EECS 145L Final Examination Solutions (Fall 2003)

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

1.1 The **differential gain of an instrumentation amplifier** is the change in output voltage V_0 divided by a change in ΔV, where $\Delta V = V_+ - V_-$

[2 points off for not making it clear that gain is a ratio of output to input]

1.2 The **actuator** transducers an electrical signal into a physical quantity

1.3 The **electronic ice point** is a temperature sensor used to correct the output of a thermocouple for changes in its reference temperature.

[6 points off for only describing the thermocouple]

[5 points off for describing the physical ice point rather than the electronic ice point]

[3 points off for not mentioning the need for a second temperature sensor]

1.4 The **ground fault interrupter circuit** monitors the difference in the currents between the hot and neutral conductors and interrupts (disconnects) both conductors when the current difference exceeds 5 mA

1.5 The **Low-pass** filter passes low frequencies and attenuates high frequencies.

1.6 A **response curve of a sensor** is the relationship between the physical input and the electrical output OR the temporal response to a step function input.

2.1 The LPF has R = 1 kΩ, C = 0.159 μF, and a corner frequency $f_c = 1/(2\pi RC) = 1$ kHz

The HPF has R = 100 kΩ, C = 0.159 μF, and a corner frequency $f_c = 1/(2\pi RC) = 10$ Hz

$$G = \frac{1}{\sqrt{1+(f/1\,\text{kHz})^2}} \frac{f/10\ \text{Hz}}{\sqrt{1+(f/10\ \text{Hz})^2}}$$

G = 0.707 at 10 Hz and 1 kHz

2.2 G = 0.1 at 1 Hz and 10 kHz

3.1 Mount a narrow-beam light emitter at the bottom of the tank aimed at a light sensor mounted on the top. Measure the absorption to determine the height of the liquid.

Vertically mount a string of 100 light emitters and sensors with 0.1 m spacing. Use the light absorption to determine which are in liquid and which are in vapor.

Shine a beam of light on the top of the liquid. Detect the beam using a horizontal array of light sensors at the top of the tank. Use geometry to determine height of liquid.

3.2 Mount a small sealed vessel at the bottom of the tank. The walls of this vessel will experience a stress proportional to the pressure of the liquid. Use strain gauges mounted on the side of the vessel to measure the pressure (and the height) of the liquid above. This method requires calibration.

Build a force sensor using 4 strain gauges and a flexible rod (same as in the 145L lab). Mount the force sensor from the top inside of the tank. Hang a second rod from the force sensor where the rod has the same density as the liquid. Due to buoyancy, the apparent weight of the vertical rod will be equal to the portion of the rod above the liquid level.

Build 100 force sensors, each using 4 strain gauges and a flexible rod. Mount the rods horizontally on the inside wall of the tank, every 0.1 m, and mount a buoyant ball on the end of each The submerged rods will be deflected upward by the buoyant force on their balls and the rods in vapor will be bent downward by the weight of the balls.

Mount strain gauges at the bottom sides of the large tank to measure the strain (and pressure) of the liquid above. This method requires calibration.

If the tank is not sitting directly on the ground but on a metal or cement foundation, mount strain gauges on the foundation wall. The vertical strain experienced by the foundation. will be proportional to the weight of the water in the tank. This method requires calibration.

If the bottom of the tank has an air space below it, mount strain gauges on the bottom to measure the downward bulging due to the weight of the water above. This method requires calibration. [this method will not work if the strain gauges are mounted to the inside floor of the tank and there is no air space below]

[a strain gauge simply suspended in the liquid will not work because it experiences a uniform hydrostatic pressure from all sides- there is no stress on the gauge]

3.3 Mount the angle sensor on the top wall of the tank. Attach one end of a long rod to the sensor and attach the other end of the rod to a float that rides on the top of the liquid (similar to the level sensor in your automobile gas tank). This method requires calibration.

Mount the angle sensor on the inside top of the tank and connect its shaft (using gears if necessary) to a bobbin/spring arrangement like the automatic retractor of a metal tape measure. A cable is wound around the bobbin with its free end connected to a float that rides on the surface of the liquid. As the liquid level changes, the bobbin rotates to take up or play out the cable and the angle sensor measures the result.

3.4 Mount an insulating tube vertically in the tank. The tube is open at the bottom so that the liquid level is the same as in the tank. Mount an electrode at the bottom of the tank and float another electrode at the surface of the liquid in the tube. Measure the resistance of the liquid in the tube to determine the height of the liquid in the tank.

Mount one electrode at the bottom side of the tank and mount the other on the opposite side. The total resistance through the liquid will depend on the height of the liquid. This method requires calibration.

Mount 100 pairs of electrodes on a vertical rod at 0.1 m intervals. The electrode pairs in the liquid will conduct and those in the vapor will not.

3.5 Mount a vertical column of 100 thermistors, with a spacing of 0.1 m. Wire each into a bridge operating at a voltage sufficient to cause considerable self-heating when the thermistor is in the vapor. The temperature of the vapor and liquid are both T_0. The temperature of the thermistor in the vapor will be T_{vap}, well above T_0. The temperature of the thermistor in the liquid T_{liq} will be much closer to T0 due to the closer thermal coupling. The outputs of the 100 bridges will thus have two distinct values, corresponding to whether the corresponding thermistor is in the liquid or in the vapor.

