EMG CONTROL

1 Background

1.1 Myoelectric Control

In this section, the EMG envelope signal is used in the control algorithm shown in Figure 1.1 to open and close the clamp on the servo. The servo is driven by the on-board PWM amplifier.

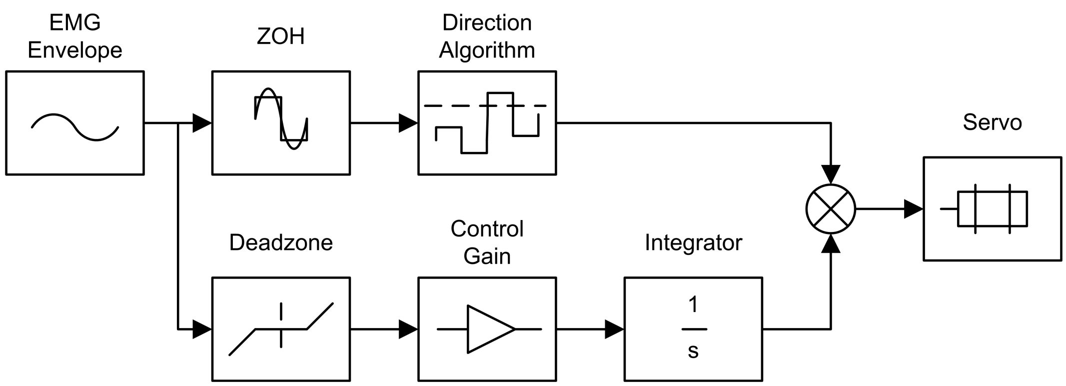


Figure 1.1: Myoelectric servo control algorithm

In order to open/close the clamps at different positions, this task-based control system has two parts: direction control and position control.

1.1.1 Servo Direction Control

The direction algorithm uses the EMG envelope signal to choose when to open or close the clamps and is illustrated in the top portion of Figure 1.1. To change the direction of the servo, i.e. from open to close or close to open, the signal must exceed a set threshold value for a certain time. Thus when the muscle is contracted more than usual, it should trigger a direction change. For example, if the signal is above the pre-defined threshold value of 0.5 V for at least 0.1 seconds then the servo direction should change.

Zero-order hold (ZOH) is typically used to reconstruct digital signals. It holds its input signal for a specified sampling period. The equation is defined as

$$y(t) = \begin{cases} u(t_i), & t - t_i < 0 \text{and} t_i - t \leq 0 \\ u(t_k), & t_k - t \leq 0 \text{and} t - t_{k+1} < 0 \end{cases} \tag{1.1}$$

where t is the current simulation time, t_i is the initial simulation time. For $k = 0, 1, 2, \ldots$ the ZOH sampling time T_s,

$$Figure 1.2 t_k = t_i + kT_s. \tag{1.2}$$

shows how the EMG envelope in sampled when passed through a ZOH with a sampling period of 0.1 seconds. If the ZOH signal exceeds a specified threshold, then the current servo direction is reversed.

