Basic Digital Audio Test Techniques

By Bill Thompson

While there are several digital audio formats in use today, one of the most widely adopted is the Audio Engineering Society/European Broadcast Union (AES/EBU) format. This standard supports a two-channel multiplexed digital audio stream with embedded clock and data in a serial format. The location of rising and falling edges of AES bits signify their state (1 or 0) versus signal levels driving transitions as in TTL or CMOS logic. The AES/EBU format supports signal resolution up to 24 bits, with 16-bit (consumer version) and 20-bit (professional version) being the most often used. It also supports sample rates between 32 and 48 kHz that equate to a maximum data rate of 3.072 MHz. Central to analyzing and troubleshooting this type of digital audio data stream is understanding the concepts of AES/EBU frames and subframes.

AES/EBU Frames and Subframes

AES/EBU digital audio data is organized in a frame structure (Fig. 1). The frame contains two subframes; the A subframe is the left channel, while the B subframe is the right channel in stereo applications. Each subframe includes 32 bits (32-bit intervals). The first 4 bits form preambles, which are synchronization characters. The next 24-bit intervals are reserved for digital audio data and are arranged from least significant bit (LSB) to most significant bit (MSB), in a 2's complement. In applications where less than 24-bit resolution is employed, unused bits are set to 0. The final 4 bits contain control information.

Bit 28 is the Validity bit *V*, which denotes the suitability of digital audio data to be converted to analog form. Bit 29 is the User bit *U*, which carries one bit from a larger User Data Block along with the digital audio data. Bit 30 is Channel Status *C*, which carries one bit of the larger Channel Status Data Block along with the digital audio data. Bit 31 is Parity *P*, which is set to "1" (even parity) in AES interfaces. These *VUCP* bits will be examined in greater detail when troubleshooting is discussed.

To effectively do its job, digital audio signal data must not be corrupted beyond the point where it can be received and interpreted without error by a downstream device. Since timing information is represented by recurring transitions of the data stream, deviations in the location of these transitions can cause problems. Short-term deviations may cause jitter. Long-term deviations will affect sample rate accuracy, which translates into unstable and inaccurate system clocks. Jitter tends to propagate throughout the chain of digital audio devices, with it getting worse at each link.

Because digital audio operates in a multi-megabit-per-second bandwidth, signals can also be obscured by noise and interference, meaning that signal paths and cables must be properly terminated. While the AES/EBU standard supports a signal amplitude specification, there are two different implementations being used today. The "professional" format uses balanced signal amplitudes of 2 V to 10 V p-p. It will drive cables up to 100 m long and offers tolerance to noise and interference. The "consumer" format uses unbalanced signal amplitudes of 200 mV to 1 V p-p. This format calls for using shorter cables, which makes equipment more susceptible to noise and interference. Unless adequate signal amplitude is supplied to a receiving device, it will be unable to accurately detect transitions in the data stream and will not lock up, causing a link failure. Other interference like reflections and ringing can also affect performance.

Equipment Incompatibility Problems

If digital audio transmitting and receiving devices are operating at different sample rates (e.g., a compact disc player sampling at 44.1 kHz and a digital tape recorder sampling at 48 kHz), you may encounter problems like audio signals that contain "clicks," other periodic artifacts, or no recording

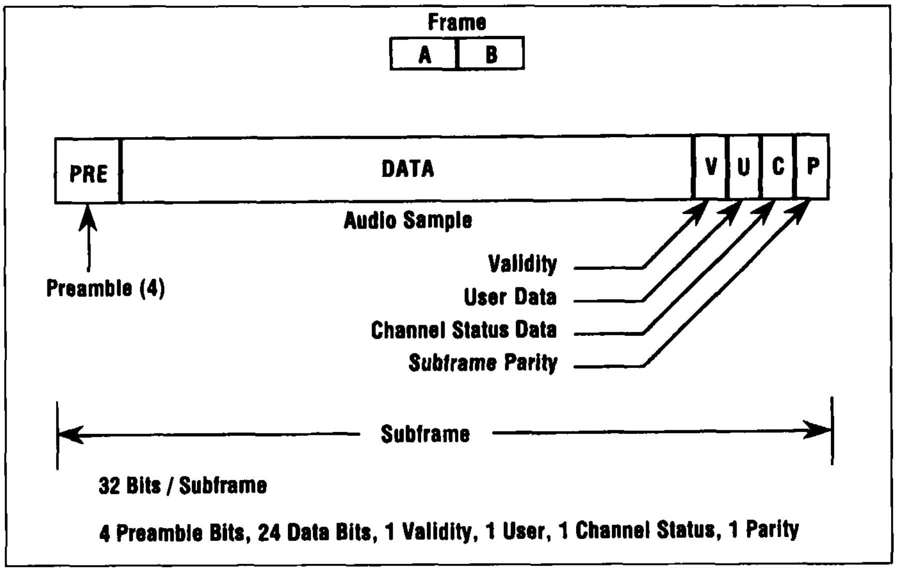

Figure 1. AES/EBU frame and subframe structure.

