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Electronics I Final

Open Book/Notes/On-line

INDIVIDUAL EFFORT

Notes: 1. Put your name on each sheet.
2. For multiple choice, select correct answer or answers.
3. There are BONUS points available at the end in addition to the core questions.

I. Electronics: Diodes

Diodes are the fundamental starting point for electronics since they represent a simple 2-terminal device based on a junction between two different materials. For a typical Si diode, the two materials are p-type and n-type doped Si.

A. Si Diodes (Circle correct answer or correct answers.)

1. (4 pts) Typical V_t at room temperature (25°C)
   (a) 10 mV
   (b) 25 mV
   (c) 35 mV
   (d) 0.7 V

2. (4 pts) The diode equation expresses I_D as f(Is, Vd, Vt); which statements are true?
   (a) I_D increases as T increases
   (b) I_D decreases as T increases
   (c) I_D increases as V_D increases
   (d) I_D decreases as V_D increases

3. (4 pts) Typical V_F
   (a) 500 mV
   (b) 700 mV
   (c) 1.2 V

B. Diode applications

4. (4 pts) The function of the diode circuit shown in Fig. 1 with a 125Vrms 60Hz sine wave input:
   (a) Half-wave rectifier
   (b) Full-wave rectifier
   (c) Doubler
   (d) Asymmetric clamp

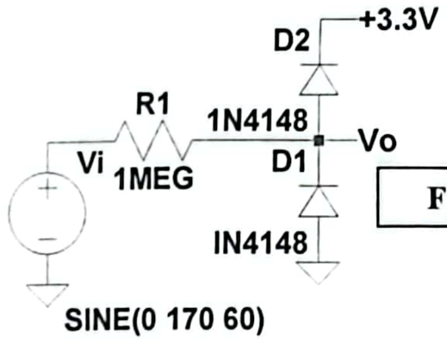

Fig. 1.

5. (4 pts) The most positive voltage of the input waveform is
   (a) +202 V
   (b) +176.7 V (Note: √2 * 125 = 176.7, but SPICE sim was done with 170 peak)
   (c) +125.0 V
   (d) 88.4 V

6. (4 pts) The most positive voltage at V_o is
   (a) + 5 V
   (b) + 4 V
   (c) + 3.3 V
   (d) + 0.7 V

7. (4 pts) The most negative voltage at V_o is
   (a) -5 V
   (b) -4 V
   (c) -3.3 V
   (d) -0.7 V

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8. (4 pts) The previous circuit could be redesigned to achieve the same function using a single
   (a) Schottky diode
   (b) Zener diode
   (c) Germanium diode
   (d) PIN diode

II. Electronics: BJTs

A. Basic BJT behavior

9. (4 pts) In Saturation the Base-Emitter junction is
   (a) Forward-Biased
   (b) Reverse-Biased
   (c) Unbiased

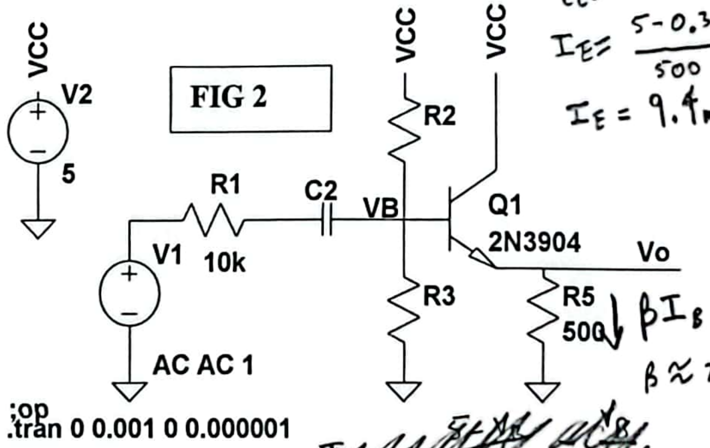
10. (4 pts) In Cut-off, the Base-Collector junction is
   (a) Forward-Biased
   (b) Reverse-Biased
   (c) Unbiased

