Superposition with Phasors (take 2)

ECE 211 Circuits I

Lecture #30

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

Superposition (take 2)

Superposition allows you to analyze circuits with multiple sinusoidal inputs. If this is the case

- Treat the problem as N separate problems, each with a single sinusoidal input.
- Solve each of the N problems separately using phasor analysis
- Add up all of the answers to get the total output.

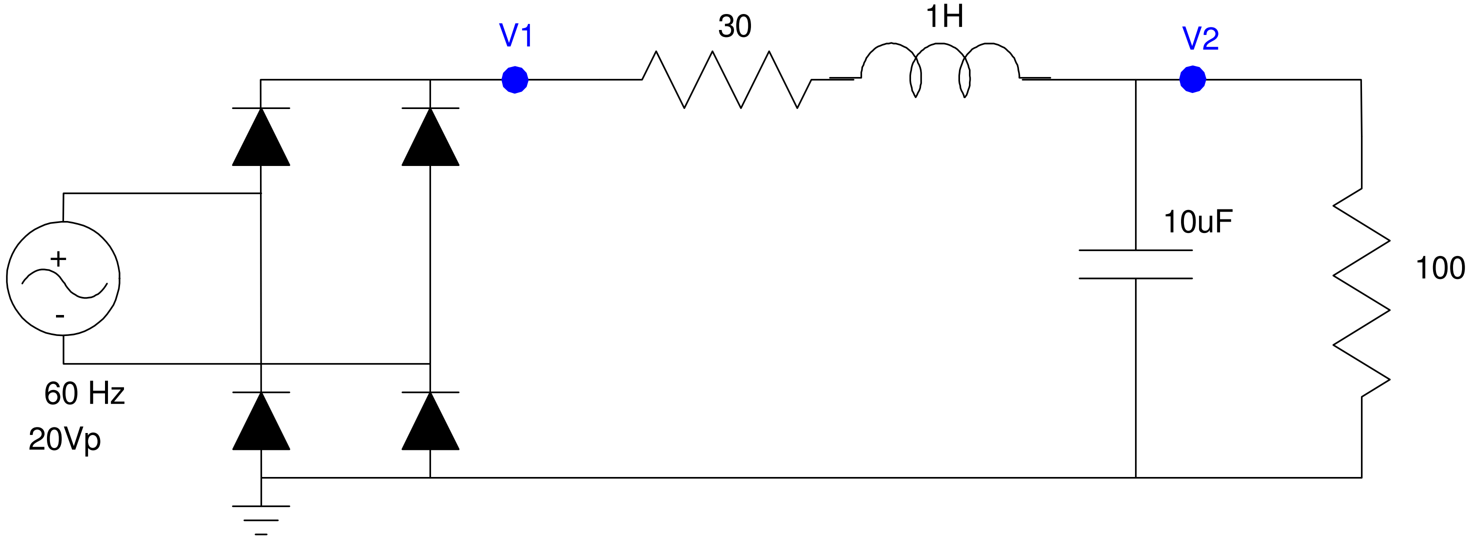
Problem:

Suppose your circuit has an input that *isn't* a sum of sinusoids. A typical engineering solution is to change the problem so that the inputs *are* sinusoids. The trick is you want to change the problem so that

- It is solvable (a big plus), and
- It keeps the flavor of the original problem.

