Analog Lab (EE2401)
Experiment 8: Signal strength detector

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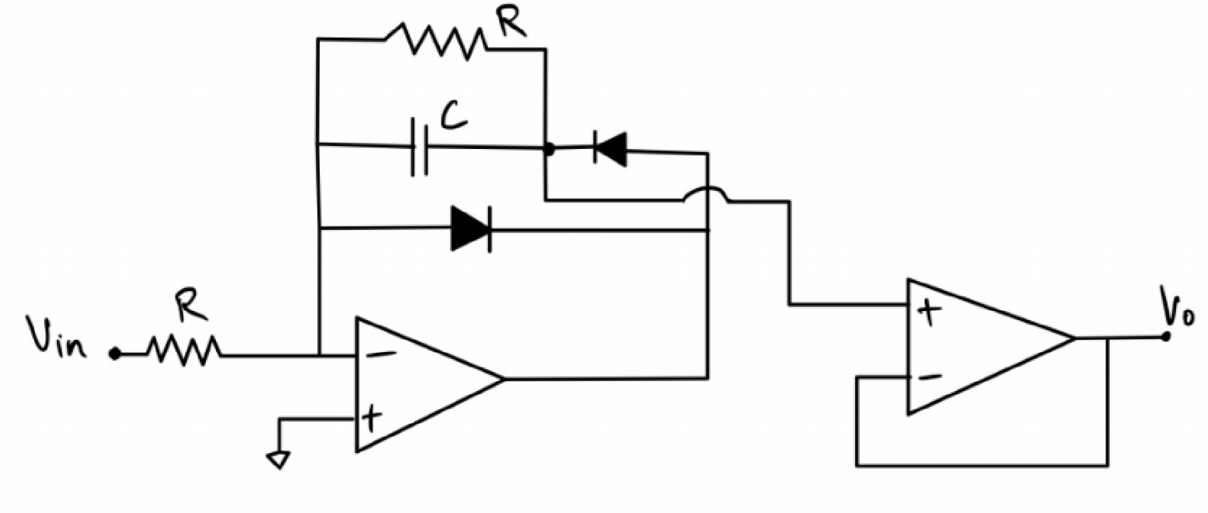
1 Aim

our aim here is to design a circuit that can detect strength of a signal using op-amp and diodes.

2 Problem statement

1. Find the frequency components (till third harmonic) of a half-wave rectified sinusoidal signal.

2. The following circuit implements a half-wave rectifier with first-order filter to give an output corresponding to the input signal strength (rms).



. • Input frequency: 0.1 kHz -5 kHz

. • Choose RC to reject the lowest input frequency

. • LF347 opamp with +5V/-5V dual supply

. • Diode 1N4148

Plot input amplitude vs average Vo for 0.1 kHz, 2.5 kHz and 5 kHz. Vary input am plitude from 0 to 5 V. Also submit a transient plot at 2.5 V amplitude for 0.1 kHz and 5 kHz.

Submit the following:

- Testbench snapshot, output plots
- Hand calculation
- Any unusual observation along-with comments

The Fourier series of a periodic function f(x) of period T is

$$f(x) = \frac{a_0}{2} + \sum_{k=1}^{\infty} a_k cos\frac{2\pi kx}{T} + \sum_{k=1}^{\infty} b_k sin\frac{2\pi kx}{T}$$

$$a_k = \frac{2}{T}\int_0^T f(x)cos\frac{2\pi kx}{T}\,dx$$

$$b_k = \frac{2}{T}\int_0^T f(x)sin\frac{2\pi kx}{T}\,dx$$

- Now we will use this equation to find frequency components(until third harmonic) for half-wave rectified sinusoidal signal.

$$a_0 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}\,dx = \frac{cos(0) - cos(\pi)}{\pi} = \frac{2}{\pi}, \quad a_1 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}cos\frac{2\pi kx}{T}\,dx = 0$$

