ECE 3042 SdzҮҮŜǊ нлмн

Homework No. 1

Due Week of a l·ề нy

Section L01, T12-3

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ECE 3042

Homework Assignment No. 1

Fall 2008 Homework Problem Set for Experiment No. 1

Due Week of September 1

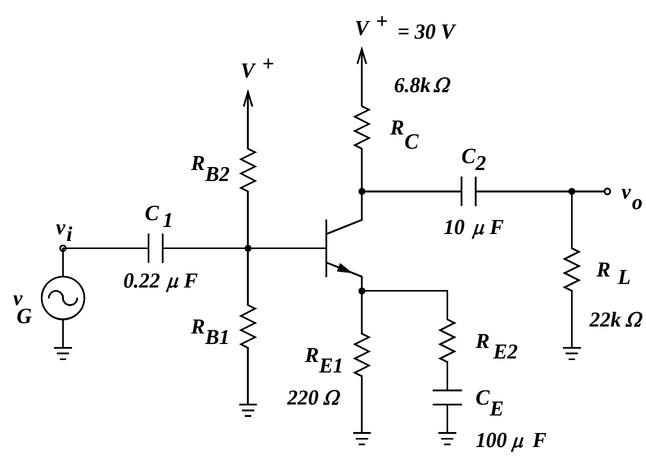
1. Shown below is a single stage common emitter amplifier using an 2N3904 NPN BJT as the active device. Design the circuit so that it clips symmetrically, viz. pick R_{B1} and R_{B2} so that the collector current is that which yields symmetric clipping. The design specification for the magnitude of the small signal midband voltage gain is 25. For the design calculations assume the the base-to-emitter dc voltage drop is 0.65 V, that the current in R_{B1} is $9I_B$, $\beta = 416$, the base spreading resistance is $10\,\Omega$, and the Early voltage is infinity.

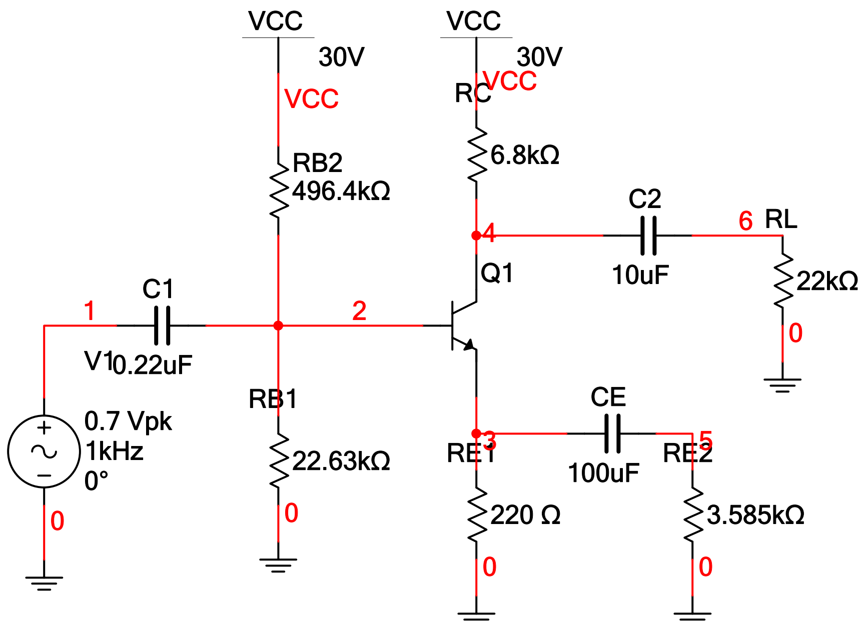
2. For the circuit parameters indicated in the diagram, use both Cadence and National Instruments SPICE to determine:

- the dc operating point of the circuit, viz. the dc voltage at each terminal of the transistor and the current flowing into the collector and base leads and out of the emitter.
- the small signal ac voltage gain, viz. a plot of the gain, A_v versus frequency where the frequency range is from $10\,\text{Hz}$ to $100\,\text{MHz}$.
- the positive and negative clipping levels, viz. the maximum and minimum possible values of the output voltage, v_o.
- plot of the output voltage versus time for 2 cycles of the input for an input signal a sine wave with a frequency of 1 kHz and a peak value $0.7\,\text{V}$.
- plot of the output voltage versus frequency for a frequency span from dc to $10\,\text{kHz}$, viz. the spectra of the output with an input signal a sine wave with a frequency of 1 kHz and a peak value $0.7\,\text{V}$. Plot the output voltage on a log scale.

Assume that the SPICE parameters for the 2N3904 NPN BJT are: saturation current, 6.734 f A; forward beta, 416; Early voltage, $74.03\,\text{V}$, zero-bias base collector capacitance, $3.638\,\text{pF}$; forward transit time, $301.2\,\text{ps}$, and base spreading resistance, $10\,\Omega$. (These are the values given in the model statement on page 7 of Experiment 1.)

3. Verify the SPICE solution for the above with a hand calculation using the parameters given for the SPICE simulation. Calculate the dc operating point, mid-band small signal voltage gain, and positive and negative clipping levels.





