BIOPAC Systems, Inc.
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APPLICATION NOTES

42 Aero Camino, Goleta, CA 93117
Tel (805) 685-0066 | Fax (805) 685-0067
info@biopac.com | **www.biopac.com**

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Application Note 190: Use of the MCE100C Micro-Electrode Amplifier

The MCE100C micro-electrode amplifier module is useful for a wide range of physiological recording applications that require the use of micro-electrodes, such as cellular single channel analysis. Micro-electrodes, due to their small physiological contact areas, present significantly high source impedances to the recording amplifier. Accordingly, for successful recording, the amplifier must incorporate extremely high input impedance.

The MCE100C amplifier has an input impedance on the order of 10 to the 15th power ohms. In theory, the MCE100C is able to measure signals with source impedances up to 10 to the 13th power ohms with only 1% signal degradation. However, practically considered, the primary issue facing high input impedance signal recording is extraneous or residual input capacitance. This capacitance results from the physical geometries of the micro-electrode probe and associated cabling in relation to the shielding present.

The extraneous input capacitance will act to low pass filter the signal coming from the high impedance source. For example, if the source impedance is 10E13 ohms and the extraneous input capacitance is 1pF, the signal will be low pass filtered according to the formula:

1/(2*PI*R*C) or 1/(2*3.1.4159*10E13*1E-12) or 16 micro-Hz

Obviously, if the signal is filtered to this extent, the result will not be very helpful because this configuration will only pass signals that reside very close to DC. A more practical upper limit of source impedance is probably on the order of one giga-ohm (1,000,000,000 ohms). If this value is substituted in the above formula, the frequency response is:

1/(2*3.1.4159*1E9*1E-12) or 160 Hz

Naturally, this frequency response may still be far to low for certain kinds of recording requirements. In these cases, to boost frequency response, it is important to negate the effects of input capacitance (to values less than 1pF) and/or drop the value of source impedance.

For example, if the input capacitance is decreased to 0.5pF and if the source impedance is reduced to 10 mega-ohms (10,000,000 ohms), the resultant frequency response will be significantly extended:

1/(2*3.1.4159*10E6*0.5E-12) or 32,000 Hz

The MCE100C incorporates two input capacity compensation methods that can be independently and optionally applied to the amplifier to aid in signal recording for high speed applications. These methods are:

1) Driven Shield Compensation
2) Negative Capacity Generation

Driven shield Compensation operates by buffering the input signal from the micro-electrode and directing this buffered output to drive the shield which surrounds the input signal cabling all the way to the micro-electrode. This technique will hold the shield at the same potential as the input signal cabling. If the shield and cabling are at the same potential, no capacitance between input and shield can develop. If no capacitance is presented to the input cabling, the frequency response will be extended significantly.

Negative Capacity Generation acts to present a negative capacitance to the amplifier input to subtract any positive capacitance that may be present. Negative capacitance is generated by buffering the input signal and directing this buffered signal though a variable gain amplifier which then drives one side of a series capacitor connected back to the amplifier input. This configuration will cause current to flow through the series capacitor to compensate the effects associated with extraneous capacitance on the input signal cabling. The variable amplifier is adjusted by the user (via the CAP ADJ trim pot) until the correct amount of negative capacitance is applied, thus resulting in a signal of maximum bandwidth.

Although the use of driven shield or negative capacity generation compensation methods can significantly can boost the recording frequency response, random noise from the buffer amplifier output will couple from the shield (or compensation capacitor, in the case of negative capacity generation), back into the input cabling. These effects are fairly subtle, but they can be enough to make recording more difficult when the source signal to noise ratio is low. Accordingly, the judicious use of these compensation techniques is recommended. The fewer the number of compensation techniques required for the recording, the better.

These compensation methods are employed in a variety of ways. One method would be to use them simultaneously. Another method would be to ground the input shields (to reduce noise) and then apply negative capacity compensation to counter the effects of the shield capacitance.