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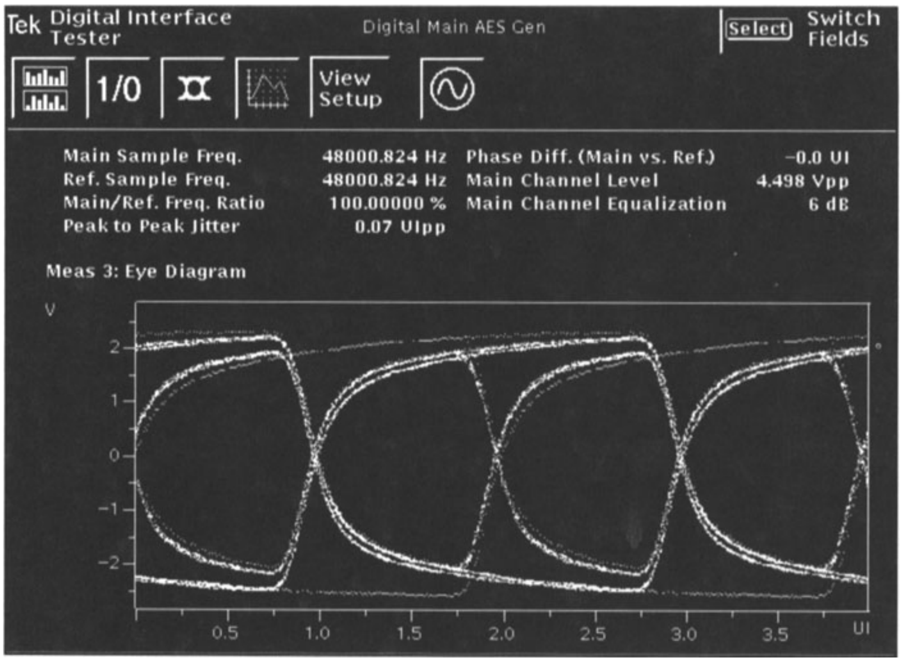

Figure 2. Eye diagram showing signal degradation in a long cable run.

at all. This will be true even if the device's inputs and outputs are electrically compatible. Further, transmitters and receivers operating in different data formats (Channel Status bit *C* set to professional or consumer) can cause similar incompatibilities.

Digital Audio Testing Technique

While some seasoned professionals may be able to resolve certain digital audio interface problems with conventional test equipment, the first-time troubleshooter may be totally baffled at the prospect. Fortunately, there is an increasing availability of special-purpose test equipment that can make things easier.

Confidence monitors with digital audio capabilities are useful to verify that signals are making their way through patch panels and cable harnesses. They can also be used to monitor and modify the state of Validity, User, Channel Status, and Parity bits within the data stream. Digital audio monitors, the modern-day equivalent of the VU meter and stereo level/phase meter, provide various indications of data stream activity including levels, data format, sample rate, and channel status. For detailed testing and analysis, audio measurement sets with advanced capabilities, such as the ability to generate eye diagrams, are used.

Eye Diagram Analysis

Eye diagram displays allow the viewing of many data stream components. They show bit transition activity and the presence and amplitude of signals. As such, various types of electrical problems are easy to detect. Problems with frequency response and interference can cause subtle changes in the appearance of rising and falling edges of the waveshape. Jitter manifests itself as a smearing of the normally crisp edges of the eye diagram, closing the diagram in a horizontal direction. Attenuation in long cable runs represent a lowering in overall eye height (Fig. 2). In all of these cases, the critical parts of the eye diagram to watch are waveshape symmetry and the central open region of the pattern.

Jitter Spectrum Analysis

Because eye diagrams only provide a representation of peak-to-peak jitter, jitter spectrum analysis is used to assess its frequency content and characteristics. By viewing jitter spectrum with an audio measurement set, the source (e.g., a 120-Hz jitter peak caused by fluorescent light) can be identified. The source can then be located through deduction. Alternately, a digital audio analyzer can be inserted in-line with the signal at various points in the chain to reclock the signal, allowing you to pinpoint the offending jitter source.

Bit Activity Monitoring

Examining the digital data stream and its associated subframes with an audio measurement set will show the presence and type of digital signal present. The bit activity monitor will display the signal as being either consumer (16 bits) or professional (24 bits). It will also show a bar reading of each bit hovering at approximately midpoint in the display. This representation shows a 50% bit probability, since bits in the audio word are 2's complement and will either be 1 or 0 equal amounts of time. If any bits vary from this 50% probability, or are stuck high or low, the signal type being supplied or the integrity of the hardware device being tested should be questioned.

Other aspects of data stream activity can also be monitored using the bit activity display. Because Validity bit usage differs among manufacturers, some equipment may produce a high Validity bit whenever error correction is used. Certain downstream receivers may or may not reproduce audio when presented with this high validity bit. The absence of User and Channel Status bits can be detected in a similar manner.

Data Monitoring

Incompatibilities in data format are very difficult to detect because Channel Status blocks are transmitted one bit at a time and spread over 192 subframes of the data stream. An audio measurement set or digital audio monitor is needed to view this contiguous Channel Status block of 24, 8-bit bytes in their order of transmission. With these testers, the data can be viewed in its raw binary form or decoded and displayed according to its encoded format in English language.

Conclusion

Understanding the basics of how AES/EBU data streams work and how digital audio devices communicate are important when dealing with digital audio products. This, coupled with knowing that the right test equipment is available, will help unravel the mysteries of this new gear and make troubleshooting considerably easier.