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BJT_NPN_VIRTUAL*

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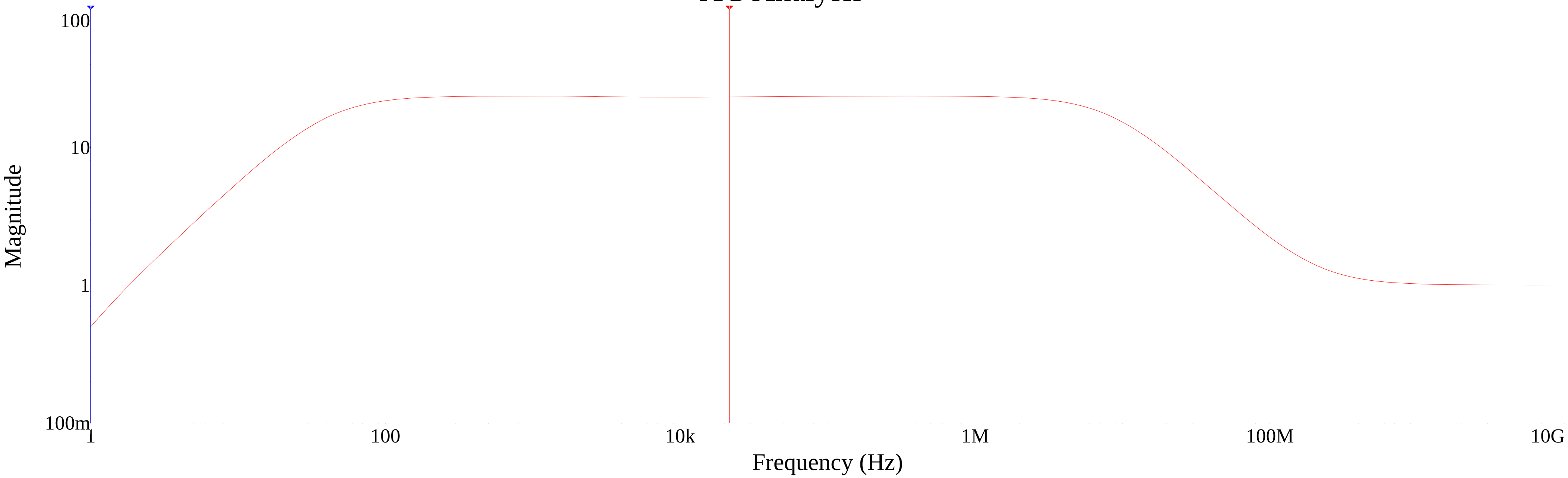
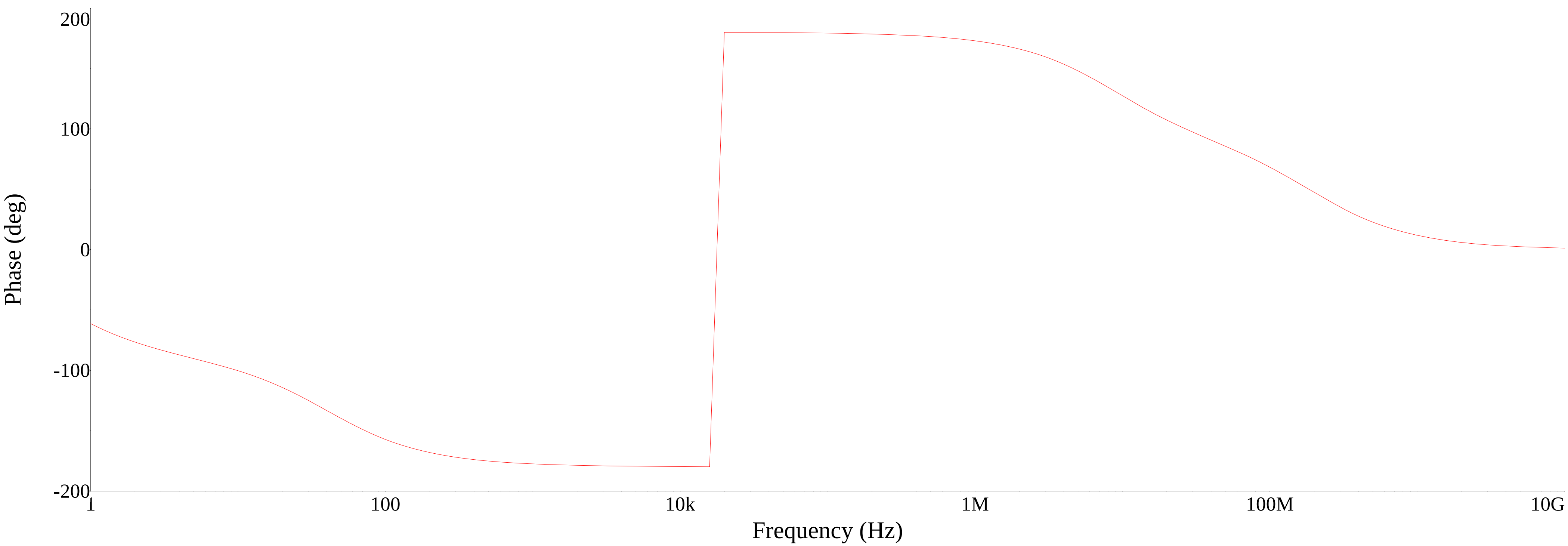
AC Analysis



Traces: V(6),

	x1	y1	x2	y2	min x	max x	min y	max y	offset x	offset y
V(6):	21.5307k	23.5643	1.0000	496.6534m	1.0000	10.0000G	496.6534m	23.5643	0.0000	0.0000



