Expt 8 – Precision Rectifier and Active Filters

Oct 1, 2021 (Friday)

EE 230 Analog Circuits Lab

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2021-22/I

Summary

- Precision Rectifiers
  - Half-wave Precision Rectifier - Standard circuit
  - Improved Half-wave Precision Rectifier (Circuit A)
  - Improved Half-wave Precision Rectifier (Circuit B)
  - Precision Full-wave Rectifier

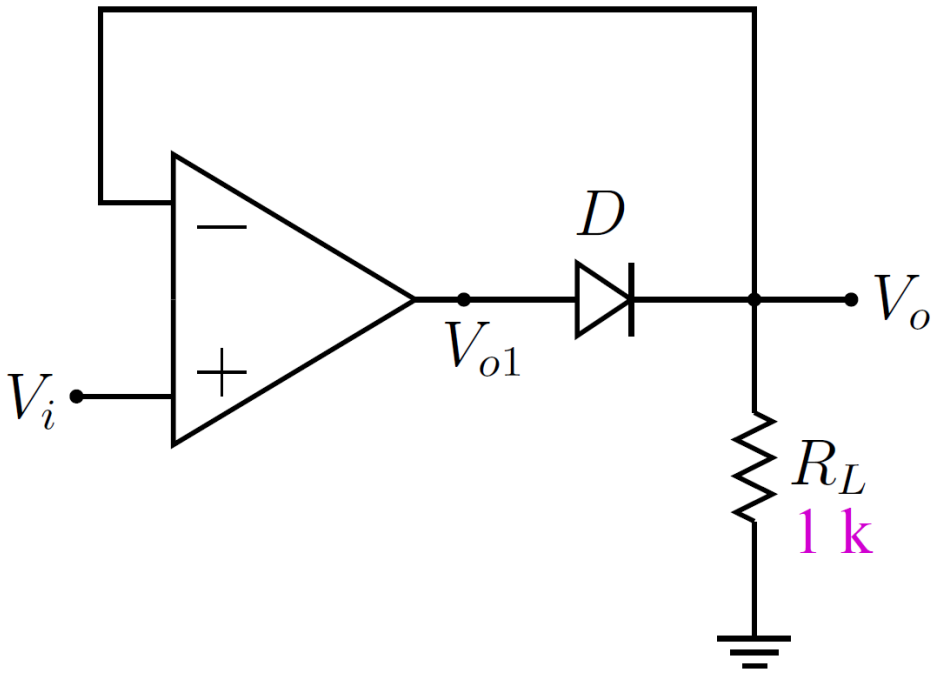
- Active Filters
  - Single-pole (LPF and HPF)
  - Sallen-Key (2-pole) – LPF and HPF

Precision Rectifiers

- Rectifier circuits diode drops neglected (as these drops typ. 0.7 V)
  - were much smaller compared to the input ac signal, roughly 20 sin ωt.
- What about if the signal (to be rectified) – of the order of the diode drops or much smaller.

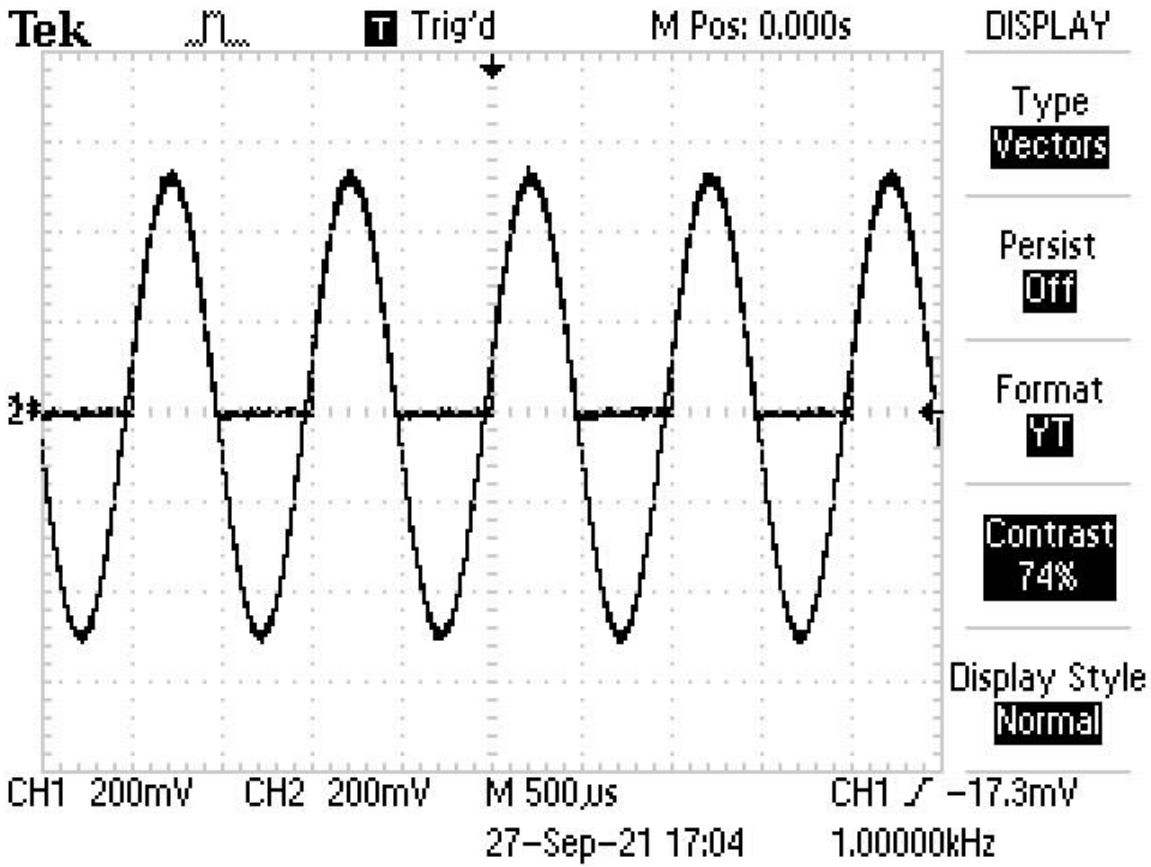
- We can combine a diode and an Opamp (with negative feedback)
  - Problem can be easily addressed.
  - Combination of an Opamp and a diode is often called a ‘Super diode’ or a ‘Precision Rectifier’ circuit.