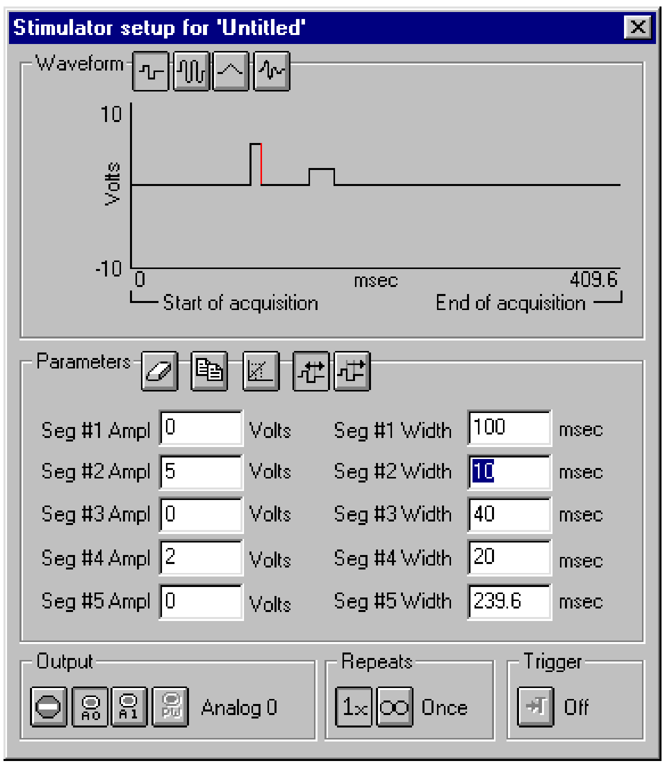
One additional feature of the MCE100C is the integral current clamp. Similar to the input capacity compensation methods, the MCE100C current clamp feature can be optionally applied to the recording setup. The MCE100C current clamp is controlled via an applied voltage signal. The current clamp will direct current into or out of the micro-electrode connected to the physiological signal source (e.g. neuron or other cell). With a the control voltage set to zero, the current clamp can be adjusted to 0 nA through the use of the IB ADJ trim pot.

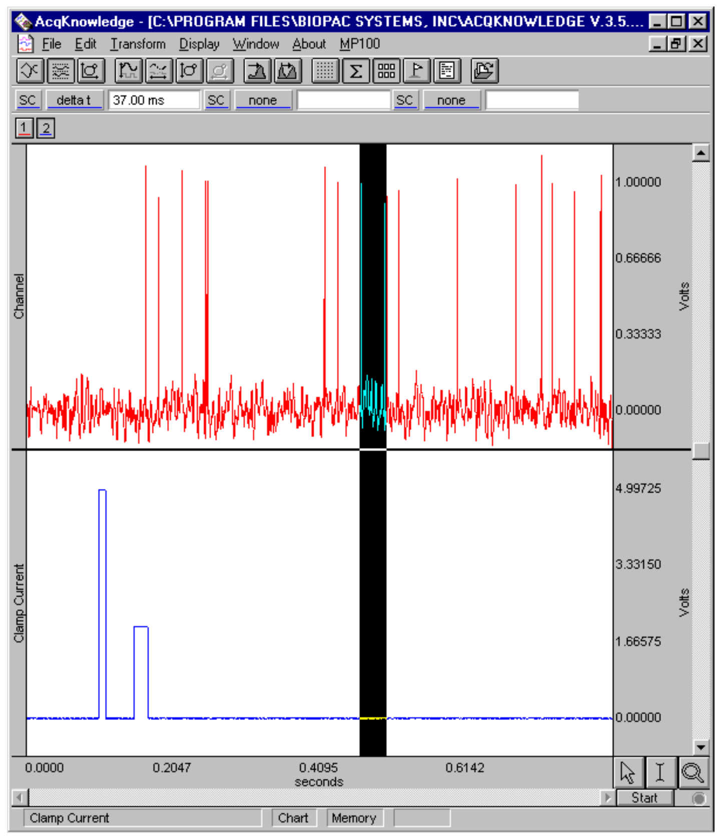
The current through the cell is held constant and is proportional to the controlling voltage (100mV per nA). Because the current is voltage controlled, the current can be changed during recording in a automated user-specified way by using the MP100 or MP150 to output a stimulus voltage waveform synchronously with the recording from the micro-electrode.

The Stimulator dialog setup below shows a possible stimulator voltage control signal that is used to control the clamp current during recording. In this case, at 100ms after the recording starts, the MCE100C will direct 50nA of current for 10ms through the micro-electrode. Then, after an additional 40ms, a 20 nA current for 20ms will be directed through the micro-electrode.

