Subject: Can't reproduce a square wave
Posted by tailgunner on Sun, 14 Mar 2004 18:41:10 GMT
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Much has been made of the possibility to be coherent enough to reproduce a square wave. The closet thing I know is a planar speaker, but some say they can get there other ways. Your thoughts?
Can't reproduce a square wave

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Subject: Re: Can't reproduce a square wave
Posted by Dean Kukral on Wed, 17 Mar 2004 03:36:54 GMT
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Several problems exist.1. What is a "square wave?" (in air)2. What do you mean by "reproduce a square wave." a. How do you "produce" a "square wave" (whatever that is) on a speaker to begin with? b. How do you produce a "square wave" input signal (we know what that is, at least mathematically)to a speaker?Mathematics can easily describe a square wave, but mathematics also assumes a continuous world. However, the world is not continuous, but discrete. Even if you assume that space and time are continuous, "air" is not, at least on the microscopic level. Mathematically a square wave is discontinuous, but the world (as seen by mathematics) is essentially continuous. However, a "shock wave" is a "discontinuity" in the air caused by something travelling through the air ***faster than the speed of sound in the air***. This almost closes the question right here. If you could make the piston of the speaker move any way you want it to (without consideration of how you do it), then what is the motion of the piston that would create a "square wave," whatever that is??How do you produce a signal to the speaker that is a square wave signal? Certainly not with electronics. Electronics is closer to being continuous than air. A person throwing a switch on and off very rapidly could not produce a square wave signal, so certainly no transistor nor tube could.

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Subject: Re: Can't reproduce a square wave
Posted by Wayne Parham on Wed, 17 Mar 2004 05:42:07 GMT
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Agreed. A perfect square wave movement by a perfect piston produces a differentiated pressure pulse in the air.

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Subject: Re: Can't reproduce a square wave (some can)

Posted by Tom Danley on Wed, 17 Mar 2004 21:09:51 GMT
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HiThe reason a square wave has long been used in Ham radio and electronics in general as a test signal is because on an oscilloscope, in order to look "good" a flat phase and amplitude was required to about to a factor of 10 X both ways from the fundamental.It is an easy signal to see and any condition other than zero degrees phase and flat amplitude will not preserve this or any other complex waveshape.Yes, it is true a Manger can reproduce a square wave (by eye as above) or other complex signal midband, I have measured one. (on the other hand they are also high in distortion). Perhaps a different way to look at it that the speaker has essentially "no" spreading in time of the signal or zero group delay.  You would think that a goal would be to preserve the  waveshape but for the most part, speakers do not and for a number of reasons.Some people are apparently sensitive to this, others not.Cheers,Tom DanleyNice forum Wayne!

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Subject: Re: Can't reproduce a square wave
Posted by Wayne Parham on Wed, 17 Mar 2004 22:17:44 GMT
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I'm not sure that this is an important issue, but it's fun to talk about nonetheless.  As I see it, even if there are perfect phase relationships between harmonics, there is another issue that keeps the measurement microphone from seeing a square wave, especially at lower frequencies.  That is the fact that pressure dissipates in air, creating a differentiated pulse instead.A square wave requires two well-defined potentials.  Each half cycle is represented by a specific potential.  In electrical terms, this is voltage, in mechanical, it is position and in acoustic or pneumatic, it is pressure.  Here's the problem with the square wave thing:  Even if you have a perfect piston driven by the perfect square wave, the pressure developed in open air dissipates.  If you are pressurizing a perfectly sealed chamber, you can keep pressure from dissipating, but not out in the open.  Outside the speaker cabinet, it's like a very lossy system.  That makes it act like a differentiator.  So whether or not this is an issue worth noting is probably debatable.  But making static pressure changes outdoors from a loudspeaker is pretty tough to do.  It's easier to do as frequency goes up, but one could say it is impossible down low, at least without calling upon the Vogon Constructor Fleet from the Hitchhiker's Guide to the Galaxy.

