Faculty of Engineering and Natural Sciences

Department of Electrical and Electronics Engineering

ELECTRONIC 2

Experiments Manual Report

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Lab Sheet

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Content

FET TRANSISTOR EXPERIMENTS

1. EXPERIMENTS

1.1 Biasing And Amplifier Circuits (Common Source)

1.2 Introductıon

Main objective of this experiment unit is to physically study working principles of common source biasing and amplifier circuits using FET transistor.

Although FET transistors are made of semiconductor materials, they have some advantages such as unipolar structure, high input impedance and better thermal stability over BJT transistors. However, their important disadvantage is that product of gain and bandwidth is lower than that of BJT transistor. Additionally, main difference of two kind transistors is FET transistor is voltage controlled whereas BJT transistor is current controlled.

In a biasing circuit using FET transistor input voltage is applied one terminal and output is obtained from another terminal of transistor. There are three different exapmles to biasing circuits in Figure 1, which contain same property. That is input is applied to gate terminal and output is obtained from drain terminal. In this condition biasing circuit is named as common source.

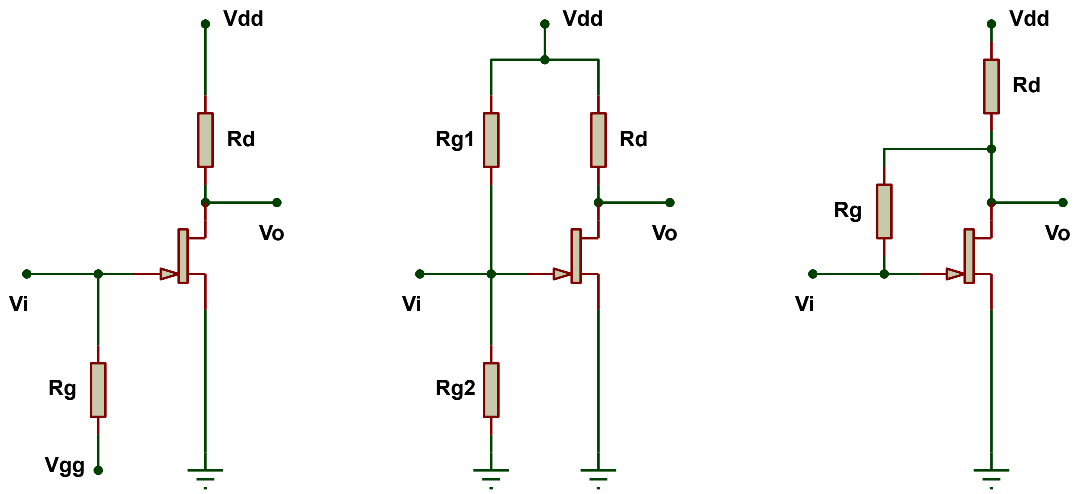


Figure 1. Common source biasing circuits using FET transistor without source resistor

Common source biasing circuits are more generally used than other type biasing circuits. That is because this biasing type provides more gain stability. It is also possible to use source resistor in common source biasing circuits in order to increase gain stability. In that case former examples are as in Figure 2.

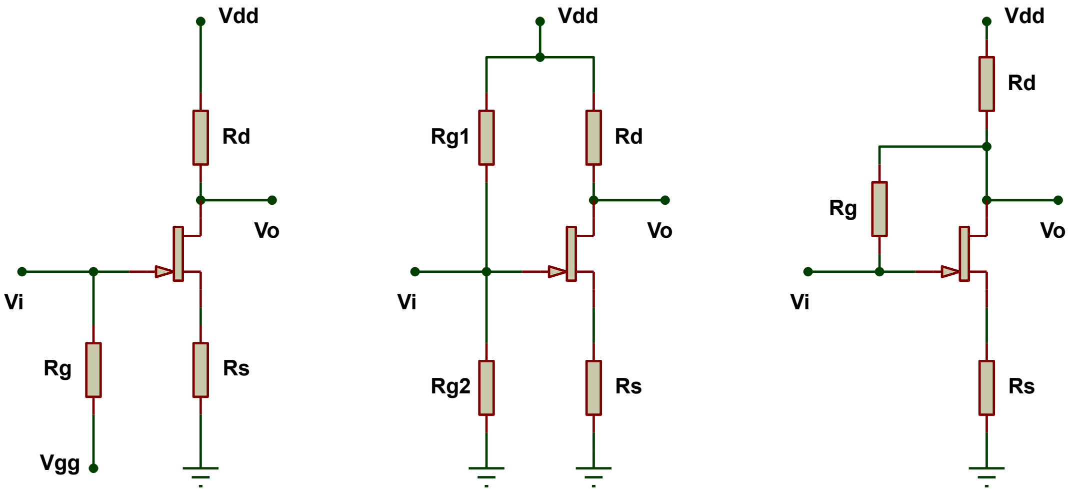


Figure 2. Common source biasing circuits using FET transistor with source resistor

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- FET transistor
- Vi = 1V, 1KHz, Sinus
- Rg = 1 MΩ
- Rd = 2,2 KΩ
- Rs = 1 KΩ
- C = 1 µF

Experiment 1

- Build the circuit in Figure 3 on breadboard without applying AC signal.
- Fill in Table 1 when V_{DD} = 12V.
- Draw in scale I_D versus V_{GS} graphic on a squared lines paper.
- Fill in Table 2 when V_{GG} = 12V.
- Draw in scale I_D versus V_{DS} graphic on a squared lines paper.

Experiment 2

- Build the circuit in Figure 3 on breadboard with applying AC signal (1V, 1KHz, Sinus) when V_{DD} = 12V and V_{GG} = -5V.
- Measure output voltage with oscilloscope.
  - V_o =
- Calculate voltage gain.
  - $A_V = V_o / V_i$ =

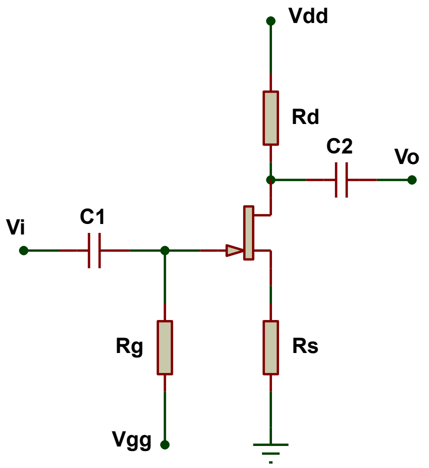


Figure 3. Common source biasing circuit using FET transistor

Table 1. I_D and V_{DS} values, V_{DD} = 12V

V_{GG} (V)	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
I_D (mA)												
V_{GS} (V)												
V_{DS} (V)												

Table 2. I_D and V_{DS} values, V_{GG} = -12V

V_{DD} (V)	1	2	3	4	5	6	7	8	9	10	11	12
I_D (mA)												
V_{GS} (V)												
V_{DS} (V)												

2.EXPERIMENTS

2.1 Biasing And Amplifier Circuits (Common Drain)

2.2. Introductıon

Main objective of this experiment unit is to physically study working principles of common drain biasing and amplifier circuits using FET transistor.

