ANALOG CIRCUIT LAB PROJECT (EE254)

Group - 14

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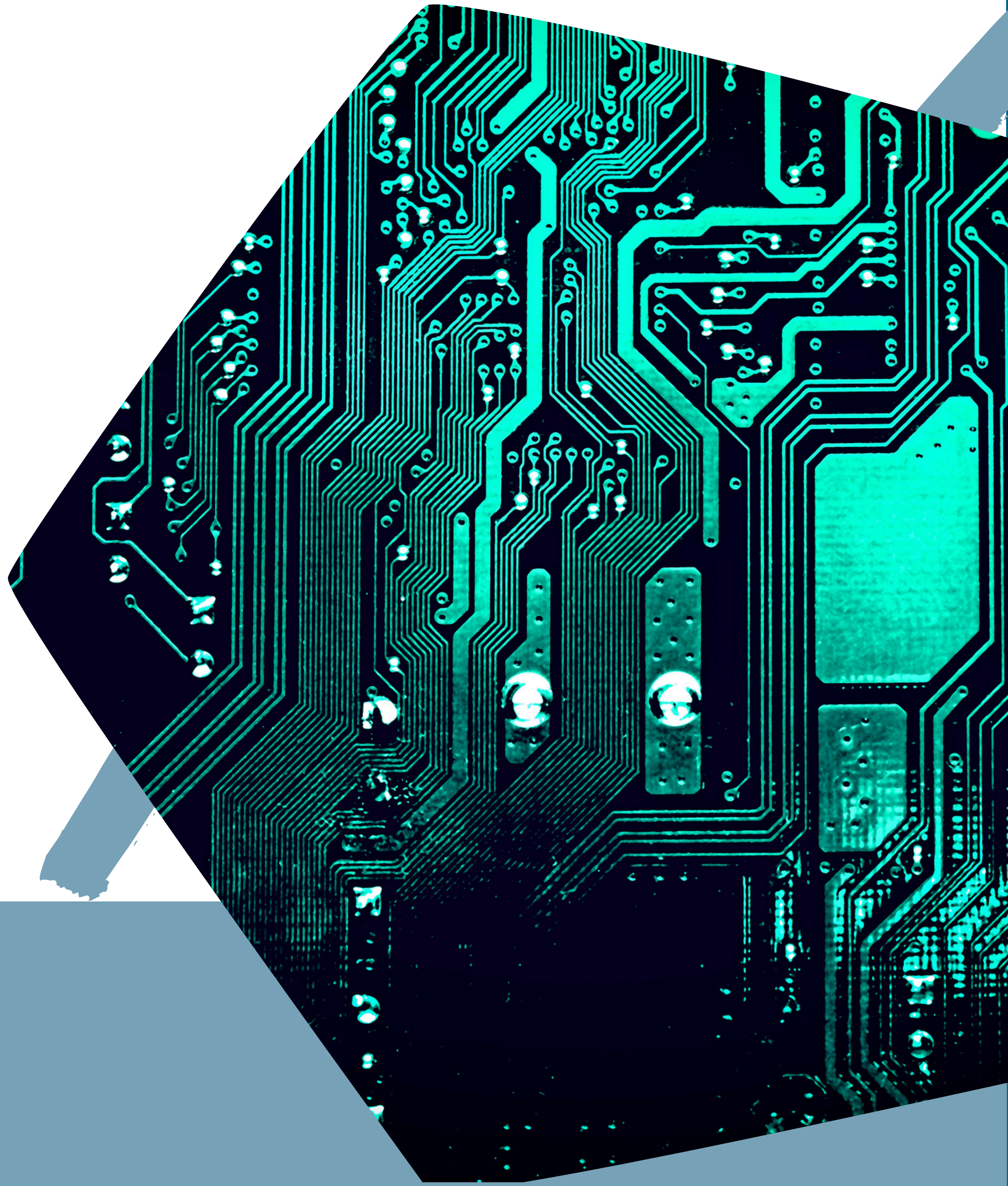
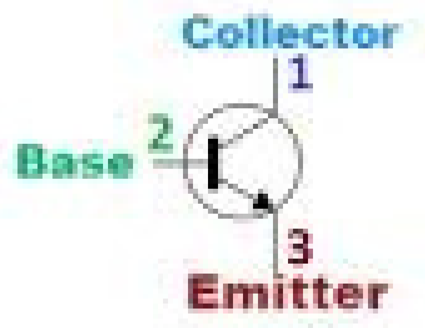


April 29, 2025 @ 4:15 P.M.