Half-wave Precision Rectifier - Standard circuit

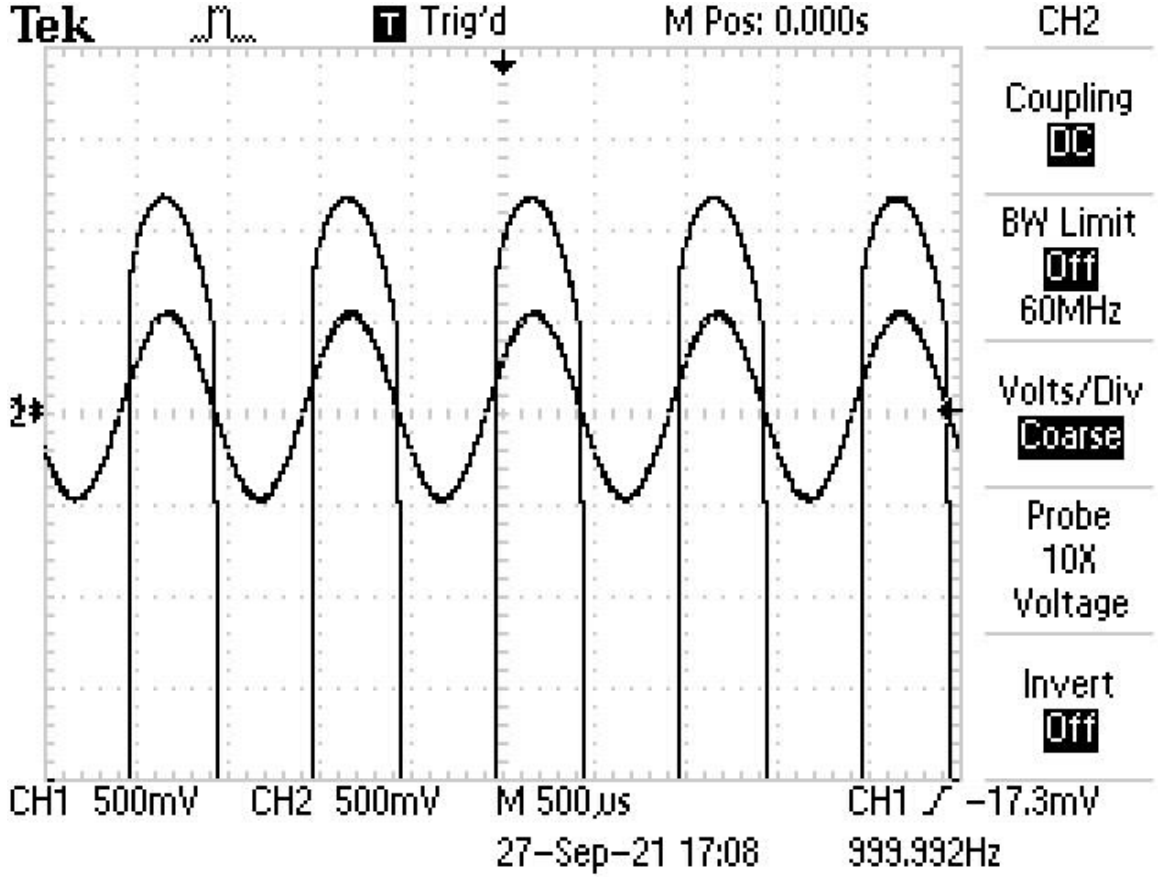


Half−wave rectifier

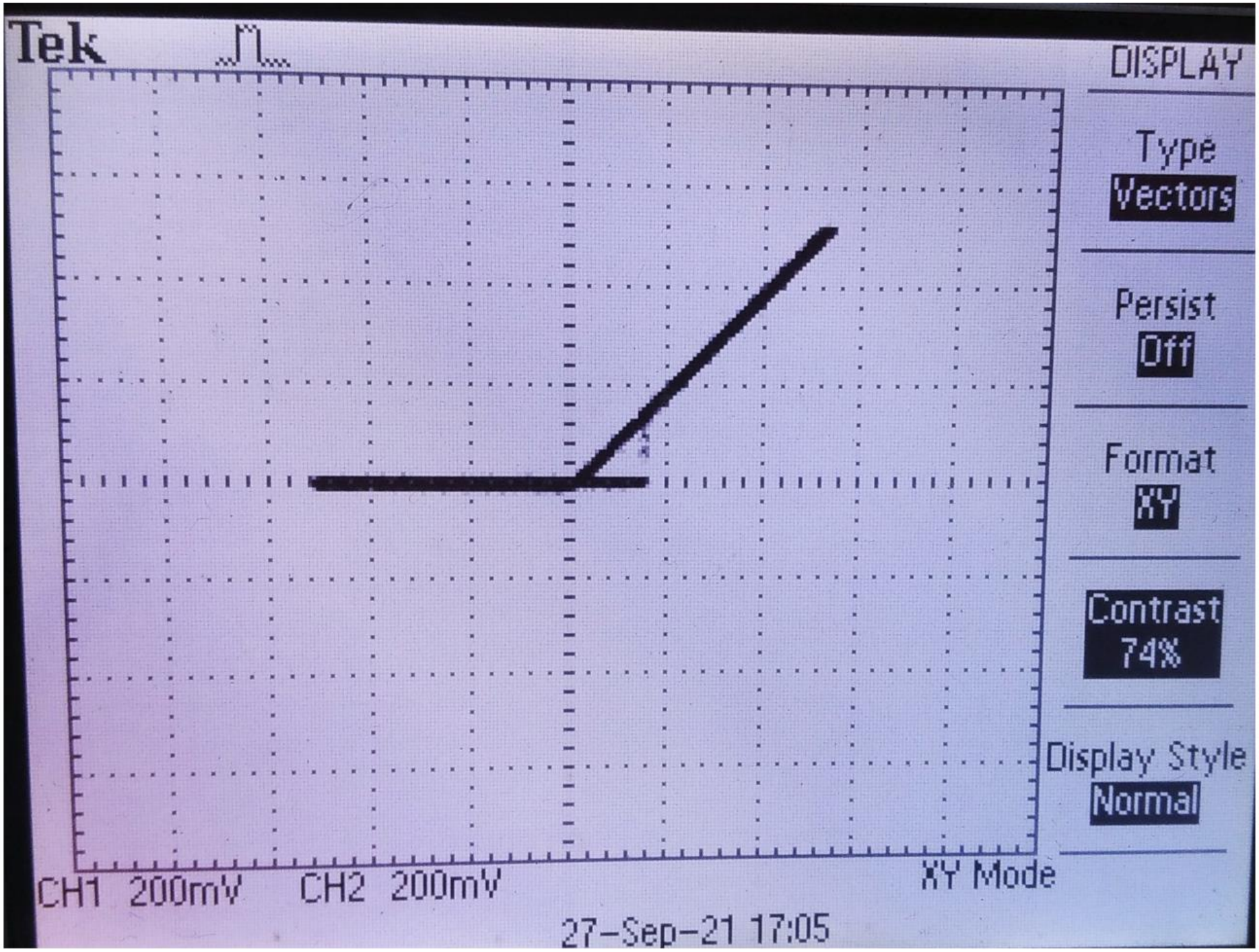
- Here, $V_o = V_i$, when $V_i > 0$; $V_o = 0$, when $V_i < 0$
- Problems
  - When $V_i < 0$, Opamp is saturated
  - Will affect its switching speed


Tek
T Trig'd
M Pos: 0.000s
DISPLAY
Type
Vectors
Persist
Off
Format
YT
Contrast
74%
Display Style
Normal
CH1 200mV
CH2 200mV
M 500µs
CH1 ƒ -17.3mV
27-Sep-21 17:04
1.00000kHz

V_o

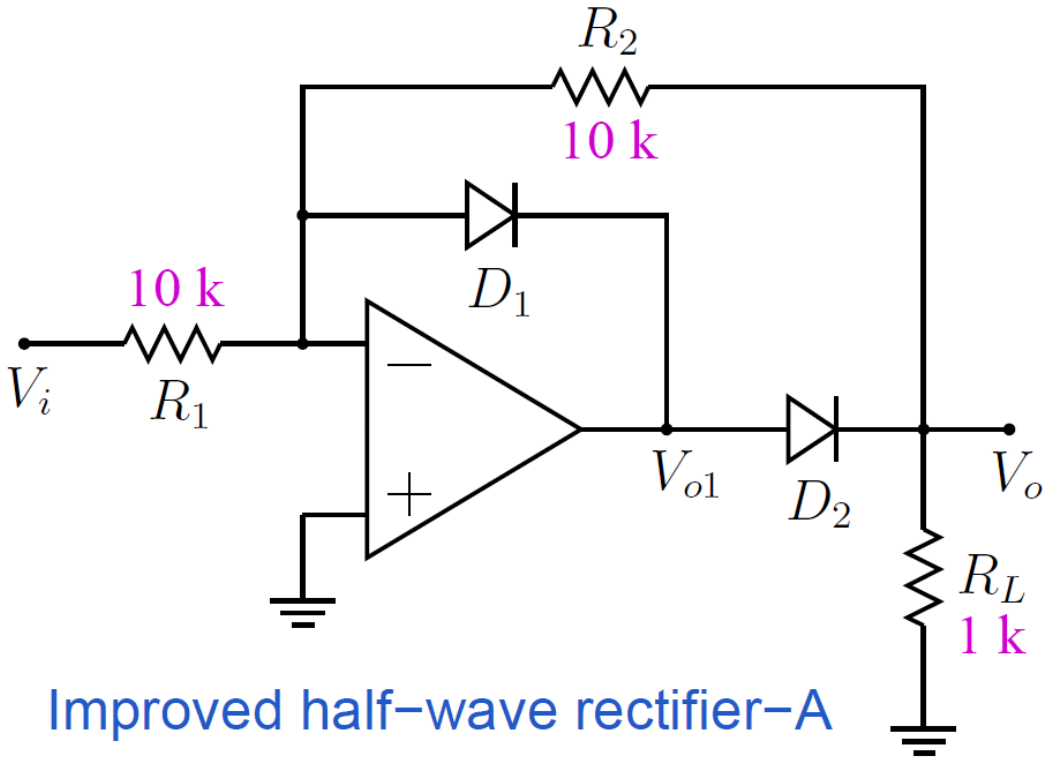

Tek
T Trig'd
M Pos: 0.000s
CH2
Coupling
DC
BW Limit
Off
60MHz
Volts/Div
Coarse
Probe
10X
Voltage
Invert
Off
CH1 500mV
CH2 500mV
M 500µs
CH1 ƒ -17.3mV
27-Sep-21 17:08
999.992Hz

V_{o1}


Tek
DISPLAY
Type
Vectors
Persist
Off
Format
XY
Contrast
74%
Display Style
Normal
CH1 200mV
CH2 200mV
XY Mode
27-Sep-21 17:05

