CALIFORNIA STATE UNIVERSITY
SACRAMENTO

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 108L
Electronics I_ Laboratory, 1 unit

Summer_ 2022

Lab - 01 Report

Submitted to

Riaz Ahmad

By

Vigomar Kim Algador **Dated: 07-17-2022**

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INTRODUCTION:

In this laboratory, the students were assigned to investigate a simple circuit given using PSPICE simulation. Using the techniques and methods taught for this laboratory, the students need to apply to the hand calculation and the step-by-step method for simulation. This laboratory is divided into three mahor types of analyses for student to experiment: DC sweep, AC sweep, and Transient Simulation.

Part1 – Preliminary Calculations

1. Transfer Function:

   H(s) = $\frac{\boldsymbol{R_1}}{\boldsymbol{R_1+R_2+R_1R_2sC}} = \frac{\mathbf{10\ 638.30}}{\boldsymbol{s} + \mathbf{33\ 365.57}}$

2. At frequency = 0, the capacitor considered an open circuit. $\boldsymbol{Z_c} = \infty$

3. | H(jw) | = $\frac{\mathbf{10\ 638.30}}{\sqrt{\boldsymbol{s}^2 + (\mathbf{33\ 365.57})^2}}$

   At frequency = 0, w = 0 :

   Magnitude of the transfer function (| H(jw) |) = 0.3188

4. At frequency = ∞ , the capacitor considered a short circuit. $\boldsymbol{Z_c} = \mathbf{0}$

5. | H(j$\boldsymbol{\omega}$) | = $\frac{\mathbf{10\ 638.30}}{\sqrt{\boldsymbol{s}^2 + (\mathbf{33\ 365.57})^2}}$

   At frequency = ∞, $\boldsymbol{\omega}$ = ∞:

   Magnitude of the transfer function (| H(j$\boldsymbol{\omega}$) |) = 0

6. At $\boldsymbol{v_s}$ = -1.5V, -1.0V, -0.5V, 0.0V, 0.5V, 1.0V, 1.5V,

   the $\boldsymbol{v_2}$ are -0.478V, -0.319V, -0.159V, 0V, 0.159V, 0.319V, 0.478V, respectively.

7. The time constant ($\boldsymbol{\tau}$) = 29.97 $\boldsymbol{\mu}$s.

8. The cutoff frequency is 5310.30 Hz.

9. The magnitude and phase of $\boldsymbol{v_2}$ at the given frequencies: 1kHz, 5kHz, 10kHz, and -3dB are 0.313, 0.232, 0.150, 0.225, and the phase angles are - 10.66°, - 43.28°, - 62.03°, - 45°, respectively.

10. The risetime of $\boldsymbol{v_2}$ is 67.2 $\boldsymbol{\mu}$s.

11. The bandwidth is 5.21 kHz.

Part2 - Simulations Results

DC Sweep:

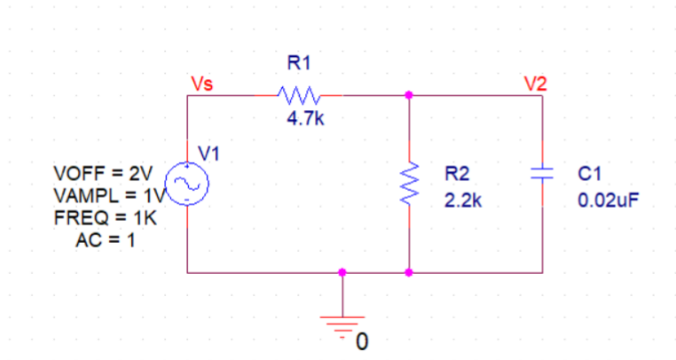


Figure 1. The Circuit in PSPICE.

