BY AL INGLE

This month, we continue our series on serial busses. Having previously discussed evolution and protocols (synchronous and asynchronous), we now focus on their fundamental electrical characteristics. A serial bus is typically represented as a voltage that varies over time (time domain), but there is another key characteristic of a serial bus that is shown in the *frequency domain.* Remember that ***f****requency* is the reciprocal of the period or ***t****ime* of an event or:

$$f = 1 / t$$

A sine wave is a waveform in which the slope is constantly changing in a uniform, consistent manner. If you look closer at the leading or trailing edge of a sine wave, it is smooth and without abrupt changes in voltage. In contrast, the square wave, by design, has abrupt changes in voltage to maximize time at its zero (low) or one (high) state. In a perfect databus, the pulses would never transition from state to state but be at one or another. In the real world, engineers attempt to approach this ideal by increasing the databus baud and decreasing the associated bit rise/fall times.
Refer to Figure 1 below.

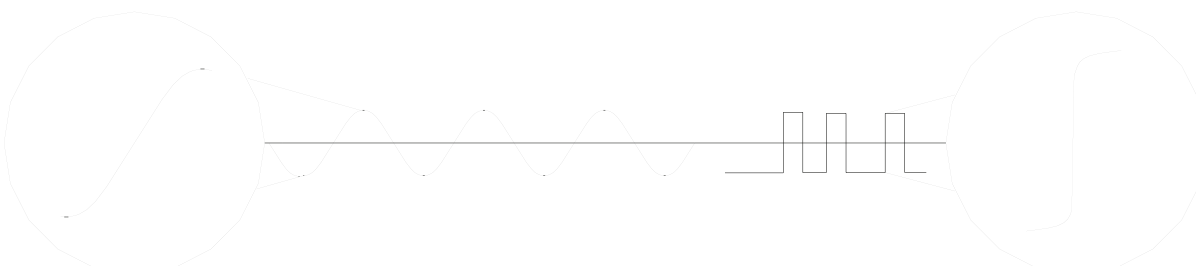

Figure 1: Expanded Sine/Square Wave Projection

There are several methods of viewing a signal in the frequency domain. One method, analog in design, is to sweep a receiver across the frequency band of interest while monitoring the level of output for a given set frequency. This is analogous to tuning a radio across its band looking for your station of choice. Every received station would be heard at a signal level/clarity that depends upon the power of its transmitter, the distance to the receiver and the atmospheric effects. The spectrum analyzer is a precision receiver that displays signals at their corresponding frequency and amplitude (typically, dB/division to compress large signals and maintain dynamic range).

There is another method of breaking down a signal into its constituent frequencies. With the technology gains in microprocessors and digital sampling, the Fast Fourier Transform (FFT) has become a popular alternative. Here, the signal is sampled in the time domain, like an oscilloscope, and the rate of change of amplitude, or slope, is mathematically converted into frequency components using the concept of **f = 1 / t.** What you discover when you do this is, all signals are the composite of many different discrete frequencies added together.

Refer to Figure 2 on the following page. Shown here is a 1 KHz sine wave on Channel 1 and its constituent frequency component(s) on Channel 2. Time travels from left to right on Channel 1and frequency increases from left to right on Channel 2. The center vertical reference on the screen — designated “T” — has been set to 5 KHz. Each horizontal division represents 1 KHz. Remember, by definition, a sine wave has a uniform, continually changing slope. This means when the voltage on Channel 1 is sampled, the rate of change is constant per unit of time. What you see is a fundamental frequency of 1 Khz (four divisions down from 5 Khz reference) and no discernable harmonics. This is a very pure, low distortion signal.

Likewise, we represent the same frequency waveform as a square wave in Figure 3 on the following page.

