

ARINC 818 - An analysis methodology

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Abstract

As aircraft video networks are becoming more complex, the need for reliable high-bandwidth video protocols is getting more crucial. The ARINC 818 video protocol is emerging in numerous flight programs thanks to its ability to operate high-bandwidth, low-latency uncompressed video over optical fibres. Though ARINC 818 has been standardized over the past 20 years, its main drawback remains non-interoperability. In fact, to operate together, ARINC 818 video sources and receivers need to share prior information via a document known as an ICD. This document shall define information on supported physical link characteristics, video format and video timing. In this article, we will discuss the main challenges encountered by professionals working with ARINC 818 video sources with partial or erroneous ICD. A methodology of analysis requiring the least amount of prior knowledge on the characteristics of the video source will be introduced. This methodology has shown good results identifying the characteristics of various video sources and validating that a video source is compliant to a given ICD.

Key words: ARINC 818, Digital Video, Avionics

Introduction

The ARINC 818: Avionics Digital Video Bus (ADVB) is a video protocol that defines a method for transmitting uncompressed video data from a video source to a video receiver. Since its publication in 2007, this standard has been implemented in multiple civil and military aircraft programs. In this work, we will introduce the fundamentals of this standard and highlight its great flexibility. We will then show how this flexibility conflicts with interoperability and how the standard resolves this trade-off by introducing a program-specific document called ICD. We will demonstrate the challenges arising from this choice during the integration and testing phases of an ARINC 818 equipment. Finally, we will show how it is possible to validate an equipment step by step while relying as little as possible on the ICD.

ARINC 818 standard

The ARINC 818 standard was elaborated by a consortium of aircraft manufacturers and avionic suppliers. It was released in 2007 and further expanded in 2013 and then in 2018.

The ARINC 818 standard is based on the Fibre Channel Audio Video (FC-AV) standard. It was designed to support the high bandwidth required for transporting uncompressed video while maintaining low-latency and high reliability.

The ARINC 818 standard inherits the packet structure of the FC-AV, which allows it to operate multiple video streams on a single link and to

implement switching between multiples video sources and/or sinks.

The standard imposes no restriction on the physical medium for data transport; any medium supporting high speed serial communication can therefore be used, although optical fibre is generally preferred.

These architectural choices make the ARINC 818 standard a top choice for video bus intended for aircraft programs as it compares favourably both with other video centric protocols like SDI, DisplayPort and HDMI and with other packet-based protocols (primarily Ethernet variations) – see [1].

ADVB Container and Frame structure

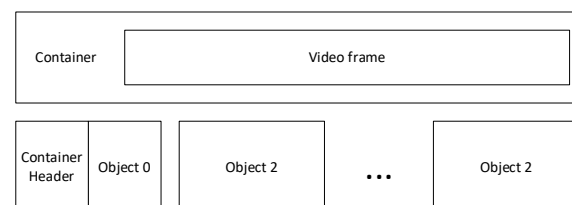


Fig. 1. Example of ADVB Container structure.
Progressive video. No audio. Container header segmented.

The ARINC 818 data structure lies mostly on two layers:

- 1) The ADVB Container is the upper-level layer which encompass a complete video frame and may also contains associated audio and/or ancillary data.

- 2) The ADVB Frame is the lower-level, packet-like layer which encompass typically a fraction of a video line or audio data or ancillary data.

The Fig. 1 represents a typical ADVB structure, transporting progressive video without audio. The ADVB Container is composed of multiple ADVB Frames, the first one typically holding the container-level header and Object 0 payload (ancillary data) separated from the following ones holding Object 2 payload (video data). In this example, the data stream contains no Object 1 (Audio data) ADVB frames and no Object 3 ADVB frames that are only used for interlaced video scan.

Each ADVB Frame is delimited by a Start of Frame (SOF) and an End of Frame (EOF) 32b-word. In addition to its payload data, each ADVB Frame carries a small (6x32b-word) header and a checksum.

At the link level, ARINC 818 transmit each ADVB Frame separated by Idle words in between. An 8b/10b line code is used to achieve long term DC balance, and manage clock recovery at the receiver. ARINC 818 leverages 8b/10b features to distinguish special characters from normal data. The main special characters are

- Idle: used to separate ADVB frames
- SOFi: Start of Frame Initiate, marks the start of the first ADVB frame of an ADVB container.
- SOFn: Start of Frame Normal, marks the start of any other ADVB frame
- EOFt: End of Frame Terminate, marks the end of the last ADB frame of an ADVB container.
- EOFn: End of Frame Normal, marks the end of any other ADVB frame.