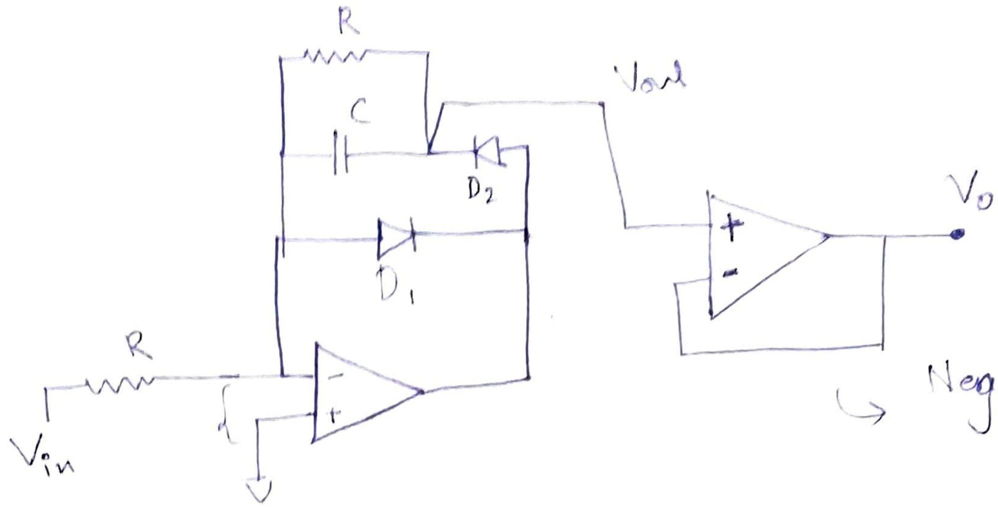
$$a_2 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}cos\frac{4\pi kx}{T}\,dx = \frac{-2}{3\pi}, \quad a_3 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}cos\frac{6\pi kx}{T}\,dx = 0$$

$$b_1 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}sin\frac{2\pi kx}{T}\,dx = \frac{1}{2}$$

$$b_2 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}sin\frac{4\pi kx}{T}\,dx = 0$$

$$b_3 = \frac{2}{T}\int_0^{T/2} sin\frac{2\pi kx}{T}sin\frac{6\pi kx}{T}\,dx = 0$$

$$f(x) = \frac{1}{\pi} + \frac{-2}{3\pi}cos\frac{4\pi x}{T} + \frac{1}{2}sin\frac{2\pi x}{T} + ...$$



↳ Negative feedback

when $V_{in} > 0$.

then D_1 is forward biased.

$$\Rightarrow V_{out} = 0$$

when $V_{in} < 0$

D_1 is reversed biased and D_2 is forward biased

and is in negative feedback.

Due to virtual short.

$$\frac{V_{in} - 0}{R} = \frac{0 - V_{out}}{\frac{R}{1 + sRC}}$$

$$\Rightarrow V_{out} = \frac{-V_{in}}{1 + sRC}.$$

Therefore it essentially acts like a lowpass with $f_0 = \frac{1}{2\pi RC}$.

Here input range is 0.1 - 5KHZ.

