Expt 10 – Opamp based Sinusoidal RC Oscillators and Astable Multivibrators

Oct 22, 2021 (Friday)

EE 230 Analog Circuits Lab

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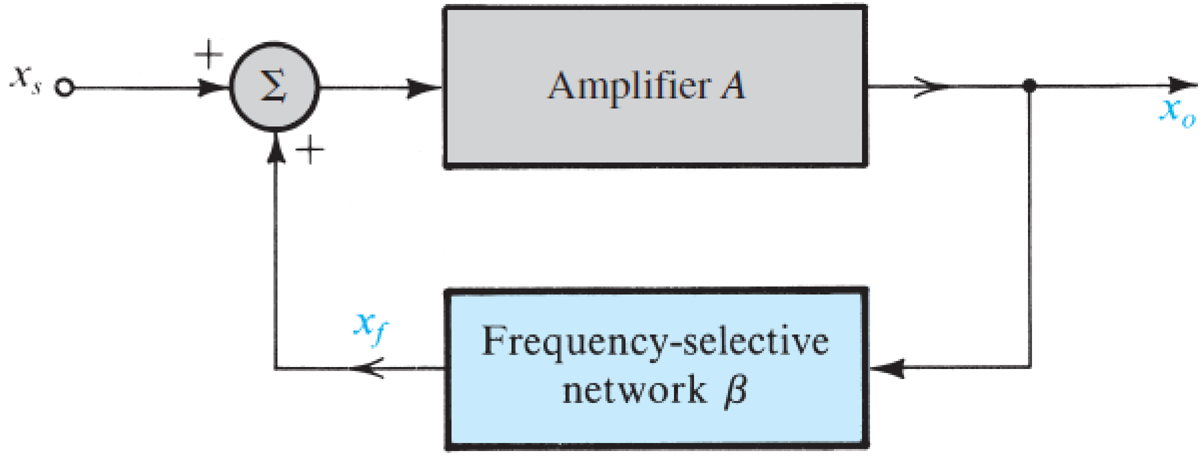
2021-22/I

Summary

- Introduction to Oscillators and Multivibrators
- Wien-bridge Oscillator
- Phase-shift Oscillator
- Astable Multivibrator

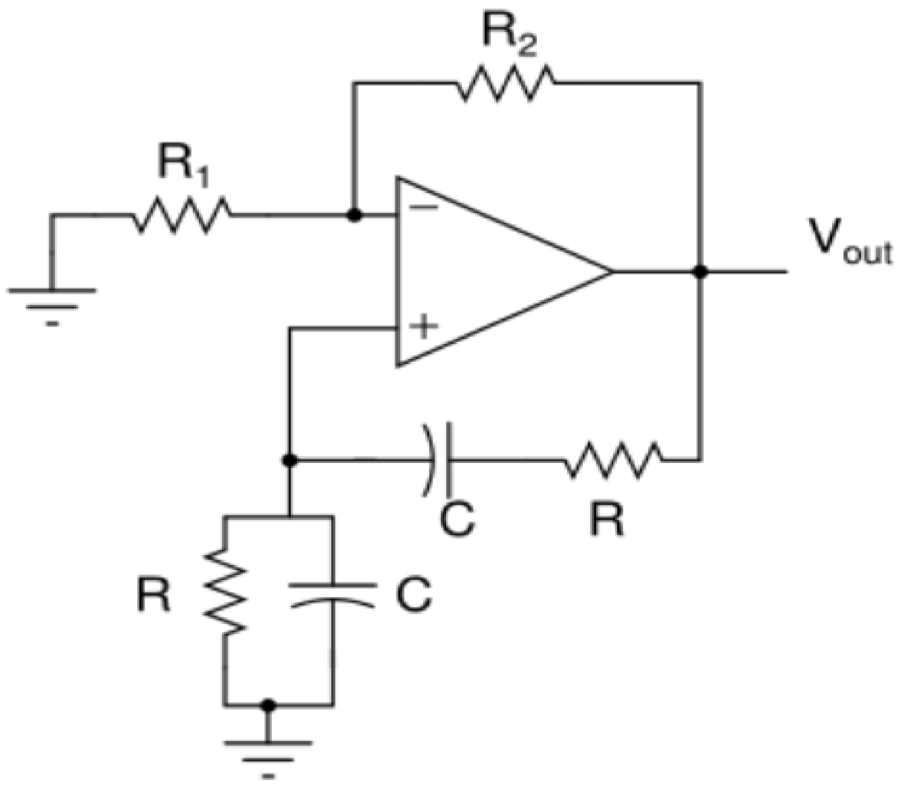
Introduction



- Loop-gain = A β
- $L(j\omega_0) \equiv A(j\omega_0)\ \beta(j\omega_0) = 1$
  - At ω_0 the phase of the loop gain should be zero, and
  - the magnitude of the loop gain *should be unity.*
- **Barkhausen criterion**.