There are two different exapmles to biasing circuits in Figure 4, which contain same property. That is input is applied to gate terminal and output is obtained from source terminal. In this condition biasing circuit is named as common source.

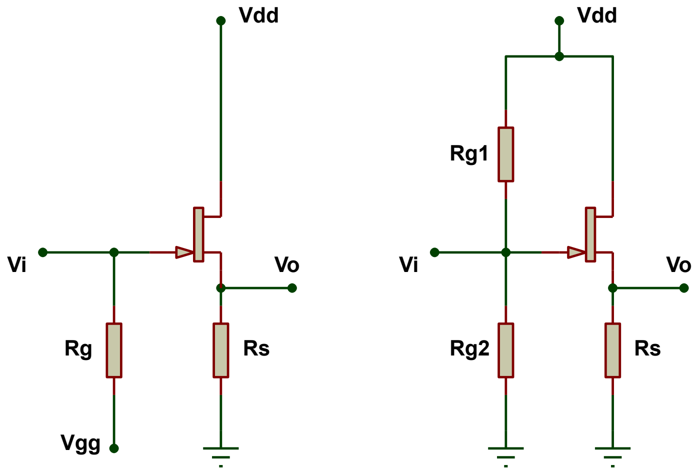


Figure 4. Common drain biasing circuits using FET transistor

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- FET transistor
- Vi = 1V, 1KHz, Sinus
- Rg = 1 MΩ
- Rs = 1 KΩ
- C = 1 μF

Experiment 1

- Build the circuit in Figure 5 on breadboard without applying AC signal.
- Fill in Table 3 when V_{DD} = 12V.
- Draw in scale I_D versus V_{GS} graphic on a squared lines paper.
- Fill in Table 4 when V_{GG} = 12V.

- Draw in scale I_D versus V_{DS} graphic on a squared lines paper.

Experiment 2

- Build the circuit in Figure 5 on breadboard with applying AC signal (1V, 1KHz, Sinus) when V_{DD} = 12V and V_{GG} = -5V.
- Measure output voltage with oscilloscope.
  - V_o =
- Calculate voltage gain.
  - $A_V = V_o / V_i$ =

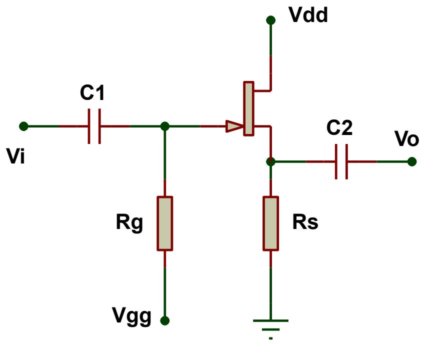


Figure 5. Common drain biasing circuit using FET transistor

Table 3. I_D and V_{DS} values, V_{DD} = 12V

V_{GG} (V)	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
I_D (mA)												
V_{GS} (V)												
V_{DS} (V)												

Table 4. I_D and V_{DS} values, V_{GG} = -12V

V_{DD} (V)	1	2	3	4	5	6	7	8	9	10	11	12
I_D (mA)												
V_{GS} (V)												
V_{DS} (V)												

3.EXPERIMENTS

3.1 Biasing And Amplifier Circuits (Common Gate)

3.2 Introduction

Main objective of this experiment unit is to physically study working principles of common gate biasing and amplifier circuits using FET transistor.

There is exapmle to biasing circuits in Figure 6. Input is applied to source terminal and output is obtained from drain terminal. In this condition biasing circuit is named as common drain.

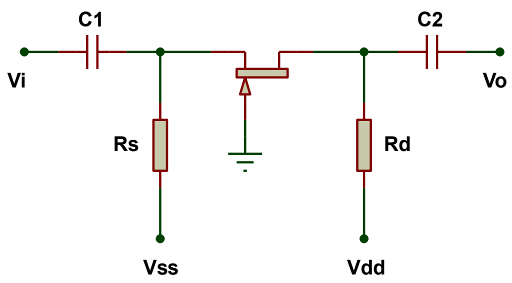


Figure 6. Common gate biasing circuit using FET transistor

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- FET transistor
- Vi = 1V, 1KHz, Sinus
- Rd = 2,2 KΩ
- Rg = 1 MΩ
- Rs = 1 KΩ
- C = 1 µF

Experiment 1

- Build the circuit in Figure 6 on breadboard without applying AC signal.
- Fill in Table 5 when V_{DD} = 12V.
- Draw in scale I_D versus V_{GS} graphic on a squared lines paper.
- Fill in Table 6 when V_{SS} = 12V.
- Draw in scale I_D versus V_{DS} graphic on a squared lines paper.

Experiment 2

- Build the circuit in Figure 6 on breadboard with applying AC signal (1V, 1KHz, Sinus) when V_{DD} = 12V and V_{SS} = -5V.
- Measure output voltage with oscilloscope.

- V_o =

- Calculate voltage gain.
    - $A_V = V_o / V_i$ =

Table 5. I_D and V_{DS} values, V_{DD} = 12V

V_{GG} (V)	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12
I_D (mA)												
V_{GS} (V)												
V_{DS} (V)												

Table 6. I_D and V_{DS} values, V_{SS} = -12V

V_{DD} (V)	1	2	3	4	5	6	7	8	9	10	11	12
I_D (mA)												
V_{GS} (V)												
V_{DS} (V)												

4.EXPERIMENTS

4.1 Multistage Amplifier Circuits

4.2 Introduction

Main objective of this experiment unit is to physically study working principles of multistage amplifier circuits using FET transistor.

Biasing circuits using FET transistor are generally designed to work in middle frequency region. However, gain decreases in low and high frequency regions due to capasitive effects depending on frequency values. Conclusively, multistage amplifier circuits are employed to increase gain. These circuits consist of more than one transistor and each stage can be same or different in terms of common source, common drain and common gate configurations.

There is exapmle to multistage circuits in Figure 7. Common source configuration is employed in each stage. Voltage is applied to input of first stage circuit and voltage is obtained from output of second stage circuit. Gain is equal to product of each gain of stages.