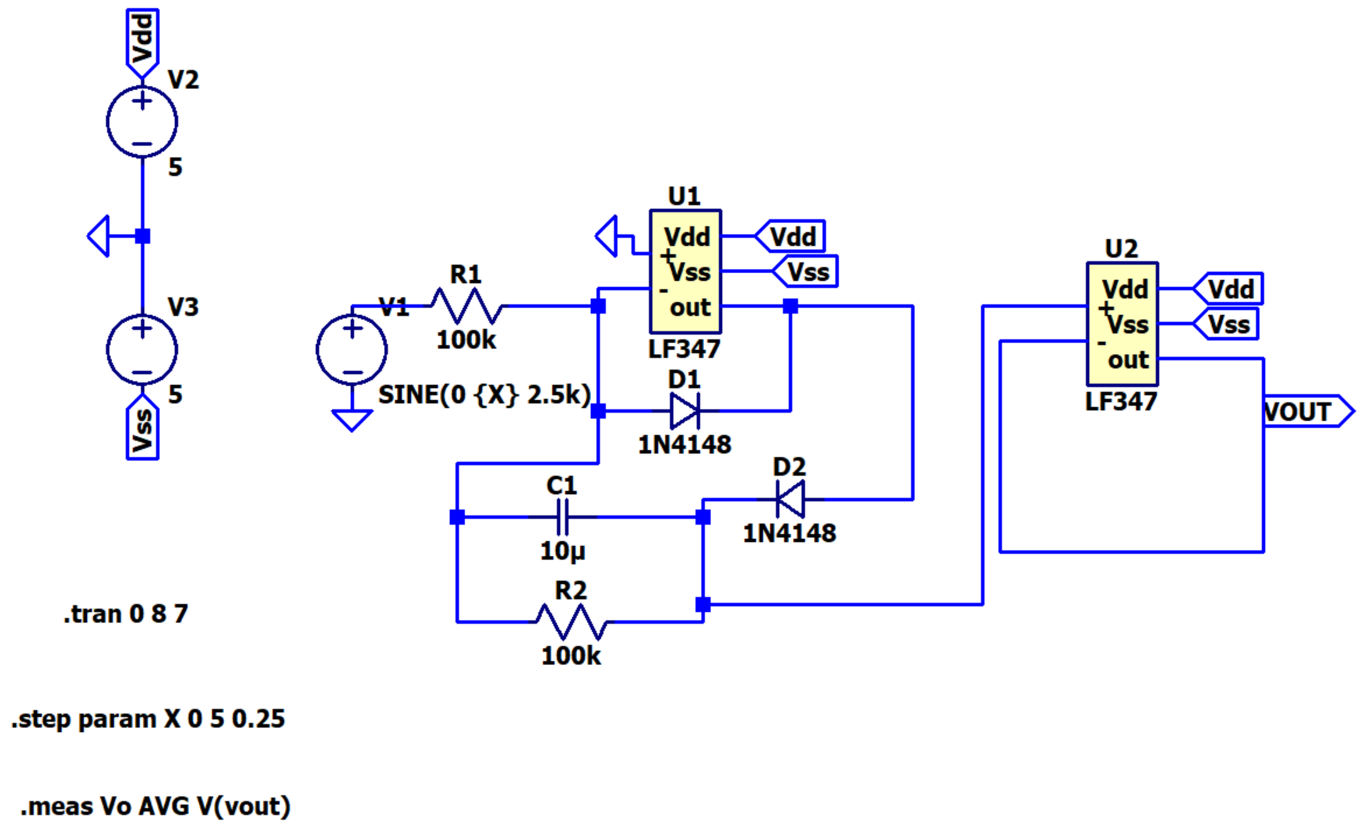
$\Rightarrow \frac{1}{2\pi RC} < 0.1\,KHz$ to have any dC component of input. i.e. $\frac{1}{\pi}$ of component

Now the capacitor will get charged and as a result In steady state the output itself will be maintained at $\frac{1}{\pi}$.

and since when $V_{in} > 0$, there is no current through capacitor So, $\frac{1}{\pi}$ will be maintained.

op-amp 2 is just a negative feedback with output same as input.

