Laboratory Five — Transient Response

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Pre-Lab

I

a

$\tau = RC = 1k\Omega \cdot 0.1 \times 10^{-6} = 1 \times 10^{-4} s$

b

$v_0 = 1V$
$v_R(t) = 1 - v_c(t)$
$v_c(t) = v_0(1 - e^{\frac{-t}{\tau}} = 1 - e^{\frac{0.001}{0.0001}} = 1V$

Element	$v_{PPK}(V)$
$v_{C,PPK}$	1
$v_{R,PPK}$	1

Table 1: Data for Pre-Lab 1b

c

We can assume the circuit reaches steady state because there are more than five time constants in that time period.

d

The capacitor must charge, so v_c increases with time. As this occurs, the voltage across the resistor must drop, as $v_0 = v_R + v_c$.

II

a

v_c charges when $v_0 = 1V$ and discharges when $v_0 = 0V$. Since $v_0 = v_R + v_c$, v_R is 1 when v_c is 0 and v_R is 0 when v_c is 1.

b

$v_c(t) = 1 - e^{\frac{0.001}{0.0001}} = 1V$
$v_0 = v_R + v_c$

Element	$v_{PPK}(V)$
$v_{C,PPK}$	1
$v_{R,PPK}$	2

Table 2: Data for Pre-Lab 2b

III

a

$v_c(t) = 1 - e^{\frac{-2.5\times10^{-4}}{0.0001}} = 0.918V$
The time constant has increased by a factor of 2.5, which means the circuit has not reached steady state.

b

$f_{max} = 1000Hz$
The circuit has not reached steady state because five time constants have not passed.

IV

a

$\omega_0 = 422.577$

b

Resistance ($k\Omega$)	**Damping Factor** α (s^{-1})	**Decay Time** $5/\alpha$ (s)	ω_d (rad/s)	f_d (kHz)
0.5	2500	$\frac{1}{500}$	422569	2.37×10^{-6}
1	50000	$\frac{1}{10000}$	419608	2.38×10^{-6}
8.45	422500	$\frac{1}{84500}$	8066	1.24×10^{-4}
25	1250000	$\frac{1}{250000}$	N/A	N/A