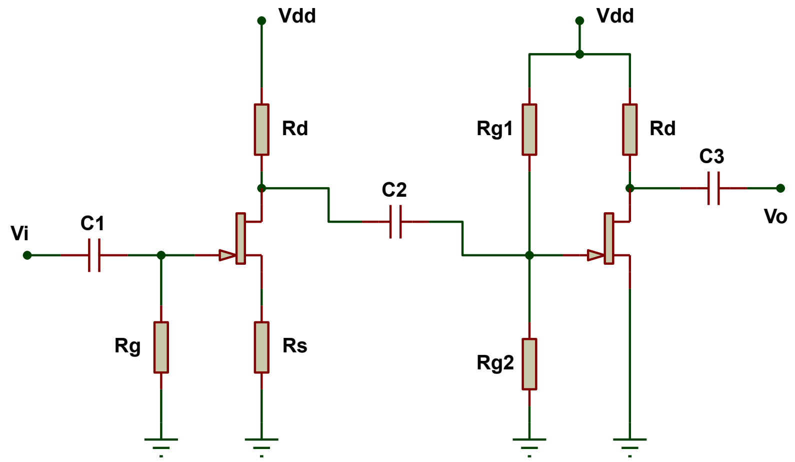


Figure 7. Multistage amplifier circuit using FET transistor

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- FET transistor
- Vdd = 12V
- Rd = 2,2 KΩ
- Rg = 1 MΩ
- Rs = 1 KΩ
- C = 1 µF

Experiment 1

- Build the circuit in Figure 7 on breadboard.
- Apply AC voltage (1V, 1KHz, Sinus) to input, measure output voltage with oscilloscope and calculate voltage gain.
  - Vi = 1V, 1KHz, Sinus
  - Vo =
  - Av = Vo / Vi =

5.EXPERIMENTS

5.1 Cutoff Frequencies Of Amplifier Circuits

5.2 Introduction

Main objective of this experiment unit is to physically study working principles of frequency response of amplifier circuits using FET transistor.

A general circuit is accepted to work adequately if it produces output power at least half or more. Output voltage must be at 0.707 rate or more in this condition considering that voltage and current are directly proportinal in accordance with ohm law and power defition is product of voltage and current. This rate can be accepted %70. Additionally it is also named as 3dB decrasing of output voltage in logarithmic-time domain. Working of circuit in this limit determines its cutoff frequency value.

Biasing circuits using FET transistor are generally designed to work in middle frequency region. However, gain decreases in low and high frequency regions due to capasitive effects depending on frequency values. Region of lower frequencies than low cutoff frequency is named as low frequency range. In this range input and output capacitors cause to decrease gain. On the contrary, range of higher frequencies than high cutoff frequency is named as high frequency range. In this range input and output capacitors have very low impedance values. However, capacitive effects between terminals such as Cgs, Cgd and Cds occur and they cause to decrease gain. Conclusively, most productive region is middle frequency region for amplifier circuits which is limited through low cutoff frequency and high cutoff frequency values.

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- FET transistor
- Vdd = 12V
- Rd = 2,2 KΩ
- Rg1 = 1 MΩ
- Rg2 = 100 KΩ
- Rs = 1 KΩ
- C = 1 μF

Experiment 1

- Build the circuit in Figure 8 on breadboard.
- Apply AC voltage (1V, 1Hz, Sinus) to input and measure output voltage with oscilloscope.
- Increase frequency until V_o / V_i = %70 and determine cutoff frequency.
    - V_i = 1V, 1Hz, Sinus
    - V_0 = 0.7V, 1Hz, Sinus
    - f_L =

Experiment 2

- Build the circuit in Figure 8 on breadboard.
- Apply AC voltage (1V, 1MHz, Sinus) to input and measure output voltage with oscilloscope.
- Decrease frequency until V_o / V_i = %70 and determine cutoff frequency.
  - V_i = 1V, 1Hz, Sinus
  - V_0 = 0.7V, 1Hz, Sinus
  - f_H =

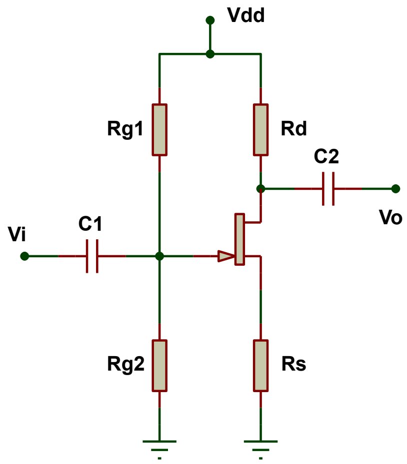


Figure 8. Common source biasing circuit using FET transistor

OPAMP EXPERIMENTS

6.EXPERIMENTS

6.1 Amplifier Circuits

6.2 Introduction

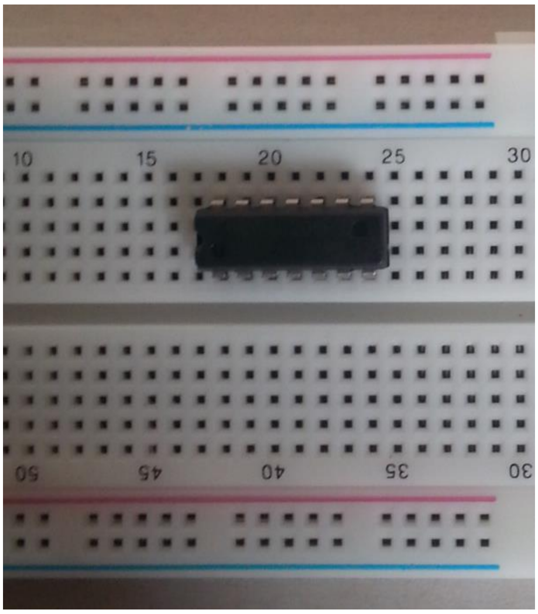
Main objective of this experiment unit is to physically study working principles of inverting, non-inverting and alternance amplifier circuits using opamp.

Opamp terminals and how to place them on breadboard must be well known before starting circuit experiments using opamp. Opamp terminals are listed in Table 7.

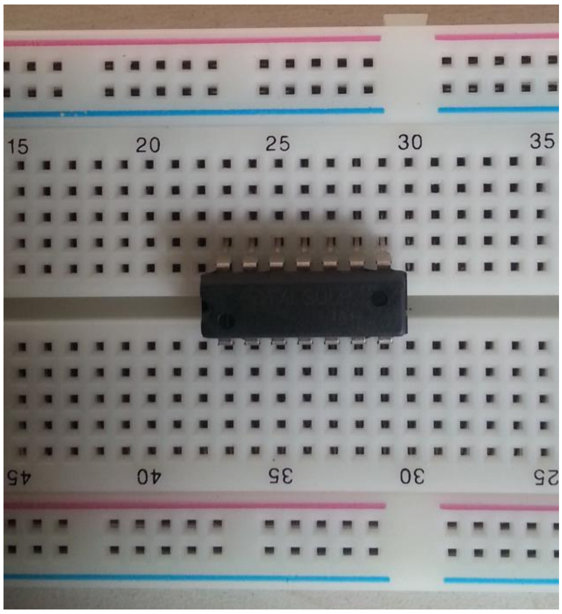
Table 7. Opamp terminals

Pin number	Terminal name
1	negative off-set
2	negative input
3	positive input
4	negative supply
5	positive offset
6	output
7	positive supply
8	test or empty