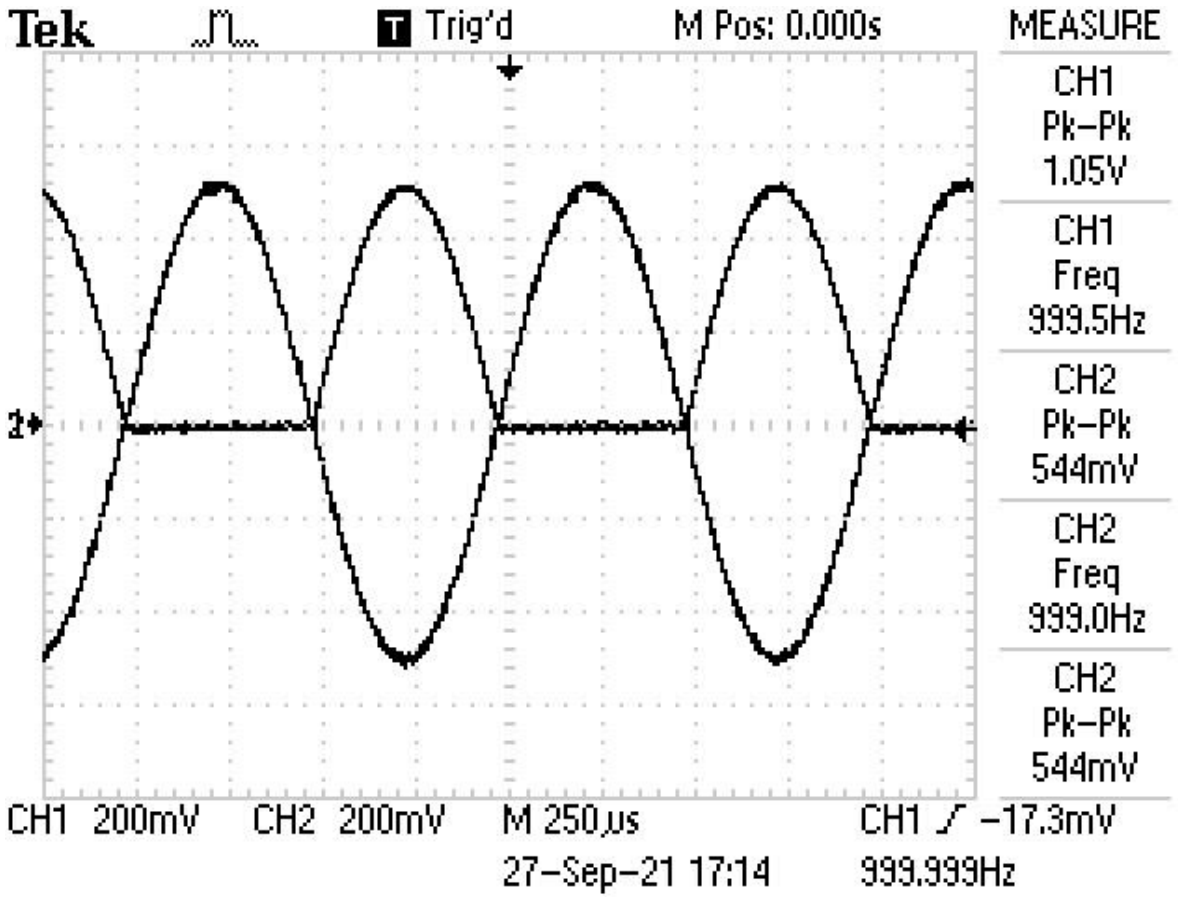
V_o vs V_i

Improved Half-wave Precision Rectifier (Circuit A)

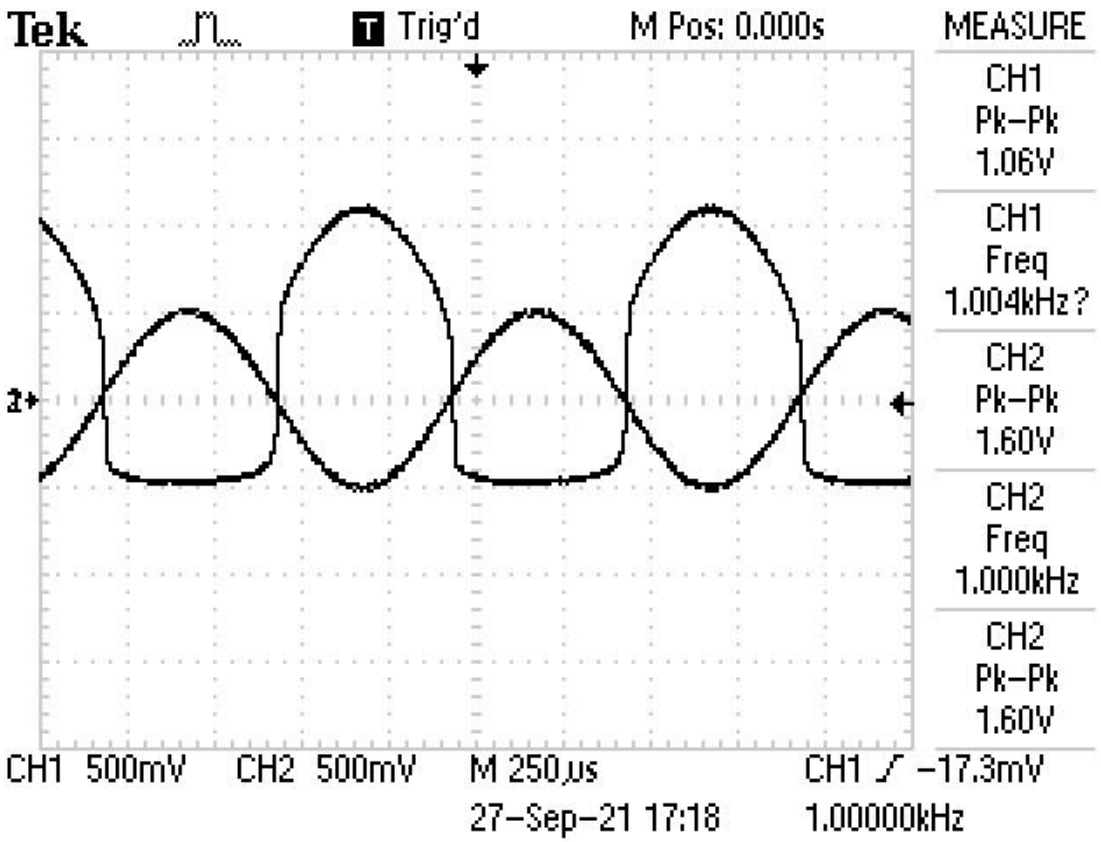


Improved half−wave rectifier−A

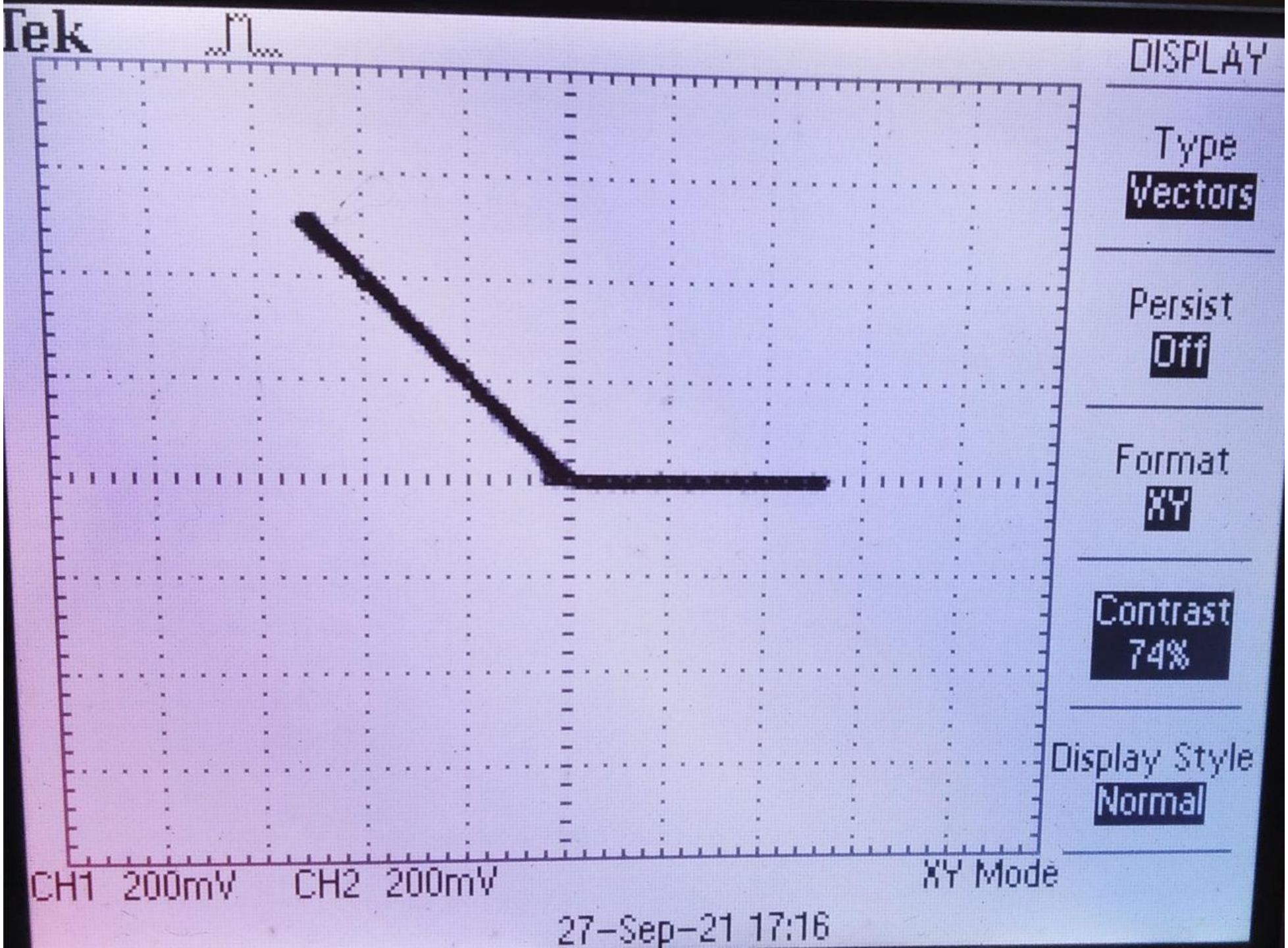
- One more diode introduced
- Opamp in linear region at all times
- Speeds improved