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Subject: Re: Can't reproduce a square wave
Posted by Tom Danley on Thu, 18 Mar 2004 02:55:58 GMT
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Hi WayneIt can be argued as you have in the past that in the home, a sound reproducer that preserves the waveshape of the input signal is not strictly necessary.In sound cancellation however the exact waveshape must be produced if it is to cancel an offending noise. I have built transducers for this application as well and am familiar with what is involved.It would seem the question of how much a speaker can screw up waveshape or corrupt the time element and still be listenable is separate from the conditions needed for preserving a complex input.Your "creating a differentiated pulse" issue with this at low frequencies is based on an incorrect assumption. Radiating into space, the radiator motion (for a direct radiator) that produces an acoustic square wave is a triangle motion, not a physical square wave.It is the radiator volume velocity that produces pressure and as long one is about 10 X higher than the low cutoff (owing to the requirements to have a good looking square wave), there is no problem going down in frequency and radiating a "square wave" assuming the flat pressure and phase region had sufficient bandwidth.(at least from the stand point of having made acoustic sources systems which preserve waveshape down into the single digits)Cheers,TomAre you going to NSCA?

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Subject: Re: Can't reproduce a square wave
Posted by Wayne Parham on Thu, 18 Mar 2004 04:18:07 GMT
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You wrote:>> "Radiating into space, the radiator motion (for a direct radiator) that produces an acoustic square wave is a triangle motion, not a physical square wave."That's my point.  If you apply a square wave electrical signal to a loudspeaker cone, you will get movement of a physical square wave with constant displacement.  Only if you modify the waveform, such that a constant displacement pump (loudspeaker) generates a constant volume can you generate an acoustic square wave.I am not sure if we are talking apples and oranges on the square wave thing or not. What I am saying seems fairly obvious to me.  You can't pressurize an open space with a constant displacement pump.  The pressure dissipates.  So you can't maintain pressure on alternate half cycles either.  You can only hope to get an approximation at high frequencies.An electrical square wave presented to a loudspeaker is the functional equivalent of a pump operating at a constant pressure in one direction, and then rapidly changing to the other.  But loudspeakers energizing a large space are like a lossy system, in that you aren't able to maintain the increased atmospheric pressure on a compression cycle, nor can you maintain reduced atmospheric pressure on a vacuum or rarefaction cycle.Electrical square waves presented to a loudspeaker make positive pressure on one half cycle and negative pressure on the other.  The problem is that the pressure isn't maintained.  It rapidly falls off.  So the top of the square wave trails off, modifying it so that it looks like it has passed through a differentiator.  At high frequencies, you can approximate an acoustic square wave but not at low frequencies, because pressure dissipates before each half-cycle has passed.Modifying a square wave to create a triangular shaped signal will increasingly pressurize a room, so that the falloff from dissipation is counteracted by the increase from the rising wave.  That sort of acts like pre-compensation by sending an integrated signal to the speaker, which pre-compensates for the differentiator formed by the dissipation falloff in pressure.  The acoustic pressure can be made to resemble a square wave using this technique.   But the signal presented to the speaker wouldn't be a square wave in this case.

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Subject: Kinda reproducing a square wave
Posted by Dean Kukral on Thu, 18 Mar 2004 13:00:52 GMT
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So, you are saying that you can deal with something that is sort of like a square wave, but not really a square wave - it just looks like a square wave in the center?If you are discussing real square waves, then you surely agree that they are impossible to produce electronically and acoustically.But for Engineering purposes ("the second order term is small, so we ignore it" :), you mean something pretty "close" to a square wave. Now you are discussing speaker design philosophy, which is over my head, and I will butt out...