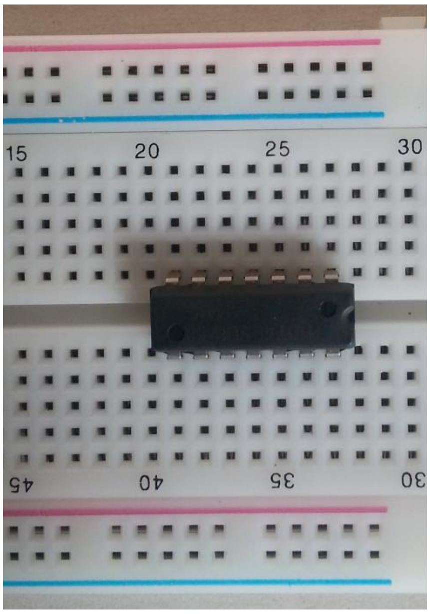
Four different samples to place opamp on breadboard are shown in Figure 9. Although not being opamp, it represents opamp placing because integrateds have similar placing rules. In examine these exapmles, first sample (a) is wrong placed because opposite terminals are short-circuited. Second sample (b) is also wrong placed due to the fact that top terminals are not placed on the nearest line. Opamp terminals both on top and bottom must be placed the nearest line on breadboard, otherwise opamp is not completely placed and contacting errors occur. Third sample (c) is not technically wrong, as a matter of fact opamp, is placed upside down, thus this sample is not recommended. Fourth sample (d) is true in the end. Conclusively, notch mark of opamp must be in left side and terminals placed the nearest lines.



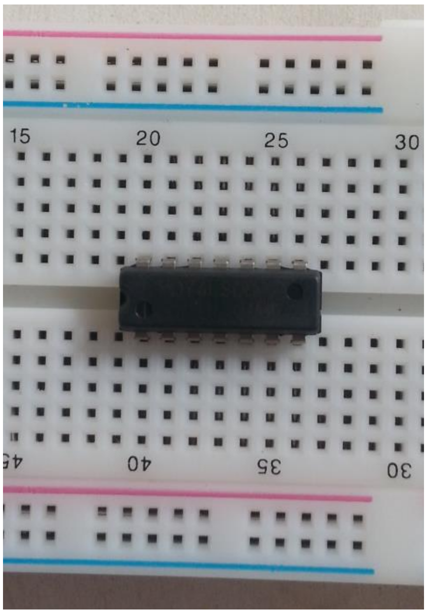
a)



b)



c)



d)

Figure 9. Opamp placing examples on breadboard

In Figure 10, inverting amplifier circuit using opamp is shown. This circuit has negative feedback and that is because its structure is named as closed-loop. Such a circuit has more input impedance and less output impedance values over open-loop opamp circuit. Ground voltage is virtually held in positive input because the difference of input values is very small, it can be accepted as zero in closed-loop opamp circuit. When input voltage is applied, input current reaches virtual ground voltage point and completely flows output with passing through feedback resistor due to very high input resistor value of opamp. For this reason, opamp output voltage is represented as in equation 1. Minus sign in the equation indicates 180º phase difference between input and output voltages.

$$A_V = \frac{-R_f}{R_i} \times V_i \quad (1)$$

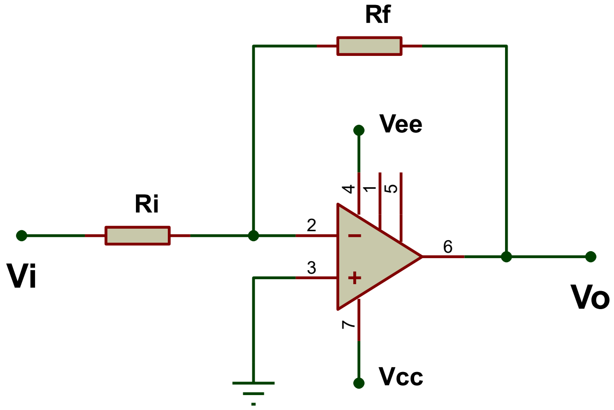


Figure 10. Inverting amplifier circuit using opamp

Non-inverter amplifier circuit using opamp is displayed in Figure 11. This circuit also has feedback and so it has as similar input and output impedance values as does inverting circuit in terms of open-loop condition. Input voltage is virtually held in negative input due to reasons explained in former circuit. When input voltage is applied, current flows in opposite direction this time. Current reaches virtual input voltage point and completely flows ground with passing through input resistor due to very high input resistor value of opamp. For this reason, opamp output voltage is represented as in equation 2. There is not minus sign in the equation and it indicates that contrary to inverter circuit, there is no phase difference between input and output voltages.

$$A_V = (1 + \frac{R_f}{R_i}) \times V_i \quad (2)$$

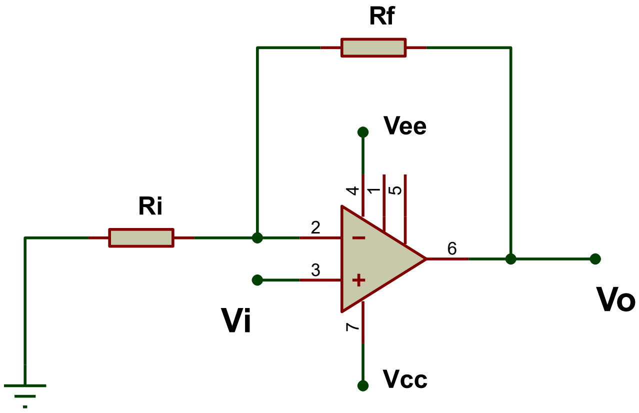


Figure 11. Non-inverting amplifier circuit using opamp

It can be necessary that positive and negative alternances of input voltage are differently amplified. In that case, feedback must be provided for both alternances through different conductive paths. For this purpose, diodes can be used to obtain different feedbacks. Conclusively, alternance amplifier circuit using opamp is as in Figure 12. Opamp output voltage is represented as in equation 3 and equation 4.

$$A_{V+} = \frac{-R_{f+}}{R_i} \times V_i \quad (3)$$

$$A_{V-} = \frac{-R_{f-}}{R_i} \times V_i \quad (4)$$

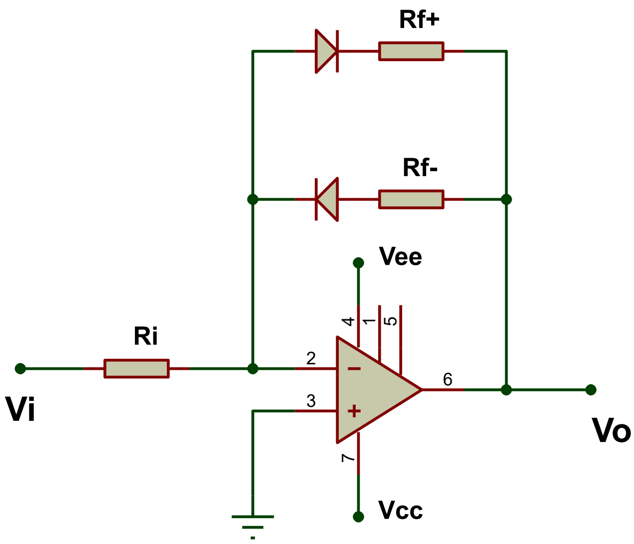


Figure 12. Alternance amplifier circuit using opamp

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- Opamp
- Diodes
- Vcc / Vee = ±12V
- Rf = 4,7 KΩ
- Rf- = 4,7 KΩ
- Rf+ = 8,6 KΩ
- Ri = 2,2 KΩ