Design a colpitts oscillator to generate 22 MHz using BJT amplifier configuration.

Components used:

- Transistor 2N2222 (NPN BJT)
- Resistors 1 kΩ, 1.5 kΩ, 10 kΩ, 5kΩ, 2.2kΩ
- Inductor 1 μH
- Capacitors 100 nF, 100pF



**due to unavailability of 8.2kΩ 5kΩ+2.2kΩ+1kΩ used*

Introduction to Colpitts' Oscillator

Colpitt Oscillator is a type of LC Oscillator circuit that generates high frequency sinusoidal signals . The oscillator uses a combination of inductors and two capacitors to determine its oscillation frequency with capacitive voltage divider forming key part of feedback network . This design makes the Colpitts' Oscillator easily tunable and has good frequency stability . This circuit is used in radio frequency applications and signal generation circuits .

Working Principle

When powering the transistor , it amplifies a small voltage from the capacitor divider circuit , which is then fed back into LC tank circuit . The energy exchange between the inductor and capacitors creates ,continuous oscillations at a frequency determined by component values .

The phase shift provided by BJT amplifier circuit is 180 degrees however , the LC tank circuit also ensures that phase shift provided is 180 degrees so that there is no resultant phase shift of the output signal , satisfying the Barkhausen criterion for oscillations

Calculations

Frequency for Colpitts' Oscillator $= 1/2\pi\sqrt{(L*C_{eq})}$.

where , $C_{eq} = C1*C2 / (C1+C2)$

Gain of LC tank circuit = $-(C2/C1)$.

For 22MHz frequency , we choose C1=C2=100pF and L=1.03uH

we choose standard value for inductor i.e. L= 1uH .

Now , we can expect the frequency to be around 22.5MHz considering the new standard values used for components . While the gain of the LC tank circuit is -1 as , both capacitor values taken are equal .

Calculations

Since , the magnitude of LC tank gain is 1 , we would expect the magnitude of gain of amplifier to be slightly greater than 1 to start the oscillations .

*There are few points we need to remember while designing an amplifier using common emitter BJT configuration *

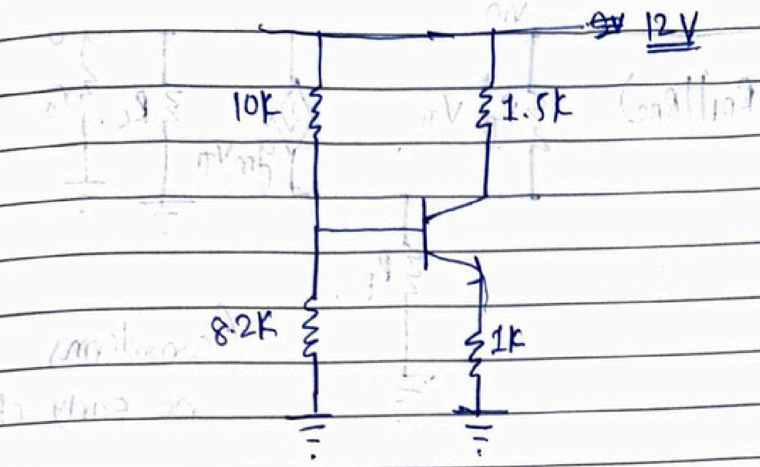
1. The BJT must be in the active region so as to to ensure amplification of the signal is to be taking place . For BJT to be in active region , Junction BE should be forward biased while Junction BC should be reversed biased

2. The gain of BJT based amplifier should be slightly greater than 1 .

Considering these points , we have made calculations for the amplifier to amplify the signals with gain just above 1 . (these are theoretical approximations results may vary a bit practically due to effects like early effect, parasitics , etc .

Calculations for Amplifier Gain and corresponding desirable components

DC Analysis:



$V_B = \frac{8.2}{18.2} \times 12\,V = 5.406\,V.$

$V_{BE} = 0.7V \Rightarrow V_B - V_E = 0.7V$

$\therefore V_E = V_B - 0.7 = 4.706\,V$

$\therefore I_E = 4.706\,mA.$

$I_c = \frac{\beta}{\beta+1} \cdot I_E$

$\therefore I_c = \frac{75}{76} \cdot (4.706) = \cancel{4.66}\ 4.644\,mA$

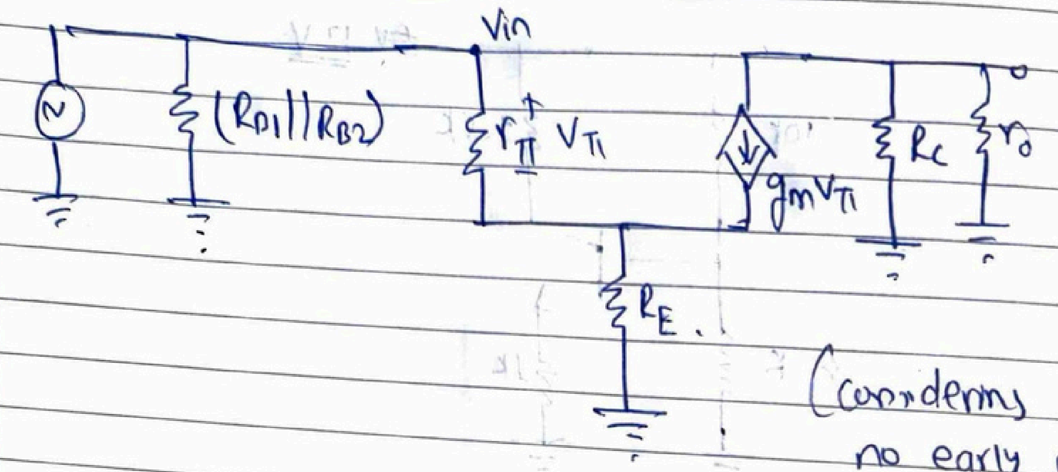
$\therefore V_c = 12 - (4.644m)(1.5k) = 5.034\,V$

$\therefore \boxed{V_{BC} = 0.373V} < 0.4 \Rightarrow$ rev. biased BC.

$\Downarrow$

active region.

Small Signal Analysis:



(considers no early effect)

$i_c(t) = g_m \cdot V_\pi$

$g_m = \frac{I_C}{V_T} = 0.18576\ A/V$

$r_\pi = \frac{\beta}{g_m} = \frac{75}{0.18576} = 403.746$

$A_V = \frac{V_o}{V_{in}} = \frac{-g_m \cdot R_C}{1 + \frac{R_E}{r_\pi} + g_m \cdot R_E}$ $(r_o \to \infty)$

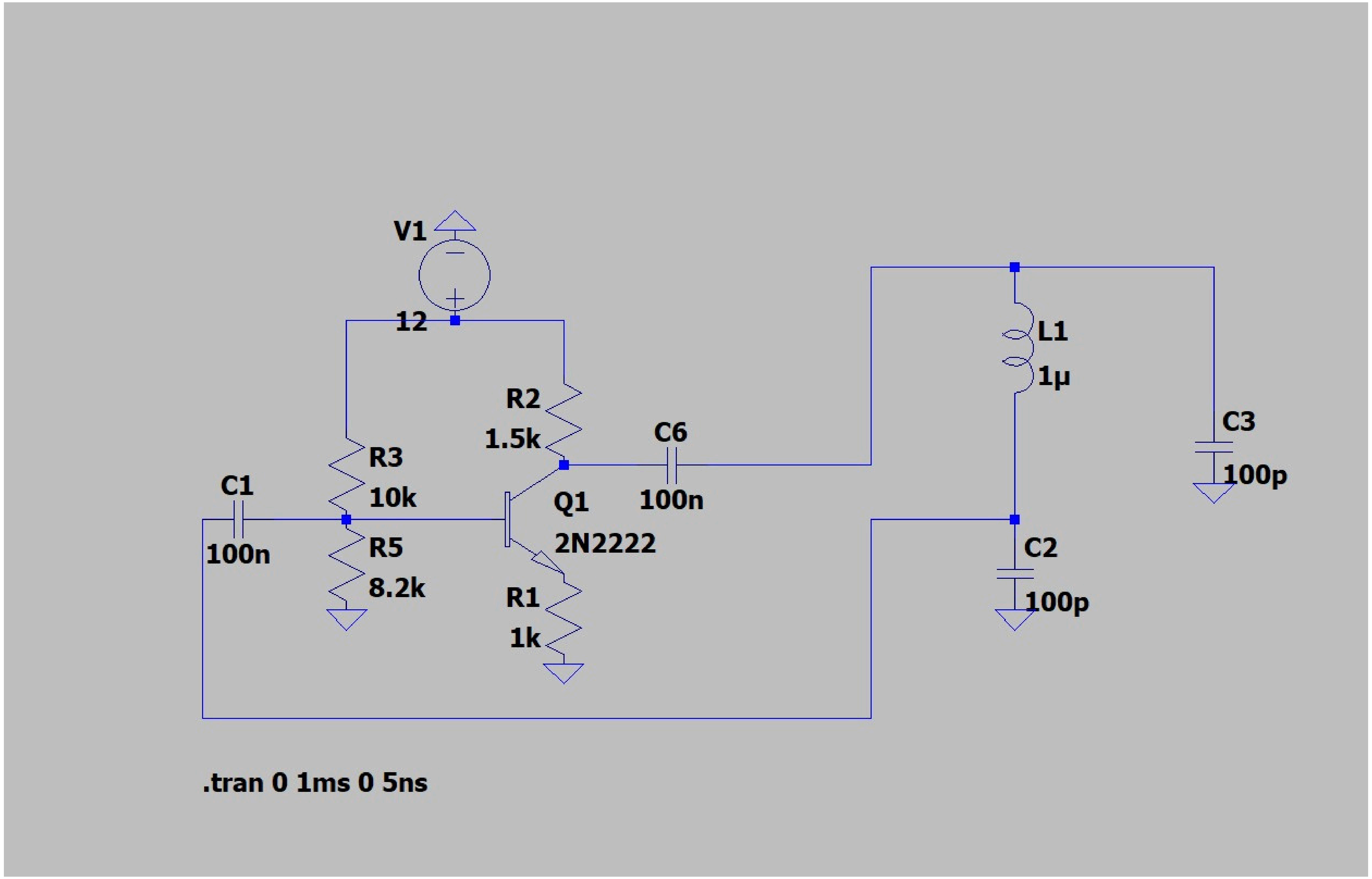
$= \frac{-(0.18576)(1.5k)}{1 + 2.477 + 187.56}$