Traces: V(6),

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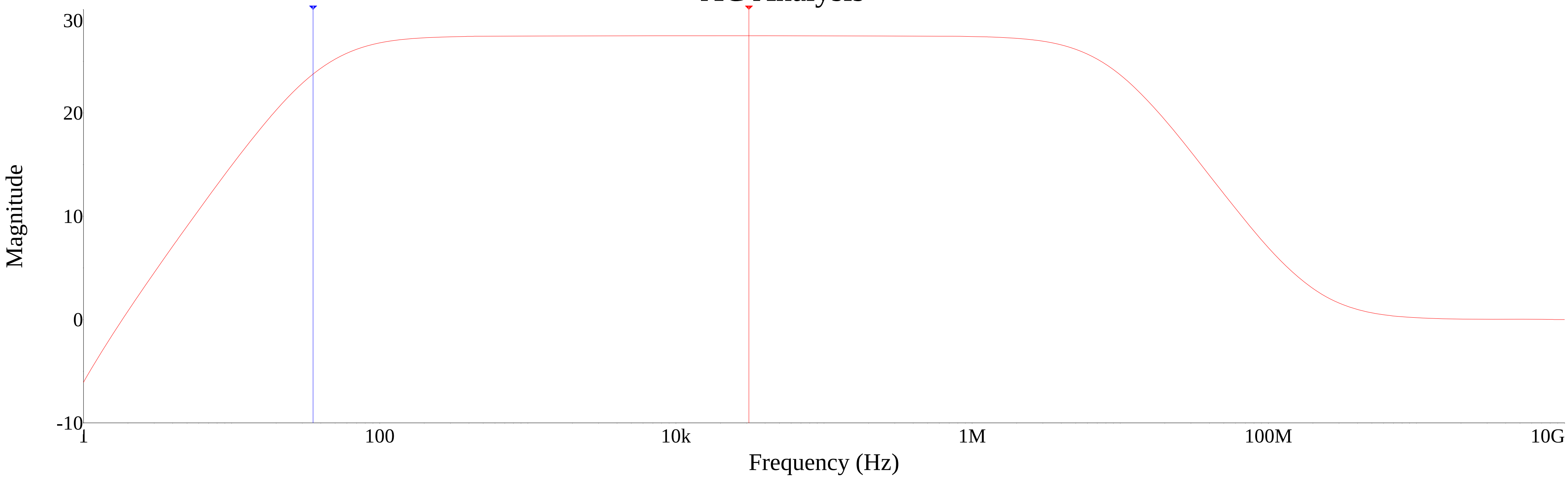
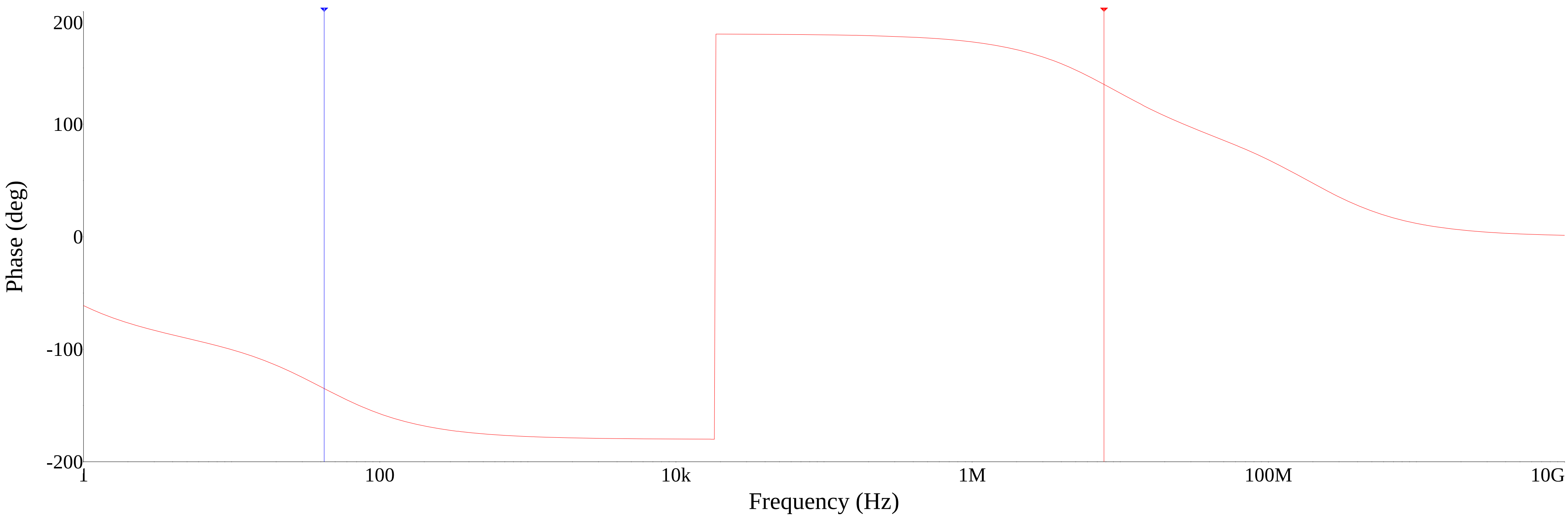
AC Analysis



