UAVCAN/CAN Physical Layer Specification v0.1

Revision 2021-07-18

Overview

The UAVCAN/CAN physical layer specification (UCANPHY) defines electromechanical conventions for UAVCAN/CAN optimized for use in the avionics of manned and unmanned aircraft as well as in high-integrity robotic systems. The goal of UCANPHY is to maximize cross-vendor compatibility, ensure consistency across the ecosystem, and prevent some common design pitfalls.

UAVCAN is an open technology for real-time intravehicular distributed computing and communication based on modern networking standards. The name UAVCAN stands for *Uncomplicated Application-level Vehicular Computing And Networking.*

UAVCAN/CAN is a standard transport layer protocol defined by the UAVCAN specification for use with the CAN[1] protocol.

[1] Controller Area Network

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1 Introduction

This is a non-normative chapter covering the basic concepts that govern development and maintenance of the specification.

1.1 Overview

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The development and maintenance of the UCANPHY specification is carried out by the members of the UAVCAN Consortium. Information on the Consortium is available via the official website at uavcan.org.

Information on UAVCAN and its CAN-based transport named UAVCAN/CAN is published in a separate document available from the official website.

1.2 Document conventions

Non-normative text, examples, recommendations, elaborations, and other optional items are contained in footnotes[2] or highlighted sections as shown below.

> Non-normative sections such as examples are enclosed in shaded boxes like this.

Throughout the document, "CAN" implies both Classic CAN and CAN FD, unless specifically noted otherwise.

1.3 Management and conformance

The UAVCAN Consortium is tasked with maintaining and advancing this specification, as well as performing voluntary conformance testing. The policies that govern these activities are published on the official website.

Products whose conformance with this specification has been confirmed by the Consortium are entitled to feature the official *UAVCAN Conformity Mark* subject to the policies published on the official website.

1.4 Referenced sources

The specification contains references to the following sources:

- CiA 103 — Intrinsically safe capable physical layer.
- CiA 801 — Application note — Automatic bit rate detection.
- IETF RFC2119 — Key words for use in RFCs to Indicate Requirement Levels.
- ISO 11898-1 — Controller area network (CAN) — Part 1: Data link layer and physical signaling.
- ISO 11898-2 — Controller area network (CAN) — Part 2: High-speed medium access unit.

1.5 Revision history

1.5.1 v1.0 – work in progress

This is the initial version of the document. The discussions that shaped the initial version are available to the members of the UAVCAN Consortium.

[2] This is a footnote.

2 CAN bus physical layer

As can be seen from its specification, UAVCAN is mostly agnostic of the parameters of the physical layer. Despite that, vendors should follow the recommendations provided in this section in the interest of maximizing the cross-vendor compatibility.

2.1 Classic CAN

Table 2.1 lists the recommended parameters of the ISO 11898-2 Classic CAN physical layer. The estimated bus length limits are based on the assumption that the propagation delay does not exceed 5 ns/m, not including additional delay times of CAN transceivers and other components.

Parameter	**Value**				**Unit**
Bit rate	1000	500	250	125	kbit/s
Permitted sample point location	75–90	85–90	85–90	85–90	%
Recommended sample point location	87.5	87.5	87.5	87.5	%
Maximum bus length	40	100	250	500	m
Maximum stub length	0.3	0.3	0.3	0.3	m

Table 2.1: ISO 11898-2 Classic CAN physical layer parameters

Designers are encouraged to implement CAN auto bit rate detection when applicable. Refer to the CiA 801 application note for the recommended practices.

> UAVCAN allows the use of a simple bit time measuring approach, as it is guaranteed that any functioning UAVCAN network will always exchange node status messages, which can be expected to be published at a rate no lower than 1 Hz, and that contain a suitable alternating bit pattern in the CAN ID field. Refer to the UAVCAN Specification for details.

2.2 CAN FD

This section is under development and will be populated in a later revision of the document.

Table 2.2: ISO 11898-2 CAN FD physical layer parameters

Parameter	**Segment**	**Value**				**Unit**
Bit rate	Arbitration	1000	500	250	125	kbit/s
	Data	4000	2000	1000	500	
Permitted SPL	Arbitration	TBD	TBD	TBD	TBD	%
	Data	TBD	TBD	TBD	TBD	
Recommended SPL	Arbitration	TBD	TBD	TBD	TBD	%
	Data	TBD	TBD	TBD	TBD	
Maximum bus length		TBD	TBD	TBD	TBD	m
Maximum stub length		TBD	TBD	TBD	TBD	

3 Connectors

The UCANPHY standard defines several connector types optimized for different applications: from highly compact systems to large deployments, from low-cost to safety-critical applications. Each connector type specification includes an integrated power supply interface (section 4).

