

IPC-2591-Version 1.6

2023 - March

Connected Factory Exchange (CFX)

Supersedes IPC-2591, Version 1.5

July 2022

An international standard developed by IPC



BUILD ELECTRONICS BETTER

IPC Mission

IPC is a global trade association dedicated to furthering the competitive excellence and financial success of its members, who are participants in the electronics industry.

In pursuit of these objectives, IPC will devote resources to management improvement and technology enhancement programs, the creation of relevant standards, protection of the environment, and pertinent government relations.

IPC encourages the active participation of all its members in these activities and commits to full cooperation with all related organizations.

About IPC Standards

IPC standards and publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for their particular need. Existence of such IPC standards and publications shall not in any respect preclude any entity from manufacturing or selling products not conforming to such IPC standards and publication, nor shall the existence of such IPC standards and publications preclude their voluntary use.

IPC standards and publications are approved by IPC committees without regard to whether the IPC standards or publications may involve patents on articles, materials or processes. By such action, IPC does not assume any liability to any patent owner, nor does IPC assume any obligation whatsoever to parties adopting an IPC standard or publication. Users are wholly responsible for protecting themselves against all claims of liabilities for patent infringement.

IPC Position Statement on Specification Revision Change

The use and implementation of IPC standards and publications are voluntary and part of a relationship entered into by customer and supplier. When an IPC standard or publication is revised or amended, the use of the latest revision or amendment as part of an existing relationship is not automatic unless required by the contract. IPC recommends the use of the latest revision or amendment.

Standards Improvement Recommendations

IPC welcomes comments for improvements to any standard in its library. All comments will be provided to the appropriate committee.

If a change to technical content is requested, data to support the request is recommended. Technical comments to include new technologies or make changes to published requirements should be accompanied by technical data to support the request. This information will be used by the committee to resolve the comment.

To submit your comments, visit the IPC Status of Standardization page at www.ipc.org/status.



IPC-2591-Version 1.6

Connected Factory Exchange (CFX)

Developed by the IPC-CFX Standard Task Group (2-17a) of the
Electronic Product Data Description Committee (2-10) of IPC

Supersedes:

IPC-2591, Version 1.5 -
July 2022
IPC-2591-Version 1.4 -
December 2021
IPC-2591-Version 1.3 -
February 2021
IPC-2591-Version 1.2 -
September 2020
IPC-2591-Version 1.1 -
January 2020
IPC-2591 -
March 2019

Users of this publication are encouraged to participate in the
development of future revisions.

Contact:

IPC
3000 Lakeside Drive, Suite 105N
Bannockburn, Illinois
60015-1249
Tel 847 615.7100
Fax 847 615.7105

This Page Intentionally Left Blank

Acknowledgment

Any document involving a complex technology draws material from a vast number of sources across many continents. While the principal members of the IPC-CFX Standard Task Group (2-17a) of the Electronic Product Data Description Committee (2-10) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

Electronic Product Data Description Committee	IPC-CFX Standard Task Group	Technical Liaison of the IPC Board of Directors
Chair Michael Ford Aegis Software	Co-Chairs Thomas Marktscheffel ASMPT GmbH & Co. KG Michael Ford Aegis Software	Bob Neves Microtek (Changzhou) Laboratories

IPC recognizes this A-Team for their exceptional leadership and effort in the development of this standard.

Plug & Players A-Team

Tim Burke Arch Systems	Wes Karpiak Celestica	Zakary Smith Mata Inventive
YenChi Chang Mata Inventive	Michael Kimpton Fuji America Corporation	Lorenzo Stilo The Manufacturing Technology Centre
Michael Ford Aegis Software UK	Thomas Marktscheffel ASMPT GmbH & Co. KG	John Walls Aegis Software
Alexis Fouquet Europlacer	Neil Martin The Manufacturing Technology Centre	Jarrod Webb Lockheed Martin Missiles & Fire Control
Helena Gurusamy CloudVidia	Dmitrii Pesterev Continental Automotive Hungary Kft.	
Ula Hijawi The Manufacturing Technology Centre	Michael Rauter Flextronics International GmbH	
Naim Kapadia The Manufacturing Technology Centre	Neaven Seo Keysight Technologies	

