Superposition (take 3)

ECE 211 Circuits I

Lecture #32

Please visit Bison Academy for corresponding
lecture notes, homework sets, and solutions

Superposition (take 3)

Recap: Buck Converter

- V1 wasn't a sine wave
- We changed the problem so that it was a sine wave

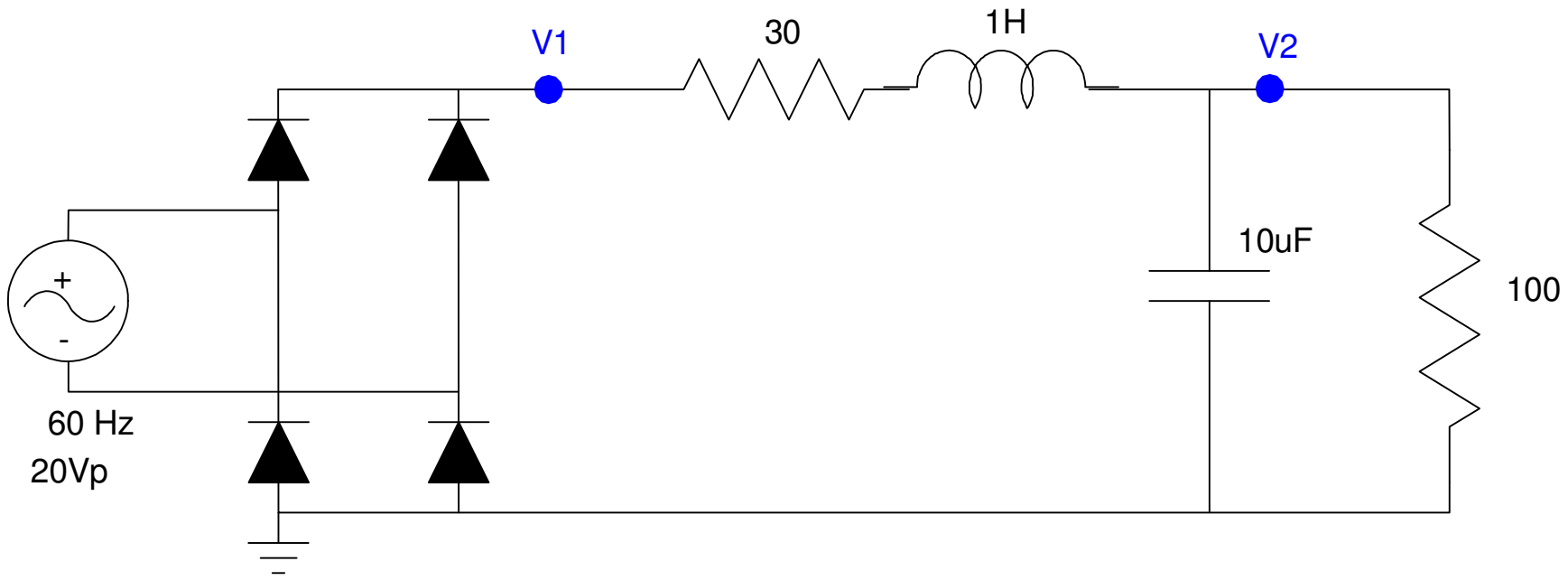
With Fourier Transforms, we don't have to make any approximations

