



<b>Microdrive Motor Controller MC2</b>	<b>ND1MC2</b>
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**Single-channel Microdrive Motor Controller for Miniature Microdrive Neural Recording Systems**

- 1 motor drive channel
- USB host control interface
- Field upgradeable firmware
- Automatic control of MC2 Adapter motor operation isolation circuits
- Microsoft Windows (R) Win32 driver and control program

- Single 5 VDC supply available from USB or power adapter
- Internal current limited unipolar motor drivers
- Auxiliary USB I/O options



**Ordering Information**

Configuration	Model Number
Single-channel Motor Controller MC2	ND1MC2
Single-channel Motor Controller MC2 Plus	ND1MC2+
Replacement external 5 VDC adapter	MC2PDC

**Absolute Maximum Ratings**

Characteristic	Symbol	Min	Typ	Max	Unit
Input DC Supply Voltage	$V_{DC}$	-0.3	5.0	5.5	V
Input DC Supply Isolation to Ground	$V_{SISO}$	700			V
Motor Circuit Current	$I_{MOT}$	0		500	mA
Motor Circuit Voltage	$V_{MOT}$	2.4		4.6	V
Output Short-Circuit to Ground Duration	$t_{SC}$			$\infty$	sec
Operating Temperature	$T_A$	0		70	°C
Storage Temperature	$T_S$	-40		85	°C
USB Host VBus	$V_{VBUS}$	-0.3	5.0	5.5	V
USB Host D+, D-	$V_{USBD}$	-0.5		5.25	V

## Specifications

At  $T_A = +25^\circ\text{C}$ ,  $V_{DC} = 5\text{V}$ , unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
Input DC Supply Voltage (in operation)	$V_{DC}$	4.5	5.0	5.5	V
Operating Supply Current	$I_S$		250	500	mA
Motor Drive Signal (Individual)					
Output Voltage Magnitude (sinking)	$V_{\text{sink}}$	0.0	0.4	0.4	V
Output Voltage Magnitude (sourcing)	$V_{\text{source}}$	2.4	2.5	4.5	V
Output Current Limit	$I_{\text{lim}}$	0.0	100	1225	mA
Motor Step Period	$T_{\text{Step}}$	2	25	4095	ms
Motor Step Rate	$F_{\text{Step}}$	0.24	40	500	step/sec
Step Counter Range (32-bit signed int)		-2147483648		2147483647	step

## Description

The ND1MC2/ ND1MC2+ Microdrive Motor Controller is a table top module that connects to the motor within an ND1HS1 or ND1HS2 Single-Drive Neural Headstage. The motor controller connects to the headstage motor via the rear panel RJ-45 **Motor connector**. RP Metrix supplies various adapters from this RJ-45 interface to a headstage.

The MC2 connects via the rear panel **USB Host connector** (USB Type B) to a user supplied host computer. The computer provides power and control of the MC2 and attached headstage motor.

The MC2+ provides additional options. An external 5V DC power supply may be connected via the **5VDC connector** and the **Power switch**. The motor may be controlled via a user supplied USB peripheral device attached via the **USB Port connector** (USB Type A). Standard firmware supports a USB mouse. Contact RP Metrix to request support for other devices.

The Motor connector has two LED indicators, one green and one yellow. When the controller is active, one of the LEDs is illuminated. Green indicates the extract direction and yellow indicates the insert direction. The LEDs also flash briefly when the controller powers up.

The Motor connector mates to a standard Ethernet style 8-wire RJ-45 cable. The motor cable carries motor drive signals for a 3-wire delta connected brushless DC motor. The three motor drive signals differentially supply current to selected motor coils. The motor drive circuits drive the motor in one of 6 phases such that at any time, one signal is grounded, one signal supplies a positive drive voltage, and one signal is floating at high-impedance.

The motor connector also carries these auxiliary signals: Optional 5V DC power and ground to energize an external adapter, a motor activation signal, and a USB 1.2 compatible differential signal pair. The activation signal can be used to energize relays or signal blanking functions in an external device.

A CDROM supplied with the MC2 or available from [www.rpmetrix.com](http://www.rpmetrix.com) contains software for installation in a user supplied PC running Microsoft Windows 2000 (R), Windows XP (R), or a compatible operating system. A USB driver and user application programs are included.

The MC2 is normally used in at least two configurations: **Head stage assembly** and **head stage operation**.