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Subject: Re: Kinda reproducing a square wave
Posted by Tom Danley on Thu, 18 Mar 2004 15:33:14 GMT
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HiIt is true that in extreme "fundamentalists" view, a square wave cannot be re-produced by any speaker, or even produced in the first place by any real world electronics, passed by any cable or be realized by physical action.. Every thing we deal with in the real world (outside of fundamental theory) has a high frequency limit and so a finite slew rate and so cannot instantly go from one value to another without traversing the area in between.On the other hand, a square wave has been used in electronics as an analytical signal for at least a half century because it is simple to see and is effected by a signal bandwidth much much larger than the repetition rate suggests.The rule of thumb in electronics is that one needs about a factor of 10 in flat amplitude and phase in each direction past the center frequency in order to have a good looking square wave on an oscilloscope (a standard instrument which displays a signal voltage over time).This would mean that for a speaker that was flat in amplitude AND had zero degrees phase from 20 Hz to 20KHz, that it would satisfy the requirements of producing a square wave from about 200 Hz to about 2000Hz.This would also be just as true for any part of the chain like a CD player or amplifier.Part of what makes it useful is after learning to interpret it.For example in a "simple" system, the rise and fall times are directly related to the high frequency response while any tilt in the "flat parts" is governed by the low frequency response. Phase shift will alter the position of the slew within the waveshape as well as determine the final shape.While consideration of a square wave or the idea of preserving the waveshape of the input signal are two ways to look at it, there is another, that is time.If one fed a speaker an imaginary signal that covered a wide frequency bandwidth and then looked at the sound as it emerged from the speaker, one finds the speaker spreads the signal out in time if it is not able to preserve the waveshape.In other words, the original waveshape or impulse occupies X time, if the speaker cannot preserve the waveshape, it is also spreading the signal out in time and / or is altering the time relationships between various parts of the spectrum.The Manger remains the "best" speaker in time I have ever measured although it is not a "clean" speaker or suited to high level operation unless one is insensitive to large amounts of harmonic distortion.At least to me, I see anything that alters the original signal significantly as distortion, this includes the popular harmonic distortion, but also amplitude distortion and being dispersive in the time domain. Cheers,Tom

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Subject: Re: Can't reproduce a square wave
Posted by Tom Danley on Thu, 18 Mar 2004 16:53:58 GMT
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Hi WayneInside a sealed box speaker, the pressure wave shape IS exactly related to the displacement. If one wanted a square wave pressure in a box, the cone has two positions, in or out with a fast transition between.If you placed this box in an air tight room and operated it at a frequency where you are much lower than the lowest room resonance, one also finds the sound pressure out side the box IS also related to the displacement.On the other hand, if one were in full or fractional space or in a room well above the lowest room resonance, then the conditions are different.Radiated acoustic power from an acoustically small source (like a woofer) is NOT displacement but Volume velocity.For a sine wave (easy to picture) signal, in a sealed box or acoustically small room (as above), one finds the pressure is "in phase" with the displacement.Easy to imagine the woofer's outward position is compressing the air in the room etc.Once one is outdoors or higher up in frequency in the room, one finds the radiated pressure is actually 90 degrees from the displacement,That is to say, the greatest positive and negative radiated pressures coincide with the driver when it is at ZERO displacement (because that is where its radiator velocity (and there for volume velocity) is highest).So far as audibility of waveshape preservation and adaptive crossovers, it turns out there are a few others interested in this.http://www.ocf.berkeley.edu/~ashon/audio/phase/phaseaud2.htmHere is a fellow on the same "non-integer" crossover path as used on the Unity's we discussed some long time back.http://www.geocities.com/kreskovs/John1.htmlIf you are going to LasVegas for the NSCA trade show this week end, you could stop at our booth and hear a speaker that does a decent job with preserving waveshape (within band) and see if it sounds any different.I would bet that it is the acoustic transition from pressure to volume velocity that  is the part you refer to as a differentiator, I can see that it could look like that..As in your (1st order) differentiator example, there is also the 90 degree phase shift going between pressure and volume velocity parts of the radiator motionYou are correct also  that the piston motion does have to follow a path that results in a radiated "square wave" or other complex signal and that this is not the same shape as the acoustic pressure (because it is the volume velocity or Uo, not displacement or position which radiates acoustic power.)For a square wave of any frequency radiated into some space (that is not acoustically small and  contained), a constant radiated pressure requires a constant volume velocity, a constant velocity (with periodic reversals) traces out a triangle wave, that is the needed piston motion if radiating a square wave into space.There is no frequency limitation on a square wave here other than (the bandwidth requirement as in the other post and) a pressure / frequency one set by the maximum displacement and driver linearity.Cheers,Tom