Schematic of signal strength detector



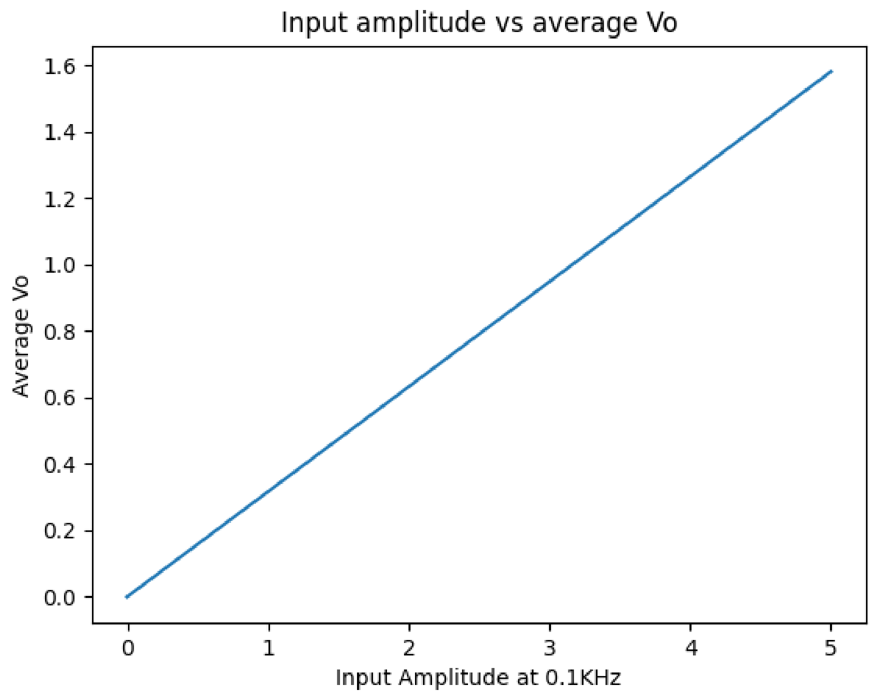
circuit schematic

.tran 0 8 7

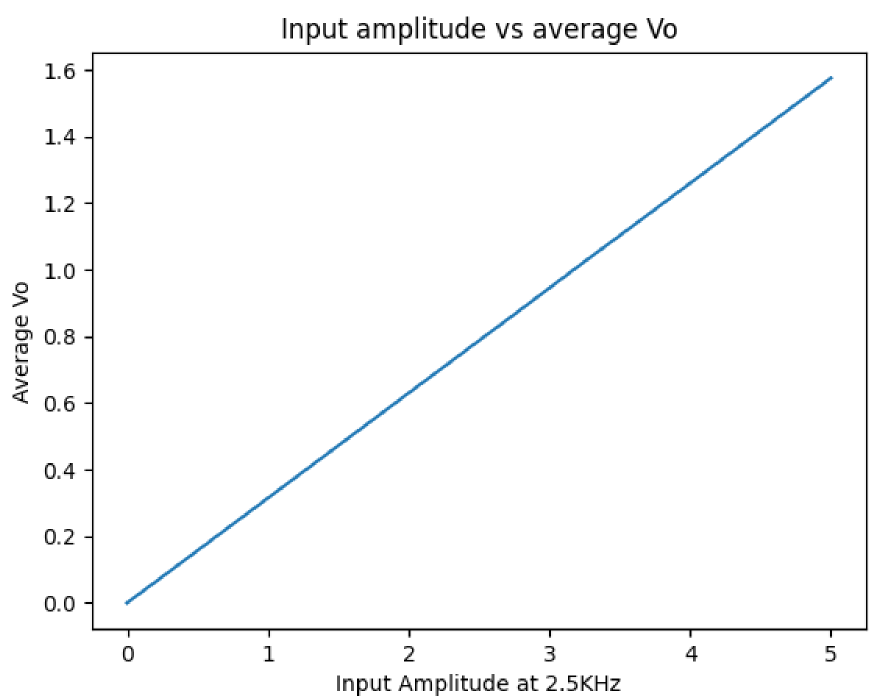
.step param X 0 5 0.25

.meas Vo AVG V(vout)