Experiment 1

- Build the circuit in Figure 10 on breadboard.
- Apply DC voltage (1V) to input, measure output voltage with multimeter and calculate voltage gain.
  - V_i = 1V
  - V_o =
  - $A_v = V_o / V_i$ =
- Apply AC voltage (1V, 1KHz, Sinus) to input, measure output voltage with oscilloscope and calculate voltage gain.
  - Vi = 1V, 1KHz, Sinus
  - Vo =
  - Av = Vo / Vi =

Experiment 2

- Build the circuit in Figure 11 on breadboard.
- Apply DC voltage (1V) to input, measure output voltage with multimeter and calculate voltage gain.
  - Vi = 1V
  - Vo =
  - Av = Vo / Vi =
- Apply AC voltage (1V, 1KHz, Sinus) to input, measure output voltage with oscilloscope and calculate voltage gain.
  - Vi = 1V, 1KHz, Sinus
  - Vo =
  - Av = Vo / Vi =

Experiment 3

- Build the circuit in Figure 12 on breadboard.
- Apply AC voltage (1V, 1KHz, Sinus) to input, measure output voltage with oscilloscope, calculate voltage gain for both alternances.
  - Vi+ = 0.5V, 1KHz, Sinus
  - Vi- = -0.5V, 1KHz, Sinus
  - Vo+ =
  - Vo- =
  - Av+ = Vo+ / Vi- =
  - Av- = Vo- / Vi+ =

7.EXPERIMENTS

7.1 Adder and Subtractor Circuits

7.2 Introduction

Main objective of this experiment unit is to physically study working principles of adder and subtractor circuits using opamp.

The circuit in Figure 1 has two negative inputs and it is similar to inverter circuit. Output voltage of this circuit is represented as in equation 5.

$$V_o = -\frac{R_3}{R_1} \times V_{i1} - \frac{R_3}{R_2} \times V_{i2} \quad (5)$$

If all resistors are used as $R = R_1 = R_2 = R_3$, output voltage is held as in equation 6. Minus sign in the equation indicates 180° phase difference between input and output voltages. In this condition the circuit in figure 13 can be named as adder circuit using opamp.

$$V_o = -(V_{i1} + V_{i2}) \quad (6)$$

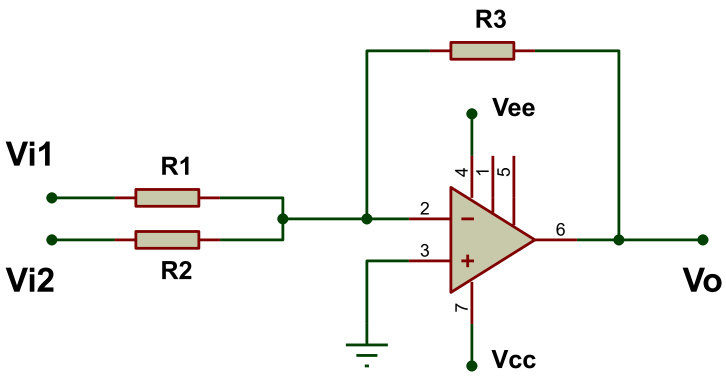


Figure 13. Adder circuit using opamp

The circuit in Figure 14 has both positive and negative inputs. Output voltage of this circuit is represented as in equation 7.

$$V_o = -\frac{R_3}{R_1} \times V_{i1} + (1 + \frac{R_3}{R_2})(\frac{R_4}{R_3+R_4}) \times V_{i2} \quad (7)$$

If all resistors are used as $R = R_1 = R_2 = R_3 = R_4$, output voltage is held as in equation 8. There is not minus sign in the equation and it indicates that there is no phase difference between input and output voltages. In this condition the circuit in figure 1 can be named as subtractor circuit using opamp.

$$V_o = (V_{i2} - V_{i1}) \quad (8)$$

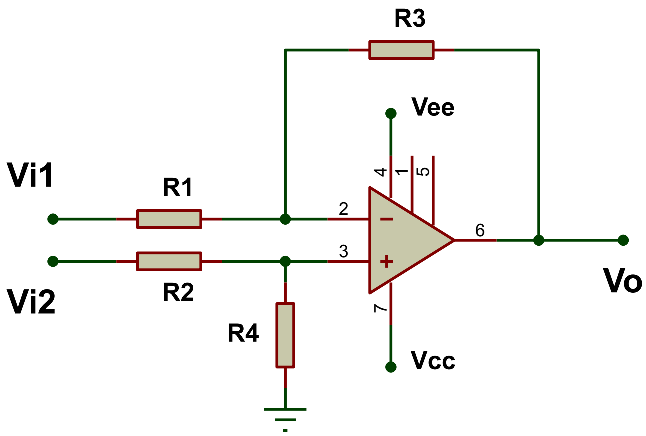


Figure 14. Subtractor circuit using opamp

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- Opamp
- Vcc / Vee = ±12V
- R = 2,2 KΩ

Experiment 1

- Build the circuit in Figure 13 on breadboard.
- Apply DC voltages (V_{i1} = 5V, V_{i2} = 1V) to inputs and measure output voltage with multimeter.
  - V_{i1} = 5V
  - V_{i2} = 1V
  - V_o =

Experiment 2

- Build the circuit in Figure 14 on breadboard.
- Apply DC voltages (V_{i1} = 5V, V_{i2} = 1V) to inputs and measure output voltage with multimeter.
  - V_{i1} = 5V
  - V_{i2} = 1V
  - V_o =

8.EXPERIMENTS

8.1 Derivator and Integrator Circuits

8.2 Introduction

Main objective of this experiment unit is to physically study working principles of derivator and integrator circuits using opamp.

Derivator circuit produces output being directly proportional to rate of change of input voltage. If there is no change in input voltage, circuit doesn't produce output. Basic derivator circuit using opamp is shown in Figure 15. Output is higher if input fastly changes. On the other hand, output is lower if input slowly changes. Conclusively, output voltage is defined as in equation 9.

$$V_o = -R_f.C.\frac{dV_i}{dt} \tag{9}$$

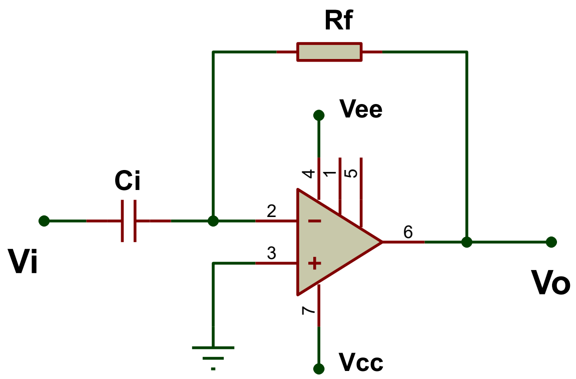


Figure 15. Basic derivator circuit using opamp

Main problem of basic derivator circuit is that impedance of capacitor decreases with increasing frequency. So circuit doesn't work properly in high frequencies. Improved derivator circuit is displayed in Figure 16. Ri- resistor is added to circuit's properly working in high frequency range. Maksimum high frequency value is determined in equation 10. Additionally, Ri+ resistor is used for current compensation.

