EXPERIMENT 2 ELECTROMYOGRAM (EMG) MEASUREMENT

2.0 OBJECTIVE

The purpose of this experiment is to help students to understand the change of electrical potential on different muscular activities, including the conscious controls and triggering events of muscle. Besides, through this exercise students can learn the change of muscle force when skeletal muscle works on isotonic or isometric contraction.

2.1 PHYSIOLOGICAL PRINCIPLE

Skeletal muscle supports the weight of our body. The skeletal muscle can rotate by means of a joint, and the striated muscle directly attaches to a bone or by means of tendon. Two or multiple groups of skeletal muscle antagonize each other. It means that when one contracts, the other(s) elongates. The skeletal muscle is composed of poly-nucleus cells, and bundles of muscle fiber are lined up uniformly. Action potential propagates from motor nerve to the muscle fiber controlled by the nerve. The propagation will cause an instant increase of calcium ion inside the muscular cell and launch after molecular mechanism related to muscular contraction.

The basic component of skeletal muscle is the motor unit, which can be activated consciously. A number of the motor units construct a so-called muscle fiber. When a single motor unit (SMU) is activated by stimulation, a potential waveform with an amplitude of 20~2000 μV, a discharge frequency of 6~30 Hz, and an interval of 3~10 ms is observed. Thus, contraction of muscle fibers leads to a potential signal with larger amplitude and higher frequency. It is electromyogram (EMG). The motor unit regulates the fiber of skeletal muscle. Therefore, when a motor nerve is excited, the fibers controlled by this motor unit will all be activated.

This process includes the production of action potential and contraction of muscle fibers. A single piece of muscle may be probably regulated by hundreds of motor units. The nervous system makes an attempt to control different degrees of muscle activities by means of stimulating diverse numbers of motor units. More the motor units are excited, more the muscle fibers are activated. Thus, the number of excited motor units decides the extent of muscle activity. Similar to ECG, EMG can be recorded from the surface of body by electrodes. Consciously muscular activity usually produces great variations in EMG signals. Different from ECG, EMG signal is formed by irregular waveforms.

When muscle is in isotonic contraction state, energy is consumed in order to maintain a constant strain and the length of muscle is changed. At that time, muscle is under load and will move a certain distance to complete an effective work. When the muscle is in isometric contraction condition, a minimal shortening almost close to the length of muscle occurs, but the strain is greatly increased. Although the isometric contraction does not lead to body movement, it definitely consumes energy which will be transformed to heat and strain. Since there is no displacement in isometric contraction, no real work is realized.

2.2 PRINCIPLE OF CIRCUIT DESIGN

1. Block Diagram of EMG Measurement Circuit

As described in the previous section, EMG signals are the change of action potential when the fibers of muscle are activated. To decrease the interference of different muscle fibers, it is important to consider the activation of a single muscle fiber when we are going to decide a specific movement in experiment. The present experiment focuses on the biceps of skeletal muscle which controls principally the bend movement of upper arm. One electrode is put on the biceps muscle of one hand for EMG measurement, and the reference testing point can be anyplace of the other hand. In addition, in order to avoid electrical shock caused by leakage of power supply or testing instrument, the isolation circuit is necessary when designing an EMG detection circuit. Figure 2.1 shows circuit blocks for the process of EMG signals. A surface electrode placed on an upper arm is used to measure the slight change of potential in biceps muscle. An instrumentation amplifier with a gain of 10 is adopted as preamplifier for picking up the unipolar EMG signals. The isolation circuit separates signal and power source. It can be achieved by using an optical method. The bandwidth of band-pass filer is from 100 to 1000 Hz and the gain amplifier is for 50 or 100 times. Then, we can use oscilloscope to show EMG signals. After half-wave rectifier, the signals will be integrated to estimate the force of muscle.

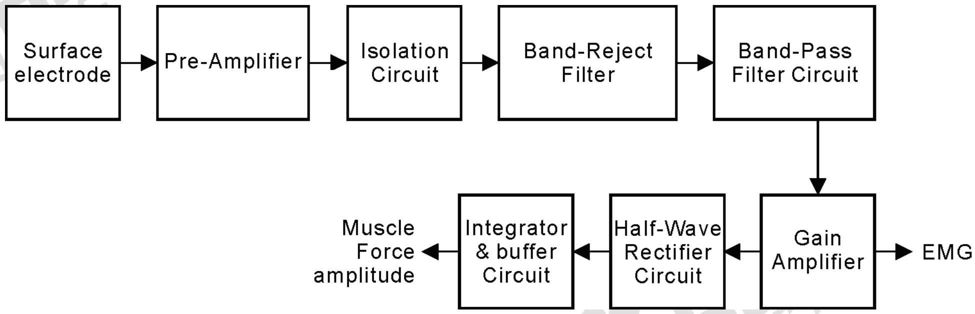


Figure 2.1 Block diagram of EMG measurement.

2. Surface Electrode

Human body consists of numerous liquid cells which contain different electrolyte ions. The intracellular liquid includes ions of potassium, sodium and chloride. Action potential comes from the variations of ion concentration. When an electrode is used to detect action potential, the so-called interface potential will be generated. Imagine, when a metal electrode touch certain electrolyte solution, two kinds of chemical reactions will simultaneously occur. One is oxidation reaction in which metal atoms will release electrons and become metal ions. The other is reduction reaction in which electrons and metal ions will be combined together and become metal atoms. In the interface between metal and electrolyte liquid, the ions with positive and negative charges will move in an opposite direction and produce two ion layers with opposite electricity. The potential difference between two ion layers is called interface potential. Immersing different metals into electrolyte liquids will lead to different levels of interface potential. Thus, for measuring biological signals, it is necessary to choose a metal with low interface potential as an electrode material. This can avoid the excessive interface potential during measurement. In general, the biological signal range is from 50μV to 1mV and the interface potential of metal is in the range of 0.1~1V. Additionally, the interface potentials of electrodes vary with time. Nowadays silver-silver chloride (Ag/AgCl) is the most used material for the production of electrodes. This kind of electrode is principally made by silver. There is a thin layer of AgCl formed by the contact between silver and electrolyte solution. And AgCl provides silver (Ag^+) and chlorine (Cl^-) ions a bi-directional exchange, without forming a compound layer. It explains why the interface potential will not be high. In KL-720, jelly surface electrodes are used, as shown in Figure 2.2. At the top of electrode is a silver-silver chloride electrode, at the middle is a hollow chamber filled with jelly, and on the bottom an adhesive-back rubber disc used to keep the electrode on the skin.

