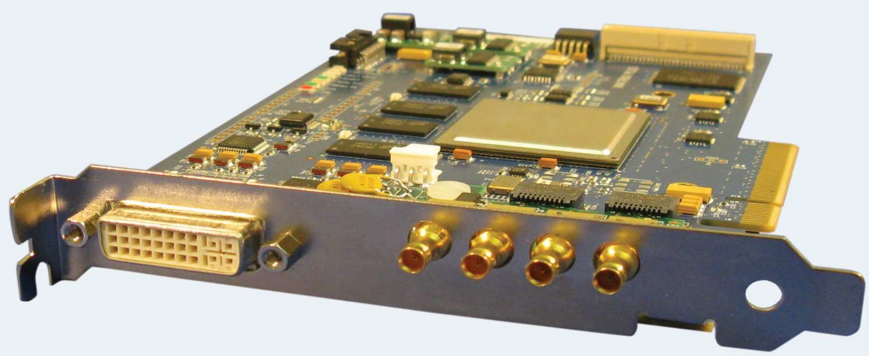
ARINC 818 on Copper

The Successor to HOTLink II Video Links?

A White Paper by Jon Alexander



GRT's new Matrix ARINC 818 card with High Speed Coax (HSC)

Common RG59 coaxial cable with DIN 1.0/2.3 connector

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1 Introduction

HOTLink™, the name Cypress Semiconductor applies to a family of 8b/10b Serializers/Deserializers (SerDes), has been around since 1992. HOTLink II™, introduced in 2001, supports speeds up to 1.5 Gbps and has been embraced by the military and aerospace community for its simplicity and flexibility. But as modern military and aerospace video systems demand more bandwidth, designers are looking for a new solution. ARINC 818-2 on copper provides the perfect solution.

ARINC 818-2 is the 2013 update of ARINC 818, which is the Avionics Digital Video Bus. It is proposed as a viable replacement because it is similar to HOTLink II and provides much higher bandwidth, standardization, and built-in error checking.

2 The HOTLink II Precedent

So widely used and so popular, the name HOTLink II™ has become the moniker for any custom 8b/10b encoded link with minimal protocol overhead—whether implemented with Cypress chips or not.

With HOTLink II™, designers have had ultimate flexibility for defining a video link. They opt for whatever best serves the system requirements. In fact, HOTLink II™ implementations have been about the simplest protocols imaginable. Users have simply picked a sufficient link rate and defined a simple protocol using the available set of special characters (Kchars) to delimit packets of data and video.

For instance, video line data might designate a start-of-line (SOL) Kchar as K28.3 and an end-of-line (EOL) Kchar as a K28.4. Non-video data packets might be designated by a K28.2. Implementers have liked the fact that HOTLink II™ is not tied to a particular physical transmission medium. This is essential for upgrade applications constrained by an existing cable choice. In military and aerospace, the HOTLink II™ physical transmission medium has mostly been twisted shielded pair (TSP) or coaxial copper.

With HOTLink II™ implementations, different link rates and many protocol choices result in proprietary interfaces not compatible with off-the-shelf test equipment. Other link attributes, such as packet sizes and delivery timing, almost guarantee that one HOTLink II™ enabled product will not be compatible with another—unless designed to the very same interface document.

The flexibility and simplicity of HOTLink II™ has been its strength and its weakness.

3 Next-Generation Needs

There is currently a need to go beyond the 1.5 Gbps bandwidth limit of Cypress HOTLink II™ Physical Layer Devices (Phys) and to improve achievable distances—especially at higher bandwidths. There are many choices for a next-generation solution, many that can reach beyond 10 Gbps. But like HOTLink II™, any next-generation interface will need to be flexible. At the same time there would be significant benefit from standardization—creating the possibility for off-the-shelf tools for development and testing.