Table 3: Data for Pre-Lab 4b

c

$R = \frac{2L}{\sqrt{LC}} = 8451\Omega$

Lab Data

Series RC

Element	**Measured Value**
R_1	985.92Ω
C	$101.5nF$

Table 4: Measured values for circuit elements

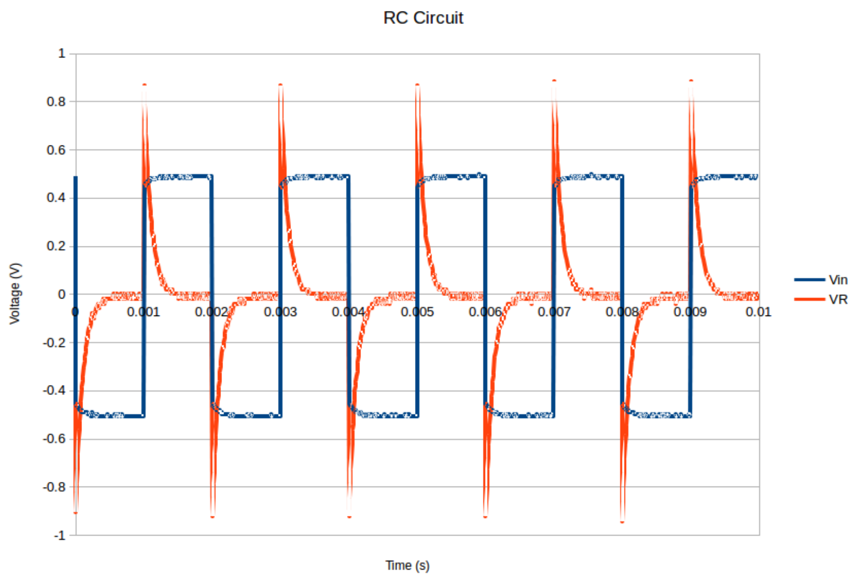

Figure 1: Plot of RC circuit measuring V_R

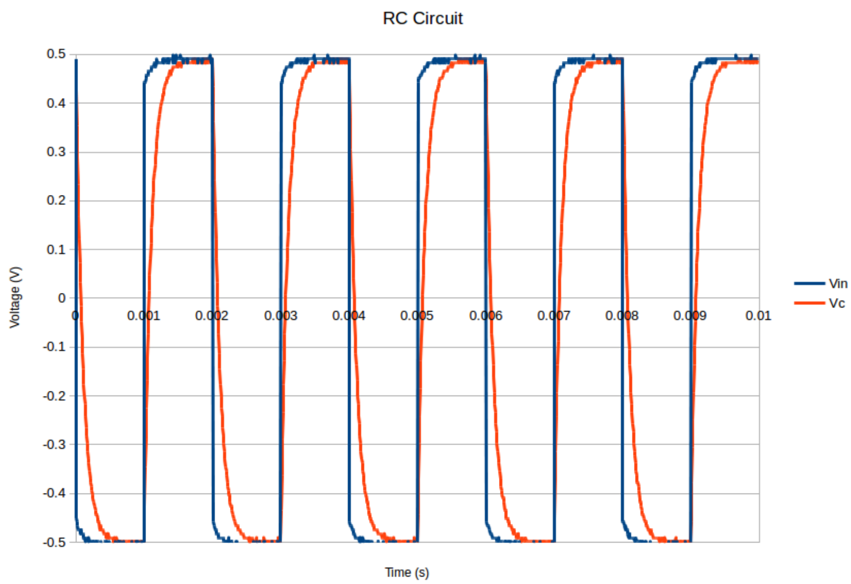

Figure 2: Plot of RC circuit measuring V_c

Nonzero DC Offset

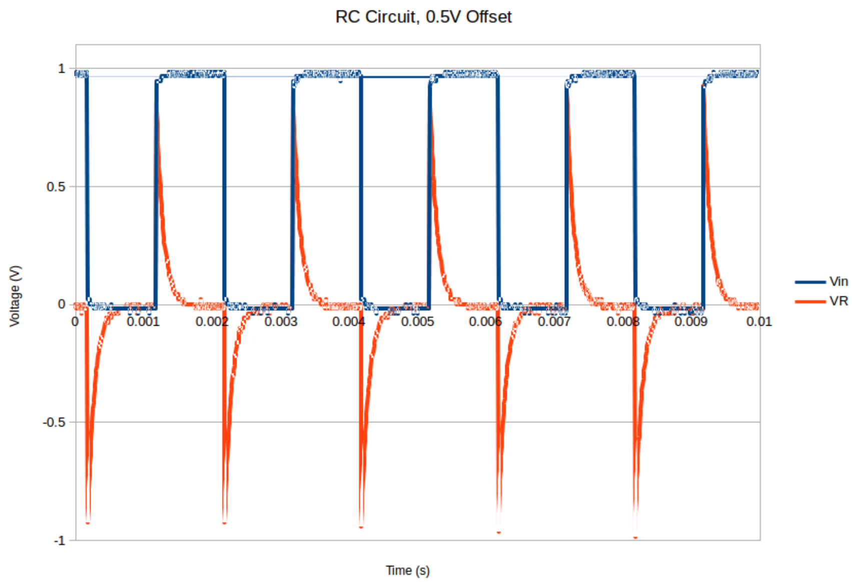

Figure 3: Plot of RC circuit, 0.5V offset measuring V_R

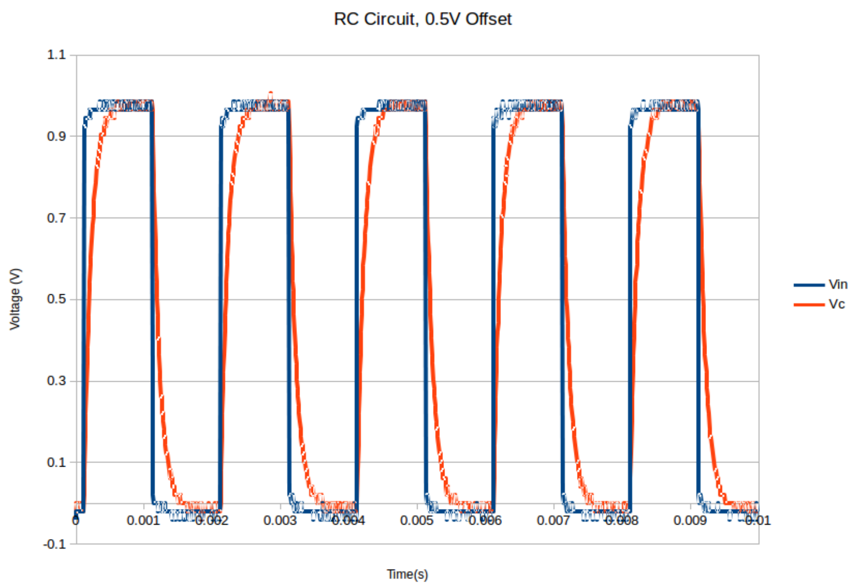