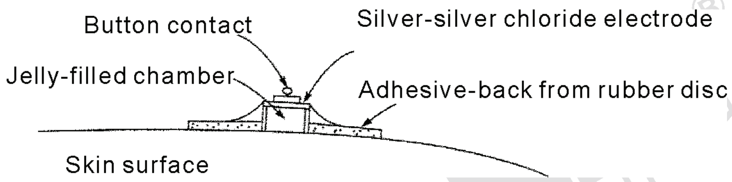


Figure 2.2 Surface electrode.

3. Preamplifier Circuit

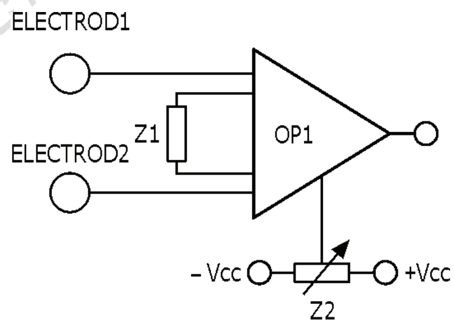


Figure 2.3 Preamplifier circuit.

Figure 2.3 shows the preamplifier circuit which is an instrumentation amplifier OP1. The gain of the preamplifier circuit can be expressed by Equation (2.1):

$$Av = \frac{49.4K}{Z_1} + 1 \tag{2.1}$$

4. Isolation Circuit

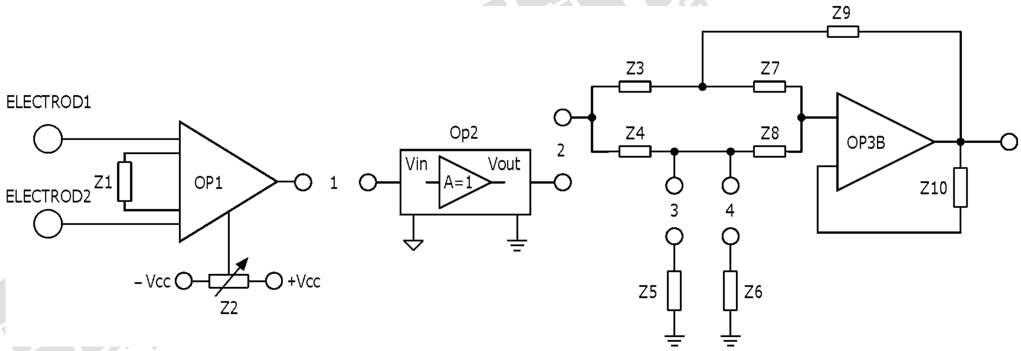


Figure 2.4 Isolation circuit.

Figure 2.4 shows the isolation circuit which is formed by OP3. Here, the isolation is completed by an optical approach.

5. Band-Reject Filter

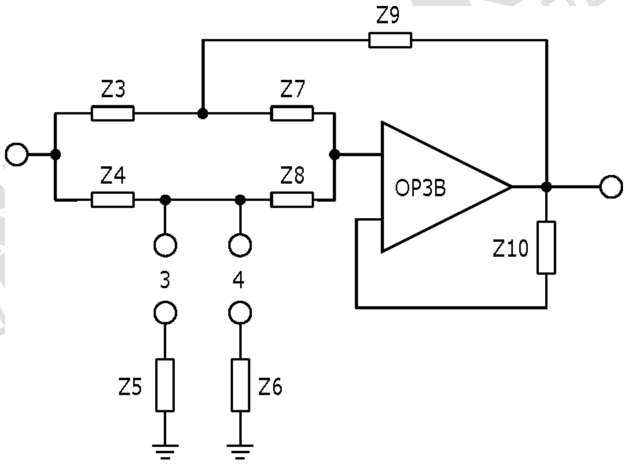


Figure 2.5 Band-reject filter circuit.

Figure 2.5 shows a twin-T band-reject filer composed by RC networks, including OP3B, Z_3, Z_4, Z_5 (or Z_6), Z_7, Z_8 and Z_9. If $Z_3 = Z_7$, $Z_4 = Z_8$, $Z_5 = 0.5Z_3$ (or $Z_6 = 0.5Z_3$) and $Z_9 = 2Z_4$, the center frequency can be calculated by Equation (2.2).

$$f = \frac{1}{2\pi Z_3 Z_4} \tag{2.2}$$

6. Band-Pass Filter Circuit

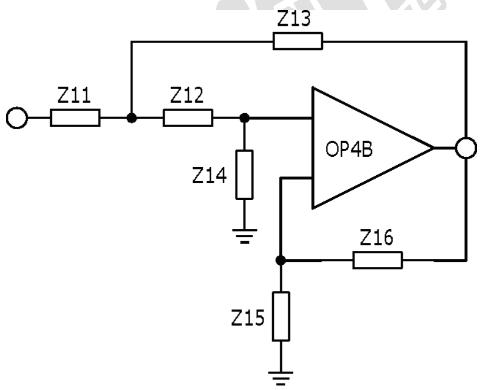


Figure 2.6 2nd-order low-pass filter.