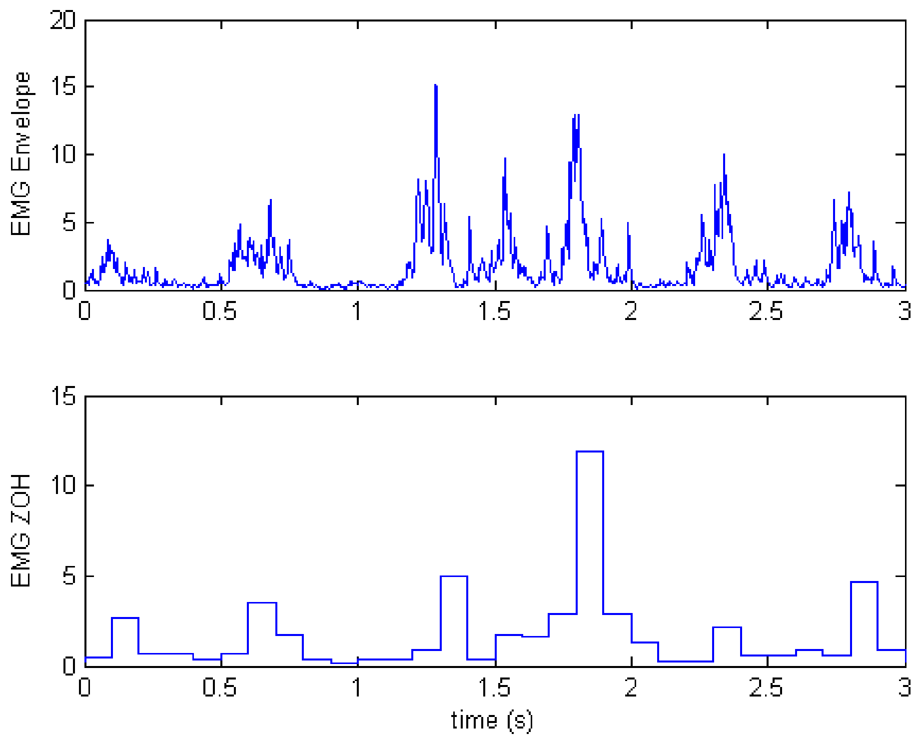


Figure 1.2: Zero-order hold of EMG envelope

The direction function is then

$$\text{dir} = \begin{cases} 1, & \epsilon < y_{\text{env}}(t) \\ -1, & y_{\text{env}}(t) \leq \epsilon \end{cases} \tag{1.3}$$

where ϵ is the threshold and $y_{\text{env}}(t)$ is the envelope of the EMG signal.

1.1.2 Servo Position Control

The position of the servo/clamp is proportional to the voltage fed to the PWM amplifier that drives it (i.e. no feedback design required). As shown in Figure 1.1, a dead zone is used to remove any small amplitude signals from the EMG envelope that may cause the servo to move from minor muscle contractions. Basically this prevents the servo from drifting when the muscles are at rest.

As shown in Figure 1.1, the envelope of the EMG signal is amplified by a control gain and passed through an integrator. This generates a voltage that controls the position of the servo. The gain has to be tuned according to the EMG signal. Saturation limits on the integrator ensure the clamp does not close or open passed its limits. The voltage command to the servo can be defined as

$$u(t) = \begin{cases} V_{\text{high}}, & V_{\text{high}} < u \\ V_{\text{low}}, & u < V_{\text{low}} \\ \dfrac{dir\, k_i y_{\text{env}}}{s}, & \text{otherwise} \end{cases} \tag{1.4}$$

were the upper integrator saturation is V_{high}, the lower integrator limit is V_{low}, the integral gain is k_i, the EMG envelope signal is $y_{\text{env}}(t)$, and the dir function is defined in Equation 1.3.

1.2 EMG Control Virtual Instrument

The virtual instrument used to configure the ZOH, and control the servo position is shown in Figure 1.3 and Figure 1.4.