Implementations should provide two identical parallel connectors for each CAN interface per device instead of relying on T-connectors. T-connectors should be avoided because typically they increase the stub length, weight, and complexity of the wiring harnesses. All signals of the paired connectors, including those that are unused, shall be interconnected one to one.

Connector name	Base connector type	Integrated power	Known compatible standards
UCANPHY D-Sub	Generic D-Subminiature DE-9	24 V, 3 A	De-facto standard connector for CAN, supported by many current specifications.
UCANPHY M8	Generic M8 5-circuit B-coded	24 V, 3 A	CiA 103 (CANopen)
UCANPHY Micro	JST GH 4-circuit	5 V, 1 A	Dronecode Autopilot Connector Standard

Table 3.1: Standard UAVCAN/CAN connector types

3.1 UCANPHY D-Sub

The UCANPHY D-Sub connector type is based upon, and compatible with, the D-Subminiature DE-9 CAN connector (this is the most popular CAN connector type, in effect the de-facto industry standard). This connector is fully compatible with CANopen and many other current specifications.

Advantages	Disadvantages
• Highest level of compatibility with the existing commercial off the shelf (COTS) hardware. Connectors, cables, termination plugs, and other components can be procured from many different vendors. • High-reliability options suitable for safety-critical systems are available from multiple vendors. • Low-cost options are available from multiple vendors. • Both PCB-mounted and panel-mounted types are available.	D-Subminiature is the largest connector type defined by UCANPHY. Due to its significant size and weight, it may be unsuitable for some applications.

The UCANPHY D-Sub connector is based on the industry-standard **D-Sub DE-9** (9-circuit) connector type. Devices are equipped with the male plug connector type mounted on the panel or on the PCB, and the cables are equipped with the female socket connectors on both ends (figure 3.1).

If the device uses two parallel connectors per CAN bus interface (as recommended), then all of the lines of the paired connectors, including those that are not used by the current specification, shall be interconnected one to one. This will ensure compatibility with future revisions of the specification that make use of currently unused circuits of the connector.

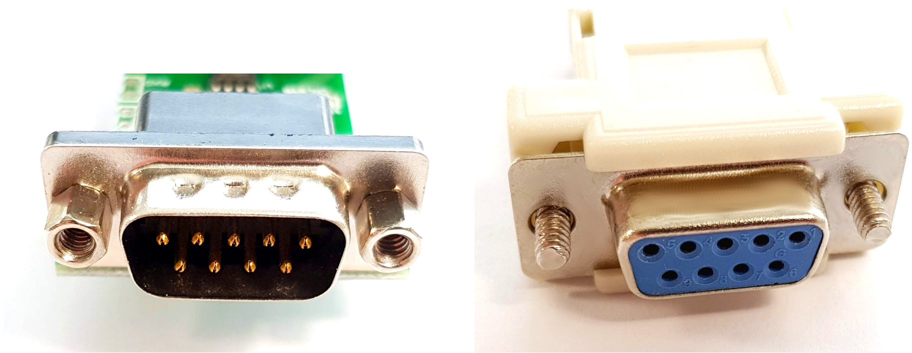
The CAN physical layer standard that should be used with this connector type is ISO 11898-2[3].

Devices that deliver power to the bus are required to provide 23.0–30.0 V on the bus power line, 24 V nominal. Devices that are powered from the bus should expect 18.0–30.0 V on the bus power line. The current shall not exceed 3 A per connector.

Table 3.1 documents the pinout specification for the UCANPHY D-Sub connector type. Signals “CAN High” and “CAN Low” shall belong to the same twisted pair. Usage of twisted or flat wires for all other signals remains at the discretion of the implementer.

#	Function	Note
1		
2	CAN low	Twisted with “CAN high” (pin 7).
3	CAN ground	Shall be interconnected with “Ground” (pin 6) within the device.
4		
5	CAN shield	Optional.
6	Ground	Shall be interconnected with “CAN ground” (pin 3) within the device.
7	CAN high	Twisted with “CAN low” (pin 2).
8		
9	Bus power supply	24 V nominal. See the power supply requirements.

Table 3.2: UCANPHY D-Sub connector pinout



Device (left) and cable (right) connectors.
Figure 3.1: UCANPHY D-Sub connectors

3 Also known as *high-speed CAN*.

3.2 UCANPHY M8

The UCANPHY M8 connector type is based on the generic circular M8 connector type. This is a popular industry-standard connector; there are multiple vendors that manufacture compatible components: connectors, cables, termination plugs, T-connectors, and so on. The pinning, physical layer, and supply voltages used in this connector type are compatible with CiA 103 (CANopen) and some other CAN bus standards.