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Subject: Re: Can't reproduce a square wave
Posted by Wayne Parham on Thu, 18 Mar 2004 18:39:21 GMT
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Agreed.  If the box is sealed then pressure will rise as volume is decreased by the woofer.  But if the woofer is driving open air, then a change in volume doesn't mean much.  Speakers are a constant displacement pump.  We'd need a constant volume pump to do the low frequency square wave thing we're talking about here, and I'm not sure we would want a pump like that for sound reproduction.It's kinda cool to think about though. To change atmospheric pressure in an open space requires a constant flow of a large volume of air, which requires a different kind of system. The larger the space, the more volume required of the pump. This is the kind of thing important to engineers setting up cabin pressurization systems, 'cause their systems must modulate the amount of pressure to compensate for altitude. Neat stuff.

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Subject: Re: Kinda reproducing a square wave
Posted by Wayne Parham on Thu, 18 Mar 2004 18:55:40 GMT
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Certainly, there is the issue of slew rate and overring. I would suggest an acceptable limit of minimum slew rate and maxiumum overring. If we were to quantify the issue, it would remove ambiguity.I agree that no perfect square wave is possible, and that is a mathematical curiosity since a perfect sine wave is realizable. The perfect square wave isn't possible because of the fact harmonics content would have to be infinite.But if we set limits, say slew rate less than 10µS and overring less than 0.1%, then we can discuss a realizable square wave. And I think that is realistic. That at least puts us in the realm of possibility, and I would argue that a square wave having 10µS rise/fall time and less than 0.1% overrring would sound absolutely perfect. It's a great goal. That then leaves us with the other issues to discuss.We won't have much trouble finding signal generators and amplifiers capable of square waves with 10µS rise/fall time and less than 0.1% overrring, but we'll have a hell of a time finding electro-mechanical devices that can do it and an almost certainty of inability to find electro-mechanico-acoustic devices that can generate this waveform between 20Hz and 20kHz.

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Subject: Okay, thanks
Posted by Dean Kukral on Fri, 19 Mar 2004 12:41:12 GMT
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My original post asked for definitions, and this gives them, so it brings the discussion into perspective.Obviously, an acoustic square wave is a discontinuity in pressure, which no speaker (piston) can produce.As I see it, you are saying that the trained eye can readily detect speaker anomolies by examing the smearing at the transition areas in the measured output of the speakers when fed the proper signal. (I am a little fuzzy on how a triangle was related to "reproducing a square wave," however.)Interesting. I'll buy that, but leave the discussion of what that means acoustically to others. ;)Thanks.

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Subject: Off topic - Air compression linearity

Posted by Wayne Parham on Thu, 01 Apr 2004 11:16:09 GMT
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Hey, Tom - What do you make of this? Do you have any references for research data that shows the onset of air compression non-linearity?I assumed it must be somewhere between 1.5 and 2 atmospheres for a sinusoidal piston motion that creates alternating compression and rarefaction. I also would guess that plenums, vents and other resonant chambers would have certain frequencies where they were more sensitive due to resonant conditions. At frequencies where a vent or plenum is resonanting, we'll get a ram-charge effect where critical pressures are reached at lower piston excursions.But putting resonance aside, I wonder where air rarefaction/compression starts becoming noticably asymmetrical, causing non-linear distortion. Kinda thought you might know a reference or two.