In the **head stage assembly** configuration, manual control of the motor is useful to install and position shuttles and complete electrode attachment and installation. In this situation, the MC2+

needs only the local power adapter and a simple cable to the motor circuits of the headstage. The MC2+ mouse control functions can be used to step the motor forward or backward, or run the motor continuously until manually stopped. The operator typically observes the motor, shuttle, and electrodes visually during these procedures.

In the **head stage operation** configuration, computer control of the motor is expected, so that electrode positioning and neural data collection can be efficiently interleaved. The MC2Player application program included with the MC2 permits an operator to control motor position, direction, and speed via a USB connection to a user supplied PC. The MC2 sends motor control signals via the motor cable and adapter to the headstage. The MC2 optionally sends a motor activity control signal to the adapter; causing appropriate adapters and preamplifiers to release the motor isolation relays and to clamp the electrode signal buffers to ground. The MC2 can obtain DC power from the host computer so the MC2 DC power adapter is not required.

### USB Mouse Operation (MC2+)

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The MC2+ supports limited control via a USB mouse connected to the USB Port connector.

A **left** click on the mouse activates the motor in the **extract** direction (the Motor connector green LED illuminates). Ten steps are taken.

A **right** click on the mouse activates the motor in the **insert** direction (the Motor connector yellow LED illuminates). Ten steps are taken.

Moving the mouse with neither button pressed deactivates the motor.

I/O Information

**MC2-J1 (USB Type B) 4-Pin USB Host Interface Connector**

Pin #	Signal	Input/Output
1	VBUS	Input
2	D-	Input
3	D+	Input
4	Ground	-----

**MC2-J2 (USB Type A) 4-Pin USB Port Interface Connector (MC2+ only)**

Pin #	Signal	Input/Output
1	USBA2 VBUS	Input
2	USBA2 D-	Input
3	USBA2 D+	Input
4	Ground	-----

**MC2-J3 (RJ-45 Jack) 8-Pin Motor Interface Connector**

Pin #	Signal	Input/Output
1	USBA1 VBus (5V DC)	Output
2	USBA1 Ground	-----
3	Motor Drive 1	Output
4	Motor Drive 2	Output
5	Motor Drive 3	Output
6	Motor Active Indicator	Output
7	USBA1 D+	Input/Output
8	USBA1 D-	Input/Output

**MC2-J4 (5.8 mm Jack<sup>1</sup>) 2-Pin DC Power Jack Interface Connector (MC2+ only)**

Pin #	Signal	Input/Output
1 (center)	V <sub>DC</sub> Supply	Input
2 (barrel)	V <sub>DC</sub> Return (Gnd)	Input

<sup>1</sup> CUI, Inc., PJ-005B

## Software Installation

Included with the MC2 (or available via [www.rpmetrix.com](http://www.rpmetrix.com)) is a software installation CDROM. Check the RP Metrix web site ([www.rpmetrix.com](http://www.rpmetrix.com)) for information about the latest software, which may be newer than the version described in this document. The top-level “RP Metrix” folder contains these items:

File Name	Description
RedPill.inf	Windows USB driver information
RedPill.sys	Windows USB driver
MC2Player.exe	User program to operate the MC2 motor controller
ND2_LV.dll	LabVIEW <sup>2</sup> and Python <sup>3</sup> compatible application program interface
ND2X.ocx	MATLAB <sup>4</sup> compatible ActiveX control and application program interface
Doc	Documentation folder (see below)
Example	Example user application program folder (see below)
Firmware	Firmware maintenance folder (see below)

The “Doc” folder contains these items:

File Name	Description
Basic MC2 instructions.pdf	Minimal single page of operating instructions.
MC2_FirmwareUpgrade.pdf	Instructions for field upgrade of MC2 firmware.
ND2_LV_EntryPoints.pdf	Description of ND2_LV.dll programming interface
ND2X_EntryPoints.pdf	Description of ND2X.ocx programming interface
ND1MC2.doc	MC2 datasheet and description (this document)

The “Example” folder contains these items:

File Name	Description
*.m	Various MATLAB demonstration scripts.
*.py	Various Python demonstration programs.
*.vi	Various LabVIEW demonstration virtual instruments.

The “Firmware” folder contains these items:

File Name	Description
LoadBoard.exe	Maintenance program to upgrade firmware
mc2.iic	Backup copy of MC2 firmware (this name may depend on the version)

This software is designed for use on a PC running Windows (R) 2000 or Windows XP. This software can not be used with Windows 98, Me, NT or earlier versions of Windows. Only Administrators can install the USB driver. After that, any user can operate the motor controller with MC2Player.exe or use the programming interfaces.

