Introduction to Bode Plots

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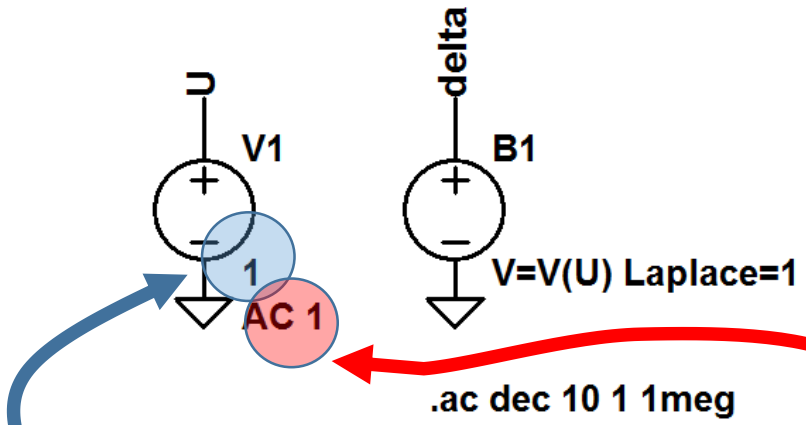
Bode was a person!

- In electrical engineering and control theory, a **Bode plot** /ˈboʊdi/ is a graph of the frequency response of a system. It is usually a combination of a **Bode magnitude plot,** expressing the magnitude (usually indecibels) of the frequency response, and a **Bode phase plot,** expressing the phase shift. Both quantities are plotted against a horizontal axis proportional to the logarithm of frequency. Given that the decibel is itself a logarithmic scale, the Bode amplitude plot is log–log plot, whereas the Bode phase plot is a lin-logplot.[1]

https://en.wikipedia.org/wiki/Bode_plot

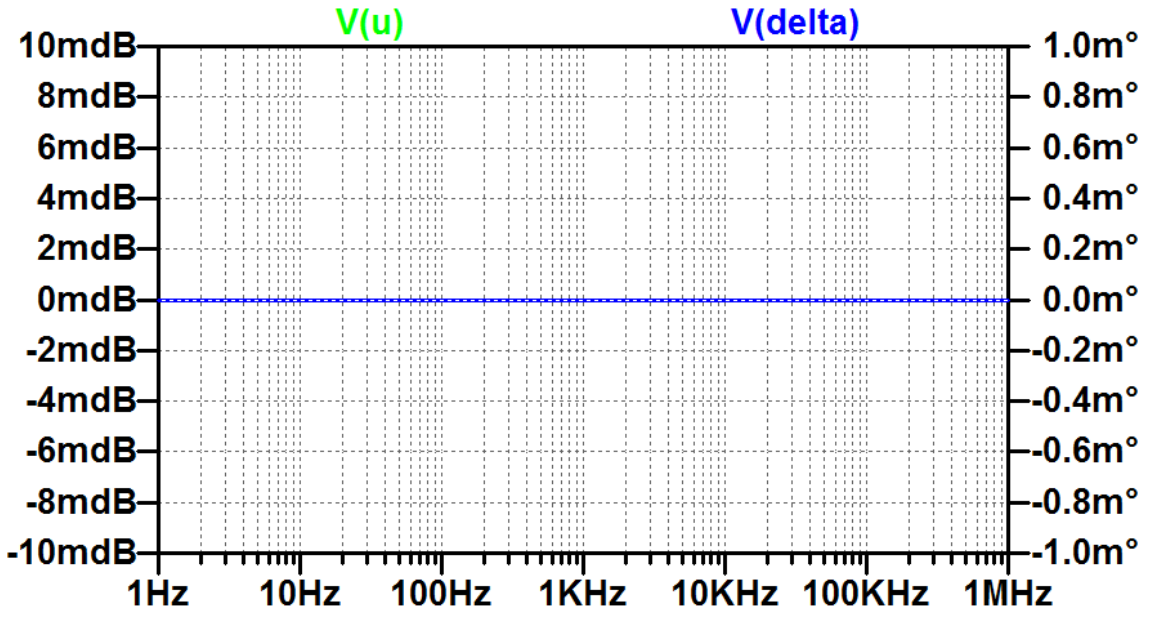
Keep it simple: Laplace transform of δ function=1 (No Frequency dependence.)



B1 is a behavioral voltage source. In this case it depends on V(u) which is a step function in time domain and a delta response in the frequency domain. You can enter in an s-domain transfer function!

V_1 is step function in the time domain because is has a DC value of 1, and since in Ltspice there is no negative time simulated, V_1 is zero for t<0, there it and all DC voltages in LTspice are step functions.