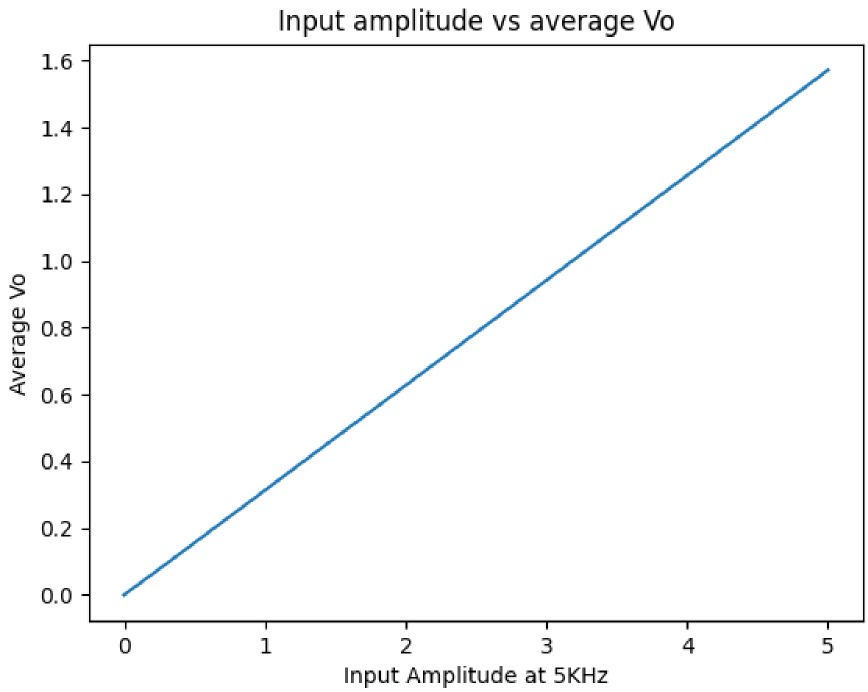
Input amplitude vs average Vo



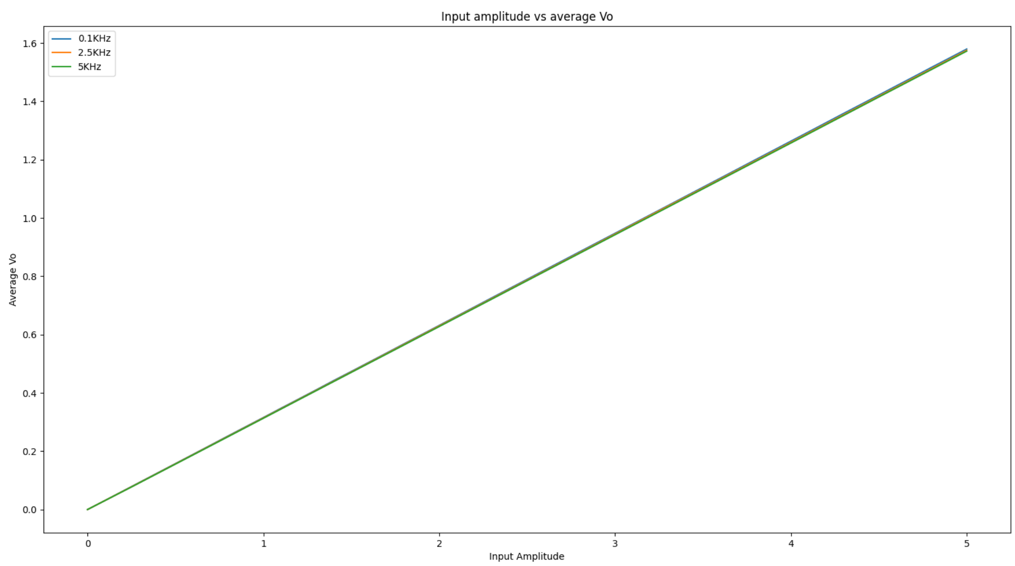
Input amplitude vs average Vo at 0.1KHz



