

IPC-2591-Version 1.5

2022 - July

**Connected Factory
Exchange (CFX)**

Supersedes IPC-2591, Version 1.4
December 2021

An international standard developed by IPC



BUILD ELECTRONICS BETTER

The Principles of Standardization

In May 1995 the IPC's Technical Activities Executive Committee (TAEC) adopted Principles of Standardization as a guiding principle of IPC's standardization efforts.

Standards Should:

- Show relationship to Design for Manufacturability (DFM) and Design for the Environment (DFE)
- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

Standards Should Not:

- Inhibit innovation
- Increase time-to-market
- Keep people out
- Increase cycle time
- Tell you how to make something
- Contain anything that cannot be defended with data

Notice

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 his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of IPC from manufacturing or selling products not conforming to such Standards and Publication, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than IPC members, whether the standards to be used either domestically or internationally.

Recommended Standards and Publications are adopted by IPC without regard to whether their adoption may involve patents on articles, materials, or processes. By such action, IPC does not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Recommended Standard or Publication. Users are also wholly responsible for protecting themselves against all claims of liabilities for patent infringement.

IPC Position Statement on Specification Revision Change

It is the position of IPC's Technical Activities Executive Committee that the use and implementation of IPC publications is voluntary and is part of a relationship entered into by customer and supplier. When an IPC publication is updated and a new revision is published, it is the opinion of the TAEC that the use of the new revision as part of an existing relationship is not automatic unless required by the contract. The TAEC recommends the use of the latest revision. Adopted October 6, 1998

Why is there a charge for this document?

Your purchase of this document contributes to the ongoing development of new and updated industry standards and publications. Standards allow manufacturers, customers, and suppliers to understand one another better. Standards allow manufacturers greater efficiencies when they can set up their processes to meet industry standards, allowing them to offer their customers lower costs.

IPC spends hundreds of thousands of dollars annually to support IPC's volunteers in the standards and publication development process. There are many rounds of drafts sent out for review and the committees spend hundreds of hours in review and development. IPC's staff attends and participates in committee activities, typesets and circulates document drafts, and follows all necessary procedures to qualify for ANSI approval.

IPC's membership dues have been kept low to allow as many companies as possible to participate. Therefore, the standards and publications revenue is necessary to complement dues revenue. The price schedule offers a 50% discount to IPC members. If your company buys IPC standards and publications, why not take advantage of this and the many other benefits of IPC membership as well? For more information on membership in IPC, please visit www.ipc.org or call 847/597-2872.

Thank you for your continued support.



IPC-2591-Version 1.5

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 1.4 -

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 105 N
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 IPC extend their gratitude.

(2-10) Electronic Product Data Description Committee	(2-17a) IPC-CFX Standard Task Group	Technical Liaison of the IPC Board of Directors
Chair Michael Ford Aegis Software	Co-Chairs Michael Ford Aegis Software Thomas Marktscheffel ASM Assembly Systems GmbH & Co. KG	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

Frederic Bourdat MBtech	Ramesh Kandasamy Getech Automation	Sarumathi Ramasamy Getech Automation
David Bures DCT USA, LLC	Jeff Kennedy ZESTRON Americas	Michael Rauter Flextronics International GmbH
Tim Burke Arch Systems	Michael Kimpton Fuji America Corporation	Naveen Ravindran ZESTRON Americas
Benoit Fillastre MBtech	Martin Kubicek PBT Works s.r.o.	Vladimir Sitko PBT Works s.r.o.
Michael Ford Aegis Software	Thomas Marktscheffel ASM Assembly Systems GmbH & Co. KG	John Striker ITW EAE
Alexis Fouquet Europlacer	John Neiderhiser Vitec Systems Soltec	John Walls Aegis Software
Wayne Gaglia Pure Automation	Dimitri Pasterev Continental Automotive Hungary Kft.	Jarrold Webb Lockheed Martin Missiles & Fire Control
John Hall Aqueous Technologies Corporation		

