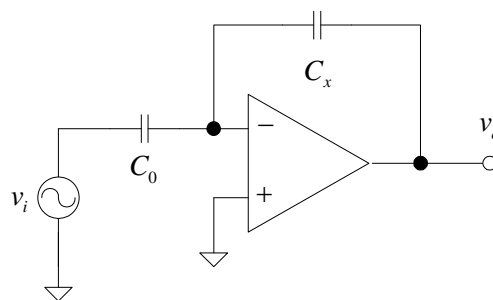


## Final Exam (Spring 2009)

\* 20 points/problem and 5 problems total. Your answer should not exceed 2 pages.

- (1) Your job is to design a wireless ECG telemetry system. You should include 20 wearable mobile battery-powered ECG devices in the system and one central monitor. Each mobile device sends measured analog ECG signal of a patient through an amplitude modulated (AM) wireless transmitter. The central monitor receives AM ECG signals from all 20 devices and displays all 20 signals on one large LCD monitor. The baseband of each ECG signal is from 0.05 to 100Hz. Using the frequency division multiplexing (FDM), design the entire system. Try to provide as much details as possible.
- (2) Design a disposable ECG electrode. Provide a method to evaluate its equivalent circuit model of the electrode-electrolyte interface.
- (3) Your job is to design a heart rate detector using a capacitive sensor. You made a conducting plate with  $5\text{cm}^2$  surface area. You plan to place the plate on the skin of the thorax of a patient. The distance  $x(t)$  between the plate and the skin changes as  $x(t) = 1 + 0.2\sin(2\pi ft)$  [mm] as the heart is beating. Here,  $f$  is the fundamental frequency of the beating heart. You are going to measure  $x(t)$  using the following circuit. Note that  $\epsilon_0 = 8.8 \times 10^{-12}\text{F/m}$ . Assume that the heart rate is 60bpm.



- (a)  $C_x$  is the capacitance between the plate and the skin. Express  $C_x$  as a function of the distance  $x(t)$ . Find its maximal and minimal values.
- (b) Assume that  $v_i(t) = \sin(2\pi \times 10^4 t)$  V,  $C_0 = 4.4\text{pF}$ . Find and plot  $v_o(t)$ .
- (c) Design a phase-sensitive demodulator to extract  $x(t)$  from  $v_o(t)$ .

- (4) Your patient has a systolic pressure of 120mmHg and diastolic pressure of 80mmHg. Her heart rate is 60bpm. Assume that the arterial pressure in her upper arm changes as a sinusoidal wave.
- (a) Plot her arterial pressure signal in the upper arm for 20 second.
  - (b) You are measuring her systolic and diastolic pressure using an NIBP device. The device already inflated the cuff so that the cuff pressure reached 140mmHg at time 0. From time 0, it starts deflating the cuff with  $-4\text{mmHg/s}$  rate until the cuff pressure becomes 60mmHg. Overlay the cuff pressure signal measured by using a semiconductor pressure sensor on top of the plot in (a).
  - (c) The device high-pass filters the measured cuff pressure. Plot the waveform at the output of the high-pass filter.
  - (d) Explain how to determine the systolic and diastolic pressure from the waveform in (c).
- (5) Propose a structure of an ECG monitor including dc power supply (or supplies). Include details of your design for electrical safety. You are supposed to use two microprocessors. One is used in the isolated (or floating side) and the other in the earth grounded side.