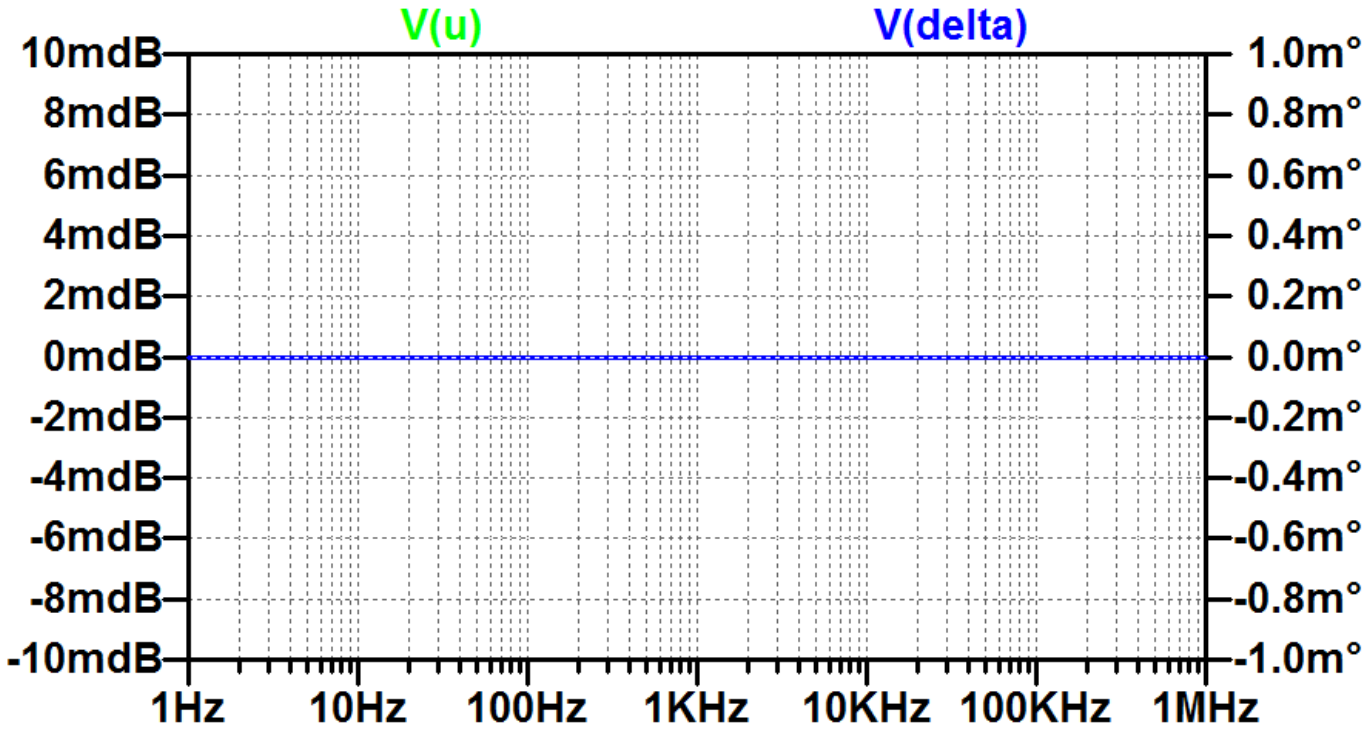
In the Frequency domain the AC magnitude and Phase are 1 and zero and there for it is a impulse response in the frequency domain (s)



Note: Frequency is in on a log scale

https://www.dropbox.com/s/jajke6mavhtx9iw/Bode_1.asc

A Bode Plot can be seen as a plot of the magnitude and phase of the output if the input were a sin wave with a magnitude and phase.



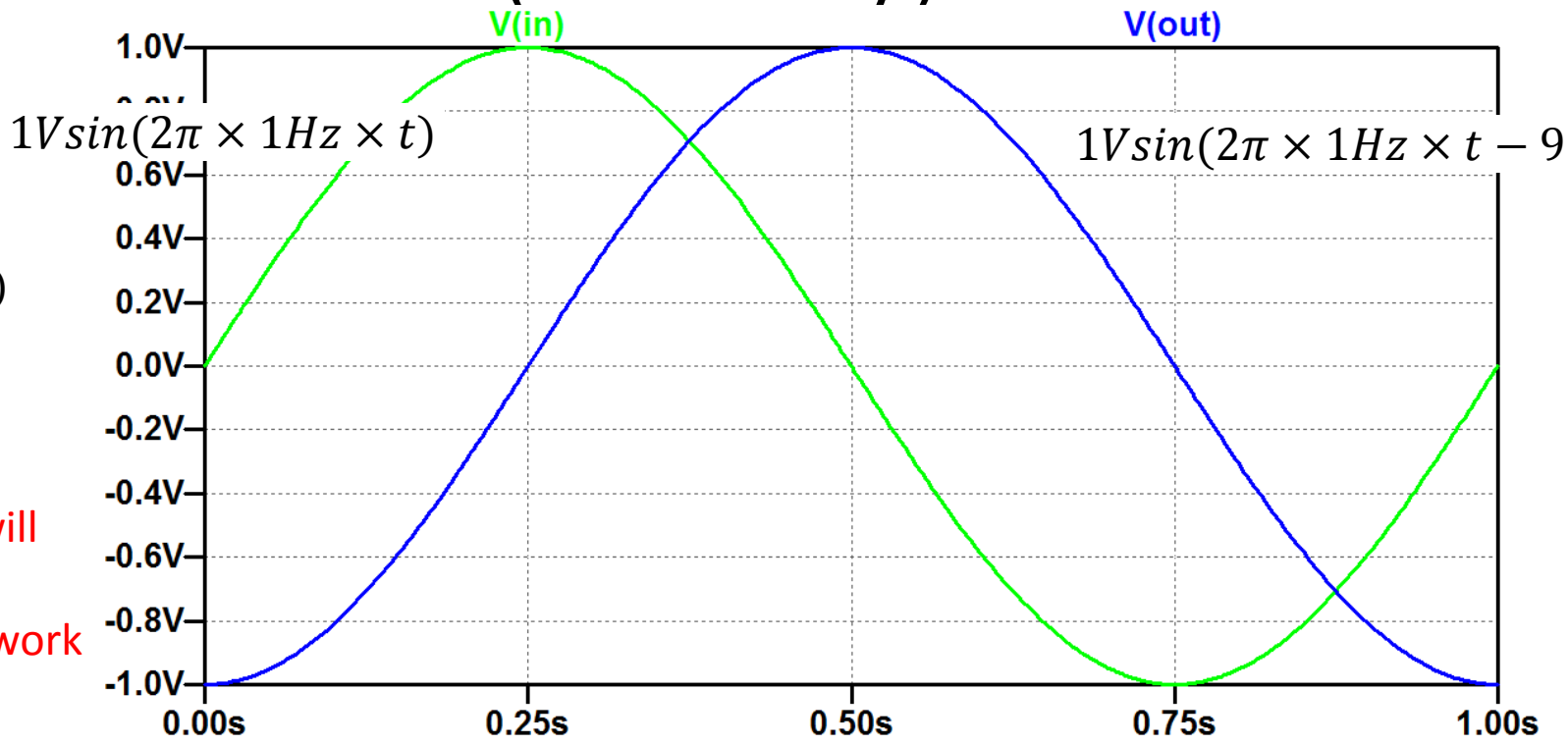
$$Magnitude\ (dB) = 20 \times log\left(\frac{V_{magnitude\ of\ output}}{V_{magnitude\ of\ input}}\right)$$

$$Phase = ATAN\left(\frac{Imaginary\ Part\ of\ H(s)}{Real\ Part\ of\ H(s)}\right)$$

Physically phase is delay that is normalized to the period of a sin wave. We will go into this next slide.