Synchronisation Classes

A distinct feature of the ARINC 818 standard is that it proposes four synchronisation classes to choose from:

- Class A: asynchronous
- Class B: frame synchronous
- Class C: line synchronous
- Class D: pixel synchronous

Each of these classes defines how strictly the video stream must adhere to a specific transmission timing. The two most used classes in avionics, are frame synchronous and line synchronous. Frame synchronous means the timing of each new video frame (i.e. ADVB container) is set but video lines (i.e. ADVB

frames) are transmitted freely within that time frame. Line synchronous means the timing of each video lines is set, typically all start of line are aligned on a set line frequency.

The ability to defines a synchronisation class is key to achieve low latency at the system level. For instance, in a line synchronous context, each subsystem can process the video stream using only a line-sized FIFO instead of buffering the full video frame. Thus, the impact of each subsystem on system latency will be limited to the transmission duration of a few lines of video.

Pixel and Video Format

The ARINC 818 standard does not restrict the pixel and video format, which opens up a whole range of possibilities from standard video format to fully custom format.

Video resolution and refresh rate can be freely customized as well as colour model, pixel resolution and pixel packing.

Flexibility and Inter-operability

As exposed above in this paper, the ARINC 818 standard let plenty of space to the system architect to shape the protocol according to his specific system requirements. Flexibility is one of the key features of ARINC 818 but it also has a major drawback: limited interoperability.

ARINC 818 devices are not plug-and-play. By opening all these customization options, the standard has made it impossible for a receiver to handle all possibilities. A device could handle some of them but development costs would quickly become prohibitive as the number options increased.

The solution that is recommended by the standard to the users is to document the specific implementations choices that have been made as precisely as possible. Within the standard, this document is called an Interface Control Document (ICD), and its content is suggested but not imposed.

Typically, a device will support one or a few determined ICD. In an aircraft program, the program leader must identify the ICD(s) and communicate them to all relevant suppliers.

ICD Content

This paper will focus on the 4 following categories of information in the ICD:

- 1) Link characteristics
- 2) Video format
- 3) ADVB transmission
- 4) Video timing

Please note that this does not cover exhaustively the information the ICD may contain, as attached to the A818 standard, since additional information may be included depending on the specific options of the standard used (ancillary data, cursor, ...).

In the link characteristics category, the most essential information is the data rate which range from 1.0625Gbps (Fibre Channel 1x rate) to 28.05Gbps (Fibre Channel 32x rate).

Video format category covers all information relative to a video stream (resolution, scan type, frame rate) down to pixel format and resolution. In the case of multiple video streams on the same link, each video stream calls for a dedicated section in the ICD.

ADVB transmission category describe how the video payload is segmented and packetized into ADVB frames.

Video timing category should describe all the relevant timing constraints that the ADVB frames must meet, depending on the chosen synchronisation class. This section should cover both nominal timing and acceptable deviation from the face value.

Container Header and Object 0

In addition to the information provided by the ICD, the container header and the Object 0 also contain relevant information embedded in the data stream.

As shown in Fig. 1, container header and Object 0 are typically carried in a unique ADVB frame, at the start of the container. Object 0 may contain custom ancillary data but the 4 first 32b-words of the Object 0 are specified by the standard.

The following information are spanned over the container header and the 4 first words of the Object 0:

- Video frame rate
- Video resolution
- Video scan type
- Colour format and resolution

As can be seen, this information overlaps with the content of the ICD.

System Integration and Test

Integrating and testing an ARINC 818 system can be a challenging task. Notably, as interoperability stands only if all equipment shares a common ICD, issues may arise around this document.

The ICD may be missing, incomplete or contain errors. Such problems are less likely to occur in equipment made specifically for an aircraft

program according to a system level ICD but are not uncommon in the case of commercial off-the-shelf products.

Another possible issue is that conflict may occur between information of the ICD and information of the container header and object 0. In a worst-case scenario, Object 0 may even be completely devoid of information.

To circumvent these issues, we recommend a bottom-up approach to integrate, test and validate an ARINC 818 equipment. Ideally, this approach should rely as little as possible on the information contained in the ICD. This approach will start at the link level and work all the way up to video timing validation.

Link Level Test

At link level, the main issue is data rate. If the actual data rate is unknown, an ARINC 818 receiver will likely fail in the initial stages of deserialization: clock recovery and comma detection.