Input amplitude vs average Vo at 2.5KHz



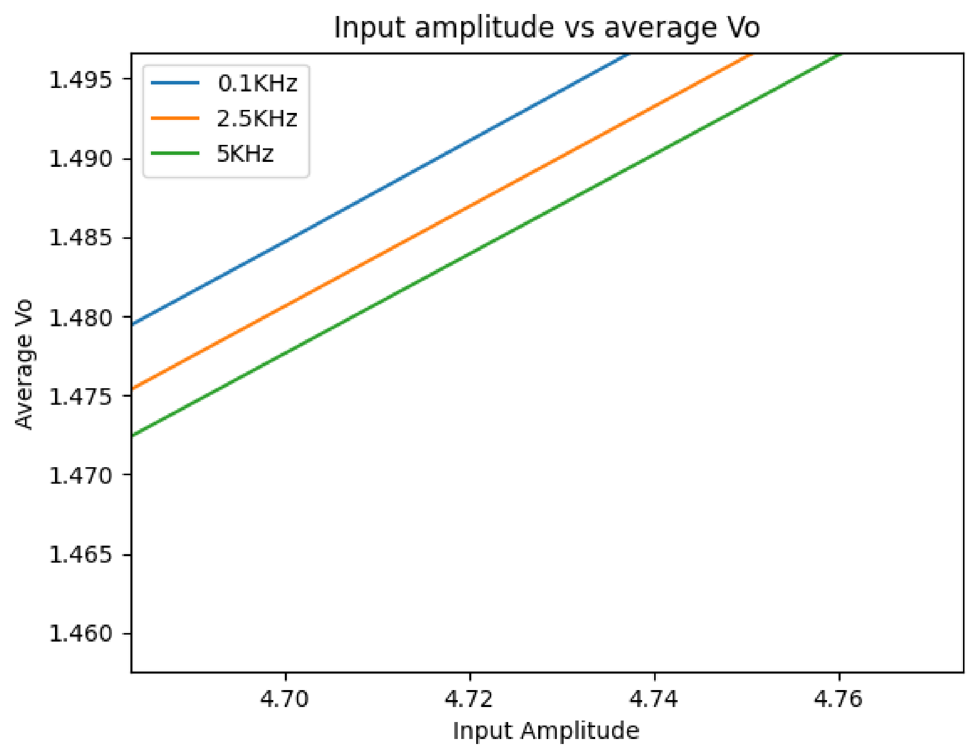
Input amplitude vs average Vo at 5KHz

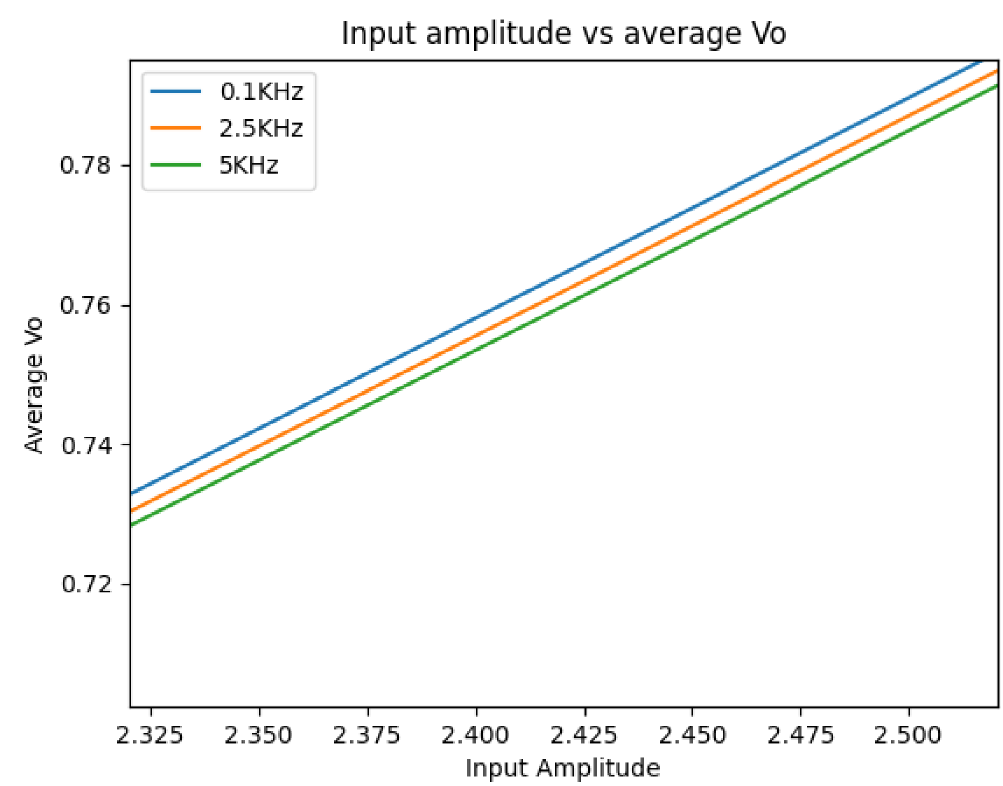


Input amplitude vs average Vo at 0.1KHz,2.5KHz,5KHz