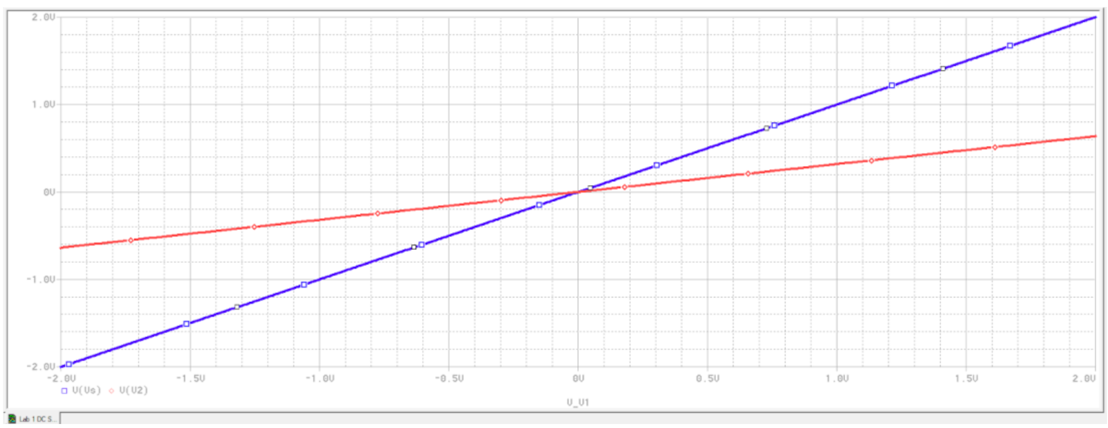


Figure 2. The output graph for v_s and v_2.

The student input the circuit in PSPICE shown in figure 1 and gave the result shown in figure 2. The blue line shows the v_2 while the red line shows v_s.

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	-1.5000	-1.0000	-500.000m
	CURSOR 1,2	V(Vs)	-1.5000	-1.0000	-500.000m
		V(V2)	-478.261m	-318.841m	-159.420m

Figure 3. Output data for v_s = -1.5, -1.0

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	-500.000m	0.000	-500.000m
	CURSOR 1,2	V(Vs)	-500.000m	0.000	-500.000m
		V(V2)	-159.420m	0.000	-159.420m

Figure 4. Output data for v_s = -0.5, 0.0

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	500.000m	1.0000	-500.000m
	CURSOR 1,2	V(Vs)	500.000m	1.0000	-500.000m
		V(V2)	159.420m	318.841m	-159.420m

Figure 5. Output data for v_s = 0.5, 1.0

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	1.5000	1.5000	0.000
	CURSOR 1,2	V(Vs)	1.5000	1.5000	0.000
		V(V2)	478.261m	478.261m	0.000

Figure 6. Output data for v_s = 1.5

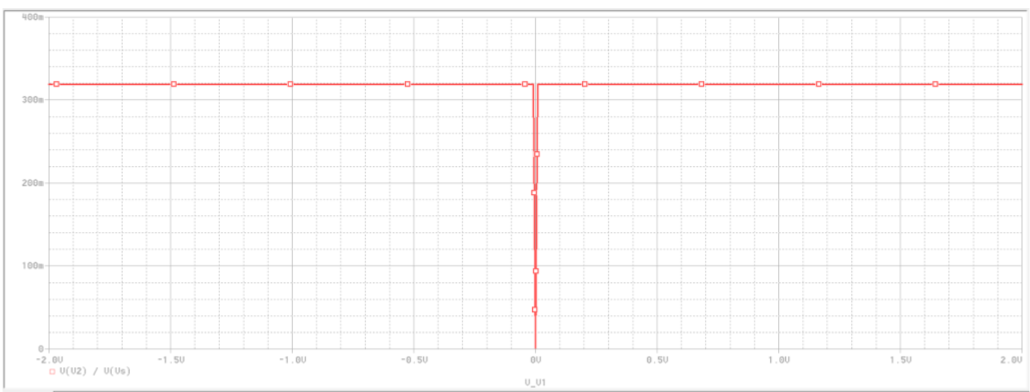


Figure 7. The simulation result for ${}^{v_2}/_{v_s}$

From figures 3,4, 5, and 6, it shows the data for v_2 with corresponding v_s of -1.5 V, -1.0 V, -0.5V, 0.0V, 0.5V, 1.0V, and 1.5V. For the figure 7, it shows the result for ${}^{v_2}/_{v_s}$.