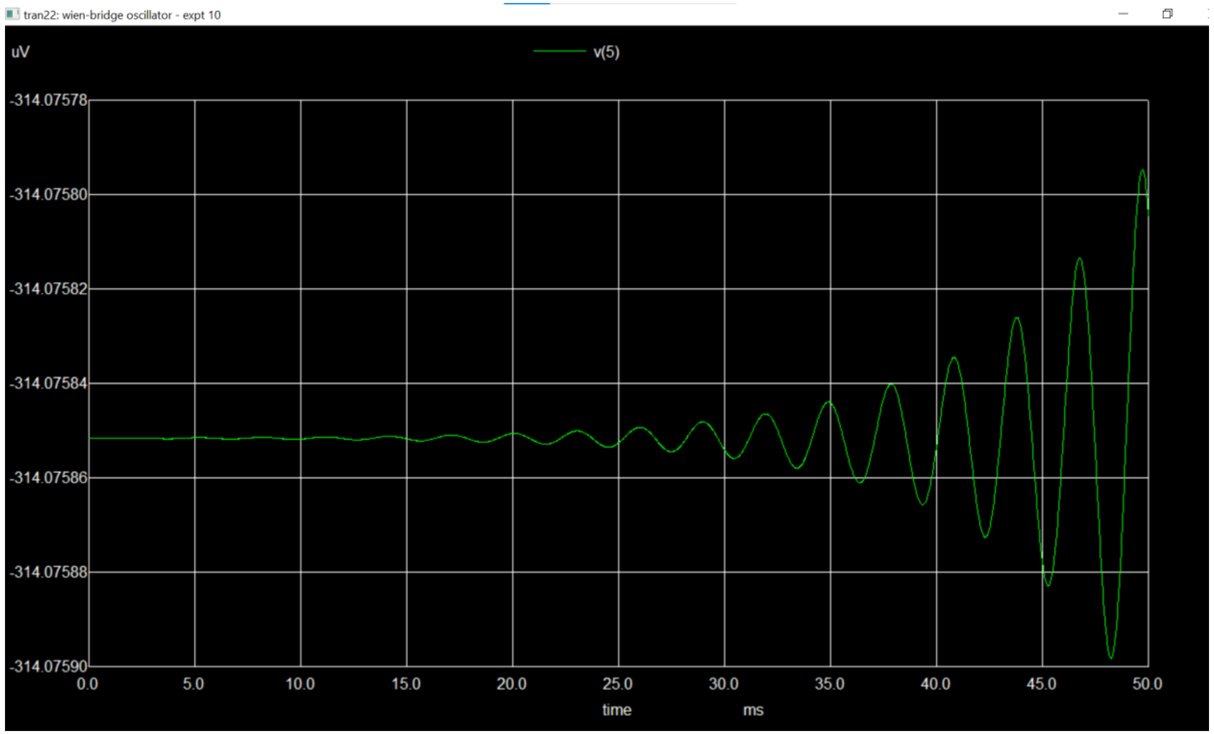
Source: Sedra & Smith, 7ed., Chap 18

Wien-bridge Oscillator

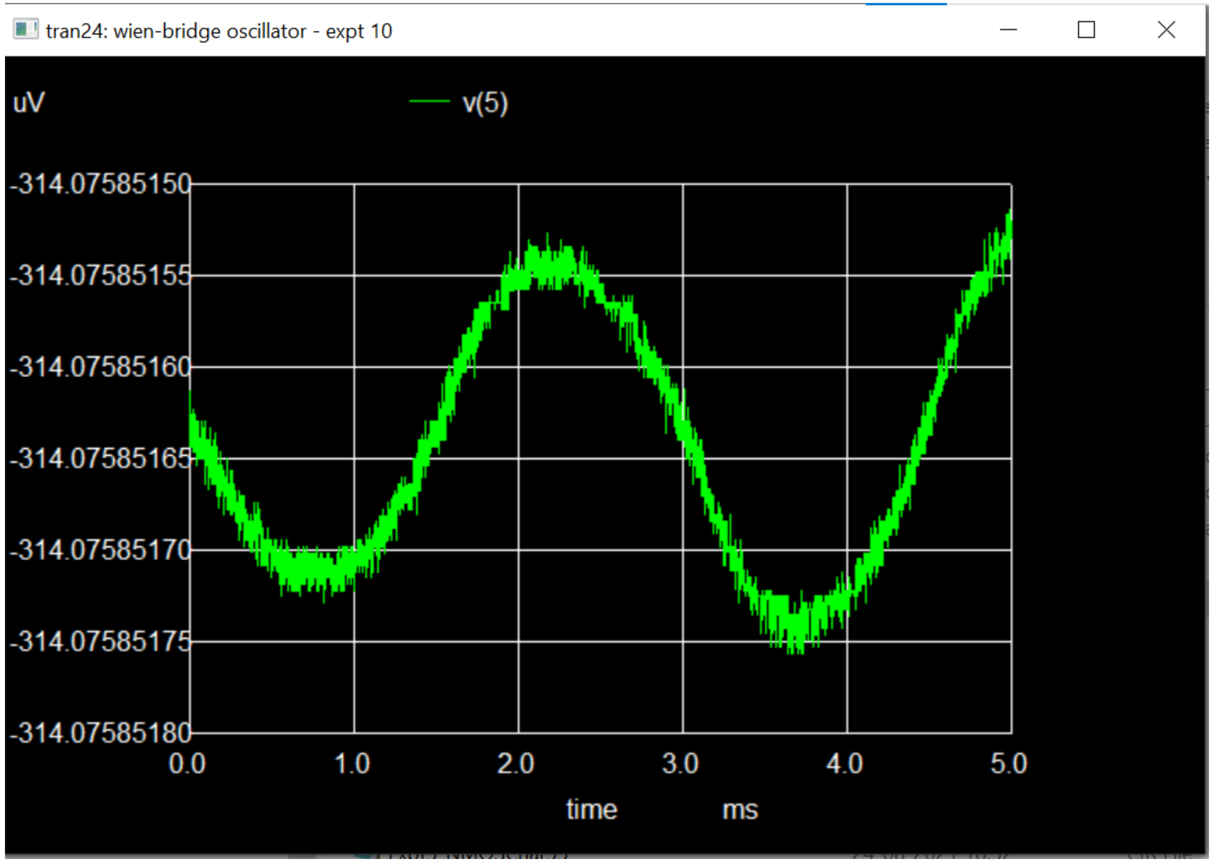


- Opamp: UA741
- Circuit values: +Vcc = +12 V, -Vcc = -12 V;
- R_2 = 10 kΩ, R1 = 4.7 kΩ,
- R = 4.7 kΩ, C = 0.1 μF

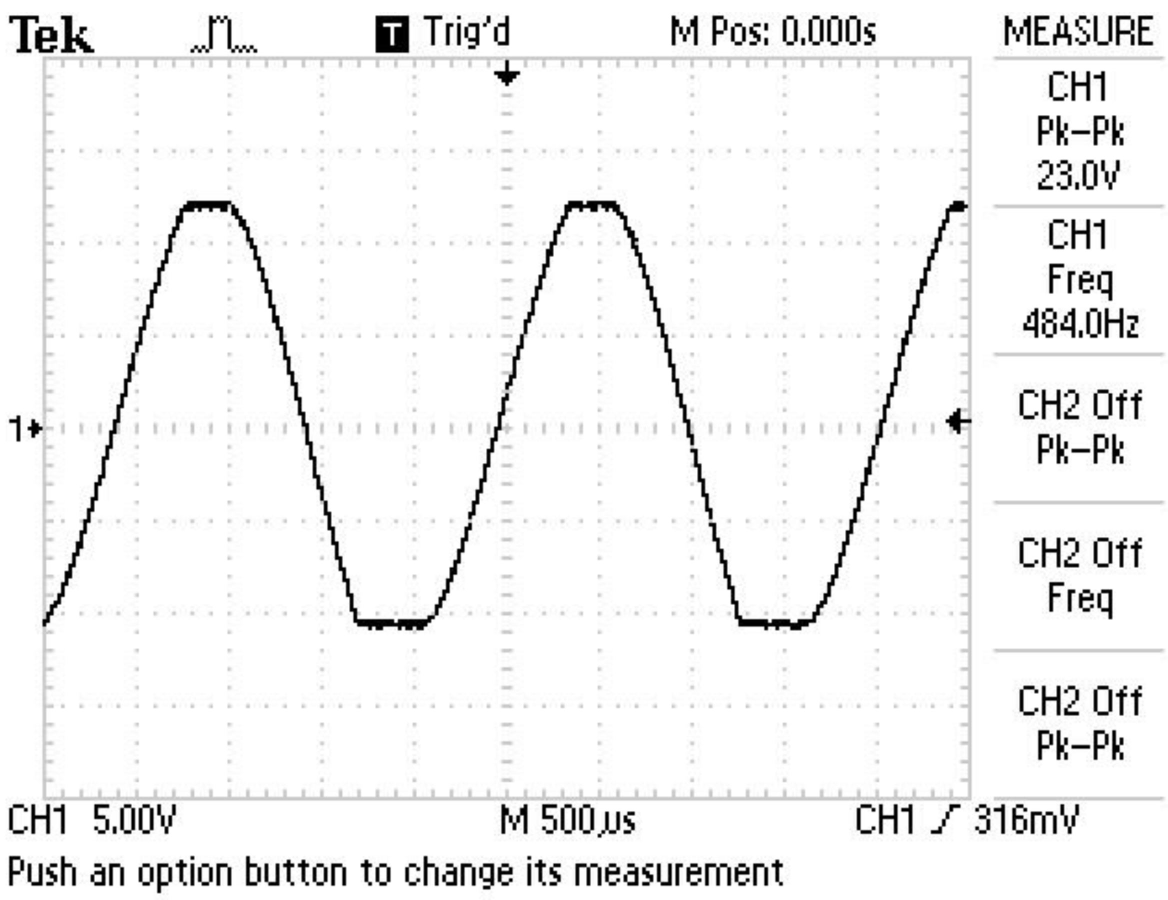
- Two parts:
  - a non-inverting amplifier with (resistors R_2 and R_1 for gain), and
  - a bandpass filter circuit made up of the RC Wien network.
  - At $\omega_o = 1/RC$, BPF amplitude of the transfer function = (1/3) with zero phase angle.
  - Circuit will work as an oscillator, if the voltage gain ≥ 3 V/V.
  - For sustained oscillations, R_2/R_1 should be slightly > 2.

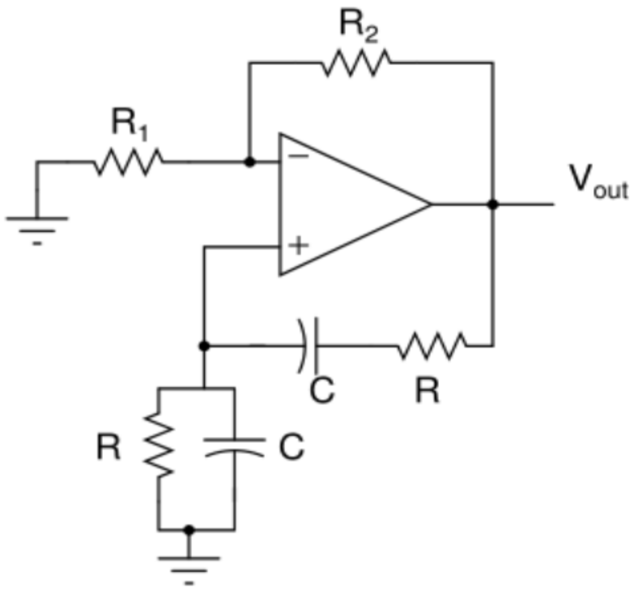


tran22: wien-bridge oscillator - expt 10
uV
v(5)
-314.07578
-314.07580
-314.07582
-314.07584
-314.07586
-314.07588
-314.07590
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
time
ms



tran24: wien-bridge oscillator - expt 10
uV
v(5)
-314.07585150
-314.07585155
-314.07585160
-314.07585165
-314.07585170
-314.07585175
-314.07585180
0.0
1.0
2.0
3.0
4.0
5.0
time
ms

