CG1111A Engineering Principles & Practice I

Tutorial 3 (28 & 29 Sep 2022)

AC-to-DC Conversion, DC Motors, and Op-amp Basics

1. The primary voltage of a transformer is 65 V RMS, and the number of turns in the primary and secondary windings are 60 and 90, respectively. Calculate the RMS voltage across the secondary winding of the transformer.

   Ans: 97.5 V RMS

2. Calculate the number of turns required in the primary winding of a transformer, if the primary voltage is 25 V RMS, and the secondary voltage is 90 V RMS. There are 36 turns in the secondary winding.

   Ans: 10

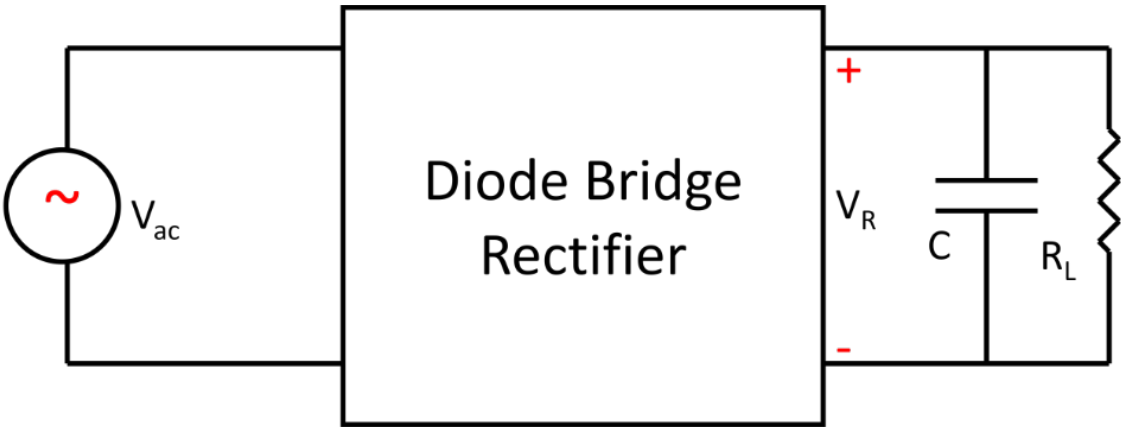
3. The secondary voltage of a given transformer was 100 V RMS when its primary voltage was 30 V RMS. Calculate the primary voltage required to obtain a secondary voltage of 225 V RMS.

   Ans: 67.5 V RMS

4. The primary voltage of a transformer is given by $325 \angle 0°$. A series RL load is connected at the secondary side, with voltage magnitudes $|V_{\mathrm{R}}| = 6\ \mathrm{V}$, and $|V_{\mathrm{L}}| = 8\ \mathrm{V}$. Calculate the turns ratio (i.e., N_p/N_s) of the transformer.

   Ans: 32.5

5. Derive an expression for the voltage ripple at the load R_L in the following circuit, in terms of the average load voltage V_{Load}, the AC power supply's frequency f_s, the capacitance C, and the load resistance R_L.



Ans: $\Delta V \approx \frac{V_{\mathrm{Load}}}{R_{\mathrm{L}}} \times \frac{1}{2 f_{\mathrm{s}}} \times \frac{1}{C}$

6. A full-wave rectifier is connected to a resistive load of R = 100 Ω, with an average voltage of 9 V. The AC source has a frequency of 100π rad/s. Assume the diodes are ideal with no voltage drop. If a 1.5 mF capacitor is connected as a filter, calculate the voltage ripple.

Ans: $\Delta V \approx 0.6$ V

7. A full-wave rectifier needs to deliver a current of 0.2 A with an average voltage of 15 V. The AC source has a frequency of 50 Hz. The peak-to-peak voltage ripple is to be less than 0.5 V. Assume the diodes are ideal with no voltage drop. Find the minimum value of the filter capacitor needed.

Ans: 4 mF

8. For a PMDC motor powered by a 12 V DC source, the no-load speed and stall torque are 3800 RPM and 30 mNm, respectively. If the motor is running at 2500 RPM, find

   a) Rotor current (I_m),

   b) Shaft torque (T_{shaft}),

   c) Back emf (E_b),

   d) Total electrical power consumed,

   e) Shaft power, and

   f) Power loss in rotor coil.

   Ans: a) 10.4 mNm, b) 346 mA, c) 7.85 V, d) 4.15 W, e) 2.72 W, f) 1.44 W

9. For the motor of Q8 with load condition unchanged, it is desired to spin it at 1500 RPM.

   a) What are the rotor current (I_m), and the required motor voltage (V_m)?

   b) What should be the PWM duty cycle if the DC source is still 12 V?

   c) Find the ON duration and OFF duration if the PWM frequency is 5 kHz.

   d) What is the total electrical power consumed?