(2-17a) IPC-CFX Standard Task Group

Nicolas Bartschat ERSA GmbH	Zhiman Chen ZHUZHOU CRRC TIMES ELECTRIC CO., LTD	Wayne Gaglia Pure Automation
Jennifer Bennett IBM Corporation	Sean Clancy HZO Inc	Mahendra Gandhi Northrop Grumman Space Systems
Frederic Bourdat MBtech	Julie Cliche-Dubois Cogiscan Inc	John Hall Aqueous Technologies Corporation
David Bures DCT USA, LLC	Benoit Fillastre MBtech	Tom Hamelinckx ST Engineering iDirect
Tim Burke Arch Systems	Michael Ford Aegis Software	Ryan Heartfield Exalens
Javier Caraccioli Lockheed Martin Missiles & Fire Control	Alexis Fouquet Europlacer	Richard Helou 3D Photonix

Ula Hijawi The Manufacturing Technology Centre	Miles Moreau KIC	Simon Smith Pillarhouse International, Ltd.
Ramesh Kandasamy Getech Automation	Bruno Muller Essemtec (USA) LLC	Lorenzo Stilo The Manufacturing Technology Centre
Wes Karpiak Celestica	John Neiderman Vitronics Soltec	John Striker ITW EAE
Noriyuki Kato Omron Manufacturing Netherlands	Catalina Pamatmat Temic Automotive (Phils.) Inc.	Raj Takhar Assent Compliance Inc.
Jeff Kennedy ZESTRON Americas	Dmitrii Pesterev Continental Automotive Hungary Kft.	John Walls Aegis Software
Martin Kubicek PBT Works s.r.o.	Colas Peyrelier LACROIX Electronics Beaupreau	Jeff Wayne NAS Electronics
Michael Lange Northrop Grumman	Sarumathi Ramasamy GETECH	Jarrod Webb Lockheed Martin Missiles & Fire Control
Geoffrey Leeds Insulectro	Michael Rauter Flextronics International GmbH	Perla Wehbe I.F. Engineering
Goncalo Leitao SMT Worldwide	Naveen Ravindran ZESTRON Americas	Chih Wen Suzhou LinkWays Tech Co., Ltd.
Te-ming Liao Sunsda Technology Co., Ltd.	Raquel Rodriguez Quintero INSYTE, S.A.	Chia-Wei Wu Sunsda Technology Co., Ltd.
Thomas Marktscheffel ASM (Assembly Systems) GmbH & Co. KG	Jacky Shu Flextronics Electronics Technology (Suzhou) Co. Ltd.	Mike Xu Lof Intelligent Technology Co., Ltd
Zohair Mehkri Flextronics International	Vladimir Sitko PBT Works s.r.o.	

