1. Fig. 1 shows a classical CMOS class-AB output stage. For the case that Q_1 and Q_2 are matched, Q_N and Q_P are matched, $V_{DD} = V_{SS} = 3.3V$, $V_{tn} = |V_{tp}| = 0.7V$, $I_Q = 5mA$, $I_{BIAS} = 0.4mA$, $k_n' = 300\mu A/V^2$, $k_p' = 150\mu A/V^2$, and each transistor operates at $V_{ov} = 0.15V$. Please answer the following questions.

(a) Derive V_{GG} in terms of V_{tp}, V_{tn}, I_{bias}, k_n, k_p, W and L.

(b) Please find the value of V_{GG}.

(c) Derive the relationship between I_{BIAS} and I_Q.

(d) Find (W/L) for each of Q_1, Q_2, Q_N and Q_P.

(e) Find v_i if in the quiescent state with $v_o = 0V$.

(Hint: For Q_1, $I_{D1} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_1 (V_{GS1} - V_{tn})^2$)

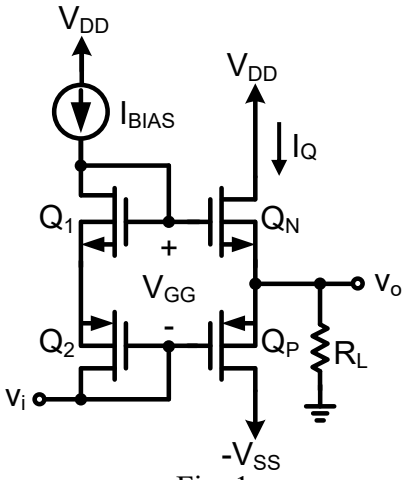

Fig. 1

2. Fig. 2 shows a source-follower output stage, whose M_2 is biased at a constant current $I_{BIAS} = 2.5mA$. Note that $R = 1\ k\Omega$, $V_{DD} = 5V$, $V_{CM} = 0.5V_{DD}$, $V_{ov} = 0.2V$ for all MOSFETs.

(a) Which type of the output stage is it? Explain your answer.

(Hint: Class-A / class-B / class-AB / class-C / class-D)

(b) Please describe the definition of power conversion efficiency.

(c) If output voltage (v_{OUT}) is an 2-V-peak sinusoid with common mode voltage V_{CM}, please find the power conversion efficiency of Fig. 2.

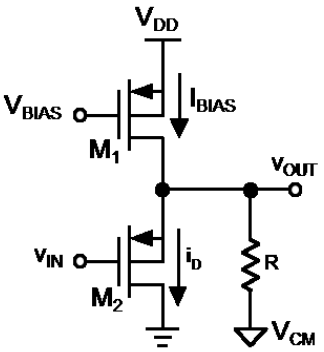

Fig. 2

3. Fig. 3(a) shows a bistable multivibrator circuit, where output saturation voltages $L_+ = |L_-| = 10V$, $R_1 = 1k\Omega$ and $R_2 = 4k\Omega$. Fig. 3(b) shows a triangular-wave generator, which comprises the multivibrator circuit used in Fig. 3(a) and an integrator.

(a) Find the threshold voltages **V_{TH} and V_{TL} of Fig. 3(a)**.

(b) Sketch the transfer characteristic curve of Fig. 3(a), i.e. **v_A-to-v_B plot**.

(c) Let $R_3 = 100k\Omega$, $C = 10pF$, find **the frequency of the triangular wave at v_A** in Fig. 3(b).