IPC-CFX Standard Task Group

Nicolas Bartschat ERSA GmbH	Sean Clancy HZO Inc	Tom Hamelinckx ST Engineering iDirect
Jennifer Bennett IBM Corporation	Julie Cliche-Dubois Cogiscan Inc.	Richard Helou 3D Photonix
Frederic Bourdat MBtech	Benoit Fillastre MBtech	Ula Hijawi The Manufacturing Technology Centre
Tim Burke Arch Systems	Michael Ford Aegis Software UK	Ramesh Kandasamy Getech Automation
Javier Caraccioli Lockheed Martin Missiles & Fire Control	Alexis Fouquet Europlacer	Naim Kapadia The Manufacturing Technology Centre
YenChi Chang Mata Inventive	Christian Fritsch SICK AG	Wes Karpiak Celestica
Zhiman Chen ZHUZHOU CRRC TIMES ELECTRIC CO., LTD	Mahendra Gandhi Northrop Grumman Space Systems	Noriyuki Kato Omron Manufacturing Netherlands
	Helena Gurusamy CloudVidia	

Jeff Kennedy ZESTRON Americas	Dmitrii Pesterev Continental Automotive Hungary Kft.	Raj Takhar Assent Compliance Inc.
Martin Kubicek PBT Works s.r.o.	Colas Peyrelier LACROIX Electronics Beaupreau	Lauren Tori HGC Westshore LLC
Michael Lange Northrop Grumman	Bart Piwowar DarwinAI	John Walls Aegis Software
Geoffrey Leeds Insulectro	Sarumathi Ramasamy Getech Automation	Jeff Wayne NAS Electronics
Goncalo Leitao SMT Worldwide	Michael Rauter Flextronics International GmbH	Jarrold Webb Lockheed Martin Missiles & Fire Control
Te-ming Liao Sunsda Technology Co., Ltd.	Naveen Ravindran ZESTRON Americas	Perla Wehbe I.F. Engineering
Thomas Marktscheffel ASMPT GmbH & Co. KG	Raquel Rodriguez Quintero INSYTE, S.A.	Ronny Witzgall SMA Solar Technology AG
Neil Martin The Manufacturing Technology Centre	Jacky Shu Flextronics Electronics Technology (Suzhou) Co. Ltd.	Chih Wong Suzhou LinkWays Tech Co., Ltd.
Zohair Mehkri Flextronics International	Vladimir Sitko PBT Works s.r.o.	Chia-ta Wu Sunsda Technology Co., Ltd.
Miles Moreau KIC	Zakary Smith Mata Inventive	Mike Xu Lof Intelligent Technology Co., Ltd
Bruno Muller Essemtec AG	Lorenzo Stilo The Manufacturing Technology Centre	
John Neiderman Vitronics Soltec	John Striker Vitronics Soltec	
Catalina Pamatmat Temic Automotive (Phils.) Inc.		