$= \frac{278.64}{191.037}$

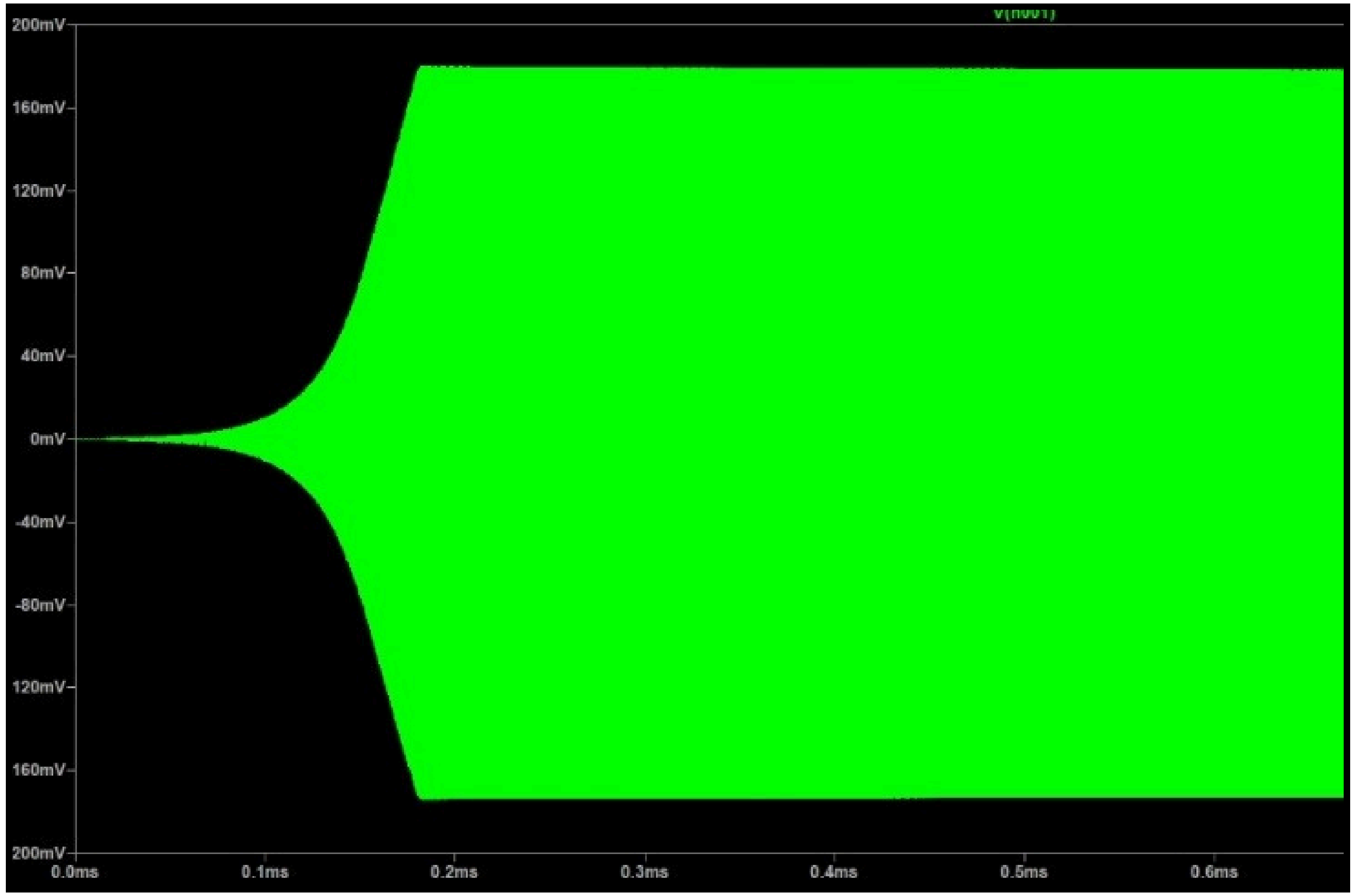
$\boxed{A_V = 1.46}$

However the gain will be less