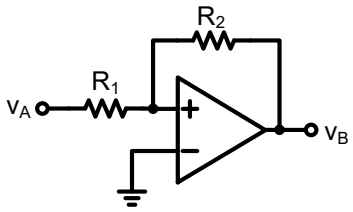

Fig. 3(a)

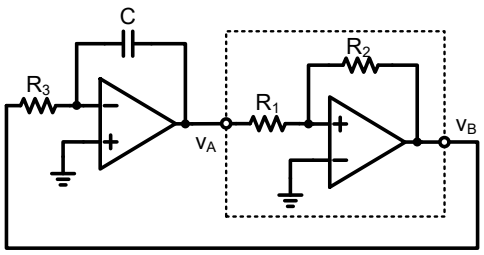

Fig. 3(b)

4. Fig. 4 shows a general form of LC-tuned oscillator circuit. Please answer the following questions.

(a) Please describe the Barkhausen criterion.

(b) Based on Fig. 4, please draw the Collpitts oscillator.

(Hint: Two capacitors C_1, C_2 and one inductor L are needed.)

(c) Based on (b), please derive the oscillation frequency.

(d) Based on (b), please draw the Collpitts crystal oscillator and explain how it works.

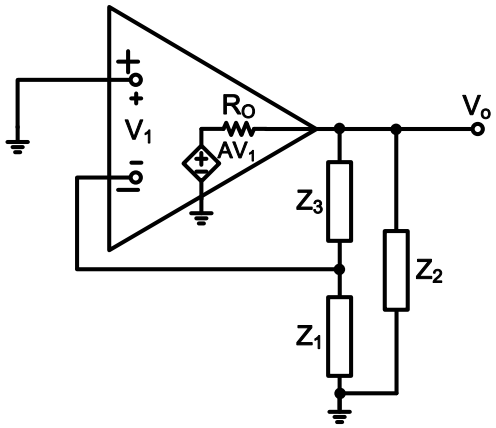

Fig. 4

5. Figs. 5(a) and (b) show two bistable circuits. Let the output saturation vlotages $L_+ = -L_- = 20V$, the threshold voltages $V_{TH}=-V_{TL}=5V$, and $R_1=15k\Omega$.

(a) Please find R_2 in Fig. 5(a).

(b) Please sketch the transfer characteristic curve in Fig. 5(a).

(c) If a DC voltage $V_{DC}=4V$ is inserted, as shown in Fig. 5(b), please sketch its transfer characteristic curve.

(Note: Each transfer characteristic curve should include marks of L_+, L_-, V_{TH}, V_{TL}, and the direction of the transfer operation.)

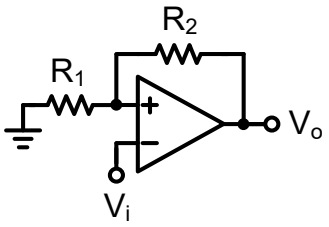

Fig. 5(a)

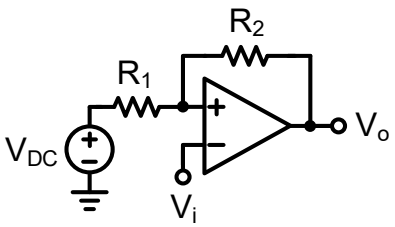

Fig. 5(b)

6. Figs. 6(a) and (b) show two crystal oscillators, and the configuration in Fig. 6(b) is the most commonly used configuration nowadays. Please answer the following questions.

(a) Describe the Barkhausen criterion.

(b) Draw the small signal model and derive the loop gain of Fig. 6(a).

(c) According to the results in (b), prove that the oscillation frequency $\omega_0 = \dfrac{1}{\sqrt{L\dfrac{C_1C_2}{C_1+C_2}}}$.

(d) Explain how the oscillator works in Fig. 6(b).

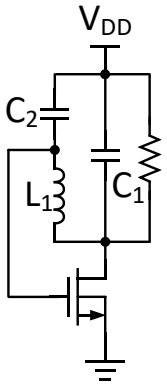

Fig. 6(a)

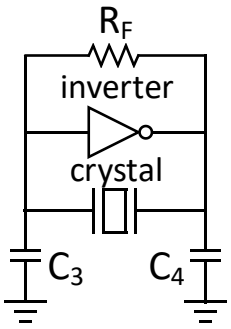

Fig. 6(b)

7. Please briefly describe the definitions of the following terms.

(a) Total harmonic distortion

(b) Crossover distortion

(c) Inter-modulation distortion

(d) Explain (i) class A, (ii) class B, and (iii) class AB amplifier.