<sup>2</sup> LabVIEW® is a registered trademark of National Instruments Corp.

<sup>3</sup> Python® is a registered trademark of the Python Software Foundation.

<sup>4</sup> MATLAB® is a registered trademark of The MathWorks.

When the MC2 is first connected to a PC USB port, the operating system will detect a new unrecognized device. Depending on the type of Windows (R) operating system, you will be prompted by the Found New Hardware Wizard to install the new driver. The steps listed below are for Windows 2000. Follow the wizard prompts to:

- Search for a suitable driver for my device.
- Specify a location.
- Browse to the CDROM (or a copy), browse into the RP Metrix folder, then select RedPill.inf and click Open.
- Confirm that windows found RedPill.inf in the proper folder and click Next.
- If a Digital Signature Not Found window pops up for "RP Metrix MC2 USB device", click Yes to continue the installation.
- Close the wizard by clicking Finish.

You should now be able to run the application programs.

### **Upgrading Firmware with LoadBoard**

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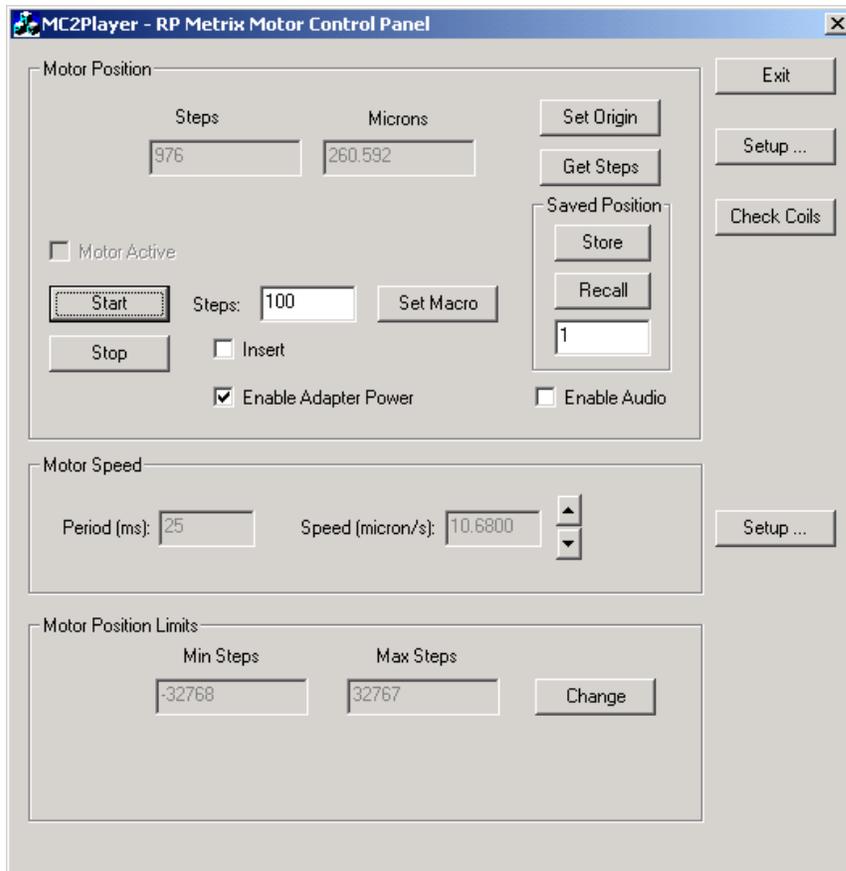
After the USB driver is installed, the LoadBoard.exe program can be used upgrade the firmware in the MC2, if necessary. This program can also make the MC2 unusable, so use this program only as directed by your technical support representative.

## Controlling Motors with MC2Player

After the USB driver is installed, the MC2Player.exe program can be used to control motors via the MC2. MC2Player can initiate motor activity from the operator's computer.

The MC2 is polled at one second intervals to check for changes in the motor position. Any changes cause the display to update. If audio is enabled, the PC will beep. The position is displayed in units of steps (1/6 of a motor rotation), and in microns. The step to micron scale factor defaults to the ND1HS1 scaling. This can be changed with the "Setup..." button.