11. (4 pts) Collector current, i_C is related to base current, i_B by
   (a) $i_C = i_B$
   (b) $i_C = \beta i_B$
   (c) $i_C = i_B/\beta$
   (d) $i_C = \beta^2 i_B$

B. BJT Applications

12. (4 pts) BJTs used as logic switches are designed to be in only two states:
   (a) Active and Saturation
   (b) Active and Cut-Off
   (c) Saturation and Cut-Off

13. (4 pts) For the "Emitter Follower" (also termed "Common Collector") circuit shown in Fig. 2, a Q point can be established to ensure that the output will not be distorted for a 1 Vpp (peak-to-peak) sine wave input at 100kHz for values of
   (a) R2 = 1kΩ, R3 = 100Ω
   (b) R2 = 50kΩ, R3 = 50kΩ
   (c) R2 = 50kΩ, R3 = 5kΩ



$V_{CE} = 0.3V$

$I_E = \frac{5-0.3}{500}$

$I_E = 9.4mA$

βI_B

$\beta \approx 200$

$V_B = 0.7 + 500 \cdot \beta I_B$

III. Electronics: MOSFETs

A. MOSFET Basics

14. (4 pts) The three regimes of MOSFET operation include
   (a) Saturation
   (b) Active
   (c) Triode
   (d) Cut-Off

15. (4 pts) The expression for K for a MOSFET is a function of
   (a) μ_n, electron mobility
   (b) Geometry (Width, Length)
   (c) C_{ox}, gate oxide capacitance
   (d) V_A, Early voltage

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16. (4 pts) The expression for g_m for a MOSFET is $2K(V_{GS}-V_T)$. If $K= 0.125\ mA/V^2$, $V_{GS}= 4.5V$, and $V_T= 1.5V$, compute g_m

(a) $g_m= 0.75\ mA/V$
(b) $g_m= 7.5\ mA/V$
(c) $g_m= 75\ mA/V$

17. (4 pts) When V_{ds} is very small, i_D can be expressed as $i_D = K[2(V_{GS}-V_T)VDS]$

(a) TRUE
(b) FALSE

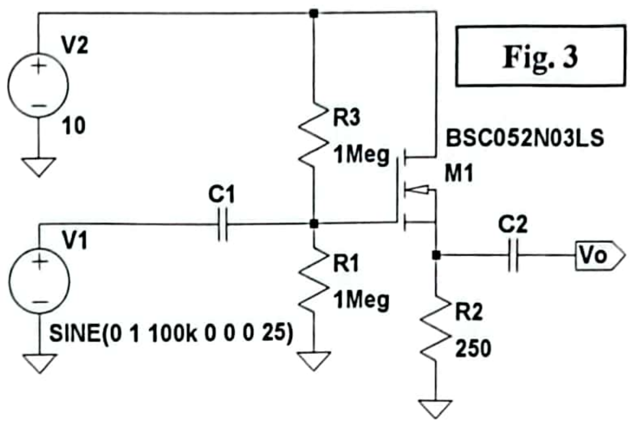
18. (4 pts) For the basic MOSFET model, the controlled source is $g_m V_{GS}$ shunted with r_o. r_o is

(a) $r_o = V_{GS}/I_D$
(b) $r_o = V_A/I_D$
(c) $r_o = V_{DS}/I_D$

B. MOSFET Applications

19. (4 pts) For the Source-Follower (aka "Common Drain") amplifier constructed using an NMOS transistor shown in Fig. 3, what is the bias voltage on the Gate of the device for the supply voltage, V2, of 10V?

(a) 1 V
(b) 4.3V
(c) 5 V
(d) 5.7 V



20. (4 pts) What is the approximate gain of the circuit? (A "follower" as the name implies, means the output should be close to the input magnitude.)

(a) 0.1 V/V
(b) 1 V/V
(c) 10 V/V
(d) 100 V/V

21. (4 pts) What is the closest minimum value of C1 that will both block dc and provide low loss (no more than -3dB attenuation) at 100kHz?