Because of its flexibility, low overhead, and higher speeds, ARINC 818 Supplement 2 (ARINC 818-2) is a strong candidate for a next-generation solution. Like HOTLink II™, ARINC 818 is independent of the physical transmission media. Both fiber and copper can be used. But unlike HOTLink II™ implementations, ARINC 818 has standardized the basic transport layer, enabling the possibility of generic test and development equipment.

For very high bandwidth applications, ARINC 818 implementations on fiber optic can reach 12 Gbps and distances exceeding 500 meters. But in cases where fiber optic is not suitable, ARINC 818 implementations on copper are possible and make an ideal next-generation replacement for HOTLink II™. Implementations on coaxial cable can reach 6 Gbps and, depending on bit rate and chosen cable type, can achieve distances greater than 100 meters (see Section 4.3).

Like HOTLink II™ implementations, ARINC 818 link rates and protocol are ultimately flexible for the needs of the application. Many link rates are defined, and any video resolution, pixel type, and timing can be achieved.

4 Comparison of HOTLink II™ and ARINC 818 Implementations

Table 4 makes a quick comparison between HOTLink II™ implementations for video links and ARINC 818.

Table 4. HOTLink II™ video links and ARINC 818 comparison

Feature	***HOTLink II™ Implementations***	***ARINC 818***
Link Encoding	8b/10b	8b/10b
Flexible physical layer?	Yes, any physical	Yes, any physical
Copper physical support?	Yes, any copper physical	Yes, any copper physical
Special Characters/Link primitives	12 different Special Characters, no constraints for use	8 different Ordered Sets, 4 characters each, usage defined by the standard.
Transport layer	User defined	Packet structure defined by standard
Flexible link rates?	Any link rate up to the limit of the Phy	11 8b/10b link rates defined by the standard
Flexible video resolution/pixel definition?	Any video resolution/pixel definition	Any video resolution/pixel definition
Allows for precise video timing?	Yes	Yes
Protocol overhead	< 2%	< 3%
Standardized transport layer?	No	Yes
Support ancillary data transport?	Yes—user proprietary	Yes—defined by standard
Supports return path?	Requires separate HL2 interface	Can be achieved on single coax cable

4.1 Encoding

HOTLink II™ serial is an 8b/10b encoded link that provides 12 special characters (K28.0, K28.1, K28.2, K28.3, K28.4, K28.5, K28.6, K28.7, K23.7, K27.7, K29.7, and K30.7) for use as delimiters on the link. The special characters can be used to indicate start of video frame, end of video frame, start of line, end of line, idles, or other needed control characters.

Typically HOTLink II™ implementations use the K28.5 as the "stuffing" character between packets of data.

ARINC 818 is also an 8b/10b encoded link but has the additional protocol requirement that all transmitted data be in 4-byte chunks. For example, the "stuffing" characters, instead of being the single character K28.5, is the 4-character Idle ordered set: K28.5, D21.4, D21.5, D21.5. The Idle ordered set, like all ordered sets used in ARINC 818, are a Kchar followed by 3 data characters (see section 3.4).

4.2 Link speeds

HOTLink II™ link rates can be chosen at any rate supported by the Phy. This is essentially anything between 330 and 1500 Mbps when using Cypress devices. In contrast, the ARINC 818 standard defines the allowable link rates in Table 4.2

Table 4.2. ARINC 818 Link Speeds.

Bit Rate (Gbps)	***Equivalent Fibre Channel Rate***
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	
6.375	FC 6x rate
8.5	FC 8x rate
12.75	FC 12x rate

4.3 Copper physical

Important additions to the ARINC 818-2 standard (over ARINC 818-1) paved the way for improved copper physical layers. Specifically envisioned was the use of newer active equalizer chips to greatly improve bandwidth and distance on coaxial cable. Included in ARINC 818 are methods to implement a return communication path (from video receiver to video source) on the same coaxial cable. Therefore, a complete camera or sensor interface can be achieved with a single high-bandwidth coaxial cable.