Table of Contents

1	SCOPE	1	2.3	International Organization for Standardization (ISO)	4
1.1	Purpose	1	2.4	SEMI	4
1.2	Application of This Standard	1	3	GENERAL REQUIREMENTS	4
1.3	CFX and the Hermes Standard	1	3.1	Guidance on the Use of This Standard	4
1.4	Updates to This Standard	2	3.1.1	Technical Reference	4
1.5	Definition of Requirements	2	3.1.2	Application Reference	4
1.6	Order of Precedence	2	3.2	Users of CFX	4
1.6.1	Conflict	2	3.2.1	Automated Assembly Processes	4
1.6.2	Clause References	2	3.2.2	In-House Manufacturing Solution Development	5
1.7	Acronyms	2	3.2.3	MES Software Solutions	5
1.8	Terms and Definitions	2	3.3	Software Development Environment	5
1.8.1	Activity	2	3.4	CFX Support Declaration	5
1.8.2	Component	2	4	CFX STRUCTURAL OVERVIEW	5
1.8.3	Dashboard	2	4.1	Primary Transport Layer: AMQP v1.0	5
1.8.4	Data Integrity	3	4.1.1	CFX Message Channels	6
1.8.5	Endpoint	3	4.1.2	Channel Configuration	7
1.8.6	Factory Resource	3	4.1.3	CFX Message Types	7
1.8.7	Lane	3	4.1.4	CFX Compression	7
1.8.8	Lock	3	4.1.5	CFX – AMQP Message Properties	7
1.8.9	Material Carrier	3	4.2	Encoding: JSON	8
1.8.10	Material Chain	3	4.2.1	JSON Data Types	8
1.8.11	Material Location	3	4.3	CFX-Defined Content	8
1.8.12	Material Package	3	4.4	CFX Key Parameters	8
1.8.13	Material Traceability	3	4.4.1	Endpoint Identification (CFX Handle)	8
1.8.14	Materials	3	4.4.2	TransactionID	8
1.8.15	Operator	3	4.5	CFX Message Envelope	9
1.8.16	Process Endpoint (Station)	3	4.6	Operator Information	9
1.8.17	Production Unit	3	4.7	CFX Endpoint Configuration	9
1.8.18	Recipe	3	4.7.1	Specific CFX Endpoint Configuration Addresses	10
1.8.19	Root	3	4.8	Message Attachments	11
1.8.20	Setup	3	4.8.1	Specifying Message Attachments	11
1.8.21	State (Production State)	3	4.8.2	In-Band Message Attachments	11
1.8.22	Station (Process Endpoint)	3	4.8.3	Out-of-Band Attachments	12
1.8.23	Stage	3	4.8.4	Supported Tabular Data Formats For Message Attachments	12
1.8.24	Sub-assembly	3	4.9	Supported Message Attachment Types	12
1.8.25	Symptom	3	4.9.1	SolderPasteInspection.SolderPasteMeasurement	12
1.8.26	Tool	4	4.9.2	PCBInspection.OffsetMeasurement	13
1.8.27	Transactional Endpoint	4	4.10	Messages Supporting Attachments	14
2	APPLICABLE DOCUMENTS	4			
2.1	IPC	4			
2.2	ECMA International	4			

4.10.1	CFX.Production.TestAndInspection.UnitsInspected Attachments	14	7.4	CFX.Materials (Level 1)	29
5	CFX OPERATIONAL MODELING	14	7.4.1	CFX.Materials.Management (Level 2)	29
5.1	Equipment State Model	14	7.4.2	CFX.Materials.Storage (Level 2)	30
5.2	Station Fault Event Model	16	7.4.3	CFX.Materials.Transport (Level 2)	30
5.3	Production Unit Architecture	16	7.5	CFX.Production (Level 1)	30
5.3.1	Production Unit Status	17	7.5.1	CFX.Production.Application (Level 2)	31
5.3.2	Production Endpoint Decision-Making Categories	18	7.5.2	CFX.Production.Assembly (Level 2)	32
5.3.3	Examples of Production Unit Status	18	7.5.3	CFX.Production.Hermes (Level 2)	32
5.4	Production Station Process Model	20	7.5.4	CFX.Production.LoadingAndUnloading (Level 2)	32
6	CFX TOPICS AND DYNAMIC STRUCTURES	21	7.5.5	CFX.Production.Processing (Level 2)	33
6.1	Hierarchy of CFX Topics	21	7.5.6	CFX.Production.ReworkAndRepair (Level 2)	33
6.1.1	CFX Topic Support Declaration	22	7.5.7	CFX.Production.TestAndInspection (Level 2)	33
6.2	CFX Message Names	22	7.6	CFX.ResourcePerformance (Level 1)	33
6.3	CFX Structures	22	7.6.1	CFX.ResourcePerformance.PressInsertion (Level 2)	34
6.4	CFX Dynamic Structures	22	7.6.2	CFX.ResourcePerformance.SMTPlacement (Level 2)	34
6.5	CFX Messaging Requirements by Equipment Type	22	7.6.3	CFX.ResourcePerformance.SolderPastePrinting (Level 2)	35
7	CFX MESSAGES	27	7.6.4	CFX.ResourcePerformance.THTInsertion (Level 2)	35
7.1	Root Level Messages	27	7.7	CFX.Sensor (Level 1)	35
7.2	CFX.InformationSystem (Level 1)	27	7.7.1	CFX.Sensor.Identification (Level 2)	35
7.2.1	CFX.InformationSystem.ProductionScheduling (Level 2)	27	7.8	CFX Message Flow	35
7.2.2	CFX.InformationSystem.UnitValidation (Level 2)	28	7.8.1	Production Endpoint (Station) Connection	36
7.2.3	CFX.InformationSystem.WorkOrderManagement (Level 2)	28	7.8.2	Station State Transition	37
7.2.4	CFX.InformationSystem.DataTransfer (Level 2)	28	7.8.3	Station Processing	38
7.3	CFX.Maintenance (Level 1)	28	8	CFX TECHNICAL REFERENCE	38
				APPENDIX A – Version Updates	39
				APPENDIX B – Acronyms and Abbreviations	47