- The results are more accurate
- But the problem gets a lot harder

Example 1: AC to DC Converter

$$V_1 = |19.3\sin(377t)| - 0.7$$

Determine the voltage at V2



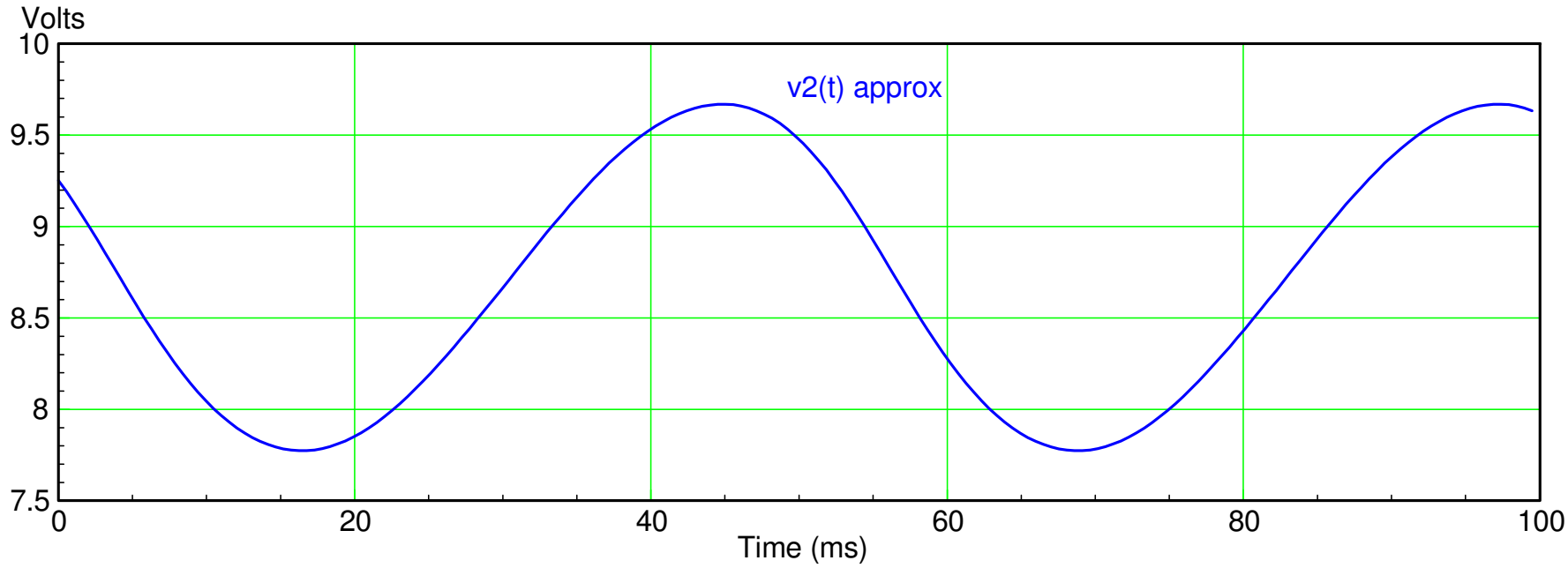
AC to DC Converter covered in ECE 320 Electronics I

ECE 320 Solution (approximate)

$$v_1(t) = |19.3\sin(377t)| - 0.7$$

$$v_1(t) \approx 11.33 + 9.35\cos(754t)$$

$$v_2(t) \approx 8.70 + 1.082\cos(754t - 119^0)$$



Fourier Transform Solution

$$v_1(t) = |19.3 \sin(377t)| - 0.7$$

$$v_1(t) = 11.331 - 8.488\cos(754t) - 1.698\cos(1508t)$$
$$-0.728\cos(2262t) - 0.404\cos(3016t) + \ldots$$

