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Analog Electronics Interview Questions

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Diode circuits

1. What does a clamper circuit do, and why does it need a capacitor?

A clamper shifts the dc level of a waveform without changing its shape. The capacitor charges through the diode to a peak value and then acts like a series battery that adds this fixed voltage to the input. It works as intended when the RC time constant is much longer than the signal period.

2. What is the difference between a half-wave rectifier and a full-wave bridge rectifier?

A bridge uses four diodes and conducts in both half-cycles, so the average output is $2V_m/\pi$ against V_m/π for a half-wave circuit. Its ripple is at twice the supply frequency, against the supply frequency for a half-wave circuit, so it needs less filtering. These figures assume ideal diodes and a resistive load.

3. Why is a series resistor always used with a Zener diode shunt regulator?

The resistor drops the difference between the input and the Zener voltage and sets the current. Without it, the Zener current would be limited only by the source and could exceed the power rating. Regulation also holds only while the Zener stays in breakdown, so the resistor must keep its current above the knee value.

4. A full-wave bridge rectifier with ideal diodes is fed from a 12 V rms sinusoidal secondary and drives a resistive load. Find the average load voltage.

The average load voltage is 10.8 V, found from $V_{dc} = 2V_m/\pi$ with $V_m = 12\sqrt{2} \approx 16.97$ V, taking the diodes as ideal and the load as purely resistive.

WORKING

1. $V_m = 12\sqrt{2} = 16.97$ V
2. $V_{dc} = 2V_m/\pi$
3. $V_{dc} = 2 \times 16.97/3.1416 = 10.8$ V

BJT and MOSFET biasing and DC analysis

5. What is the Q-point of a transistor amplifier, and why does it matter?

The Q-point is the dc collector current and collector-emitter voltage with no signal applied. It keeps the device in the active region so the signal swings without clipping. It also fixes the small-signal parameters, since for a BJT $g_m = I_C/V_T$ depends directly on the bias current.

6. How does voltage-divider bias differ from fixed bias in its sensitivity to β?

In fixed bias the collector current is proportional to β, so the Q-point shifts widely from one transistor to another. In voltage-divider bias the divider sets the base voltage and the emitter resistor sets the current, so I_C is nearly independent of β. This holds when the divider current is much larger than the base current.

7. A BJT is fixed-biased from a 12 V supply through a 470 kΩ base resistor, with a 2 kΩ collector resistor. Take $\beta = 100$ and $V_{BE} = 0.7$ V. Find V_{CE}.

The collector-emitter voltage is 7.19 V, so the transistor is in the active region, since V_{CE} is well above the saturation value of about 0.2 V for a silicon device.

WORKING

1. $I_B = (12 - 0.7)/470\,\text{k}\Omega = 24.04\ \mu\text{A}$
2. $I_C = \beta I_B = 2.404$ mA
3. $V_{CE} = 12 - I_C R_C = 12 - 2.404\,\text{mA} \times 2\,\text{k}\Omega = 7.19$ V

Small-signal amplifiers

8. What is the Miller effect in an inverting amplifier?

A capacitance C between the input and output of an inverting stage of gain $-A$ appears at the input as $C(1 + A)$. The input node therefore sees a much larger capacitance than the physical one. This lowers the high-frequency cut-off of the stage, and it matters most for common-emitter and common-source amplifiers.

9. What is the difference between a common-emitter stage and an emitter follower?

A common-emitter stage gives a large inverted voltage gain with a high output resistance. An emitter follower gives a voltage gain just below 1, with no inversion, a high input resistance and a low output resistance. The follower is therefore used as a buffer between a weak source and a heavy load.

10. Why is a current source used as the tail of a differential amplifier?

A current source has a very high output resistance, so the tail current barely changes with the common-mode input. This makes the common-mode gain very small and raises the common-mode rejection ratio. It also keeps the bias current of the pair fixed, independent of the input common-mode level.

11. A BJT is biased at $I_C = 1$ mA with $\beta = 100$. Take $V_T = 25$ mV. Find the small-signal input resistance r_π.

The input resistance r_π is 2.5 kΩ, obtained from $r_\pi = \beta / g_m$ with $g_m = 40$ mS at this bias current, using the standard small-signal model of the transistor.

WORKING

1. $g_m = I_C / V_T = 1\,\text{mA}/25\,\text{mV} = 40$ mS
2. $r_\pi = \beta / g_m = 100/0.04\,\text{S}$
3. $r_\pi = 2500\ \Omega = 2.5\ \text{k}\Omega$

Feedback amplifiers and oscillators

12. How does voltage-series negative feedback change the gain and the input and output resistances of an amplifier?

Gain falls by the factor $1 + A\beta$, giving $A/(1 + A\beta)$. Series mixing at the input raises the input resistance by the same factor, and voltage sampling at the output lowers the output resistance by it. The amplifier then behaves more like an ideal voltage amplifier, with gain set mainly by β.

13. Why does negative feedback increase the bandwidth of an amplifier?

Feedback lowers the gain by $1 + A\beta$, and for an amplifier with a single dominant pole the upper cut-off frequency rises by the same factor. The gain-bandwidth product stays roughly constant, so the amplifier

trades gain for bandwidth. The result holds while the feedback network itself adds no further poles.