At 1Hz V(u) and V(delta) are 1Hz sin waves with a magnitude of 1V or, 0dB and zero delay or phase. (The sin waves overlap 100%.) A trick in Ltspice is to set the input to 1V amplitude, and zero degrees phase so that the resulting plots come out automatically as a Bode plots. This will work in simulation, but a 1V magnitude sin wave going into an amplifier of 10 and a voltage range output limit of 1 to 5 Volts, will be clipped in reality.

Two sin waves with the same amplitude but with a -90° Phase Shift (or Delay)



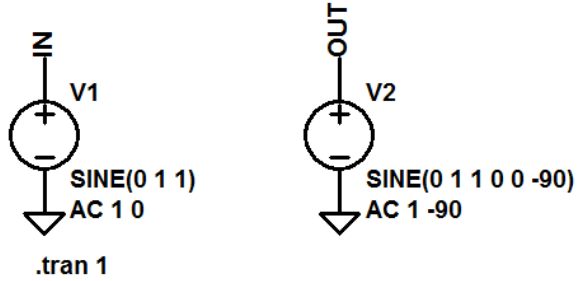
$1Vsin(2\pi \times 1Hz \times t)$

$1Vsin(2\pi \times 1Hz \times t - 90^o)$

$1Vsin(2\pi \times 1Hz \times t - 90^o)$

Yes, the units are incorrect between the phase and the time component. While it will not work in calculations, everyone documents their work this way.

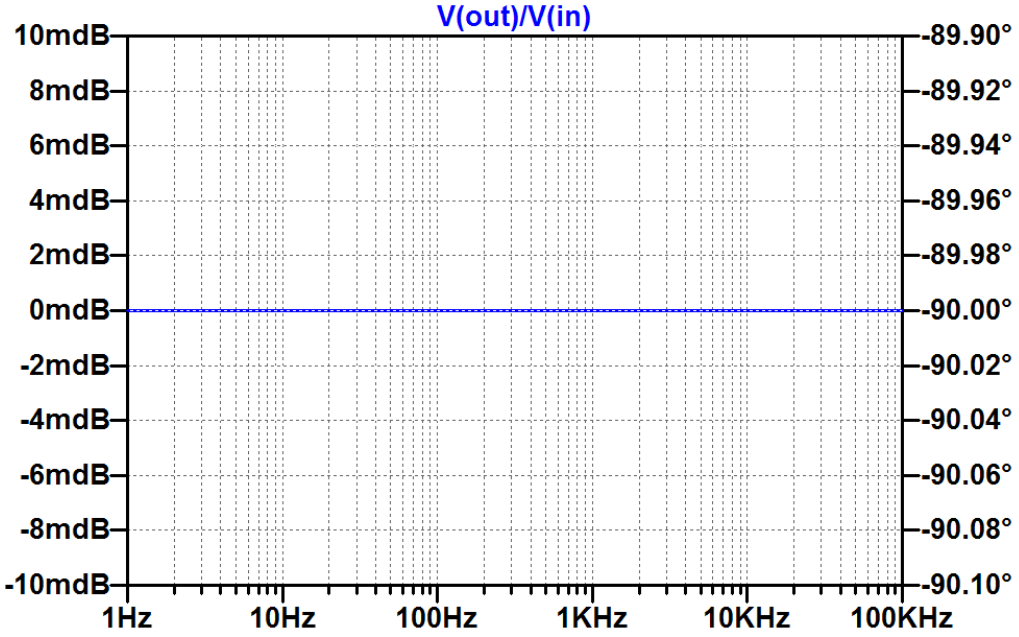
0T	1/4T	1/2T	3/4T	T
0°	90°	180°	270°	360°
0π	½π	1π	1 ½π	2π



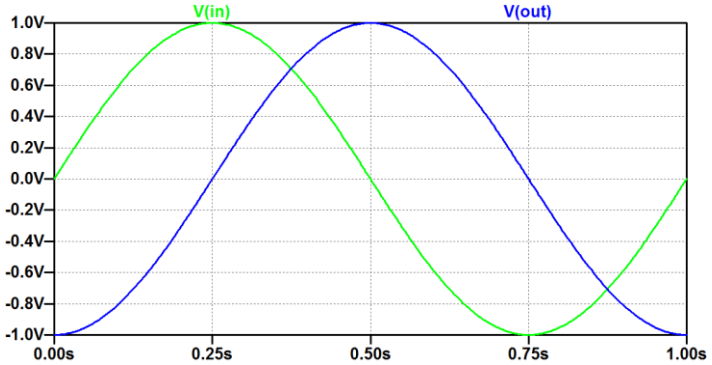
$$Phase = \frac{Delay}{Period} \times 360^o = \frac{.25s - .5s}{1s} \times 360^o = -90^o$$

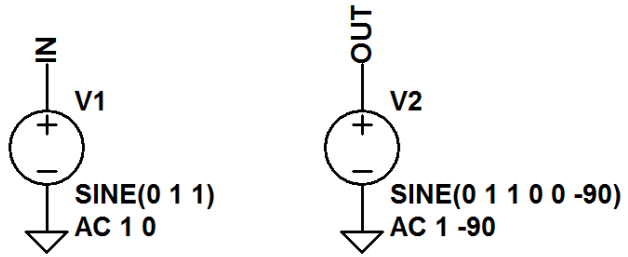
https://www.dropbox.com/s/stihtlsctyelrtz/Bode_2.asc

How does this look in a Bode Plot?



