EECS 145L Final Examination Solutions (Fall 2001)

UNIVERSITY OF CALIFORNIA, BERKELEY
College of Engineering, Electrical Engineering and Computer Sciences Department

1a The **ideal op-amp** has infinite differential gain while the **ideal instrumentation amplifier** has a fixed differential gain (set by external resistors) over a range of frequencies.

[3 points off for ideal op amp gain falling as 1/f, which is a property of the realistic op-amp]

[2 points off for ideal instrumentation amplifier having infinite differential gain]

1b The **ground fault interrupter** interrupts the circuit when there is >5 mA imbalance between the hot and neutral conductors to protect humans. A **circuit breaker** interrupts the circuit when the current is large enough to damage equipment or cause a fire.

[3 points off if GFI tests current rather than current difference]

1c The **thermocouple** consists of two dissimilar metals joined in two junctions. The output voltage is linearly proportional to the difference in temperature between the two junctions. The **thermistor** is a **semiconductor** whose resistance decreases exponentially with increasing temperature.

[3 points off for not stating that thermocouple consists of dissimilar wires and thermistor is a semiconductor]

1d The **common mode gain** is the amplification factor for the **average** of the two inputs. The **differential gain** is the amplification factor for the **difference** between the two inputs.

$V_0 = G_C (V_+ + V_-)/2 + G_\pm (V_+ - V_-)$

1e A **light emitting diode** converts current into light intensity and a **photodiode** converts light intensity into current.

[2 points off if current not mentioned]

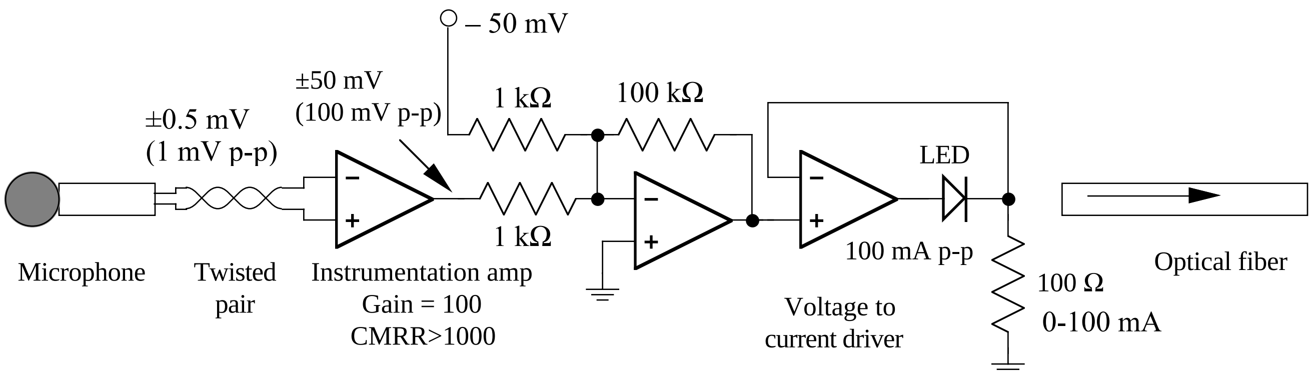
1f **Stress** is the applied force per unit area. **Strain** is the fractional change in length.