(e) Class-D amplifier

(f) Barkhausen criterion

(g) Astable mutlibrator

(h) Darlington configuration npn compound device

(i) Demonstrate that even harmonics are eliminated in a balanced push-pull amplifier

(j) Show that the maximum conversion efficiency of idealized class B push-pull circuit is 78.5%

(k) Power conversion efficiency

(l) Non-linearity

8. Figs. 8(a) and (b) show two multivibrator circuits. Fig. 8(c) shows the waveforms of the circuit in Fig. 8(a). Fig. 8(d) shows the waveform of v_{O3} in Fig. 8(b). Let the inverter's transition threshold voltage $V_T = 0.5V_{DD}$ and the forward bias voltage across the diode is zero.

(a) Which type of the multivibrator is it? (Hint: bistable, astable, or monostable)

(b) Please find the oscillation frequency of the circuit in Fig. 8(a) **in terms of R_1 and C_1**.

(c) Please explain the sudden rises and drops in the waveform of node v_{X1} in Fig. 8(c).

(d) Please explain why the peak voltage of $V_X(t)$ is $V_{DD}+V_T$.

(e) Please explain the difference between Fig. 8(a) and (b) when $R_2 \neq R_3$.

(f) In Fig. 8(b) and (d), let C_2=15nF and T=60μs. Please find R_2 and R_3.

(Hint: RC circuit response $v(t) = v(\infty)+[v(0)-v(\infty)]e^{-t/\tau}$)

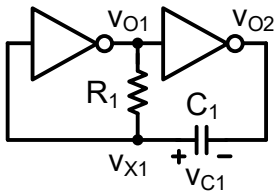

Fig. 8(a)

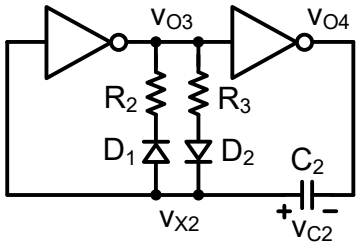

Fig. 8(b)

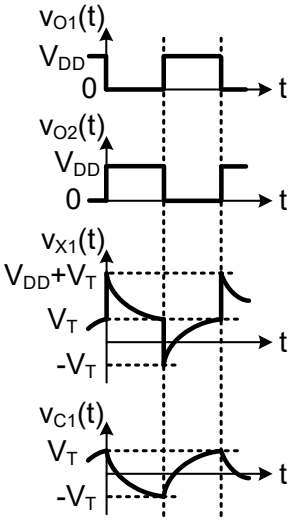

Fig. 8(c)

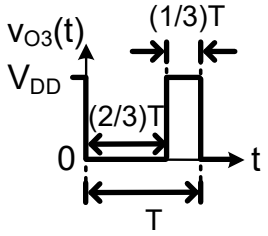

Fig. 8(d)

9. Fig. 9 shows a phase-shift oscillator with two unity-gain buffers and an ideal negative-gain amplifier (gain = -K). Let R=2kΩ, C=200pF. Please

(a) describe the Barkhausen oscillation criterion.

(b) derive its loop gain L(s) **in terms of R, C and K**.

(c) find the oscillation frequency of the oscillator.

(d) find K.

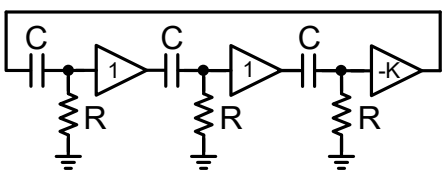

Fig. 9

10. Figs. 10(a) and (b) show a power transistor operated at junction temperature T_J of 160°C with the case attached to a heat sink. The heat sink temperature T_S is found to be 85°C. The total thermal resistance θ_{JA} =6.75°C/W. If the ambient temperature T_A is 25°C, please calculate

(a) case temperature T_C and heat sink temperature T_S.

