

BC-MPNV100

**Burns Consulting
Psychrometric Measurement
System (BCPMS)
User's Guide**

v3.3

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Congratulations!

You have just purchased a precision preamplifier and multiplexer capable of amplifying nanovolt (10^{-9}) and microvolt signals (10^{-6}). This affordable combined instrument, the BC-MPNV100, will allow you to observe small signals from six low source impedance sensors and signal generators simply and cleanly.¹ Along with its BCPMS software, it forms the Burns Consulting Psychrometric Measurement System (BCPMS).

The Burns Consulting Psychrometric Measurement System (BCPMS) is a Windows based system which allows the user's PC to simultaneously operate up to six psychrometers in the Psychrometric or Isopiestic mode for water potential measurements of plants or soil. Examples of psychrometers compatible with the BCPMS in its psychrometric mode² are the Wescor C-52, C-30, L-51, L-51A, PCT-55 and PST-55 models as well as the Merrill 75-2C and similar models. Examples of psychrometers compatible with the BCPMS in its isopiestic mode are those made by Isopiestic, Inc. The BC-MPNV100 multiplexed preamplifier allows the user to control the gain, analog zero offset voltages, inject cooling current, and switch between up to six psychrometers. The BCPMS software allows the computer to control, digitally filter, zero offset correct, and record the psychrometer measurements.

I. Setting Up the Nanovolt Amplifier

The first step in operating your nanovolt amplifier is to be sure you have all of the necessary equipment. Below we list the components that are provided with BC-MPNV100. They are as follows:

- the electronic amplifier box,
- the shielded power cable with integral power filter and conditioner,
- custom DB-37 to DB-9 adapter
- DB-9 Radio Frequency Interference (RFI) filter module

¹ The BC-MPNV100 will function with any size source resistance, however the noise performance will degrade with increasing source resistance. For source resistances above 400Ω , other amplifier designs will offer lower noise performance than the BC-MPNV100. For low-noise amplifiers for signal sources or sensors with source impedances greater than 400Ω , contact Burns Consulting.

² Psychrometric mode is also known as the "Wet Bulb" or "Peltier" mode.

-
- User's Guide
 - 50Ω BNC terminator
 - Six copper-copper male plugs, OMEGA Engineering part number SMPW-U-F
 - Software to run the BC-MPNV100,
 - Visual Basic™ software library allow the user to easily write their own software for the BC-MPNV100,

Apart from the items included in the BC-MPNV100 package, there are several items that the user must supply in order to operate the system:

- A computer with a Keithley Metrabyte DAS-1600/1400/1200 compatible analog-to-digital card. There are advantages to having a chart recorder on hand, if possible.
- Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.
- Microsoft Visual Basic™ installed on the computer.
- Hand-held digital voltmeter.
- Two 12 volt batteries. These may be lantern batteries, car batteries or lead-acid gel-packs such as the type that data loggers use. The amplifier should have its own pair of 12 volt batteries without any other equipment drawing power from them for best results.

II. Assembling the BC-MPNV100 Nanovolt Amplifier System

In this section, we explain how to assemble the various parts of BC-MPNV100 nanovolt amplifier system. The set-up instructions refer to the various controls and connectors on the BC-MPNV100 electronics box with the numbers shown in Figures II.1 and II.2 below:

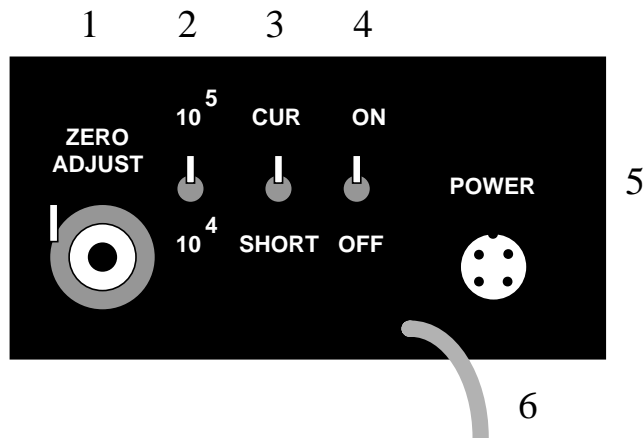


Figure II.1 -- Side panel of the amplifier.

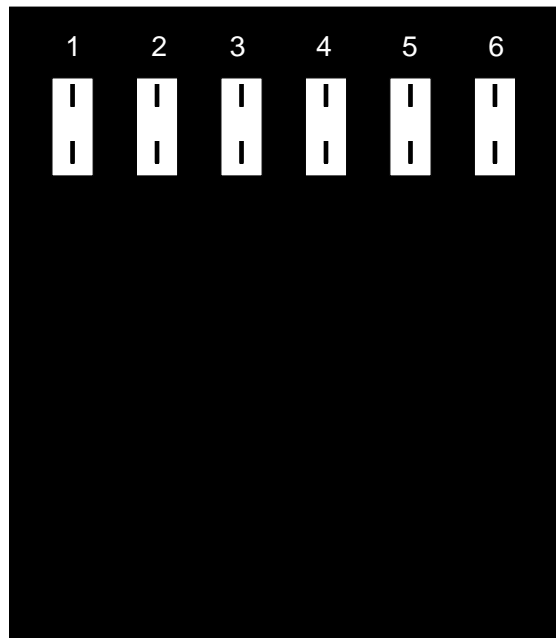


Figure II.2 -- Top of the amplifier.

Before you start, please touch a grounded object such as a faucet in order to discharge any static electricity you may have built up on your person. This is especially important when the humidity is low as in the winter in areas that see snow or severe cold.

STEP 1: Battery check

The first step is to check the batteries by checking them with the hand-held digital voltmeter. They should be nominally 12 volts and more importantly, they should read within 10 millivolts of each other.

STEP 2: Power Cable Battery Connection

Make sure the power is *not* plugged into the power cable receptacle (5). Attach the spade ends of the shielded power cable with its integral power filter and conditioner to the two 12 volt batteries as illustrated in Figure II.3 below. The black wire is connected to -12 volts, the white wire to +12 volts, and the two-conductor green wire is connected as the power ground tying the + terminal on one battery to the terminal on the other.