Figure 4: Plot of RC circuit, 0.5V offset measuring V_c

Frequency Response

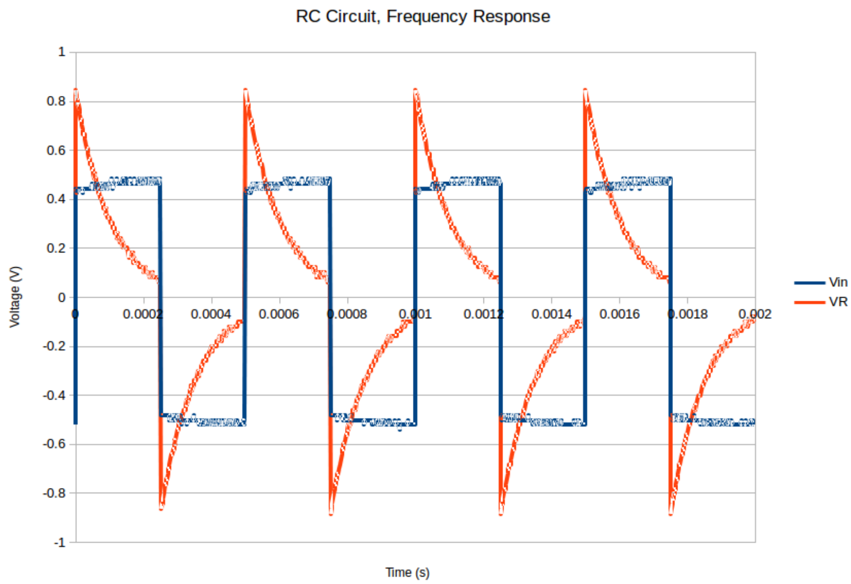

Figure 5: Plot of RC circuit, 2kHz measuring V_R

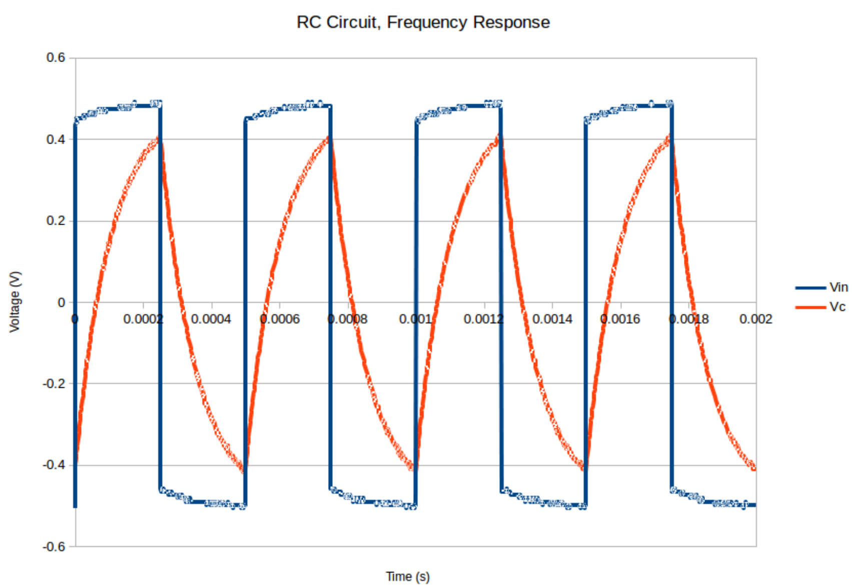

Figure 6: Plot of RC circuit, 2kHz measuring V_c

First Order OP Amp Circuit

Element	Measured Value
R_1	985.92Ω
R_2	981.50Ω
R_3	987.64Ω
C	$101.5nF$

Table 5: Measured values for circuit elements

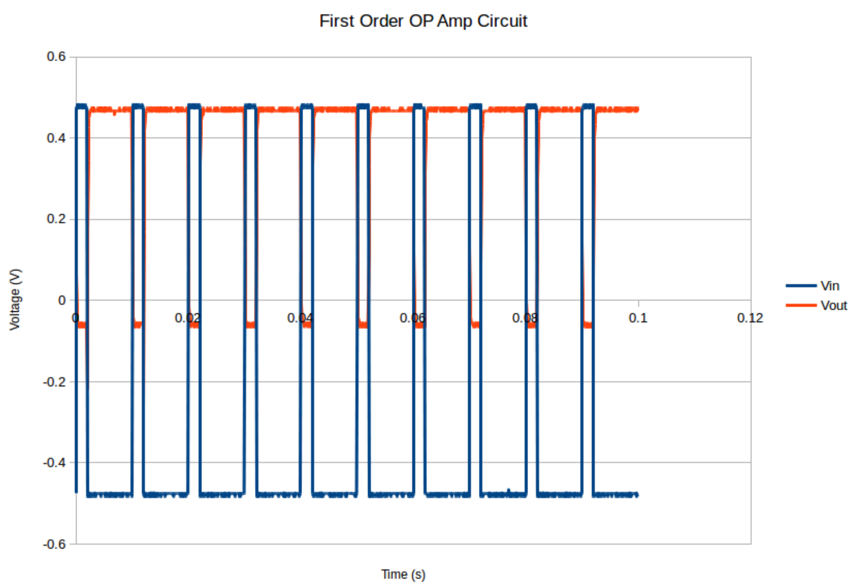

Figure 7: Plot of first order op amp circuit, 20% duty cycle, 100Hz

