Applied Analogue Electrincs

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Chapter 1

Operational Amplifiers

Operational amplifiears are high gain differential Amplifiers with very high input impedance and low output impedance. They are used in many applications such as amplifiers, filters, oscillators, comparators, integrators and differentiators.

Inverting Amplifier Non-inverting Amplifier Unity gain buffer Open-ended comparators Low pass active filters High pass active filters multivibrator

infinite gain infinite input impedance zero output impedance infinite bandwidth (gain-bandwidth product) offset voltage

LM324 quad LM358 dual single power supply CA3140 single opamp single power CA3240 dual opamp single power MCP6002 dual opamp single power MCP6022 NE5532 dual opamp dual power supply TL072 dual opamp dual power supply

1.0.1 Unity Gain Buffer(Valtage Follower)

1.0.2 Inverting Amplifier

1.0.3 Non-inverting Amplifier

1.0.4 Summing Amplifier

1.0.5 differential Amplifier

1.0.6 Low Pass Active Filter

1.0.7 High Pass Active Filter

1.0.8 Multivibrator(square wave generator)

1.0.9 Integrator(Triangle wave generator with out put of vibrator as input)

1.0.10 Digital MCP6002

1.0.11 Light activated switch

1.0.12 Schmit Trigger

1.1 Oscillators

asytable multivibrator Wien bridge oscillator phase shift oscillator crystal oscillator LC oscillator RC oscillator relaxation oscillator ring oscillator voltage controlled oscillator current controlled oscillator quartz crystal oscillator tuned oscillator

1.2 Amplifiers

circuit that increases the amplitude of a signal

1.2.1 class A

linear poor efficiency conduction angle 360

1.2.2 class B

conduction angle 180 linear proportional to input high efficiency limited bandwidth

1.2.3 class AB

more than 180 less than 360 bias point set higher that the trsnsistor working regionn overlap

1.2.4 class C

1.2.5 class D

1.2.6 class E

Chapter 2

Amplifiers

Amplifiers are electronic devices designed to increase the amplitude or strength of a signal, such as electrical voltage or current. They play a crucial role in various applications, including audio systems, telecommunications, and electronic instrumentation. Amplifiers work by taking a weak input signal and producing a stronger output signal without altering the original waveform.

There are different types of amplifiers, each serving specific purposes. Common categories include:

Audio Amplifiers: These amplify audio signals for applications like music playback, public address systems, and home entertainment.

Operational Amplifiers (Op-Amps): These are versatile, high-gain amplifiers used in a wide range of electronic circuits, such as filters, oscillators, and voltage regulators.

Power Amplifiers: They provide sufficient power to drive speakers or other loads, commonly found in audio systems and radio transmitters.

Radio Frequency (RF) Amplifiers: These amplify signals in the radio frequency range, crucial for wireless communication systems.

Instrumentation Amplifiers: Designed for precise measurement of small signals, often used in scientific and industrial instrumentation.

Differential Amplifiers: These amplify the difference between two input signals, commonly used in audio and measurement applications.

Amplifiers are characterized by parameters such as gain, bandwidth, input impedance, and output impedance. The choice of an amplifier depends on the specific application requirements, and selecting the right type is essential for achieving optimal performance. Additionally, advancements in technology have led to the development of various amplifier configurations, such as transistor amplifiers, operational amplifier circuits, and digital amplifiers, contributing to the diversity and efficiency of amplification systems.

Here's a summary of the different classes of amplifiers:

Class A Amplifiers:

Characteristics: Utilizes the entire input waveform for amplification over 360 degrees. Conduction Angle: 360 degrees. Efficiency: Relatively low (typically around 25Application: High-fidelity audio applications where linearity and low distortion are crucial. Class B Amplifiers:

Characteristics: Conducts for only half of the input waveform cycle (180 degrees), with one transistor handling positive and another handling negative cycles. Conduction Angle: 180 degrees. Efficiency: Higher than Class A (around 78.5Application: Audio power amplifiers where efficiency is prioritized over perfect linearity. Class AB Amplifiers:

Characteristics: Combines features of Class A and Class B, conducting slightly more than 180 degrees but less than 360 degrees. Conduction Angle: Between 180 and 360 degrees. Efficiency: Improved over Class A but with better linearity than Class B (typically 50-70Application: Balanced approach for audio amplifiers seeking a compromise between efficiency and distortion. Class C Amplifiers:

Characteristics: Conducts for less than 180 degrees of the input waveform cycle, highly efficient but introduces significant distortion. Conduction Angle: Less than 180 degrees. Efficiency: High (typically greater than 80Application: Primarily used in RF amplifiers where high efficiency is crucial, and distortion can be tolerated. Class D Amplifiers:

Characteristics: Utilizes digital switching to rapidly switch the output devices on and off. Efficiency: Very high (typically over 90Application: Audio amplifiers, especially in portable devices, where high efficiency and compact size are essential. Class E, F, and G Amplifiers:

Characteristics: These are variations with specific design features for improved efficiency and performance. Applications: Class E for RF amplifiers, Class F for high-frequency power amplifiers, and Class G for audio amplifiers with varying supply voltages to improve efficiency. Each amplifier class has its strengths and weaknesses, making them suitable for different applications depending on factors like power efficiency, linearity requirements, and distortion tolerance. The choice of amplifier class depends on the specific needs of the intended application.