$$f_{max} = \frac{1}{2.\pi.R_{i-}.C} \tag{10}$$

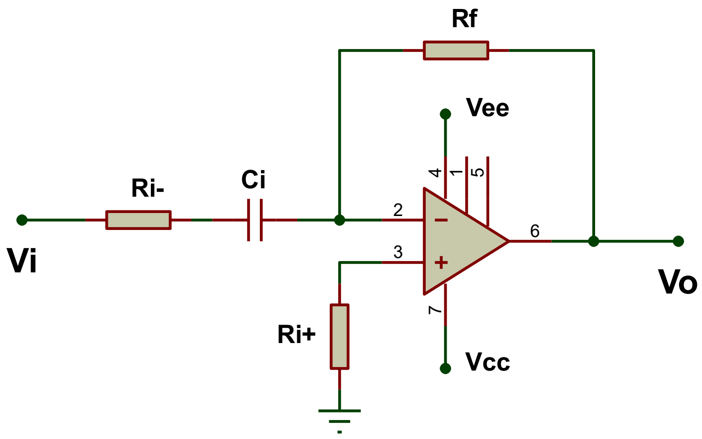


Figure 16. Improved derivator circuit using opamp

Integrator circuit is obtained if resistor and capacitor change their places. Integrator circuit produces output being reversely proportional to rate of change of input voltage. If there is change in input voltage, circuit produces output. Basic integrator circuit using opamp is shown in Figure 17. Output is lower if input fastly changes. On the other hand, output is higher if input slowly changes. Conclusively, output voltage is defined as in equation 11.

$$V_o = -\frac{1}{R.C}.\int V_i dt \tag{11}$$

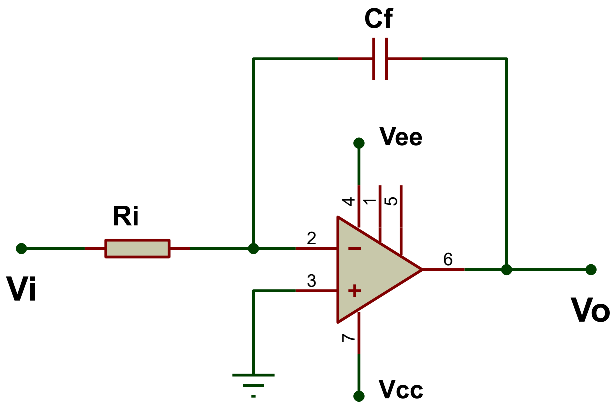


Figure 17. Basic integrator circuit using opamp

Main problem of basic derivator circuit is that impedance of capacitor decreases with decreasing frequency. So circuit doesn't work properly in low frequencies. Improved integrator circuit is displayed in Figure 18. Rf resistor is added to circuit's properly working in low frequency range. Minimum low frequency value is determined in equation 12. Additionally, Ri+ resistor is used for current compensation.

$$f_{min} = \frac{1}{2.\pi.R_f.C} \quad (12)$$

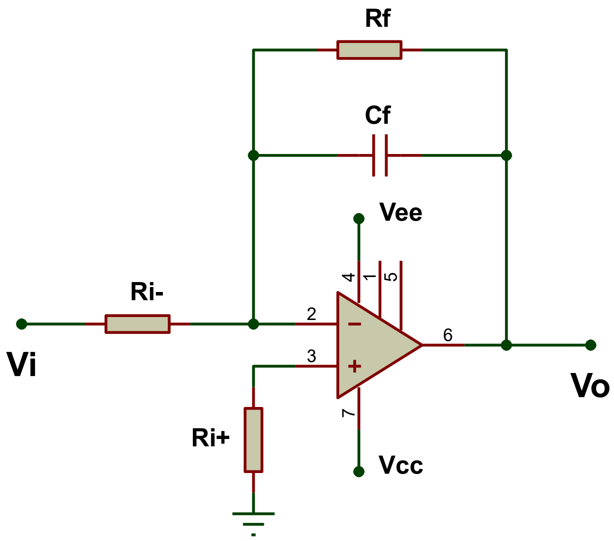


Figure 18. Improved integrator circuit using opamp

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- Opamp
- Vcc / Vee = ±12V
- Rf = 10 KΩ → derivator
- Ri- = 0,22 KΩ → derivator
- Ri+ = 10 KΩ → derivator
- Ci = 22 nF → derivator
- Rf = 82 KΩ → integrator
- Ri- = 10 KΩ → integrator
- Ri+ = 10 KΩ → integrator
- Cf = 22 nF → integrator

Experiment 1

- Build the circuit in Figure 17 on breadboard.
- Apply AC voltage (1V, 1KHz, Sinus) to input and measure output voltage with oscilloscope.
  - V_i (waveform) = sinus / cosinus
  - V_0 (waveform) =
- Apply AC voltage (1V, 1KHz, Triangle) to input and measure output voltage with oscilloscope.
  - V_i (waveform) = triangle
  - V_0 (waveform) =

Experiment 2

- Build the circuit in Figure 18 on breadboard.
- Apply AC voltage (1V, 1KHz, Sinus) to input and measure output voltage with oscilloscope.
    - V_i (waveform) = sinus / cosinus
    - V_0 (waveform) =
- Apply AC voltage (1V, 1KHz, Square) to input and measure output voltage with oscilloscope.
    - V_i (waveform) = square
    - V_0 (waveform) =

9.EXPERIMENTS

9.1 Logarithmic Circuits

9.2 Introduction

Main objective of this experiment unit is to physically study working principles of logarithmic circuits using opamp.

Logarithmic circuits are based on non-linear property of pn junction. Main method to obtain a logarithmic circuit is using diode in place of feedback resistor. Logarithmic circuit with diode using opamp is shown in Figure 19. Output of this circuit is proportional to logarithm of input voltage as in equation 13.

$$V_o = -V_D = -\eta V_T \ln\left(\frac{V_i}{R_i I_0}\right) \tag{13}$$

where η is production process parameter, V_T is temperature voltage and its value is approximately 26 mV, I_0 is leakage current and its value is approximately 10^{-12} A.