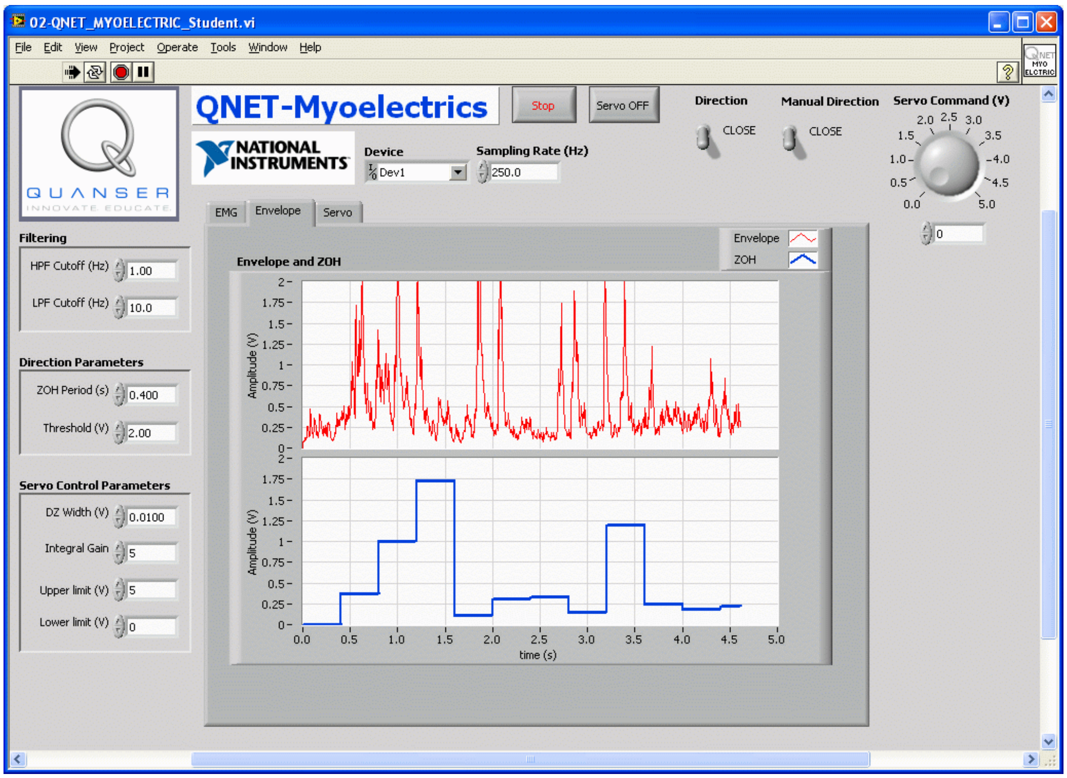


Figure 1.3: QNET Myoelectric VI: Configure the ZOH

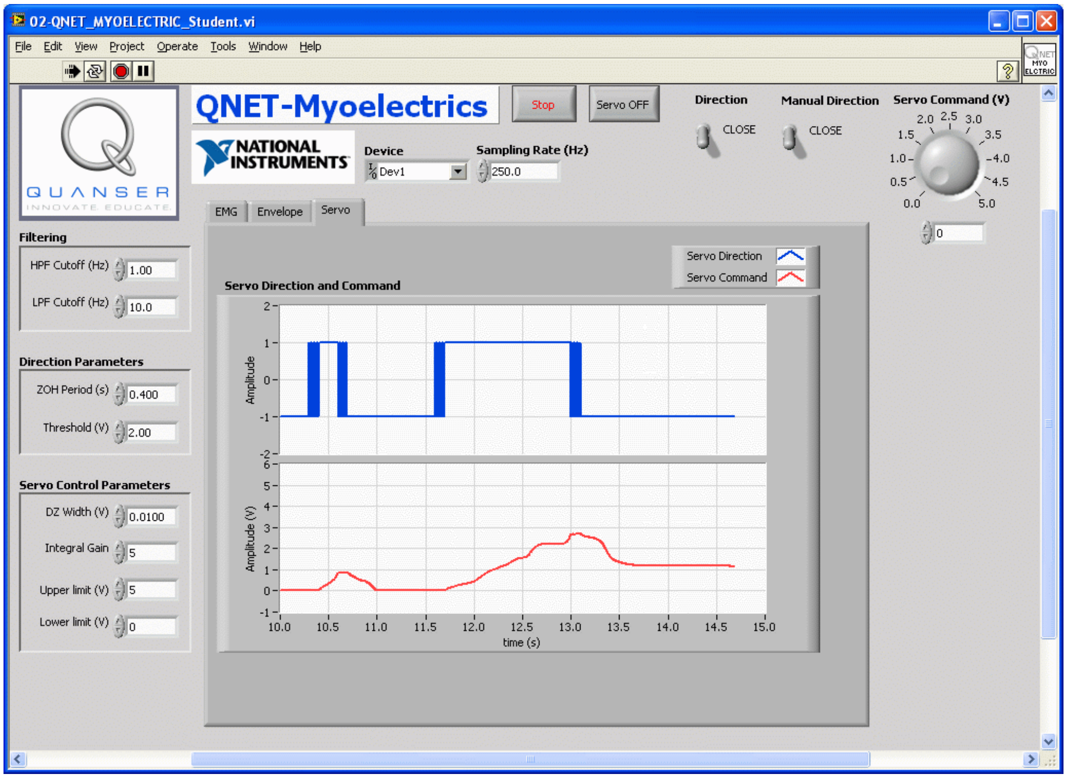


Figure 1.4: QNET Myoelectric VI: Servo tab

2 In-Lab Exercise

2.1 Servo Direction Change

1. Make sure you have gone through the exercises in the EMG Sensor Setup laboratory experiment. The EMG envelope should be configured for a smooth response.

2. Open the `QNET_MYOELECTRIC_Student.vi`. **Make sure the correct Device is chosen.**

3. Run the VI.

4. Select the Envelope tab. As illustrated Figure 1.3, the bottom plot shows the zero-order hold (ZOH) of the envelope.

5. Adjust the sampling period of the zero-order hold, ZOH Period, so the output signal is responsive enough to the peaks of the envelope. You need to restart the VI in order for the new ZOH period to take effect. When tuning the period, keep in mind that the ZOH signal will be used to change the direction of the servo when it exceeds a user-defined value. Attach a capture of the response and record the ZOH period used.