GRT offers ARINC 818 High-Speed Coax (HSC) frame grabbers, video generators, converter modules, and switches. GRT's ARINC 818 HSC products use the same physical media as used by the CoaXpress™ standard. Like CoaXpress™, these products support a low-speed control path from a video receiver to a video source. Figure 4.3 shows GRT's evaluation system, where two camera interfaces are multiplexed onto a single coaxial cable. A single frame grabber acts as the controller for two cameras.

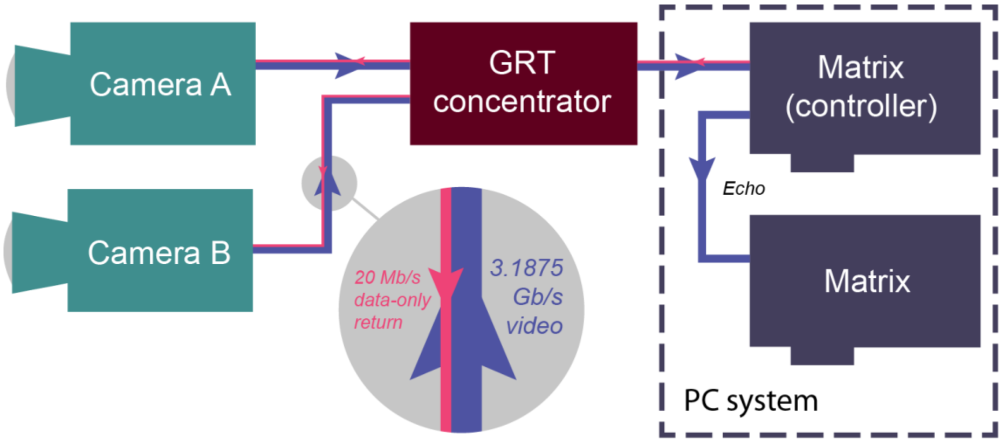

Figure 4.3. GRT's evaluation system for ARINC 818 on High Speed Coax

Figures 4.3a and 4.3b show achievable distances over coaxial cable for GRT ARINC 818 HSC products using common coaxial cable types. Table 4.3 shows the impressive results using 75-ohm coax.

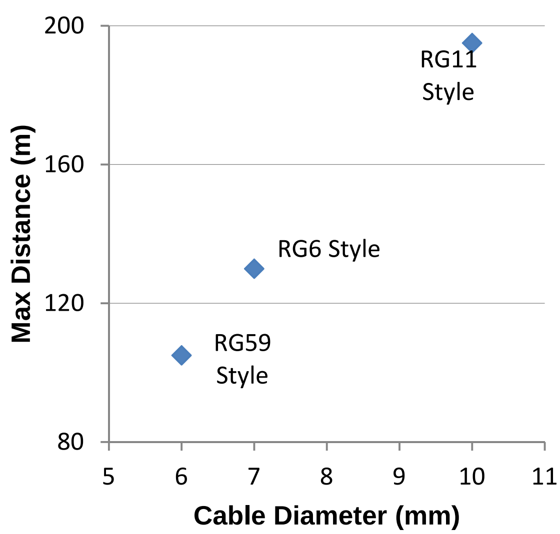

Figure 4.3a. Max Distances @ 1.0625 Gbps (for common 75-ohm coax cable types)

