Subject: Holism and Reductionism - Fourier Series
Posted by Wayne Parham on Thu, 03 Jul 2003 19:27:25 GMT
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When we look at a system any more complicated than a wheel or a wedge, we often find complex systemic behavior that arises from simple processes. An example is the interaction between sound sources generated by a loudspeaker. Each motor and diaphragm moves in pretty simple and predictable ways. The crossover filters are also pretty simple circuits. But when you combine the cumulative effects of crossover filters, dispersion changes with respect to frequency and position of the sound sources, you find that systemic behaviour has developed. This is why the peaks and nulls occur at various places in the listening environment, and why you cannot expect coverage to be equal at all places and all frequencies, simultaneously. The response caused by comb-filtering is an example of non-minimum phase behavior, and is the result of the interaction of simple systems giving rise to a complex pattern.In the late 1700's, Jean Baptiste Joseph, Baron de Fourier realized that all sounds were complex waveforms that were formed from a composite of simple pure tones. The pure tones are called sine waves (or cosines, same thing but 90o apart). So this allows some abstractions to be realized. One can view a complex waveform holistically - seeing the waveform in its entirety - or it can be viewed as a collection of pure tones, which is to reduce it to several very simple components. One can "build" every waveform from a square wave to the waveshape of a spoken word, using a collection of sines in the proper proportions. The abstraction is helpful in a myriad of ways, and it allows conceptual processes to be developed, such as formulas and methods for analyzing and processing complex waveshapes.Crossovers are filters that work because of the fact that each complex waveshape is made of of Fourier's composite sines. A waveform is literally split into groups of composites - some high and some low - and each group is sent to its respective subsystem. There are processes in nature that do the same thing, such as the dissipation of high frequencies due to humidity or foliage. This is an acoustic low pass filter that has the same properties as the low pass filter in your woofer's crossover circuit. It effectively separates the LF content from the HF, effectively shunting it just like a short circuit to ground.But in the case of loudspeakers, the designer hopes to recombine the signals using the air as a medium. A good loudspeaker will make a close approximation of the original signal, both in the amplitude of each composite sine and its relative position. It can be shown that it is possible to recombine both accurately in systems containing only minimum-phase components, but that it is not necessarily possible in systems that contain non-minimum phase components. This is due to the fact that some information is scattered and lost.Something of interest to many DIY speaker builders is the quadrature generator. It is simply a sine/cosine pair, which is nothing more than a pair of sine waves, each 90o apart. The one that is advanced 90o is a cosine signal and the other is a sine. These are used in positioner circuits and a whole lot of other things - The Lissajous (rolling quarter) pattern you may have seen on an oscilloscope is formed by a quadrature pair. And the reason this is significant to a DIY speaker builder is that it is exactly the situation found in a first-order crossover.If the two sound sources are of equal distance to the listener, then the crossover sums nicely, with output at the crossover frequency being 0.707 - simple Pythagoreans theorem. The two sound sources are each 90o apart, so they are neither fully constructive nor fully destructive. Their energy combines as a vector, and the system operates as a quadrature generator. But when the distances between sound sources are made different, this condition is no longer met. So the system acts very nicely on-axis, but will not necessarily sum the same off-axis or at any position where the system no longer acts in quadrature, but instead has unequal path lengths. There are an infinite number of positions that introduce non-minimum phase interaction between sound sources. The same is true of any crossover configuration.Anyway, below are links to some papers I found about the reductionistic view of composite sines, and about the Fourier series that expresses them. The last three links even include a neat little tool that allows you to build any two waveforms as a collection of sines, and to process them in various ways.Gut-Level Fourier Transforms, by Bob MastaA Gentle Introduction to the FFT, by Nigel RedmonFourier Analysis Made Easy, by C. LangtonA Basis for Functions: The Fourier Series, by David MazelFFT's, DFT's and the Relationship Between the Time and Frequency Domains, by Geoff MartinFFTW C subroutine library for computing the discrete Fourier transform, by Matteo Frigo and Steven JohnsonDownload the "Signal.exe" Signal Processor, written by Roger Easton (139Kb, PC Executable,Zip format)Users Manual for the "Signal.exe" Signal Processor ProgramOne and Two Dimensional Harmonic Oscillations, lab projects for use with the "Signal.exe" Signal Processor