plug or VPD State Diagram	619
Figure 8-153 Source Startup Structured VDM Discover Identity State Diagram	620
Figure 8-154 Cable Plug Structured VDM Enter Mode State Diagram	622
Figure 8-155 Cable Plug Structured VDM Exit Mode State Diagram	623
Figure 8-156 Source EPR Mode Entry State Diagram	624
Figure 8-157 Sink EPR Mode Entry State Diagram	626
Figure 8-158 Source EPR Mode Exit State Diagram	627
Figure 8-159 Sink EPR Mode Exit State Diagram	628
Figure 8-160 BIST Carrier Mode State Diagram	629
Figure 9-1 Example PD Topology	637
Figure 9-2 Mapping of PD Topology to USB	638
Figure 9-3 USB Attached to USB Powered State Transition	639
Figure 9-4 Any USB State to USB Attached State Transition (When operating as a Consumer)	640
Figure 9-5 Any USB State to USB Attached State Transition (When operating as a Provider)	640
Figure 9-6 Any USB State to USB Attached State Transition (After a USB Type-C Data Role Swap)	641
Figure 9-7 Software stack on a PD aware OS	641
Figure 9-8 Enumeration of a PDUSB Device	642
Figure 10-1 SPR Source Power Rule Illustration	652
Figure 10-2 SPR Source Power Rule Example	652
Figure 10-3 Valid EPR AVS Operating Region	659
Figure B-1 External Power supplied downstream	664
Figure B-2 External Power supplied upstream	668
Figure B-3 Giving Back Power	674
Figure D-1 Circuit Block of BMC Finite Difference Receiver	695
Figure D-2 BMC AC and DC noise from VBUS at Power Sink	696
Figure D-3 Sample BMC Signals (a) without [USB 2.0] SE0 Noise (b) with [USB 2.0] SE0 Noise	697
Figure D-4 Scaled BMC Signal Derivative with 50ns Sampling Rate	697
Figure D-5 BMC Signal and Finite Difference Output with Various Time Steps	698
Figure D-6 Output of Finite Difference in dash line and Edge Detector in solid line	698
Figure D-7 Noise Zone and Detect Zone of BMC Receiver	699
Figure D-8 Circuit Block of BMC Subtraction Receiver	699

Figure D-9 (a) Output of LPF1 and LPF2 (b) Subtraction of LPF1 and LPF2 Output	700
Figure D-10 Output of the BMC LPF1 in blue dash curve and the Subtractor in red solid curve	700
Figure E-1 Example FRS Capable System	701
Figure E-2 Slow V_{BUS} Discharge.....	702
Figure E-3 Fast V_{BUS} Discharge	703
Figure E-4 Sequence Diagram for slow VBUS discharge (it discharges after FR_Swap message is sent).....	706

This document is a preview generated by EVS

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 can 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 [\[USB 2.0\]](#), [\[USB 3.2\]](#), [\[USB Type-C 2.0\]](#) 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:

- Works seamlessly with legacy USB Devices
- Compatible with existing spec-compliant USB cables

- Minimizes potential damage from non-compliant cables (e.g., ‘Y’ cables etc.)
- 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 VCONN to a powered cable.

To facilitate optimum charging, the specification defines two mechanisms a USB Charger can Advertise for the Device to use:

1. A list of fixed Voltages each with a maximum current. The Device selects a Voltage and current from the list. This is the traditional model used by Devices that use internal electronics to manage the charging of their battery including modifying the Voltage and current actually supplied to the battery. The side-effect of this model is that the charging circuitry generates heat that may be problematic for small form factor devices.
2. A list of programmable Voltage ranges each with a maximum current (PPS). The Device requests a Voltage (in 20mV increments in SPR PPS Mode and in 100mV increments in EPR AVS Mode) that is within the Advertised range and a maximum current. The USB Charger delivers the requested Voltage until the maximum current is reached at which time the USB charger reduces its output Voltage so as not to supply more than the requested maximum current. During the high current portion of the charge cycle, the USB Charger can be directly connected (through an appropriate safety device) to the battery. This model is used by Devices that want to minimize the thermal impact of their internal charging circuitry.

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:

- [\[USB 2.0\]](#), [\[USB 3.2\]](#) in band requests for high power interfaces.
- [\[USBBC 1.2\]](#) mechanisms for supplying higher power (not mandated by this specification).
- [\[USB Type-C 2.0\]](#) mechanisms for supplying higher power.

Initial operating conditions remain the USB Default Operation as defined in [\[USB 2.0\]](#), [\[USB 3.2\]](#), [\[USB Type-C 2.0\]](#) 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 [\[USB 2.0\]](#), [\[USB 3.2\]](#), [\[USB Type-C 2.0\]](#) 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 [\[USB 2.0\]](#), [\[USB 3.2\]](#), [\[USB Type-C 2.0\]](#) 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, illustrates 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.