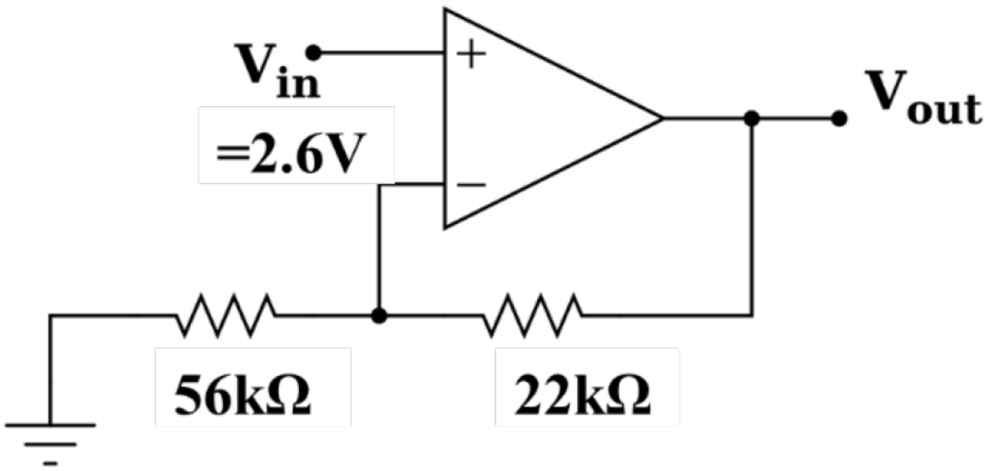
   e) What is the power loss in the rotor coil?

   Ans: a) 346 mA and 8.86 V, b) 73.8%, c) 147.6 μs and 52.4 μs, d) 3.07 W, e) 1.44 W

10. A PMDC motor is rigidly coupled to a fan; the fan load torque is described by the expression $T_L = 0.05\omega + 0.001\omega^2$, where the units of torque (T_L) and speed (ω) are Newton-meter and radians per second, respectively. The torque constant (K_t) of the motor is 2.42 N.m/A, and the rotor resistance is 0.2 Ω. If the motor is powered by a 50 V DC supply, what will be the speed of the motor and fan?

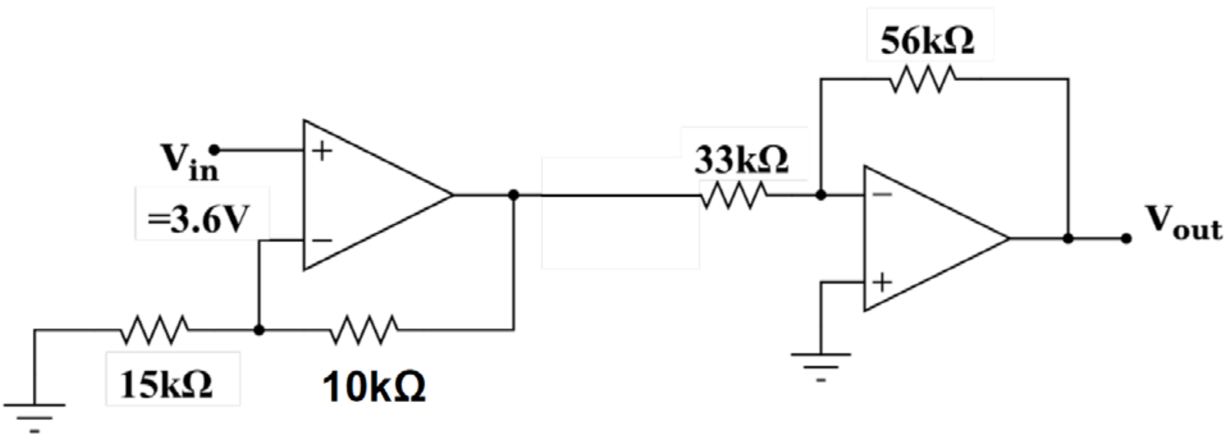
    Ans: 197 RPM

11. Calculate all the voltage drops and currents in the following circuit, complete with arrows for the current's direction and polarity markings for voltage polarity. Then, calculate the overall voltage gain of this amplifier circuit (A_V), both in V/V, and in units of decibels (dB).