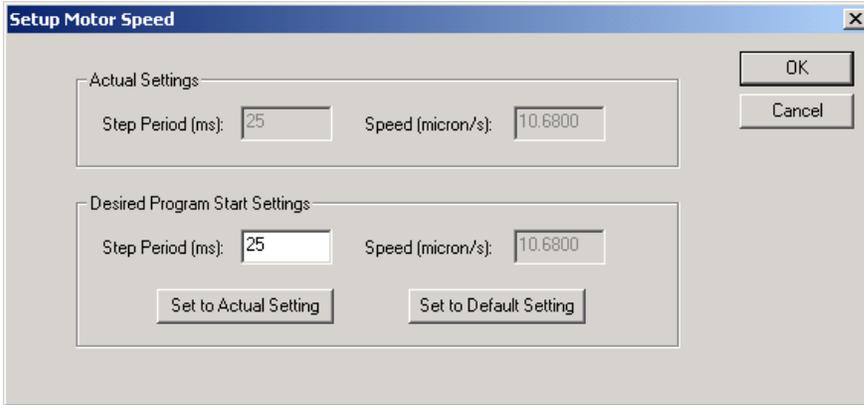
The "Get Steps" button reads the motor position counters in the MC2 immediately. These counters can be reset zero with the "Set Origin" button. This is the power up state of the MC2.



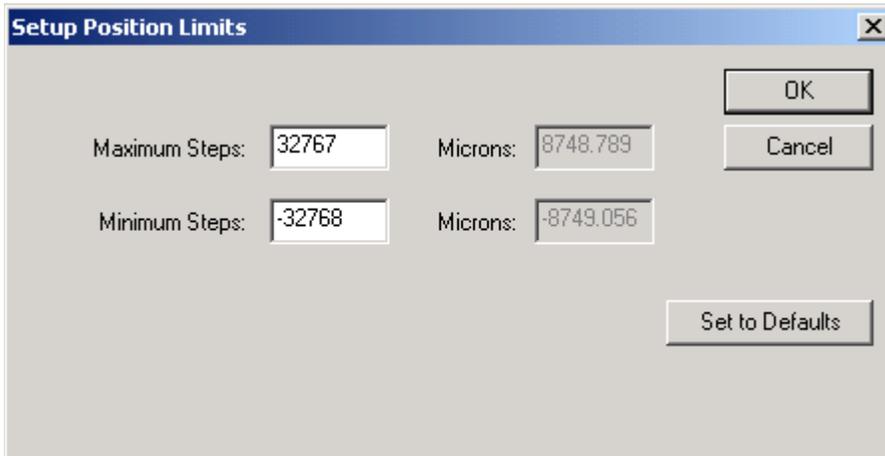
The program moves a motor in units of **macro steps**. The start up macro step value is 100 motor steps, but can be changed by entering a new value and clicking "Set Macro". The new value is written to the MC2.

The "Start" button causes one macro step to begin for the motor. Motor direction is determined with the "Insert" check box. If unchecked, the direction is extract (increasing step count). If checked, the direction is insert (decreasing step count).

Motor speed can be adjusted by clicking up arrow (Faster) or down arrow (Slower). The adjustment changes the step period, and the corresponding speed in micron/s is displayed. The "Setup" button next to the speed control can be used to determine the speed setting at program start. The pop up dialog is shown here:



MC2Player will not allow itself to change the position beyond the limits shown in the "Motor Position Limits" group. There is no such constraint on mouse input operation, since the operator is expected to be observing the headstage. These limits can be adjusted via the "Change" button. The units shown on the main display are basic steps, but the pop up box for changing the limits will also show them in units of microns, based on the current scale factor. The limit values are not currently saved. The pop up dialog to change the position limits for a motor is shown here:



Note that the current firmware uses a signed 32-bit counter to keep track of a motor position. The MC2 adds and subtracts steps from this counter as it moves a motor. If a motor rotates past the limits of the counter, it will wrap to the other end of the range and continue changing from there. The MC2 will not try to prevent a counter wrap.

MC2Player can configure selected settings within the MC2 whenever the program is started. These options are controlled via the top "Setup..." button, which pops up the dialog box shown here:

Desired Settings

Device ID: RP Metrix, MC2, Oct 06 2009 22:15:34 ID:3001

Microns per step: 0.267 ND1HS1 1-Motor Microelectrode

Enable Adapter Power at program start

Waveform Magnitude

Desired Settings: 2500 2.500 Volts

Actual Settings: 2500 2.500 Volts

Set at program start

Motor Current Limits [WARNING: High values may permit motor damage]

Desired Settings: 40 0.200 Amps

Actual Settings: 40 0.200 Amps

Set at program start

Support log

Enable

File name: MC2PlayerLog.txt

For information, the Setup dialog shows the Device ID, which is read from the MC2. The identification includes the manufacturer, device name, firmware version, and serial number.