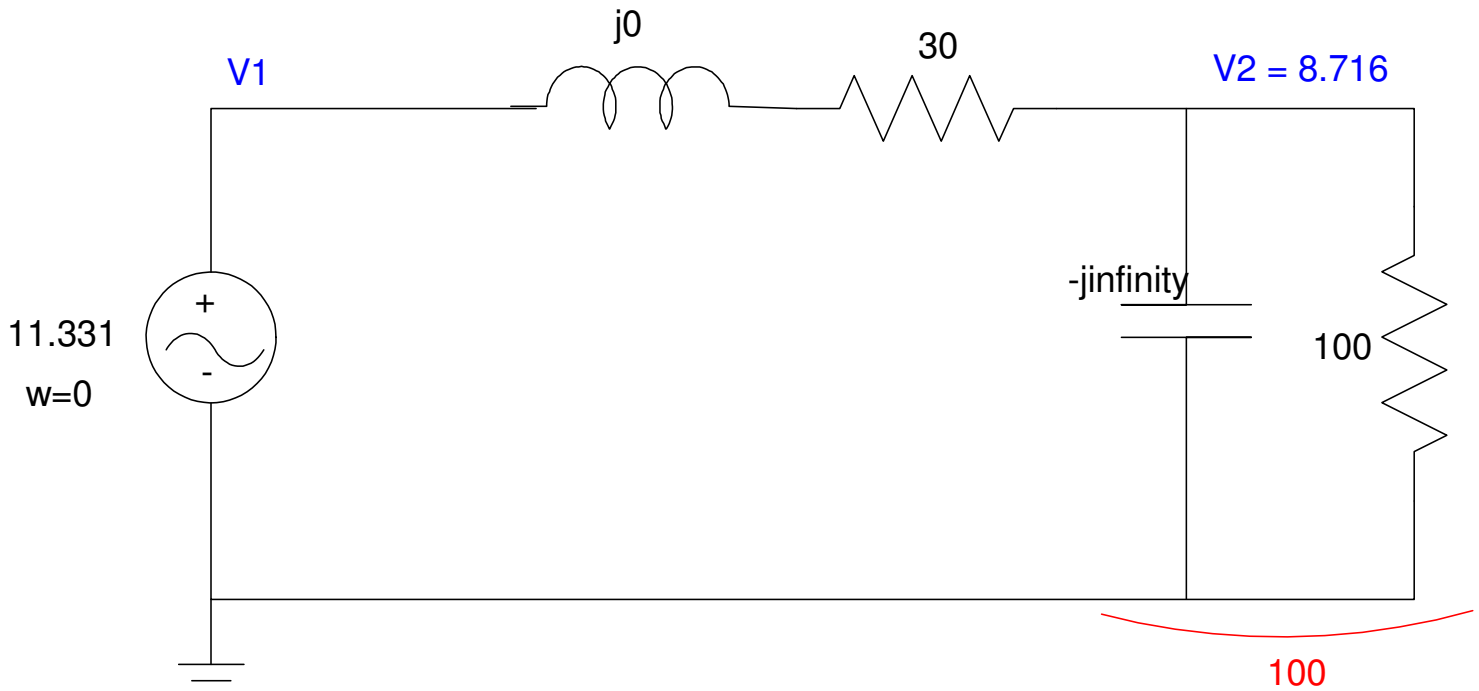
Now solve using superposition

DC Term:

$$V1 = 11.331$$

$$V_2 = \left(\frac{100}{100+30}\right) \cdot 11.331$$

$$V_2 = 8.716$$



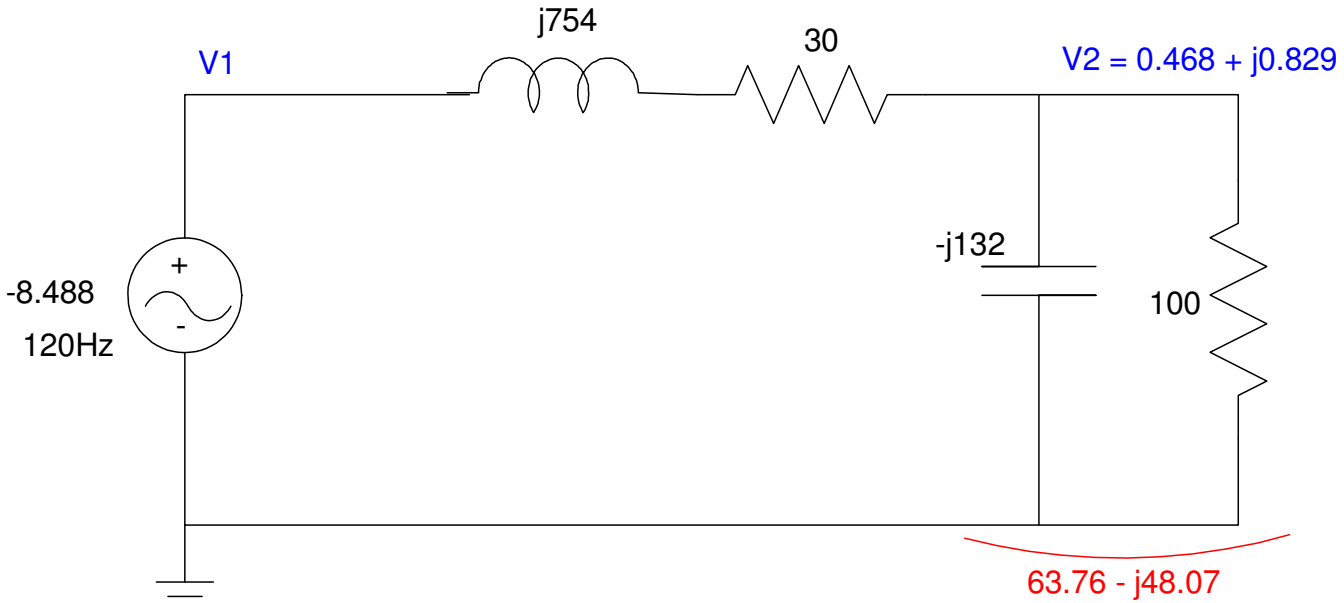
1st Harmonic (120Hz)

$$v_1(t) = -8.488\cos(754t)$$

$$V_2 = \left(\frac{(63.76 - j48.07)}{(63.76 - j48.07) + (30 + j754)}\right) \cdot (-8.488 + j0)$$

$$V_2 = 0.468 + j0.829$$

$$v_2(t) = 0.468\cos(754t) - 0.829\sin(754t)$$



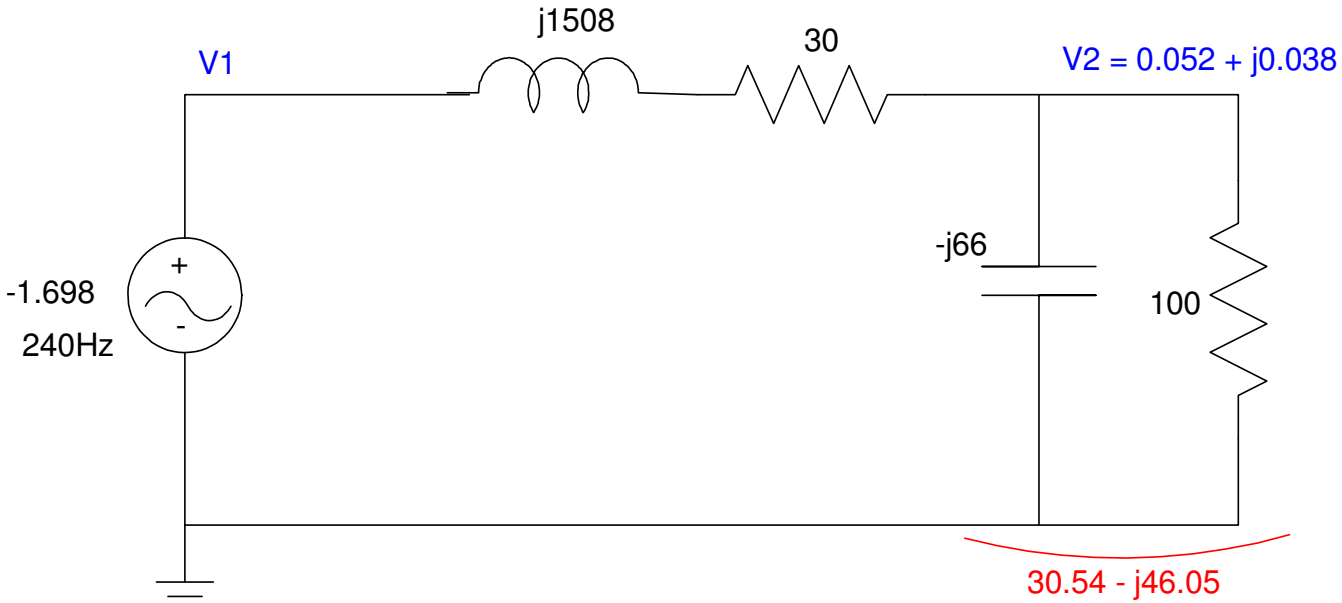
2nd Harmonic (240Hz)