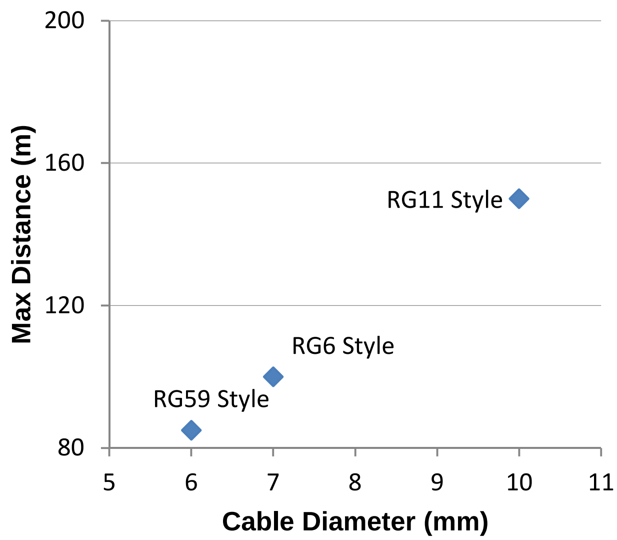

Figure 4.3b: Max Distances @ 3.1875 Gbps (for common 75-ohm coax cable types)

4.3.1 Ordered Sets

As mentioned, ARINC 818 is also an 8b/10b encoded link, but unlike HOTLink II™ all primitives are 4 characters wide. In HOTLink II™ implementations, the designer can choose any of the 12 Kchars for protocol delimiters. In contrast, ARINC 818 has several defined OS used to denote such things as the beginning/end of a video frame, beginning/end of a video line payload packet. Table 4.3.1 lists the allowable OS used in ARINC 818 and describes their use.

Table 4.3.1. ARINC 818 Ordered Sets

Name	***Ordered Set***	***Usage***
Idle	K28.5 D21.4 D21.5 D21.5	Idle "stuffing" character
SOF Initiate Class 1 (SOFi1)	K28.5 D21.5 D23.2 D23.2	Indicates the start of a video frame
SOF Initiate Class 3 (SOFi3)	K28.5 D21.5 D22.2 D22.2	Indicates the start of a video frame
SOF Normal Class 1 (SOFn1)	K28.5 D21.5 D23.1 D23.1	Indicates the beginning of a packet of video payload
SOF Normal Class 3 (SOFn3)	K28.5 D21.5 D22.1 D22.1	Indicates the beginning of a packet of video payload
EOF Normal (EOFn)	K28.5 D21.4 D21.6 D21.6	Indicates the end of a packet of video payload
	K28.5 D21.5 D21.6 D21.6	Indicates the end of a packet of video payload
EOF Terminate (EOFt)	K28.5 D21.4 D21.3 D21.3	Indicates the end of a video frame
	K28.5 D21.5 D21.3 D21.3	Indicates the end of a video frame

Typically an implementation will use either Class 1 or Class 3 ordered sets.

4.3.2 ARINC 818 Packets

Unlike HOTLink II™ implementations, where packet construction is free-form, ARINC 818 has precise rules for constructing a packet. The ARINC 818 standard refers to the basic transport mechanism (packet) as an ADVB frame. It is important to refer to these packets as "ADVB frames" rather than simply "frames" to eliminate potential confusion with video frames.

Figure 4.3.2. Structure of ADVB Frame.

The start of an ADVB frame is signaled by an SOFx ordered set and terminated with an EOFx ordered set as shown in Figure 4.3.2. Every ADVB frame has a header comprised of six 32-bit words. These header words pertain to such things as the ADVB frame origin and intended destination and the ADVB frame's position within the sequence. The payload can be video or associated data. The payload in one ADVB frame can vary in size but cannot be greater than 2112 bytes. Finally, all ADVB frames have a 32-bit CRC calculated for all data between the SOFx and the CRC word for built-in error checking. The CRC is the same 32-bit polynomial calculation defined for Fibre Channel.

The ARINC 818 Specification defines a container as a set of ADVB frames used to transport a single video frame. In other words, a video image and associated data is encapsulated into a container that spans many ADVB frames.

Within a container, ARINC 818 defines objects that contain certain types of data. That is, certain ADVB frames within the container are part of an object. Although there are four types of objects, most implementations use only two objects—ancillary data (Object 0) and progressive scan video (Object 2).

4.3.3 Data payload

In ARINC 818 nomenclature, the data object is referred to as Object 0, and it is typically the first packet sent along with each video image. Most implementations require less than the 2112-byte limit for a single-packet data object, but there is no limit to the size of the data object, and several packets may be used.

