

Bad Behavior of V-I Limiters in Bridged Amplifiers

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12/15/2022

The use of V-I Limiters to achieve output stage safe operating area (SOA) protection in audio power amplifiers has a somewhat well-deserved bad reputation. Premature activation or the interaction of its positive feedback with complex loads, such as those presented by a speaker, can result in audible and possibly damaging waveforms. This has been discussed many times. This mini-paper addresses another issue that is seldom discussed: the bad behavior of V-I limiters in bridged amplifiers even with ideal resistive loads.

To clarify and demonstrate the problem, I performed a simulation in LTSpice® using one of my designs for the bridged amplifiers but with their SOA protection circuitry simplified and a triangle drive waveform to ease interpretation of the resulting plots.

For the positive (NPN) side of the output stage, a single slope V-I limiter is used when the amplifier output is above the amplifier's signal ground. The higher the output voltage, the lower the voltage across the output transistors, and the higher the allowed current. When the output is below ground, a fixed current limit is employed. For the negative (PNP) side of the output stage, the single slope V-I limiter is used when the amplifier output is below signal ground and the fixed current limit is employed when the output is above ground. In this simulation, limiting occurs on the negative side before the positive side.

Bridging is accomplished in the simulation by driving the amplifiers 180° out of phase and connecting the load between the two amplifier positive outputs. The drive signal results in a no-load full scale ($50 V_{PEAK}$) triangle wave output on each amplifier. Without limiting, the voltage across the load is twice the output of an individual amplifier. The load is purely resistive with a value selected so that the V-I limiters are activated.

In the plot below, the traces are as follows:

Green - non-inverting amplifier output voltage referenced to input signal ground

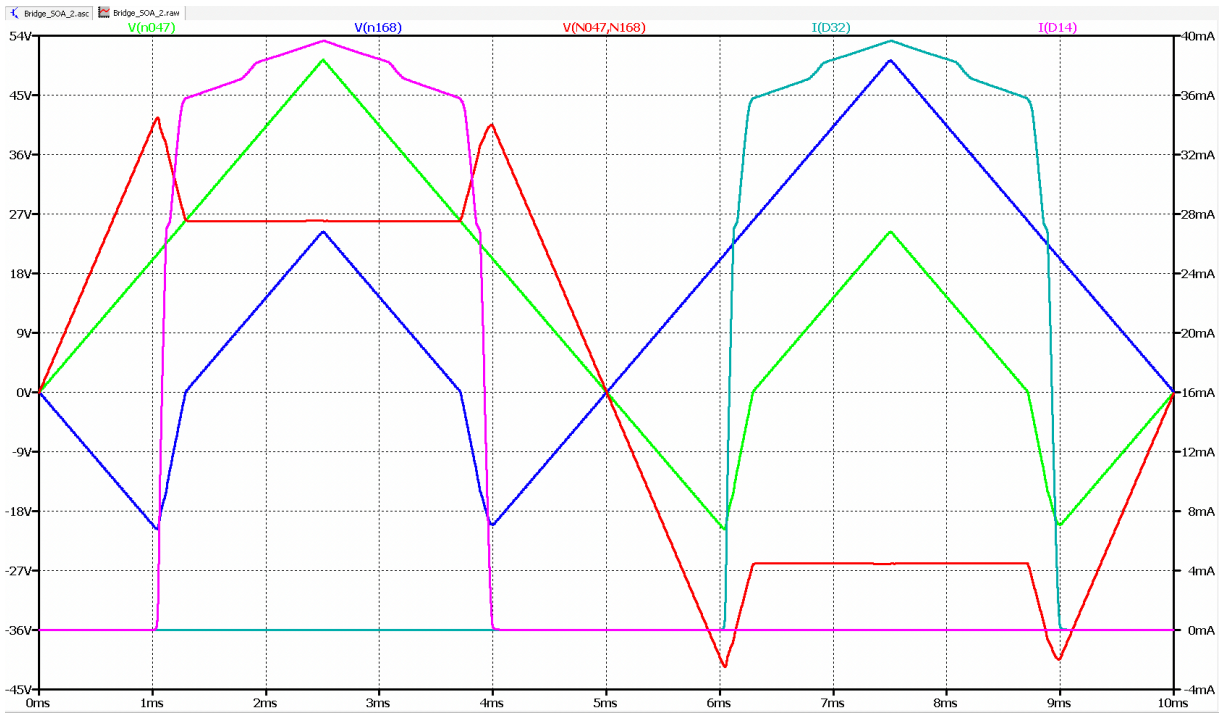
Blue - inverting amplifier output voltage referenced to input signal ground

Red - voltage across the load (green-blue)

Teal - non-inverting amplifier negative limiter current

Magenta - inverting amplifier negative limiter current

At $T = 0$, the non-inverting amplifier output (green trace) begins to move positive; the inverting amplifier output (blue trace) negative. The inverting amplifier goes into current limiting first. This occurs at approximately 1 ms and is indicated by the magenta trace going high. The inverting amplifier now looks like a current source, so the non-inverting amplifier never limits and continues to “pull” the load up, forcing the inverting amplifier to “fold back” its output current. Its output snaps quickly to ground. This causes a sharp decrease in load voltage, producing the left “bat ear” on the red trace. When the non-inverting amplifier pulls the inverting amplifier's output above ground, the inverting amplifier switches to fixed current limiting mode and the two outputs track together. The voltage across the load (red trace) is thus constant until the inverting output is once again below ground (~ 3.7 ms). Now, back in the V-I limiter mode, the inverting amplifier can sink increasing current as its output drops



further below ground. This causes its output to snap negative and the voltage across the load to snap positive, producing the right “bat ear” on the red trace at ~ 4 ms.

The second half of the waveform (starting at $T = 5$ ms) is like the first half with the amplifier roles reversed. This produces a symmetrical, but still ugly waveform across the load. The height of the “bat ears” is a function of where limiting begins.

The simulation shows that V-I limiting in bridged amplifiers can produce a load waveform with spikes at the onset and conclusion of limiting. Such a waveform has a much higher harmonic content than one with simple flat tops and bottoms.