   Caution **Make sure the ZOH period is an integer multiple of the VI sampling interval.** For instance, by default the VI has a sampling rate of 250 Hz, so the ZOH period must be a multiple of 0.004 seconds (e.g. 0.18, 0.26). Otherwise, an error will be prompted saying "The discrete step size must be an integer multiple of the step size".

6. Click on the Stop button to stop running the VI.

7. Go into the block diagram of the `QNET_MYOELECTRIC_Student.vi` and find the area that is depicted in Figure 2.1, below. Change the block diagram such that the servo direction, i.e. the Direction indicator, changes when the output from the ZOH block exceeds the value in the Threshold (V) control. Use the case structure and remove the constant Boolean values (they are just place holders so the VI can be compiled and ran). Copy and paste this section of the block diagram and attach it.

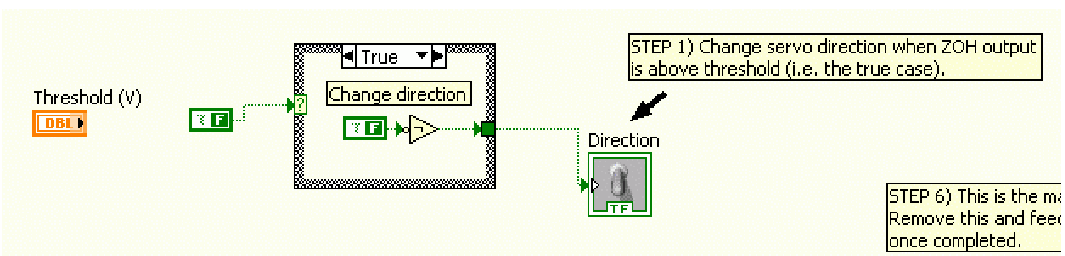
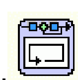


Figure 2.1: Add code to change servo direction when ZOH output exceeds threshold value

Hint: Use the memory VI from the LabVIEW Simulation Module. 

8. Run the VI and verify that the direction is working. The top plot in the Servo tab shows the direction of the servo. The clamps on the servo should be **open** when it's -1 (FALSE), and **closed** when it's 1 (TRUE).