Table of Contents

1	SCOPE	1	2	APPLICABLE DOCUMENTS	4
1.1	Purpose	1	2.1	IPC	4
1.2	Application of This Standards	1	2.2	ECMA International	4
1.3	CFX and The Hermes Standard	1	2.3	International Organization for Standardization (ISO).....	4
1.4	Updates to This Standard.....	1	2.4	SEMI	4
1.5	Definition of Requirements	2	3	GENERAL REQUIREMENTS	4
1.6	Order of Precedences.....	2	3.1	Guidance on the Use of This Standard	4
1.6.1	Conflict	2	3.1.1	Technical Reference	4
1.6.2	Clause References	2	3.1.2	Application Reference	4
1.7	Acronyms.....	2	3.2	Users of CFX.....	4
1.8	Terms and Definitions	2	3.2.1	Automated Assembly Processes.....	5
1.8.1	Activity	2	3.2.2	In-House Manufacturing Solution Development	5
1.8.2	Component	2	3.2.3	MES Software Solutions	5
1.8.3	Dashboard	2	3.3	Software Development Environment.....	5
1.8.4	Data Integrity	2	3.4	CFX Support Declaration	5
1.8.5	Endpoint	3	4	CFX STRUCTURAL OVERVIEW	5
1.8.6	Factory Resource	3	4.1	Primary Transport Layer: AMQP v1.0.	5
1.8.7	Lane	3	4.1.1	CFX Message Channels.....	6
1.8.8	Lock	3	4.1.2	Channel Configuration	7
1.8.9	Material Carrier	3	4.1.4	CFX Compression.....	7
1.8.10	Material Chain.....	3	4.1.5	CFX – AMQP Message Properties.....	7
1.8.11	Material Location.....	3	4.2	Encoding: JSON.....	7
1.8.12	Material Package	3	4.2.1	JSON Data Types.....	8
1.8.13	Material Traceability	3	4.3	CFX-Defined Content	9
1.8.14	Materials	3	4.4	CFX Key Parameters.....	9
1.8.15	Operator	3	4.4.1	Endpoint Identification (CFX Handle).	9
1.8.16	Process Endpoint (Station)	3	4.4.2	TransactionID	9
1.8.17	Production Unit.....	3	4.5	CFX Message Envelope.....	10
1.8.18	Recipe	3	4.6	Operator Information.....	10
1.8.19	Root	3	4.7	CFX Endpoint Configuration	10
1.8.20	Setup.....	3	4.7.1	Specific CFX Endpoint Configuration Addresses.....	11
1.8.21	State (Production State)	3	4.8	Message Attachments	12
1.8.22	Station (Process Endpoint)	3	4.8.1	Specifying Message Attachments	12
1.8.23	Stage	3	4.8.2	In-Band Message Attachments	12
1.8.24	Subassembly.....	3	4.8.3	Out-of-Band Attachments	13
1.8.25	Symptom	3			
1.8.26	Tool.....	4			
1.8.27	Transactional Endpoint	4			

4.8.4	Supported Tabular Data Formats For Message Attachments	13	7.2.4	CFX.InformationSystem.DataTransfer (Level 2).....	33
4.9	Supported Message Attachment Types	14	7.3	CFX.Maintenance (Level 1) Messages related to Maintenance.....	33
4.9.1	SolderPasteInspection.SolderPaste Measurement	14	7.4	CFX.Materials (Level 1)	34
4.9.2	PCBInspection.OffsetMeasurement.....	14	7.4.1	CFX.Materials.Management (Level 2).....	34
4.10	Messages Supporting Attachments	15	7.4.1.1	CFX.Materials.Management.MSDManagement (Level 3).....	35
4.11	CFX Message Recorder	15	7.4.2	CFX.Materials.Storage (Level 2)	35
5	CFX OPERATIONAL MODELING	16	7.4.3	CFX.Materials.Transport (Level 2)	36
5.1	Equipment State Model	16	7.5	CFX.Production (Level 1).....	36
5.2	Station Fault Event Model.....	18	7.5.1	CFX.Production.Application (Level 2)	38
5.3	Production Unit Architecture.....	18	7.5.2	CFX.Production.Assembly (Level 2).....	38
5.3.1	Production Unit Status	20	7.5.2.1	CFX.Production.Assembly.PressInsertion (Level 3).....	38
5.3.2	Production Endpoint Decision-Making Categories	20	7.5.3	CFX.Production.Hermes (Level 2).....	39
5.3.3	Examples of Production Unit Status	21	7.5.4	CFX.Production.LoadingAndUnloading (Level 2)	39
5.3.3.1	Processing Station.....	21	7.5.5	CFX.Production.Processing (Level 2)	39
5.3.3.2	Processing Station Creating Scrap	21	7.5.6	CFX.Production.ReworkAndRepair (Level 2).....	39
5.3.3.3	Inspection Station Identifying Potential Defect.....	21	7.5.7	CFX.Production.TestAndInspection (Level 2)	40
5.3.3.4	Review/Repair Station Resolving Failed Production Unit.....	22	7.6	CFX.ResourcePerformance (Level 1).....	40
5.3.3.5	Review/Repair Station Scrapping Failed Production Unit.....	22	7.6.1	CFX.ResourcePerformance.PressInsertion (Level 2).....	41
5.4	Production Station Process Model	23	7.6.2	CFX.ResourcePerformance.SMTPlacement (Level 2).....	42
6	CFX TOPICS AND DYNAMIC STRUCTURES	23	7.6.3	CFX.ResourcePerformance.SolderPastePrinting (Level 2).....	42
6.1	Hierarchy of CFX Topics.....	24	7.6.4	CFX.ResourcePerformance.THTInsertion (Level 2).....	42
6.1.1	CFX Topic Support Declaration.....	25	7.7	CFX.Sensor (Level 1)	42
6.2	CFX Message Names	25	7.7.1	CFX.Sensor.Identification (Level 2)	42
6.3	CFX Structures	25	7.8	CFX Message Flow	43
6.4	CFX Dynamic Structures.....	25	7.8.1	Production Endpoint (Station) Connection.....	43
6.5	CFX Messaging Requirements by Equipment Type	25	7.8.2	Station State Transition.....	44
7	CFX MESSAGES	31	7.8.3	Station Processing.....	45
7.1	Root Level Messages.....	31	8	CFX TECHNICAL REFERENCE	46
7.2	CFX.InformationSystem (Level 1).....	32	APPENDIX A	Version Updates	47
7.2.1	CFX.InformationSystem.ProductionScheduling (Level 2).....	32	APPENDIX B	Index of Acronyms and Abbreviations ..	57
7.2.2	CFX.InformationSystem.UnitValidation (Level 2)	32			
7.2.3	CFX.InformationSystem.WorkOrderManagement (Level 2)	32			