AC Sweep:

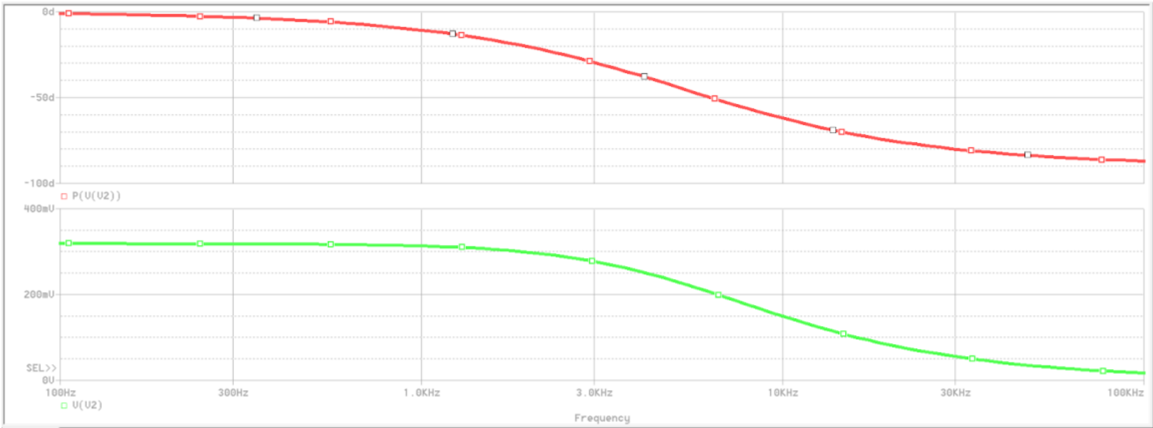


Figure 8. The simulated curves for magnitude and phase v_2

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	1.0000K	5.0079K	-4.0079K
		V(V2)	313.333m	231.959m	81.374m
	CURSOR 1,2	P(V(V2))	-10.665	-43.321	32.656

Figure 9. Output data for frequencies = 1K, 5K

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	10.000K	5.3120K	4.6880K
		V(V2)	149.537m	225.387m	-75.850m
	CURSOR 1,2	P(V(V2))	-62.030	-44.994	-17.037

Figure 10. Output data for frequencies = 10K and cutoff frequency

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	5.3120K	100.000	5.2120K
	CURSOR 1,2	V(V2)	225.387m	318.784m	-93.397m
		P(V(V2))	-45.009	-1.0788	-43.930

Figure 11. The phase of the v_2 at the upper -3dB frequency

With the AC Sweep, we are able to simulate the curves for magnitude and phase for v_2. We are also able to gather data for each frequencies given in the instruction: 1k, 5k and 10k and cutoff frequencies shown in figures 9, 10, and 11.

TRANSIENT:

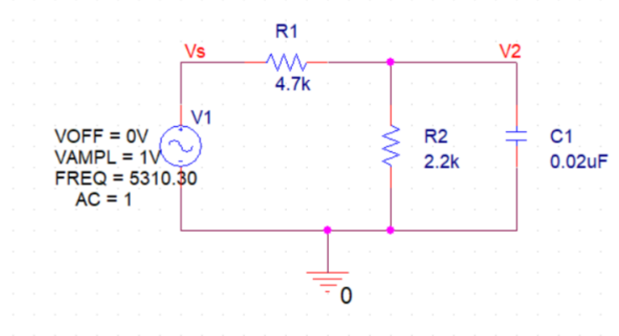


Figure 12. Circuit for the Transient analysis

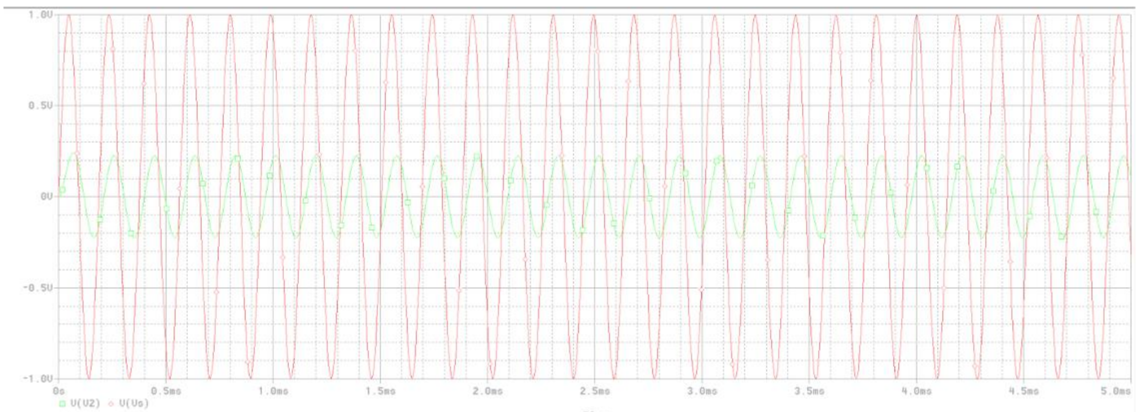


Figure 13. Simulation plot for v_2 and v_s

Using the transient simulation, we are able to obtain the $\boldsymbol{v_2}$ and $\boldsymbol{v_s}$ as functions of time. We are able to show the simulation plot for $\boldsymbol{v_2}$ and $\boldsymbol{v_s}$ shown in figure 13. The green line shows $\boldsymbol{v_2}$ while the red line shows $\boldsymbol{v_1}$. We see that the peak-to-peak value for $\boldsymbol{v_s}$ is 1.0V and for $\boldsymbol{v_2}$ is 0.5 V.

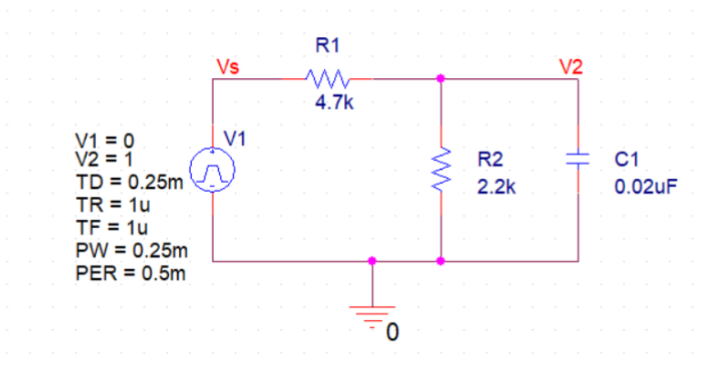


Figure 14. circuit for Transient replacing vsin voltage source with a vpulse source

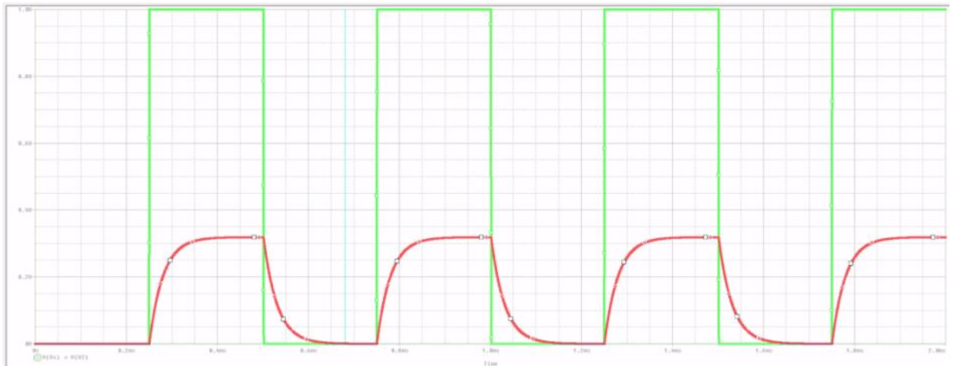


Figure 15. Simulated plot for v_2 and v_s

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		318.040m		
		X Values	929.944u	0.000	929.944u		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	CURSOR 1,2	V(V2)	318.040m	0.000	318.040m		0.000	0.000	318.040m	0.000	159.020m
		V(Vs)	1.0000	0.000	1.0000		681.960m	0.000	1.0000	0.000	500.000m

Figure 16. data for risetime

After, we replaced the vsin voltage source with a vpulse source shown in figure 14. With that, we are able to simulate and show the plot in figure 15. From this simulation, we are able to determine the 10% to 90% risetime which we got is 68.1 μs shown in figure 16.