Tek
Trig'd
M Pos: 0.000s
MEASURE
CH1
Pk-Pk
1.05V
CH1
Freq
999.5Hz
CH2
Pk-Pk
544mV
CH2
Freq
999.0Hz
CH2
Pk-Pk
544mV
CH1 200mV
CH2 200mV
M 250µs
CH1 ƒ -17.3mV
27-Sep-21 17:14
999.999Hz

V_o

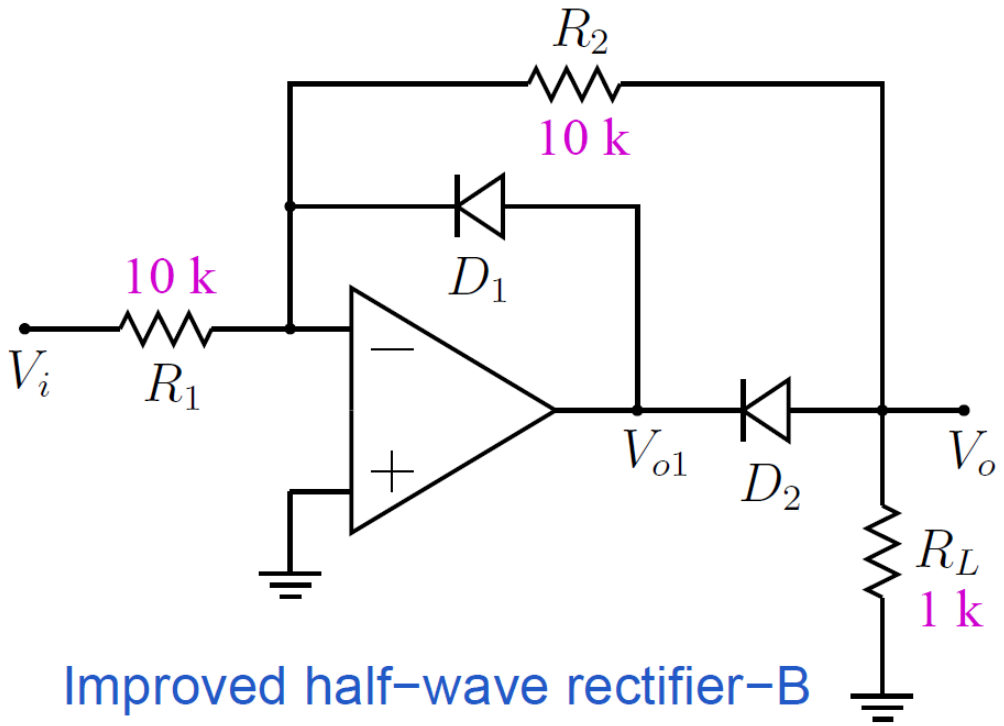

Tek
Trig'd
M Pos: 0.000s
MEASURE
CH1
Pk-Pk
1.06V
CH1
Freq
1.004kHz?
CH2
Pk-Pk
1.60V
CH2
Freq
1.000kHz
CH2
Pk-Pk
1.60V
CH1 500mV
CH2 500mV
M 250µs
CH1 ƒ -17.3mV
27-Sep-21 17:18
1.00000kHz

V_{o1}


Tek
DISPLAY
Type
Vectors
Persist
Off
Format
XY
Contrast
74%
Display Style
Normal
CH1 200mV
CH2 200mV
XY Mode
27-Sep-21 17:16

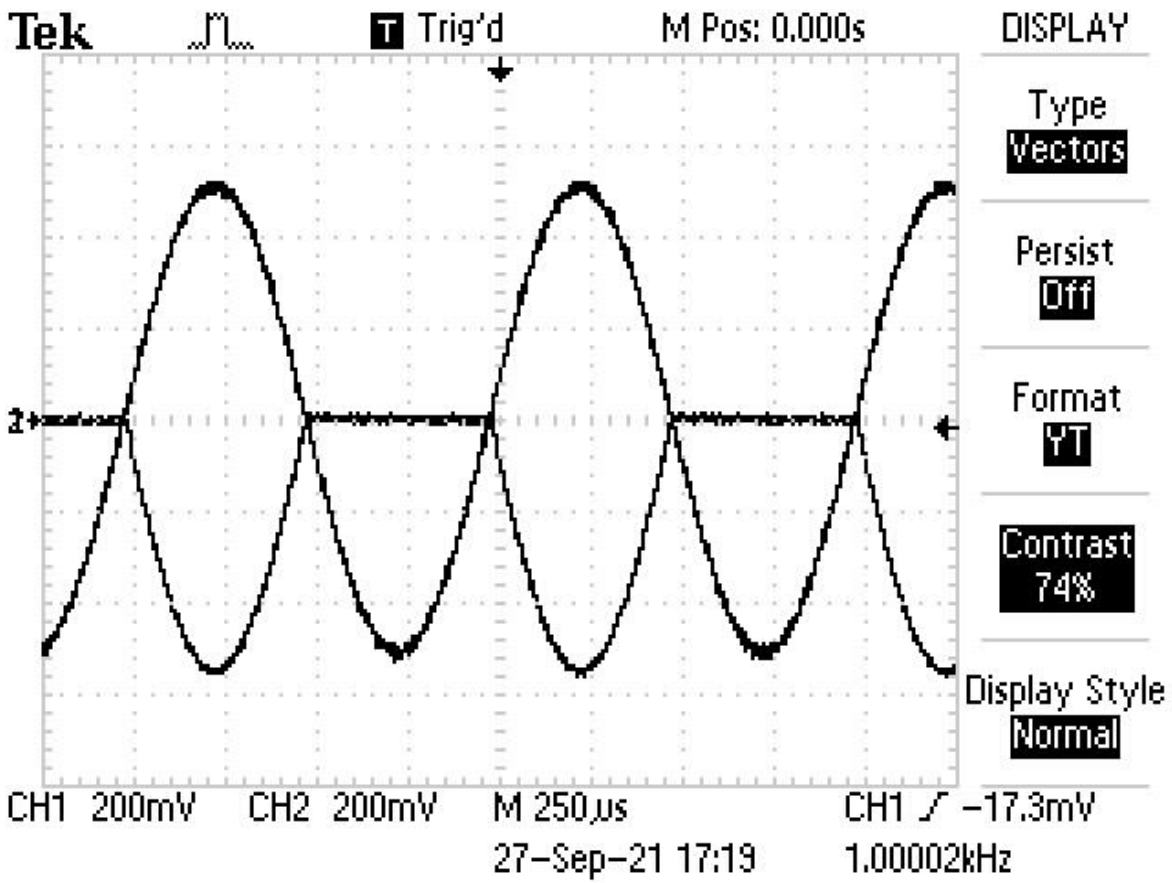
V_o vs V_i

Improved Half-wave Precision Rectifier (Circuit B)