The Bode plot shows the magnitude and phase if the inputs were sin waves with the frequency's shown.





The Bode plot is like re-running a time domain(transient) simulation, while changing the frequency of the sin wave to 1Hz, 10Hz, 12.2096Hz etc. and plotting the ratio of the magnitudes of the output and input along with the phase between input and the output.

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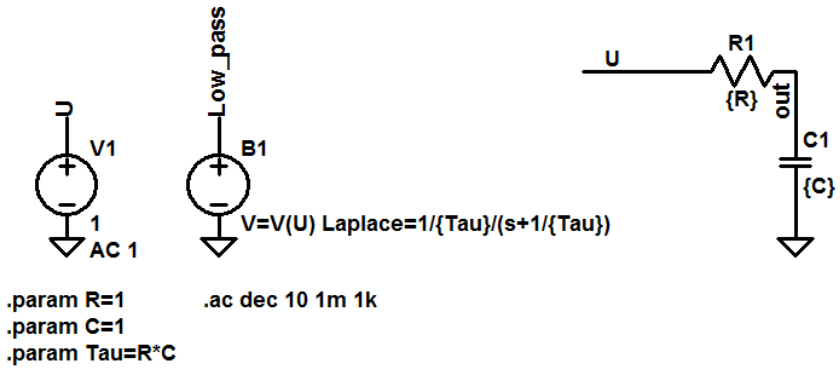
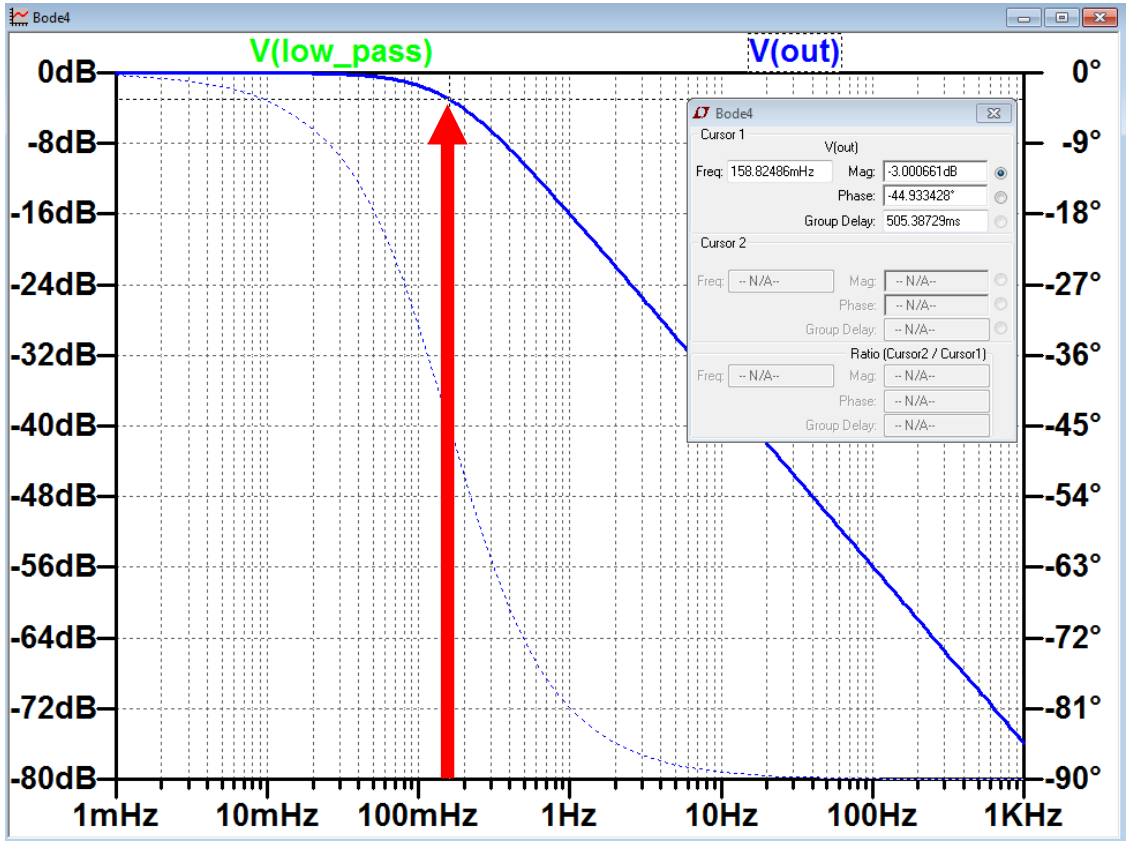
Low pass filter