In designing EMG measurement circuit, OP4B is used to construct an active 2nd-order low-pass filter, as shown in Figure 2.6. The cutoff frequency (f_H) of filter is set at 1000 Hz, and can be calculated using Z_{11}, Z_{12}, Z_{13} and Z_{14}, as expressed in Equation (2.3),

$$f_H = \frac{1}{2\pi\sqrt{Z_{11}Z_{12}Z_{13}Z_{14}}} \qquad (2.3)$$

And, the passband gain is explained in Equation (2.4).

$$\frac{Z_{15}+Z_{16}}{Z_{15}} = 1.56 \qquad (2.4)$$

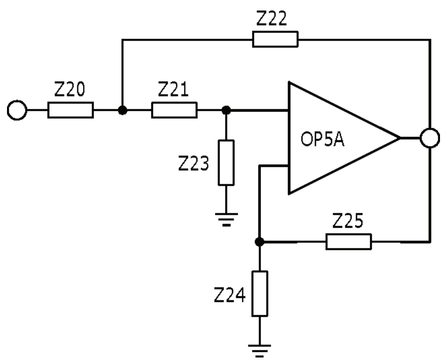


Figure 2.7 2nd-order high-pass filter.

Figure 2.7 shows an active 2nd-order high-pass filter which is formed by OP5A. The cutoff frequency (f_L) of filter is set at 100 Hz, and can be determined by Z_{20}, Z_{21}, Z_{22} and Z_{23}, as expressed in Equation (2.5),

$$f_L = \frac{1}{2\pi\sqrt{Z_{20}Z_{21}Z_{22}Z_{23}}} \quad (2.5)$$

And, the passband gain is described in Equation (2.6).

$$\frac{Z_{24}+Z_{25}}{Z_{24}} = 1.56 \quad (2.6)$$

This high-pass filter is used to remove drift phenomenon caused by the low-frequency noise in order to facilitate the measurement of muscle force.

7. Gain Amplifier

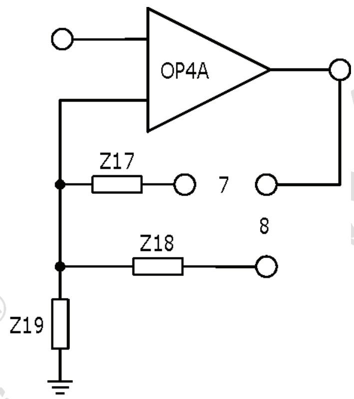


Figure 2.8 Gain amplifier circuit.

Figure 2.8 shows a non-inverting amplifier composed by OP4A. In the amplifier, Z_{17} or Z_{18} is for the gain adjustment, as expressed in Equation (2.7).

$$A_V = \frac{Z_{19}+Z_{17}}{Z_{19}} \;\; \& \;\; A_V = \frac{Z_{19}+Z_{18}}{Z_{19}} \quad (2.7)$$

8. Precise Half-Wave Rectifier Circuit

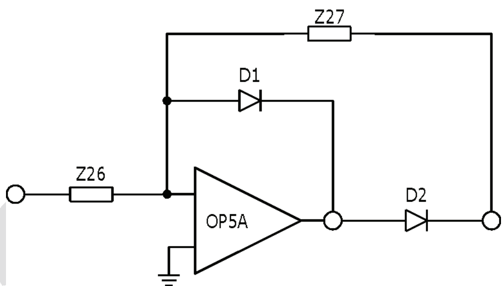


Figure 2.9 Precise half-wave rectifier circuit.

For the measurement of muscle force, the signal passing through the gain amplifier needs to be further rectified and integrated. Figure 2.9 shows a precise half-wave rectifier which is formed by OP5A, D_1, D_2, Z_{26} and Z_{27}. The function of rectifier is different from that of a rectifier constructed by two diodes because there is always a 0.7V voltage drop across each diode. In other words, when the diodes are forward-biased, the rectified signal is less 0.7 V than the original. Here, the precise half-wave rectifier uses internal current of OP AMP to avoid the transfer between ON and OFF states of the diodes. Thus, no 'turn on' voltage drop happens in whole rectifier circuit.

9. Integrator Circuit

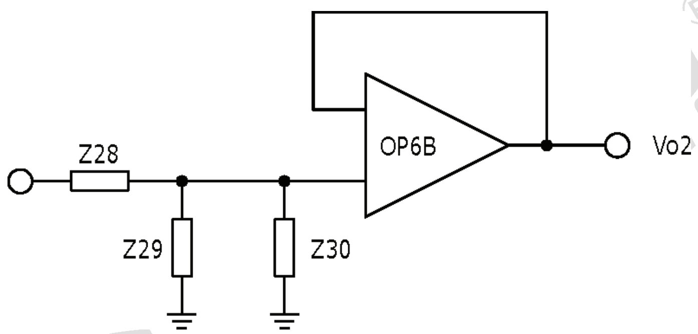


Figure 2.10 Integrator circuit.

Figure 2.10 shows an integrator circuit constructed by OP6B, Z_{28}, Z_{29} and Z_{30}, in which OP6B serves as a voltage follower.

2.3 EQUIPMENT REQUIRED

1. KL-72001 Main Unit
2. KL-75002 Electromygram EMG Module
3. Body Surface Electrodes
4. Digital Storage Oscilloscope
5. KL-79101 5-Conductor Electrode Cable
6. 5-kg Dumbbell
7. Alcohol Prep Pads
8. Electrode Leads
9. DB9 Cable
10. BNC Cables
11. RS-232 Cable
12. Connecting Wires
13. 10-mm Bridging Plugs
14. Trimmer

