Analog Video to ARINC 818

A White Paper by Paul Grunwald

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ABSTRACT

Many commercial and military aircraft still use analog video, such as RS-170, RS-343, or STANEG 3350. Though the individual digital components many be inexpensive, the cost to certify and retrofit an entire aircraft fleet may be prohibitively expensive. A partial or incremental upgrade program where analog cameras remain in use but data is converted and processed digitally can be an attractive option. This paper describes Great River Technology's experience in converting multiple channels of RS-170 and multiplexing them through a concentrator to put them onto a single fiber or cable. The paper will also discuss alternative architectures and how ARINC 818 can be utilized with legacy systems.

1. INTRODUCTION

Many aircraft, both commercial and military, are still using analog video such as RS-170, RS-343, or STANEG 3350. Though the individual digital components many be inexpensive, the cost to certify and retrofit an entire older aircraft fleet may be prohibitively expensive. Cost drivers include the physical labor to fabricate, replace, and install new cabling and wiring in the aircraft. Certifications and regulatory approvals can also be costly and time consuming. One solution to address some of these cost drivers is a hybrid system that would reuse some of the existing components such as displays, camera, or cabling with the benefits of a modern protocol such as ARINC 818.

In 2005, Airbus and Boeing felt a need to add further capabilities for the new 787 and A400M programs, and a new standardization effort was initiated through the Digital Video Subcommittee of ARINC. The primary driver for the standard was the need to consolidate many proprietary standards that existed in the avionics supply chain. For example, display manufacturers such as Honeywell, Rockwell Collins, and Thales each had its own protocols for its products. The ARINC 818-1 specification was ratified in January 2007 with the participation from wide range of aerospace suppliers. Revision 2 of the specification adding features and capabilities was ratified in December of 2015.

This paper will cover three main topics: (1) lessons learned converting between analog (RS-170) video and ARINC 818, (2) methods to put multiple video streams on ARINC 818, and (3) use of CoaXPress in a legacy installation.

2. ANALOG VIDEO CAPTURE

There are multiple analog video protocols used in avionics. The most common are RS-170 and RS-343 in the United States. In Europe, STANEG 3350 is very common. We will focus on a RS-170 implementation as it is probably the most common world-wide. RS-170 is very closely related to NTSC video which was the North American television standard approved in 1953. This became RS-170A with the move to color television. Most analog television broadcasts stopped in 2009 with the switch to digital television.

Table 1. Analog Video Protocols

	Total lines	*Active lines*	*Fields per sec*	*Frames per sec*	*Comment*
NTSC EIA RS-170	525	480	60 i	30	
NTSC Color RS-170A	525	480	60 i	30 + NTSC color	
PAL	625		50 i	25 + PAL color	
PAL non-interlaced	312			50	
SECAM	625		50i	25 + SECAM color	
RS-343	875 (up to 1023)			60	
STANAG 3350 Class A	625			60	similar to RS-343
STANAG 3350 Class B	625			50	similar to PAL
STANAG 3350 Class C	525			60	similar to NTSC RS-170A

There are many implementations of RS-170 and the differences are sometimes very subtle. For the purposes of our example, we will be as generic as possible. Originally, RS-170 was 29.97 interlaced frames of video per second. Each frame has 262.5 scan lines for a total of 525. The visible raster was 483 lines. The non-visible lines are the blanking interval was there for the originally, tube-based, CRT systems to return the beam to the start of the image. More modern implementations of RS-170 are non-interlaced.

