

SpaceWire

SpaceWire is a spacecraft communication network based in part on the IEEE 1355 standard of communications. It is coordinated by the European Space Agency (ESA) in collaboration with international space agencies including NASA, JAXA, and RKA.

Within a SpaceWire network the nodes are connected through low-cost, low-latency, full-duplex, point-to-point serial links, and packet switching wormhole routing routers. SpaceWire covers two (physical and data-link) of the seven layers of the OSI model for communications.

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Architecture

Physical layer

SpaceWire's modulation and data formats generally follow the data strobe encoding - differential ended signaling (DS-DE) part of the IEEE Std 1355-1995. SpaceWire utilizes asynchronous communication and allows speeds between 2 Mbit/s and 400 Mbit/s, with initial signalling rate of 10Mbit/s.^[1] DS-DE is well-favored because it describes modulation, bit formats, routing, flow control, and error detection in hardware, with little need for software. SpaceWire also has very low error rates, deterministic system behavior, and relatively simple digital electronics. SpaceWire replaced old PECL differential drivers in the physical layer of IEEE 1355 DS-DE by low-voltage differential signaling (LVDS). SpaceWire also proposes the use of space-qualified 9-pin connectors.

SpaceWire Specifications

Created by	<u>European Space Agency</u>
Speed	2.0–400 Mbit/s
Style	<u>Serial</u>
Hotplugging interface	Yes
External interface	Yes

SpaceWire Connector Specifications

Type	Data connector	
Production history		
Designer	<u>European Space Agency</u>	
General specifications		
Hot pluggable	Yes	
External	Yes	
Audio signal	No	
Video signal	No	
Pins	9	
Connector	<u>Micro-D</u>	
Data		
Data signal	Yes	
Bitrate	2.0–400 Mbit/s	
Protocol	Serial	
Pin out		
Pin	Name	Description
Pin 1	DIN+	Data In Pos.
Pin 2	SIN+	Strobe In Pos.
Pin 3	Inner Shield	Ground

SpaceWire and IEEE 1355 DS-DE allows for a wider set of speeds for data transmission, and some new features for automatic failover. The fail-over features let data find alternate routes, so a spacecraft can have multiple data buses, and be made fault-tolerant. SpaceWire also allows the propagation of time interrupts over SpaceWire links, eliminating the need for separate time discretes.

Link layer

Each transferred character starts with a Parity bit and a Data-Control Flag bit. If Data-Control Flag is a 0-bit, an 8-bit LSB character follows. Otherwise one of the control codes, including end of packet (EOP).^[2]

Pin 4	SOUT-	Strobe Out Neg.
Pin 5	DOUT-	Data Out Neg.
Pin 6	DIN-	Data In Neg.
Pin 7	SIN-	Strobe In Neg.
Pin 8	SOUT+	Strobe Out Pos.
Pin 9	DOUT+	Data Out Pos.

Network layer

The network data frames look as follows:

Address byte	Address byte...	Protocol ID	Frame data
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One or more address bytes are used for the routing. Addresses are either physical ones (0-31), or logical ones. The difference is that the physical addresses are deleted from the frame header during routing - which is used for hop-based routing (based on path specified in the frame itself). Logical addresses may be deleted as well, depending on the router configuration.

Interconnection

The hardware devices may be connected either directly, or via a SpaceWire router. In the former case, usually pairs of devices are used to guarantee a fail-safe operation - which is however handled by the software.

A SpaceWire router is usually a crossbar switch-type device, operating in wormhole switching mode. This also may limit the speed of the communication to the lowest common speed.^[3] The routing decisions are based on the programmed routing table and the initial incoming frame contents.

Uses

SpaceWire is used all around the globe.^[4] Its use began primarily in ESA projects, but it is currently used by NASA, JAXA, RKA, and many other organizations and companies. Some NASA projects using it include the James Webb Space Telescope, Swift's Burst Alert Telescope, the Lunar Reconnaissance Orbiter, LCROSS, the Geostationary Operational Environmental Satellite (GOES-R), and the SCaN Testbed, previously known as the Communications, Navigation, and Networking Reconfigurable Testbed (CoNNeCT). It has also been selected by the United States Department of Defense for Operationally Responsive Space. SpaceWire initiatives are being coordinated between several Space Agencies in the frame of CCSDS in order to extend its communication model to the Network and Transport Layers of the OSI model.

SpaceWire supports highly fault-tolerant networks and systems, which is one reason for its popularity.^[5]

Protocols

The ESA has a draft specification in place for the Protocol ID.