2.4 PROCEDURE

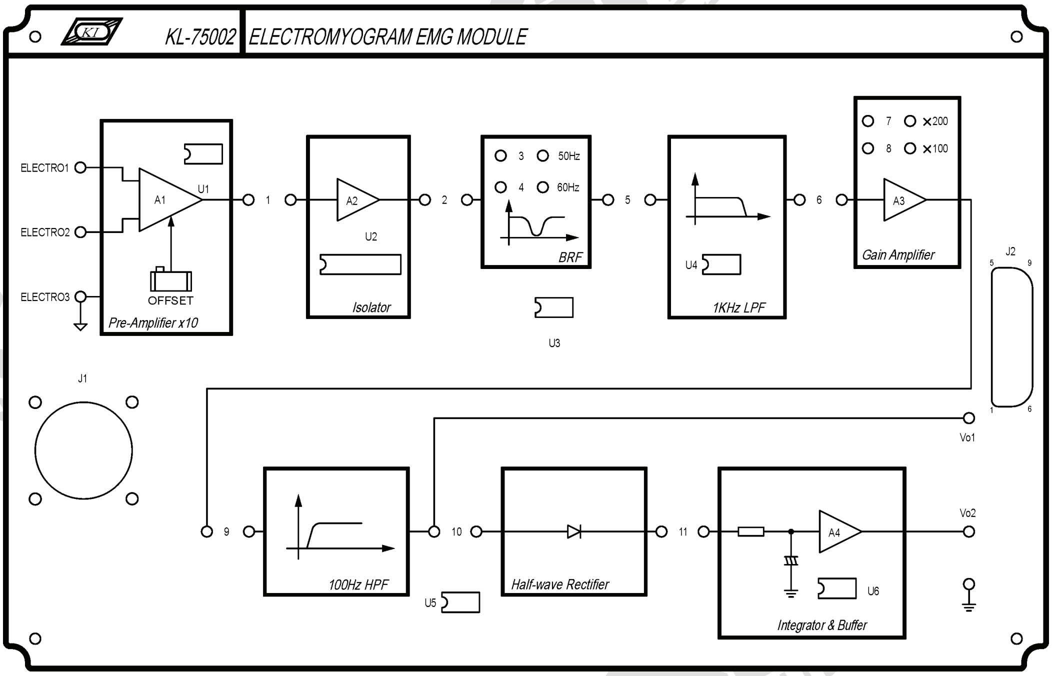


Figure 2.11 Front panel of KL-75002 EMG Module.

A. Calibrating the Pre-Amplifier Circuit

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	—	9-Pin	→	—	J2

KL-75002 EMG Module				
Block	Terminal	To	Block	Terminal
Pre-Amplifier x 10	Electro1	→	Pre-Amplifier x 10	Electro2
Pre-Amplifier x 10	Electro2	→	Pre-Amplifier x 10	Electro3

2. Turn power on.
3. Connect the positive probe of DVM to the output terminal of the Pre-Amplifier output and the negative probe to the Electro3 terminal.

4. Adjust OFFSET potentiometer to make the output DC voltage indicated by DVM equal to 0 V.
5. Turn power off and disconnect circuit.

B. Measuring the Characteristics of Band-Reject Filter (BRF)

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	BRF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	BRF	Output

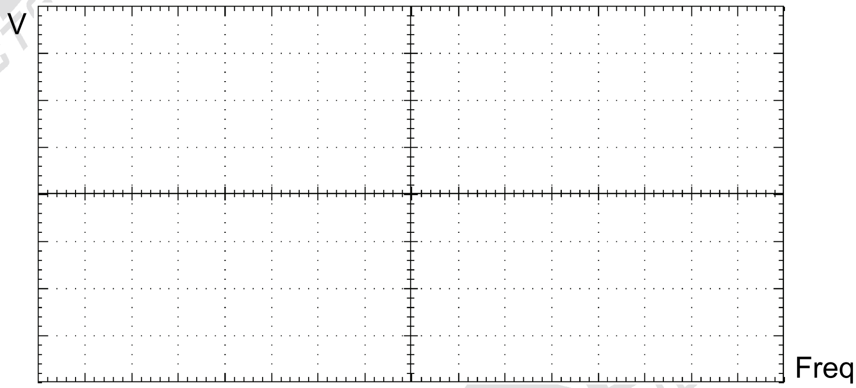
2. Insert a bridging plug into position 3 or 4 to set the center frequency of BRF to 50 or 60 Hz (according to local line frequency).
3. Turn power on.
4. Apply a 1 Hz, 1 Vpp sine signal to BRF input by adjusting FREQUENCY and AMPLITUDE of FUNCTION GENERATOR, then observe CH1 trace from the oscilloscope screen.
5. Observe BRF output signal displayed on CH2 trace and record the amplitude in Table 2.1.
6. Without changing the amplitude of input sine signal, repeat Steps 4 and 5 for other frequency values listed in Table 2.1.

Table 2.1 Measured output amplitude of BRF.

Input Freq	5Hz	10Hz	20Hz	30Hz	50 or 60Hz	100Hz	200Hz	500Hz	1KHz
BRF Output (Vpp)									

7. According to the recorded data in Table 2.1, plot the characteristic curve of band-reject filter in Table 2.2.

Table 2.2 Characteristic curve of BRF.



8. Turn power off and disconnect circuit.

C. Measuring the Characteristics of Low-Pass Filter (LPF)

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	1KHz LPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	1KHz LPF	Output

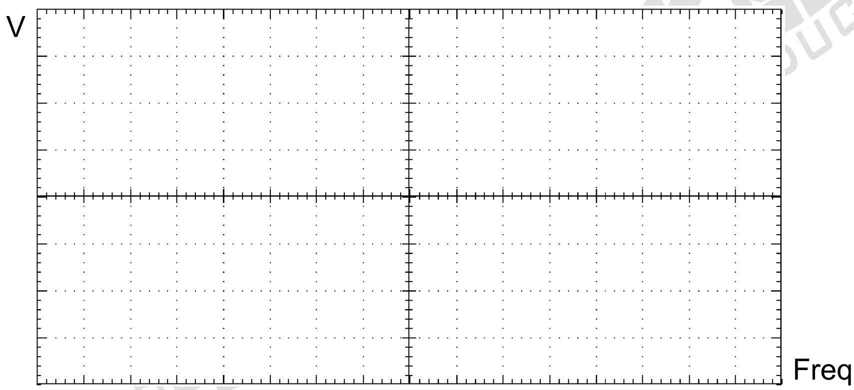
2. Turn power on.
3. Apply a 1 Hz, 1 Vpp sine signal to LPF input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe CH1 trace from the oscilloscope screen.
4. Observe LPF output signal displayed on CH2 trace and record the amplitude in Table 2.1.
5. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for other frequency values listed in Table 2.3.