There are only a few rules for Object 0 construction. First, all Object 0 packets must be constructed per Figure 4.3.2 and have the defined 24 bytes of ADVB frame header. Second, the first 88 bytes after the packet header are defined by ARINC 818 as the container's header. In other words, these are reserved, must be present, and must have the correct data for the link to be ARINC 818 compliant. Among other things, the container header has a video frame counter, timestamp fields, and size and offset values for all container objects (essentially the number of bytes of video payload data and ancillary data).

Unlike HOTLink II™ implementations, where there is no requirement to transport data (in some implementations only video payload exists), ARINC 818 requires that at least one Object 0 packet be transmitted with each container (video image). The first ADVB frame, which carries only Object 0 (ancillary data) and the container header, is 128 bytes.

4.3.4 Video payload

In ARINC 818, video payload data is transported in a series of ADVB frames. The typical application transports a single line in an integer number of equal-size ADVB frames. For video lines requiring more than the 2112 byte limit, two or more ADVB frames are used.

An example of how ARINC 818 transmits color XGA provides a good overview. XGA RGB requires about 141 Mbytes/s of data transfer (1024 pixels x 3 bytes per pixel x 768 lines x 60 Hz). Adding the protocol overhead and blanking time, a standard link rate of 2.125 Gbps is required. ARINC 818 packetizes video images into ADVB frames. An ADVB frame is defined in Figure 4.3.4, where the maximum size of the payload is 2112 bytes. Each ADVB frame begins with a 4-byte ordered set, called an SOFx (start of frame), and ends with an EOFx (end of frame). Additionally, a 4-byte CRC is included for data integrity.

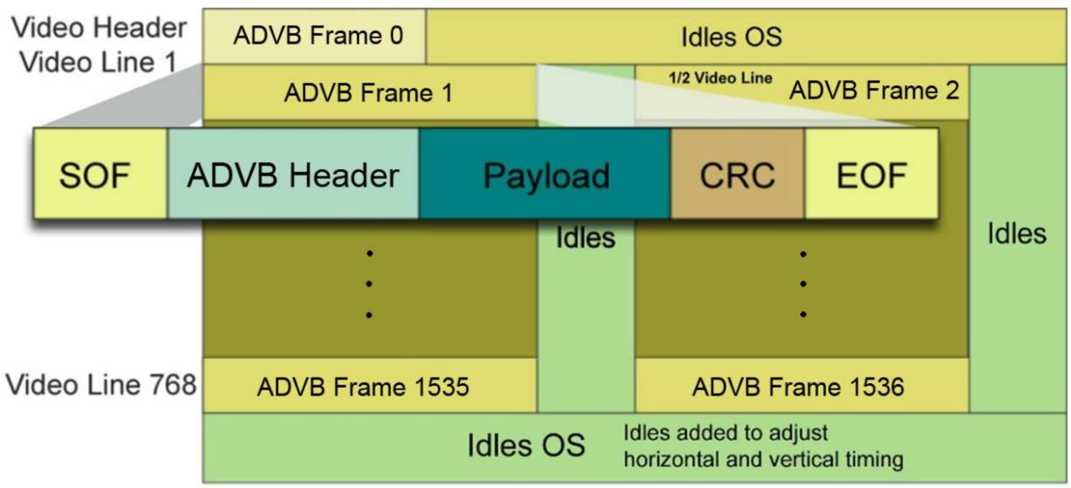

Figure 4.3.4. Color XGA example sequence of ADVB frames.

Each XGA video line requires 3072 bytes, which exceeds the maximum ADVB payload length; therefore, each video line is divided into two ADVB frames. Transporting an XGA image requires 1536 ADVB frames per image. The first ADVB frame, which that carries the Object 0 data and the container header, brings the total to 1537 ADVB frames.