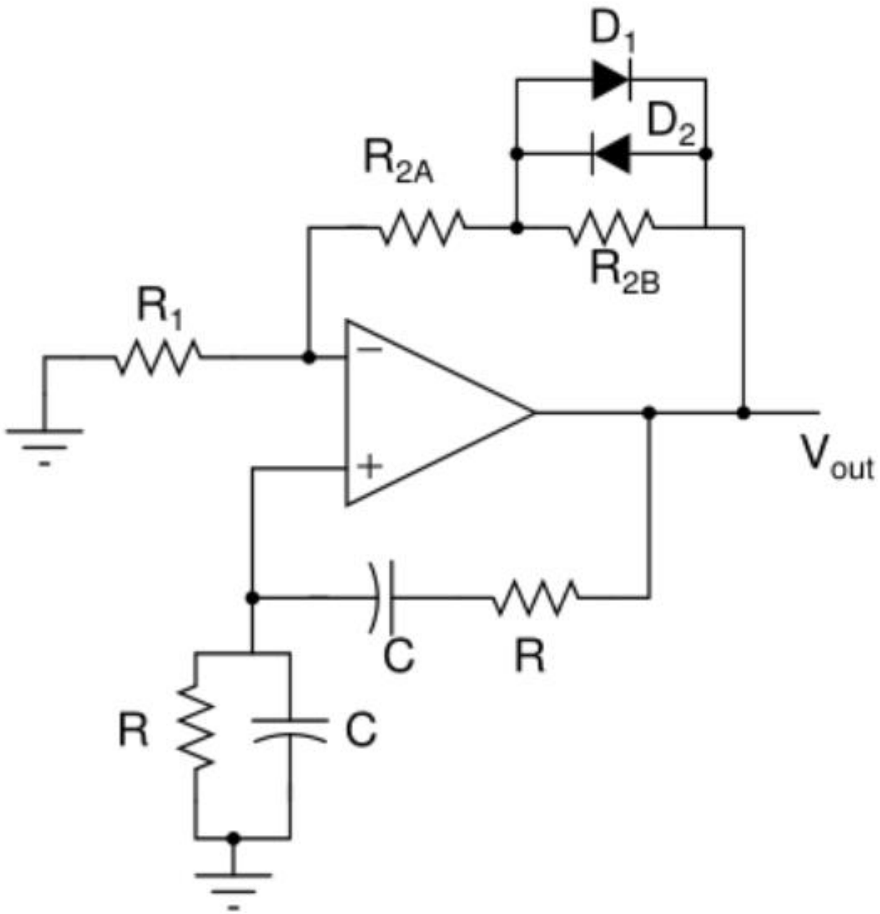




- R_2 = 10 kΩ, R_1 = 4.7 kΩ
- If $R_2 >> 2 R_1$, V_{out} would saturate (distorted sinewave)

No scheme for amplitude stabilization

Wien-bridge Oscillator with Amplitude Stabilization



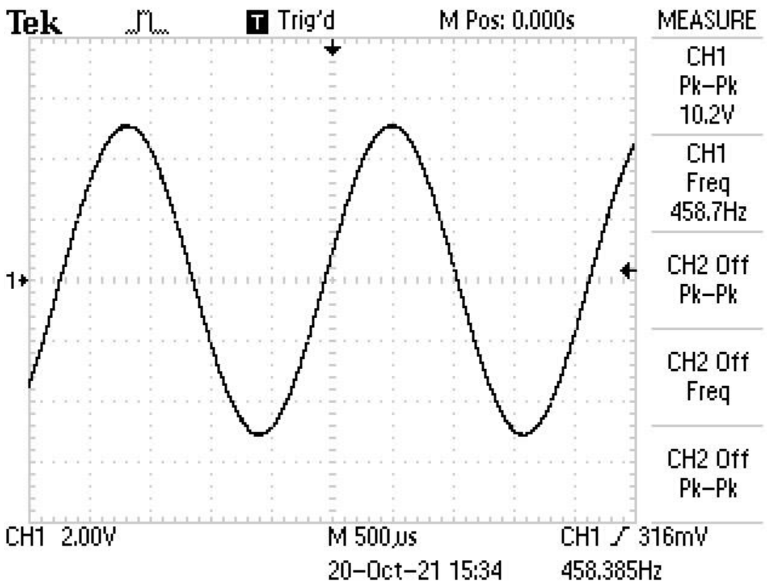
- Purpose
- Keep voltage gain close to 3 V/V
- Control V_{out} amplitude through non-linear means, $R_2 = R_{2A} + R_{2B}$

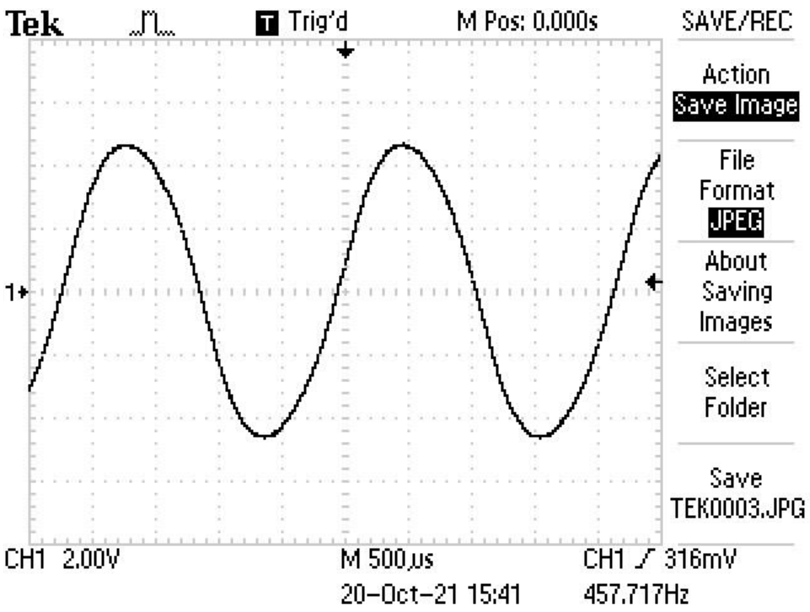
- Choice of R_{2B} would decide the overall V_{out} amplitude

THE WIEN-BRIDGE OSCILLATOR:

The Wien bridge consisting of four resistors and two capacitors was invented in 1891 by Max Wien, a Prussian physicist, for inductance measurement. Much later, William Hewlett (cofounder in 1939 of Hewlett-Packard), while working toward his master's degree at Stanford University, realized the importance of placing part of the Wien bridge in a positive-feedback loop to form what was called the Wien-bridge oscillator. The first product in 1939 of the new Hewlett-Packard Company was the HP200A, a flexible, precision sine-wave generator using vacuum tubes to implement the amplifier and a tungsten lamp to control the loop gain and thus the amplitude of the sine wave.

Source: Sedra & Smith, 7ed., Chap 18



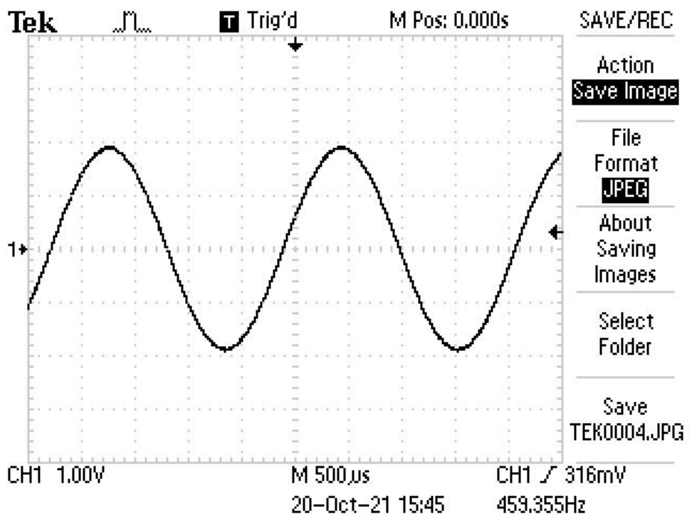


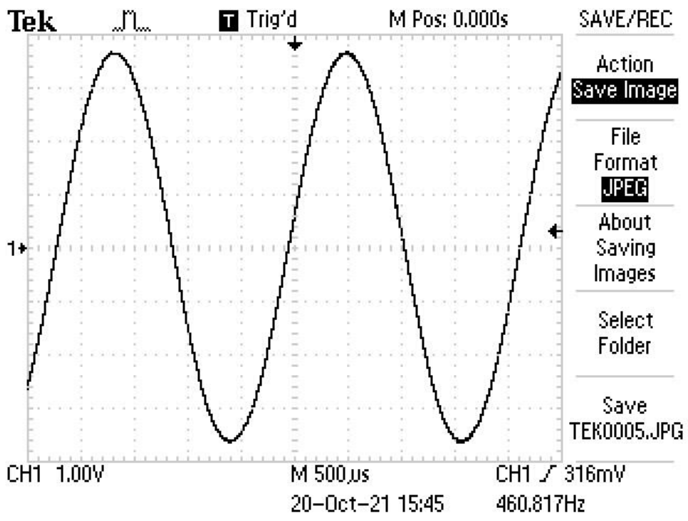
Good sinewaves

(R_{FA} = 6.8 k Ω, R_{FB} = 10k pot – adjusted just sufficient to oscillate)