Figures

Figure 1-1 Version Change Tracking Example 2

Figure 4-2 The CFX TransactionID 9

Figure 5-1 SEMI E10 Equipment State Model 15

Figure 5-2 Examples of Groupings of Production Units..... 19

Figure 5-3 Panelized Printed Board (Top View)..... 20

Figure 5-4 CFX Unit Locations Identified on Multiple-Board Panel (Top View) 20

Figure 5-5 Panel Processing Example – No Defects Found..... 21

Figure 5-6 Panel Processing Example – One Production Unit Scrapped..... 21

Figure 5-7 Panel Inspection Example – One Production Unit Failure..... 22

Figure 5-8 Panel Review/Repair Example – One Production Unit Repaired..... 22

Figure 5-9 Panel Review/Repair Example – Whole Panel Scrapped..... 22

Figure 5-10 CFX Production Station Process Model ... 23

Figure 7-1 CFX Station Connection Example Message Flow 43

Figure 7-2 CFX Station State Transition Example Message Flow 44

Figure 7-3 CFX Station Processing Example Message Flow 45

Tables

Table 4-1 Types of CFX Messages 7

Table 4-2 CFX – AMQP Message Properties..... 8

Table 4-3 CFX Message Envelope 10

Table 4-4 Format of Attachments Array Entries..... 12

Table 4-5 Columns for SolderPasteMeasurement Attachment Type 14

Table 4-6 Columns for OffsetMeasurement Attachment Type 15

Table 5-1 Station Event Fault Model 18

Table 6-1 CFX Capability Requirements by Equipment..... 26

Table 6-2 Required Messages by Capability 28

Table 7-1 CFX.Root Messages 32

Table 7-2 CFX.InformationSystem.ProductionScheduling Messages 32

Table 7-3 CFX.InformationSystem.UnitValidation Messages..... 32

Table 7-4 CFX.InformationSystem.WorkOrder Management Messages 33

Table 7-5 CFX.InformationSystem.DataTransfer Messages 33

Table 7-6 CFX.Maintenance Messages..... 34

Table 7-7 CFX.Materials.Management Messages.... 35

Table 7-8 CFX.Materials.Management.MSDManagement Messages..... 35

Table 7-9 CFX.Materials.Storage Messages..... 36

Table 7-10 CFX.Materials.Transport Messages 36

Table 7-11 CFX.Production Messages..... 37

Table 7-12 CFX.Production.Application Messages.... 38

Table 7-13 CFX.Production.Assembly Messages 38

Table 7-14 CFX.Production.Assembly.PressInsertion Messages 38

Table 7-15 CFX.Production.Hermes Messages..... 39

Table 7-16 CFX.Production.LoadingAndUnloading Messages 39

Table 7-17 CFX.Production.Processing Messages..... 39

Table 7-18 CFX.Production.ReworkAndRepair 40

Table 7-19 CFX.Production.TestAndInspection Messages 40

Table 7-20 CFX.ResourcePerformance Messages 41

Table 7-22 CFX.ResourcePerformance.SMTPlacement Messages 42

Table 7-23 CFX.ResourcePerformance.SolderPaste Printing Messages..... 42

Table 7-24 CFX.ResourcePerformance.THTInsertion Messages 42

Table 7-25 CFX.Sensor.Identification Messages 43

This Page Intentionally Left Blank

Connected Factory Exchange (CFX) Version 1.6

1 SCOPE

This standard establishes the requirements for the omnidirectional exchange of information between manufacturing processes and associated host systems for assembly manufacturing. This standard applies to communication between all executable processes in the manufacture of printed board assemblies – automated, semiautomated and manual – and is applicable to related mechanical assembly and transactional processes.

1.1 Purpose With the growth and acceptance of digital modeling and practices in manufacturing, the lack of a holistic Industrial Internet of Things (IIoT) standard for the transfer of information between machines, systems and processes has become a severe limitation to the growth of digitization and computerization in the electronics manufacturing industry, inhibiting technology innovations such as Industry 4.0 and Smart Factories being available to all companies in the industry, regardless of size, sector and location.