Use a large heater to put a pulse of heat into the gas. The thermistors in the gas will respond but the thermistors in the liquid will respond very little, and with considerable delay.

Lower a single thermistor at constant speed toward the liquid level. Operate the thermistor in a bridge at a sufficient voltage to cause considerable self-heating. When the thermistor reaches the surface, its temperature, its resistance, and the bridge output will abruptly change. Knowing the amount of lowering determines the liquid level.

Use a large heater to put a pulse of thermal energy into the liquid. Measure the temperature change of the liquid to determine the volume of the liquid. [It is essential that the new temperature be reached before significant heat transfer with the surrounding air]

Provide a radiant heat source at the top of the tank. Float a thermistor in a small float on the top of the liquid so that the thermistor is in the vapor, not the liquid. The temperature of the thermistor will depend on the distance to the radiant source, and thus on the liquid level.

[Applying heat energy to the liquid and measuring the equilibrium temperature of the does not work because it is as dependent on the outside air temperature and the wind velocity as the heat being applied]

[Mounting 100 thermistors and using evaporative cooling will not work when the liquid is rising and will not work when the liquid takes longer to fall 0.1 m than it takes to evaporate]

3.6 Mount a speaker and microphone at the top of the tank. Use the speaker to send a pulse of sound toward the liquid level. Use a microphone to detect the echo from the liquid surface use the echo return time to determine the liquid level.

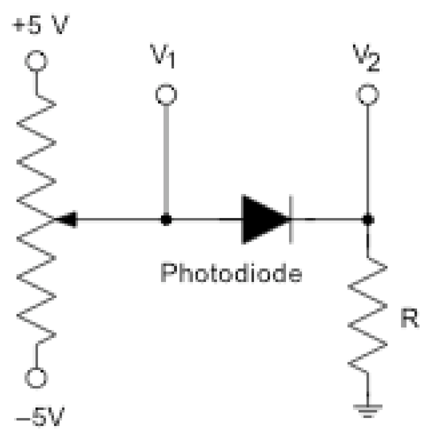
Mount a speaker on the inside roof of the tank and float a microphone on the surface. Use the time delay to measure the height of the air above the liquid.

Mount a speaker at the top of the tank and emit sound at a variety of frequencies (white noise, variable frequency oscillator, etc.). Use the microphone to measure the resonant frequency in the vapor (like an organ pipe or a partially filled bottle) and determine the height of the column of vapor.

Mount a 100 pairs of speakers and microphones spaced 0.1 m apart. on a vertical rod. The microphones in the liquid will have better acoustic coupling to their speakers that those in the vapor.

Mount a microphone at the top of the tank and mount an automatic hammer at the outside base of the tank. The frequency of the resulting sound will depend on the liquid level in the same way that the frequency of the sound of a glass of water when tapped will depend on the liquid level in the glass.

4.1



[6 points of if circuit does not allow control of V_{diode} or I_{diode}]