Table 2.3 Measured output amplitude of LPF.

Input Freq	100Hz	500Hz	700Hz	800Hz	1KHz	1.2KHz	1.3KHz	1.5KHz	5KHz
LPF Output (Vpp)									

6. According to the recorded data in Table 2.3, plot the characteristic curve of low-pass filter in Table 2.4.

Table 2.4 Characteristic curve of LPF.



7. Turn power off and disconnect circuit.

D. Measuring the Characteristics of Gain Amplifier

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Gain Amplifier	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Gain Amplifier	Output

2. On KL-75002 EMG Module, insert a bridging plug in position 8. This sets the Amplifier gain to 100.
3. Turn power on.
4. Apply a 100 Hz, 100 mVpp sine signal to Gain Amplifier input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe the CH1 trace on oscilloscope.
5. Observe the Gain Amplifier output signal displayed on CH2 trace and record the amplitude in Table 2.5.

Table 2.5 Measured output amplitude of Gain Amplifier.

Amplifier Gain Setting	Amplifier Output Voltage (Vpp)
100	
200	

6. Remove the bridging plug from position 8 to position 7. This changes the Amplifier gain from 100 to 200. Repeat Steps 4 and 5.
7. Turn power off and disconnect circuit.

E. Measuring the Characteristics of High-Pass Filter (HPF)

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	100Hz HPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	100Hz HPF	Output (Vo1)

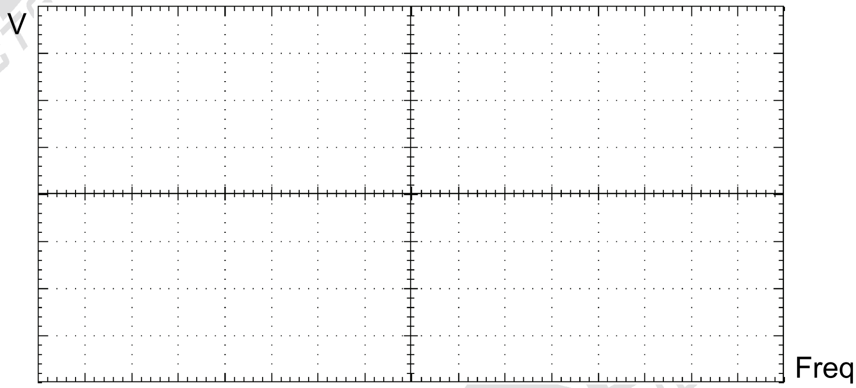
2. Turn power on.
3. Apply a 1 KHz, 1 Vpp sine signal to HPF input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe the CH1 trace on oscilloscope.
4. Observe HPF output signal displayed on CH2 trace and record the amplitude in Table 2.6.
5. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for other frequency values listed in Table 2.6.

Table 2.6 Measured output amplitude of HPF.

Input Freq	1KHz	200Hz	150Hz	110Hz	100Hz	90Hz	50Hz	20Hz	1Hz
HPF Output (Vpp)									

6. According to the recorded data in Table 2.6, plot the characteristic curve of HPF in Table 2.7.

Table 2.7 Characteristic curve of HPF.



7. Turn power off and disconnect circuit.

F. Measuring the Characteristics of Half-Wave Rectifier

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

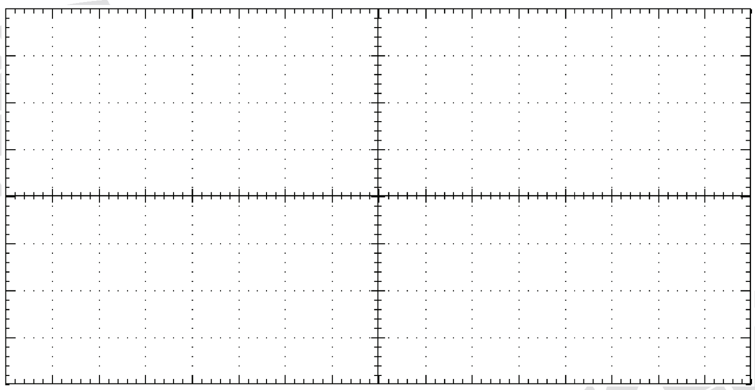
KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Half-wave Rectifier	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Half-wave Rectifier	Output

2. Turn power on.
3. Apply a 1 KHz, 1 Vpp sine signal to the input of Half-wave Rectifier by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe the CH1 trace on oscilloscope.
4. Observe Half-wave Rectifier output signal displayed on CH2 trace and record the output waveform in Table 2.8.

Table 2.8 Measured output waveform of half-wave rectifier.

CH1 (Input signal) / CH2 (Output signal)



5. Turn power off and disconnect circuit.

G. Measuring the Characteristics of Integrator & Buffer

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	—	OUTPUT	→	SCOPE ADAPTOR	—	CH1
SCOPE ADAPTOR	—	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	—	CH2 (BNC)	→	CH2 input of the oscilloscope		