The scaling in microns from one motor step to the corresponding electrode motion can be changed via this screen.

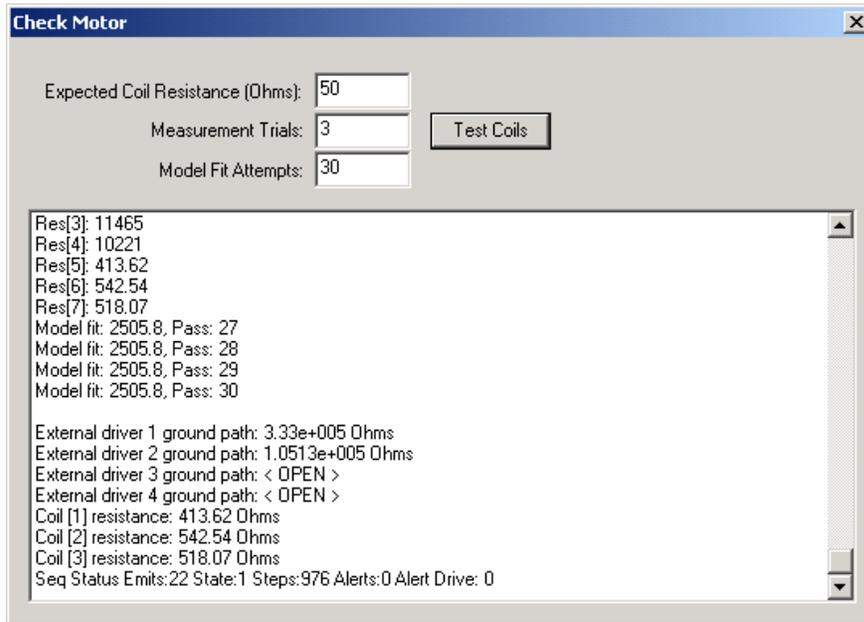
The waveforms generated by the MC2 to activate the motors can also be changed here. The MC2 generates a square waveform on successive pairs of the three Motor Drive outputs. These waveforms are unipolar, that is, one drive signal is positive and another is grounded. The magnitudes of each waveform can be configured on the Setup screen. The Magnitude setting is in millivolts, and ranges from 2400 to 4500 millivolts.

The MC2 limits the magnitude of the current flowing out of the positive Motor Drive circuit. The current limits help protect the motors from damage, have priority over the voltage magnitude settings, and will automatically limit the actual voltage of the outputs. Use extreme care when increasing these limits, since motor damage can result. The setting is a number in the range 0 to 255. This is also shown in units of Amps. The default value is chosen for the ND1HS1. A value corresponding to 0.1 Amps is typical.

MC2Player can be enabled to write a log file via the Setup dialog. The path and file name of the log file can also be changed. This file may be useful if technical support is needed to resolve problems with the software or hardware. The log is not enabled normally. Your manufacturer support representative may ask for a log file to be created and transmitted to assist in diagnosing any problems.

The “Check Coils” button on the main screen will access a utility to measure the motor coil network. A typical headstage motor contains 3 rotor coils interconnected in delta fashion. Each coil has a DC resistance which is typically tens of Ohms, but only combined resistances can be measured between any pair of the motor leads. The MC2 contains resistors from the drive circuits to ground to provide a reference network. The combined network of motor coils, MC2 reference resistors, tether wires, and potential inadvertent shorts or open connections is modeled via the coil check function. The MC2 energizes various paths through the network with voltages selected to cause small amounts of DC current, then adapts the network model resistances to the measured current data. (A short circuit trips the MC2 current limiting protection feature, terminating the test.)

Clicking the coil check button will bring up the coil measurement pop up dialog:



When the “Test Coils” button is clicked, the program will measure the current through various paths of the network multiple times, as determined by the Measurement Trials parameter. The averaged current values will then determine the goal for the network model. The model parameters will be adjusted until good convergence to the goal values is obtained, or the number of Model Fit Attempts is exhausted. The fitting process may take several seconds to complete.

At the end of the process, the estimated coil resistances are as shown, as well as estimates of external MC2 driver resistances to ground. In the example output shown here, the computed coil resistances are much larger than the expected values. There was no motor connected in this example. There were no ground shorts in the network, so the model external ground path resistances were very large, as expected.