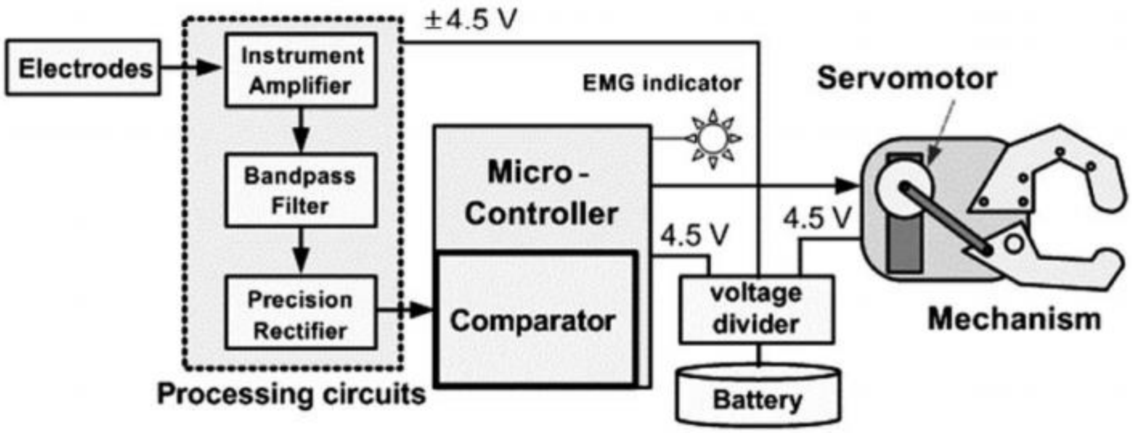
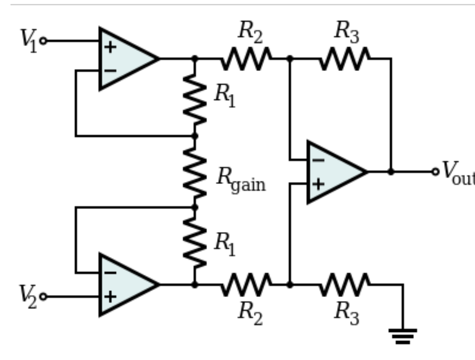
ELG4139: Myoelectrically Controlled Partial-hand Prosthesis System



Suppose you are asked to design myoelectrically controlled partial-hand prosthesis system. The proposed prosthesis consists of three main parts: 1) electromyogram (EMG) signal-processing circuits; 2) the microcontroller and the embedded program; and 3) the prosthesis mechanism. The typical amplitude of EMG ranges from 10–1000 μV. The EMG signals generated from a contracting muscle and detected by physiological signal **electrodes** are first sent to the **instrumentation amplifier**, then to **bandpass filter**, and a **precision rectifier circuits**. Three **electrodes** are required to acquire the EMG. Two of these **electrodes** (**electrodes** I and II) are attached to the bicepps and serve as the differential inputs to the **instrumentation amplifier**, while the third (ground, GND) is arbitrarily attached to a different location on the arm as a ground reference and is connected to the ground of the system. The resulting signals are used as inputs to a **microcontroller** and are converted to digital ones by a **comparator** embedded in the microcontroller. According to the digital signals, the program built in the microcontroller can make precise decisions and then output PWM signals to control the **servomotor** to drive the prosthesis. The amplifier is used as a first stage differential amplifier with a gain of 20. This amplifier exhibits **a high rejection of noise**. This component is also selected for its compactness. Differential inputs allow the direct current (dc) component to be eliminated from the electrodes. A bandpass filter with a gain 100, consisting of a high-pass and a low-pass filter, was designed with a low power op amp. The cutoff frequency of the low-pass filter was 500 Hz while that of the high-pass filter was 50 Hz. Meanwhile, the total gain of the combination of the instrument amplifier and the bandpass filter is 3000. This gain is high enough to amplify the obtained EMG signals to a level suitable for processing during the subsequent precision rectifier stage. After the signal passes through the bandpass filter, the precision rectifier reshapes the pulses that can be fed successively into the comparator embedded in the microcontroller.

To save energy and for convenience, a 9-V is used to power the entire system. However the available voltage is 12-V. Moreover, a resistor divider is utilized to generate 4.5 and 4.5 V dc; both can serve as dc sources for op amps in a signal-processing circuit. The 4.5-V source also supplies the microprocessor and the servomotor. The power consumption and compactness must be considered so that selecting a motor is challenging. A servomotor commonly used for control applications consumes much current and is oversized and expensive. Because a stepping motor loses step under some conditions, it unsuitable in this application. Following a survey of products, an R/C servomotor is adopted herein to drive the prosthesis mechanism. The R/C servomotor, equipped with a position feedback control circuit and a decelerating gearbox assembly, provides a simple control mechanism. The R/C servomotor is controlled by a PWM signal, which can drive the motor to a desired position according to the width of the pulse. In this design, the Mitsubishi M51660L control chip is adopted as an R/C servomotor controller.

Question 1: Design an appropriate instrumentation amplifier for a signal from the electrodes to be amplified to a level of 10 V (rms). The impedance of the electrodes is R_s = 10 kΩ and the output voltage from the electrodes 10 mV (rms).



Question 2: Design and draw a proper bandpass filter for the system. Select the following cut-off frequencies: 500 Hz and 1500 Hz.

Question 3: Design and draw a two-diode rectifier that provides a DC output signal of 10 V. It is also needed to design a proper filter using a resistor and a capacitor in order to remove the output ripple.

Question 4: Design and draw a voltage divider if a 9V battery is needed to supply two 4.5 V loads.

Question 5: The servo motor is controlled by PWM signal. When the signal is high, we call this “on time”. To describe the amount of “on time”, we use the concept of duty cycle. Duty cycle is measured in percentage. Draw a simple graph that illustrates each of the following three scenarios.

25% duty cycle of period 20 ms	
50% duty cycle of period 20 ms	
100% duty cycle of period 20 ms	