4.3.5 Video timing

Like HOTLink II™ implementations, ARINC 818 links can impose precise video timing on the transported video payload. This is not required by the standard, and implementations may transport single-image snapshots with un-timed lines. But in cases where the link carries live video, both video frame and video line timing may be imposed.

The timing details for an ARINC 818 implementation are captured in the ICD for the link (see section 4.5).

As shown in Figure 4.3.4, vertical and horizontal line timing is achieved by adjusting the Idle ordered set stuffing characters between ADVB frames.

4.4 Interface Control Document and interoperability

Like HOTLink II™ implementations, ARINC 818 allows for flexibility in the implementation of the video interface. This flexibility is desirable, because of the diverse resolutions, grayscales, pixel formats, and frame rates of mil/aero video systems. However, this flexibility is a problem for equipment venders hoping for some degree of interoperability.

The ARINC 818 committee intended that any implementation of an ARINC 818 serial interface be accompanied by an Interface Control Document (ICD).

A particular piece of equipment that is compliant with ARINC 818 is not necessarily interoperable with another piece of equipment compliant with ARINC 818. It all depends on the ICD. The ICD will specify parameters of the link, such as link speed, image resolution, synchronization scheme, frame rate, etc. Typically, a military program or commercial avionics development program will have an ICD associated with it.

ARINC 818 interfaces that are designed to a particular ICD will be interoperable. When specifying that equipment be ARINC 818 compatible, a particular ICD should be referenced.

Unlike HOTLink II™ implementations, ARINC 818 has standardized the basic transport layer, enabling the possibility of generic test and development equipment.

To support the development of ARINC 818 transmitters, GRT offers a protocol analyzer product that is compatible with any ARINC 818 implementations from 1x to 4x link rates. Similarly, for supporting the development of ARINC 818 receivers, GRT offers a flexible video source product, Xf Tuner, that is compatible with any ARINC 818 implementations from 1x to 4x link rates.

4.5 FPGA implementation

In almost all cases, electronic devices capable of implementing 8b/10b interfaces (such as Cypress HOTLink II™) will be capable of implementing ARINC 818—that is, up to the bandwidth limit of that device. It would be possible, for instance, to use the Cypress HOTLink II™ Phy to achieve an ARINC 818 link running a 1.0625 Gbps.

The same is true for FPGA devices with high-speed 8b/10b SerDes. Xilinx and Altera dominate the landscape for PLDs and FPGAs. Both vendors offer products with built-in high-speed serial interface blocks capable of ARINC 818 interfaces. In most cases these are simple 8b/10b SerDes that can be used to fulfill existing serial standards (such as Fibre Channel, PCI Express, XAUI, SONET, Gigabit Ethernet, etc.) and can be used for ARINC 818 interfaces.

IP Core: Unlike HOTLink II™, ARINC 818 has a defined protocol. This lends itself to using an IP core to implement ARINC 818 into a design. GRT offers ARINC 818 IP cores for most popular Xilinx and Altera devices. These IP cores are being used in numerous aerospace products and have undergone DO254-Level A certification.

4.6 Conclusion

With HOTLink II™, designers have had ultimate flexibility for defining a video link. Implementers have been able to define simple protocols using the available set of special characters to delimit packets of data and video.

Like HOTLink II™ implementations, ARINC 818 allows for a low-overhead, flexible implementation of a video interface. But unlike HOTLink II™ implementations, ARINC 818 has standardized the basic transport layer, enabling the possibility of generic test and development equipment.

ARINC 818 supports link rates from 1.0625 Gbps to 12.75 Gbps, all using familiar 8b/10b encoding.

Important additions to the recent ARINC 818-2 standard have permitted the use of copper physical layers using of newer active equalizer chips. These copper interfaces have impressive band widths and maximum distances when using common coaxial cable.

In addition, it is possible to have a return communication path (from video receiver to video source) on the same coaxial cable. Therefore, a complete camera or sensor interface can be achieved with a single high-bandwidth coaxial cable.