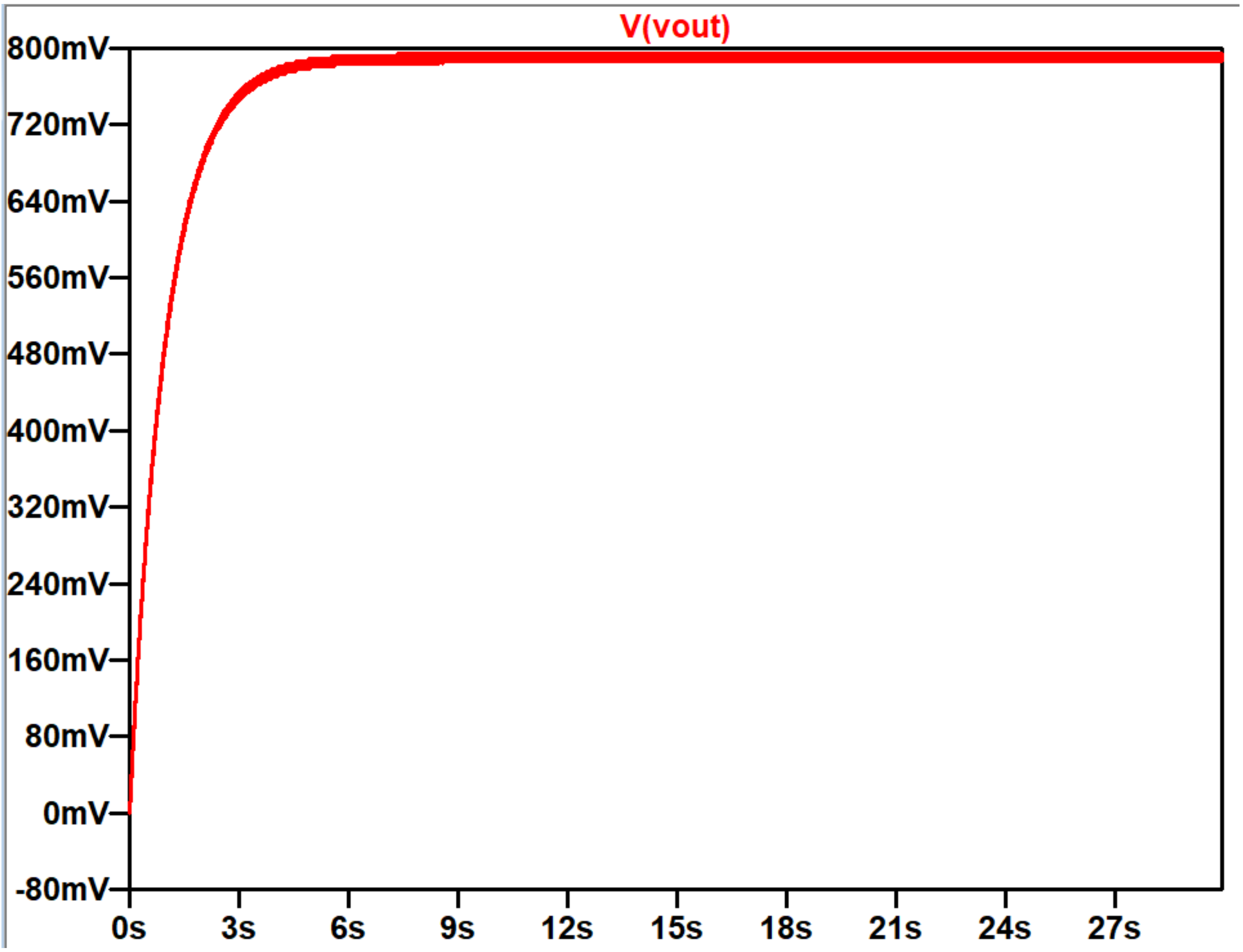
- As we can see that the average Vo is approximately $\frac{A}{\pi}$ where A is the input amplitude as expected.