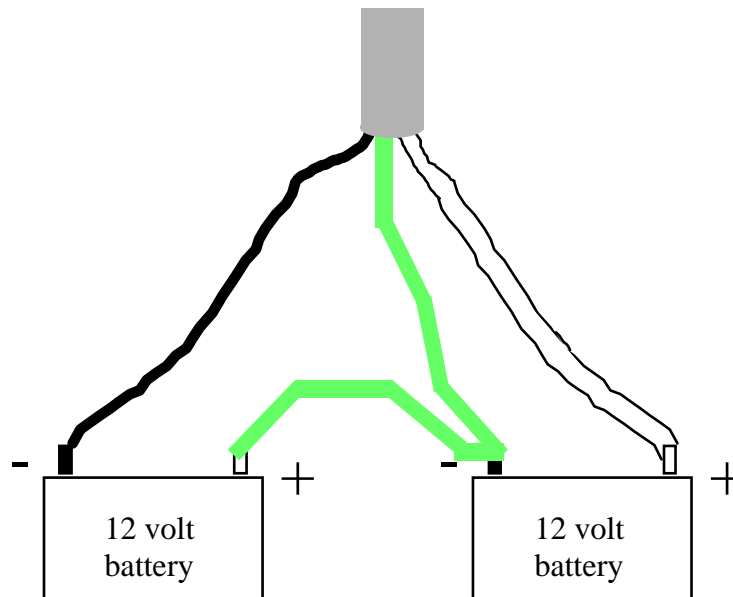


Figure II.3 -- Power cable connections.

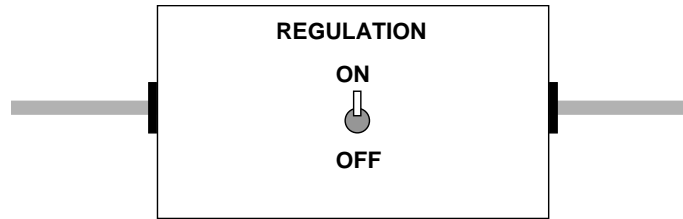


Figure II.4 -- Power cable connections

In Figure II.4 is shown the shielded power filter and conditioner box embedded in the power cable. This box contains a set of pi-filters for RFI filtering of the +12 and -12 volts from the batteries. In addition, when the REGULATION switch is set to ON a pair of ± 8 volt regulators is activated supplying RF filtered ± 8 volts to the BC-MPNV100 unit. When the REGULATION switch is set to OFF, RF filtered unregulated ± 12 volts from the batteries is supplied to the BC-MPNV100 unit. Generally, you will find that the zero will be different when the REGULATION switch is set to OFF from when the REGULATION switch is set to ON. Use whichever switch setting gives the best performance in your location. If the performance seems similar apart from a zero shift, we recommend that you run with the REGULATION switch is set to ON.

STEP 3: Input Connection

Connect the thermocouple under test to a compatible male copper-copper OMEGA plug. Isopiestic psychrometers from Isopiestic Company come correctly prewired to a male copper-copper OMEGA plug. Other psychrometers need to be connected per the instructions in the *Electrical connections for psychrometer sensors* section of this User's Guide.

The inputs of the BC-MPNV100 are true differential inputs, so do not ground either lead. Appropriate input bias current return paths have been provided internal to the amplifier. The BC-MPNV100 is not to be used in any system for use with human subjects and the manufacturer will not be responsible for the results of such misapplication of this device.

STEP 4: Output Connection

Turn off the computer. Since all of the connector housing components are metallic for electromagnetic shielding purposes, if you accidentally bump the metal DB-37 connector housing into the pins on the back of the Keithley board, you have a finite chance of momentarily shorting the computers +5V power

supply to the computer ground. If you do short that supply to ground even for a few milliseconds while the computer is running, the computer power supply shuts itself down to protect itself. If you are lucky no damage will occur to the computer, but if it was in the process of writing to the hard disk when the power goes down, the hard disk may be scrambled and all files corrupted.³

Connect the DB-37 to DB-9 adapter to the 37-pin receptacle on the Keithley DAS-1600 series board. If the BNC connector on the DB-37 connector on the DB-9 to DB-37 adapter gets in the way so that you have trouble plugging it into the Keithley board, move the board to another slot in the computer. Do NOT use the 37-pin ribbon cables that came with the board as an extension cable. The amp, all shields (including the cooler) are grounded through the computer chassis so the metal DB37 connector must be plugged directly into the Keithley board.

If not already attached, connect the DB-9 RFI filter module to the DB-9 connector on the BC-MPNV100 unit. Connect the DB-9 cable, with the DB-9 RFI filter module to the DB-9 connector on the DB-37 to DB-9 adapter. *Never connect the DB-9 connector of the BC-MPNV100 unit to a computers serial port (DB-9 connector on a computer or terminal). Doing so may damage the BC-MPNV100 unit or the computer or both. Burns Consulting will not be responsible for damage to any equipment including the BC-MPNV100 unit, resulting from such misuse.*

The warning above that the computer should be turned off while connecting the DB-37 cable is also true if you are connecting and disconnecting the DB-9 connector that is inline between the amp and computer. If you accidentally bump anything metallic into the pins of the DB-9 connector of the DB-37 to DB-9 adapter, you have a finite chance of momentarily shorting the computers +5V power supply to the computer ground. If you do short that supply to ground even for a few milliseconds while the computer is running, the computer power supply shuts itself down to protect itself. If you are lucky no damage will occur to the computer, but if it was in the process of writing to the hard disk when the power goes down, the hard disk may be scrambled and all files corrupted.⁴

Connect the green wire from the power cable connector attached to the BC-MPNV100 unit to the shield stud of the cooler.

³ Burns Consulting is not responsible for computer damage or data loss from the user manipulating cables to or from a powered computer.

⁴ Burns Consulting is not responsible for computer damage or data loss from the user manipulating cables to or from a powered computer.

The final connected assembly for use with Isopiestic Company's psychrometers is illustrated in Figure II.5. *Note: The multiplexer section of the BC-MPNV100 is powered by +5 volts derived exclusively from the computer via this 37-pin connector bypassing the BC-MPNV100 analog power ON-OFF switch. As long as the 37-pin connector is attached to the computer, the multiplexer section of the BC-MPNV100 is energized.*

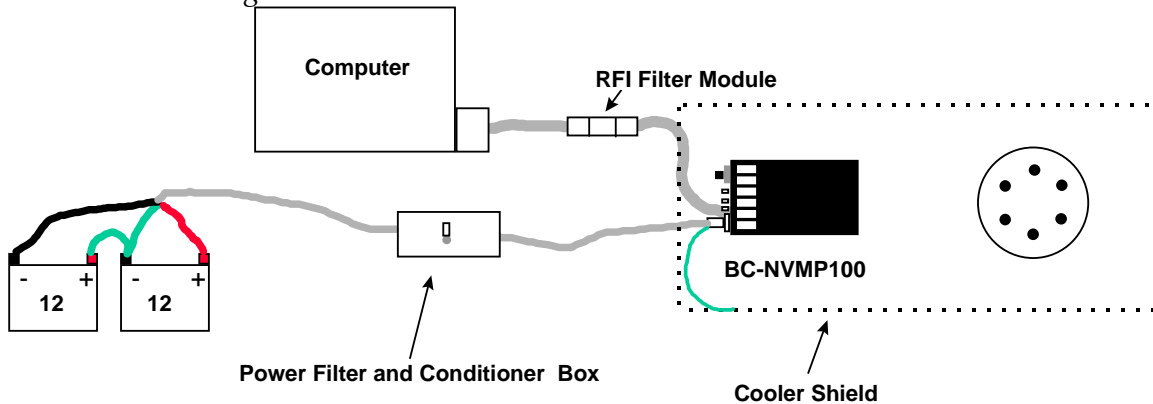


Figure II.5 – BC-NVMP100 cable connections for Isopiestic Company's psychrometers.