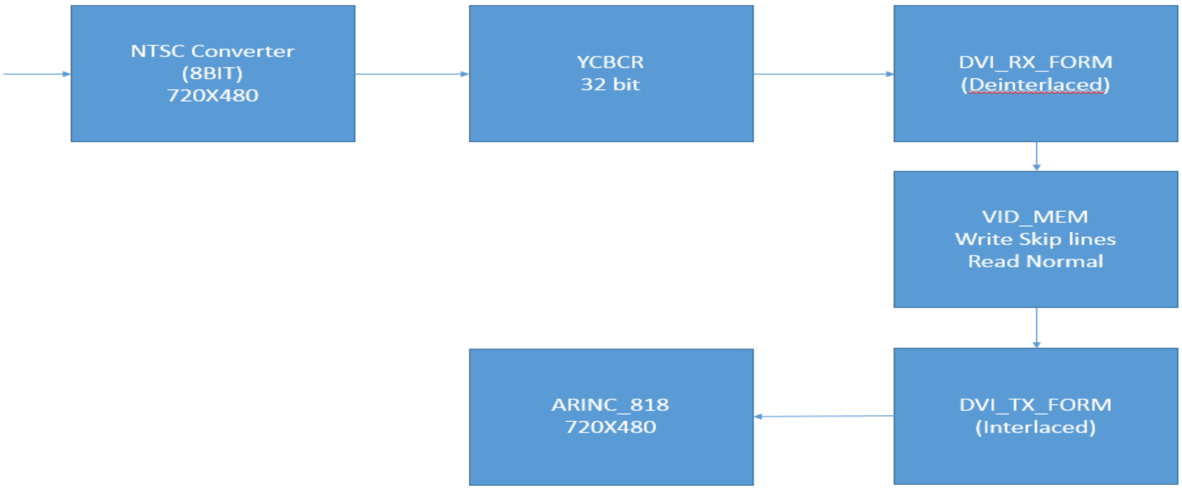

Figure 1. NTSC video in 60 Hz.

Our example is receiving 60Hz of color NTSC video. An Analog Devices ADV7180BCPZ 10-Bit, 4× Oversampling SDTV Video Decoder is used to digitize the video to 720x480 YcBcR format. The converter looks for embedded data for vsync and hsync to enable on. Data is delayed and only enabled for every 4th instance of the 8 bit data-in to create a 32 bit YCBCR signal. It looks for number of lines that are considered ancillary data and removes them from enable, also creates a generated vsync after the last line of active data. This data is then loaded into an image buffer where it is essentially stored as if it was received from a more modern DVI interlaced buffer. This was done to make it compatible with the existing GRT ARINC 818 FPGA core.

3. DESIGN CONSIDERATIONS

The video resolution captured is the standard 4:3 but each video line could be sampled at a higher or lower resolution (i.e., 640 x 480). PAL data is normally sampled at 768 x 573 for example. The NTSC1 spec allows for ancillary data in the blanking periods and this data could be captured and put in to ARINC 818 ancillary data. This could include items such as data such as teletext, time, position, or camera settings. Closed captioning can also be captured. The color-depth of the digitized video is also optional. It could be left as YcBcR or converted to 8, 16, or 24-bit depending on the fidelity required and available bandwidth for the system.

In the above example, we captured the data as non-interlaced and placed the data in ARINC 818 object 2 (progressive scan) format. One could also capture the video interlaced and use the ARINC 818 Object 2 and Object 3 containers. NTSC also carries audio so that could be captured and put in an ARINC 818 Object 1 container.

In the above example, the entire video frame is put into a video memory buffer. For a mission or safety critical application, or if an application that cannot tolerate a full frame of latency, it may be advisable to use a FIFO buffer that would only hold a single line of video. These architecture considerations have to be made at both a system level as well as in the context of items like DO-254 certification or obtaining a TSO.

4. ANALOG OUTPUT

On the output, the data is taken from the ARINC 818 memory buffer and converted to the YcBcR color space and then feed to an analog output chip in the reverse of the above capture. In our example, we did not capture additional non-image data but if it existed, it would also be loaded into the chip with the video data for insertion into the video stream.

The most critical design and implication criteria would be to ensure that the output video stream was compatible with the video display. This would include the horizontal and vertical blanking periods and line and scan timings. For many implementations, this would just be a matter of setting up the DA chip but also physical considerations such as output levels, cable and line loss, etc.

5. MULTIPLEXING ARINC 818

Another advantage of digitizing analog signals such as RS-170 is bandwidth. Many legacy systems are constrained with one source or one display per cable. By digitizing and multiplexing, many legacy video or even data streams, could be put on a legacy coax or a single fiber.