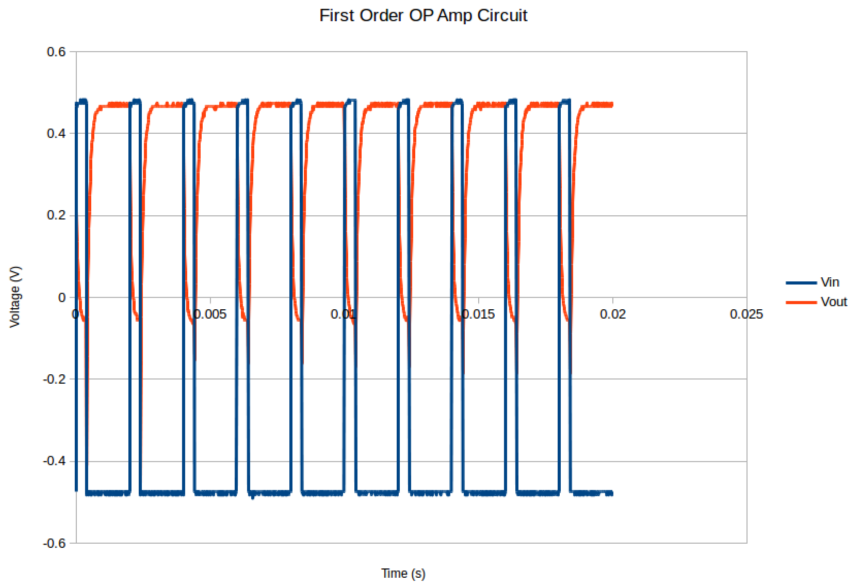

Figure 8: Plot of first order op amp circuit, 20% duty cycle, 500Hz

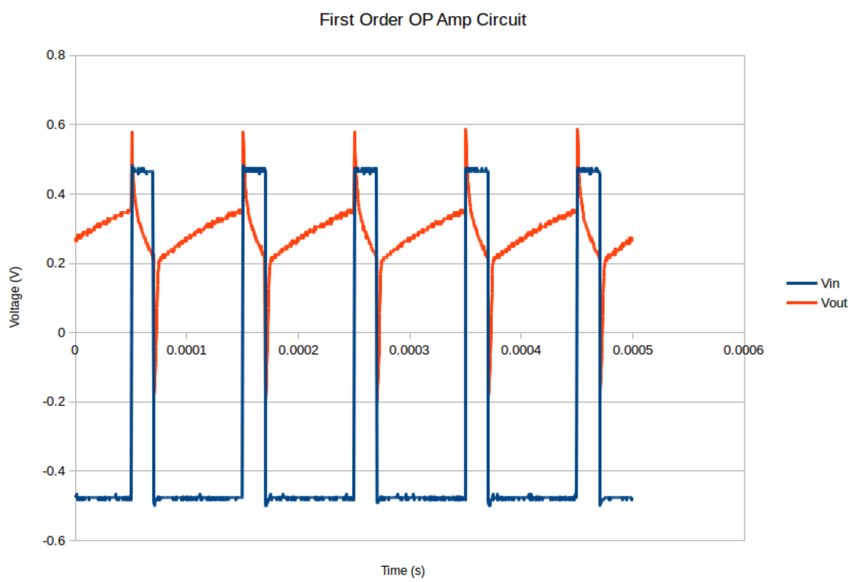

Figure 9: Plot of first order op amp circuit, 20% duty cycle, 10kHz

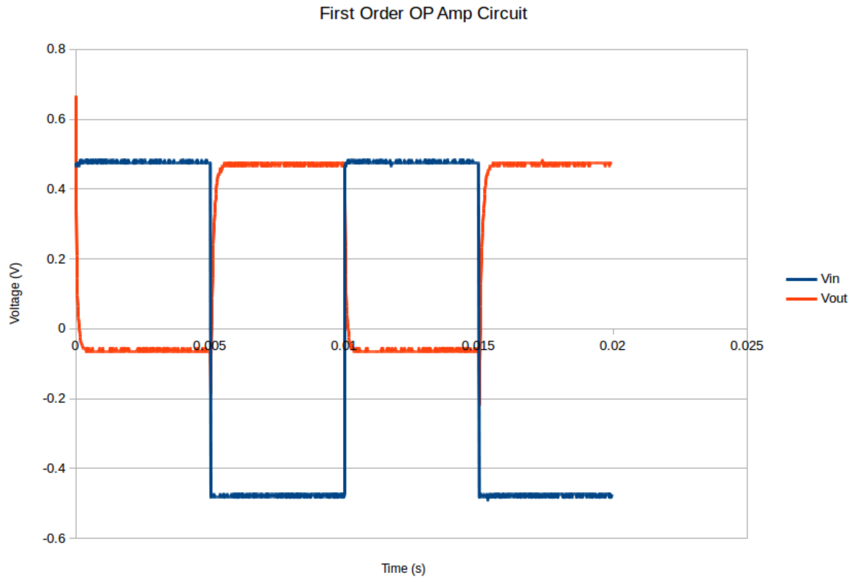

Figure 10: Plot of first order op amp circuit, 50% duty cycle, 100Hz

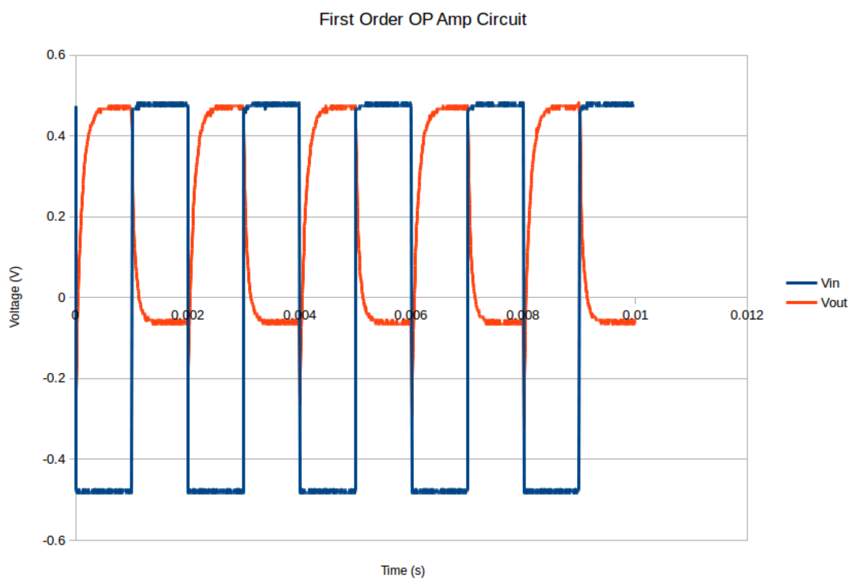

Figure 11: Plot of first order op amp circuit, 50% duty cycle, 500Hz

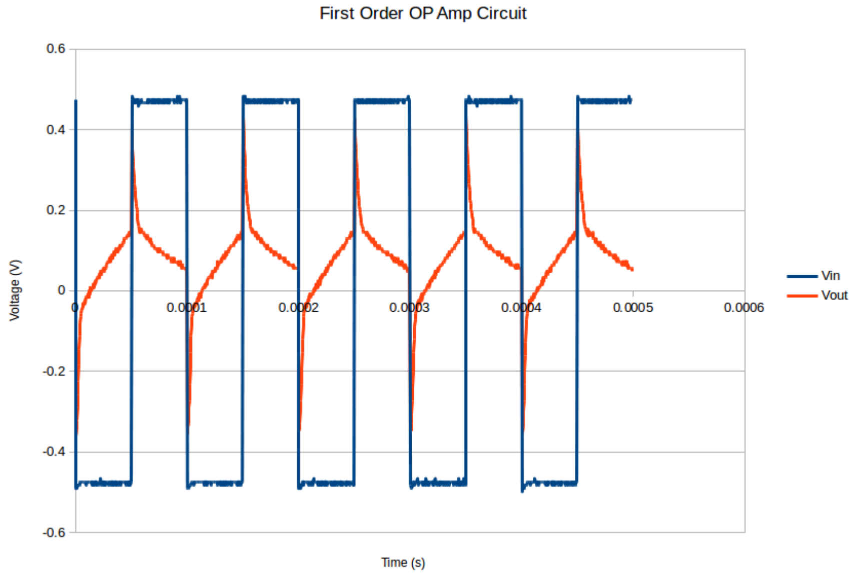