The clock recovery circuit is essentially a phase-locked loop that recover the phase and frequency from the data stream using a reference clock. This reference clock must be sufficiently close to the actual data rate for clock recovery to work.

The reference clock source must be chosen carefully and deliver a low phase jitter (<100fs rms). If the data rate is unknown, a programmable reference clock source should be used so that its frequency can be adjusted.

Container Header and Object 0 Test

Assuming that an ARINC 818 receiver is locked onto the correct data rate, the Container Header and Object 0 can be decoded.

The ICD usually defines thoroughly the expected value for each field in the Container Header and Object 0. It is therefore recommended to decode each field and cross-check it against the ICD information.

ADVB Segmentation

At this stage, ADVB transmission can be parsed, that is:

- The data stream can be segmented into ADVB frames by removing all "Idle" special characters and detecting the SOF_n, SOF_i, EOF_n and EOF_t special characters.
- The ADVB container can be delimited by using the SOF_i and EOF_t special characters.

The total payload size of the container must match the sum of object sizes as defined in the container header.

The total size of video payload (total payload size of the container minus size of non-video payload) should match the product of video height, video width and pixel width as defined in the Object 0.

Video Line Segmentation

Typically, in avionics system, the data stream will be both container header segmented and line segmented. The former means the Container header & Object 0 will be the only data in the first ADVB frame and the later means video lines are distributed across an integer number of ADVB frames. This can be verified, provided that video width and pixel width has been validated beforehand, by checking that the product of video width by pixel width, divided by the ADVB Frame payload size is an integer.

Video Timing Test

In addition to verifying the organization of the video data, video timing and synchronization must be thoroughly checked. As noted above, video synchronization is a feature of ARINC 818 that is essential to achieve low system latency and the proper operation of each subsystem. Therefore, the validation process should include the measurement of the following:

- Frame Period: timing from one SOFi to the subsequent SOFi
- Back Porch: timing from SOFi to the SOFn of the first ADVB frame containing video (Object 2) payload
- Front Porch: timing from EOFt to SOFi.
- Line Period: timing from SOFn to subsequent SOFn.
- ADVB Frame Length: timing from SOFn to EOFn.
- Interline: timing from EOFn to SOFn within a video line.
- Interline: timing from EOFn of the last ADVB frame of the video line to SOFn of the subsequent ADVB frame.

These timings are not necessarily constant throughout the data stream. They may vary depending on the synchronization class and on specific implementation details of the video source. Therefore, rather than using a raw measurement value, it is generally more meaningful to compute minimal statistics of those values over time. These statistics should at least include minimum, maximum and mean value of the aforementioned timings.

Analysing Equipment

From all the considerations above, we have developed an analysing equipment intended for acquiring an ARINC 818 data stream without depending on the ICD.

This equipment features an adjustable clock circuit that the user can adjust until clock recovery is achieved. It then captures and record the raw 10b data stream.

From the recording of the 10b data stream record, this equipment can:

- Check the validity of the 10b stream, flagging any invalid 10b symbol or running disparity error.
- Check the format and CRC of each ADVB frame.
- Decode and display Container Header and Object 0 content
- Measure video timings and calculate basic statistics of these timings over time.
- Decode and display the video frames using either the pixel format automatically decoded from Object 0 or a user-defined value.

Because it is ICD-independent, this equipment has been successfully used to resolve various issues related to missing, incomplete or incorrect ICD, or missing Object 0 data, occurring during integration and testing of ARINC 818 sub-systems.

Conclusions

Throughout this work, we have shown that the interoperability of the ARINC 818 standard depends entirely on an ICD. This dependency can pose a major obstacle during the integration and testing of an ARINC 818 system if the ICD is missing, incomplete or incorrect. We have presented an approach for testing and validating ARINC 818 video sources with minimal reliance on the ICD, and we have developed an analysing equipment consistent with this approach. This equipment has proven useful for identifying various problems under actual operating conditions. Future work could involve addressing some of the limitations of our analysing equipment, such as supporting a wider range of pixel formats.

References

- [1] T. Keller and D. Finnegan, "Standardizing Video-Based Avionics and Mission Systems around the ARINC 818-3 Video Bus," 2024 AIAA DATC/IEEE 43rd Digital Avionics Systems Conference (DASC), San Diego, CA, USA, 2024, pp. 1-9, doi: 10.1109/DASC62030.2024.10748847.