The following Protocol ID's have been assigned in ECSS-E-ST-50-11:

Protocol ID	Name	Description
1	<i>Remote Memory Access Protocol (RMAP)</i>	used to remotely access/alter register configuration of the devices
2	<i>CCSDS Packet Transfer Protocol</i> [6]	a common protocol used for sending Telecommands and receiving Telemetry
238	Proposal for <i>Reliable Data Delivery Protocol (RDDP)</i>	used on <u>GOES-R</u>
239	<i>Serial Transfer Universal Protocol (STUP)</i>	Used on SMCS-332 <u>ASIC</u>

References

- "SpaceWire's User Guide" (https://www.star-dundee.com/wp-content/star_uploads/2019/05/SpaceWire-Users-Guide.pdf) (PDF). *Star-dundee.com*. Retrieved 27 October 2019. "chapter 3.3.5"
- "SpaceWire Characters" (<https://www.star-dundee.com/knowledge-base/spacewire-characters>). *Star-dundee.com*. Retrieved 28 October 2018.
- "Radiation-Tolerant 10x SpaceWire Router" (<https://www.gaisler.com/doc/rt-spw-router.pdf>) (PDF). *Gaisler.com*. Retrieved 28 October 2018.
- "Who Uses SpaceWire? - STAR-Dundee" (<https://www.star-dundee.com/knowledge-base/who-uses-spacewire>). *Star-dundee.com*. Retrieved 28 October 2018.
- Dr Barry M Cook; Paul Walker. "Ethernet over SpaceWire - software issues" (https://www.4links.co.uk/application/files/2315/4445/5441/10_Ethernet_Software_Issues.pdf). 4links.co.uk, p. 2
- "Space Packet Transfer Protocol" (<https://public.ccsds.org/Pubs/133x0b1c2.pdf>) (PDF). *Public.ccsds.org*. Retrieved 28 October 2018.

Other sources

- ECSS-E-ST-50-12C - SpaceWire - Links, nodes, routers, and networks (http://www.ecss.nl/forum/s/ecss/_templates/default.htm?target=http://www.ecss.nl/forums/ecss/dispatch.cgi/standards/docProfile/100654/d20080802144344/No/t100654.htm), ESA-ESTEC.
- ECSS-E-50-12A (SUPERSEDED only document number has been changed to ECSS-E-ST-50-12C) SpaceWire - Nodes, links, and networks (http://www.ecss.nl/forum/s/ecss/_templates/default.htm?target=http://www.ecss.nl/forums/ecss/dispatch.cgi/standards/showFolder/100630), ESA-ESTEC.
- ECSS-E-ST-50-11C Draft 1.3 "Space engineering - SpaceWire protocols" (http://www.ecss.nl/forum/s/ecss/_templates/default.htm?target=http://www.ecss.nl/forums/ecss/dispatch.cgi/standards/docProfile/100654/d20080802144344/No/t100654.htm)

External links

- SpaceWire Homepage (ESA) (<http://spacewire.esa.int/>)
- European Cooperation for Space Standardisation - ECSS (<http://www.ecss.nl>)
- 4Links Publications (<https://www.4links.co.uk/index.php/papers>)
- International SpaceWire Conference 2007 (<https://web.archive.org/web/20070613182431/http://spacewire.computing.dundee.ac.uk/>)

- [International SpaceWire Conference 2008 \(https://web.archive.org/web/20090409065252/http://spacewire2008.astro.isas.jaxa.jp/\)](https://web.archive.org/web/20090409065252/http://spacewire2008.astro.isas.jaxa.jp/)
- [International SpaceWire Conference 2010 \(http://2010.spacewire-conference.org\)](http://2010.spacewire-conference.org)
- [International SpaceWire Conference 2011 \(http://2011.spacewire-conference.org\)](http://2011.spacewire-conference.org)
- [International SpaceWire Conference 2013 \(http://2013.spacewire-conference.org/\)](http://2013.spacewire-conference.org/)
- [STAR-Dundee Knowledge Database \(http://www.star-dundee.com/SpaceWireKB\)](http://www.star-dundee.com/SpaceWireKB)
- http://www.interfacebus.com/SpaceWire_Avionics_Bus.html

Commercial providers of SpaceWire equipment:

- [STAR-Dundee \(http://www.star-dundee.com\)](http://www.star-dundee.com)
- [Spacewire.fr \(http://www.spacewire.fr\)](http://www.spacewire.fr)
- [Aeroflex \(https://web.archive.org/web/20071016133234/http://ams.aeroflex.com/ProductPages/RH_spacewire.cfm\)](https://web.archive.org/web/20071016133234/http://ams.aeroflex.com/ProductPages/RH_spacewire.cfm)
- [Aeroflex Gaisler \(http://www.gaisler.com/cms/index.php?option=com_content&task=view&id=109&Itemid=35\)](http://www.gaisler.com/cms/index.php?option=com_content&task=view&id=109&Itemid=35)
- [Astrium](#)
- [Microchip \(http://www.atmel.com/dyn/products/devices.asp?family_id=641#787\)](http://www.atmel.com/dyn/products/devices.asp?family_id=641#787)
- [Aurelia Microelettronica \(https://web.archive.org/web/20090713171212/http://www.caen.it/micro/family.php?cat=space\)](https://web.archive.org/web/20090713171212/http://www.caen.it/micro/family.php?cat=space)
- [Ingespace \(http://www.ingespace.com\)](http://www.ingespace.com)
- [Dynamic Engineering \(http://www.dyneng.com/spacewire.html\)](http://www.dyneng.com/spacewire.html)
- [4Links \(http://www.4links.co.uk\)](http://www.4links.co.uk)
- [SKYLAB Industries \(http://www.skylab-corporate.com/en_skylab-30.html\)](http://www.skylab-corporate.com/en_skylab-30.html)
- [RUAG Space \(http://www.ruag.com/space\)](http://www.ruag.com/space)
- [PnP Innovations \(http://www.pnpinnovations.com/products.php?subCategoryID=43&categoryID=16\)](http://www.pnpinnovations.com/products.php?subCategoryID=43&categoryID=16)
- [TELETEL SA \(http://www.teletel.eu/isaft-spacewire-mil-std-1553-can-recorder\)](http://www.teletel.eu/isaft-spacewire-mil-std-1553-can-recorder)
- [TTTech \(https://www.tttech.com/products/aerospace/flight-rugged-hardware/space-ceramic/tte-switch-controller-space/\) - Gateway for SpaceWire to 1GbE Ethernet, with Leon-2FT CPU](https://www.tttech.com/products/aerospace/flight-rugged-hardware/space-ceramic/tte-switch-controller-space/)

SpaceWire IP Cores:

- [4Links \(https://www.4links.co.uk/index.php/portfolio/project-title-2-2-3\)](https://www.4links.co.uk/index.php/portfolio/project-title-2-2-3)
- [STAR-Dundee \(http://www.star-dundee.com/products/SpaceWire%20IP.php\)](http://www.star-dundee.com/products/SpaceWire%20IP.php)
- [Aeroflex Gaisler \(http://www.gaisler.com/cms/index.php?option=com_content&task=view&id=275&Itemid=183\)](http://www.gaisler.com/cms/index.php?option=com_content&task=view&id=275&Itemid=183)
- [Astrium SpaceWire RMAP \(http://www.esa.int/TEC/Microelectronics/SEMD6M52OCH_0.html\)](http://www.esa.int/TEC/Microelectronics/SEMD6M52OCH_0.html)
- [CEA IRFU \(http://irfu.cea.fr/\)](http://irfu.cea.fr/)
- [CESR CNRS \(http://spacewire.cesr.fr/\)\(CeCILL-C license\)](http://spacewire.cesr.fr/)
- [NASA Goddard - tech transfer \(https://web.archive.org/web/20100527230633/http://ipp.gsfc.nasa.gov/ft_tech_spacewire.shtm\)](https://web.archive.org/web/20100527230633/http://ipp.gsfc.nasa.gov/ft_tech_spacewire.shtm)
- [OpenCores.org \(SpaceWire \(http://opencores.org/project,spacewire\) and SpaceWire Light \(http://opencores.org/project,spacewire_light\)\)](http://opencores.org/project,spacewire)
- [SpaceWire UK \(http://www.spacewire.co.uk/\)](http://www.spacewire.co.uk/)
- [European Space Agency \(http://www.esa.int/TEC/Microelectronics/SEM7N20P0WF_0.html\)](http://www.esa.int/TEC/Microelectronics/SEM7N20P0WF_0.html)
- [PnP Innovations \(http://www.pnpinnovations.com/products.php?subCategoryID=38&categoryID=18\)](http://www.pnpinnovations.com/products.php?subCategoryID=38&categoryID=18)

Articles:

- [NASA article on SpaceWire used on JWST spacecraft \(http://www.nasa.gov/vision/universe/watc_htheskies/jwst_spacewired.html\)](http://www.nasa.gov/vision/universe/watc_htheskies/jwst_spacewired.html)
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