Example 1: AC to DC Converter

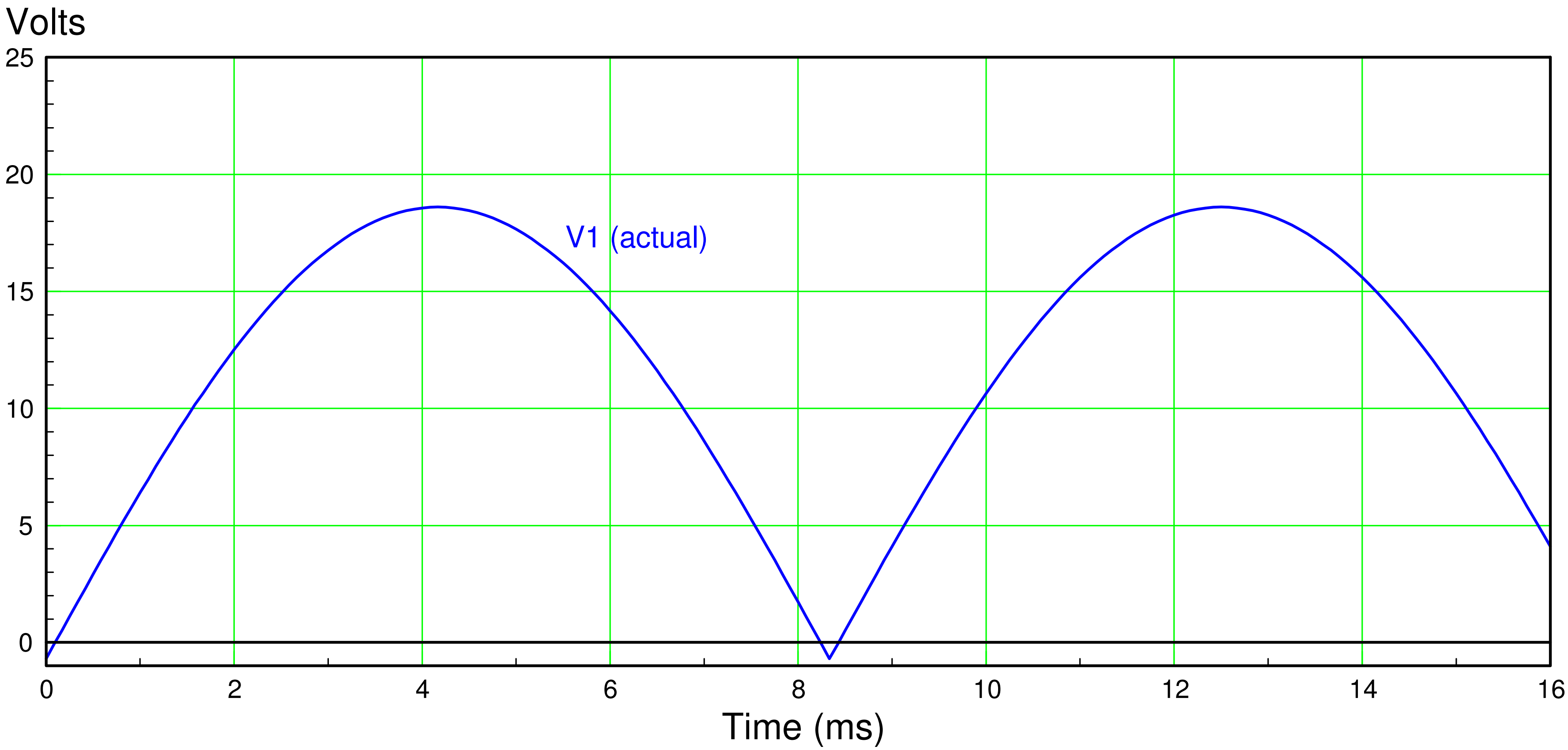
The following circuit is an AC to DC converter that we'll cover in ECE 320 Electronics I. Determine the voltage at V2:



AC to DC Converter covered in ECE 320 Electronics I

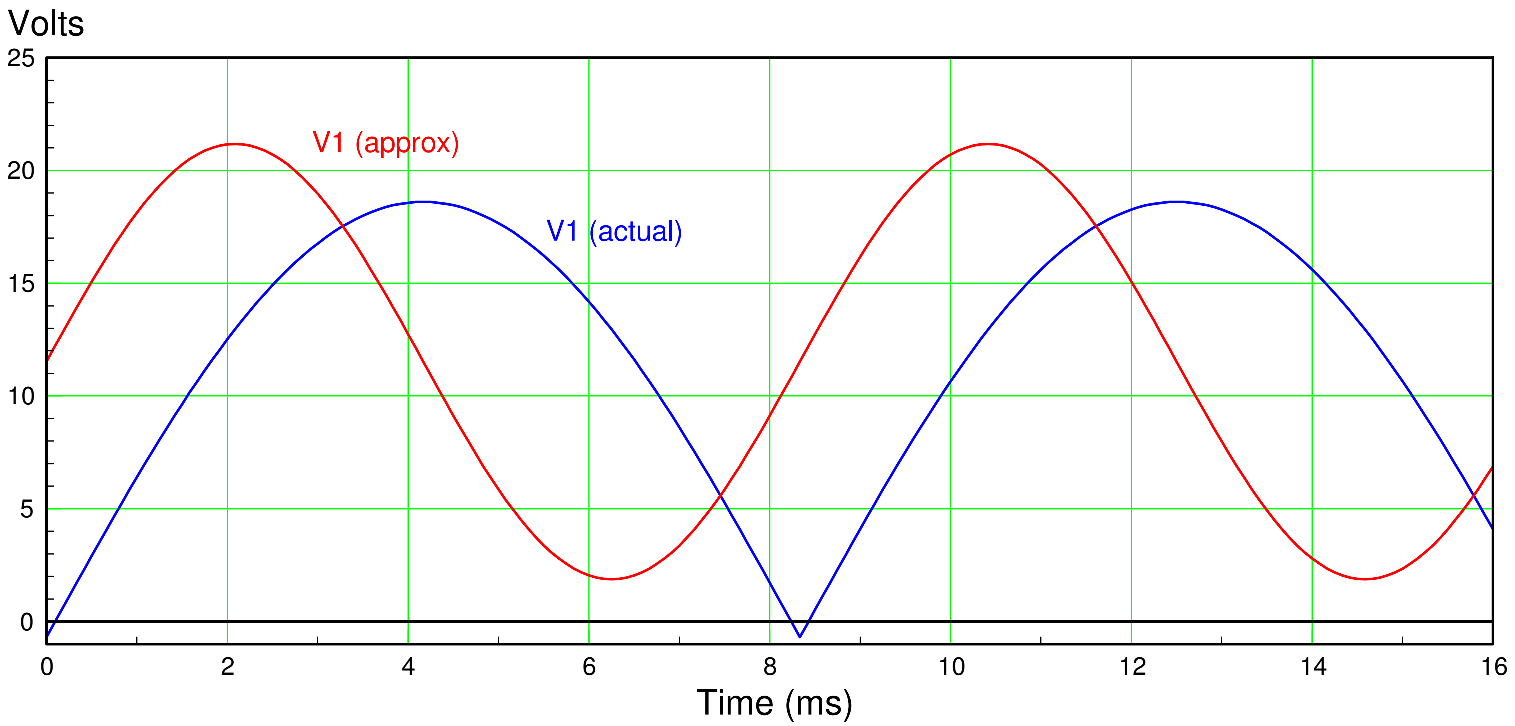
Problem: V1 isn't a sine wave

$$V_1 \approx |19.3\sin(754t)| - 0.7$$



Change the problem:

- The DC level of V1 is 11.31V
- The frequency of V1 is 120Hz (754 rad/sec)
- V1 = 19.3Vpp



Solve usine Superposition

$$V_1(t) = 11.31 + 9.65\cos(754t)$$

DC Analysis: The capacitor is open and the inductor is a short. By voltage division