14. State the Barkhausen criterion for sustained oscillation.

A circuit sustains oscillation at a frequency where the loop gain $A\beta$ has magnitude 1 and a phase shift of 0 degrees, or a multiple of 360 degrees. In practice the loop gain starts slightly above 1 so oscillation builds up, and a nonlinearity then limits the amplitude.

15. A Wien bridge oscillator uses two equal resistors of 10 kΩ and two equal capacitors of 10 nF in its frequency-selective network. Find the oscillation frequency.

The oscillation frequency is about 1.59 kHz, from $f = 1/(2\pi RC)$ for the Wien bridge with equal resistors and equal capacitors in its frequency-selective network. At this frequency the network's gain is 1/3, so the amplifier needs a gain of 3 to sustain the oscillation.

WORKING

1. $f = 1/(2\pi RC)$
2. $RC = 10^{4} \times 10^{-8} = 10^{-4}$ s
3. $f = 1/(2\pi \times 10^{-4}) \approx 1592$ Hz ≈ 1.59 kHz

Op-amp circuits

16. What is the virtual short in an op-amp circuit, and when does it not hold?

With negative feedback and a very high open-loop gain, the differential input voltage is almost zero, so the inverting input sits at the potential of the non-inverting input. The inputs also draw almost no current. It fails when there is no negative feedback, as in a comparator, or when the output saturates.

17. What is the difference between an inverting and a non-inverting op-amp amplifier?

The inverting amplifier has gain $-R_f/R_1$, an inverted output and an input resistance of about R_1. The non-inverting amplifier has gain $1 + R_f/R_1$, which is never below 1, with no inversion and a very high input resistance. Both results assume an ideal op-amp.

18. Why does the slew rate limit the large-signal output of an op-amp?

The internal compensation capacitor can be charged only by a finite current, so the output voltage can change at no more than a fixed rate, the slew rate. A sine wave of peak V_p needs a rate of $2\pi f V_p$. Above the frequency where this exceeds the slew rate, the output turns triangular and distorts.

19. An op-amp has a slew rate of 0.5 V/µs and drives a sinusoidal output of 5 V peak. Find the highest frequency at which the output is free of slew-rate distortion.

The highest undistorted frequency is about 15.9 kHz, found by equating the peak rate of change of the sine, $2\pi f V_p$, to the slew rate of the op-amp.

WORKING

1. Peak slope of the sine is $2\pi f V_p$
2. $2\pi f V_p \le SR = 0.5\ \text{V}/\mu\text{s} = 5 \times 10^{5}\ \text{V/s}$
3. $f \le 5 \times 10^{5}/(2\pi \times 5) = 15.9$ kHz

Active filters and waveform circuits

20. What is a Schmitt trigger, and what problem does it solve?

A Schmitt trigger is a comparator with positive feedback, which gives it two switching thresholds, an upper and a lower one. This hysteresis stops a noisy input that hovers near a single threshold from producing repeated false output transitions. Once the output has switched, it switches back only when the input crosses the other threshold.

21. What is the difference between a first-order and a second-order active low-pass filter?

A first-order filter rolls off at 20 dB per decade beyond its cut-off, while a second-order filter rolls off at 40 dB per decade, so it separates wanted and unwanted frequencies more sharply. A second-order stage such as the Sallen-Key also has a quality factor that sets the shape near the cut-off.

22. Why is the duty cycle of a basic 555 astable multivibrator always above 50%?

In the standard astable circuit the timing capacitor charges through $R_A + R_B$ but discharges only through R_B. The output is high for the longer charging time and low for the shorter discharge time. The duty cycle is $(R_A + R_B)/(R_A + 2R_B)$, which stays above 50% for any positive R_A.

Noise, interference, shielding and grounding

23. What is thermal noise, and what does its magnitude depend on?

Thermal noise is a random voltage across a resistor caused by the thermal motion of its charge carriers, present at any temperature above absolute zero even with no current flowing. Its mean-square value is $4kTR\Delta f$, so it grows with temperature, resistance and bandwidth, and its spectrum is flat (white).

24. What is the difference between thermal noise and shot noise?

Thermal noise comes from the random motion of carriers and exists even with no dc current, depending on temperature and resistance. Shot noise comes from the discrete nature of charge crossing a potential barrier, so it exists only when a dc current flows. Its mean-square current is $2qI\Delta f$.

25. Find the rms thermal noise voltage of a 100 kΩ resistor at 300 K over a bandwidth of 10 kHz. Take $k = 1.38 \times 10^{-23}$ J/K.

The rms thermal noise voltage is about 4.07 µV, from $v_n = \sqrt{4kTR\Delta f}$ for this resistance, temperature and bandwidth, with the noise treated as white over the band.

WORKING

1. $v_n^2 = 4kTR\Delta f$
2. $v_n^2 = 4 \times 1.38 \times 10^{-23} \times 300 \times 10^5 \times 10^4 = 1.656 \times 10^{-11}\ \text{V}^2$
3. $v_n = \sqrt{1.656 \times 10^{-11}} = 4.07\ \mu\text{V}$

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