Traces: V(6),

	x1	y1	x2	y2	min x	max x	min y	max y	offset x	offset y
V(6):	31.0771k	27.4451	35.4549	23.7409	1.0000	10.0000G	496.6534m	23.5643	0.0000	0.0000



Traces: V(6),

	x1	y1	x2	y2	min x	max x	min y	max y	offset x	offset y
V(6):	7.7598M	135.3429	42.1959	-134.9463	1.0000	10.0000G	-179.9967	179.9973	0.0000	0.0000

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DC Operating Point

	DC Operating Point	
1	V(4)	13.96126
2	V(2)	1.20334
3	V(3)	519.96452 m
4	(V(vcc)-V(4))/6800	2.35864 m

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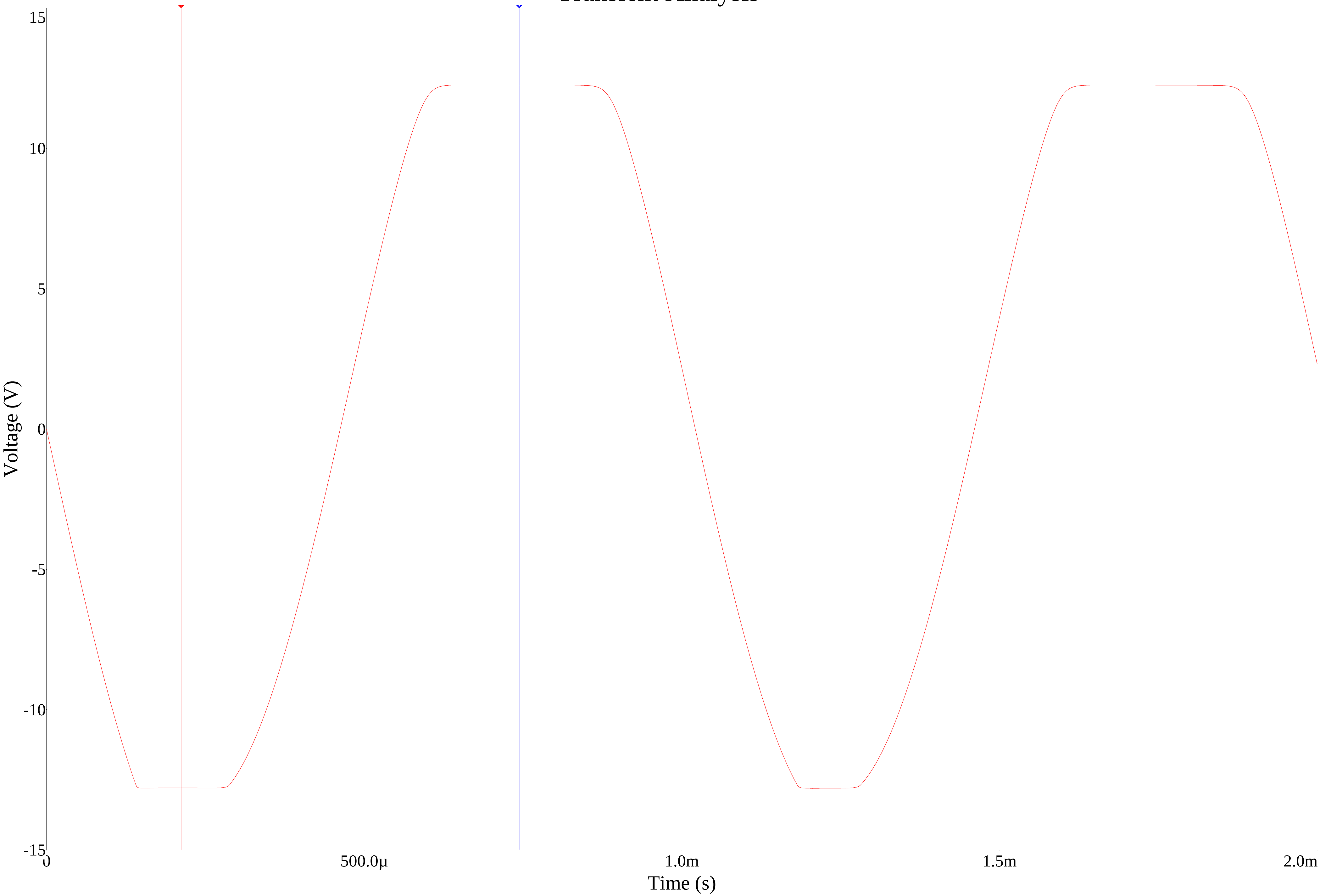
Transient Analysis



