Instrumentation Amplifier and Filter Design for Biopotential Acquisition System

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

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Abstract

INSTRUMENTATION AMPLIFIER AND FILTER DESIGN FOR BIOPOTENTIAL ACQUISITION SYSTEM

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This work describes an instrumentation amplifier and a filter designed for biopotential readout front-end. For the biopotential readout front-end design, the challenges are common-mode interference from mains, inherent flicker noise of electrical circuit, electrode offset generated at the skin-electrode interface and amplitude and bandwidth characteristics of biopotential signals. To deal with these problems, a low noise low power current balancing instrumentation amplifier (CBIA) with high common mode rejection ratio is implemented as the core amplifier in this work. To further reduce the noise, chopping modulation technique is adopted to reduce the flicker noise. Furthermore, AC coupling technique introduced to filter the offset generated by the electrode. The instrumentation amplifier using these two kinds of technique is called AC coupling chopping modulated instrumentation amplifier (ACCIA). This work focuses on the implementation of ACCIA. Moreover, due to the amplitude and bandwidth characteristics of biopotential signals, this ACCIA is designed to have a configurable gain and filter characteristics. To further enhance the signal quality, a high-dynamic-range 2.4 Hz-to-10 kHz wide-range tunable 5th-order Butterworth lowpass filter is implemented in this work too. For capacitance savings with consequent silicon area reduction, a novel capacitor multiplier is proposed for the filter design.

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LIST OF ABBREVIATIONS

ACCIA	AC coupling chopping modulated instrumentation amplifier
ADC	Analog-to-Digital converter
AEP	Auditory evoked potentials
AF	flicker noise exponent
CBIA	current balancing instrumentation amplifier
Cext	external capacitor
CMRR	common mode rejection ratio
CSF	Chopping Spike Filter
CT	continuous-time
DRL	Driven Right Leg Circuit
ENG	Electroneurogram
ERG	Electroretinogram
EOG	Electro-oculogram
EEG	Electroencephalogram
EP	Evoked potentials
EMG	Electromyography
ECG	Electrocardiogram
f	frequency
gm	transconductance
I_d	DC drain current of transistor
IMR	isolation voltage (or mode) rejection
IA	instrumentation amplifier

k	Boltzmann's constant
KF	flicker noise coefficient
LPF	low pass filter
MUAP	Motor unit action potential
OTA	operational transconductance amplifier
Op amp	operational amplifier
PGS	programmable gain stage
PSD	power spectral density
R	resistance
RLC	resistor, inductor and capacitor
RGC	regulated cascade current mirrors
$\mathbf{R_{ds}}$	resistance between drain and source of transistor
$\mathbf{R_{out,eq}}$	equivalent output resistance
SEP	Somatosensory evoked potentials
SEMG	Surface EMG
SFEMG	Single-fiber Electromyography
SC	switch-capacitor
T&H	track and hold
$\mathbf{V_{cm}}$	common-mode Voltage
VEP	Visual evoked potentials
$\mathbf{V_{ref}}$	reference voltage

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