$$X = 11.31 + j0$$

$$\omega = 0$$

$$V_2 = \left(\frac{100}{100+30}\right) 11.31V$$

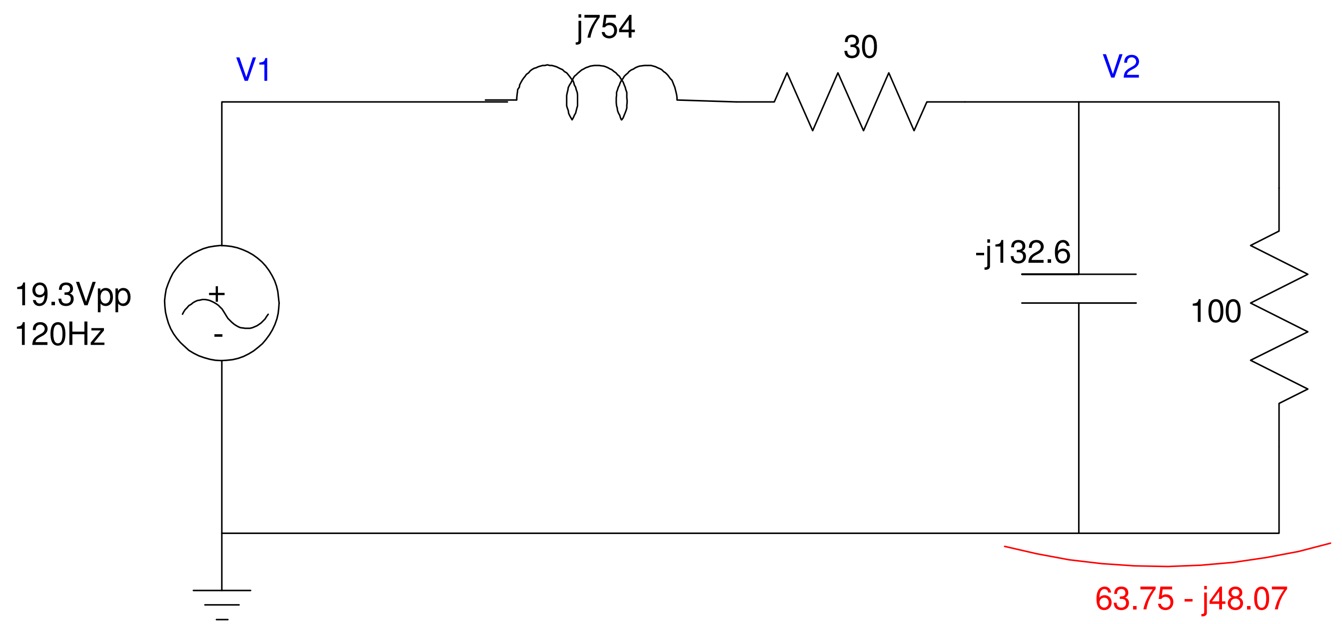
$$V_2 = 8.70V$$

AC Analysis:

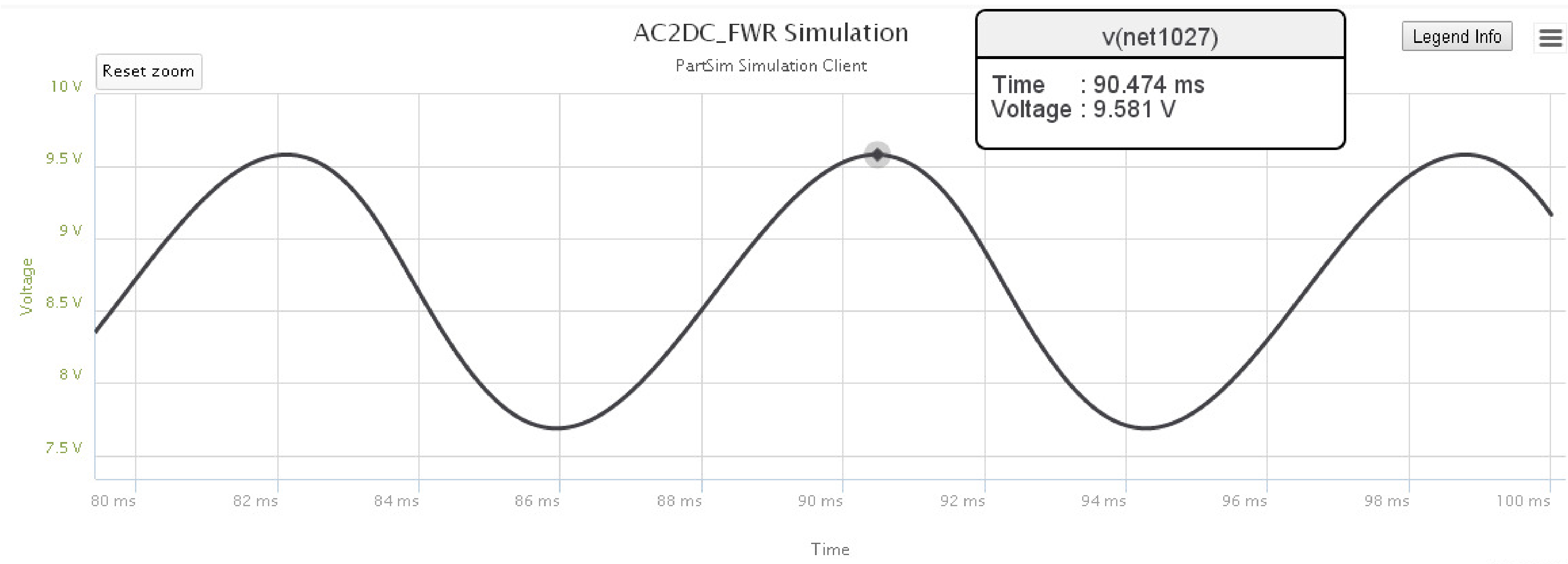
- Convert to Phasors & Solve

$$V_2 = \left(\frac{(63.75 - j48.07)}{(63.75 - j48.07) + (30 + j754)}\right) \cdot (19.3 V_{pp})$$

$$V_2 = 2.164 V_{pp}$$



Simulation Results:



	Calculated V2	PartSim V2
DC Value	8.70 V	8.634 V
AC Value	2.164 Vpp	1.895 Vpp

Note:

- The answers are fairly close. We kept the flavor of the problem
- The answers are a little off. This isn't surprising since the input isn't a pure sine wave like assumed.

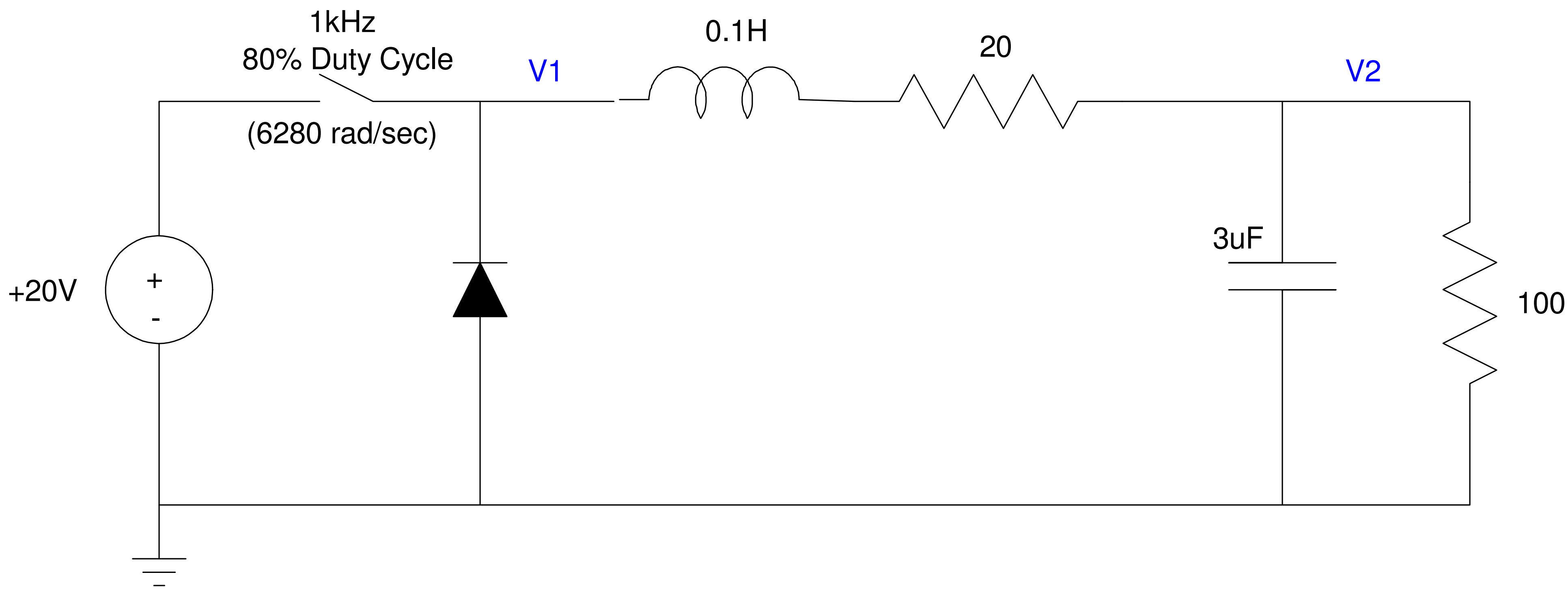
Even though the input is *very* different from a sine wave, the output is almost a pure sine wave with a DC offset. This means that treating this as a superposition problem with two terms

- A DC term, and
- A 120Hz term

was a pretty good assumption.