STEP 5: Restart the computer

Turn the computer on and let it boot itself up.

STEP 6: Thermal Isolation

Important!!! Thermal emf's are usually in the range of 10's of $\mu\text{V}/^\circ\text{C}$. This means that you need to have the BC-MPNV100 (or any other nanovolt amplifier) as thermally stable as possible. For best results the amplifier should be placed out of the way for drafts and away from windows or direct sunlight. For best results, place the BC-MPNV100 in a cooler and lay cloth over the input terminals (1).

STEP 7: Gain Setting

Set the gain switch (2) to the gain setting you will be using. If you are not sure, it is best to use the 10^4 setting. The 10^5 setting provides a gain of $\times 100,050$ and the 10^4 setting provides a gain of $\times 10328$.

STEP 8: Warm-up

Attach the power cable to the receptacle (5) and turn on the amplifier using the power switch (4). *Please allow at least 3 hours after applying power to the amplifier, before proceeding so that the amplifier's internal components can reach their steady safe operating temperatures.*

STEP 9: Zero Adjustment

If necessary, adjust the zero adjustment setting (1) to bring the signal level to where you want it. Set this only once at the beginning of a series of measurements. *We recommend that you leave this set to "5.0" and instead have the computer measure and correct for the offset as this will provide greater accuracy. The BC-MPNV100 software can perform this function.*

STEP 10: Auxiliary Thermocouple

If an auxiliary thermocouple is going to be used to monitor temperature, the output of the thermocouple reader⁵ is input into the BNC connector mounted on the side of the DB-37 connector of the DB-37 to DB-9 adapter. The thermocouple⁶ should be equipped with a shield, and the shield should be grounded to the cooler ground. When this input is not used, the thermocouple should be removed from the cooler, disconnected from the BNC, and the BNC should be covered with the 50Ω BNC terminator provided with the DB-37 to DB-9 adapter.

⁵ An example of which is the Fluke 80TK Thermocouple Module, type-K thermocouple reader which outputs 1mV/ ° C. The Fluke 80TK Thermocouple Module is manufactured by the John Fluke Manufacturing Co., Everett, Washington.

⁶ Any of the OMEGA CLAD thermocouple probes are fine. Shields on probes can be 304 stainless steel (SS) or Inconel. Junction should be UNGROUNDED. The OMEGA Low Noise Standard Thermocouple Probes with the external ground strap are recommended. For extension wire, use twisted/shielded thermocouple wire. In addition, OMEGA will supply any thermocouple wire with 304 SS, Inconel or Tinned Copper overbraiding. Use the OMEGA low noise connectors which match your shielded probe. See the OMEGA Temperature handbook. OMEGA Engineering, One Omega Drive, P.O. Box 4047, Stamford CT 06907-0047 1-800-826-6342

STEP 11: Software

The 3.5 inch floppy disk that came with this manual contains the software and libraries to operate the BC-MPNV100 and to also allow the user to write custom programs to control the BC-MPNV100. It is assumed that the user has previously installed the Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package. The software installation instructions are in the README.TXT file on the floppy.

At this point, your BC-MPNV100 is ready to run. Happy data collection!

III. Software Operation

BCPMS.exe - Psychrometer Measurement System Software

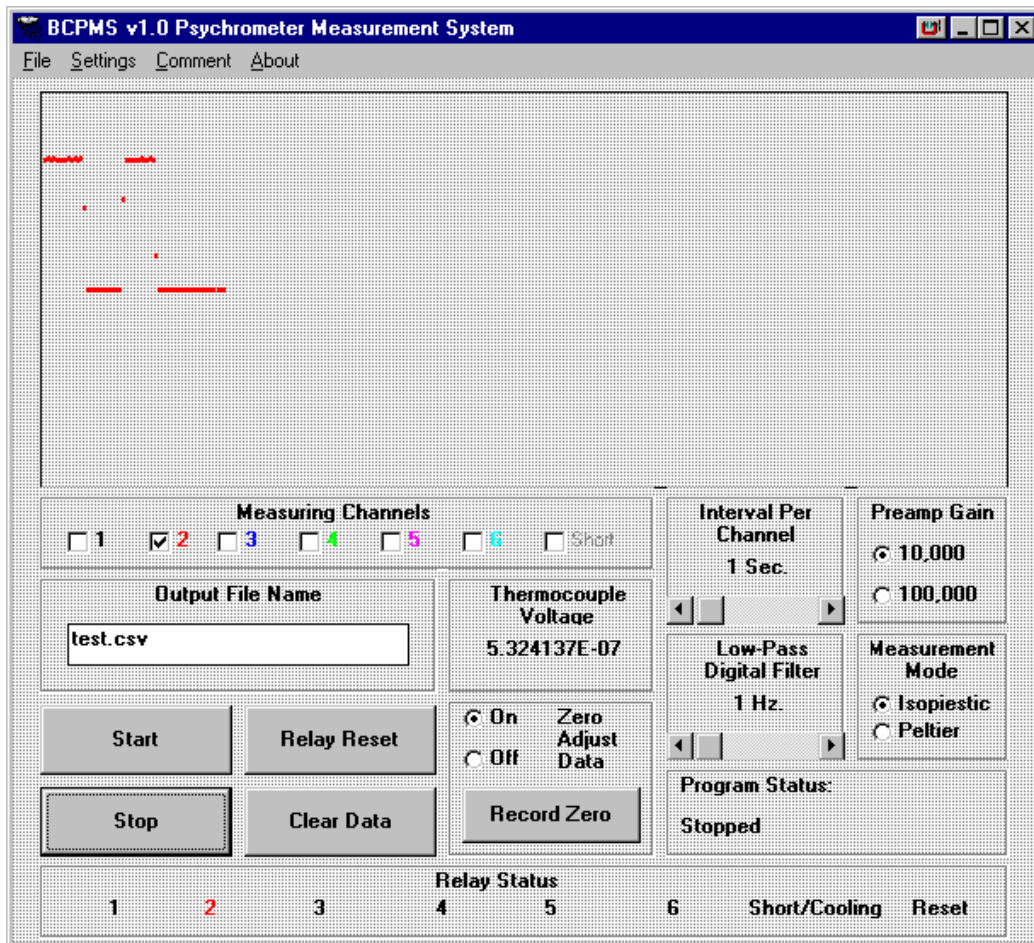


Figure III.1 - BCPMS.exe software control panel.