due to factors like early effect, voltage drops, etc.

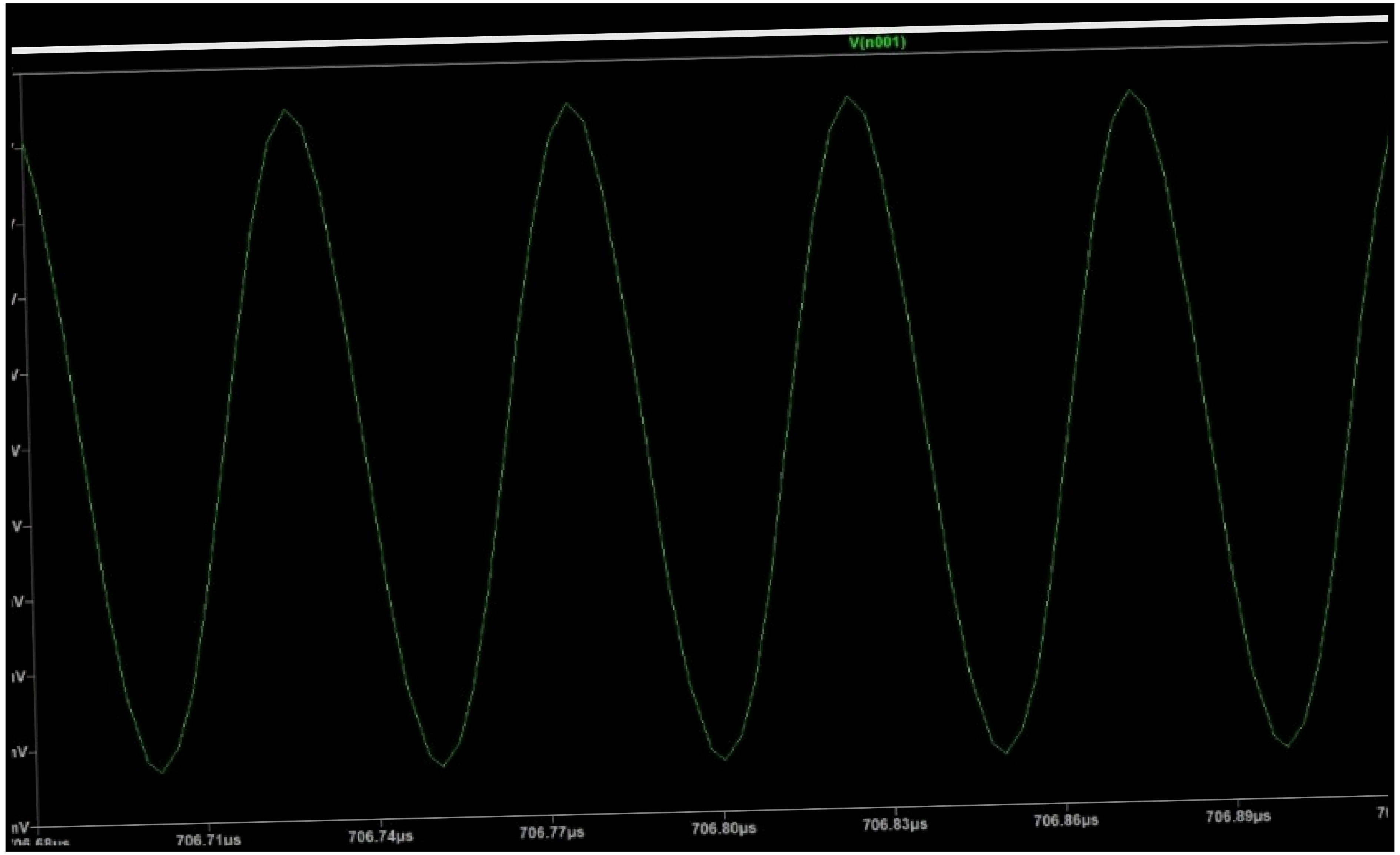
Simulation (LT Spice)