Advantages	Disadvantages
• Compatibility with existing COTS hardware. Connectors, cables, termination plugs, and other components can be purchased from many different vendors. • High-reliability options suitable for safety-critical systems are available from multiple vendors. • Low-cost options are available from multiple vendors. • Reasonably compact. M8 connectors are much smaller than D-Sub. • PCB-mounted and panel-mounted types are available.	• M8 connectors may be a poor fit for applications that have severe weight and space constraints. • The level of adoption in the industry is noticeably lower than that of the D-Sub connector type.

The UCANPHY M8 connector is based on the **circular M8 B-coded 5-circuit** connector type[4]. Devices are equipped with the male plug mounted on the panel or on the PCB, and cables are equipped with the female socket on both ends (figure 3.2).

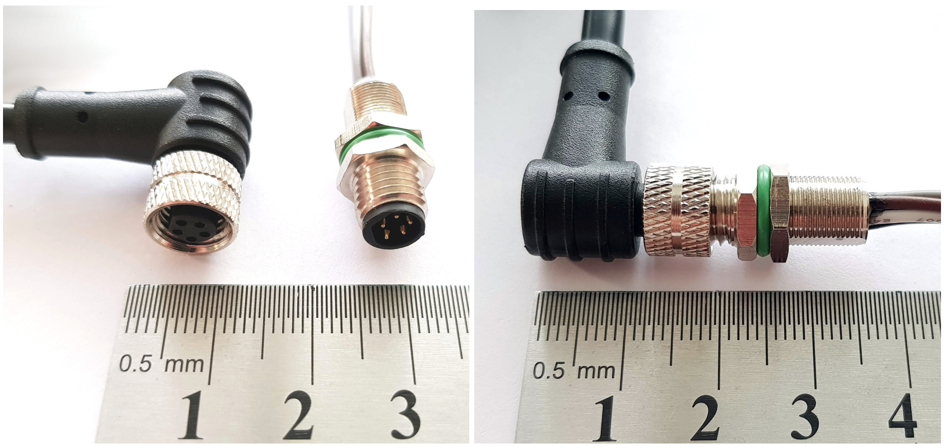
The CAN physical layer standard that should be used with this connector type is ISO 11898-2[5].

Devices that deliver power to the bus are required to provide 23.0–30.0 V on the bus power line, 24 V nominal. Devices that are powered from the bus should expect 18.0–30.0 V on the bus power line. The current shall not exceed 3 A per connector.

Table 3.2 documents the pinout specification for the UCANPHY M8 connector type. Wires "CAN high" and "CAN low" should be a twisted pair.

#	Function	Note
1	Bus power supply	24 V nominal. See the power supply requirements.
2	CAN shield	Optional.
3	CAN high	Twisted with "CAN low" (pin 4).
4	CAN low	Twisted with "CAN high" (pin 3).
5	Ground	

Table 3.3: UCANPHY M8 connector pinout



Female socket cable connector, male plug device connector, and the assembled pair.

Figure 3.2: UCANPHY M8 connectors

[4] Do not confuse A-coded and B-coded M8 connectors – they are not mutually compatible.
[5] Also known as *high-speed CAN*.

3.3 UCANPHY Micro

The UCANPHY Micro connector is intended for weight- and space-sensitive applications. It is a board-level connector, meaning that it is installed on the PCB rather than on the panel.

The Micro connector is compatible with the Dronecode Autopilot Connector Standard. This connector type is recommended for small UAV and nanosatellites. It is also the recommended connector for attaching external panel-mounted connectors (such as the M8 or D-Sub types) to the PCB inside the enclosure.

Advantages	Disadvantages
• Extremely compact, low-profile. The PCB footprint is under 9×5 millimeters. • Secure positive lock ensures that the connection will not self-disconnect when exposed to vibrations. • Low cost.	• Board-level connections only. No panel-mounted options available. • No shielding available. • Not suitable for safety-critical hardware.

The UCANPHY Micro connector is based on the proprietary **JST GH 4-circuit** connector type[6].