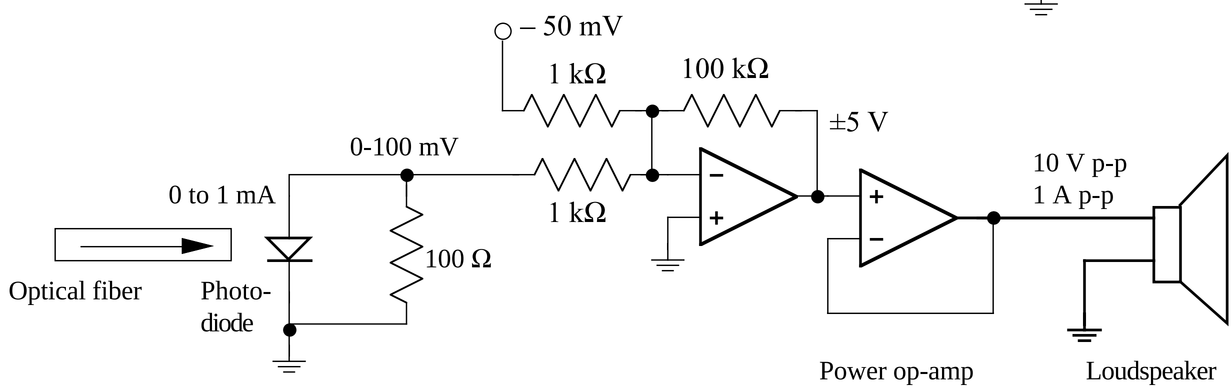
2a overall differential gain: 10 V p-p at speaker/1 mV p-p at microphone = 10,000
overall common mode gain: 10 mV at spekaer/1 mV p-p at microphone = 10
CMRR = 10,000/10 = 1,000

microphone output: 0 mV differential; 1 mV p-p 60 Hz common mode
instrumentation amplifier output: < 100 µV 60 Hz (differential gain 100, common mode gain 0.1)
inputs to summing amplifier: < 100 µV p-p 60 Hz and -50 mV d.c.
summing amplifier output: <10 mV p-p 60 Hz and +5V d.c. (shifted, amplified 100x, and inverted)
voltage to current converter: 10mA output per 1 V input (100 Ω)
LED current: 50 mA dc (midrange of 0 to 100 mA) and <100 µA 60 Hz
Photodiode output: 0.5 mA (midrange) and <1 µA 60 Hz
current to voltage converter: 1 V output per 10 mA input
produces 50 mV d.c. and < 100 µV 60 Hz
level shift by 50 mV and amplify 100x
produces 0 V and <10 mV 60 Hz input to power amplifier (gain = 1) and speaker

2b (60 Hz common mode same as **2a** above)
microphone output: 1 mV p-p (± 0.5 mV) differential
instrumentation amplifier output: 100 mV (± 50 mV) p-p
inputs to summing amplifier: 100 mV p-p and -50 mV d.c.
summing amplifier output: 0 V to 10 V (shifted, amplified 100x, and inverted)
voltage to current converter: 10 mA output per 1 V input (100 Ω)
LED current: 0 mA to 100 mA
Photodiode output: 0 mA to 1 mA
current to voltage converter: 1 V output per 10 mA input
produces 0 mV to 100 mV
level shift by -50 mV and amplify 100x
produces 10 V p-p (±5 V) input to power amplifier (gain = 1) and speaker