Figure 12: Plot of first order op amp circuit, 50% duty cycle, 10kHz

Series RLC Circuit — Underdamped Response, $R = 1k\Omega$

Element	**Measured Value**
Combined Resistance	990.57Ω
C	$575pF$
T_1	$17\mu s$
L	$10.30mH$
L_R	23.94Ω

Table 6: Measured values for circuit elements

Parameter	**Calculated Value**
$f_{d,1}$	$58823.5294Hz$

Table 7: Calculated $f_{d,1}$

Figure 13: Plot of Series RLC Circuit — Underdamped Response, $R = 1k\Omega$

Series RLC Circuit — Underdamped Response, Minimum Response

Element	**Measured Value**
Combined Resistance	1.186Ω
C	$575pF$
T_1	$17\mu s$
L	$10.30mH$
L_R	23.94Ω

Table 8: Measured values for circuit elements

Parameter	**Calculated Value**
$f_{d,1}$	$58823.5294Hz$

Table 9: Calculated $f_{d,1}$

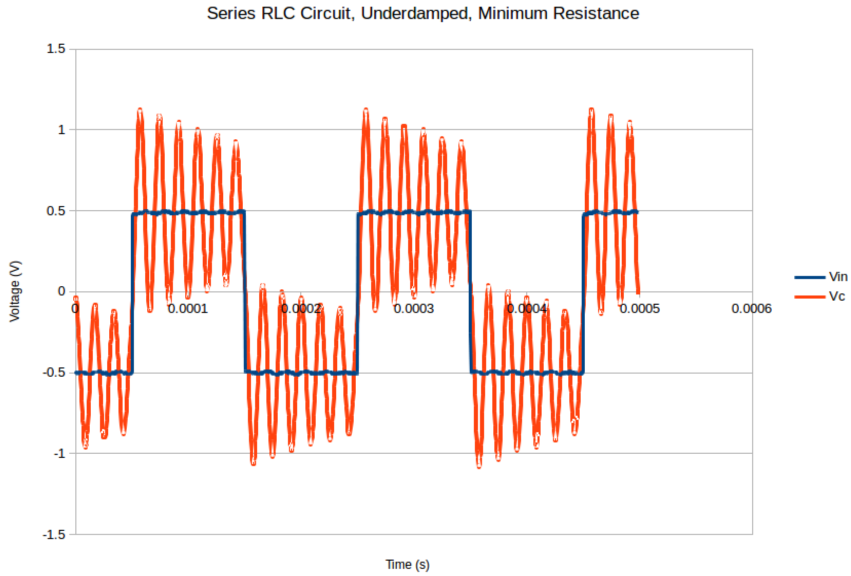

Figure 14: Plot of Series RLC Circuit — Underdamped Response, Minimum Response

Series RLC Circuit — Critically Damped Response

Element	Measured Value
Combined Resistance	$4.6208k\Omega$
C	$575pF$
L	$10.30mH$
L_R	23.94Ω