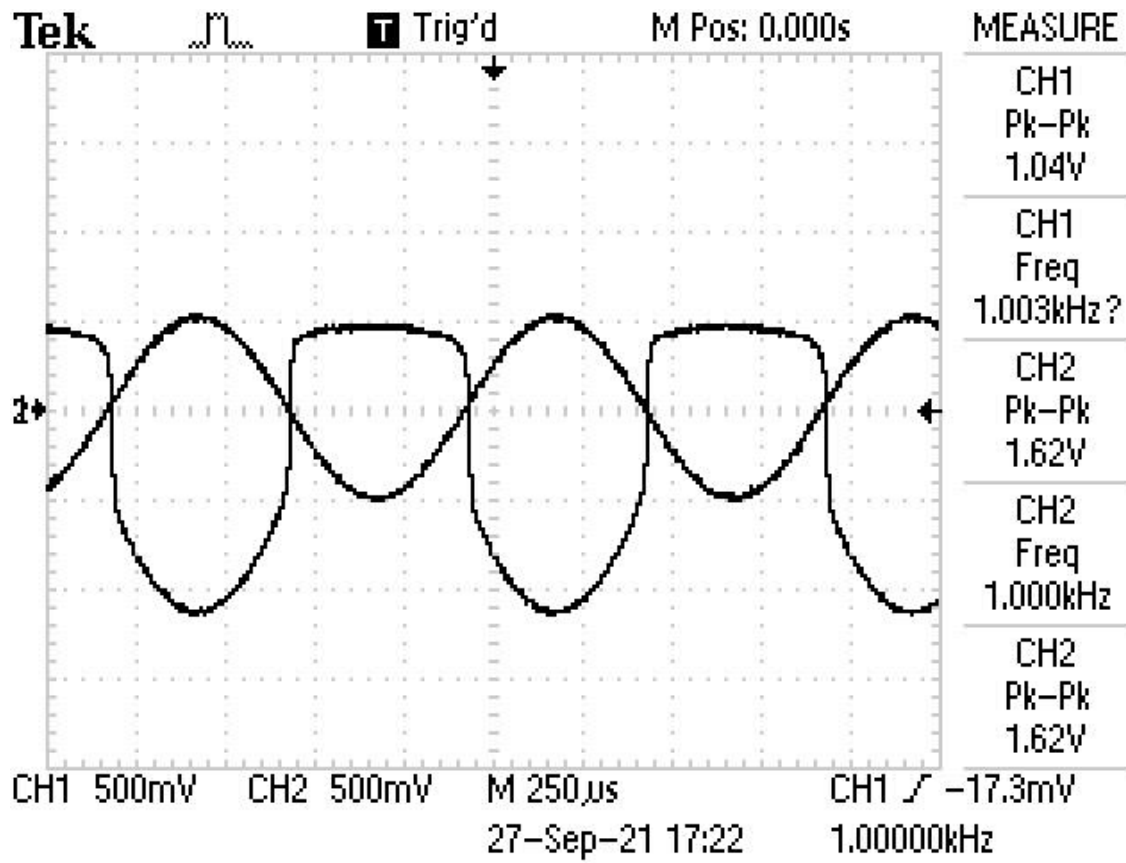


Improved half−wave rectifier−B

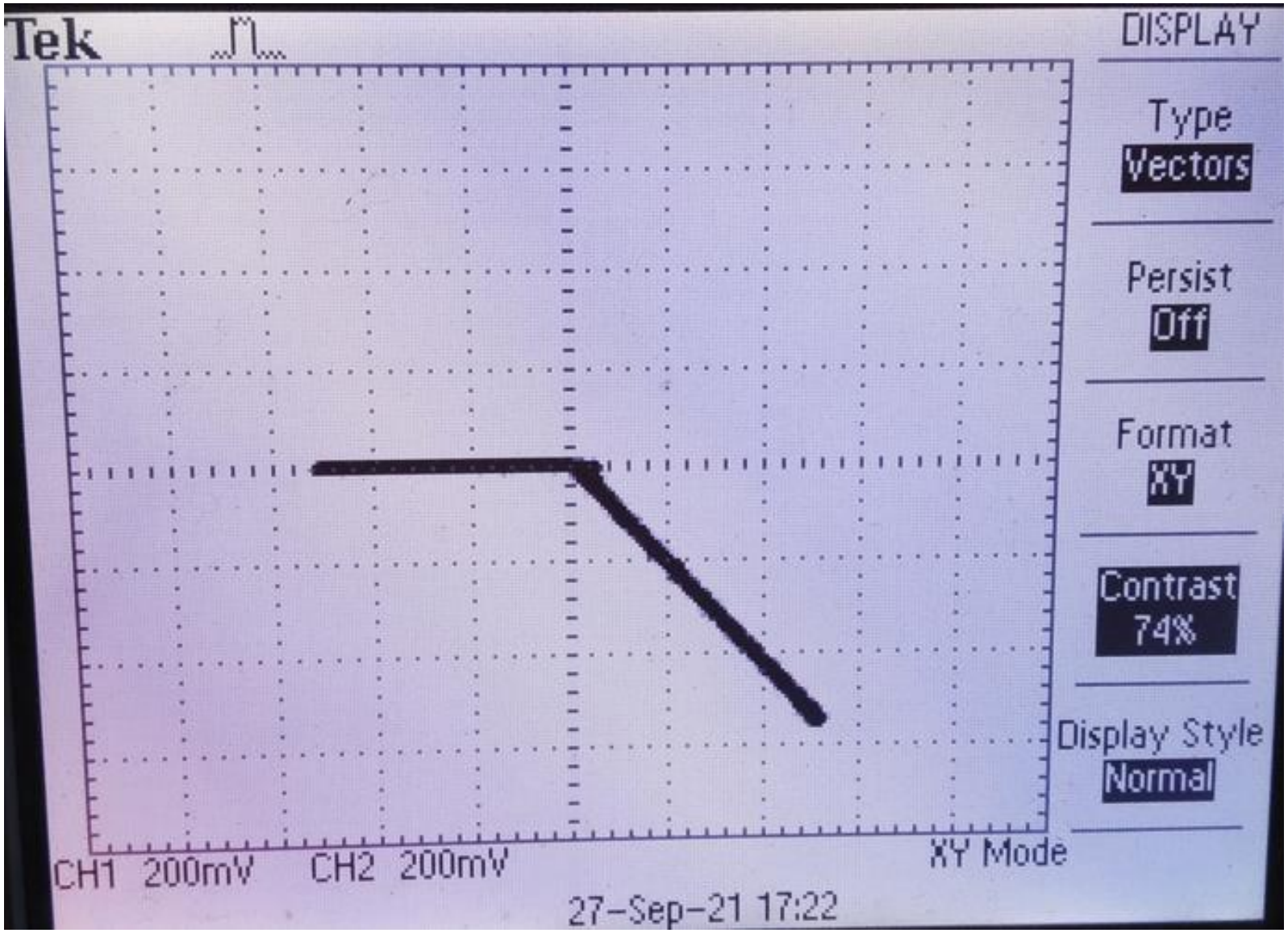
- One more diode introduced
- Opamp in linear region at all times
- Speeds improved


Tek
Trig'd
M Pos: 0.000s
DISPLAY
Type
Vectors
Persist
Off
Format
YT
Contrast
74%
Display Style
Normal
CH1 200mV
CH2 200mV
M 250µs
CH1 ƒ -17.3mV
27-Sep-21 17:19
1.00002kHz

V_o

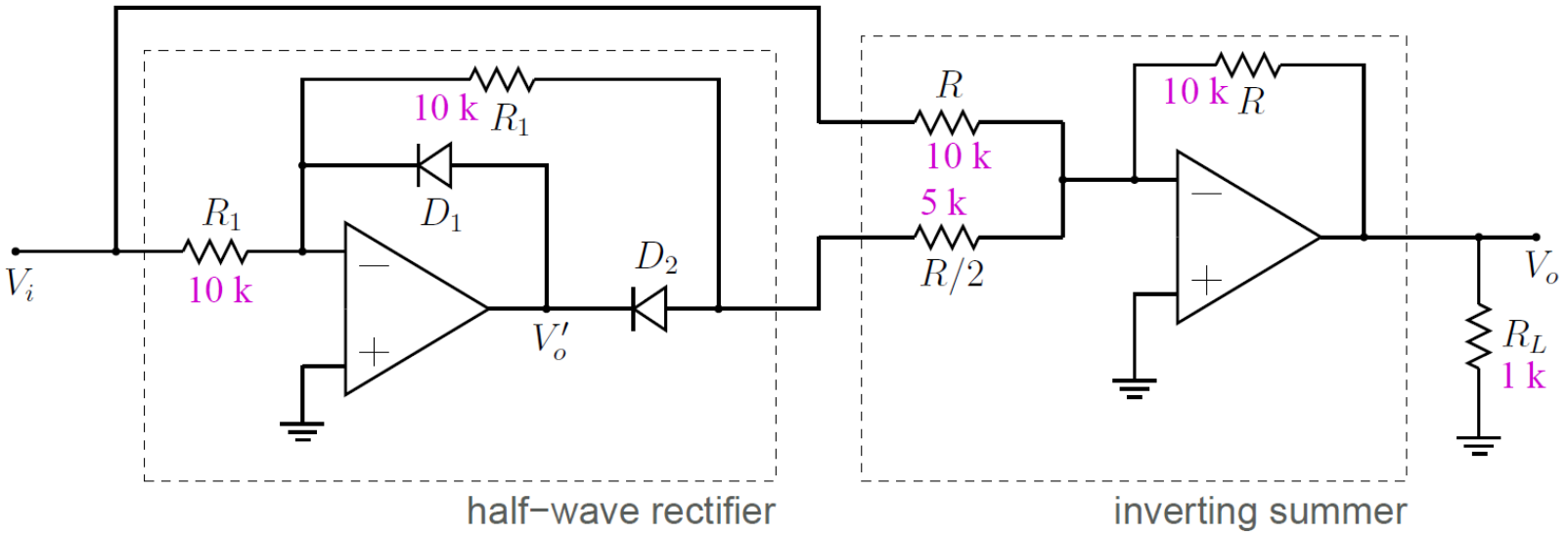

Tek
Trig'd
M Pos: 0.000s
MEASURE
CH1
Pk-Pk
1.04V
CH1
Freq
1.003kHz?
CH2
Pk-Pk
1.62V
CH2
Freq
1.000kHz
CH2
Pk-Pk
1.62V
CH1 500mV
CH2 500mV
M 250µs
CH1 ƒ -17.3mV
27-Sep-21 17:22
1.00000kHz