Traces: V(6),

	x1	y1	x2	y2	min x	max x	min y	max y	offset x	offset y
V(6):	211.8227µ	-12.7878	743.8424µ	12.2569	0.0000	2.0000m	-12.8052	12.2595	0.0000	0.0000

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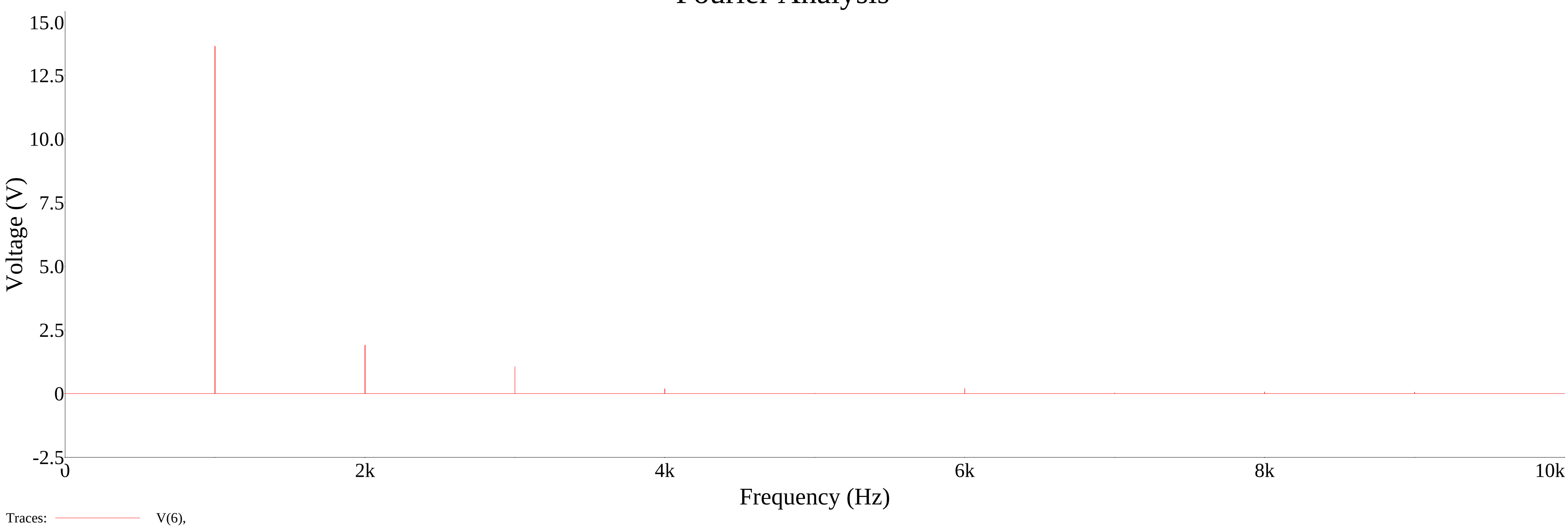
1	Fourier analysis fc					
2	DC component:	1.54492				
3	No. Harmonics:	9				
4	THD:	16.1151 %				
5	Gridsize:	256				
6	Interpolation Degr	1				
7						
8	Harmonic	Frequency	Magnitude	Phase	Norm. Mag	Norm. Phase
9	1	1000	13.6459	-176.7	1	0
10	2	2000	1.90322	99.6903	0.139471	276.395
11	3	3000	1.06229	-175.41	0.0778464	1.29969
12	4	4000	0.18746	-74.752	0.0137374	101.953
13	5	5000	0.0159872	-20.661	0.00117157	156.044
14	6	6000	0.201528	-74.953	0.0147683	101.752
15	7	7000	0.0327852	-1.2864	0.00240256	175.418
16	8	8000	0.0680078	130.178	0.00498374	306.883
17	9	9000	0.0587069	44.7043	0.00430215	221.409
18						