(b) thermal resistance θ_{JC}.

(c) thermal resistance θ_{CS}.

(d) power dissipated, P_D in the device.

(e) find the maximum power that can be dissipated safely when operated at T_A = 60°C.

(f) find the temperature of the case when the maximum power that can be dissipated safely at T_A = 50°C, with a heat sink that θ_{CA} = 7.5°C/W.

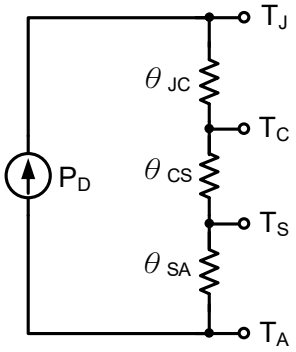

Fig. 10(a)

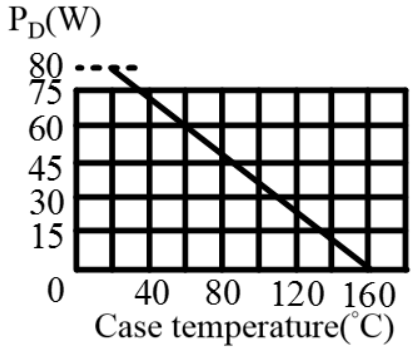

Fig. 10(b)

11. Fig. 11 shows a OPAMP-RC oscillator. Assuming that the OPAMP is ideal, please answer the following questions.

(a) Find the loop gain by breaking the loop at V_d.

(b) Find the oscillation frequency.

(c) When R_1=10kΩ, find the range of R_2.

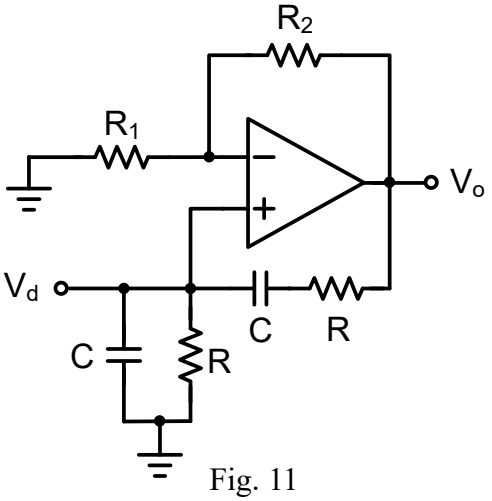

Fig. 11

12. Fig. 12 shows an source-follower output stage with a current-source load, whose gate terminal of M_1 is biased at the constant V_{BIAS}. Assume that R = 1 kΩ, V_{DD} = 5V, V_{ov} = 0.2V for all MOSFETs, and input frequency $\omega_{IN} >> \frac{1}{RC}$.

(a) Please specify the type of this output stage, and explain your answer. (class-A / class-B / class-AB)

(b) If I_{BIAS} is designed as 4mA, please find the output swing, and sketch the v_{OUT}-to-i_D transfer characteristic curve.

(c) If I_{BIAS} is designed as 2mA, please repeat (b).

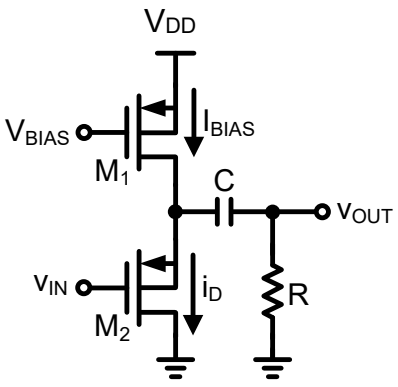

Fig. 12

13. Fig. 13 shows a multivibrator circuit and its v_O waveform. Assume that the output switches between $+V_P$ and $-V_P$. Please

(a) specify the type of this multivibrator. (bistable/ astable/ monostable)

(b) sketch the waveform of v_C.