To control the MCE100C from the MP100 or MP150 stimulator setup, simply use a CBL100 to connect the Digital to Analog Output (on the front panel of the UIM100) to the Current Control Input on the back of the MCE100C.

The MCE100C also incorporates a current monitor output so the clamp current can be monitored simultaneously with micro-electrode signal recording. The current monitor will output 100mV per nA of clamp current.





The above graph illustrates the use of current monitoring during micro-electrode signal recording. To monitor the clamp current with an MP100 or MP150 analog channel, use a CBL100 to connect The Current Monitor Output (on the back of the MCE100C) to an available analog input channel on the UIM100.

The MCE100C high frequency response can be set to either 3kHz or 30kHz. Regardless the setting, it will be necessary to sample the MCE100C output at least to double the bandwidth setting. For example, if the MCE100C low pass filter is set to 30kHz, it will be necessary to sample the output at a rate of least 60kHz (and preferably higher). For this reason, the MCE100C is typically used with a MP150 data acquisition system, as this system permits much higher throughput rates than the MP100 system. However, for very short term recordings it may be appropriate to use the MCE100C with a MP100 System, even when operating at the full 30kHz bandwidth.

The MCE100C is a very flexible amplifier and can be configured to operate in any of the following modes:

General Modes

1) Differential Amplification

2) Single-ended Amplification

3) Grounded Input Shield Operation

4) Driven Input Shield Operation

Special Modes

5) Negative Input Capacitance Generation

6) Current Clamp Control

The first four operational modes (1,2,3,4) are compatible with standard recording electrodes with Touchproof leads available from Biopac. Use the LEAD110 unshielded lead or LEAD110S shielded lead with disposable surface electrodes (such as the EL503). Use the EL254 or EL258 as an unshielded reusable electrode. Use the EL254S or EL258S as a shielded reusable electrode. Use the EL450 or EL452 for unshielded needle electrodes. Use the EL451 as a shielded concentric bipolar needle electrode. Use the JUMP100C jumpers to configure the MCE100C for single ended amplification by shorting Vin- to Ground.

When using the MCE100C with micro-electrodes and without the use of modes 5 and 6, the primary concern is electrode interfacing. If the micro-electrode terminates in a standard 1.5mm Touchproof socket, plug the electrode directly into the front panel of the MCE100C. If special cabling or connectors are required to interface with the micro-electrode, the MCEKIT is recommended.

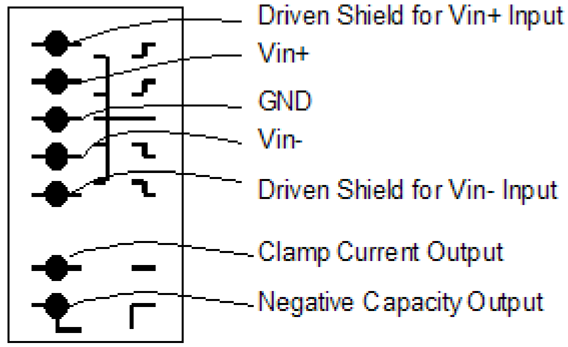
The MCEKIT is a junction box assembly that is designed to plug directly into the front panel of the MCE100C amplifier. The MCEKIT comes equipped with an assortment of wire and coaxial cable to customize the MCE100C for a variety of micro-electrode lead connectors. The MCEKIT construction permits you to mount the appropriate connector to the housing and solder wires to the respective pins.

When using the last two operational modes (5,6) with micro-electrodes, the MCEKIT is required. The following table illustrates the configuration desired. The amplifier configuration is determined via the MCEKITC. The MCEKITC connects to the MCE100C and modifies the MCE100C appropriately. See the respective figure to determine the correct MCEKITC configuration for your application.