V_{o1}


Tek
DISPLAY
Type
Vectors
Persist
Off
Format
XY
Contrast
74%
Display Style
Normal
CH1 200mV
CH2 200mV
XY Mode
27-Sep-21 17:22

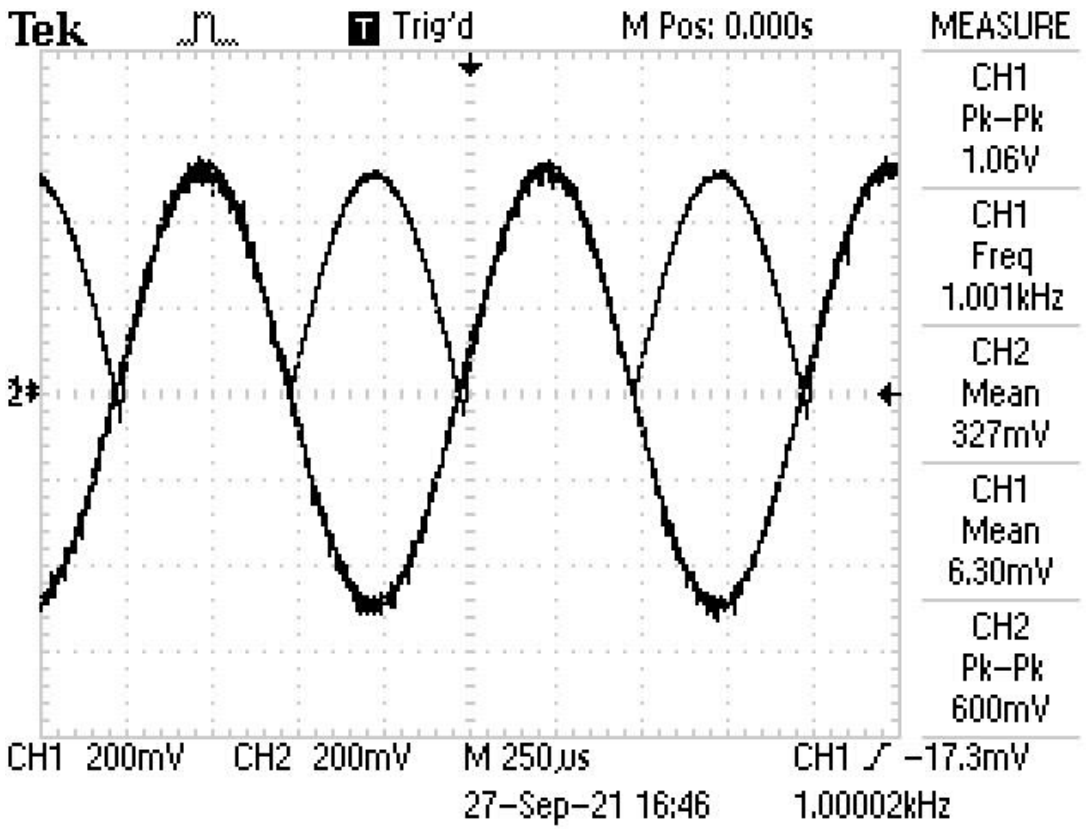
V_o vs V_i

Precision Full-wave Rectifier

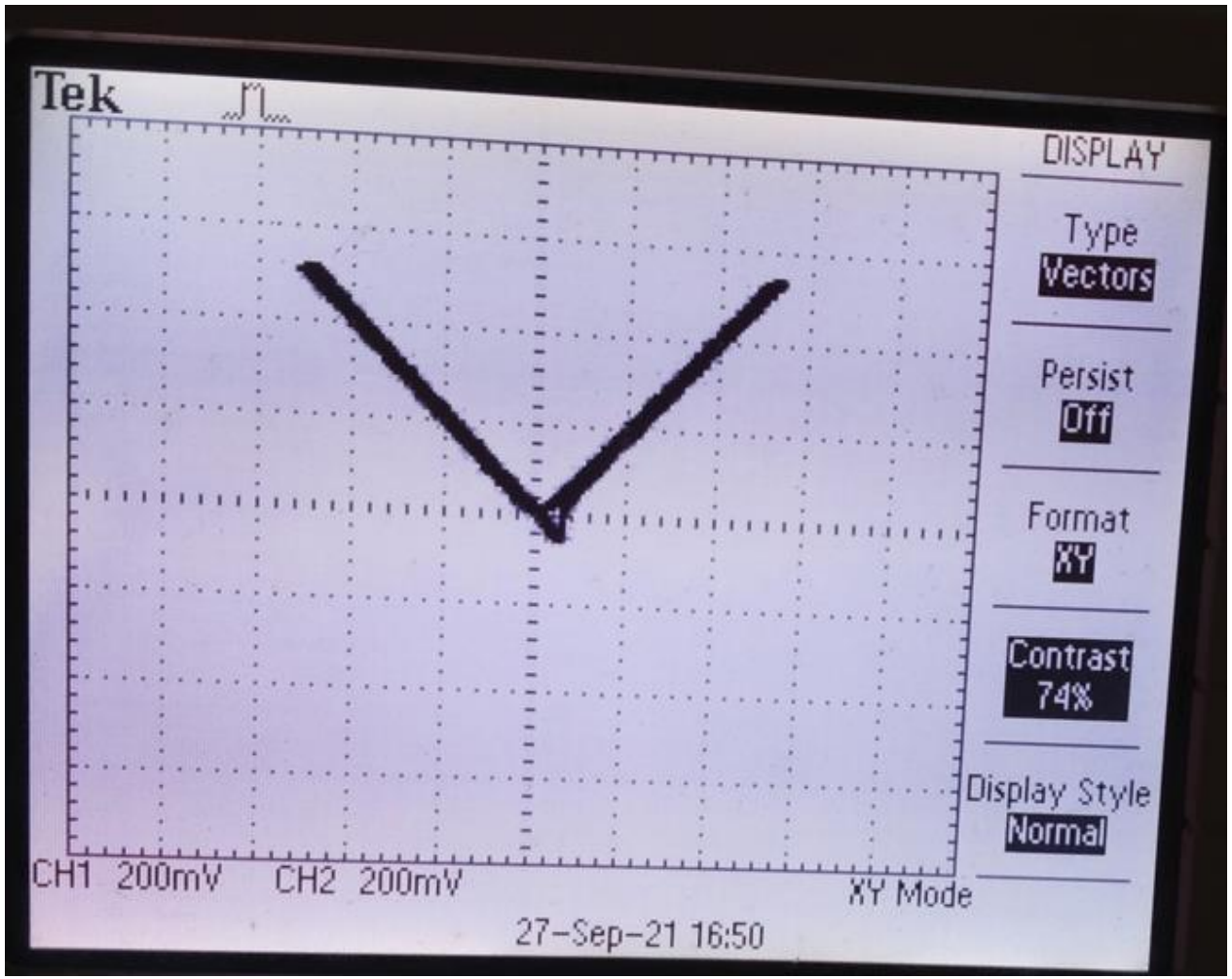


Full−wave rectifier

- Combination of a Half-wave and an inverting summer
- Half-wave rectifier output combined with Vi through a summer.

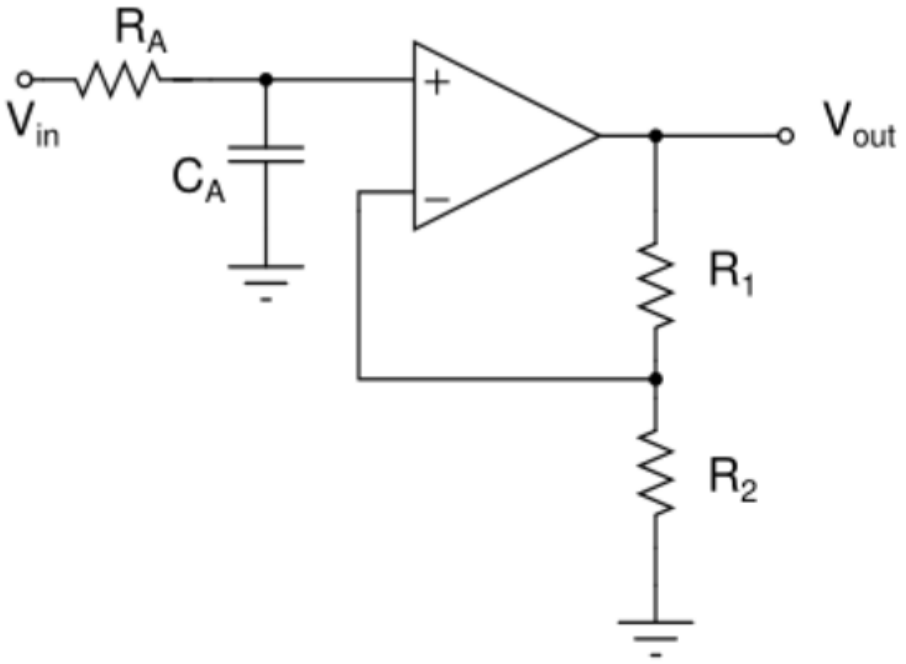

Tek
Trig'd
M Pos: 0.000s
MEASURE
CH1
Pk-Pk
1.06V
CH1
Freq
1.001kHz
CH2
Mean
327mV
CH1
Mean
6.30mV
CH2
Pk-Pk
600mV
CH1 200mV
CH2 200mV
M 250µs
CH1 -17.3mV
27-Sep-21 16:46
1.00002kHz