Conclusion:

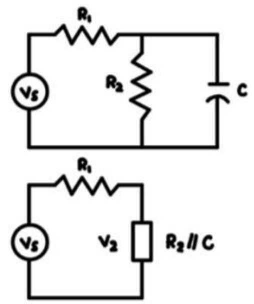
The whole laboratory shows various calculations and simulations using PSPICE. With the given instructions, the students were able to work on with the PSPICE simulation with different major analyses. With the preliminary calculations, the students were able to compare the simulation part using AC Sweep, DC Sweep, and Transient simulations. From the preliminary calculations from number 6, we are able to match the data from DC Sweep under figures 3, 4, 5, and 6. With the AC Sweep, we are able to matched the data from the hand calculations with given frequencies 1 kHz, 5 kHz, 10 kHz, and -3 dB, which is also the cutoff frequency. Lastly, the Transient lets us simulate the data for the risetime. The whole data shown below.

Table 1. Laboratory calculation and simulation comparison

	Preliminary Calculation	**Simulation**
v_2/v_s	0.3188 V	0.318 V
-1.5 V	- 0.478V	- 0.478 V
-1.0 V	- 0.319V	- 0.319 V
-0.5 V	- 0.159V	- 0.159 V
0.0 V	0V	0 V
0.5 V	0.159V	0.159 V
1.0 V	0.319V	0.319 V
1.5 V	0.478V	0.478 V
1 kHz	0.313 V	0.313 V
	∅ = - 10.66°	∅ = - 10.66°
5 kHz	0.232 V	0.231 V
	∅ = - 43.28°	∅ = - 43.32°
10 kHz	0.150 V	0.150 V
	∅ = - 62.03°	∅ = - 62.03°
-3 dB	0.225 V	0.225 V
	∅ = - 45°	∅ = - 44.99°
Risetime	67.2 μs	68.1 μs

APPENDIX

1.



$$C = \frac{1}{sC}$$

$$R_2 // C = \frac{R_2 C}{R_2 + C}$$

$$V_2 = \frac{R_2 // C}{R_1 + (R_2 // C)} \cdot V_s$$

$$\frac{V_2}{V_s} = H(s) = \frac{R_2 C / R_2 + C}{R_1 + \frac{R_2 C}{R_2 + C}} = \frac{R_2 C}{R_1 (R_2 + C) + R_2 C} = \frac{R_2 C}{R_1 R_2 + R_1 C + R_2 C}$$

$$= \frac{R_2 (1/sC)}{R_1 R_2 + (1/sC)(R_1 + R_2)} = \frac{R_2}{R_1 + R_2 + R_1 R_2 sC}$$

$$= \frac{2.2k}{4.7k + 2.2k + s(4.7k)(2.2k)(0.02 \times 10^{-6})}$$

$$= \frac{2.2}{6.9 + 2.068 \times 10^{-4} s}$$

$$= \frac{10\,638.30}{s + 33\,365.57}$$

2. $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

at frequency $= 0$ $\quad X_C = \infty$

3. $H(s) = \dfrac{10\,638.30}{s + 33\,365.57}$

$$|H(j\omega)| = \frac{10\,638.30}{\sqrt{\omega^2 + 33\,365.57^2}}$$

at $f = 0$; $\omega = 0$:

$H(j0) = 0.3188$

4. $X_C = \frac{1}{j\omega C} = \frac{1}{j(2\pi f C)}$

at $f = \infty$; $X_C = 0$

frequency $= \infty$

5. At $f = \infty$; $\omega = \infty$

$H(j\omega) = 0$

6. $\dfrac{V_2}{V_s} = \dfrac{10\,638.30}{s + 33\,365.57}$

$$V_2 = \frac{10\,638.30}{s + 33\,365.57} \cdot V_s$$

- if $V_s = -1.5V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(-1.5) = \frac{-15957.45}{s + 33\,365.57}$

  Gain: $|V_2| = \left|\frac{-15957.45}{0 + 33\,365.57}\right| = 0.478$

- if $V_s = -1.0V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(-1.0) = \frac{-10\,638.30}{s + 33\,365.57}$

  Gain: $|V_2| = \left|\frac{-10\,638.30}{0 + 33\,365.57}\right| = 0.319$

- if $V_s = -0.5V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(-0.5) = \frac{-5319.15}{s + 33\,365.57}$

  Gain: $|V_2| = \left|\frac{-5319.15}{0 + 33\,365.57}\right| = 0.159$

- if $V_s = 0V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(0.0) = 0$

  Gain: $|V_2| = 0$

- if $V_s = 0.5V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(0.5) = \frac{5319.15}{s + 33\,365.57}$