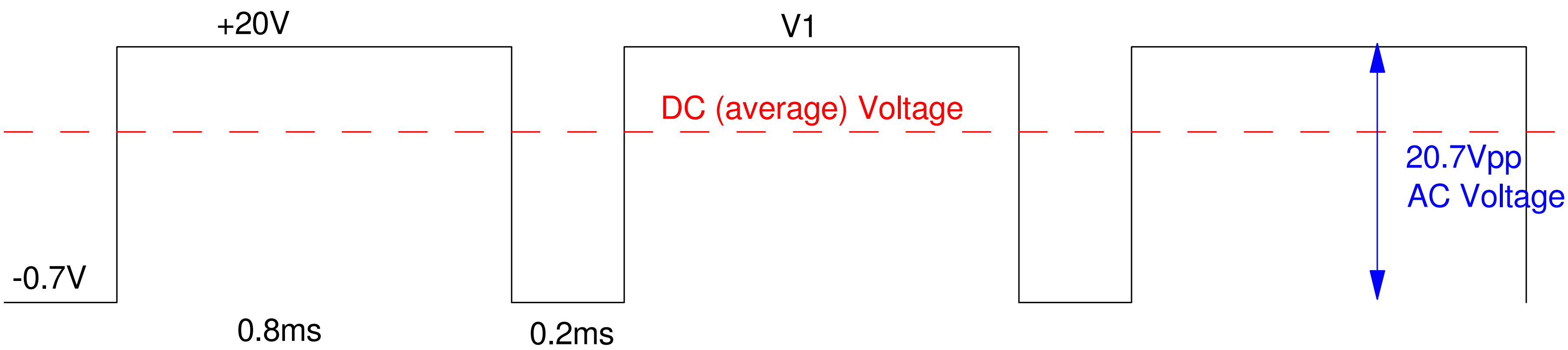
Example 2: Buck Converter

- Convert 12VDC from a car battery to 5VDC for your cell phone
- Convert 20VDC to 15.8VDC



Example 2: A Buck Converter (covered in ECE 320 Electronics I)

Problem: V1 isn't a sine wave



Voltage at V1 with a Buck Converter

Solution: Change the problem so that V1 *is* a sine wave

- Keep the DC value (15.86V)
- Keep the frequency (1kHz)
- Keep Vpp unchanged (20.7Vpp)

$$V_1 \approx 15.86 + 10.35 \cos(6280t)$$

DC Analysis:

$$V_1 = 15.86$$

$$V_2 = \left(\frac{100}{100+20}\right) V_1 = 13.21V$$

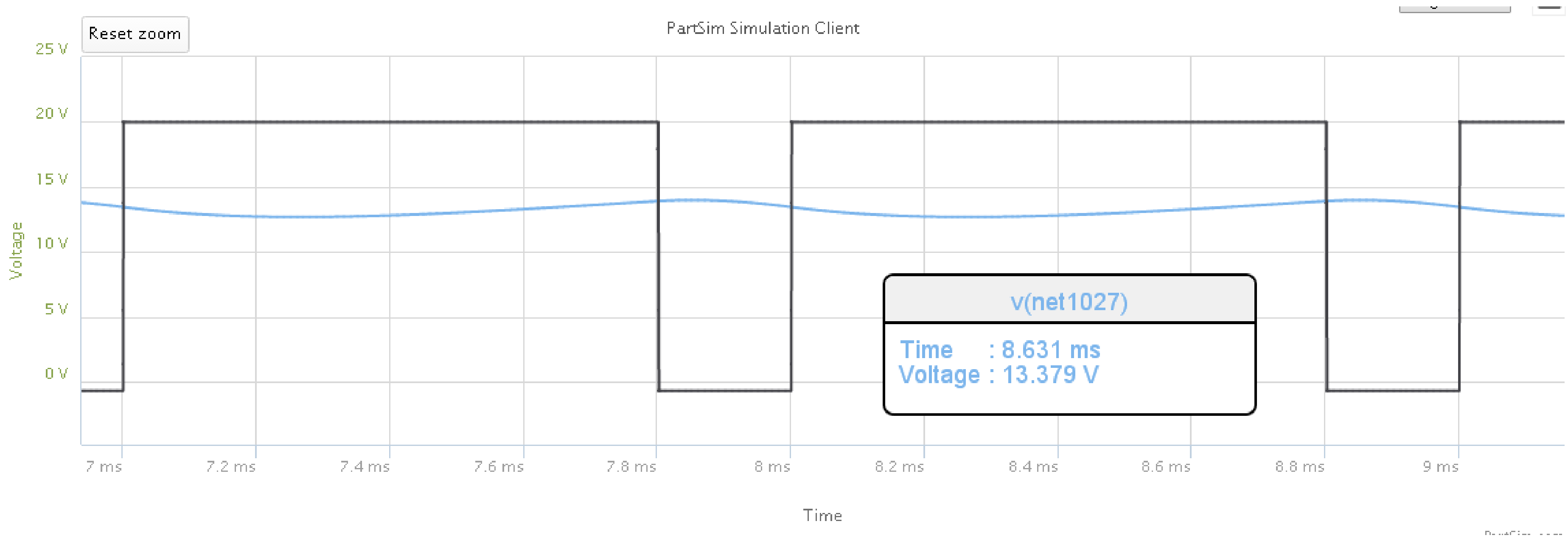
AC Analysis (1kHz)