Your BC-MPNV100 unit requires computer commands in order to operate and return data. This can be done using the BCPMS.exe program or the user may write programs to suit specific needs. Provided the correct psychrometer style is attached to the unit, the BC-MPNV100 and BCPMS.exe can take data using either the Peltier technique or the Isopiestic technique. Figure III.1 shows the BCPMS.exe control panel. In addition, a Visual Basic™ library of functions for communicating with the BC-MPNV100 is supplied in the file BCDEC.BAS. The source code for BCPMS.exe is supplied as well as all files needed to modify and recompile BCPMS.exe except for the Microsoft Visual Basic™ and the Keithley

Metrabyte DAS-1600/1400/1200 Series Function Call Driver files. It is assumed that the user owns licensed copies of Microsoft Visual Basic™ and the Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Drivers.

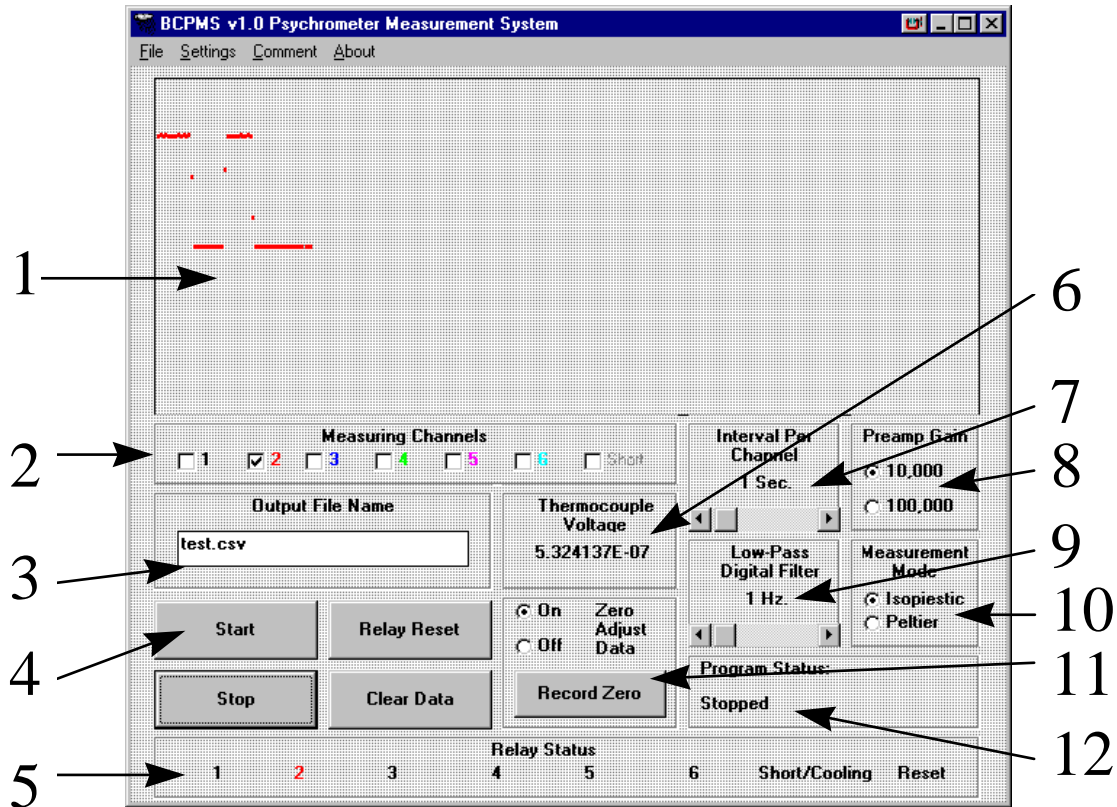


Figure III.2 - BCPMS.exe software control panel.

The BCPMS.exe software control panel can perform a number of complex functions and can be adjusted over a fairly wide range of operating parameters. The menu selections under **File**, **Settings**, **Comments** and **About** are mainly for basic functions. The bulk of the user interaction is via the various control and display areas discussed later in this section.

Under the **File** menu are two sub menus, **Name** and **Exit**. The **Name** selection allows the user to specify or change the name of the data output file. The **Exit** selection allows the user to halt execution, close the output file and exit the program.

Under the **Settings** menu are three sub menus, **Peltier**, **Isopiestic** and **Temperature Monitoring**. The **Isopiestic** selection allows the user to change the

time between switching from one channel to another (*interval per channel* setting), as well as the *digital filter* setting. The value of the *interval per channel* setting can be between 0.2 and 600 seconds between switching from one channel to another. The *interval per channel area* (7) control turns red when the program over rides the user in order to maintain compatibility with the *low-pass digital filter* setting (9). The program gives priority to the *interval per channel* setting. The **Peltier** selection allows the user to specify the cooling interval, measurement duration and interval between data points in a Peltier psychrometer measurement⁷. Checking the **Temperature Monitoring** selection activates a voltage measurement on the Keithley Metrabyte DAS-1600/1400/1200 Series board's channel 1 (channel 0 is used for reading the BC-MPNV100), presumed to be from a thermocouple reader⁸, after the last relay. This provision allows one to monitor and record the temperature inside the psychrometer cooler in case one wishes to compensate for drifting temperatures. The raw voltage is read with no conversion, so this feature may also be used for reading an arbitrary voltage.⁹

Under the **Comments** selection, the user is allowed to enter information which will be inserted in the data file.

Under the **About** selection, the user is given information about the version of BCPMS.exe and information on how to contact us if need be.

In figure III.2 we have numbered the various main panel areas and we will refer to this numbering system in the discussion which follows.

The area labeled **1** is the *data display area*. All data collected is plotted in this section of the BCPMS.exe window. The vertical axis of the plot area is automatically scaled based on the data channel with the largest measured voltage during the entire data collection period. The horizontal axis starts out at 10 minutes full scale across the window, and then is automatically scaled as time progresses. BCPMS.exe buffers between the last 1000 and 2000 data points per channel (the number is dynamic) for this display. The data points are color coded following the channel colors of the area labeled **2**.

⁷ The Peltier method is also known as the "Psychrometric" or "Wet Bulb" method.

⁸ An example of which is the Fluke 80TK Thermocouple Module, type-K thermocouple reader which outputs 1mV/ ° C. The Fluke 80TK Thermocouple Module is manufactured by the John Fluke Manufacturing Co., Everett, Washington.

⁹ Provided the voltage does not exceed the ratings of the Keithley Metrabyte DAS-1600/1400/1200 Series board.

The area labeled **2** is the *measured channels area*. The user checks the boxes to designate which channels are to be measured. If a box is checked, then the associated channel will be measured. The boxes are active during data collection, and so the user is permitted to change which channels are measured while the program is already collecting data. This allows the addition or changing of samples with minimal disturbance of the measurements in progress.