Input amplitude vs average Vo at closely





Output time domain at 0.1KHz



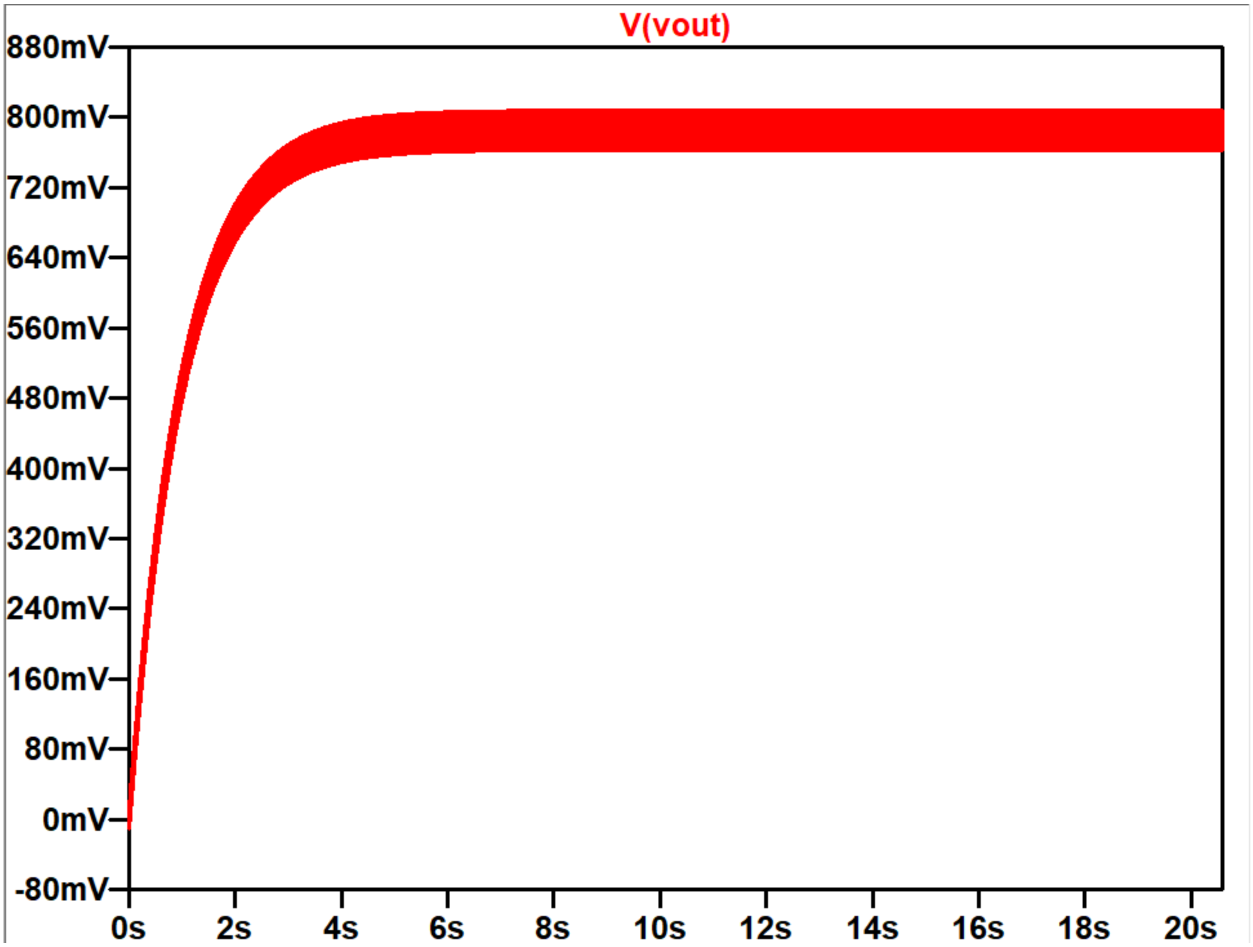
Output

- The input is sinusoid with 0.1KHz and Amplitude 2.5V.

- The output her increases until some transient period and the achieves steady state around 800mV.

- The average output matches with the expected value i.e. $\frac{2.5}{\pi}$.

Output time domain at 5KHz



Output

- The output at 5KHz is similar to the one at 0.1KHz as expected but around 780mV.


thank you