Fourier Analysis



Homework 1 Fall 2008

$$r_x := 10\Omega \quad R_C := 6.8k\Omega \quad R_L := 22k\Omega \quad R_{E1} := 220\Omega$$

$$R_p(A,B) := \frac{A \cdot B}{A + B} \quad \beta := 416 \quad V_{BE} := 0.65V \quad A_v := 25 \quad V_{plus} := 30V$$

$$R_{tc} := R_p(R_C, R_L) \quad \alpha := \frac{\beta}{\beta + 1} \quad R_{te} := \frac{\alpha \cdot R_p(R_C, R_L)}{A_v} \quad R_{E2} := \frac{1}{\frac{1}{R_{te}} - \frac{1}{R_{E1}}}$$

$$R_{E2} = 3.585 \times 10^{3}\,\Omega$$

For Symmetric Clipping

$$I_C := \frac{V_{plus}}{R_{tc} + R_C + R_{E1} + R_{te}} \quad I_C = 2.415 \times 10^{-3}\,A$$

$$I_B := \frac{I_C}{\beta} \quad I_E := \frac{I_C}{\alpha} \quad V_C := V_{plus} - I_C \cdot R_C \quad V_E := I_E \cdot R_{E1} \quad V_B := V_E + V_{BE}$$

$$I_B = 5.806 \times 10^{-6}\,A \quad I_E = 2.421 \times 10^{-3}\,A \quad V_C = 13.577\,V \quad V_E = 0.533\,V \quad V_B = 1.183\,V$$

$$I_{B1} := 9 \cdot I_B \quad I_{B2} := I_{B1} + I_B \quad R_{B1} := \frac{V_B}{I_{B1}} \quad R_{B2} := \frac{V_{plus} - V_B}{I_{B2}} \quad V_A := 74.03V$$

$$R_{B1} = 2.263 \times 10^{4}\,\Omega \quad R_{B2} = 4.964 \times 10^{5}\,\Omega \quad V_T := 25.9mV \quad r_e := \frac{V_T}{I_E}$$

$$r_{ie} := \frac{r_x}{1 + \beta} + r_e \quad V_{CB} := V_C - V_B \quad r_o := \frac{V_A + V_{CB}}{I_C} \quad r_o = 3.578 \times 10^{4}\,\Omega$$

$$r_{ic} := \frac{r_o + R_p(r_{ie}, R_{te})}{1 - \alpha \cdot \frac{R_{te}}{r_{ie} + R_{te}}} \quad A_v := \alpha \cdot \frac{R_p(r_{ic}, R_{tc})}{r_{ie} + R_{te}} \quad A_v = 23.594$$

$$v_{oplus} := I_C \cdot R_{tc} \quad v_{ominus} := -\left[V_{plus} - I_C \cdot (R_C + R_{E1})\right] \cdot \frac{R_{tc}}{R_{tc} + R_{te}}$$

$$v_{oplus} = 12.545\,V \quad v_{ominus} = -12.545\,V$$