AN ASSESSMENT PLATFORM FOR UPPER LIMB MYOELECTRIC PROSTHESIS

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ABSTRACT

An assessment platform was developed to evaluate technical performance of upper limb myoelectric prosthetic devices. It consists of an "Acquisition Module", a "Signal Capture Module", a "Programmable Signal Generation Module", and an "Activation and Measurement Module". The platform can be used to acquire and study real time electromyographic (EMG) signals, to custom-build activation signals for myoelectric prosthesis and to measure the performance of myoelectric prostheses. The assessment platform was built on a National Instrument LabVIEW data acquisition system with transducers, instrumentation amplifiers and signal processing circuits.

BACKGROUND

A myoelectric prosthesis is an electromechanical device to replace some functions of a lost limb segment. Electric elbows, wrist rotators and flexion units, and terminal devices such as electric hooks or hands are examples of upper limb myoelectric prostheses [1]. The activation signal can be a switch or a linear potentiometer controlled by the patient; or more commonly, the strength and duration of muscle contraction initiated by the patient. EMG signals captured using surface electrodes from the residual muscle groups in the amputee's stump are used to derive such myoelectric activation signals. Muscle sites for electrode placements are selected primarily on the level of amputation and socket design and typically include the pectoralis, anterior deltoid, biceps, wrist flexors, posterior deltoid, infraspinatus, teres major, triceps, and wrist extensors [2].

In recent years, new prosthetic components with increasing complexity and advanced technologies have been permeating the marketplace. A prosthetic hand may incorporate delicate sensors to detect digit position, grip force, slip and temperature [3]. These devices often claim to be easy to use by amputees and provide significantly improvement to the functional outcomes. Due to their short history and limited number of installations, very few technical reports on user experience are documented. These sophisticated new prostheses are expensive yet little is known about their technical performance, device reliability and functional outcomes.

This paper describes an assessment platform that can 1) acquire, analyze and process surface EMG signals; 2) compose myoelectric activation signals from simulation or acquired waveforms; 3) activate the myoelectric prosthesis consistently under test; and 4) measure output characteristics of a myoelectric prosthesis.

SYSTEM ARCHITECTURE

The architectural diagram of the assessment platform is shown in Figure 1. The "Acquisition Module" and transducer circuits are built with analog electronic hardware components. The "Signal Capture" and remaining modules are implemented on a National Instrument LabVIEW data acquisition platform and run on a Microsoft Window-based computer connected to the input-output (I/O) hardware.

A National Instrument NI 9215 four-channel, ±10 V, 16-bit, analog voltage input module and a NI 9263 four-channel, ±10 V, 16 bit analog voltage output module are used as the I/O interface between the hardware and software environment. This combination provides four simultaneous differential analog input channels and four analog output channels with sampling rates up to 100kS/s. This sampling frequency is 100 times the maximum frequency of the signal of interest.

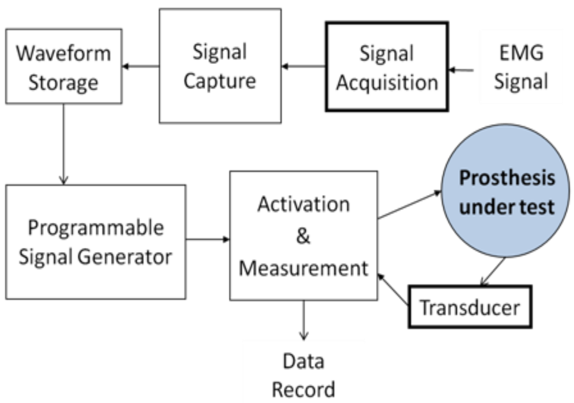

Figure 1: Assessment Platform Architectural Diagram

The following sections describe the four modules of the platform.

EMG ACQUISTION MODULE

The control signals for myoelectric prostheses are, in general, derived from the EMG acquired by a surface electrode placed on a voluntary muscle (such as the biceps brachii). The amplitude, duration and rate of amplitude change of the signal are common controlled parameters of myoelectric prostheses [4].

The "Acquisition Module" consists of a battery-powered instrumentation amplifier and analog signal processing circuitry. An AD620 low power instrumentation amplifier integrated circuit is used to build the high common mode rejection differential amplifier to pick up surface EMG signals in the order of 10 μV. The module provides 10 GΩ input impedance and a variable gain of up to 50,000 to the input signals. Selectable band pass filters (f_L = 0.05 or 90 Hz; f_H = 480 to 1.5k Hz) limits the bandwidth and removes noise from the signal. An envelope detector consists of a precision rectifier and low pass filter converts the EMG into muscle contraction signals (or myoelectric activation signals). Two sets of outputs are available: one presents the EMG signal and the other the muscle contraction signal.

SIGNAL CAPTURE MODULE

The "Signal Capture Module" has two analog input channels to import external signals such as the EMG waveforms from the "Acquisition Module". It allows the user to view a four-second segment of the waveform in real time. A "FREEZE" function allows the user to freeze the time varying waveform for inspection. The frequency spectrum of the signal is displayed next to each of the input waveforms. When the "SAVE" button is pushed, twelve seconds of the waveform (including 4 seconds prior to and four seconds after the waveform on display) is saved in a binary file. These waveform files can be imported into the "Programmable Signal Generation Module" for further analysis and processing.