(c) calculate T_1 in Fig. 13.

(d) calculate the oscillation frequency in terms of R_Y, R_X and C.

(Hint: RC circuit response: $v_C(t) = v_C(\infty) + [v_C(0) - v(\infty)]\, e^{-t/\tau}$)

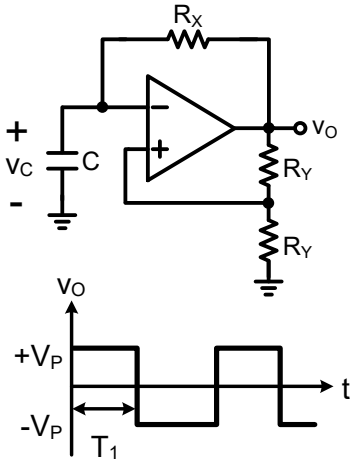

Fig. 13

14. Fig. 14 shows a phase-shift oscillator, where three-stage RC filter and the inverting amplifier are included. Assume that the op-amps are ideal, please answer the following questions.

(a) Express the oscillator's loop gain in terms of R_1, R_2 and C.

(b) Derive the oscillation frequency of the oscillator.

(c) Find the v_O-to-v_X gain attenuation and phase shift at the oscillation frequency.

(d) Find the resistor ratio R_2/R_1 to sustain the oscillation.

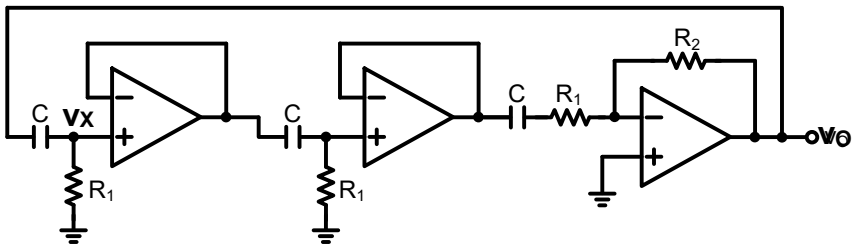

Fig. 14

15. Fig. 15 shows a multivibrator circuit and its waveforms, where R =20kΩ, C =10nF and the inverter's transition threshold voltage $V_T = 0.5V_{DD}$.

(a) Which type of multivibrator is it? (bistable/ astable/ monostable)

(b) Please sketch the waveform of the $\mathbf{V_X}$.

(c) Calculate T_1.

(Hint: RC circuit complete response: $v(t) = v(\infty)+[v(0)-v(\infty)]e^{-t/\tau}$)

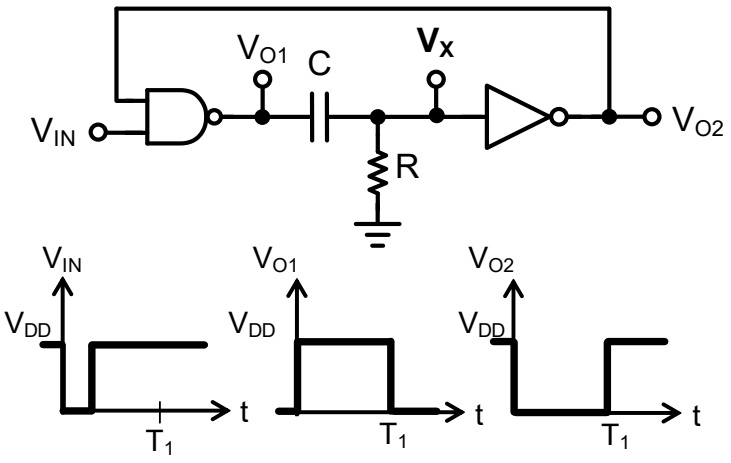

Fig. 15

16. (a) A power amplifier IC has a power-conversion efficiency of 55%. Let the average power drawn from supplies is 20W and the maximum junction temperature T_{Jmax}=150°C, please find **the maximum thermal resistance θ_{JA}** for safely operating at ambient temperature of 60°C.