The area labeled **3** is the *output file area*. Changes to this field will allow one to change the output file in which the data is stored. The output file is in a csv format and will be explained at the end of this section.

The area labeled **4** is the *control button area*. This includes the button for starting or resuming data collection (**Start**), stopping data collection (**Stop**), manually resetting the relays (**Manual Relay Reset**), or clearing the data buffers (**Clear Data**). The **Start** button initiates or resumes the measurement process. The **Stop** button halts or pauses data collection, however if the program is in the midst of a collection sweep of channels, it will complete that sweep (measure the remaining channels) before halting further measurements. The **Manual Relay Reset** opens all of the relays. The **Clear Data** button clears the display data buffers and the *data display area* (1). It does not change the other configurations settings.

The area labeled **5** is the *relay status display area*. This area of the window displays which relay is closed (1-6), whether the 7~ relay which shorts the amplifier is closed (Short/Cooling) or whether the unit is resetting all of the relays.

The area labeled **6** is the *thermocouple voltage display area*. This area displays the last voltage reading of the last channel measured. It accounts for the gain of both the preamplifier and the A/D board.

The area labeled **7** is the *interval per channel area*. The user uses the scroll bar to change the time between switching from one channel to another. The value of this setting can be between 0.2 and 600 seconds between switching from one channel to another. This control turns red when the program over rides the user in order to maintain compatibility with the *low-pass digital filter* setting (9). The program gives priority to the *interval per channel* control.

The area labeled **8** is the *preamplifier gain area*. The user selects a gain of 10,000 or 100,000 to match the switch the user has set on the BC-MPNV100 unit. For most purposes, a gain of 10,000 will be adequate.

The area labeled **9** is the *low-pass digital filter area*. The user uses the scroll bar to change the cut-off frequency, f_c . The value of this setting can be between 0.001 and 5 Hertz. The digital filter uses an unweighted averaging of the data (brick wall filter), so the signals are averaged for a time of $1/f_c$ seconds. In other words, a cut-off frequency of 5 Hz means the signal was averaged for only 20 milliseconds, while a cut-off frequency of 0.01 Hz means the signal was averaged for 100 seconds. This control is linked to the *interval per channel area 7*, in order to make sure the two controls are compatible. For example, if one wishes the have the time between switching from one channel to another be 1 second, then one could not have the cut-off frequency of 0.5 Hz as that would require averaging for 2 seconds. This control turns red when the program over rides the user in order to maintain compatibility with the *interval per channel setting (7)*. The program gives priority to the *interval per channel control*.

The area labeled **10** is the *measurement mode are*. This area allows the user to select the type of measurement required for the type of psychrometers attached to the unit. The BC-MPNV100 and BCPMS combination can perform Peltier and Isopiestic psychrometer measurements. The measurement mode is stored and remembered each time the program is run.

The area labeled **11** is the *zero offset area*. This area allows the user to command the BC-MPNV100 unit to measure the offset each channel, assuming the shorting plugs are installed, by pressing the **Record Zero** button. The value of the recorded offset is stored and remembered each time the program is run until the offset values are updated. If the user checks the **Zero Adjust Data** selector, then the computer will automatically subtract the measured zero offset from the data.

The area labeled **12** is the *program status area*. It can often be difficult, if not impossible, to tell what the program is doing, especially when data averaging for long periods of time. This display tells the user what the program is doing, or whether the program is stopped.

The data format of the output file is that of a CSV file, or comma separated value. All data files have 12 columns, recording the time (in seconds since midnight) and the voltage for each voltage measurement. Zero is filled in place of any unselected channels. For example, if channels 1 and 4 were selected, then one line of the file for a 10pm measurement would look something like:

```
79200,6.0987E-6, 0, 0, 0, 0, 79200, 6.0987E-6, 0, 0, 0,0
```

These files are compatible with standard spreadsheet program such as Microsoft Excel™

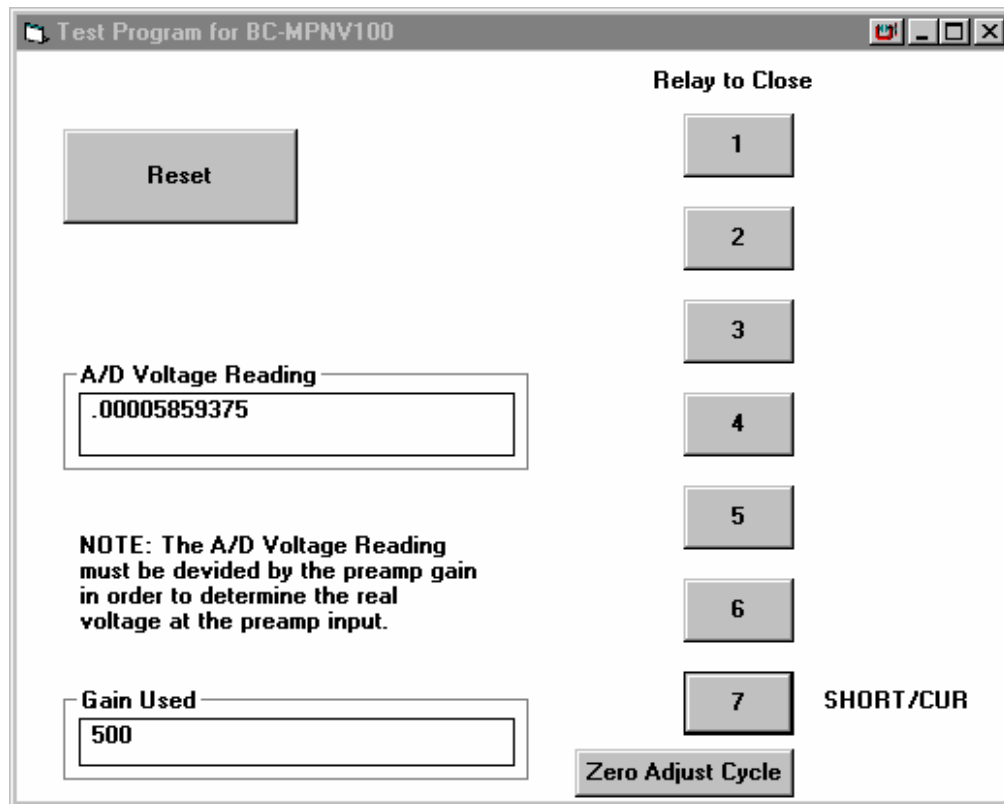
Ex.exe

Figure III.3 - EX.exe software control panel.

While BCMPNV.exe can provide a sophisticated level of measurements, occasionally one wants to do something simple, particularly while setting up an experiment or debugging a problem. We have provided a executable file and source code file for the diagnostic program, called EX.exe, used to test and adjust your BC-MPNV100 unit. The control panel for this program is shown in Figure III.3.