Figures			
Figure 1-1	Version Change Tracking Example	2	
Figure 4-1	CFX Channels Between Endpoints	6	
Figure 4-2	The CFX TransactionID	9	
Figure 5-1	SEMI E10 Equipment State Model	14	
Figure 5-2	Examples of Groupings of Production Units	16	
Figure 5-3	Panelized Printed Board	16	
Figure 5-4	CFX Unit Locations Identified on Multiple-Board Panel	17	
Figure 5-5	Panel Processing Example – No Defects Found	18	
Figure 5-6	Panel Processing Example – One Production Unit Scrapped	19	
Figure 5-7	Panel Inspection Example – One Production Unit Failure	19	
Figure 5-8	Panel Review/Repair Example – One Production Unit Repaired	19	
Figure 5-9	Panel Review/Repair Example – Whole Panel Scrapped	20	
Figure 5-10	CFX Production Station Process Model	20	
Figure 7-1	CFX Station Connection Example Message Flow	36	
Figure 7-2	CFX Station State Transition Example Message Flow	37	
Figure 7-3	CFX Station Processing Example Message Flow	38	
Tables			
Table 4-1	Types of CFX Messages	7	
Table 4-2	CFX – AMQP Message Properties	7	
Table 4-3	CFX Message Envelope	9	
Table 4-4	Format of Attachment Array Entries	11	
Table 4-5	Columns for Solder Paste Measurement Attachment Type	13	
Table 4-6	Columns for Offset Measurement Attachment Type	13	
Table 5-1	Station Event Fault Model	16	
Table 6-1	CFX Capability Requirements by Equipment Type	23	
Table 6-2	Required Messages by Capability	24	
Table 7-1	CFX.Root Messages	27	
Table 7-2	CFX.InformationSystem.ProductionScheduling Messages	27	
Table 7-3	CFX.InformationSystem.UnitValidation Messages	28	
Table 7-4	CFX.InformationSystem.WorkOrderManagement Messages	28	
Table 7-5	CFX.InformationSystem.DataTransfer Messages	28	
Table 7-6	CFX.Maintenance Messages	29	
Table 7-7	CFX.Materials.Management Messages	29	
Table 7-8	CFX.Materials.Management.MSOMManagement Messages	29	
Table 7-9	CFX.Materials.Storage Messages	30	
Table 7-10	CFX.Materials.Transport Messages	30	
Table 7-11	CFX.Production.Messages	30	
Table 7-12	CFX.Production.Application Messages	31	
Table 7-13	CFX.Production.Assembly Messages	32	
Table 7-14	CFX.Production.Assembly.PressInsertion Messages	32	
Table 7-15	CFX.Production.Hermes Messages	32	
Table 7-16	CFX.Production.LoadingAndUnloading Messages	32	
Table 7-17	CFX.Production.Processing Messages	33	
Table 7-18	CFX.Production.ReworkAndRepair	33	
Table 7-19	CFX.Production.TestAndInspection Messages	33	
Table 7-20	CFX.ResourcePerformance Messages	34	
Table 7-21	CFX.ResourcePerformance.PressInsertion Messages	34	
Table 7-22	CFX.ResourcePerformance.SMTPlacement Messages	35	
Table 7-23	CFX.ResourcePerformance.SolderPastePrinting Messages	35	
Table 7-24	CFX.ResourcePerformance.THTInsertion Messages	35	
Table 7-25	CFX.Sensor.Identification Messages	35	

This Page Intentionally Left Blank

Currently in preview, click buy full version

Connected Factory Exchange (CFX) Version 1.5

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.