Simulation (LT Spice)

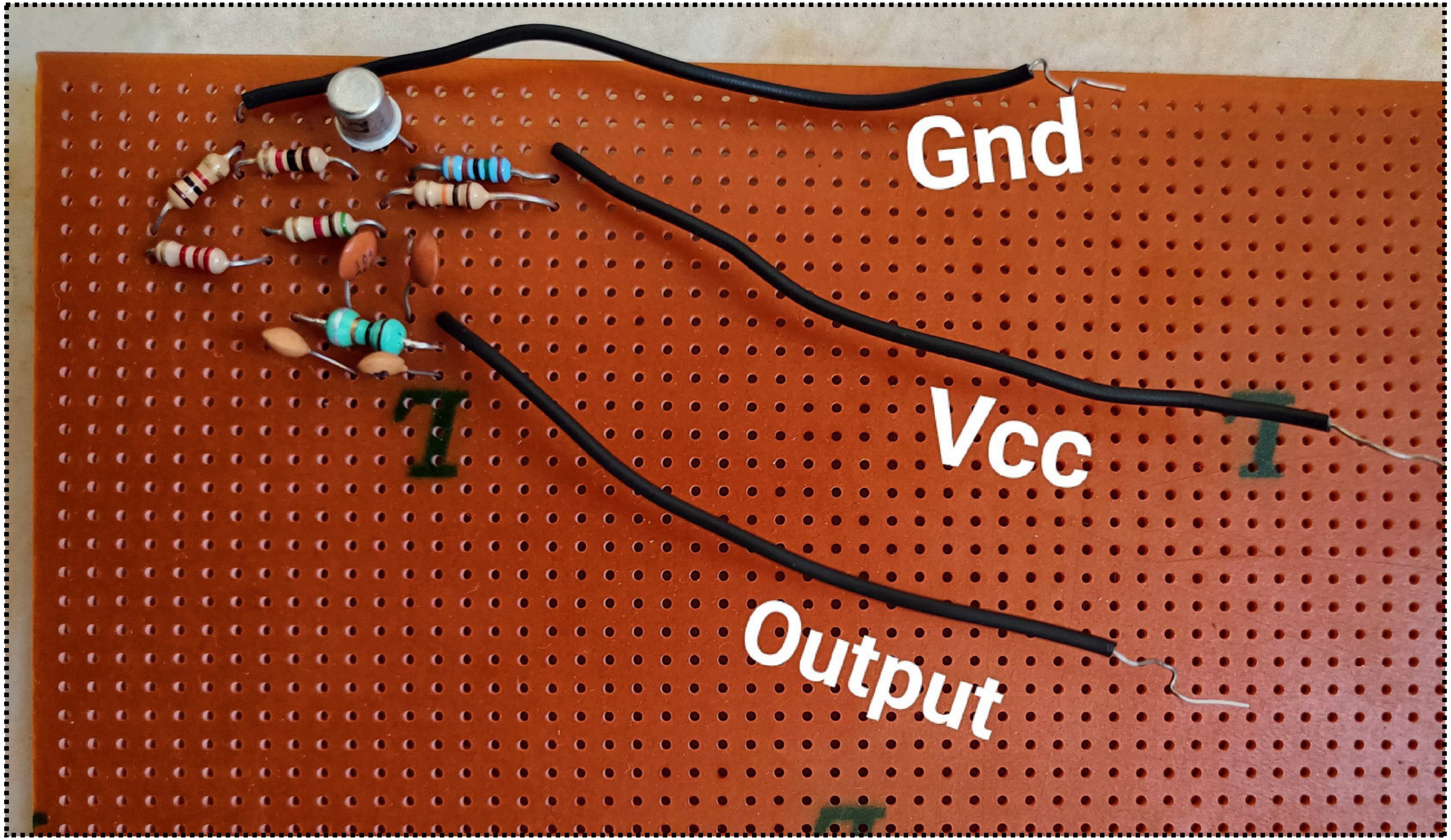


Transient State

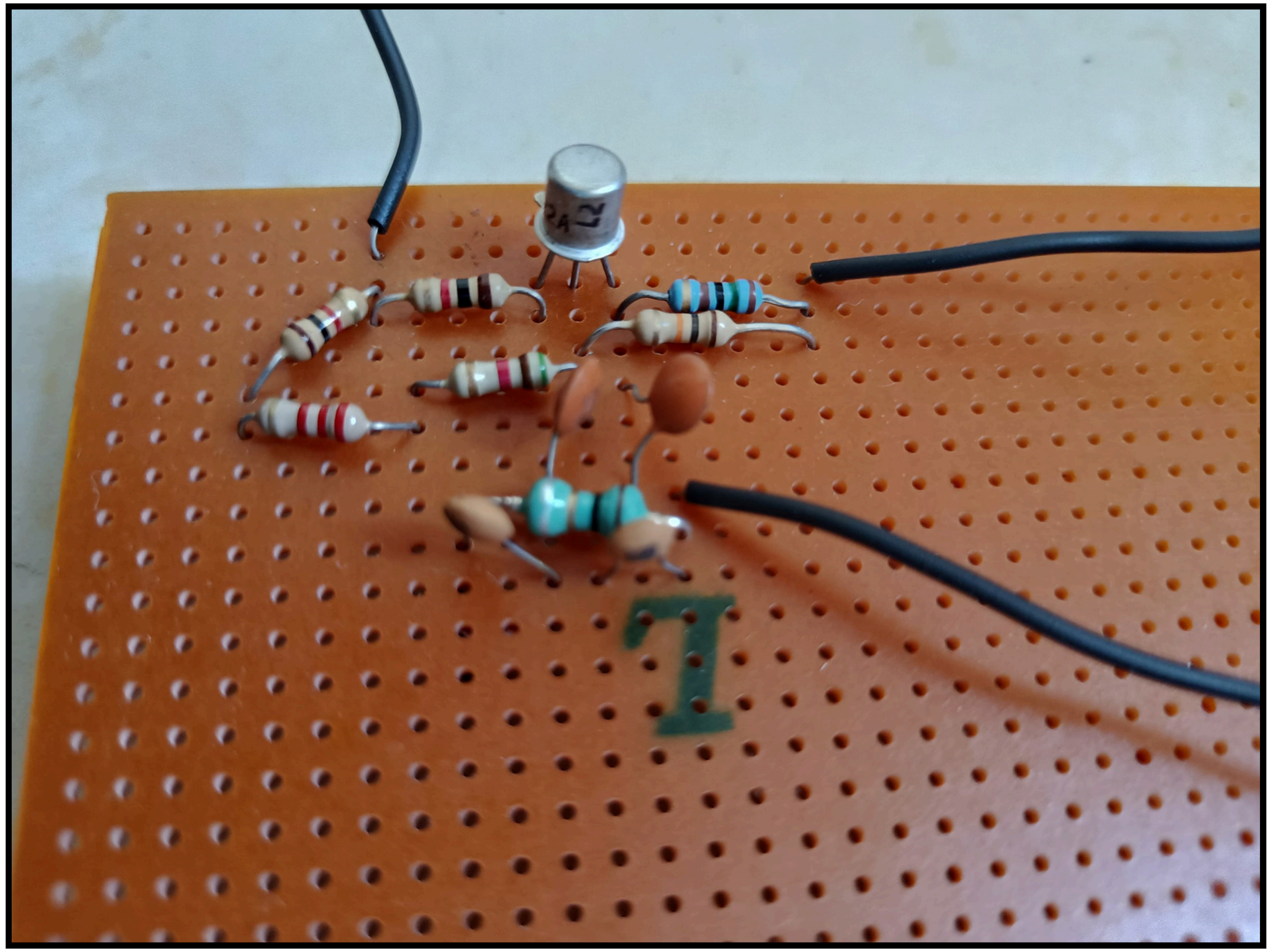


Steady State

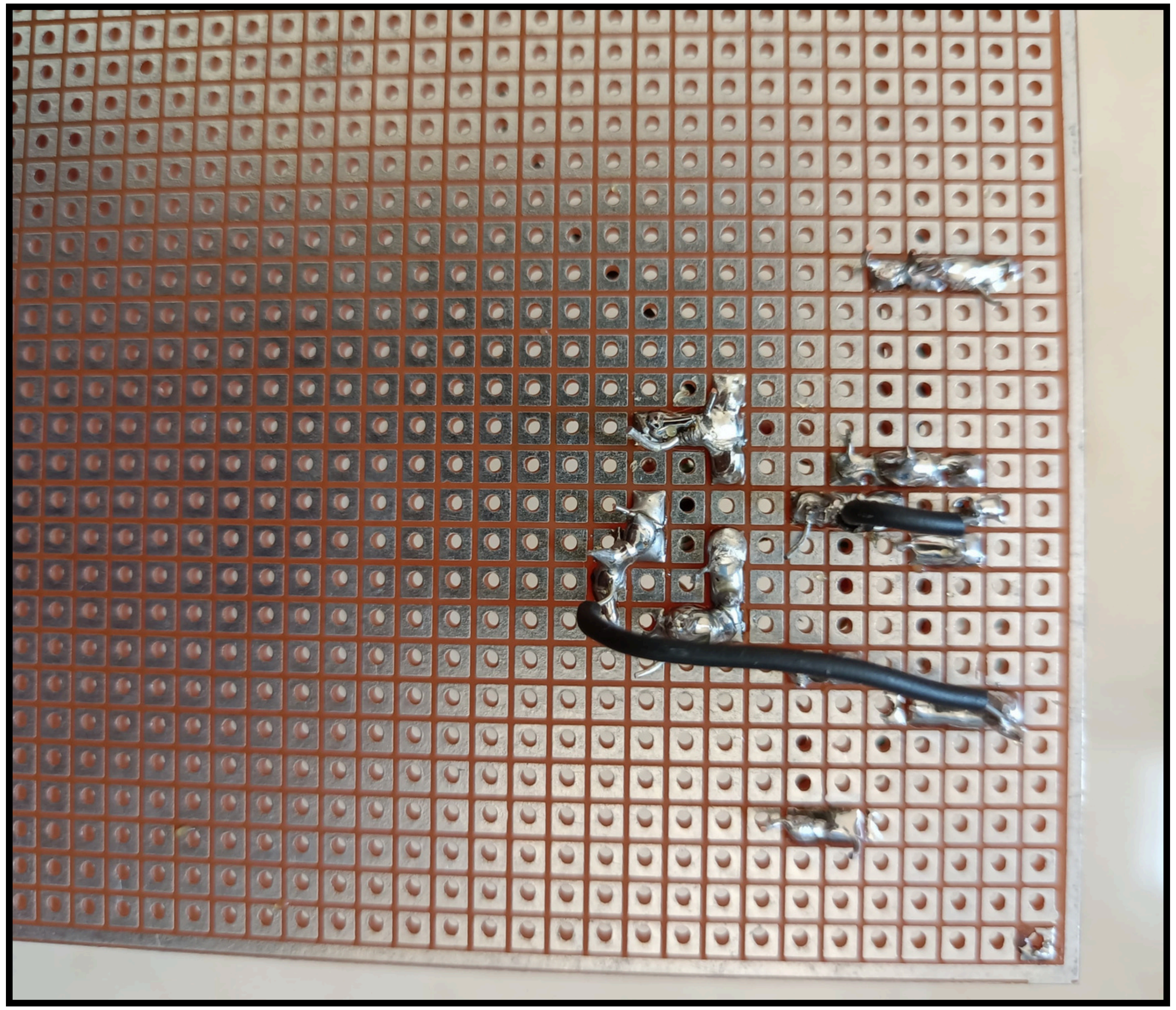
Hardware Design



Hardware Design



Front Side



Back Side

Oscilloscope Waveform

Problems faced

- The parasitic capacitance of the breadboard(due to loose connections) is comparable to the value of capacitance(0.1nF) of the capacitors used , and thus, there was too much distortion in the measured output.

- Since we were to opt for standard values of the inductor and the capacitors,we had to tweak the values appropriately to obtain the desired output.

Solutions to counter the problems

To make the connections tighter and hence reducing the resultant parasitic capacitor between wires and the breadboard , we tried and tested the same circuit on perf board by making connections tighter using solder .
There can be others ways such as :

- Dead-bug wiring (direct component-to-component soldering over a ground plane)

- Custom PCBs with careful layout

THANK YOU