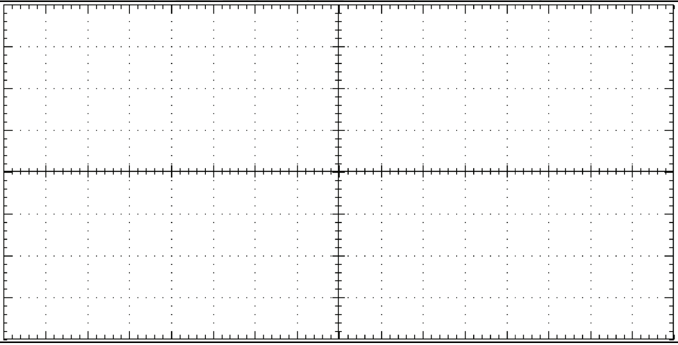
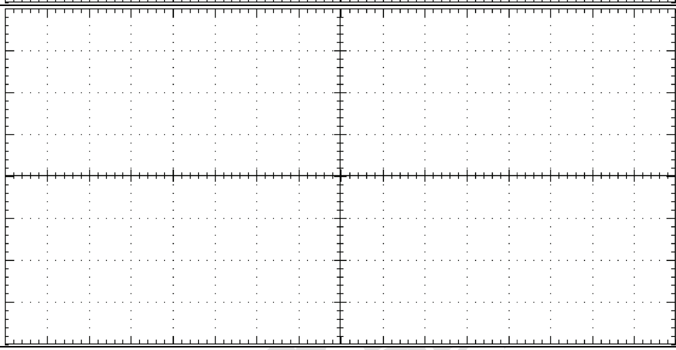
KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	—	9-Pin	→	—	J2
FUNCTION GENERATOR	—	OUTPUT	→	Half-wave Rectifier	Input
FUNCTION GENERATOR	—	GND	→	—	Ground (in the bottom right corner)
SCOPE ADAPTOR	—	CH2	→	Integrator & Buffer	Output (Vo2)

2. On KL-75002 EMG Module, insert a bridging plug in position 11.

3. Turn power on.

4. Apply a 5 Hz, 1 Vpp sine signal to the Integrator input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe the CH1 trace on oscilloscope.
5. Observe Integrator output signal displayed on CH2 trace and record the output waveform in Table 2.9.
6. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for other frequency values listed in Table 2.9.

Table 2.9 Measured output waveform of Integrator & Buffer

Frequency	CH1 (Input signal) / CH2 (Output signal)
5 Hz	
10 Hz	

7. Turn power off and disconnect circuit.

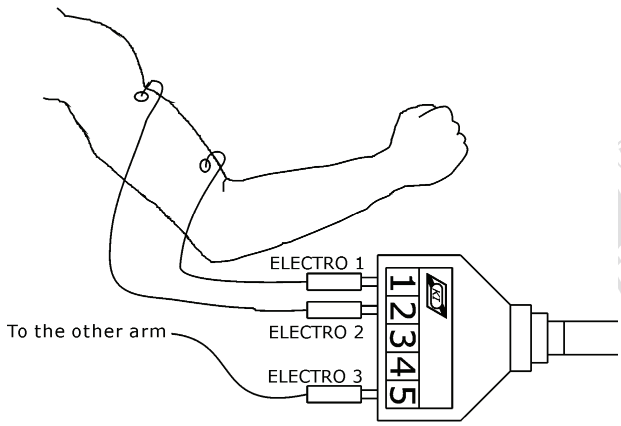
H. EMG Measurement using Oscilloscope

1. Set KL-75002 EMG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
SCOPE ADAPTOR	--	CH1	→	OUTPUT	ELECTRO-MYGRAM	Vo1
SCOPE ADAPTOR	--	CH2	→	OUTPUT	ELECTRO-MYGRAM	Vo2
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75002 EMG Module, insert bridging plugs in positions 1, 2, 4 (line frequency=60 Hz), 5, 6, 8 (gain=100), 9, 10 and 11.
3. Ask subject to take away watch and ornament from his/her hands.
4. Ask subject to stand and relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.
5. Ask subject to hold 5 Kg dumbbell, then lift it by bending his elbow. Clear the skin of biceps (on the upper right arm) with alcohol prep pads in order to reduce resistance. Then, place two electrodes on as shown below:



6. Use alcohol prep pads to clear the skin on the upper left arm for reducing skin resistance. Place the reference electrode on. Since it's just a reference point, you can choose anywhere you want on the left arm.
7. Connect electrodes to the lead side of KL-79101 5-Conductor Electrode Cable as shown above. Connect the other side of KL-79101 5-Conductor Electrode Cable to J1 connector on KL-75002 EMG Module.
8. Turn power on. Select MODULE:KL-75002 (EMG) from LCD by pressing SELECT button of KL-72001 Main Unit.
9. Set the VOLT/DIV controls of CH1 and CH2 to 1 V/div, and set the TIME/DIV control to 500 mS/div.

Notes:

a. Before starting experiment, subject must take away watch and ornament from his/her hands to avoid interference.
b. In isotonic contraction measurement, if electrodes are not well fixed and move with arm movement, please use a bandage to fix them.

c. If the impedance between skin and electrode is too high, please use alcohol prep pads to remove the oil of skin.

d. Any movement or tremble of arm (with electrodes on) may cause the transient signal which is not easy to be distinguished from EMG signals. That's why we arrange isometric experiment before isotonic experiment.

e. In muscle fatigue experiment, please repeat the lift movement several times in order to make the muscle fatigue. Otherwise, it will be difficult to observe the change of EMG signal.

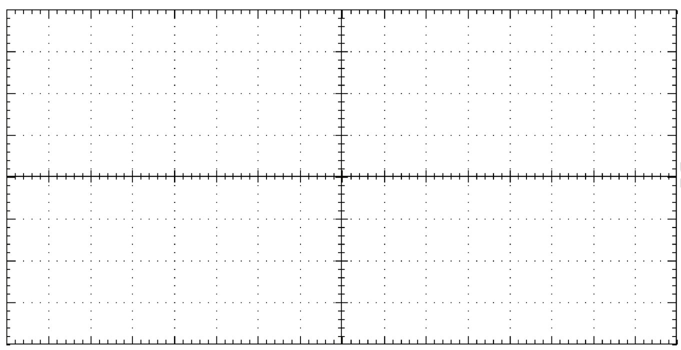
10. Isometric Contraction Measurement

10-1. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.

10-2. Observe whether the CH2 signal is stable or not. If not, it means there is high impedance between electrode and skin. (Refer to Note c)

10-3. Ask subject to bend and keep the elbow at 90 degrees. Observer puts 5Kgs dumbbell on the hand of subject for 2 seconds (Hand of sujet can't tremble), then take the dumbbell away. Observe and record the waveforms displayed on the screen in Table 2.10.