Table 2. Data Rates

720x480 @ 60 Hz RGB 8:8:8 (24 bit)	0.622 Gb/s (no overhead) 0.684 Gb/s (with overhead)
72 x 480 @ 60 Hz YCbCr (16 bit)	0.414 Gb/s (no overhead) 0.456 Gb/s (with overhead)

Many ARINC 818 implementations are running at 3.1875 Gb/s or 4.25 Gb/s on what is essentially commodity hardware and data center grade fiber. In ARINC 818-1, the following speeds (Gb/s) are supported:

- 1.0625 (FC 1x rate)
- 1.5
- 1.62
- 2.125 (FC 2x rate)
- 2.5

- 3.1875 (FC 3x rate)
- 4.25 (FC 4x rate)
- 8.5 (FC 8x rate)

Supplement 2 expanded the list to include the following link rates:

- 1.0625 (FC 1x rate)
- 1.5
- 1.62
- 2.125 (FC 2x rate)
- 2.5
- 3.1875 (FC 3x rate)
- 4.25 (FC 4x rate)
- 5.0
- 6.375 (FC 6x rate)
- 8.5 (FC 8x rate)
- 12.75 (FC 12x rate)
- 14.025 (FC 16x rate)
- 21.0375 (FC 24x rate)
- 28.05 (FC 32x rate)

Is it possible to support dozens of channels on a single link. In ARINC 818, this is done by using simple Time Division Multiple Access (TDMA) on the link. Each stream is given its own slot and by use of source ID (S_ID) in the ARINC 818 head, each container is uniquely identified.

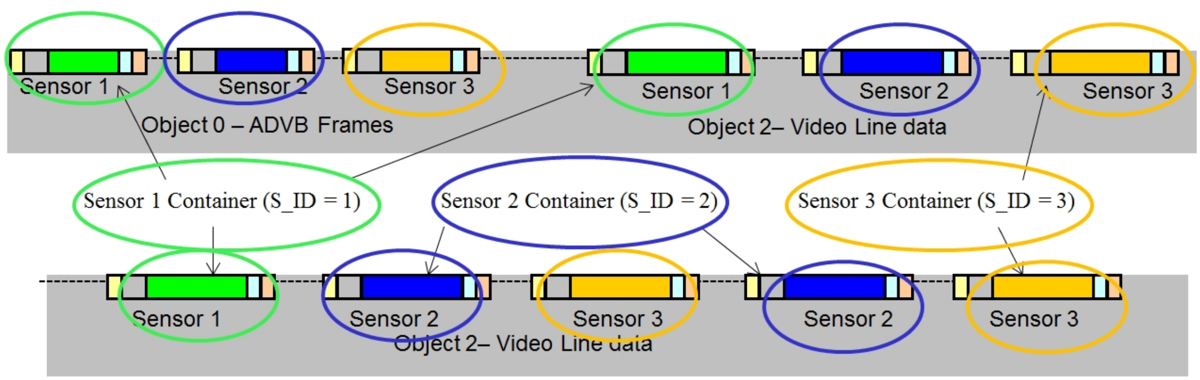

Figure 2. Container identification.

ARINC 818-2 also supports switching and with both a Source ID (S_ID) and Destination ID (D_ID), different video or data streams could be routed by an intelligent switch or concentrator/de-multiplexer. As with most ARINC 818 implementations, the system architect and designers have a great deal of freedom to specify the implementation details in the project Interface Control Document (ICD).

6. LEGACY INSTALLATIONS

Many legacy implementations are cabled with 75 ohm coax, which would be prohibitory expensive or impractical to retrofit with fiber. CoaXPress is a standard for high-speed video over coax cabling developed for the machine vision industry. CoaXPress was originally developed by Adimec, Active Silicon, and Components Express utilizing chip technology from EqcoLogic. The standard was ratified in March of 2009.

The physical layer has desirable features for aerospace and defense applications: it allows up to 6 Gb/s (12.5 Gb/s planned) communication, includes 21 Mb/s return path allowing for bidirectional communication, and provides up to

13W of power, all over a single coax connection. Because it is a copper interface, it also lends itself well to supporting rotary joints and slip rings, which can be problematic for fiber implementations.

The CoaXPress standard defines both a physical and a protocol layer. The CoaXPress video protocol is optimized for the machine vision industry and doesn't specifically address the special needs of airborne video systems. Whereas the architects of ARINC 818, not only focused on the unique requirements of airborne video systems, but also considered the requirements of commercial airworthiness standards. In many systems, ARINC 818 implementations must detect any link degradation that might compromise flight safety. From a standards perspective, ARINC 818 is physical layer agnostic and there are implementations today on both fiber and copper.