Figure 2-a shows a surface EMG with electrode lift (high amplitude spike) and Figure 2-b shows a series of five muscle contractions with different strengths recorded using the "Acquisition" and "Signal Capture" modules.

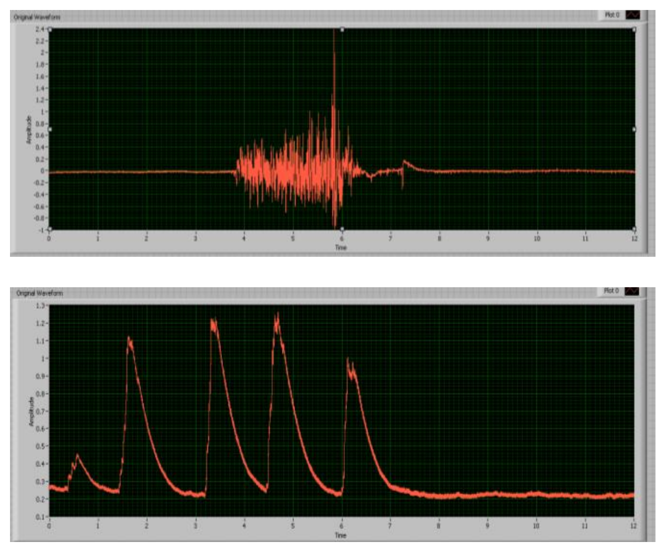

Figure 2-a EMG (above); 2-b Muscle Contraction Signals

PROGRAMMABLE SIGNAL GENERATION MODULE

The "Programmable Signal Generation Module" consists of the "signal processor" and the "waveform builder" sub-modules. Signal processing functions including amplification, attenuation, level shifting, filtering, envelop detection are built into this module. Power frequency (60 Hz) and Gaussian noise of adjustable amplitude can be added to the waveform. The imported (raw) and processed waveforms, and their respective frequency spectrums are displayed in the LabVIEW graphical user interface (GUI) on the computer monitor. The processed waveform can be stored in a binary file to be reviewed, reprocessed, or later used to build the prosthetic activation signals.

The main function of the “waveform builder” sub-module in the “Programmable Signal Generation Module” is to compose signal trains to activate a myoelectric prosthesis. A captured waveform from the “Signal Capture Module” can be used as a template for the myoelectric activation signal. Alternatively, signals of different amplitude, duration, rise and fall time may be created within this module. A mixture of captured myoelectric and simulated signals can be combined to create an activation signal train of up to 30 second duration. The train of signals, when applied to the prosthesis, may activate the prosthesis to produce a sequence of pre-programmed functional motions.

ACTIVATION AND MEASUREMENT MODULE

One of the functions of the “Activation and Measurement Module” is to activate the prosthesis with the signals created from the “Programmable Signal Generation Module”. To activate the myoelectric prosthesis, an activation signal train is loaded in one of the four output channels. Activation signals are sent in synchronous via the output interface to the prosthesis to create a single sequence of motion. Alternatively, the activation signals can be repeated for a selected number of cycles or looped continuously until it is manually interrupted.

The measurement function in this module is designed to capture the responses of the prosthesis-under-test to the activation signals. Four data acquisition channels are available to simultaneously acquire analog external voltage inputs. These inputs are programmed to acquire and process outputs from the transducers. For examples, to measure the gripping force of a myoelectric hand, a transducer circuit is built using a flexible membrane force sensor (Tekscan Flexiforce A210) to convert the gripping force to a voltage signal; a pair of optical sensors (Honeywell HOA6972) placed at a known distance from each other can be used to measure the opening/closing speed of the hand. These measured parameters can be exported to a spreadsheet file for record and analysis. An example of the data acquired after 5 cycles of activations is shown in Table 1.

The module can be used to verify technical performance of a prosthesis in respond to known activation inputs under different conditions; as well as used as a tool to evaluate functional outcome repeatability and component reliability.

Table 1: Output File of Measurement Sub-module

Cycle	**Closing Time(s)**	**Opening Time (s)**	**Grip Force (N)**	**Holding Force (N)**
1	1.41	1.24	22.1	20.4
2	1.44	1.22	21.9	20.2
3	1.38	1.30	22.3	21.1
4	1.42	1.27	23.7	21.6
5	1.39	1.26	24.5	21.9

CONCLUSION AND FUTURE WORK

An assessment platform was conceptulized, built and tested for assessing technical performance of upper limb myoelectric prosthesis. It can:

- Acquire, process and capture surface EMG
- Compose activation signals of different characteristics and noise contents
- Measure outputs of prosthesis in respond to activation signals
- Evaluate technical performance of prosthesis

The platform can be easily modified to adapt to different transducers for other prosthetic functional parameter measurements.

Although the platform was designed for myoelectric prosthetic component studies, it can be used, with minor modification and reprogramming, for other applications such as acquiring and analyzing electrocardiographic

(ECG) signals, or in evoked potential (EP) studies.

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