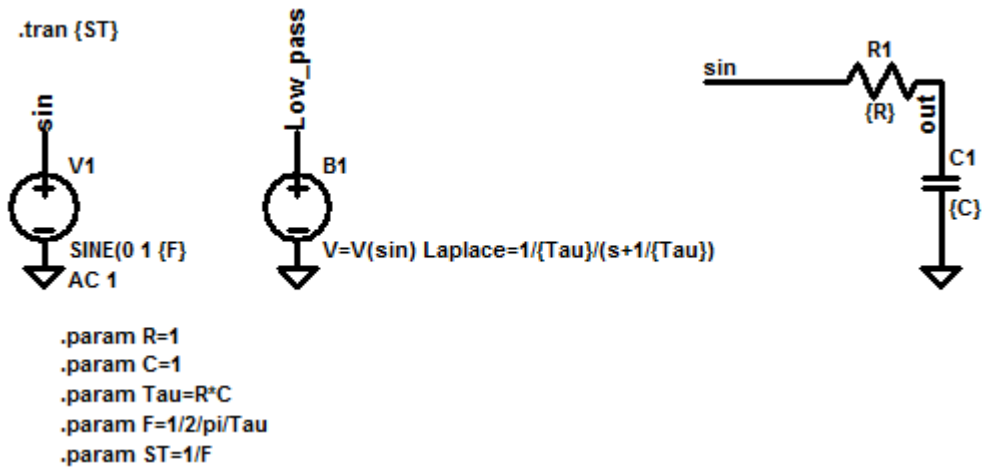


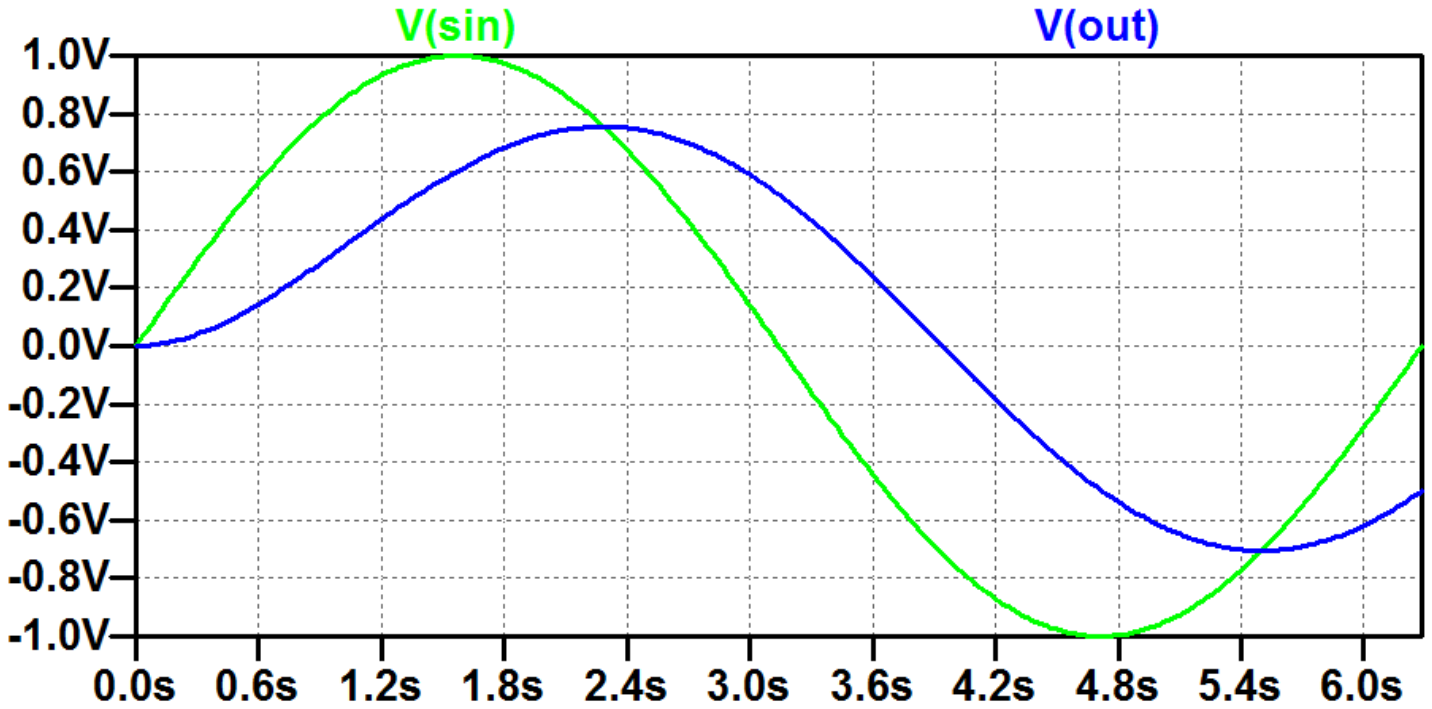
At 159mHz the Gain is -3dB and the phase is -45°. If the input was a 1V amplitude 159mHz sin wave, the out put would be

$$V_{in} = 1Vsin(2 \times \pi \times 159mHz \times t)$$

$$V_{out} = 1V \times 10^{\frac{-3dB}{20dB}} sin(2 \times \pi \times 159mHz \times t - 45) = .707Vsin(2 \times \pi \times 159mHz \times t - 45)$$