INPUT TYPE	SHIELD	CURRENT CLAMP	NEGATIVE CAPACITY	MCEKITC FIGURE
Differential	Grounded	No	No	A
Differential	Driven	No	No	B
Single-ended	Grounded	No	No	C
Single-ended	Grounded	No	Yes	D
Single-ended	Grounded	Yes	Yes	E
Single-ended	Driven	Yes	Yes	F

MCEKITC CONFIGURATIONS

LEGEND



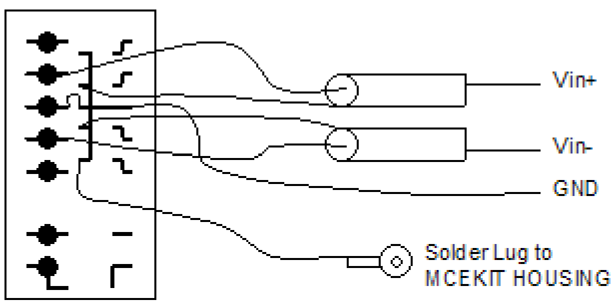


FIGURE A

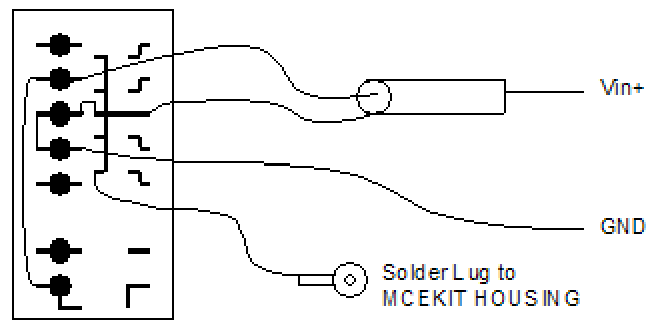


FIGURE D

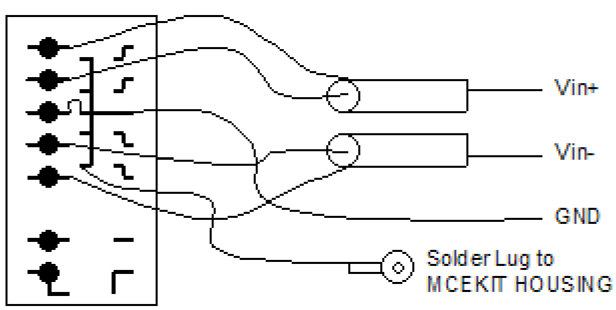


FIGURE B

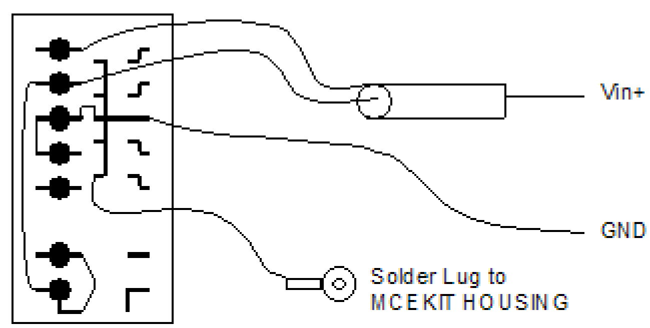


FIGURE E

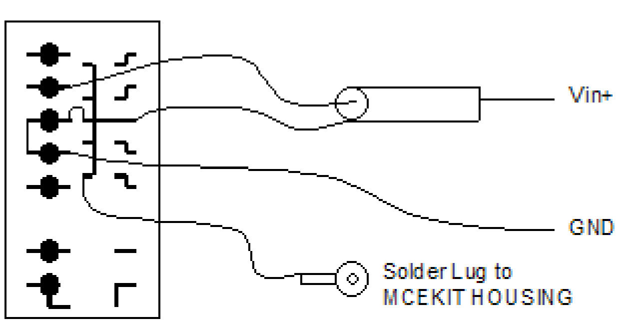


FIGURE C

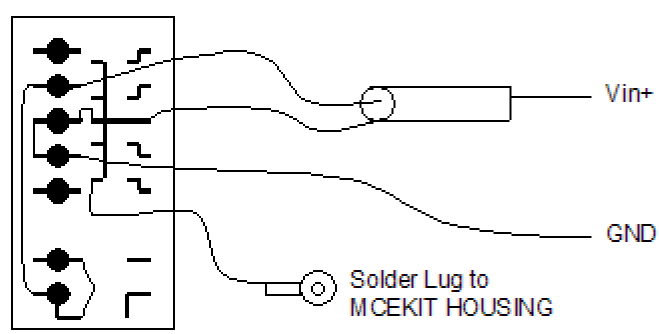


FIGURE F