This program is very simple. The **Reset** button opens all relays, and then takes one voltage measurement. Usually the result returned in the *A/D Voltage Reading* box will be 10 volts for a reset. The gain returned in the *Gain Used* box will be 1 for a reset. This reading is the voltage seen by the Keithley A/D board, NOT the preamplifier input. To convert to the preamplifier input value, divide by the preamplifier gain switch setting. If the reading is +10-8 volts, then the amplifier is saturated.

The buttons 1 through 6 close the relays 1 through 6, and then takes one voltage measurement. The values returned in the *A/D Voltage Reading* box and the *Gain Used* box will depend on what you have connected to a specific input. For an open input, it should read about the same as for a reset operation.

The button 7 closes the 7th relay, which is either a short or a 8mA current source, depending on the CUR/SHORT switch setting on the BC- MPNV100 unit. It then takes one voltage measurement. If the CUR/SHORT is set to SHORT, usually the result returned in the *A/D Voltage Reading* box will be a few millivolts and the gain returned in the *Gain Used* box will be 500. If the CUR/SHORT is set to CUR, usually the result returned in the *A/D Voltage Reading* box will be about -10-8 volts and the gain returned in the *Gain Used* box will be 1.

The **Zero Adjust Cycle** button is for performing an internal or external zero adjustment on the front end of the preamp. The **Zero Adjust Cycle** button closes the 7th relay, which is either a short or a 8mA current source, depending on the CUR/SHORT switch setting on the BC-MPNV100 unit. It then continually takes voltage measurements. If the CUR/SHORT is set to SHORT, usually the result returned in the *A/D Voltage Reading* box will be a few millivolts and the gain returned in the *Gain Used* box will be 500. If the CUR/SHORT is set to CUR, usually the result returned in the *A/D Voltage Reading* box will be about -10-8 volts and the gain returned in the *Gain Used* box will be 1. The **Zero Adjust Cycle** button is a toggled button, so pressing it a second time terminates the continuous voltage measurements but leaves the 7th relay closed. If another channel is then selected while the **Zero Adjust Cycle** is active, then the cycle will continue with the amplifier looking at the selected channel.

External Zero Adjust


An external zero adjust is performed by hitting the **Zero Adjust Cycle** button and dialing the ZERO ADJUST knob on the BC-MPNV100 unit until the value displayed in the *A/D Voltage Reading* box is minimized, or offset by the desired amount.

Internal Zero Adjust

An internal zero adjust should only be performed if there is no other way to have the voltages in the desired range. Make sure the unit has been warmed up

and has thermally stabilized before performing an internal zero adjustment. The silver button on the 4.25" x 2.5" panel opposite the panel with the switches and knobs must be removed in order to access the internal zero adjust potentiometer. The internal zero adjust potentiometer screw will be visible through the hole the button occupied. Dial the ZERO ADJUST knob on the BC-MPNV100 unit to 5.0. The internal zero adjust is performed by hitting the **Zero Adjust Cycle** button in Ex.exe and dialing the blue potentiometer at the end of the BC-NV100 board until the value displayed in the *A/D Voltage Reading* box is minimized, or offset by the desired amount. Pressing the **Zero Adjust Cycle** button a second time terminates the continuous voltage measurements but leaves the 7" relay closed. Once the potentiometer is adjusted, replace the silver button into the hole in the panel.

Exiting Ex.exe

The program can be exited by clicking on the upper right  box at any time except when a **Zero Adjust Cycle** is in progress.

IV. Measurement Technique

The Burns Consulting Psychrometric Measurement System supports measurements using the Psychrometric technique¹⁰ as well as the Isopiestic technique water potential measurements of plants or soil. Each of these techniques has its strengths and weaknesses. The psychrometric or Peltier technique is rapid and can be adapted to *in situ* stem or soil monitoring, however it is reportedly less accurate at high water potentials, and requires prior calibration against solutions with known water potentials. The Isopiestic technique purports to be more accurate than the Peltier technique and requires only two measurements per sample with no calibrations once initial offsets are determined, but it requires extremely good temperature stability of the apparatus, long measurement times, and the solutions used are susceptible to biological contamination, which can throw off the measurement.

We will assume that the reader has some familiarity with psychrometric measurements. For those unfamiliar with basic psychrometric measurements, we would suggest that the user read the items listed in the *Suggested Reading on Psychrometer Sensors and Methods* section at the back of this User's Guide.

Peltier, Dew Point or Psychrometric Mode Measurements

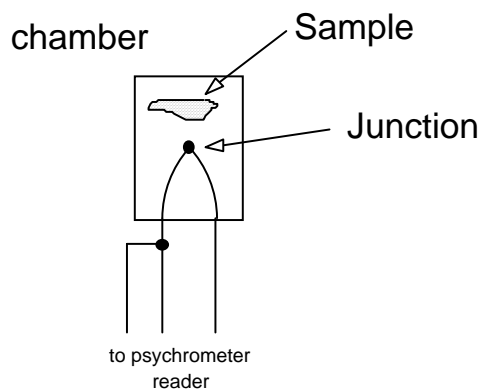


Figure IV.1 - Illustration of a psychrometer chamber which is used in a Peltier, or Dew Point, psychrometric measurement.

In this mode, which is used by sensors built by Wescor and Merrill, a small thermocouple junction is suspended in a small chamber. For psychrometers for tissue water potential measurements, the chamber is airtight

¹⁰ Psychrometric mode is also known as the "Wet Bulb" or "Peltier" mode.

and the sample is also placed in the chamber. For psychrometers for soil or *in situ* stem water potential measurements, the chamber walls are porous and the sensor is buried into the soil or stem. This type of chamber is illustrated in Figure IV.1.

After a period of time during which the air in the chamber has achieved thermal and humidity equilibrium with the sample, a small current is passed through the thermocouple junction. If the current is of the correct polarity, the junction will cool by the Peltier Effect¹¹. If the current is of the wrong polarity, the junction will heat by the Peltier Effect.

The current is applied long enough to depress the junction temperature below the dew point of the air in the chamber. In other words, it is applied long enough to cool the junction so that water condenses on it out of the air.

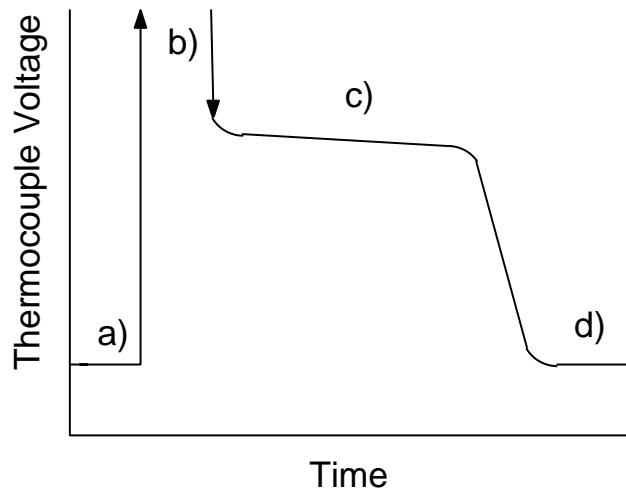


Figure IV.2 - Four portions of a Peltier psychrometer measurement. a) baseline acquisition, b) cooling of the junction, c) wet bulb depression temperature, d) return to ambient temperature and baseline

When the cooling current is halted, the temperature of the junction rapidly rises towards the ambient chamber temperature. However when it reaches a temperature where the heat leaking onto the junction is offset by the cooling of the condensed water evaporating back into the chamber air, the temperature rise will halt until all of the condensed water is gone. This temperature is called the *wet bulb depression temperature*. The thermocouple output at the wet bulb temperature is between 40 and 50 $\mu\text{V}/\text{kPa}$ at 25°C.