Table 2.10 Measured EMG waveforms of isometric contraction.

Condition	CH1 (EMG signal) / CH2 (muscle force)
Bend and keep the elbow at 90 degrees. Observer puts 5Kgs dumbbell on the hand of subject for 2 seconds, then take the dumbbell away.	

11. Isotonic Contraction Measurement

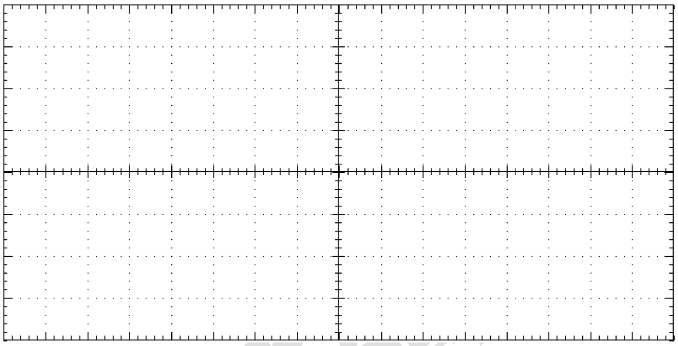
11-1. Step 10 must be completed before proceeding to the following.

11-2. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.

11-3. Ask subject to hold 5-Kg dumbbell.

11-4. Ask subject to lift the dumbbell, to bend elbow at 90 degrees for about 2 seconds, then put it down. Repeat this action for three times. Observe and record the waveforms displayed on the screen in Table 2.11.

Table 2.11 Measured EMG waveforms of isotonic contraction.

Condition	CH1 (EMG signal) / CH2 (muscle force)
Lift the dumbbell, bend the elbow at 90 degrees for about 2 seconds, then put down the dumbbell. Repeat 3 times.	

12. Muscle Fatigue Measurement

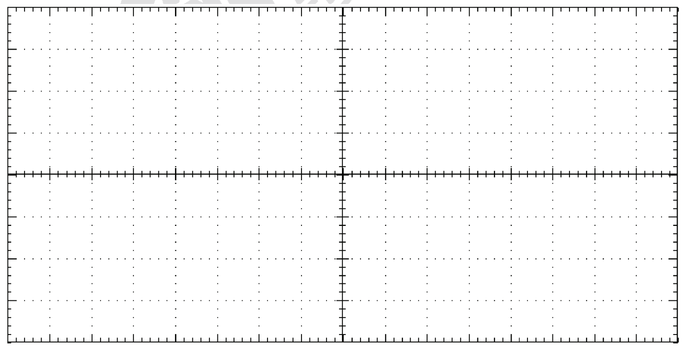
12-1. Steps 10 and 11 must be completed before proceeding to the following.

12-2. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.

12-3. Ask subject to hold the 5 Kg dumbbell.

12-4. Ask subject to lift the dumbbell, to bend elbow at 90 degrees until he feels the fatigue, then put the dumbbell down. Observe and record the waveforms displayed on the screen in Table 2.12. (Refer to Note e)

Table 2.12 Measured EMG waveforms of muscle fatigue.

Condition	CH1 (EMG signal) / CH2 (muscle force)
Lift the dumbbell, bend the elbow at 90 degrees until the fatigue occurs, then put the dumbbell down.	

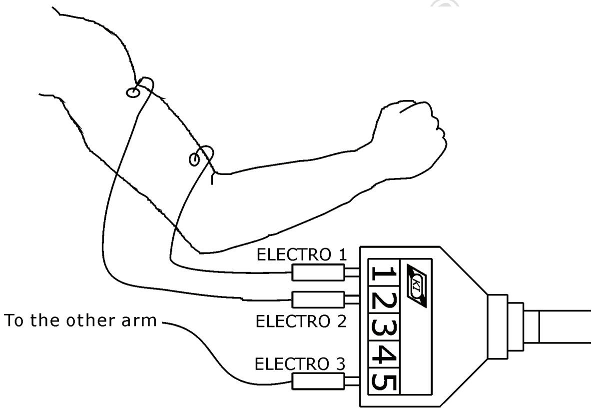
13. Remove bridging plug from position 8 to position 7. It will change the Amplifier gain from 100 to 200.
14. Repeat Steps 10 to 12 to see the effects of Amplifier gain on output waveforms.
15. Turn power off and disconnect circuit.

G. Human EMG Measurement using KL-720 software

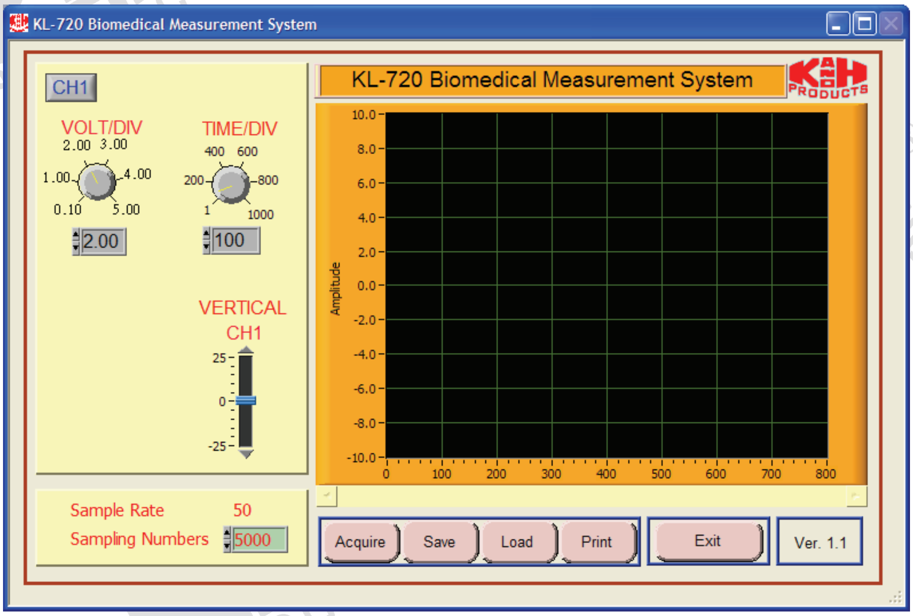
1. Set KL-75002 EMG Module on KL-72001 Main Unit. On KL-72001 Main Unit, Connect as follows:

KL-72001 Main Unit				KL-75002 EMG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

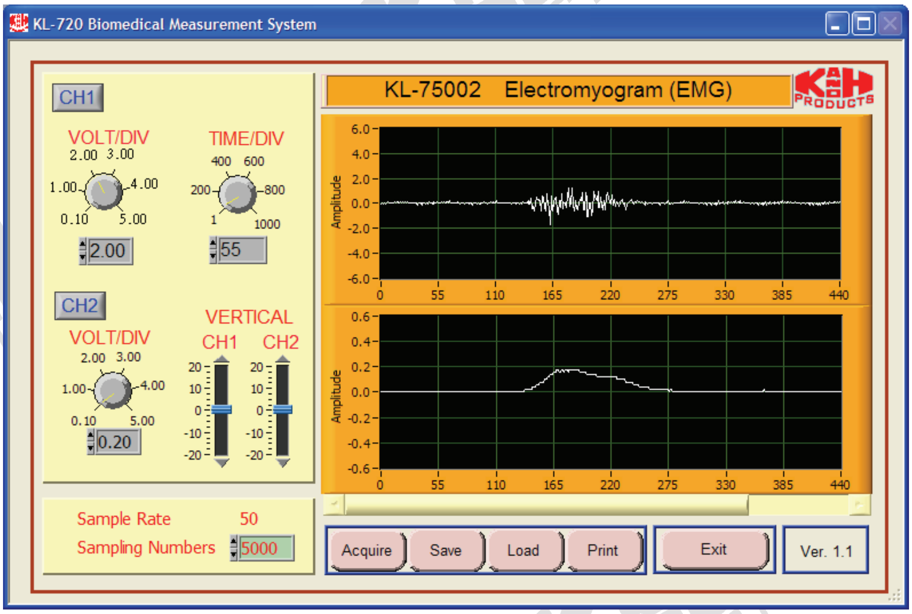
2. On KL-75002 EMG Module, insert bridging plugs in positions 1, 2, 4 (line frequency=60 Hz), 5, 6, 8 (gain=100), 9, 10 and 11.
3. Subject must take away firstly his/her watch and ornament from his/her hands to avoid interference.
4. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.
5. Ask subject to hold 5 Kg dumbbell, then lift it by bending his elbow. Clear the skin of biceps (on the upper right arm) with alcohol prep pads in order to reduce resistance. Then, place two electrodes on as shown below:



6. Use alcohol prep pads to clear the skin on the upper left arm for reducing skin resistance. Place the reference electrode on. Since it's just a reference point, you can choose anywhere you want on the left arm.
7. Connect the electrodes to the lead side of KL-79101 5-Conductor Electrode Cable as shown above. Connect the module side of KL-79101 5-Conductor Electrode Cable to J1 connector on KL-75002 EMG Module.
8. Connect RS-232 OUTPUT connector of KL-72001 Main Unit to the RS-232 port on the computer using RS-232 cable.
9. Turn power on. Select MODULE:KL-75002 (EMG) from LCD by pressing the SELECT button of KL-72001 Main Unit.
10. Boot the computer.
11. Execute KL-720 program. KL-720 Biomedical Measurement System window appears as shown below.



12. Click Acquire button. The system begins to acquire the measured data via RS-232 port and shows the waveforms in KL-75002 Electromyogram waveform windows.



Note: If the message "time out appears, please check COM port was connected the device" appears, check the connection and if RS-232 cable is well connected.

13. Adjust VOLT/DIV and TIME/DIV knobs, so the signals can be read accurately.

Notes:

a. Before starting experiment, subject must take away watch and ornament from his/her hands to avoid interference.

b. In isotonic contraction measurement, if electrodes are not well fixed and move with arm movement, please use a bandage to fix them.

c. If the impedance between skin and electrode is too high, please use alcohol prep pads to remove the oil of skin.

d. Any movement or tremble of arm (with electrodes on) may cause the transient signal which is not easy to be distinguished from EMG signals. That's why we arrange isometric experiment before isotonic experiment.

e. In muscle fatigue experiment, please repeat the lift movement several times in order to make the muscle fatigue. Otherwise, it will be difficult to observe the change of EMG signal.

14. Isometric Contraction Measurement

14-1. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.

14-2. Observe whether the CH2 signal is stable or not. If not, it means the impedance between electrode and skin is too high. (Refer to Note c)

14-3. Ask subject to bend and keep the elbow at 90 degrees. Observer puts 5Kgs dumbbell on the hand of subject for 2 seconds (Hand of sujet can't tremble), then take the dumbbell away. Observe and record the waveforms on disk.

15. Isotonic Contraction Measurement

15-1. Step 14 must be completed before proceeding to the following.

15-2. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground) and turn the palm to face forward.

15-3. Ask subject to hold the 5 Kg dumbbell.

15-4. Ask subject to lift the dumbbell, to bend the elbow at 90 degrees for about 2 seconds. Then, put down the dumbbell. Repeat the action for three times. Observe and record the waveforms on disk.

16. Muscle Fatigue Measurement

16-1. Steps 14 and 15 must be completed before proceeding to the following.

16-2. Ask subject to stand, to relax naturally his/her right hand (fingertips to the ground), and turn the palm to face forward.

16-3. Ask subject to lift the dumbbell, to bend the elbow at 90 degrees until he feels the fatigue, then put down the dumbbell. Observe and record the waveforms on disk. (Refer to Note e)

17. Remove bridging plug from position 8 to position 7. It will change the Amplifier gain from 100 to 200. Repeat Steps 14 to 16 to see the effects of Amplifier gain on output waveforms.

18. Exit KL-720 Biomedical Measurement System, turn power off and disconnect circuit.