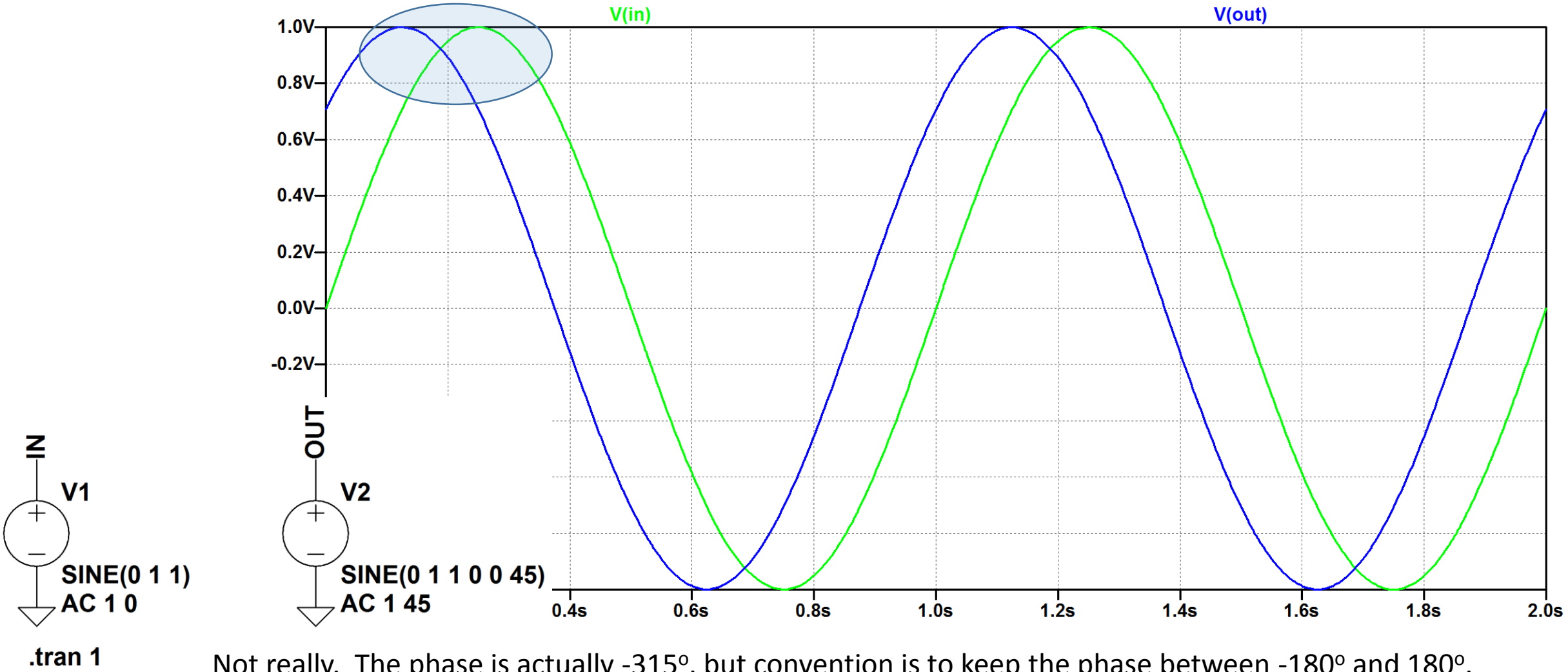
Back to Time Domain





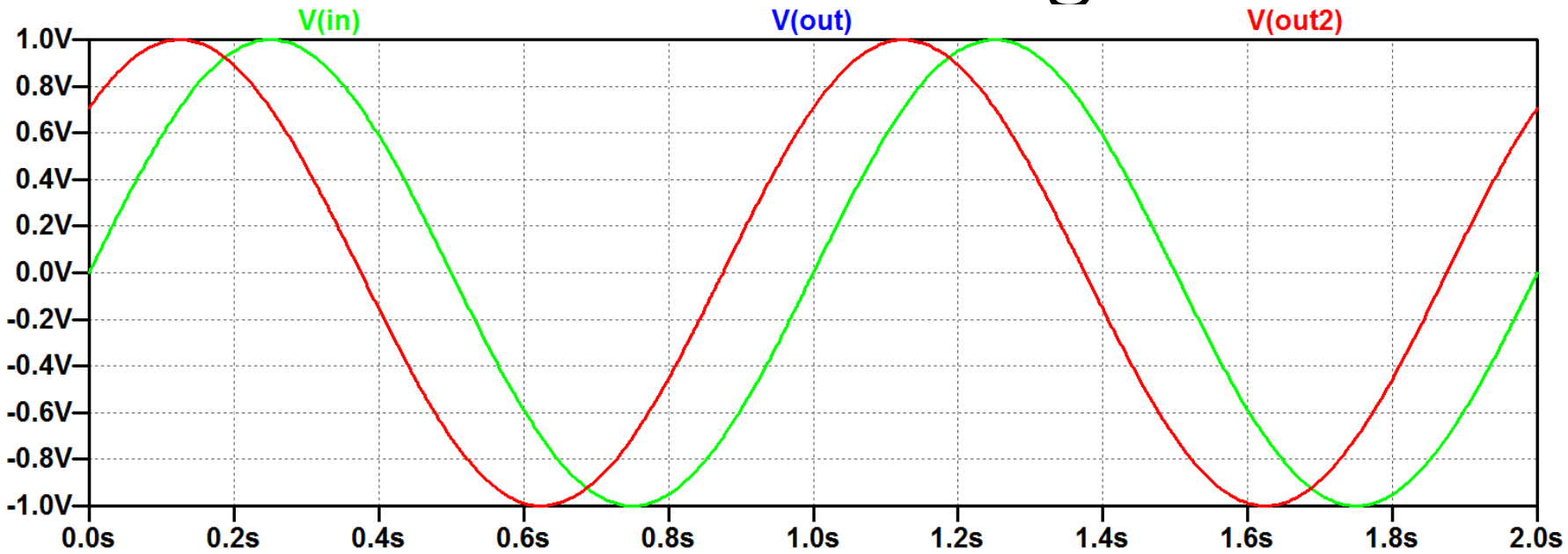
0T	1/4T	1/2T	3/4T	T
0°	90°	180°	270°	360°
0π	½π	1π	1 ½π	2π

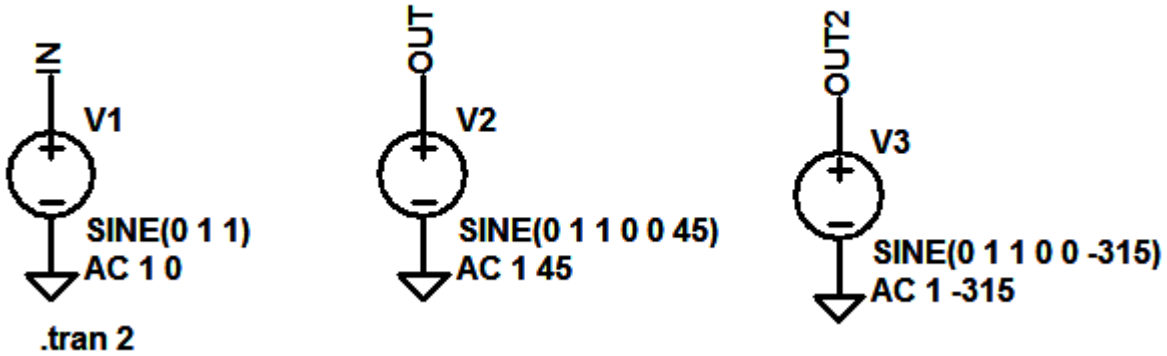
Ok, Negative Phase is delay, but positive phase sounds like the output is ahead of the input?