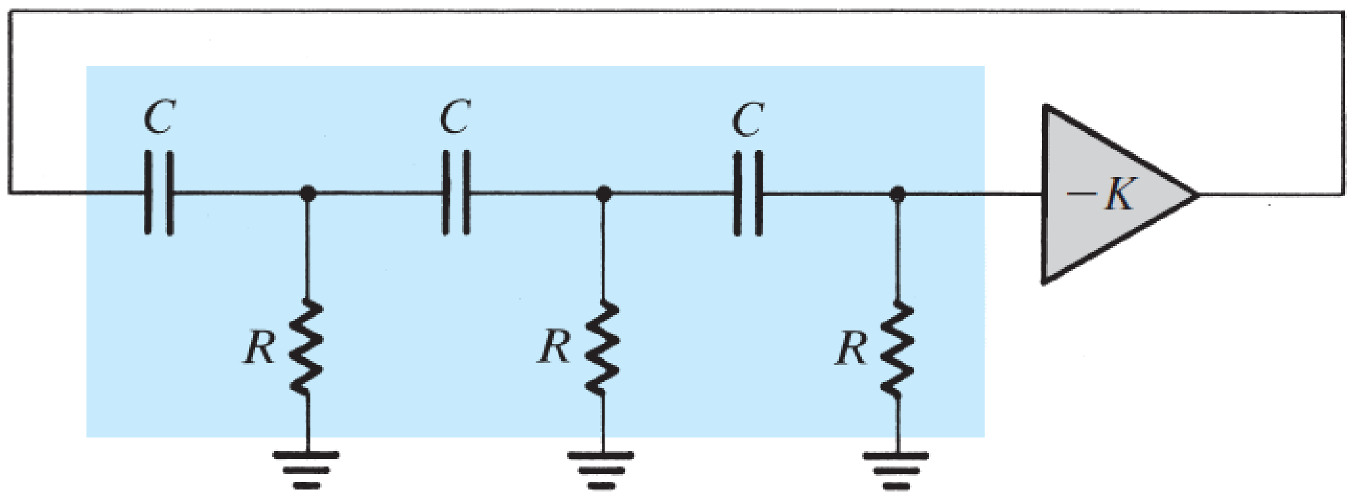
Slightly distorted sinewave

(R_{FA} = 6.8 k Ω, R_{FB} = 3.3 kΩ)





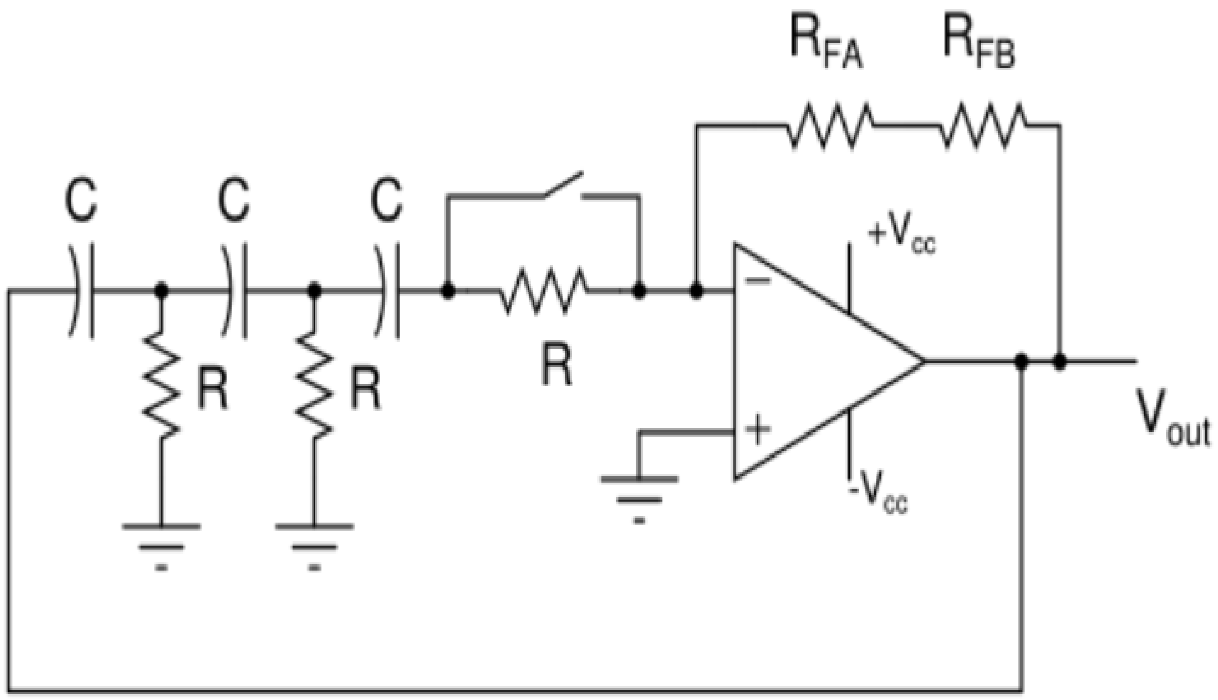
Phase-shift Oscillator



Source: Sedra & Smith, 7ed., Chap 18

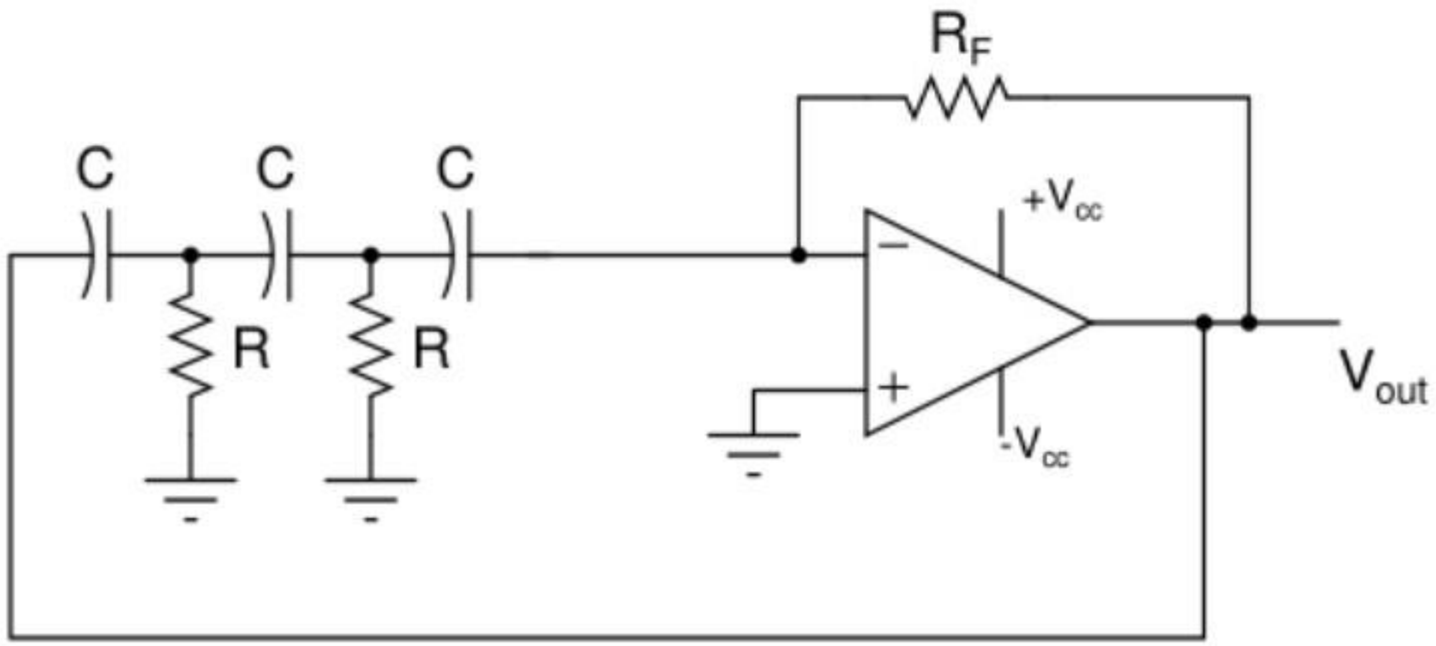
- Two parts
  - A negative-gain amplifier (–K), and
  - A three-section (third-order) RC ladder network in the feedback.
- Will oscillate at the frequency for which the phase shift of the RC network is 180°
- Each section of RC introduces 60^{o}

Phase-shift Oscillator Implementation – Suggested Options



- Difficult circuit to work with
- Not as straightforward as the Wien-bridge oscillator
- Frequency of oscillation, $\omega \neq 1/RC$