(a) C1 = 1pF
(b) C1 = 1 nF
(c) C1 = 1 uF
(d) C1 = 1000 uF

III. Systronix—the "System" of Electronics

A. Op amp and Feedback basics

22. (4 pts) Modern op amps are available with nearly ideal parameters such as

(a) $E_{os} \leq 100\mu V$
(b) $I_b \leq 10\ pA$
(c) Unity gain bandwidth of 3 MHz
(d) Dominant pole compensation near 100 Hz

23. (4 pts) The power of op amps is derived from trading excess open loop amplifier gain in closed-loop feedback topologies for behaviors defined by simple feedback elements.

(a) TRUE
(b) FALSE

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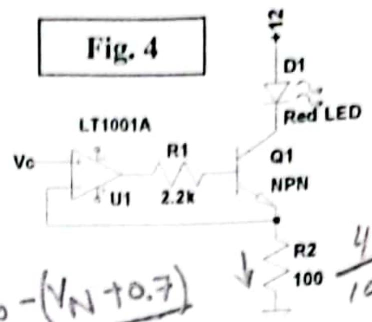
24. (4 pts) Among the advantages of employing negative feedback in an amplifier topology is/are:
   (a) Reduction in bandwidth
   (b) Increase in bandwidth
   (c) Reduction in gain sensitivity
   (d) Reduction in nonlinearities

B. Op amp applications



Combining op amps with discrete electronic devices can create very useful circuit functions. A small-signal op amp ($I_o max \leq 5mA$) is used in the circuit shown in Fig. 4 to drive a high-power LED, which requires I_F for the LED in the range of 15ma—50mA. The op amp is powered by +12V and GND.

25. (4 pts) What is the overall function of the circuit shown in Fig. 4?
   (a) Current-Controlled Voltage Source (CCVS)
   (b) Bias current compensator
   (c) Voltage-Controlled Current Source (VCCS)
   (d) Low-pass filter

26. (4 pts) If V_C is set to 4V, What is I_F through the LED?
   (a) 4000mA
   (b) 400mA
   (c) 40mA
   (d) 4mA

27. (4 pts) The purpose of Q1 is to
   (a) Provide current gain
   (b) Increase bandwidth
   (c) Control temperature
   (d) Nothing—it has no purpose, the circuit would work just as well without it.

C. Systems Concepts and Tools

28. (4 pts) Bode plots provide a convenient way to graphically represent the steady-state frequency response behavior (magnitude and phase) of a transfer function
   (a) TRUE
   (b) FALSE

29. (4 pts) The Bode plot for a constant gain, K, is
   (a) $20Log_{10}|K|$
   (b) $10Log_{10}|K|$
   (c) $20Log_{10}|K^{-1}|$

30. (4 pts) The Bode plot magnitude response for a pole—e.g., $H(j\omega) = 1/(1+j\omega/\omega_o)$ has
   (a) 0dB loss and 0° phase shift at $\omega = 0.01\omega_o$
   (b) 0dB loss and 0° phase shift at $\omega = 100\omega_o$
   (c) -40dB loss and -90° phase shift at $\omega = 100\omega_o$
   (d) -3dB loss and -45° phase shift at $\omega = \omega_o$

31. (4 pts) A good starting point for selecting a bulk capacitor is
   (a) 1μF
   (b) 10μF per 100mA, with minimum of 10μF
   (c) 0.01μF

32. (4 pts) Bypass capacitors should be
   (a) Left out—"Muntzed"—from a circuit because they are unnecessary
   (b) Typically 0.1 μF at each digital device supply pin
   (c) Typically 0.01 μF at each analog device supply pin
   (d) Grouped tightly together in one corner of a circuit board as far from ICs as possible

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33. (4 pts) Principles of good electronic interconnect to minimize effects of transmitted/received noise include
   (a) Lead wires positioned to maximize loop area
   (b) Twisted lead wires to minimize loop area
   (c) Use of shielded cables
   (d) Use of metal—or metalized--enclosures

