

## Midterm #2 Solutions – EECS 145L Fall 2004

- 1a** Technical requirements of a ground fault interrupter circuit:
- (i) open both current carrying power conductors (hot and neutral) when the difference in their currents exceeds 5 mA
  - (ii) provide a reset button
  - (iii) provide a test button
- [5 points off for describing the circuit breaker]  
[3 points off for trip if current exceeds 5 mA rather than if current difference exceeds 5 mA]  
[1 points off each for missing the reset or test features]
- 1b** How the ground fault interrupter circuit functions:
- (i) the difference in currents is converted into a 60 Hz voltage using a differential transformer
  - (ii) this voltage is rectified and amplified
  - (iii) the resulting dc voltage trips two relays which hold both conductors open until reset
  - (iv) the test button sends a 5 mA current through differential transformer
- [1 point off the operation of the test button is not described]
- 2a** Since  $R_2/(R_1 + R_2) = R_3/(R_T + R_3)$ ,  $R_2 = R_3$ , and  $R_T = 10 \text{ k}\Omega$  at  $20^\circ\text{C}$  the solution is  $R_1 = 10 \text{ k}\Omega$ .
- 2b**  $P = V_T^2/R = (0.5 \text{ volts})^2/(10 \text{ k}\Omega) = 25 \mu\text{W}$
- 2c** Amplifier output of 0.05 volts means a bridge output  $V_+ - V_- = 0.01$  volts. Using the bridge equation (supplied on the equation sheets), we have  $R_T = (10000 \Omega) * (10000 \Omega - 0.01 * 20,000 \Omega) / (10000 \Omega + 0.01 * 20,000 \Omega) = 9608 \Omega$
- [2 points off for not dividing by the amplifier gain]  
[3 points off for assuming a linear response from  $0^\circ\text{C}$  and  $0 \Omega$  to  $20^\circ\text{C}$  and  $10 \text{ k}\Omega$ ]
- 2d**  $T = 20^\circ\text{C} + (9608 \Omega - 10000 \Omega) / (-300 \Omega/\text{C}^\circ) = 21.3^\circ\text{C}$
- 2e**  $V_T = 1 - 10000 \Omega / (10000 \Omega + 9608 \Omega) = 0.490$  volts
- $P = (0.490 \text{ volts})^2 / (9608 \Omega) = 24.99 \mu\text{W}$  ( $25 \mu\text{W}$  was accepted for full credit)
- 2f** Dissipation coefficient =  $25 \mu\text{W} / (21.3^\circ\text{C} - 20^\circ\text{C}) = 19 \mu\text{W}/^\circ\text{C}$
- [2 points off for using difference between 2e and 2b in numerator]
- 3**
- [1 point off for inadequate labeling of voltage and current amplitudes]  
[3 points off for each seriously incorrect amplifier stage anywhere in circuit]  
[2 points off for incorrect gain value or inconsistent resistor values]  
[1 point off for using 60 Hz notch filter instead of a difference amplifier since it rejects 60 Hz microphone signals]  
[3 points off for not using a difference amplifier or notch filter to reject 60 Hz common mode microphone output]  
[4 points off for not using a voltage controlled current driver for LED]  
[no points off for using a  $1 \text{ k}\Omega$  resistor to convert photodiode 1 mA to 1V since GaAs photodiodes can do this (silicon saturates at 0.6 V)]

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[1 point off for using a 10 kΩ resistor to convert photodiode 1 mA to 10V]

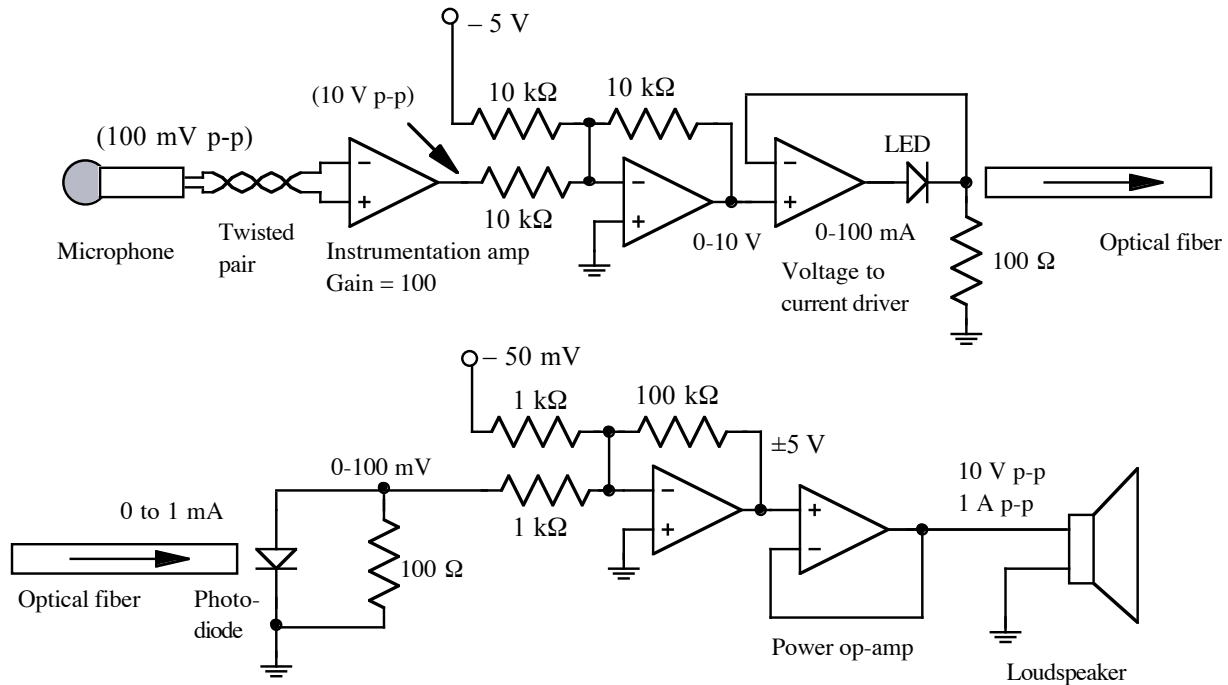
[4 points off for no detail of photodiode current to voltage circuit or open circuit ( $R > 100 \text{ k}\Omega$ )]

[6 points off for no photodiode current to voltage circuit]

[15 points off for no circuit between photodiode and speaker]

[2 points off for not indicating a power amp to drive the speaker (need 10V at 1 A)]

Note: Since the microphone waveform oscillates about zero, it is necessary to level shift before driving the LED and after the photodiode current to voltage converter. This was not required for full credit.



### 145L midterm #2 grade distribution:

#### Problem

1	16.8 (4.9 rms) (20 max)
2	37.5 (3.5 rms) (40 max)
3	36.1 (4.1 rms) (40 max)

maximum score =	100
average score =	90.4 (10.0 rms)
40-49	
50-59	
60-69	2 D
70-79	1 C
80-89	4 B
90-99	19 A
100	2 A+

3 graduate students: average = 94.3

8 BioEngineering undergraduates: average = 90.9

12 EECS undergraduates: average = 91.6