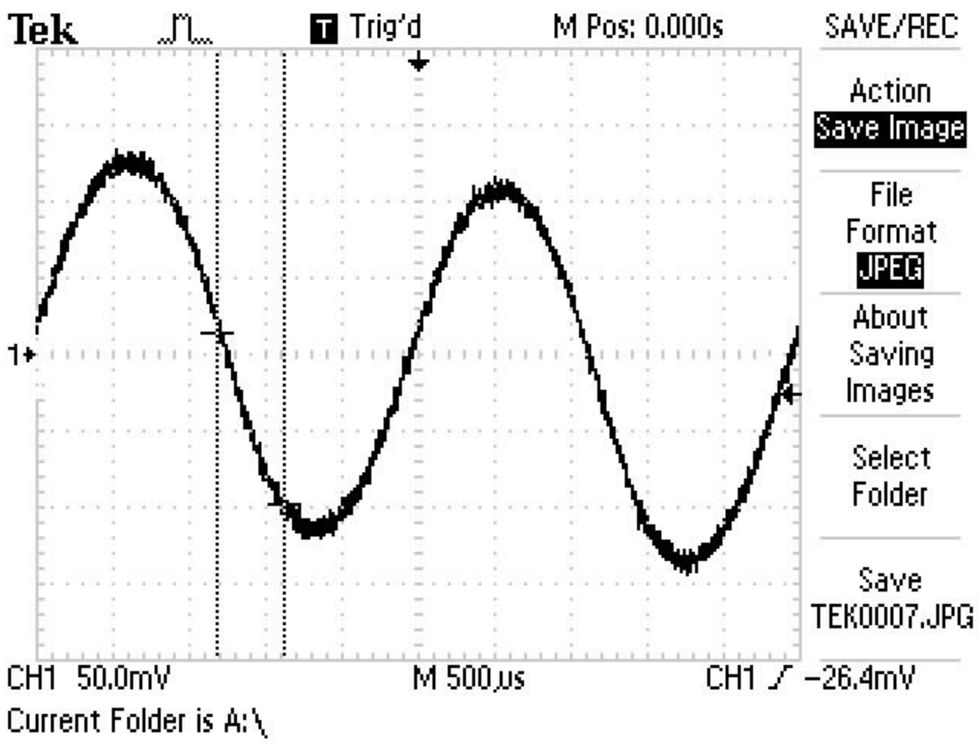
Phase-shift Oscillator circuit used (in Expt)

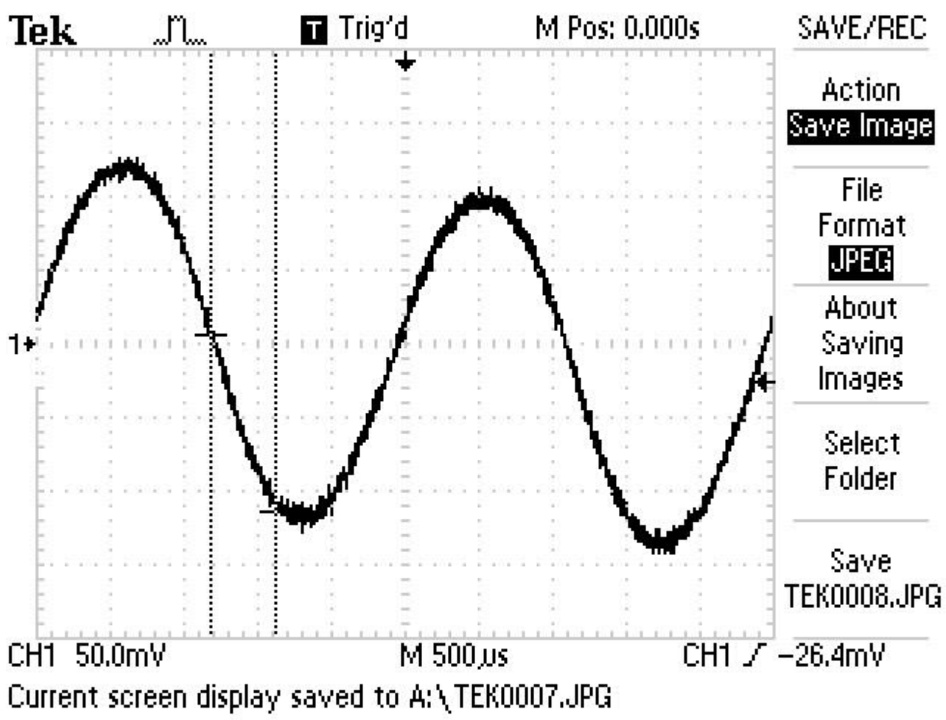


Circuit values:

- $R = 10\ k\Omega$, $C = 22\ nF$
- R_F : $120\ k\Omega$ + 100k pot

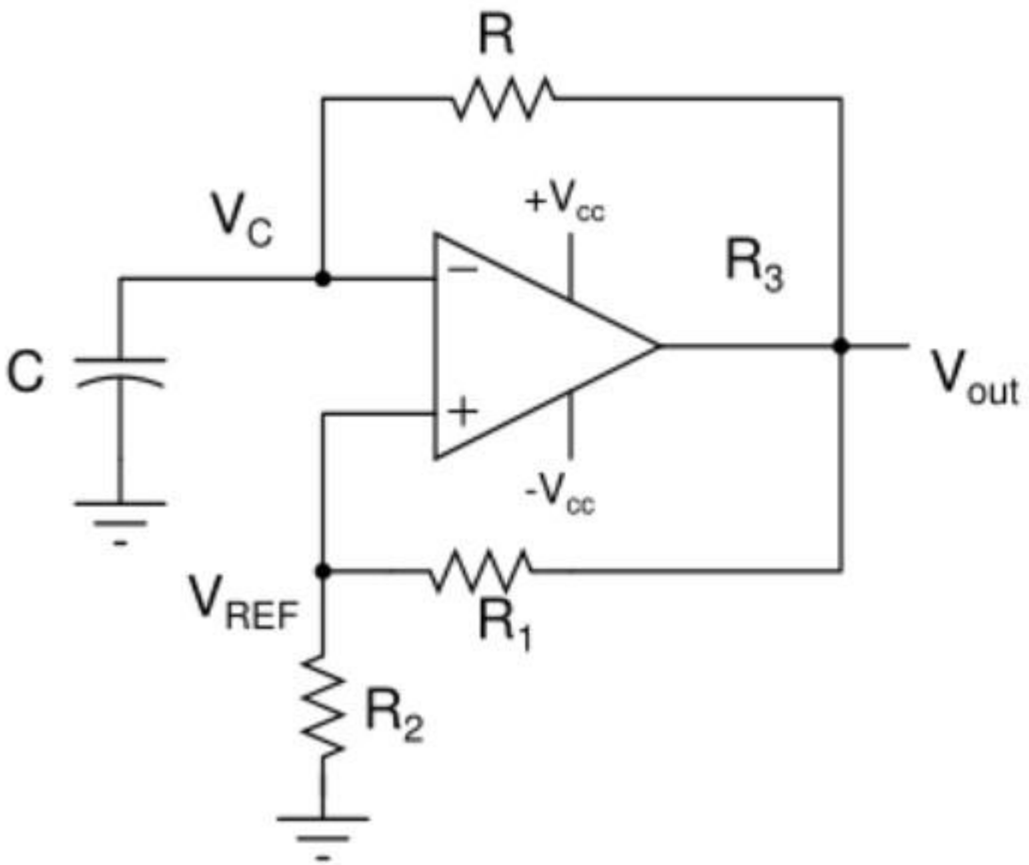
- No amplitude stabilization scheme





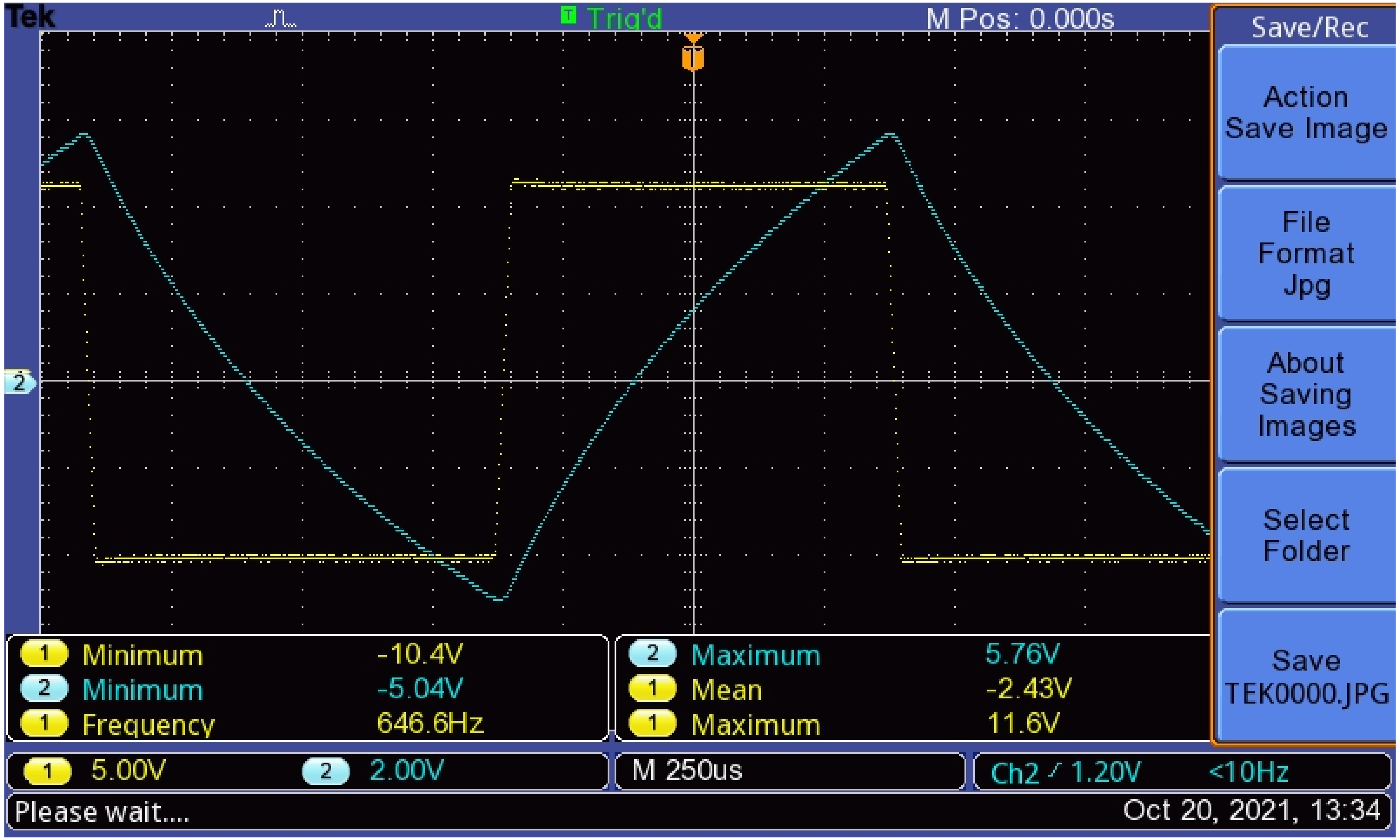
Low amplitude : 250 mv p-p

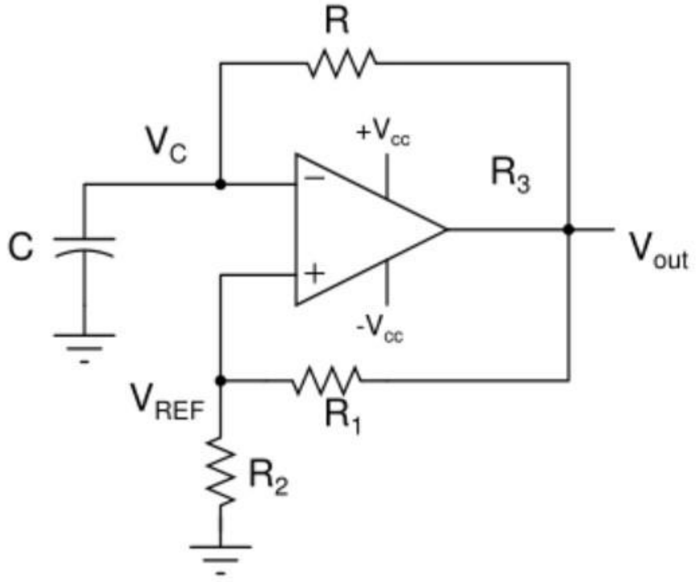
Astable Multivibrator



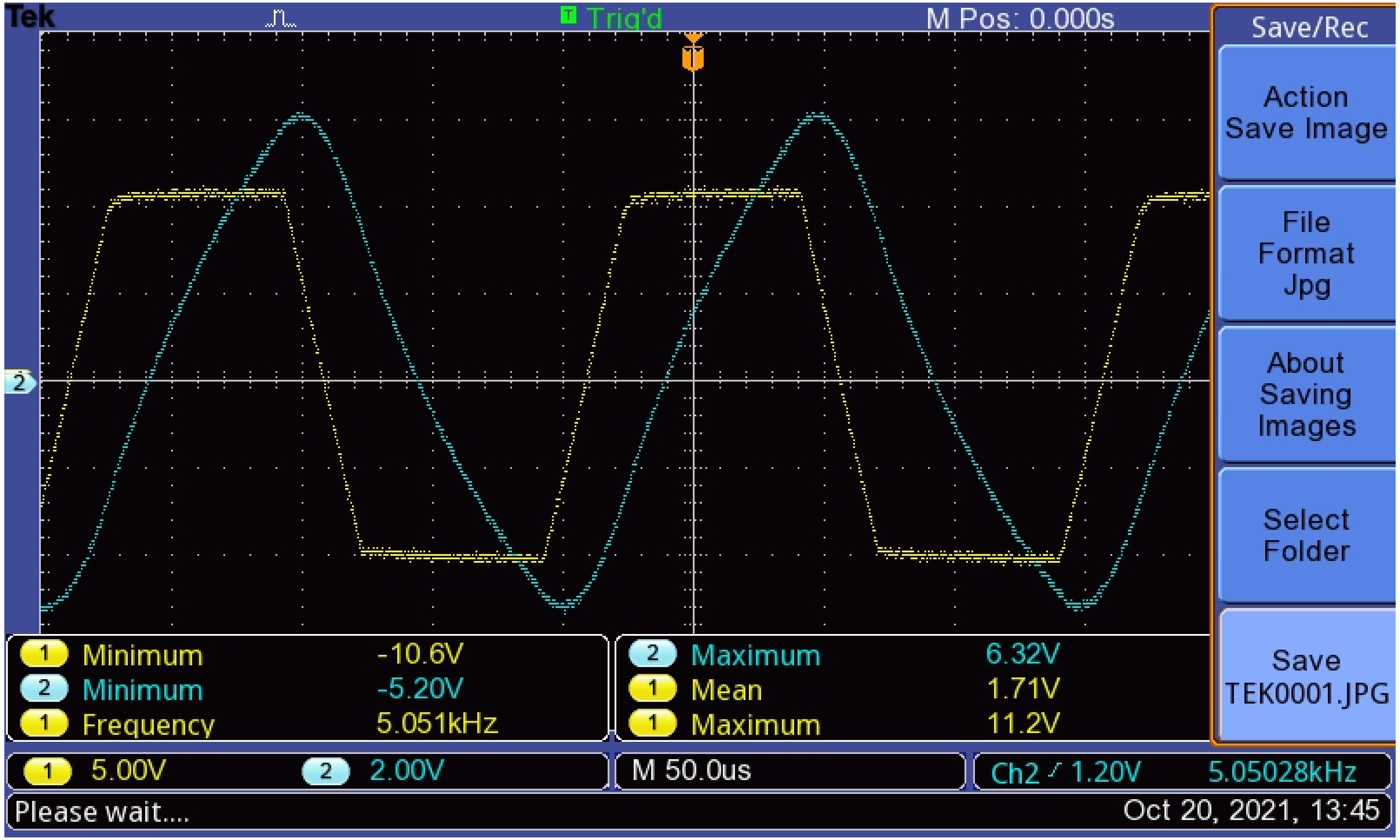
- Similar to a Schmitt Trigger Circuit
- +ve feedback (R1 and R2)
- Charging of C facilitated through R
- Free-running (astable or quasi stable)

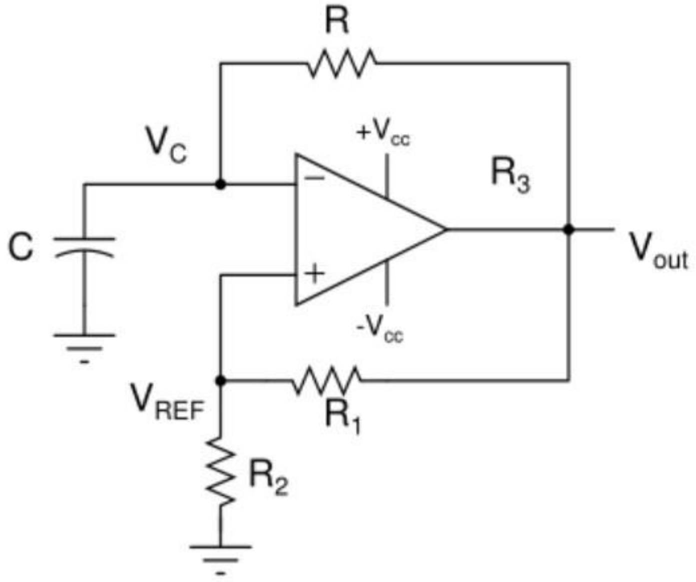
- This is a non-linear circuit (do not get confused with the RC circuit connected to the V- input)