ARINC 818 protocol, because it is packet based, allows for the time multiplexing of video streams (and or control channels) onto a single link. This fact, along with the potential of the ARINC 818 Express concept to include return path command/control of cameras and power on a single cable, could provide a superior cabling solution for airborne multi-sensor turret applications.

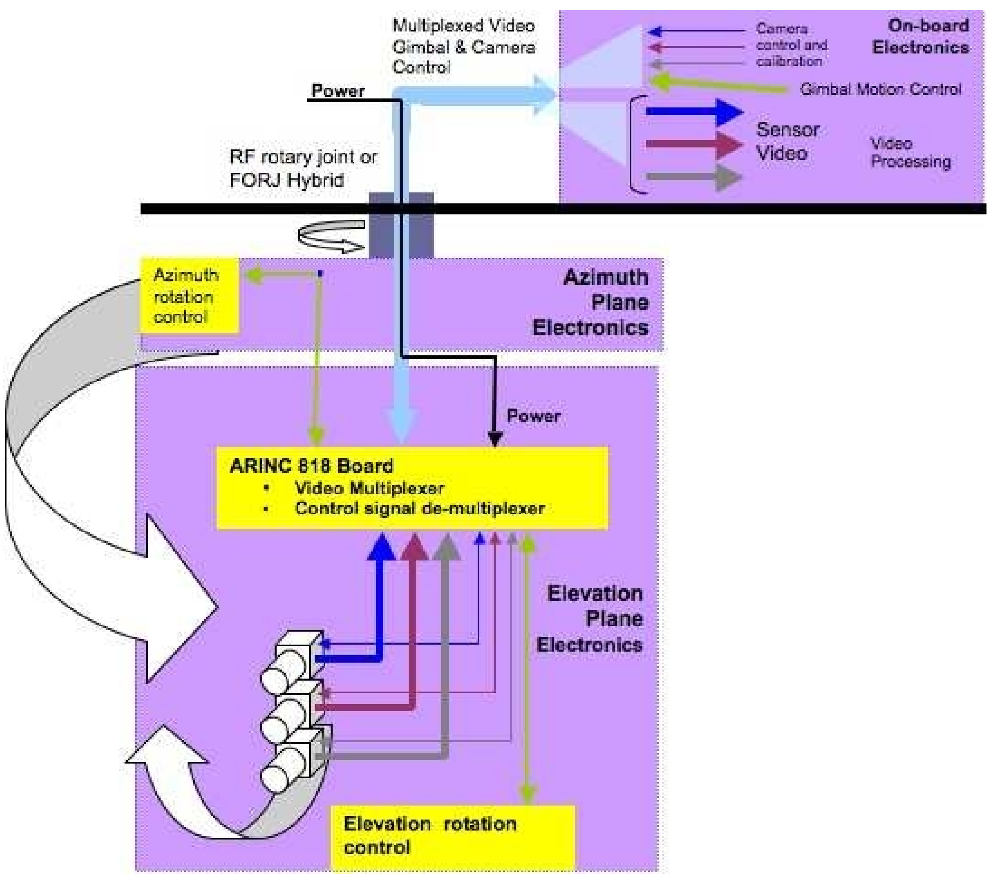

Figure 3. Example application of A818 Express.

Airborne turrets have become common for ISR applications and for enhanced vision systems (EVS). In cases where multiple cameras are installed in a turret, and where each camera must have a video cable, a control cable, and a power cable, the design for azimuth and elevation degrees of freedom can become exceedingly complex.

This shows how the ARINC 818 Express concept, used with time multiplexed video and control could be used to reduce cabling complexity, cost (by reducing the cabling that must go through the slip ring), and weight. This approach could also increase reliability by reducing the cabling flex.

From a reliability stand-point, this approach has the advantage that cabling for video, control and power, as required by each camera, could be kept very short and could occur in the elevation plane such that there is little or no flexing of the cables.

CONCLUSION

ARINC 818 is a modern data and video transport protocol that can also be applied to legacy systems. Hybrid designed with both modern and legacy components can be safely implemented in today's aircraft designs. Mixing older analog component and cabling can save money while still upgrading avionics suited to state of the art designs.

[1] https://en.wikipedia.org/wiki/RS-170