V_o


Tek
DISPLAY
Type
Vectors
Persist
Off
Format
XY
Contrast
74%
Display Style
Normal
CH1 200mV
CH2 200mV
XY Mode
27-Sep-21 16:50

V_o vs V_i

Single-pole Active Low-pass Filter



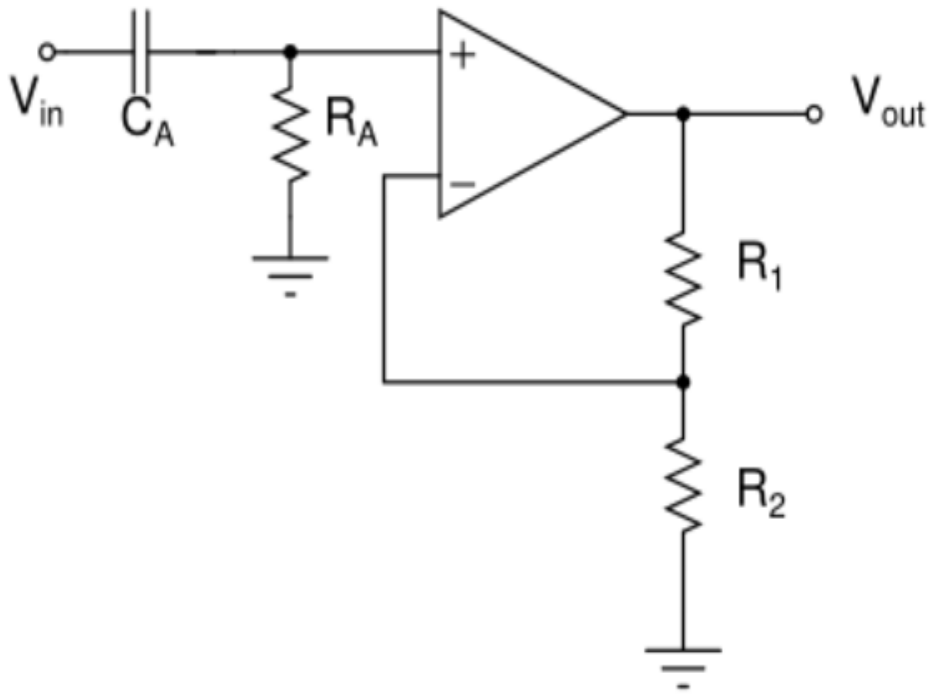
- Very popular
- Can avoid using inductors
- Gain can be provided
- RC filter + a non-inverting amplifier
- Single-pole (-20 dB/decade roll-off)

- Circuit values:

R_A = 4.7 kΩ, C_A = 0.1 µF, R_1 = 9.1 kΩ, R_2 = 1 kΩ

Voltage gain = 10

Single-pole Active High-pass Filter

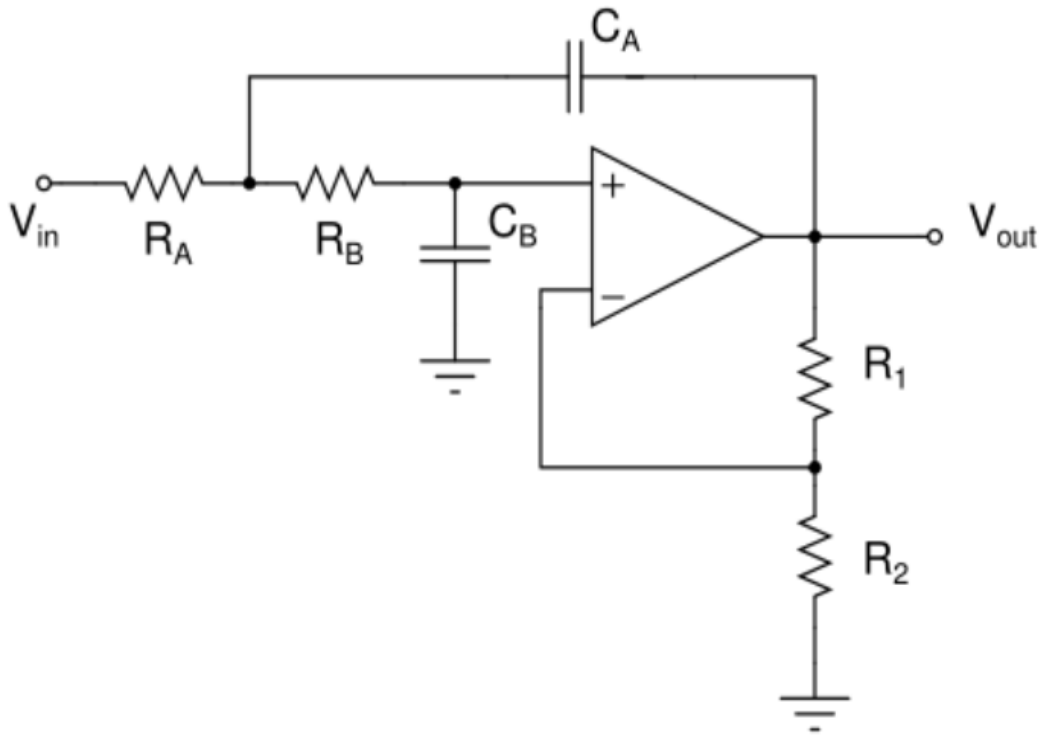


- RC filter + a non-inverting amplifier
- Single-pole (-20 dB/decade roll-off)
- Circuit values:

R_A = 4.7 kΩ, C_A = 0.1 µF,
R_1 = 9.1 kΩ, R_2 = 1 kΩ

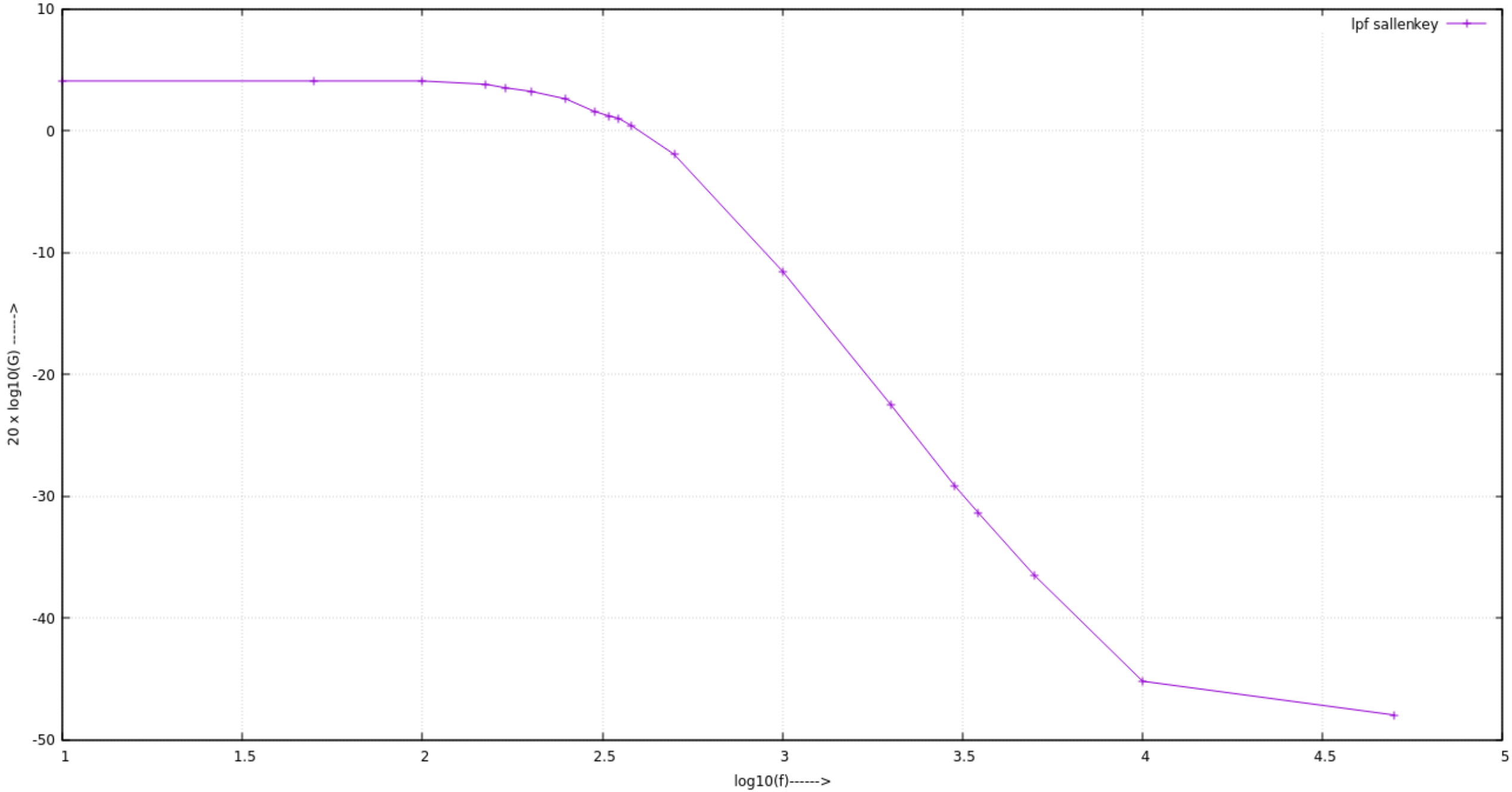
- Voltage gain = 10

Sallen-Key (2-pole) Active Low-pass Filter

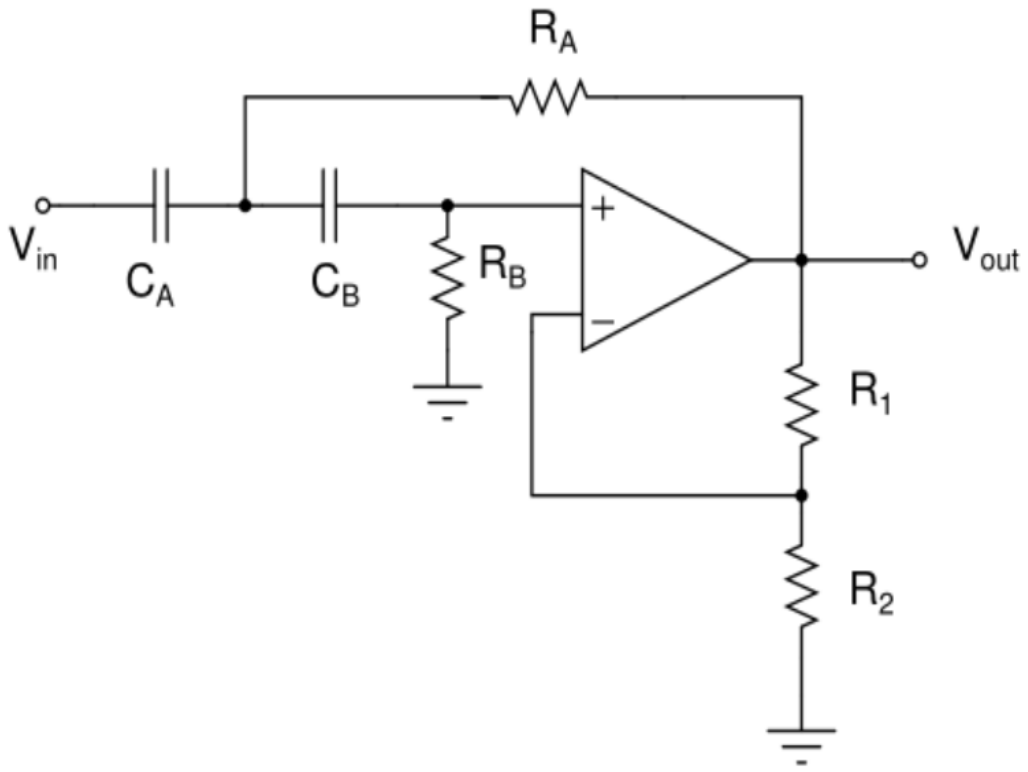


- 2-pole filter
- -40 dB/decade roll-off

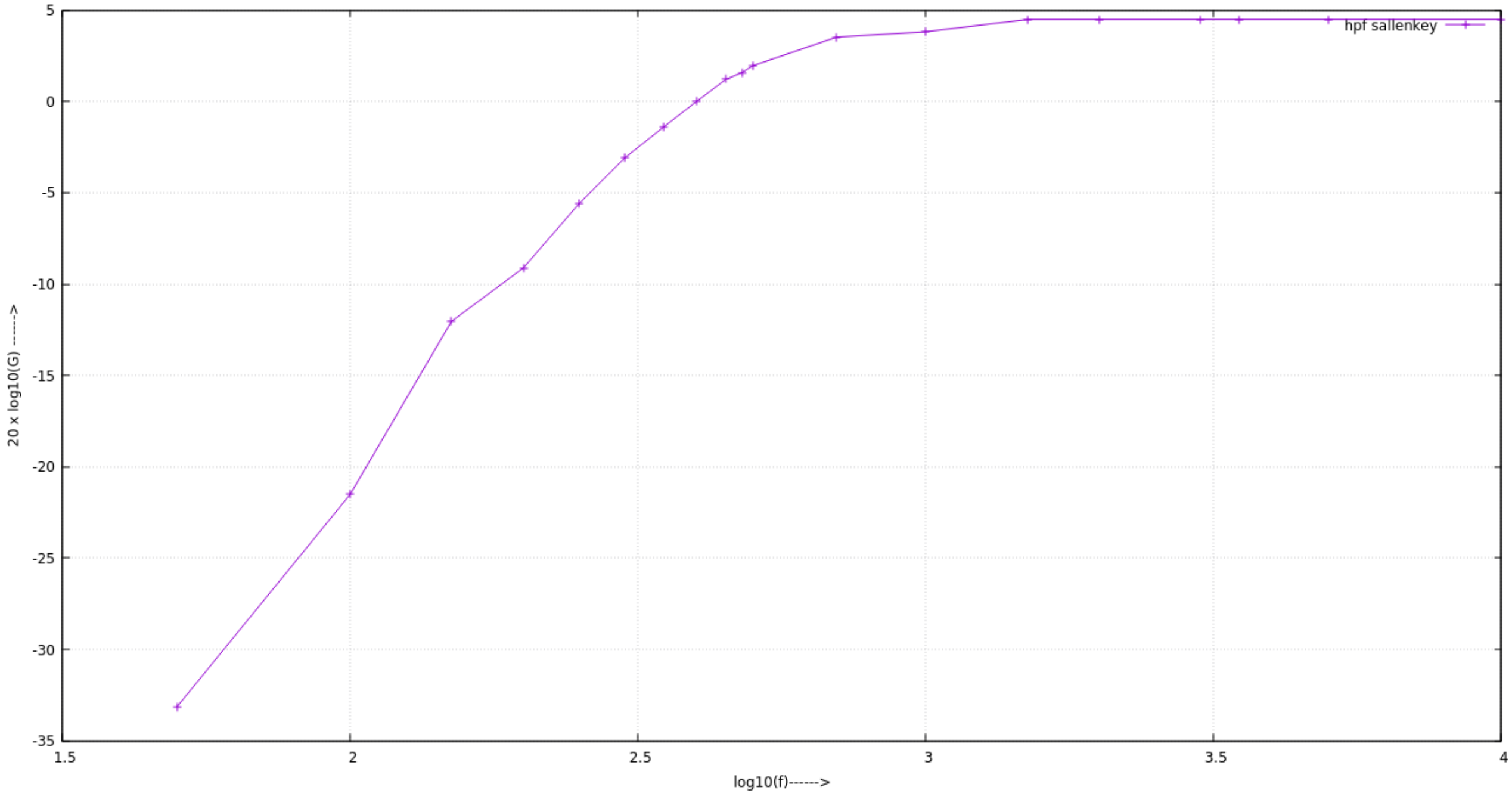
- Need to choose R_1 and R_2 carefully (to take care of damping factor)


lpf sallenkey
10
0
-10
-20
-30
-40
-50
1
1.5
2
2.5
3
3.5
4
4.5
5
20 x log10(G) ------>
log10(f)------>

Sallen-Key (2-pole) Active High-pass Filter



- 2-pole filter
- -40 dB/decade roll-off
- Need to choose R_1 and R_2 carefully (to take care of damping factor)


hpf sallenkey
20 x log10(G) ------>
log10(f)------>
5
0
-5
-10
-15
-20
-25
-30
-35
1.5
2
2.5
3
3.5
4

Announcements

- Expt Handout of Expt 8 (please use only Ver 3, Oct 1)
  - Mistakes corrected (Ver 2.1, Sep 29): Lab Report: both Precision Rectifiers and Active Filters
  - Mistakes corrected (Ver 3, Oct 1): Sec 2.2 and Sec 2.3 - R_1 = 9.1 kΩ, R_2 = 1 kΩ

- Doubts – both Expt 7 and Expt 8