$$v_1 = -1.698\cos(1508t)$$

$$V_2 = \left(\frac{30.54 - j46.05}{(30.54 - j46.05) + (30 + j1508)}\right) \cdot (-1.698 + j0)$$

$$V_2 = 0.052 + j0.038$$

$$v_2(t) = 0.052\cos(1508t) - 0.038\sin(1508t)$$



3rd Harmonic: (360Hz)

$$v_1(t) = -0.728\cos(2262t)$$

$$V_2 = \left(\frac{(16.35 - j36.98)}{(16.35 - j36.98) + (30 + j2262)}\right) \cdot (-0.728 + j0)$$

$$V_2 = 0.012 + j0.006$$

$$v_2(t) = 0.012\cos(2262t) - 0.006\sin(2262t)$$

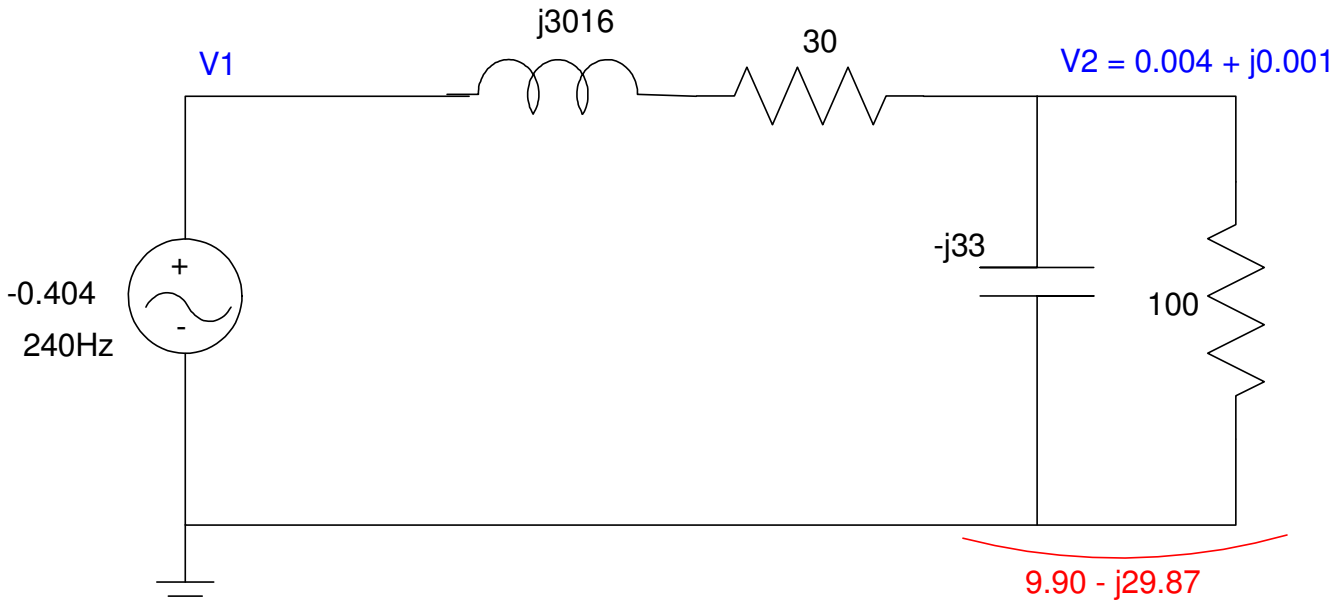
4th Harmonic: (480Hz)

$$v_1(t) = -0.404\cos(3016t)$$

$$V_2 = \left(\frac{(9.90 - j29.87)}{(9.90 - j29.87) + (30 + j3016)}\right) \cdot (-0.404 + j0)$$