¹¹ The Peltier Effect was first discovered by Jean Peltier in 1834 while studying the Seebeck effect upon which thermocouples are based, discovered a few years earlier. J.C. Peltier, *Ann. Chim. Phys.* **56**, 371 (1834); A. Seebeck, *Pogg Ann* **6**, 133 (1826)

When all of the condensed water has evaporated from the junction, the junction temperature returns to the original dry ambient chamber temperature. This sequence of events is illustrated in Figure IV.2

Before measuring a tissue sample, one must calibrate the wet bulb temperature behavior of each chamber by using sucrose solutions of known water potential. An approximate equation for the molality (m) of a sucrose solution of osmotic potential Ψ_s can be found in the excellent book, "Measuring the Water Status of Plants and Soils, 2nd Edition", John S. Boyer, (Academic Press, New York, 1995) page 99:

$$m = -5.6067 + \sqrt{31.4355 - \frac{11236 \Psi_s}{8.3143 \times 10^6 DT}}$$

where T is the temperature in Kelvin, D is the density of water¹² at temperature T in g/m^3 , Ψ_s is the osmotic potential in MPa, and m has units of $\text{mole} \cdot (\text{kg H}_2\text{O})^{-1}$.

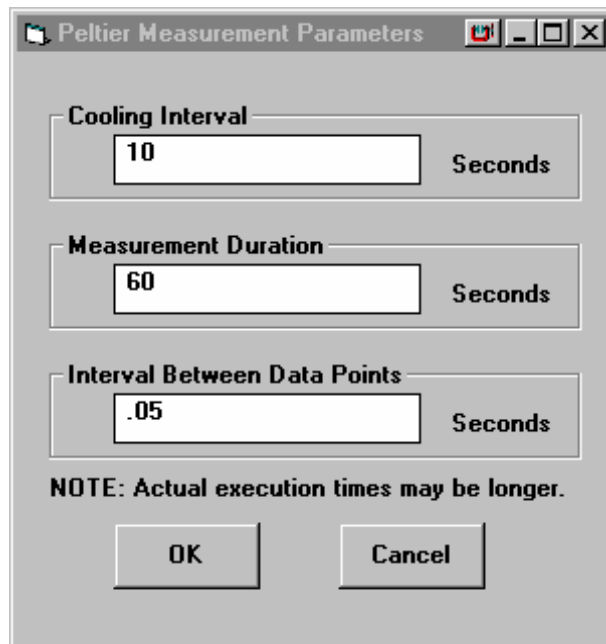


Figure IV.3 - *Peltier Measurement Parameters* window which is used in a Peltier, or Dew Point, psychrometric measurement to adjust timing of the various steps of the measurement.

As a practical matter, the BCPMS software allows the user to specify the approximate length of time the cooling current is applied, and the approximate

¹² Tables of the density of water as a function of temperature may be found in the *CRC Handbook of Chemistry and Physics*. (CRC Press, Cleveland Ohio)

total amount of time for the measurement, and the approximate data point collection interval. These parameters are adjusted in the *Peltier Measurement Parameters* window selected by choosing *Peltier* from the *Settings* pull down menu. These parameters are stored by the computer and reused every time the program is run, until the user changes them again. This window is shown in Figure IV.3

Isopiestic Mode Measurements

In this mode, which is used by sensors built by Isopiestic Company, a small thermocouple junction is suspended in a small chamber. The chamber is airtight and the sample is also placed in the chamber. The thermocouple is modified to form a small loop, from which a drop of sucrose solution can be suspended above the tissue sample. This type of chamber is illustrated in Figure IV.4.

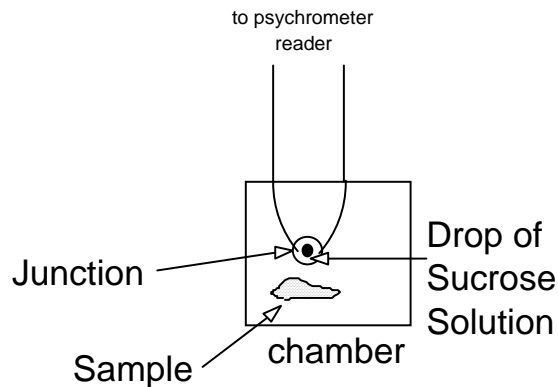


Figure IV.4 - Illustration of a psychrometer chamber which is used in a Isopiestic mode measurement.

A isopiestic measurement usually consists of four measurements, three of which can take several hours apiece. The first consists of placing the shorting plugs into the BC-MPNV100 unit and reading the offsets for each channel. The *Record Zero* button in the *Zero Adjust Data* section of the BCPMS panel can be used for this purpose, as then the user can have the computer automatically adjust each channel for the subsequent measurements.

The second and third measurements consist of placing sucrose solutions of known osmotic potential on the junctions and measuring the steady state temperatures that the junctions go to. If the solution has a more negative osmotic potential than the sample, water will move from the sample to the junction thus raising its temperature. If the solution has a less negative osmotic potential than

the sample, water will move from the junction to the sample thus cooling the junction temperature. Ideally, one wishes to use two solutions where one has a more negative osmotic potential than the samples, and the other less negative.

After a period of time whereby the air in the chamber has achieved thermal equilibrium with the sample, and a steady state of water between the sucrose drop and the sample has been achieved, the thermocouple's raised or depressed temperature is noted.

The fourth consists of placing the sample in a chamber with a dry thermocouple. After a period of time whereby the air in the chamber has achieved thermal and humidity equilibrium with the sample, the steady reading of the thermocouple is noted. Any deviation from the shorted reading may be due to heat from metabolic processes taking place in the tissue sample.

The data is analyzed by plotting (after the appropriate offsets are accounted for) the thermocouple outputs on the second and third measurements versus the osmotic potential of the sucrose solutions. One then draws a line between these two points. The osmotic potential at which this line crosses the $0\mu\text{V}$ reading during the fourth measurement is the osmotic potential of the tissue sample. A more detailed discussion may be found in "Measuring the Water Status of Plants and Soils, 2nd Edition", John S. Boyer, (Academic Press, New York, 1995).