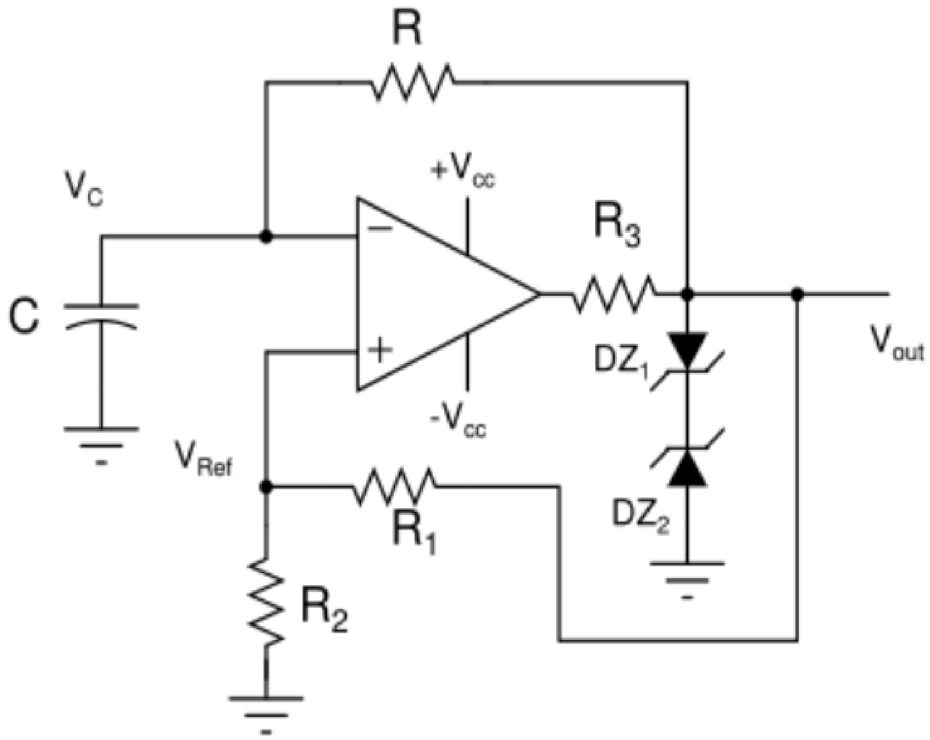
- R = 10 kΩ, C = 0.1 μF
- $R_1 = R_2$
- No Zener diodes at the output
- Problems
  - $V_{OH} = 11.6$ V
  - $V_{OL} = -10.4$ V
  - $T_H \neq T_L$
  - $T_H < T_L$



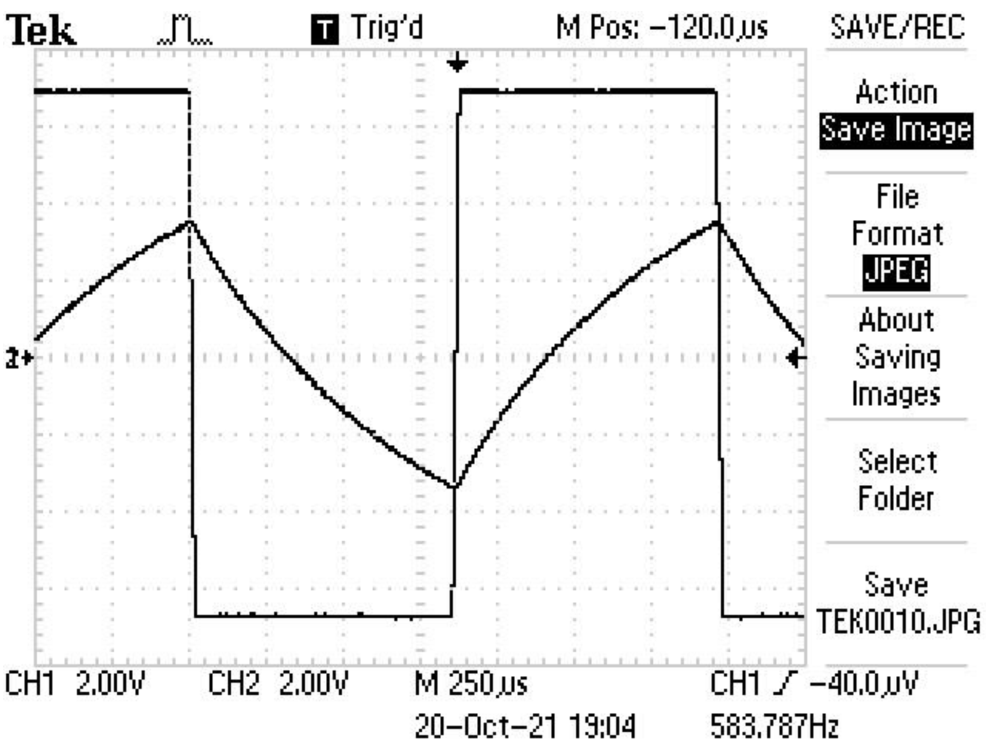


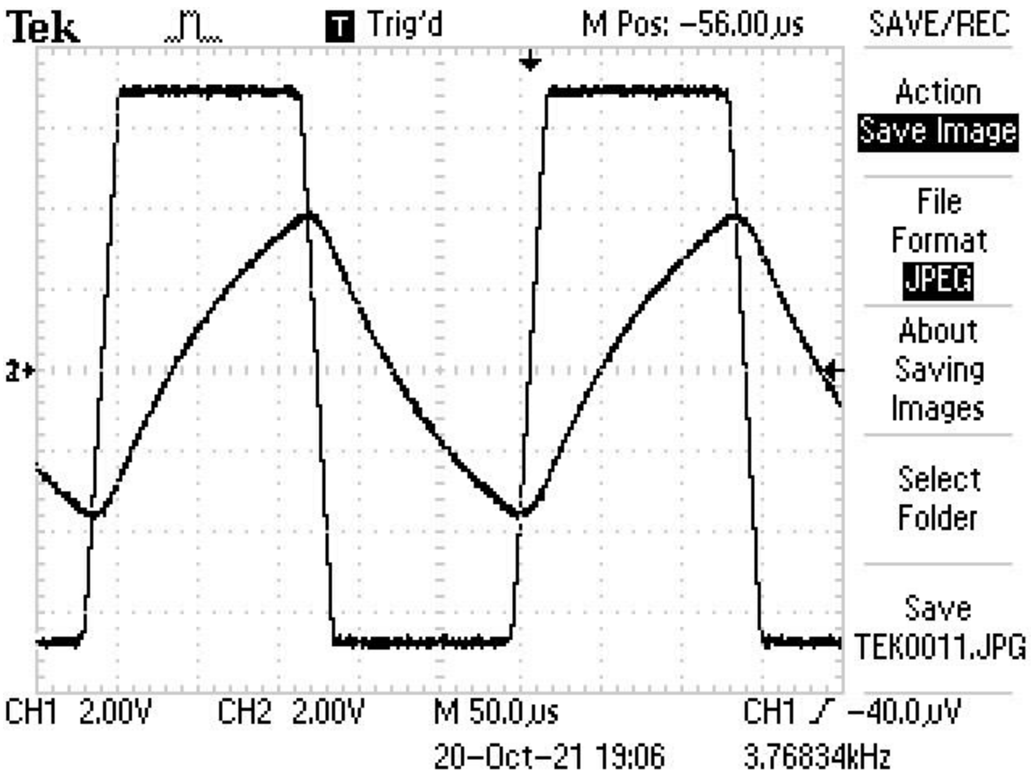
- $R = 1\ k\Omega$, $C = 0.1\ \mu F$
- $R_1 = R_2$
- No Zener diodes at the output
- Problems
  - $V_{OH} = 11.2$ V
  - $V_{OL} = -10.6$ V
- $T_H \approx T_L$
- Freq = 5 kHz
- Slew-rate problem

Astable Multivibrator – with Zener diodes at the Output



- Zener diodes connected back-to-back
- $V_{OH} = V_{OL}$
- $T_H = T_L$
- Symmetrical square wave
- To some extent, slew-rate limitation can be addressed (by lowerering V_{OH} and V_{OL} levels)