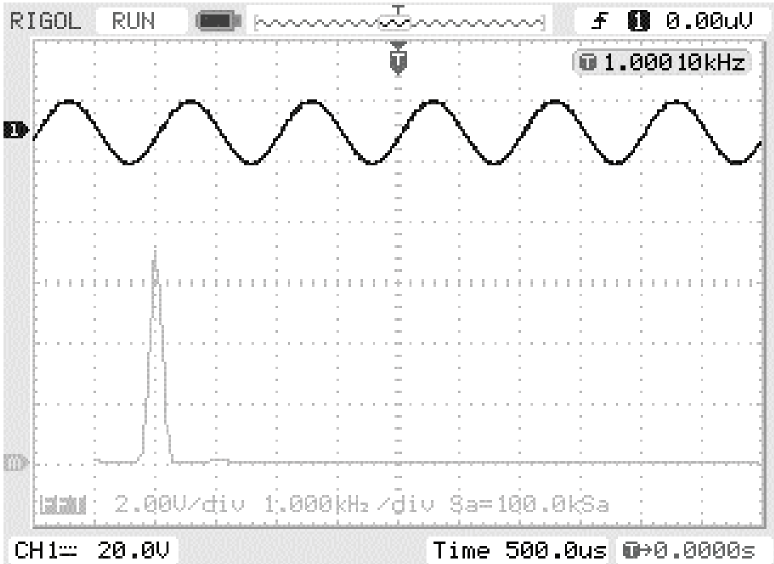

Figure 2: Sine Wave Time and Frequency Domain

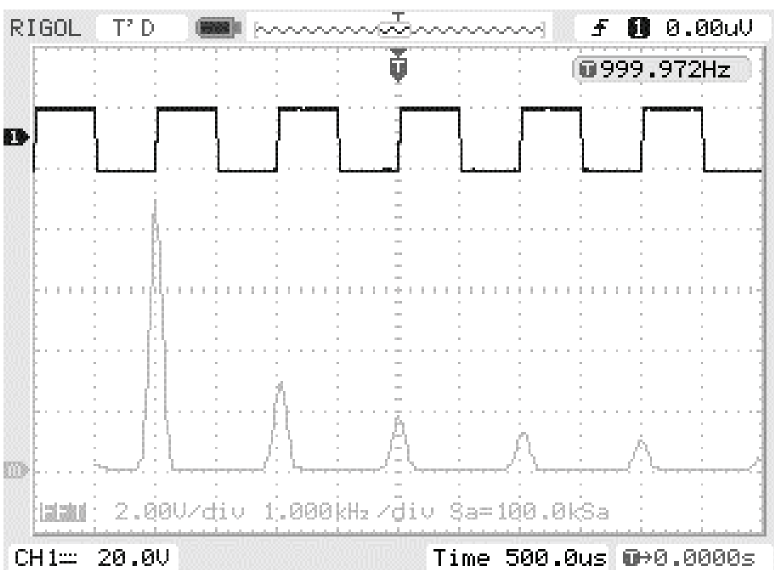

Figure 3: Square Wave Time and Frequency Domain

Note the similarities and differences between the sine and square wave frequency components. The fundamental frequency is the same, but the square wave has a significant number of odd harmonics. This is because of the varying changes in voltage amplitude during successive samples in time. In essence, a square wave has frequencies (and energy) extending from DC upward.

Why is this important in the review of serial busses? Because, in this example, there are measurable harmonics at nine times the fundamental. With our industry's serial bus bauds increasing with every generation, the databus wiring is becoming more of a transmission line than a simple, twisted shielded pair of conductors. Care must be taken to maintain the integrity of the physical wiring to prevent its degradation and subsequent loss of electrical performance. We will explore the frequency domains of popular serial busses in future articles.

Bendix/King designed the KCS 55A compass system in the 1970s, utilizing the concept of a stepper motor driving a compass card instead of the then current synchro/motor-based design. The stepper motor for the HSI's compass card was driven by quadrature signals, which are two square waves that lead or lag one another by 90°, depending upon whether you wanted clockwise or counterclockwise rotation. The company's technical representatives began to get reports of erroneous headings on the HSI, and after considerable time spent determining the cause, found the shields on the quadrature wires from the KG 102(A) directional gyro to the KI 525(A) HSI were only specified as being grounded on one end in an analog configuration. This constituted an electrostatic shield and prevented noise from being radiated into other wiring. Because the square wave's rise times were so short, the twisted pair actually needed to act as a transmission line with a better matching impedance.

Therefore, if an aircraft experienced intermittent headings, one solution was to check the wiring and ground the shields on both ends of the stepper motor wires. This is an example of high frequency effects resulting from square wave propagation. Our currently utilized serial busses are much more sensitive to impedance mismatch and require increased diligence on the part of their maintenance providers.
Next Month: More Serial Busses