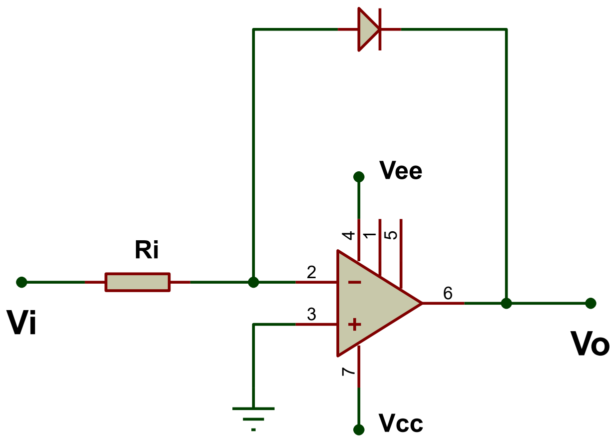


Figure 19. Logarithmic circuit with diode using opamp

One of the other methods to obtain a logarithmic circuit is using transistor instead of diode. Logarithmic circuit with transistor using opamp is shown in Figure 20. Output of this circuit is proportional to logarithm of input voltage as in equation 14.

$$V_o = -V_{BE} = -\eta V_T \ln\left(\frac{V_i}{R_i I_{ES}}\right) \tag{14}$$

where V_T is temperature voltage and its value is approximately 26 mV, I_{ES} is leakage current and its value is approximately 10^{-12} A.

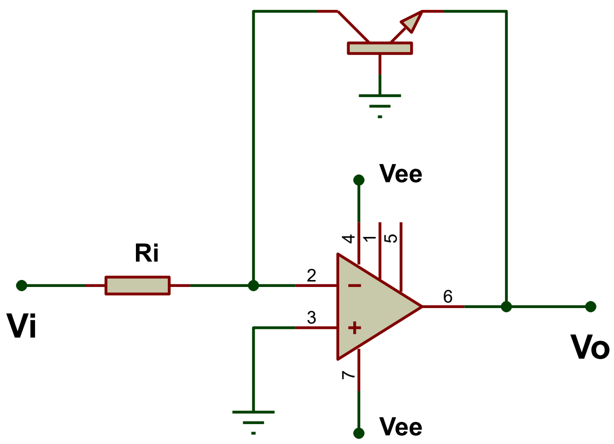


Figure 20. Logarithmic circuit with transistor using opamp

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- Opamp
- Diode
- Transistor
- Vcc / Vee = ±12V
- Ri = 82 KΩ

Experiment 1

- Build the circuit in Figure 19 on breadboard.
- Apply DC voltage (5V) to input and measure output voltage with multimeter.
  - $V_i = 5V$
  - $V_0 =$

Experiment 2

- Build the circuit in Figure 20 on breadboard.
- Apply DC voltage (5V) to input and measure output voltage with multimeter.
  - $V_i = 5V$
  - $V_0 =$

10.EXPERIMENTS

10.1 Filter Circuits

10.2 Introduction

Main objective of this experiment unit is to physically study working principles of filter circuits using opamp.

Filter circuits with amplifier device are named as active filters. These filters generally consist of opamp and frequency selective feedback circuit. Frequency selective feedback part of filter determines frequency response curve of opamp.

A general circuit is accepted to work adequately if it produces output power at least half or more. Output voltage must be at 0.707 rate or more in this condition considering that voltage and current are directly proportinal in accordance with ohm law and power defition is product of voltage and current. This rate can be accepted %70. Additionally it is also named as 3dB decrasing of output voltage in logarithmic-time domain. Working of circuit in this limit determines its cutoff frequency value.

Low pass filter circuit using opamp is displayed in Figure 21. Cutoff frequency of this circuit is in equation 15 and output voltage in this frequency value is in equation 16.

$$f_L = \frac{1}{\sqrt{R_{i1}.R_{i2}.C_f.C_i}} \quad (15)$$

$$V_o(f_L) = 0{,}71 \times V_i \quad (16)$$

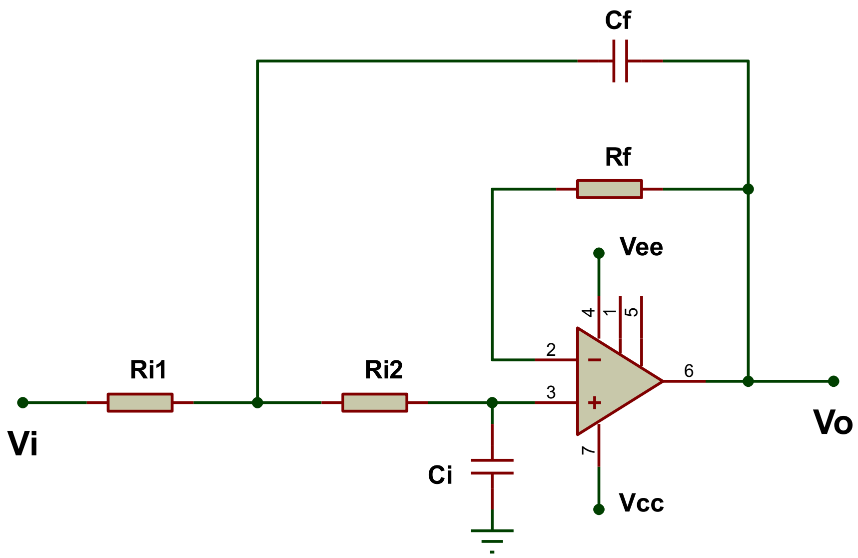


Figure 21. Low pass filter circuit using opamp

High pass filter circuit using opamp is displayed in Figure 22. Cutoff frequency of this circuit is in equation 17 and output voltage in this frequency value is in equation 18.

$$f_H = \frac{1}{\sqrt{R_{f+}.R_i.C_{i1}.C_{i2}}} \quad (17)$$

$$V_o(f_H) = 0,71 \times V_i \quad (18)$$

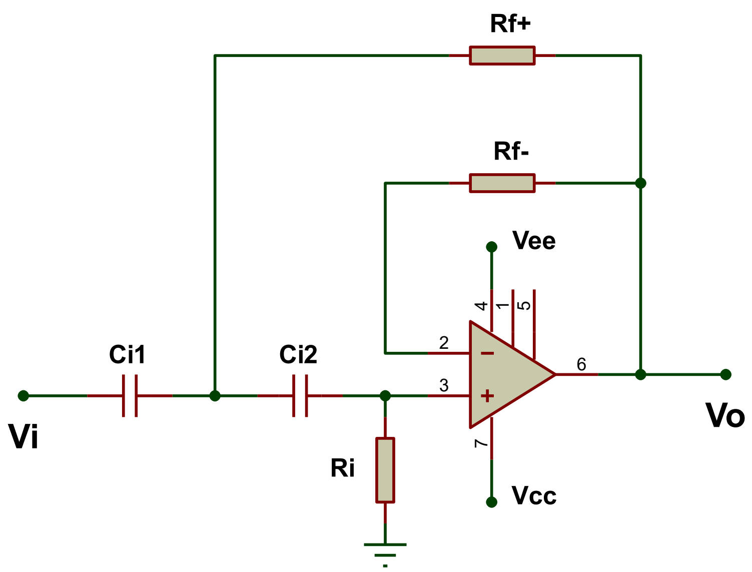


Figure 22. High pass filter circuit using opamp

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- Opamp
- Vcc / Vee = ±12V
- Rf = 22 KΩ → low pass filter
- Ri1 = 10 KΩ → low pass filter
- Ri2 = 10 KΩ → low pass filter
- Cf = 22 nF → low pass filter
- Ci = 10 nF → low pass filter
- Rf+ = 10 KΩ → high pass filter
- Rf- = 22 KΩ → high pass filter
- Ri = 22 KΩ → high pass filter
- Ci1 = 10 nF → high pass filter
- Ci2 = 10 nF → high pass filter