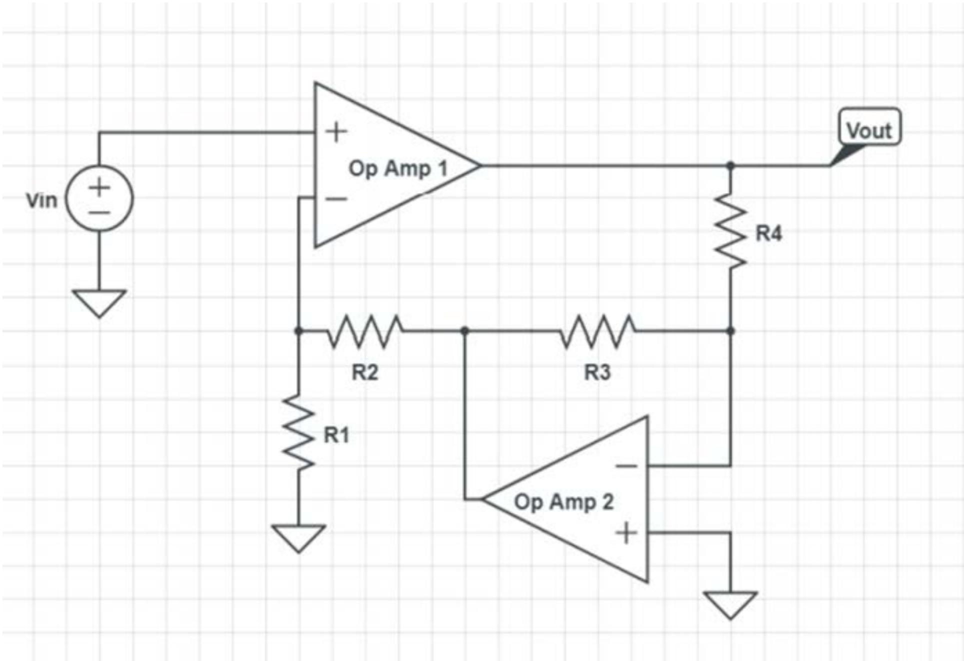
Ans: Overall voltage gain = 1.39 V/V = 2.86 dB

12. Calculate all the voltage drops and currents in the following circuit, complete with arrows for the current's direction and polarity markings for voltage polarity. Calculate the voltage gain for each stage of this amplifier circuit (both in V/V, and in units of decibels (dB)), then calculate the overall voltage gain.



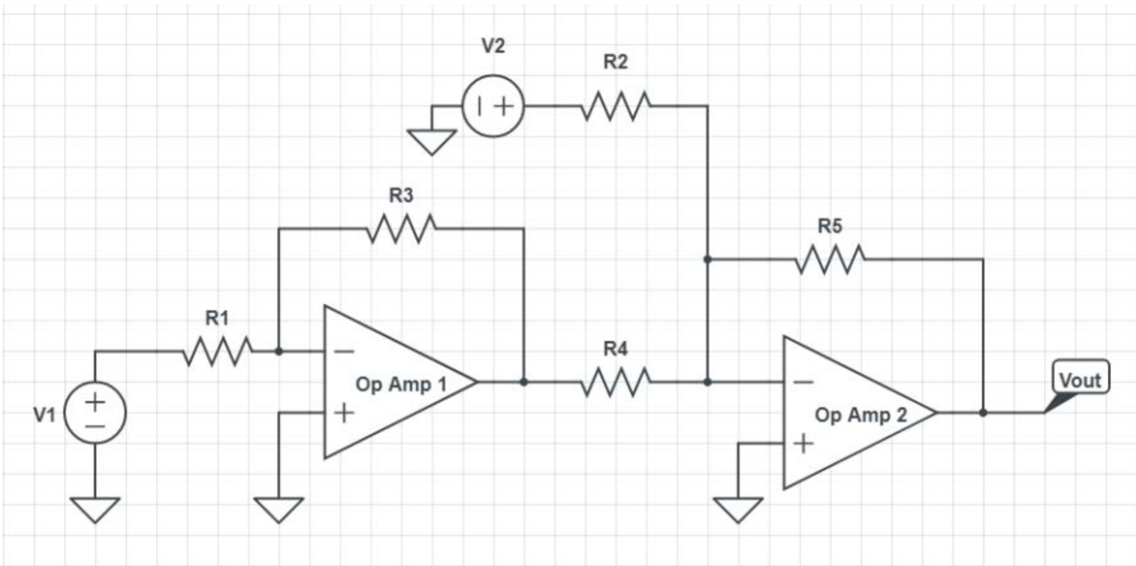
Ans: Gain of first stage = 1.67 V/V (4.45 dB)
Gain of second stage = −1.7 V/V (4.61 dB)
Overall voltage gain = −2.84 V/V (9.07 dB)

13. Calculate the voltage gain (V_{out}/V_{in}) of Op Amp 1 in the figure below:



Ans: $$\frac{V_{\text{out}}}{V_{\text{in}}} = -(1 + \frac{R_2}{R_1}) \times \frac{R_4}{R_3}$$

14. Derive the expression relating V_{out} and the two input voltages, V_1 and V_2.



After obtaining the expression relating the output to the inputs for the configuration, can you design the resistance values such that Vout is the difference between the two input signals amplified by a gain factor?

Ans: $$V_{\text{out}} = \left(\frac{R_5}{R_4} \times \frac{R_3}{R_1} \times V_1\right) - \left(\frac{R_5}{R_2} \times V_2\right)$$