9. Capture and attach sample ZOH and the Direction responses (from the Envelope and Servo tabs). Record the ZOH period and threshold used for this test as well.

10. Click on the Stop button to stop running the VI.

2.2 Servo Position Control

1. Make sure you have gone through the exercises in the Linear Envelop laboratory experiment. The EMG envelope should be configured for a smooth response.
2. Open the `QNET_MYOELECTRIC_Student.vi`. **Make sure the correct Device is chosen.**
3. Run the VI.
4. The Servo Command (V) control is directly connected to the D/A#0 that drives the PWM amplifier connected to the servo. Vary the Servo Command (V) knob in the VI and examine its affect on the actual servo position. Describe how the voltage affect the position of the servo clamps.
5. Click on the Stop button to stop running the VI.
6. Open the block diagram and find the section shown in Figure 2.2, below. Connect the output of the zero-order hold signal to a dead zone. Use DZ Width (V) control to specify the width of the dead zone function. Attach a copy of your code.

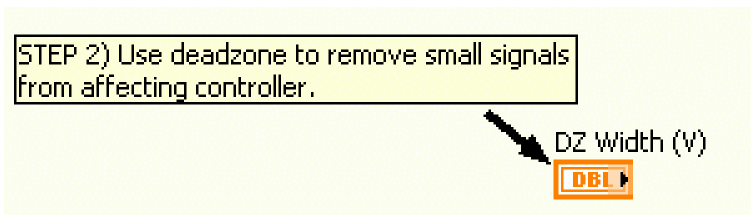


Figure 2.2: Wire ZOH output to dead zone

7. Find the section in the block diagram shown in Figure 2.3. Multiply the dead zone output by the Integral Gain control. This signal is basically the servo command rate that will later be fed to an integrator. If the direction is TRUE (i.e. positive) then the clamps should close. If the direction is FALSE (i.e. negative) then the clamps should be open. Add this logic to the code and attach an image of the block diagram.

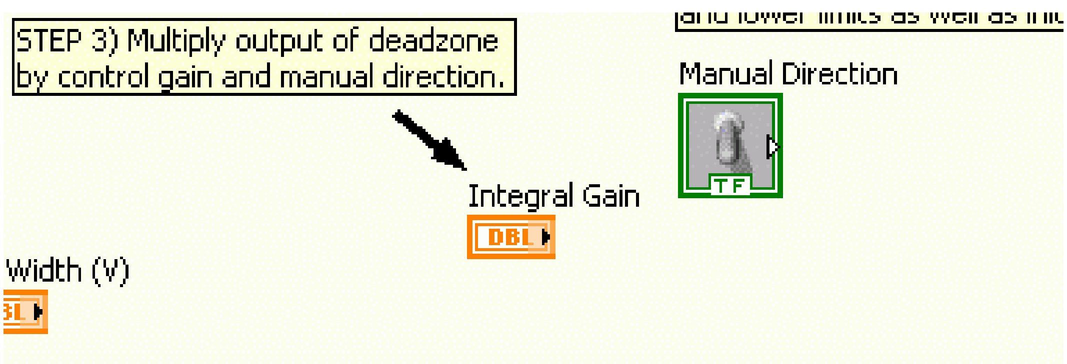


Figure 2.3: Multiply dead zone output by control gain and manual direction

8. Go to the block diagram section shown in Figure 2.4. Add an integrator and connect the signal from 7 into its input. Make sure to setup the lower and upper saturation limits of the integrator with the Upper limit (V) and Lower limit (V) controls. The initial condition should also be wired to the Lower limit (V). Attach an image of your block diagram.