(b) If the θ_{JA}=15°C/W, please find **the junction temperature** if the IC is operating at 25°C and is dissipating 5W.

17. Fig. 17 shows two bistable circuits, where the saturated output voltages of the op-amps are ±10V. Assume that R_1=25kΩ, R_2=75kΩ and the forward-biased voltage of diodes are 0.7V.

(a) In Fig. 17(a), find their negative and positive threshold voltages (V_{TL} and V_{TH}) of input triggers.

(b) Sketch the transfer characteristics of V_O vs. V_I in Figs. 17(a) and 17(b), respectively. (mark the v_O saturation voltage, V_{TH}, V_{TL}, and the direction of the transfer operation on your plots)

(c) If the maximum forward-biased current of the diode is 0.5mA and the range of the input voltages is $-2 \leqq V_I \leqq 2V$, what is the minimum value of the resistor R_3 ?

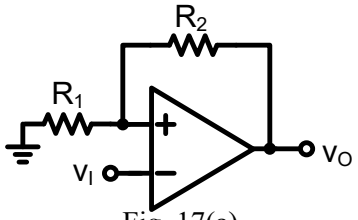

Fig. 17(a)

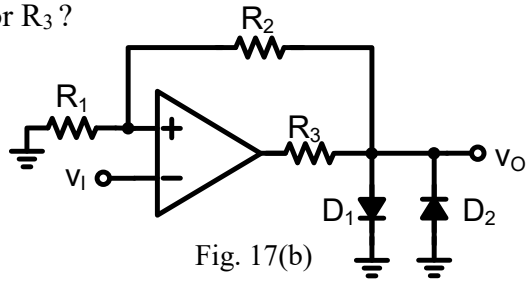

Fig. 17(b)

18. Fig. 18(a) shows a bistable circuit. Assume that its output saturation voltages $L_+ = |L_-| = 12V$, R_1=1kΩ and R_2=3kΩ.

(a) Find its threshold voltages **V_{TH} and V_{TL}**.

(b) Sketch its transfer characteristic curve, i.e. **v_A-to-v_B plot**.

(c) Fig. 18(b) shows a triangular-wave generator, which comprises the bistable circuit and an integrator. Please sketch the corresponding **time-domain waveform of v_A and v_B**.

(d) Let R_3=100kΩ, C=10pF, find **the frequency of the triangular wave at v_A** in Fig. 18(b).

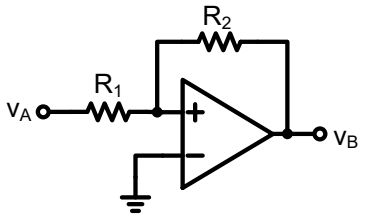

Fig. 18(a)

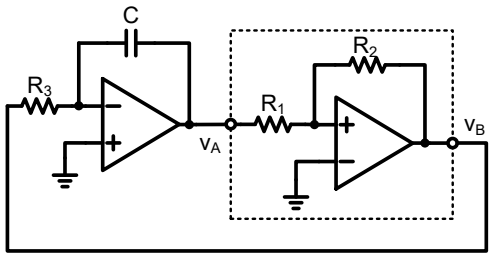

Fig. 18(b)

19. Fig. 19 shows a multivibrator circuit and its waveforms. Assume that R =100kΩ, C =1nF, and the transition threshold voltage of the inverter is $0.5 \times V_{DD}$.

(a) Which type of multivibrator is it? **(bistable / astable / monostable)**

(b) Calculate the **peak voltage of the V_X**, which is labelled as **V_P** in Fig. 19(d).