Experiment 1

- Build the circuit in Figure 21 on breadboard.
- Apply AC voltage (1V, 1Hz, Sinus) to input and measure output voltage with oscilloscope.
- Increase frequency until V_o / V_i = %70 and determine cutoff frequency.
    - V_i = 1V, 1Hz, Sinus
    - V_0 = 0.7V, 1Hz, Sinus
    - f_L =

Experiment 2

- Build the circuit in Figure 22 on breadboard.
- Apply AC voltage (1V, 100KHz, Sinus) to input and measure output voltage with oscilloscope.
- Decrease frequency until V_o / V_i = %70 and determine cutoff frequency.
    - V_i = 1V, 1Hz, Sinus
    - V_0 = 0.7V, 1Hz, Sinus
    - f_H =

11.EXPERIMENTS

11.1 Oscillator Circuits

11.2 Introduction

Main objective of this experiment unit is to physically study working principles of oscillator circuits using opamp.

Feedback is to apply some amount of output signal to input. This situation is named as positive feedback if both feedback signal and input signal are in same phase and feedback increases input signal. On the contrary, it is named as negative feedback if both feedback signal and input signal are in opposite phase and feedback decrases input signal. Due to some advantages such as stability, negative feedback is more commonly used in circuits.

Phase shift sinus wave oscillator circuit using opamp is displayed in Figure 23. Opamp has inverting configuration which means it provides 180º phase shift. Furthermore, each capacitor provides 60º phase shift. Conclusively, total phase shift is 360º or it goes without saying that there is no phase shift. This oscillator circuit produces output voltage as in equation 19 and its frequency value is determined in equation 20.

$$V_o \approx (V_{CC} - 2) + (V_{EE} + 2) \tag{19}$$

$$f_o = \frac{1}{4{,}9.\pi.R_i.C_i} \tag{20}$$

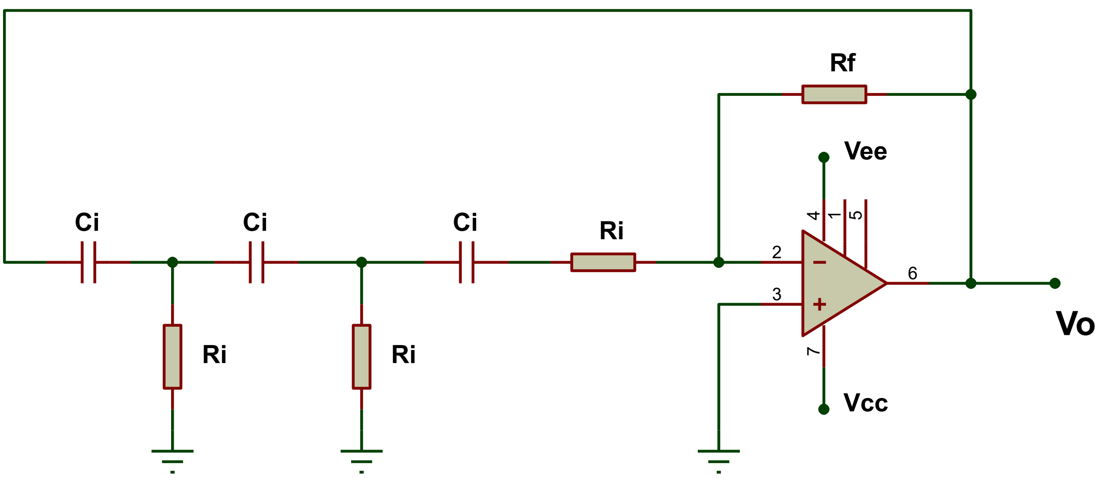


Figure 23. Phase shift sinus wave oscillator circuit using opamp

Astable square wave oscillator circuit using opamp is displayed in Figure 24. This oscillator circuit is based on charge and discharge of capacitor. Charging of capacitor increases inverting input voltage and output produces positive saturation voltage until inverting input value is more than non-inverting input value. On the contrary, discharging of capacitor decreases inverting input voltage and output produces negative saturation voltage until inverting input value is less than non-inverting value. Conclusively, circuit works in oscillation. This oscillator circuit produces output voltage as in equation 21 and its frequency value is determined in equation 22.

$$V_o \approx (V_{CC} - 2) + (V_{EE} + 2) \quad (21)$$

$$f_o = \frac{1}{2.R_{f-}.C_i.\ln\left(\frac{2.R_{f+}+R_i}{R_i}\right)} \quad (22)$$

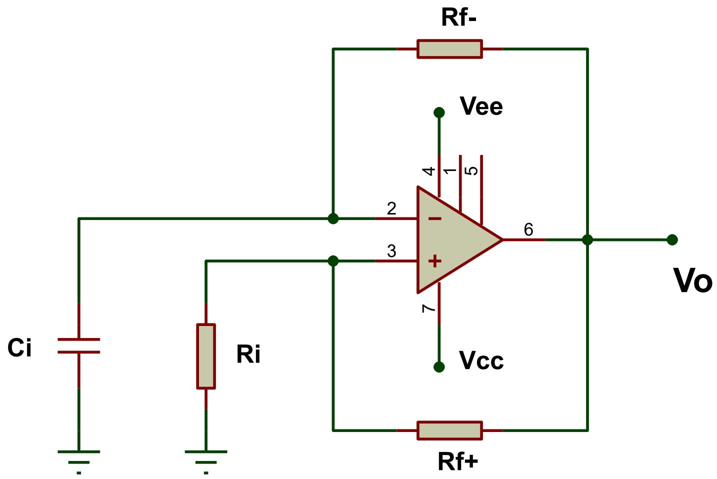


Figure 24. Astable square wave oscillator circuit using opamp

Materials and Devices to Use in Experiments

- Power supply
- Signal generator
- Multimeter
- Oscilloscope
- Opamp
- Vcc / Vee = ±12V
- Rf = 33 KΩ → sinus wave
- Ri = 1 KΩ → sinus wave
- Ci = 47 nF → sinus wave
- Rf- = 220 KΩ → square wave
- Rf+ = 10 KΩ → square wave
- Ri = 10 KΩ → square wave
- Ci = 47 nF → square wave

Experiment 1

- Build the circuit in Figure 23 on breadboard.
- Measure output voltage with oscilloscope.
    - V_o (amplitude) =
    - V_o (frequency) =
    - V_o (waveform) =

Experiment 2

- Build the circuit in Figure 24 on breadboard.
- Measure output voltage with oscilloscope.
    - V_o (amplitude) =
    - V_o (frequency) =
    - V_o (waveform) =