Table 10: Measured values for circuit elements

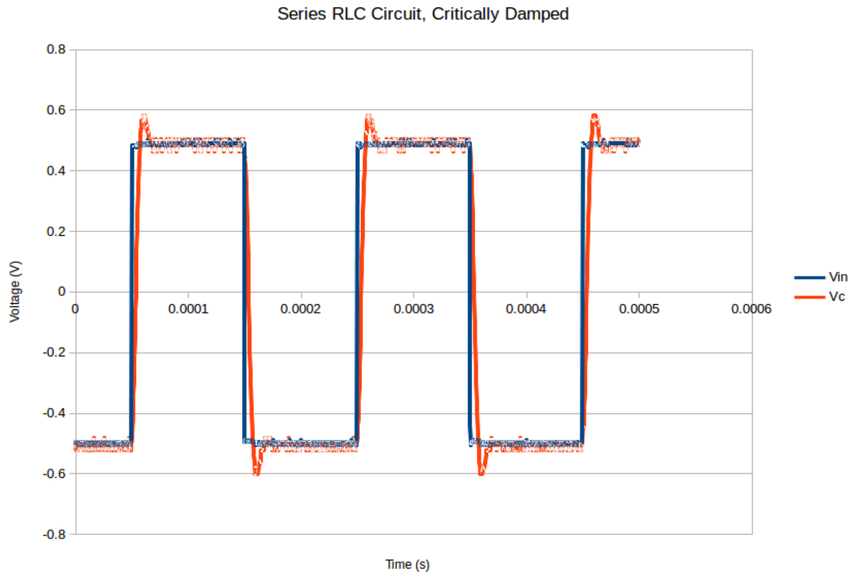

Figure 15: Plot of Series RLC Circuit — Critically Damped Response

Series RLC Circuit — Overdamped Response

Element	**Measured Value**
Combined Resistance	$0.12726 M\Omega$
C	$575 pF$
L	$10.30 mH$
L_R	23.94Ω

Table 11: Measured values for circuit elements

Figure 16: Plot of Series RLC Circuit — Overdamped Response

Post-Lab

Series RC Circuit

Zero DC Offset

$V_{C,PPK,Calculated} = 0.99995V$
$V_{C,PPK,Measured} = 0.99698V$
$PercentageError = \frac{|measured-calculated|}{calculated} = \frac{|0.99698-0.99995|}{0.99995} = 0.297\%$
These values are very close.

Nonzero DC Offset

$V_{C,PPK,Measured,ZeroOffset} = 0.99698V$
$V_{C,PPK,Measured,NonZeroOffset} = 1.04523V$
$V_{C,PPK,Measured,ZeroOffset} = 1.82915V$
$V_{R,PPK,Measured,NonZeroOffset} = 1.90955V$
The waveforms shapes are the same, except the values are shifted by 0.5V.

Frequency Response

$V_{C,PPK,Calculated} = 0.91777$
$V_{C,PPK,Measured} = 0.82814$
$PercentageError = \frac{|measured-calculated|}{calculated} = \frac{|0.82814-0.91777|}{0.91777} = 9.766\%$
These values are similar, but differ due to experimental errors.

First Order Op Amp Circuit

Dont know

Series RLC Circuit

$R = 1k\Omega$

$f_{calculated,ideal} = 50000Hz$
$f_{calculated,real} = 49705.8252Hz$
$f_{measured} = 58823.5294Hz$
$PercentageError_{ideal} = \frac{|measured - calculated|}{calculated} = \frac{|58823.5294 - 50000|}{50000} = 17.65\%$
$PercentageError_{real} = \frac{|measured - calculated|}{calculated} = \frac{|58823.5294 - 49705.8252|}{49705.8252} = 18.34\%$
$T_{calculated,ideal} = 20\mu s$
$T_{calculated,real} = 20.1184\mu s$
$T_{measured} = 17\mu s$
$PercentageError_{ideal} = \frac{|measured - calculated|}{calculated} = \frac{|17 - 20|}{20} = 15\%$
$PercentageError_{real} = \frac{|measured - calculated|}{calculated} = \frac{|17 - 20.1184|}{20.1184} = 15.50\%$
The difference between ω_d and ω_0 is dont know

Critically Damped Response

Dont know

Maximally Damped Response

The circuit does reach a new DC steady state during each half period of the square wave.