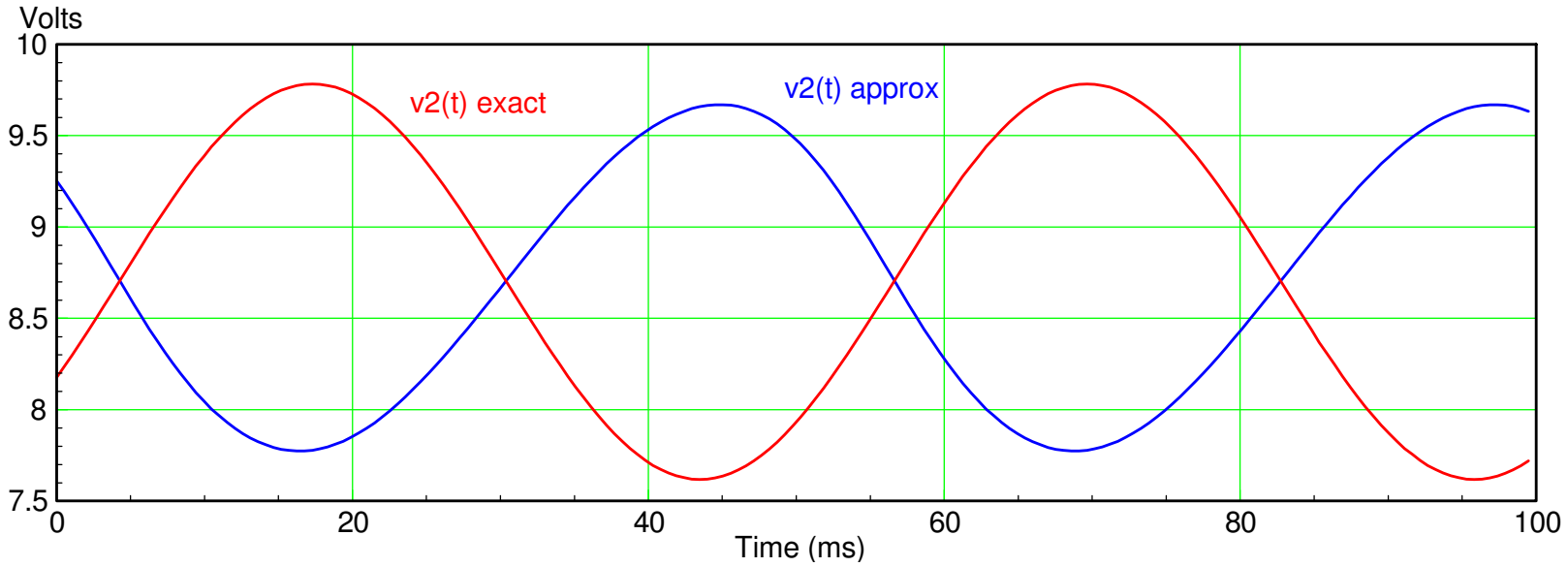
$$V_2 = 0.004 + j0.001$$

$$v_2(t) = 0.004\cos(3016t) - 0.001\sin(3016t)$$



The total answer will be the sum of all the terms

$$v_2(t) = 8.716$$
$$+0.468\cos(754t) - 0.829\sin(754t)$$
$$+0.052\cos(1508t) - 0.038\sin(1508t)$$
$$+0.012\cos(2262t) - 0.006\sin(2262t)$$
$$+0.004\cos(3016t) - 0.001\sin(3016t)$$



Note the following:

- The results using Fourier Transforms matches CircuitLab
- The reason our previous answer from lecture #30 (column #2) was off is we overestimated the 1st harmonic.
- In theory, you have to take the Fourier Series out to infinity. Actually, you can get a pretty good approximation just using the DC term and the 1st harmonic.