$$V_1 = 20.7V_{pp}$$

$$V_2 = \left(\frac{(21.98 - j41.41)}{(21.98 - j41.41) + (20 + j628)}\right)(20.7V_{pp})$$

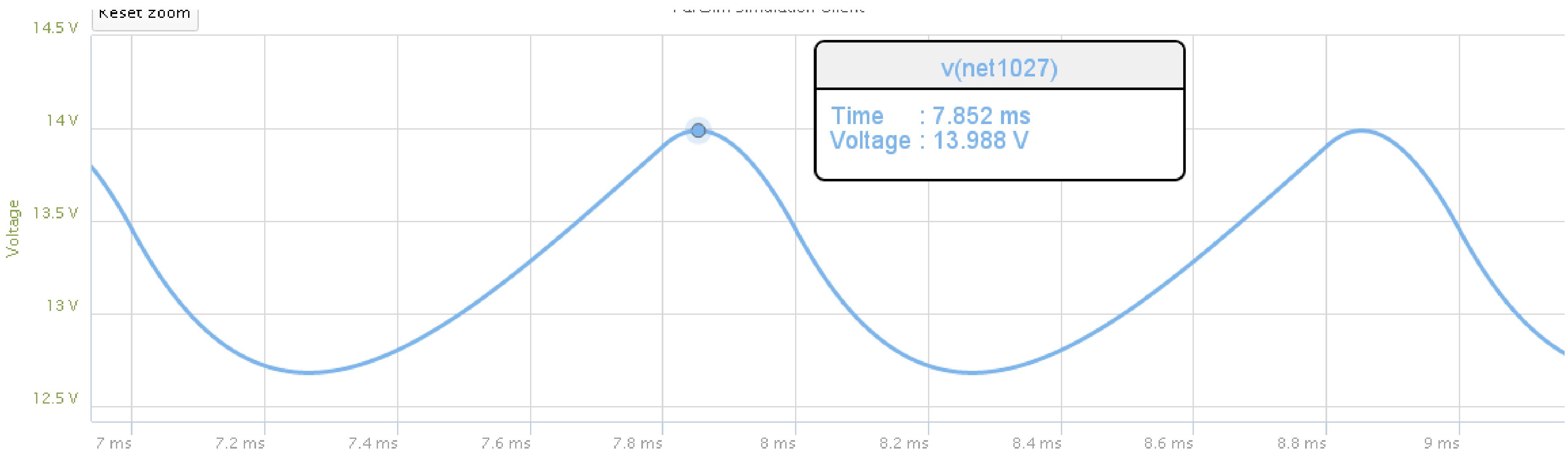
$$V_2 = 1.65V_{pp}$$ *only care about magnitude*

Simulation Results



V1 (black) and V2 (blue)

Simulation Results for V2 (expanded)



	Calculated V2	CircuitLab V2
DC Value	13.21 V	13.32 V
AC Value	1.65 Vpp	1.285 Vpp

Summary

Our results are close. By changing the problem to include

- A DC offset, and
- A sine wave

We were able to

- Solve for V2
- Without significantly changing the results (keeping the flavor of the problem)