  Gain: $|V_2| = \left|\frac{5319.15}{0 + 33\,365.57}\right| = 0.159$

- if $V_s = 1.0V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(1.0) = \frac{10\,638.30}{s + 33\,365.57}$

  Gain: $|V_2| = \left|\frac{10\,638.30}{0 + 33\,365.57}\right| = 0.319$

- if $V_s = 1.5V$: $V_2 = \frac{10\,638.30}{s + 33\,365.57}(1.5) = \frac{15957.45}{s + 33\,365.57}$

  Gain: $|V_2| = \left|\frac{15957.45}{0 + 33\,365.57}\right| = 0.478$

7. $\tau = RC$

$$= (R_1 // R_2)C$$

$$= \frac{R_1 R_2}{R_1 + R_2} \cdot C = \frac{(4.7k)(2.2k)}{4.7k + 2.2k} \cdot (0.02 \times 10^{-6})$$

$$\tau = 2.9971 \times 10^{-5}\ s$$

$$= 29.97\ \mu s$$

8. $f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi\tau}$

$$= \frac{1}{2\pi(2.9971 \times 10^{-5}\ s)}$$

$$f_c = 5310.30\ Hz$$

9. $$|V_2| = \frac{10\,638.30}{\sqrt{\omega^2 + 33\,365.57^2}}\,V_s \qquad V_s = 1\angle 0 \approx 1\,V$$

$$= \frac{10\,638.30}{\sqrt{(2\pi f)^2 + 33\,365.57^2}}\,(1)$$

At $f = 1\,kHz$: $$V_2 = \frac{10\,638.30}{\sqrt{[2\pi(1k)]^2 + 33\,365.57^2}} = 0.313 \qquad \phi = -\tan^{-1}\left[\frac{2\pi(1k)}{33\,365.57}\right] = -10.66^\circ$$

At $f = 5\,kHz$: $$V_2 = \frac{10\,638.30}{\sqrt{[2\pi(5k)]^2 + 33\,365.57^2}} = 0.232 \qquad \phi = -\tan^{-1}\left[\frac{2\pi(5k)}{33\,365.57}\right] = -43.28^\circ$$

At $f = 10\,kHz$: $$V_2 = \frac{10\,638.30}{\sqrt{[2\pi(10k)]^2 + 33\,365.57^2}} = 0.150 \qquad \phi = -\tan^{-1}\left[\frac{2\pi(10k)}{33\,365.57}\right] = -62.03^\circ$$

At $f = 5310.30\,Hz$: $$V_2 = \frac{10\,638.30}{\sqrt{[2\pi(f)]^2 + 33\,365.57^2}} = 0.225 \qquad \phi = -\tan^{-1}\left[\frac{2\pi(5310.30)}{33\,365.57}\right] = -45^\circ$$

10. $$\frac{V_2}{V_s} = \frac{10\,638.30}{s + 33\,365.57} \qquad V_s = u(t), \quad V_s(s) = 1/s$$

$$V_2 = \frac{10\,638.30}{s(s + 33\,365.57)} = \frac{A}{s} + \frac{B}{(s + 33\,365.57)}$$

$$10\,638.30 = A(s + 33\,365.57) + Bs$$

at $s = 0$: $10\,638.30 = A(33\,365.57) \longrightarrow A = 0.3188$

at $s = -33\,365.57$: $10\,638.30 = B(-33\,365.57) \longrightarrow B = -0.3188$

$$V_2 = \frac{0.3188}{s} - \frac{0.3188}{s + 33\,365.57}$$

$$V_2(t) = 0.3188 - 0.3188\,e^{-33\,365.57t} = 0.3188\,(1 - e^{-33\,365.57t})$$

For 10%: $0.1 = 0.3188\,(1 - e^{-33\,365.57t_1})$

$t_1 = 1.128 \times 10^{-5}\,s$

For 90%: $0.9 = 0.3188\,(1 - e^{-33\,365.57t_2})$

$t_2 = 1.800 \times 10^{-5}\,s$

$$t_r = t_2 - t_1 = 1.800 \times 10^{-5} - 1.128 \times 10^{-5}$$
$$= 6.72 \times 10^{-5}\,s \approx 67.2\,\mu s$$

11. $$\text{Bandwidth} = \frac{0.35}{R\,t_r} = \frac{0.35}{67.2\,\mu s} = 5.21\ kHz$$