Chapter 3

Oscillators

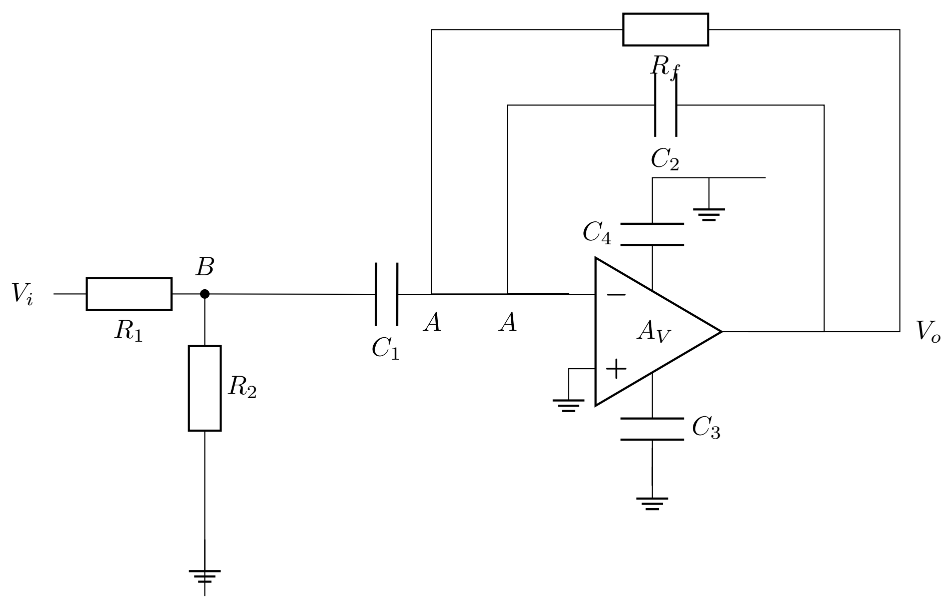
Chapter 4

Exams

4.1 Final Exam 2022

4.1.1 Question 1

Consider the op amp based active filter below. It uses a dual power supply with voltages of $\pm 5V$. Let $R_1 = 20k\Omega$ $R_2 = 10k\Omega$ $R_f = 20k\Omega$ $C_1 = 20nF$ $C_2 = 10nF$ $C_3 = 10nF$ $C_4 = 10nF$.



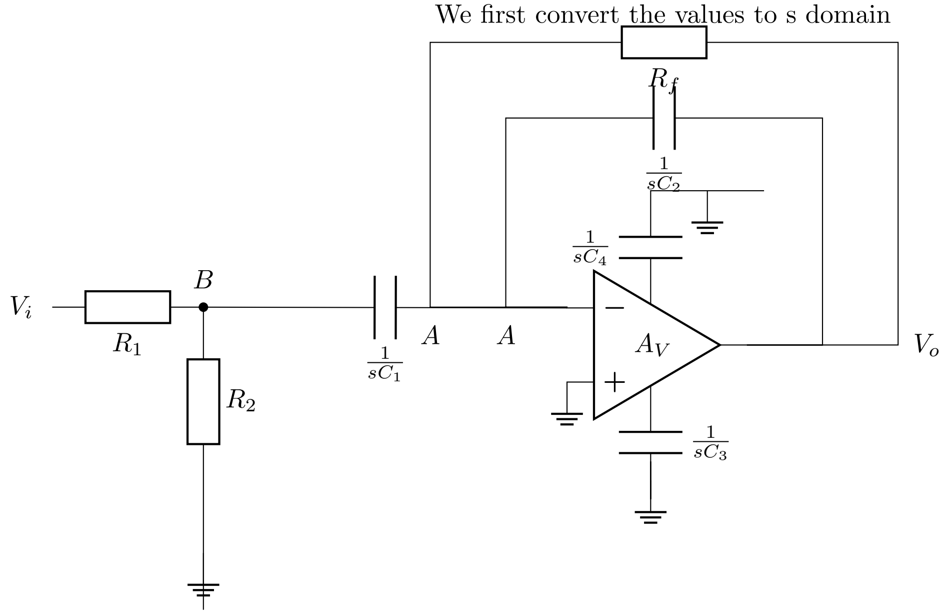
Determine the system transfer function $H(s) = \frac{V_o(s)}{V_i(s)}$ give the answer in the form

$$H(s) = \frac{A(1 + as + bs^2 + cs^3)}{(1 + ds + es^2 + fs^3)}$$

where A,a,b,c,d,e,f are real constants.