34. (4 pts) A first step in thermal management of electronic systems is to model the system as power sources combined with thermal resistances to an ambient thermal sink.
   (a) TRUE
   (b) FALSE

35. (4 pts) A Si power MOSFET has a $T_{\theta J\text{-}Case}$ of 1.0°C/W and a $T_{\theta Case\text{-}Ambient}$ of 15°C/W. If the device is operated at 10W in an ambient temperature, T_A, environment, determine the device junction temperature rise above T_A.
   (a) 100°C
   (b) 10°C
   (c) 150°C
   (d) 160°C

36. (4 pts) Good grounding practices help ensure minimum noise in systems with different subsystems including safety, analog, digital, and power. What are some practical grounding strategies you would employ for best results?
   (a) Star topology – Every ground point has a direct connection to every other ground point
   (b) Bus topology – Like devices share a common bus
   (c) Single point ground – Every type of ground is finally connected to a single point
   (d) Hybrid – A mixture of grounding strategies is employed

37. (4 pts) Use of a shield can minimize coupling of stray electromagnetic fields.
   (a) TRUE
   (b) FALSE

IV. Electronic Systems

In the end, the true power of electronics occurs when useful system-level and subsystem-level functions are implemented by combining many electronic components and concepts.

For the provided Macroelectronic circuit schematic, answer the following questions:

Circuit #1, Power Supply, Notes:

1. **This is an example circuit patterned after a 20th-Century power supply (Tektronix)—only the positive side of the circuit is shown.**
2. **The raw dc input voltages to the power supply are +33V and +11.5V.**
3. **The output voltage, Vout, is adjustable over a limited range using a potentiometer (R15 on the schematic).**

38. (4 pts) VR10 is what type of diode?
   (a) Schottky
   (b) Signal
   (c) Rectifier
   (d) Zener

39. (4 pts) What does the combination of R10 and VR10 do?
   (a) Ensure that the 11.5V supply rail does not go negative
   (b) Amplify the 11.5V supply rail
   (c) Serve as a shunt regulator to supply approximately 5.1V to the non-inverting input of U10

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40. (4 pts) What is the current flowing through R10?

(a) 1A
(b) 7.4mA
(c) 0.3mA
(d) 2μA

41. (4 pts) Assuming the output voltage, Vout, has been adjusted to +15V, what current will flow through R11?

(a) 99mA
(b) 67mA
(c) 9.9mA
(d) 6.7mA

42. (4 pts) What amplifier topology is U10 and its associated components?

(a) Op amp used as inverting amplifier
(b) Op amp used as non-inverting amplifier
(c) Op amp used as comparator
(d) Op amp used as precision rectifier

43. (4 pts) What gain equation describes U10 with its associated components?

(a) –(R13+R15)/R12
(b) +(R13+R15)/R12
(c) +{1 + (R13+R15)/R12)}
(d) –R16/R12

44. (4 pts) What is the total resistance adjustment range possible with the combination R13 + R15?

(a) Fixed at 7.5kΩ
(b) Varies from 2.5kΩ up to 7.5kΩ
(c) Varies from 7.5kΩ up to 12.5kΩ
(d) Can't be determined since it depends on the bias point of M10

45. (4 pts) What is the total adjustment range for Vout as R15 is adjusted over its full range of 0-5kΩ?

(a) 5.1VDC to 7.6VDC
(b) 0 to 15.5VDC
(c) 12.75VDC to 17.85VDC
(d) -5VDC to +5VDC

46. (4 pts) Q11 serves as an over-current detector. What is the minimum value of output load current that will cause Q11 to turn on and thereby turn off M10?

(a) 100mA
(b) 700mA
(c) 1A
(d) 10A

47. (4 pts) When the circuit is current limiting, what is the approximate Vgs of M10?

(a) 15.0V
(b) 10V
(c) 0.7V
(d) 0.2V

(BONUS, BONUS, BONUS +50 pts)

Select and analyze a circuit from the circuits shown in EDN's circuit design ideas https://www.edn.com/category/design/design-idea/