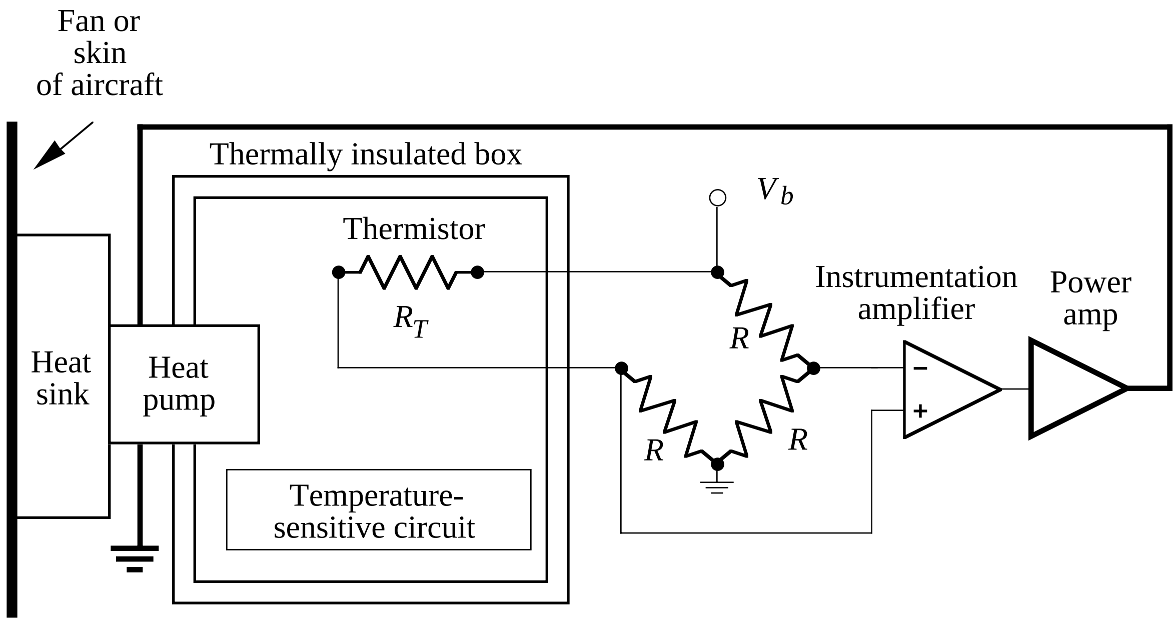
2c





[3 points off if no CMRR > 1000 (design requirement #1)]
[3 points off if no voltage to current circuit for LED]
[3 points off if gain not correct to drive LED at 0-100 mA (need gain/resistance = 100/ohm)]
[6 points off if LED is driven with -50 mA to +50 mA- level shift is needed to convert to 0 to 100 mA]
[3 points off if power amplifier not specified to drive speaker]
[3 points off if 1 mA from photodiode does not drive 10 V at speaker (need gain x resistance = 10 kΩ)]
[3 points off 60 Hz notch filter is used, since this violates design requirement #2]

3a



R = thermistor resistance at 20 °C

For maximum sensitivity and zero output at 20°C, all bridge resistors R are made equal to resistance R_T of the thermistor at 20°C. When thermistor resistance exceeds the bridge resistors R (too cold), bridge imbalance causes the power amp to drive the heat pump so as to pump heat into the insulated box. When the thermistor resistance is less than the bridge resistors (too hot), the heat pump removes heat from the box. The instrumentation amplifier gain is set high so that only a small bridge imbalance is needed to make the power amplifier control the heat pump.

[3 points off if no heat sink]

[3 points off if no power amplifier to run heat pump]

[3 points off if there is no way described for heat sink to exchange heat with the surroundings- cooling requires a finned heat sink with a fan or contact with the skin of the aircraft to remove heat from the insulated box- a simple metal plate would heat up excessively during an 18 hour flight]

[Many students got points deducted because they only sketched the electrical portion of the temperature control system and omitted the thermal portion]

3b

At 0°C: The temperature inside the insulated box is slightly below 20°C, enough to imbalance the bridge and cause the heat pump to heat the box. The heat comes from a combination of Joule heating and heat transferred from the heat sink into the box. The heat sink cools, but this process is limited by heat exchange with the surroundings (fan or skin of aircraft).

[The heat sink is not strictly necessary for heating because temperature control can be achieved by Joule heating only]

3c

At 40°C: The temperature inside the insulated box is slightly above 20°C, enough to imbalance the bridge and cause the heat pump to cool the box. The heat pump transfers heat (both from the box and Joule heating of the heat pump itself) to the heat sink. The heat sink warms, but this process is limited by heat exchange with the surroundings (fan or skin of aircraft).

[2 points off if role of heat sink is not mentioned]

145LFinal Examination score distribution:

131-140	0	141-150	0	151-160	2U
161-170	4U	171-180	4U, 2G	181-190	8U, 1G
191-200	4U, 1G				

undergraduate (U) average = 179.3
graduate (G) average = 186.0

145L Course Grade Distribution

Grade	Undergraduate Scores	Graduate Scores
A+	950	954
A	921, 921, 941, 943	926, 927
A–	901, 905, 907	
B+	879, 880, 885, 887, 890	883
B	861, 862, 869, 871	
B–		
C+	815, 825, 831	
C		
C–	780, 787	
Maximum	1000	1000
Average	878	923