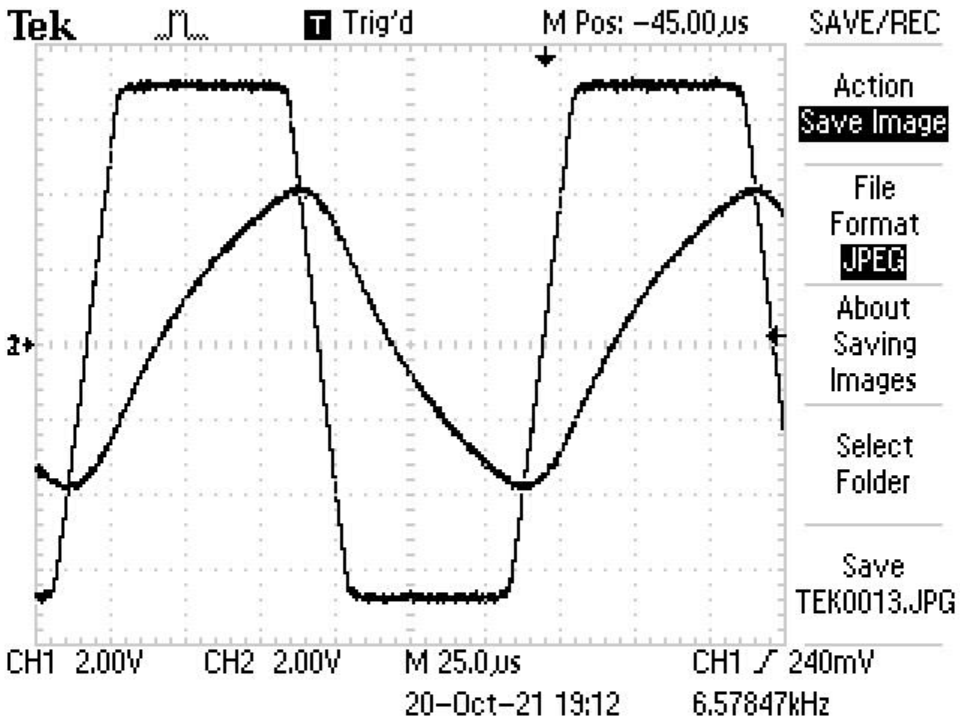


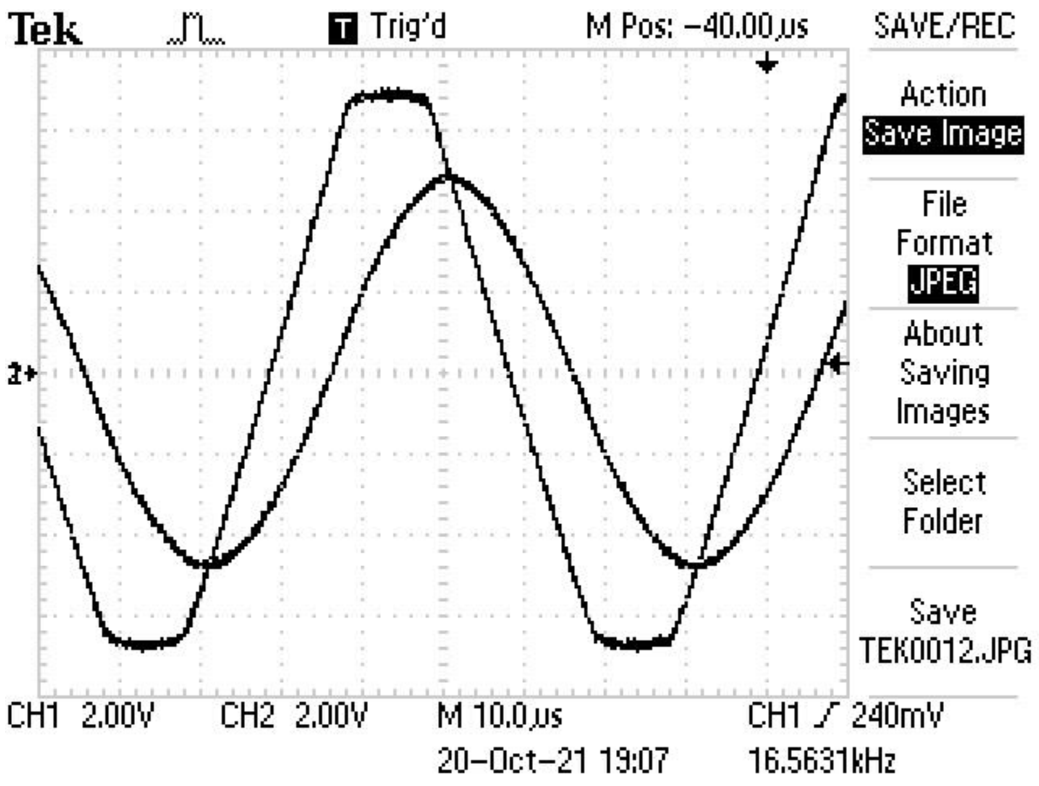


- VOH = 7 V
- VOL = -7 V

R = 10 kΩ, C = 0.1 µF

R = 10 kΩ, C = 0.01 µF

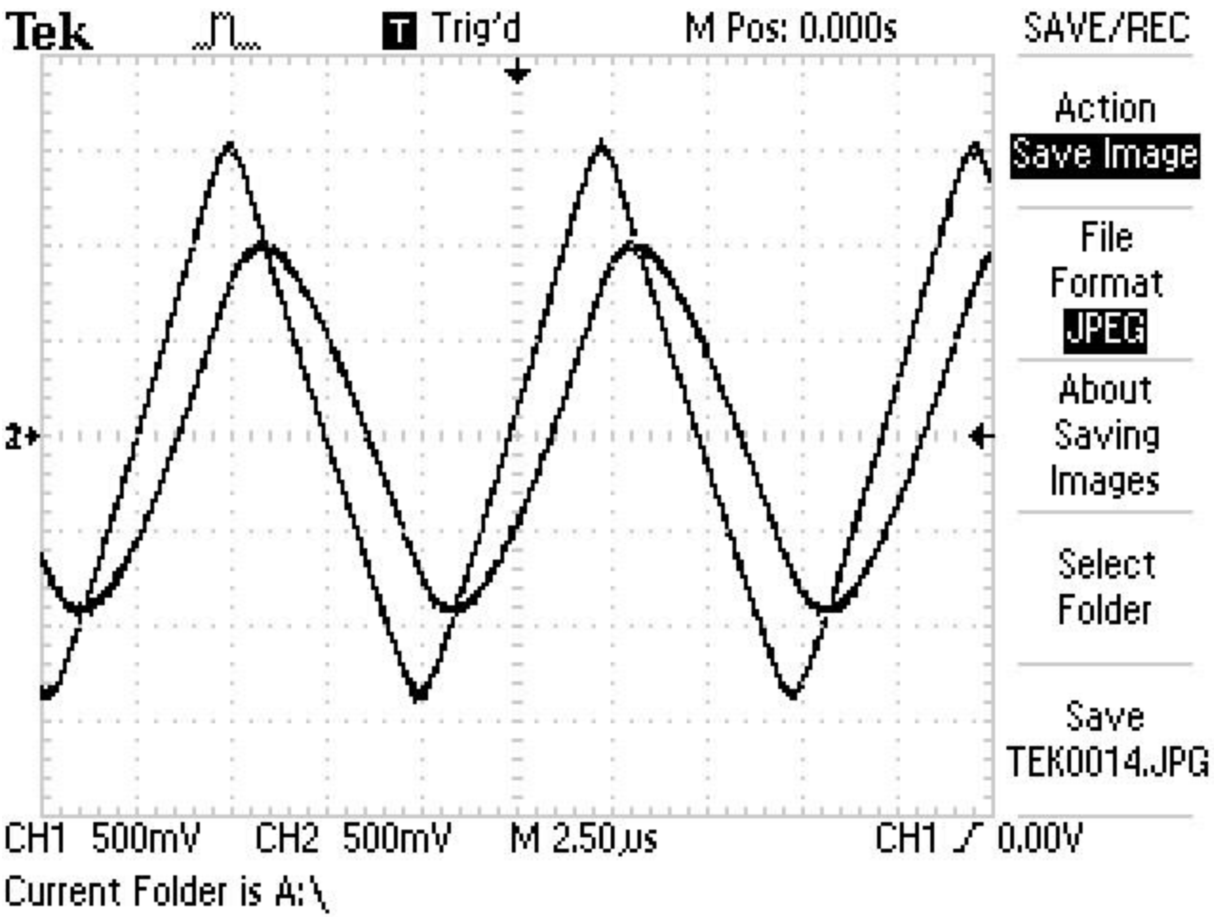




- VOH = 7 V
- VOL = -7 V

R = 10 kΩ, C = 0.005 µF

R = 10 kΩ, C = 0.001 µF



R = 10 kΩ, C = 0.1 nF

- VOH = 1.5 V
- VOL = -1.5 V

Announcements

- Quiz 8 – corrections – nearly over

- Endsem Exam – Oct 29 Fri
  - Two parts:
  - First part – SAFE Auto corrected, 1 hr ; 2:00 – 3:00pm
  - Second part - Fully image answers (conventional answer paper, with Question paper through SAFE): 1 hr, 3:30-4:30pm