In there is a conflict between a generic statement and a more specific statement, the more specific statement **Shall** apply.

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

Discard, **Discards** and **Discarded** are equivalent keywords 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

Ignore, **Ignores** and **Ignored** are equivalent keywords indicating Messages or Message fields which, when received, **Shall** result in no special action by the receiver. An **Ignored** Message **Shall** only result in returning a **GoodCRC** Message to acknowledge Message receipt. A Message with an **Ignored** field **Shall** be processed normally except for any actions relating to the **Ignored** field.

1.4.2.5 Invalid

Invalid is a keyword when used in relation to a Packet indicates that the Packet'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. When **Invalid** is used in relation to individual K-codes or K-code sequences indicates that the received Signaling falls outside of the defined specification.

1.4.2.6 May

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

1.4.2.7 May Not

May Not is a keyword that is the inverse of **May**. Indicates a choice to not implement a given feature with no implied preference.

1.4.2.8 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.

1.4.2.9 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.

1.4.2.10 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.

1.4.2.11 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.

1.4.2.12 Shall Not

Shall Not is a keyword that is the inverse of **Shall** indicating non-compliant operation.

1.4.2.13 Should

Should is a keyword indicating flexibility of choice with a preferred alternative; equivalent to the phrase “it is recommended that...”.

1.4.2.14 Should Not

Should Not is a keyword is the inverse of **Should**; equivalent to the phrase “it is recommended that implementations do not...”.

1.4.2.15 Valid

Valid is a keyword that is the inverse of **Invalid** indicating either a Packet or Signaling that fall within the defined specification or an Explicit Contract that can be maintained by the Source.

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

Document references listed below are inclusive of all approved and published ECNs and Errata:

- **[USB 2.0]** – Universal Serial Bus Specification, Revision 2.0, http://www.usb.org/developers/docs/usb20_docs/.
- **[USB 3.2]** – Universal Serial Bus 3.2 Specification, Revision 1.0, September 22, 2017. 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, September 15, 2016. <http://www.usb.org/developers/powerdelivery/>
- **[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 1.1]** – Universal Serial Bus Type-C Bridge Specification, Revision 1.1, October 10, 2017. 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.
- **[USBPD 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, Revision 1.1, September 2020 http://www.usb.org/developers/docs/devclass_docs/.
- **[USB Type-C 2.1]** – Universal Serial Bus Type-C Cable and Connector Specification, Revision 2.1, May 2021 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 62368-3]** IEC 62368-1 Audio/video, information and communication technology equipment - Part 3: Safety aspects for DC power transfer through communication cables and ports
- **[IEC 63002]** IEC 63002, Interoperability specifications and communication method for external power supplies used with computing and consumer electronics devices
- **[ISO 3166]** ISO 3166 international Standard for country codes and codes for their subdivisions. http://www.iso.org/iso/home/standards/country_codes.htm.
- **[USB4]** – Universal Serial Bus 4 Specification (USB4™), Version 1.0, August 2019. www.usb.org/developers/docs.
- **[DPTC2.0]** DisplayPort™ Alt Mode on USB Type-C® Standard, Version 2.0, 12 March 2020. www.vesa.org.
- **[TBT3]** see **[USB4]** Chapter 13 for Thunderbolt™ 3 device operation.

1.6 Terms and Abbreviations

This section defines terms used throughout this document. For additional terms that pertain to the Universal Serial Bus, see Chapter 2, “Terms and Abbreviations,” in **[USB 2.0]**, **[USB 3.2]**, **[USB Type-C 2.0]** and **[USBBC 1.2]**.

Table 1-1 Terms and Abbreviations

Term	Description
Active Cable	A cable with a USB Plug on each end at least one of which is a Cable Plug supporting SOP ¹ , that also incorporates data bus signal conditioning circuits. The cable supports the Structured VDM Discover Identity Command to determine its characteristics in addition to other Structured VDM Commands (Electronically Marked Cable see [USB Type-C 2.0]).
Active Mode	A Mode which has been entered and not exited.
Adjustable Voltage Supply (AVS)	A power supply whose output Voltage can be adjusted to an operating Voltage within its Advertised range. These capabilities are exposed by the Adjustable Voltage Supply (AVS) APDO (see Section 6.4.1.2.5). Note unlike the SPR PPS, the EPR AVS does not support current limit.
Advertised	An offer made by a Source in the Capabilities/EPR Capabilities message (e.g., an APDO or PDO).
Alternate Mode	As defined in [USB Type-C 2.0] . Equivalent to Mode in the PD Specification.
Alternate Mode Adapter (AMA)	A PDUSB Device which supports Alternate Modes as defined in [USB Type-C 2.0] . Note that since an AMA is a PDUSB Device it has a single UFP that is only addressable by SOP Packets.