This Connected Factory Exchange (CFX) standard provides a true “plug and play” Internet of Things (IoT) communication environment throughout manufacturing, where all equipment, manufacturing processes and transactional stations can communicate with each other without the need for the development and use of bespoke interfaces. CFX-enabled equipment and solutions from different vendors work seamlessly together.

There are many types of users of this CFX standard, including equipment vendors, solution providers, in-house information technology (IT) groups, etc. The many types of data included in CFX are used in different ways depending on the application; for example, closed-loop feedback systems, live production dashboards, traceability (IPC-1782), manufacturing execution systems (MES) control, lean supply chain management, active quality management, production control, etc.

As CFX data is fully omnidirectional, any CFX endpoint connection can consume data as well as create it. As an illustration, consider the scenario in which a single machine from a certain vendor is connected in-line with other machines from different vendors. CFX messages are sent from the single machine to other machines in the line, and to host systems such as MES. The single machine can also receive CFX messages from all other machines in the line, as well as from the host systems in order to optimize the machine operation and enable the vendor of the machines to create added-value functionality, such as to support machine-specific Industry 4.0. In this way, a smart, digital, Industry 4.0 factory will be comprised of many different Industry 4.0 computerization applications, each of which can be provided by different suppliers, at the machine, line, site and even enterprise levels, all working together, sharing data seamlessly through CFX.

This CFX standard supports the concept of big data by including data of different types from across the factory, including performance, materials, resources, users, quality events, product tracking, etc., all of which can be combined to create a big-data environment. CFX, therefore, provides many kinds of added value opportunities to the whole manufacturing operation, including, for example, improving operational efficiency and productivity, quality and reliability, agility and responsiveness. This CFX standard helps organizations ensure that end users/consumers will receive products and services that meet or exceed their expectations and in the timeliest and most economically viable method.

1.2 Application of This Standard This standard defines the communication protocol and content across all assembly production processes, irrespective of type or method of operation. It can also be applied to transactional operations. There are no restrictions in terms of product classification sector, size of operation or location. Surface-mount technology (SMT) production is not required to be a part of the factory. Though intended to support all aspects of printed board production, the use of CFX can be extended downstream to include, for example, mechanical assembly, personalization, packing and shipping, as well as upstream to include, for example, electrical and mechanical subassemblies.

1.3 CFX and The Hermes Standard This CFX standard is complementary to IPC-HERMES-9852. The Hermes Standard, as an advanced, intelligent Surface Mount Equipment Manufacturers Association (SMEMA) standard replacement, provides near-instant line control, passing information about production units as they pass down the line. CFX provides vertical messaging that is complementary to Hermes.

1.4 Updates to This Standard The IPC-CFX Standard Task Group intends to make frequent incremental revisions to this standard to support additional machines and processes. Version updates are identified by version number and the change (added, removed, etc.), so the reader can easily identify changes in each version. See Figure 1-1 for an example of this version change tracking using a portion of the CFX.Materials.Management table of this standard as an example.

Appendix A also provides an itemized version history.