(c) Calculate **T_1**. (Hint: RC circuit complete response: $v(t) = v(\infty)+[v(0)-v(\infty)]e^{-t/\tau}$)

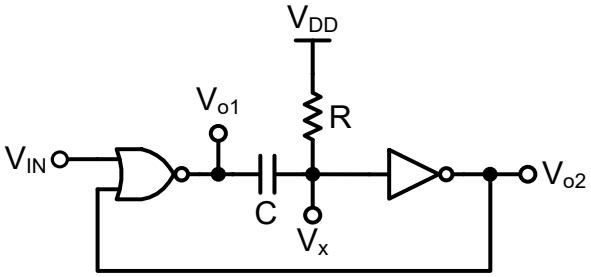

Fig. 19(a)

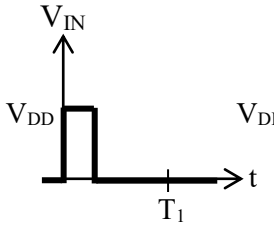

Fig. 19(b)

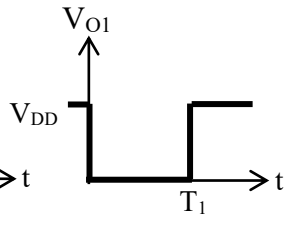

Fig. 19(c)

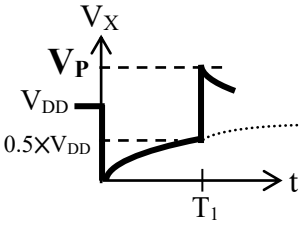

Fig. 19(d)

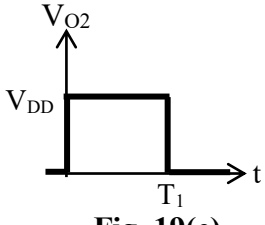

Fig. 19(e)

20. (a) Please describe the Barkhausen criterion.

(b) In **Fig. 20**, will the circuit start oscillation or not? Why?

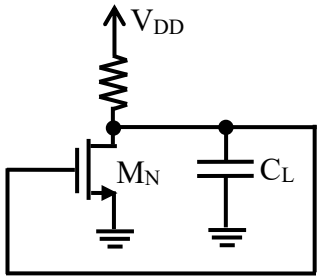

Fig. 20

21. For the circuit in Fig. 21, let the OPAMP saturation voltage be ±10V, R_1 = 100kΩ, R_2 = R = 1MΩ, and C = 0.01uF. Please draw the detailed waveforms of various nodes and derive the oscillation frequency of the circuit.

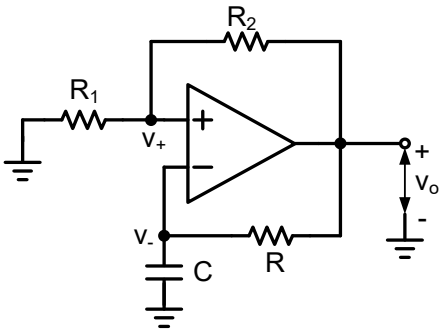

Fig. 21

22. Fig. 22 shows the block diagram of a Class-D amplifier. Please answer the following questions.

(a) Which type of modulation technique is used in Class-D amplifier? (PCM or PWM)

(b) According to the answer of (a), how to generate that kind of modulation waveform?

(c) Which type of output stage has the **largest** power conversion efficiency? (Class-A, Class-AB, or Class-D)

(d) Which type of output stage has the **lowest** power conversion efficiency? (Class-A, Class-AB, or Class-D)