4.2 Adjust potentiometer, measure V_1

Measure V_2

Voltage across diode $V_{diode} = V_1 - V_2$

Current through diode $I_{diode} = V_2/R$

Change V_1 and repeat to measure entire curve

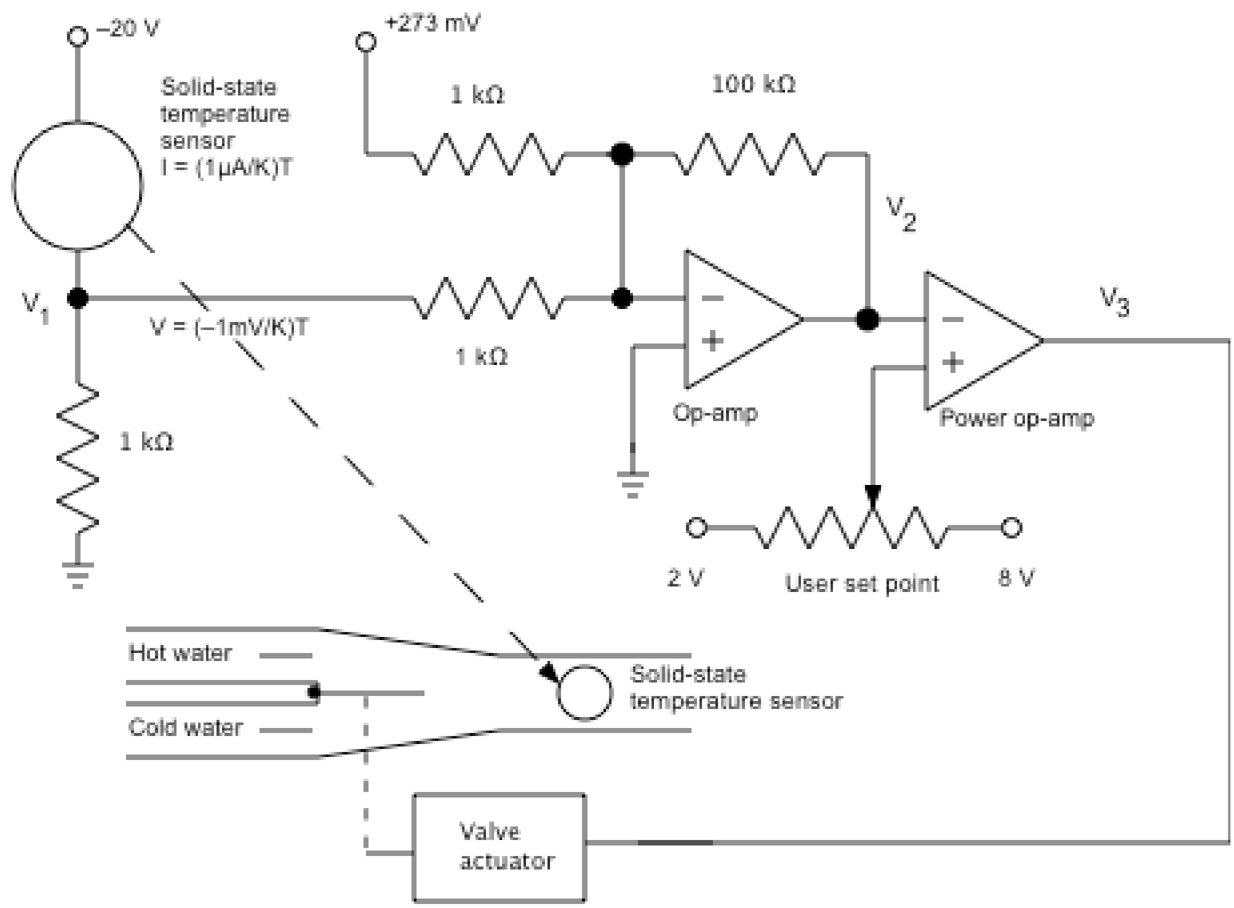
[2 points off for measuring a single V_{diode}, I_{diode} point- the problem asked for a measurement of I_{diode} as a function of V_{diode}.]

[4 points off for failing to determine I_{diode} or V_{diode}]

Its is also possible to use a voltage-controlled current driver. A series of currents is set and the voltage across the diode measured for each current.

4.3 See textbook, figure 4.36 for I_{diode} vs. V_{diode} curves

5.1



If the temperature at the output of the mixing valve is T (in °C), the output of the solid state temperature sensor is V_1 = –(T+273) mV which is summed with +273 mV to produce V_2 = (100 mV)T at the output of the summing op-amp.

[A thermocouple could also be used, but this would require keeping the reference junction at a known temperature]

[a thermistor was allowed, in spite of its nonlinear response. As may be seen in Figure 4.23 of the textbook, the thermistor bridge output is reasonably linear over a ± 30°C temperature range.]

5.2 The user set point is at 2.0V, and by the virtual short rule, V2 = 2.0 volts, which corresponds to a temperature of 20 °C, as desired. The power op-amp output V3 = –5V, as needed to pass only 20°C water through the mixing valve.

[Note that V2 is actually a bit higher than 2.0 V so that the power op-amp gain can produce –5V. Remember the basis for the virtual short rule: The op-amp produces whatever output is necessary to make both of its inputs nearly equal. The difference in inputs is 5 V divided by the large open-loop gain]

5.3 When the set point temperature is changed to 6.0 V, the output of the power op-amp will be driven strongly positive to mix in hot water. The system will come into equilibrium when V2 is approximately 6.0 V, which occurs when the solid state temperature sensor is at 60 °C, as desired.

5.4 If the hot water temperature is reduced from 80°C to 70°C, the output of the mixing valve will become cooler, and V2 will drop below the user set point of 6.0V. This will increase the voltage to the valve controller, and increase the faction of hot water in the mix. The system will again come into equilibrium when V2 is approximately 6.0 V, which occurs when the solid state temperature sensor is at 60 °C, as desired.

145LFinal Examination score distribution:

100-109	0	110-119	1	120-129	0
130-139	0	140-149	1	150-159	1
160-169	2	170-179	4	180-189	6
190-199	9	200	0		

19 undergraduates: average = 176.1, rms = 20.2
5 other students (4 graduate , 1 exchange) : average = 191.0, rms = 1.6

145L Course Grade Distribution

Grade	Undergraduate Scores	Other Scores*
A+	986	986
A	983	983
A–	932, 933, 938, 942, 943, 952, 957	931, 935, 950
B+	889, 898, 906	
B	860, 867, 874, 876	
B–	840, 851	
C+		
C		
C–		
D+		
D	708	
D–		
F		
Maximum	1000	1000
Average	901.8	957.0
rms	64.3	26.1

* 4 graduate , 1 exchange

Note: the average grade for the lab report 4,6,12,14,18 series was 95.5 and the average grade for the lab report 5, 11, 13, 17, 19 series was 95.3. No adjustment was necessary.