Not really. The phase is actually -315°, but convention is to keep the phase between -180° and 180°.

Phases of 45° and -315° give same result.





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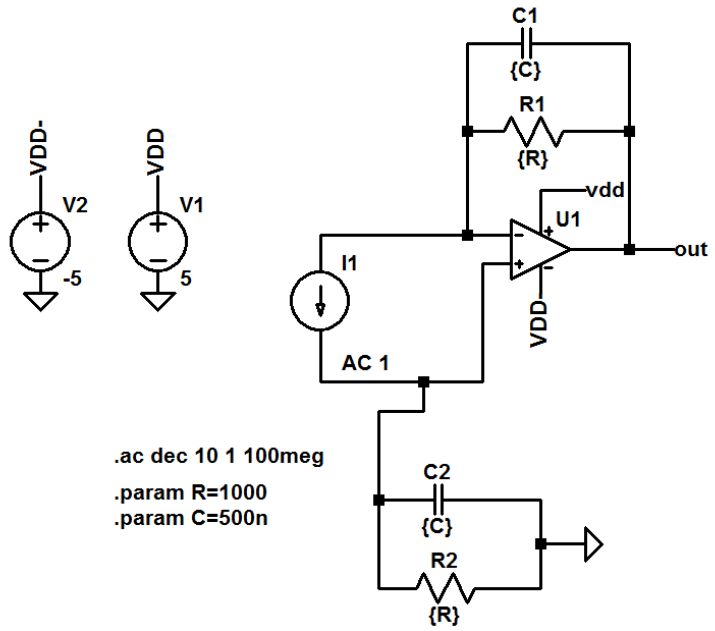
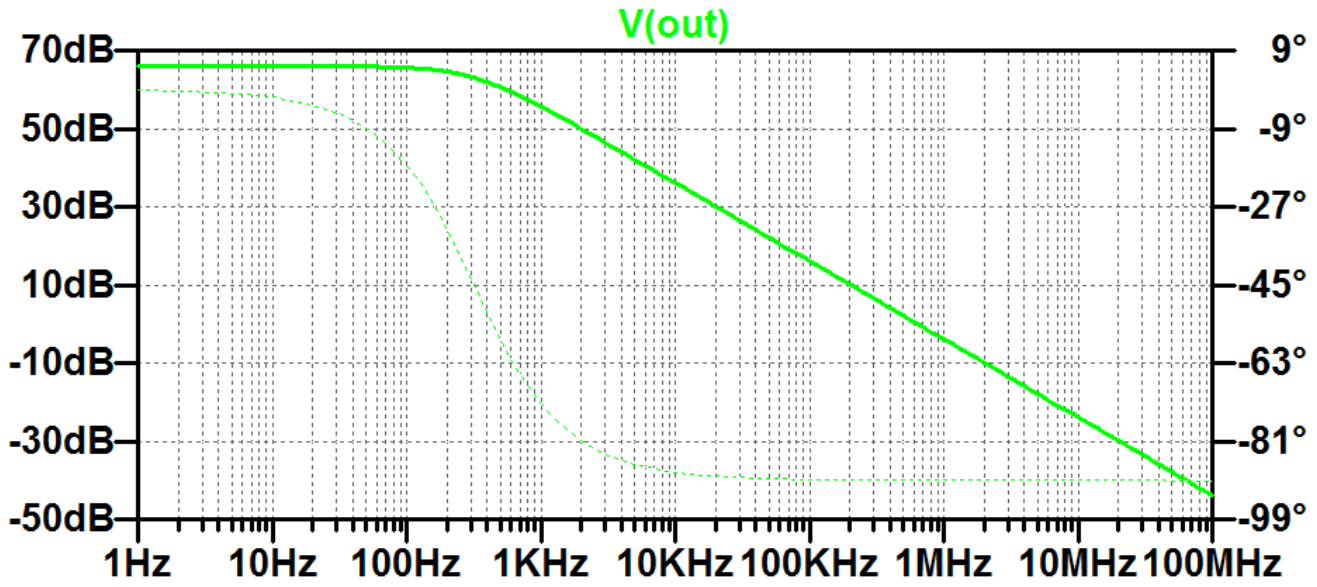
Current to voltage converter with high frequency noise reduction.