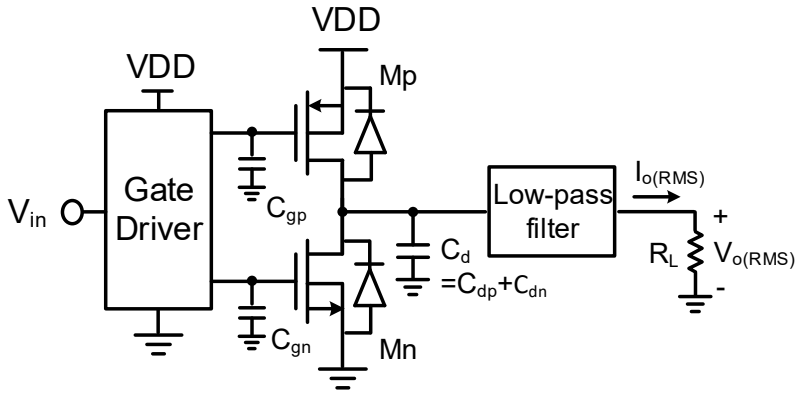

Fig. 22

23. Please explain the following terms.

(a) Static power dissipation.

(b) Dynamic power dissipation.

24. Fig. 24 shows a hysteresis comparator circuit, where output saturation voltages $L_+ = |L_-| = 10V$, $R_1 = 1k\Omega$ and $R_2 = 4k\Omega$.

(a) Which type of the multivibrator is it? (Hint: bistable, astable, or monostable)

(b) Find the threshold voltages **V_{TH} and V_{TL} of Fig. 24**.

(c) Sketch the transfer characteristic curve of Fig. 24, i.e. **V_{IN}-to-V_{OUT} plot**.

(d) Please explain why the circuit rejects input interference.

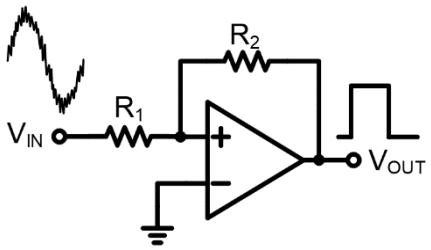

Fig. 24

25. 請問 NVIDIA 及 ATI 的主要產品為何? 請問 ATI 與成功大學電機工程學系有何關聯? 假設你創業成功，面對其他公司的併購，你會接受併購嗎? 還是拒絕併購，繼續經營並開更前瞻及創新的挑戰? 請回答並解釋你的原因。

26. Figs. 26(a) and 26(b) show two different types of CMOS class AB output stage, respectively. Assume $|V_{OV}|$=0.2V for all transistors, $|V_{tp}|$=0.8V, V_{tn}=0.7V, and dual-supply voltage V_{CC}=2.5V.

(a) Fig. 26(a) shows a class AB utilizing source followers Q_1 and Q_2, please find the **output swing range of v_o**.

(b) Fig. 26(b) shows a class AB utilizing common-source transistors Q_5 and Q_6, please find the **output swing range of v_o**.

(c) Please **draw** a modified output stage to reduce the output resistance of Fig. 26(b) **by using feedback**. Briefly explain your reason.

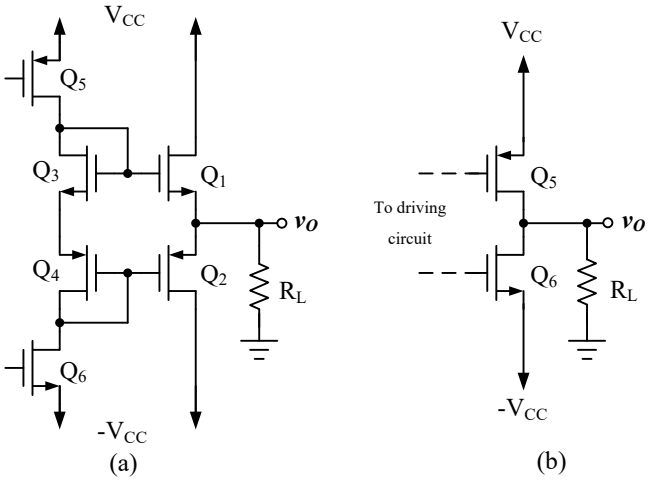

Fig. 26