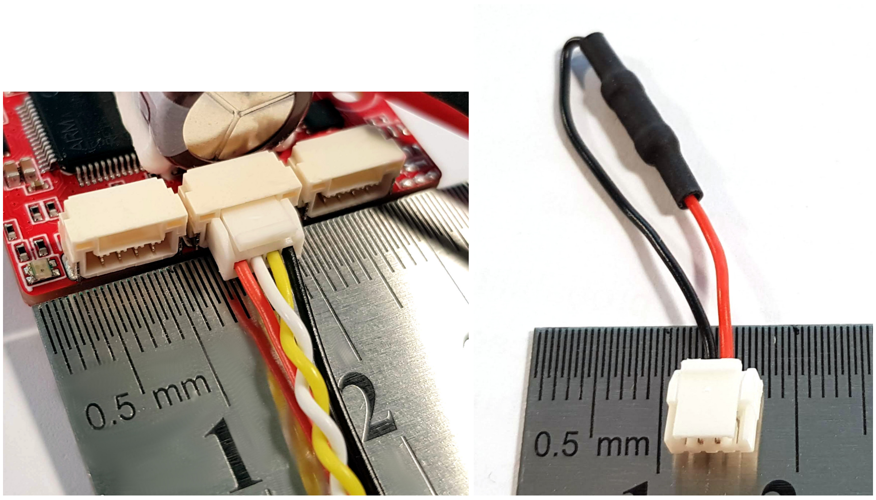
The CAN physical layer standard that can be used with this connector type is ISO 11898-2.

Devices that deliver power to the bus are required to provide 4.9–5.5 V on the bus power line, 5.0 V nominal. Devices that are powered from the bus should expect 4.0–5.5 V on the bus power line. The current shall not exceed 1 A per connector.

Table 3.3 documents the pinout specification for the UCANPHY Micro connector type. The suitable wire type is #30 to #26 AWG, outer insulation diameter 0.8–1.0 mm, multi-strand. Wires "CAN high" and "CAN low" shall form a twisted pair.

#	Function	Note
1	Bus power supply	5 V nominal. See the power supply requirements.
2	CAN high	Twisted with "CAN low" (pin 3).
3	CAN low	Twisted with "CAN high" (pin 2).
4	Ground	

Table 3.4: UCANPHY Micro connector pinout



Right-angle connector with a twisted pair cable connected; a 120Ω termination plug.

Figure 3.3: UCANPHY Micro connectors

[6] The top-entry type is not PCB-footprint-compatible with the side-entry type – its pin ordering is reversed. The wire-side pinout, however, is compatible, so both types can be used interchangeably as long as their PCB footprints are correct.

4 Integrated power supply network

Integration of the power distribution functionality with the communication infrastructure removes the need for a dedicated power distribution network, which has the potential to simplify the system design and reduce the complexity and weight of the wiring harnesses. Redundant power supply topologies can be easily implemented on top of a redundant communication infrastructure.

Designs that integrate power distribution with the communication infrastructure should follow the conventions set out in this section.

4.1 Power input

A node that draws power from the power supply network should protect its power inputs with an over-current protection circuitry that is capable of disconnecting the input if the power consumption of the node exceeds its design limits. This measure is necessary to prevent a short-circuit or a similar failure of an individual node from affecting other nodes connected to the same power supply network.

In the case of redundant power supply connections where a node is connected to more than one power supply network concurrently, each such connection should be equipped with a circuit that prevents reverse current flow from the node into the power supply network. This measure is necessary to prevent a short-circuit or a similar failure of an individual power supply network from affecting other power supply networks in the same redundant group.

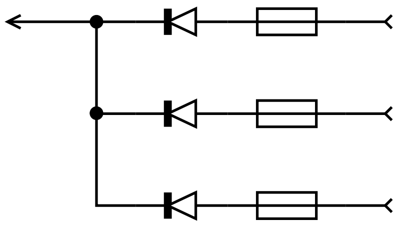


Figure 4.1: Redundant power input schematic

4.2 Power output

A node that delivers power to the power supply network should equip each of its power outputs with a circuit that prevents reverse current flow from the power supply network into the node. This measure is necessary to prevent a short-circuit or a similar failure of the node from affecting the power supply network.

In the case of redundant power output connections where a node provides power to more than one power supply network concurrently, each such connection should be equipped with a circuit that is capable of disconnecting the output if the power consumption per network exceeds the design limits. This measure is necessary to prevent a short-circuit or a similar failure of an individual power supply network from affecting other power supply networks in the same redundant group.

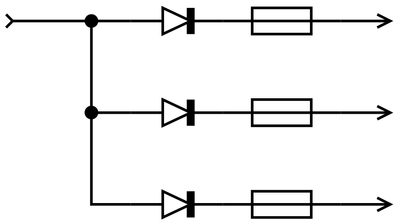


Figure 4.2: Redundant power output schematic