$$H(s) = \frac{V_o(s)}{V_i(s)}$$

We first convert the values to s domain



Voltage at node A accross the parallel combination of R and C is given by

$$V_A - V_o = i_A(R_f||C_2)$$

$$V_A - V_o = i_A\left(\frac{R_f * \frac{1}{sC_2}}{R_f + \frac{1}{sC_2}}\right)$$

$$V_A - V_o = i_A\left(\frac{R_f}{1 + sR_fC_2}\right)$$

Assuming no current flows into the op amp and the negative terminal connected to positive terminal, we get $V_A = 0$ thus

$$V_o = i_A\left(\frac{R_f}{1 + sR_fC_2}\right) \text{ equation } i$$

Using KCL at node B(considering all currents into B equal zero)

$$\frac{V_i - V_B}{R_1} + \frac{0 - V_B}{R_2} + \frac{V_A - V_B}{\frac{1}{sC_1}} = 0$$

$$\frac{V_i - V_B}{R_1} + \frac{0 - V_B}{R_2} + \frac{0 - V_B}{\frac{1}{sC_1}} = 0$$

$$\frac{V_i - V_B}{R_1} + \frac{-V_B}{R_2} + -V_BsC_1 = 0$$

$$\frac{V_i}{R_1} - \frac{V_B}{R_1} - \frac{V_B}{R_2} - V_BsC_1 = 0$$

$$\frac{V_i}{R_1} = \frac{V_B}{R_1} + \frac{V_B}{R_2} + V_BsC_1$$

$$\frac{V_i}{R_1} = V_B\left(\frac{1}{R_1} + \frac{1}{R_2} + sC_1\right)$$

$$\frac{V_i}{R_1} = V_B\left(\frac{R_2 + R_1 + R_1R_2sC_1}{R_1R_2}\right)$$

$$V_B = \frac{V_i}{R_1}\frac{R_1R_2}{R_2 + R_1 + R_1R_2sC_1}$$

$$V_B = \frac{V_i R_2}{R_2 + R_1 + R_1 R_2 s C_1}$$

Using KCL at node A(considering all currents into A equal all currents out of A) we get i_A as the current accrossC_1

$$i_A = \frac{V_B}{\frac{1}{sC1}}$$

$$i_A = V_B s C_1$$

$$i_A = \frac{V_i R_2 s C_1}{R_2 + R_1 + R_1 R_2 s C_1}$$

from equation i, we get

$$V_o = \frac{V_i R_2 s C_1}{R_2 + R_1 + R_1 R_2 s C_1} \left(\frac{R_f}{1 + s R_f C_2} \right)$$

$$V_o = \frac{V_i R_2 s C_1 R_f}{(R_2 + R_1 + R_1 R_2 s C_1)(1 + s R_f C_2)}$$

$$\frac{V_o}{V_i} = \frac{R_2 s C_1 R_f}{(R_2 + R_1 + R_1 R_2 s C_1)(1 + s R_f C_2)}$$

$$\frac{V_o}{V_i} = \frac{R_2 s C_1 R_f}{R_2 + R_1 + R_1 R_2 s C_1 + s R_f C_2 + R_1 R_2 s^2 C_1 C_2}$$

$$\frac{V_o}{V_i} = \frac{10k * s * 20n * 20k}{10k + 20k + 20k * 10k * s * 20n + s * 20k * 10n * +20k * 10k * s^2 * 10n * 20n}$$

$$\frac{V_o}{V_i} = \frac{4s}{30k + 4s + 0.0002s + 4 * 10^{-8} s^2}$$

Is this a low pass filter, high pass filter or band pass filter?

WHat is the order of the filter?

4.1.2 Question 2

Design an amplifier that produces an output voltage $V_o(t)$ governed by the expression,

$$v_o(t) = 2.5 v_1(t) - 0.4 v_2(t) + 2 v_3(t) - \frac{1}{4} v_4(t)$$

, where $v_1(t)$, $v_2(t)$, $v_3(t)$ and $v_4(t)$ are the input voltages. Show all the components and their values. Keep the number of components in your circuit as small as possible. That will reduce the cost of your amplifier and for that you will be rewarded more points.

Give two properties of an ideal op-amp.

- Infinite open loop gain
- Infinite input impedance
- Zero output impedance
- Infinite bandwidth
- Zero input offset voltage
- Infinite slew rate

4.1.3 Question 3

Consider the oscillator circuit below that uses a dual power supply at $\pm 5C$ and outputs a voltage $V_o(t) = 2.5sin(2\pi f_o t)$. The circuit parameters are $R_1 = 1.5k\Omega$ $R_3 = 1.5k\Omega$ $R_4 = 3.3k\Omega$ $C_1 = 1nF$ $C_2 = 2nF$

Certainly! Below is an example code for a Wien bridge oscillator implemented using operational amplifiers (op-amps) and the circuitikz package in LaTeX. This oscillator circuit utilizes two op-amps to create the feedback network needed for oscillation.