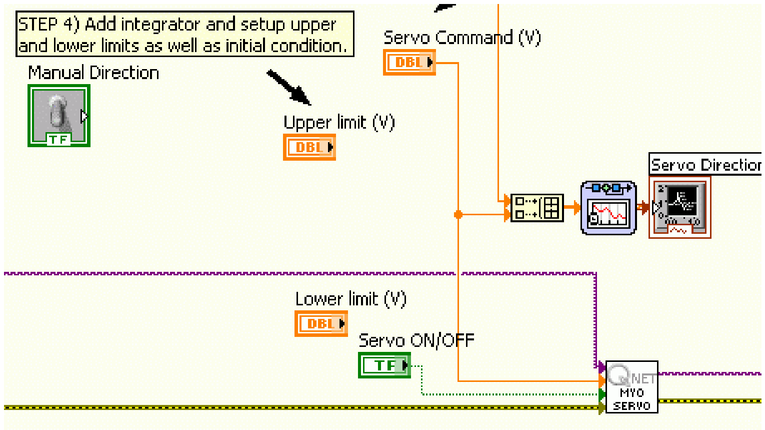


Figure 2.4: Add an integrator

9. Disconnect the Servo Command (V) control and wire the integrator output instead as shown in Figure 2.5. This should be connected to the Servo Direction and Command chart (second input of cluster) and the Servo (V) terminal on the QNET_MYOELECTRIC_Servo_Write sub-VI. Also, make sure the direction from the Manual Direction control is plotted on the Servo Direction and Command chart (first input of cluster). Attach an image of the block diagram.

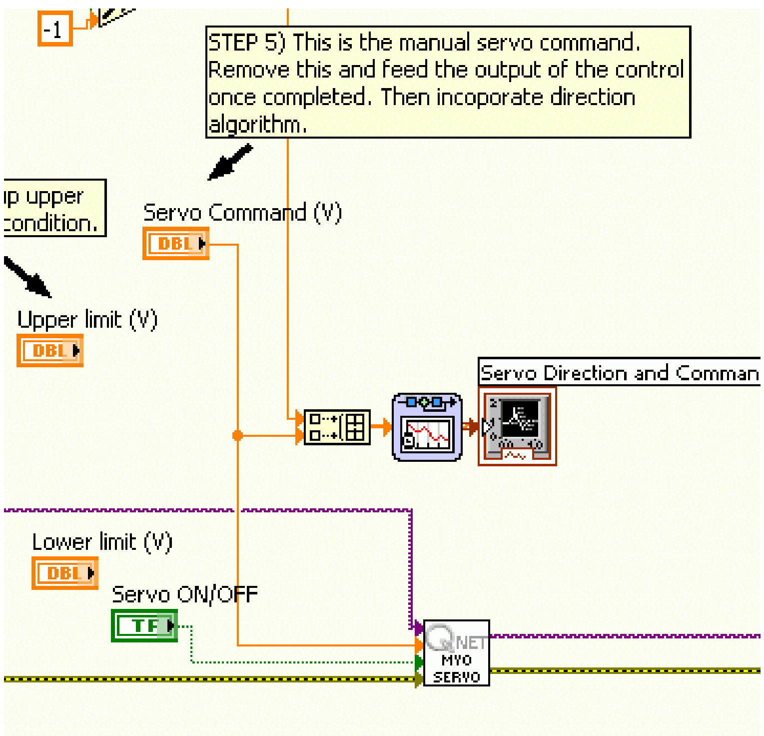


Figure 2.5: Disconnect manual servo command and use output of integrator

10. Run the `QNET_MYOELECTRIC_Student.vi`.

11. Press on the Servo OFF button to enable the servo. When the button is bright green and reads *Servo ON*, then you can feed voltage to the PWM and drive the servo.

12. Test the servo position control with the manual direction switch. On start-up the servo clamps are closed, so to open them make sure the Manual Direction control is set to True (i.e. open clamps) and contract your forearm. The servo command is based on the EMG envelope. So you will have to tune the integral gain such that the

clamp position moves at a reasonable rate. You may also have to change the dead zone width to avoid the clamps from moving when the muscle is relaxed. Attach a representative response of the Servo Direction and Command that shows the clamps opening fully and closing.

13. Click on the Stop button to stop running the VI.

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