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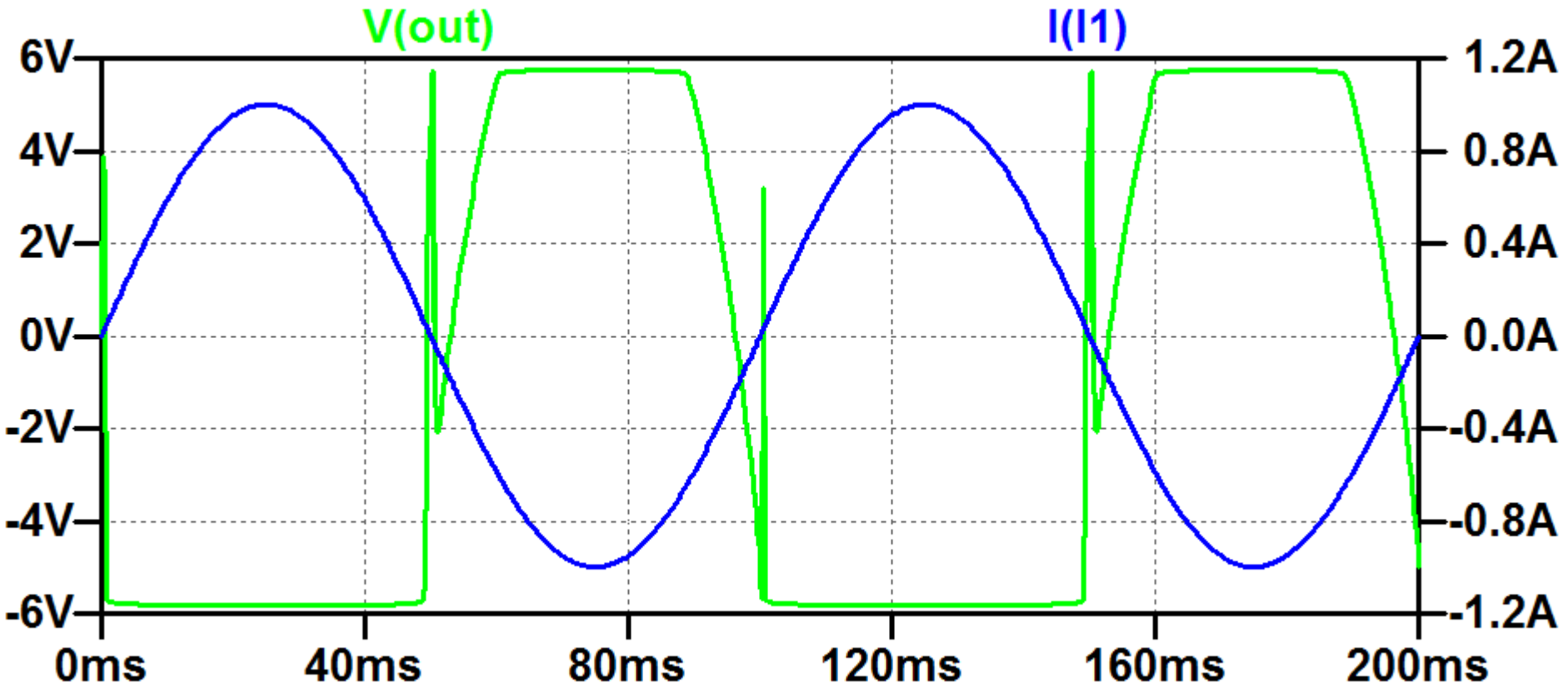
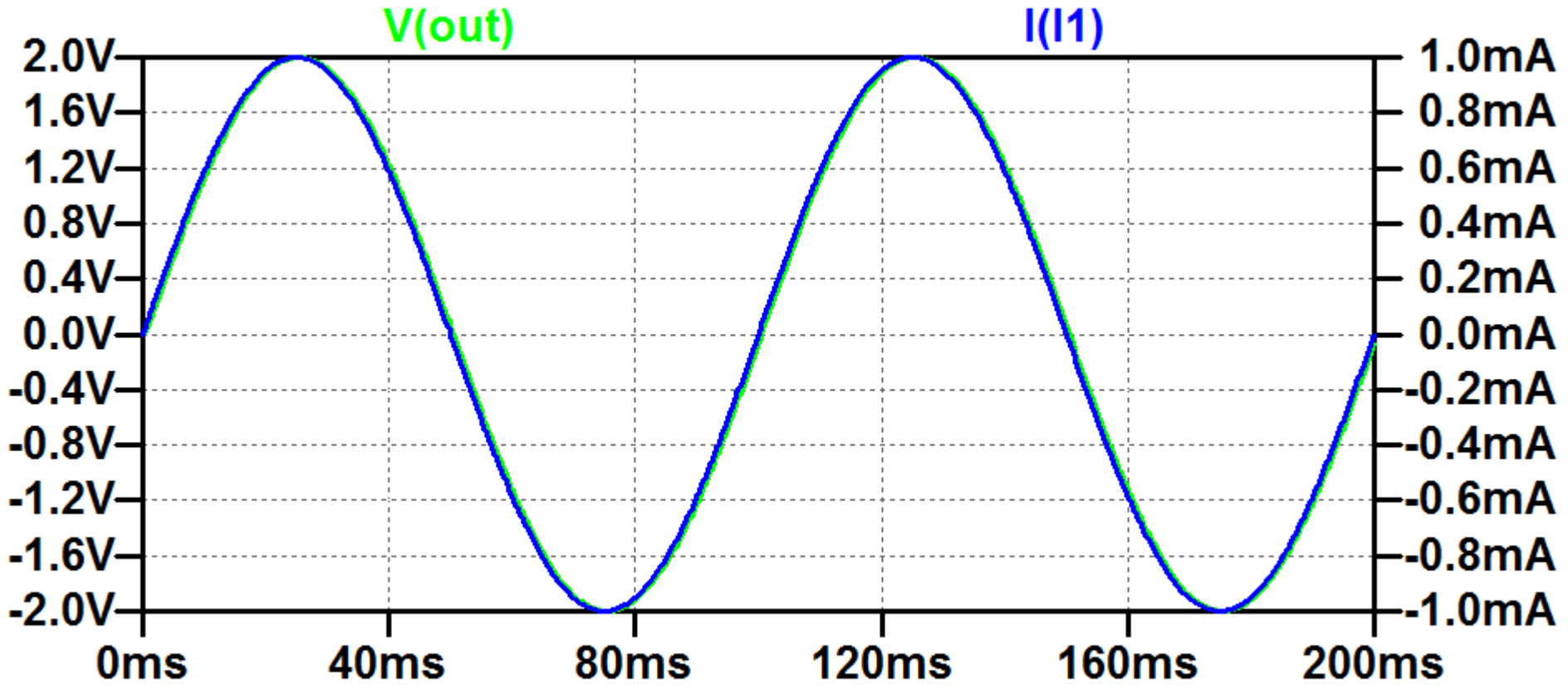
1A too much.


V(out)
I(I1)
6V
4V
2V
0V
-2V
-4V
-6V
1.2A
0.8A
0.4A
0.0A
-0.4A
-0.8A
-1.2A
0ms
40ms
80ms
120ms
160ms
200ms


V(out)
I(I1)
2.0V
1.6V
1.2V
0.8V
0.4V
0.0V
-0.4V
-0.8V
-1.2V
-1.6V
-2.0V
1.0mA
0.8mA
0.6mA
0.4mA
0.2mA
0.0mA
-0.2mA
-0.4mA
-0.6mA
-0.8mA
-1.0mA
0ms
40ms
80ms
120ms
160ms
200ms

1mA, works.