The sucrose solutions used with the isopiestic psychrometer need to be mixed by the user, and kept free of contaminants that will alter the total molality of the solutions. The largest problem is keeping bacteria from eating the sucrose and depositing metabolic wastes in the solutions. For this reason, fresh solutions should be used whenever possible, and solutions should be stored at reduced temperature until the day of use.

An approximate equation for the molality (m) of a sucrose solution of osmotic potential Ψ_s can be found in the excellent book written by Prof. John Boyer, the inventor of this technique, "Measuring the Water Status of Plants and Soils, 2nd Edition", (Academic Press, New York, 1995) page 99:

$$m = -5.6067 + \sqrt{31.4355 - \frac{11236 \Psi_s}{8.3143 \times 10^6 D T}}$$

where T is the temperature in Kelvin, D is the density of water at temperature T in g/m^3 , Ψ_s is the osmotic potential in MPa, and m has units of $\text{mole} \cdot (\text{kg H}_2\text{O})^{-1}$.

As a practical matter, the BCPMS software allows the user to specify the approximate interval between when each psychrometer is measured, and the approximate total amount of time for the measurement, and the approximate data point collection interval. These parameters are adjusted in the *Isopiestic Measurement Parameters* window selected by choosing *Isopiestic* from the *Settings* pull down menu. These parameters are stored by the computer and reused every time the program is run, until the user changes them again. This window is shown below in Figure IV.5

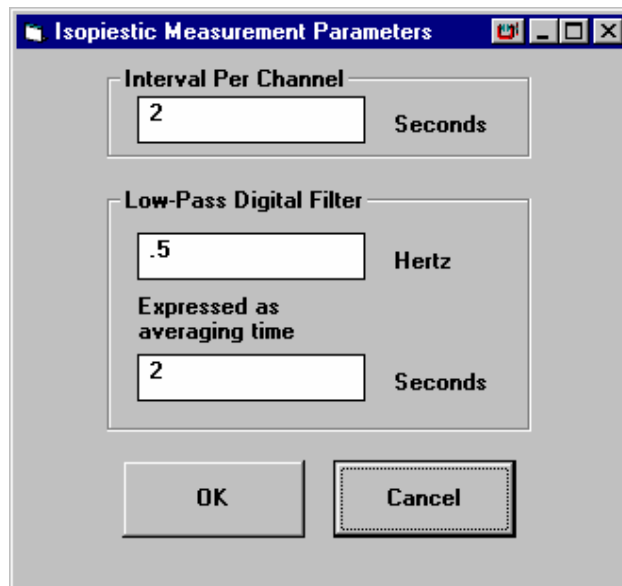


Figure IV.5 - *Isopiestic Measurement Parameters* window which is used in a *Isopiestic* measurement to adjust timing of the various steps of the measurement.

V. Library Routines

BCDEC2.bas

The software package with your BC-MPNV100 unit contains a library of 14 routines for communicating between a PC and the BC-MPNV100 unit. The program BCMPMS.exe heavily uses the routines in the BCDEC2.bas library. The routines are listed below, and on subsequent pages are short explanations and example snippets of code.

The library routines are:

- Delay
- Digital_Out
- Digital_Read
- Error_Codes
- Init_Board
- Inject_Current_In_Thermocouple
- Read_Filtered_Volts
- Read_Volts
- Reset_Multiplexer
- Rest_State
- Set_Inject_Current_In_Thermocouple
- Set_Multiplexer_Channel
- Short_Amplifier_and_Thermocouple
- Short_Amplifier_Input
- Stop_Inject_Current_In_Thermocouple
- Toggle_Digital_Out
- Variable_Toggle_Digital_Out

Below we discuss each routine, its calling syntax, its resource requirements and its known features and bugs.

Delay (X)

X is the number of seconds that the user wants to delay, and can be an integer or a single precision number. Since the timing accuracy of a PC is limited by the system clock ticks, which were standardized at 18 ticks per second (-5.5 milliseconds) long ago in the PC dark ages, this routine cannot time to shorter than ~5 milliseconds. The routine uses a Do While DoEvents loop so that system interrupts can take place during the delay period. This also means that the program buttons remain active during a delay.

Additional Resources Required: none

Usage example:

```
*
*
If YN <> 7 Then Call Error Codes
End If
Call Delay(.1)
Call Rest State
*
*
```

Digital_Out (OLine_0, OLine_1, OLine_2, OLine_3)

This routine sets the digital output lines on the Keithley Metrabyte DAS-1600/1400/1200 Series boards and leaves the lines in that state. The variables OLine_0 through Oline_3 are integers. It should be noted that this routine sets the bits exactly as specified by the user. The BC-MPNV100 unit wants bit 4 inverted. Its is recommended that the user use the routines Toggle Digital Out and Variable Toggle Digital Out for communicating with the BC-MPNV100 unit. The Toggle Digital Out and Variable Toggle Digital Out automatically perform the bit 4 inversion so that relay 7 is on when the user sets bit 4 to 1, and off when the user sets bit 4 to 0.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series

Function Call Driver package installed on the computer.

Usage example:

```
*  
*  
If YN <> 7 Then Call Error Codes  
End If  
Call Digital_Out ( 0, 1, 0, 1)  
Call Rest State  
*  
*
```

Digital_Read (ILine_0, ILine_1, ILine_2, ILine_3)

This routine reads the digital input lines on the Keithley Metrabyte DAS-1600/1400/1200 Series boards. The variables ILine_0 through ILine_3 are integers.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```
*  
*  
If YN <> 7 Then Call Error Codes  
End If  
Call Digital_Read (ILine_0, ILine_1, ILine_2, ILine_3)  
*  
*
```

Error_Codes

This routine examines the global variable wDASErr and displays the information for each error code contained on Appendix A of the DAS-1600/1400/1200 Series Function Call Driver User's Guide (Rev. B).

Additional Resources Required: none

Usage example:

```

*
*
If wDASErr <> 0 Then
    msg$ = "Error " + Hex$(wDASErr) + " occurred during
        driver call K DIRRead in subroutine DRead.
        Would you like more details?'"
    YN = MsgBox(msg$, 260, "Burns 1400 Toolkit")
    If YN <> 7 Then Call Error_Codes
End If
*
*
```

Init_Board

This routine initializes the DAS1401 board. It looks at the DAS1600.CFG file to determine how the Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Drivers are to be configured.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
Sub Form Load ()
Call Init_Board
*
*
```

Inject_Current_In_Thermocouple_(NRelay, TogLength!)

This routine sets the 7th latching relay and the relay specified in NRelay to inject cooling current into thermocouple NRelay. The current is injected for a period of time set by TogLength in seconds. The subroutine leaves NRelay set, so that voltage measurements can be started immediately. NRelay is an integer, TogLength is single precision.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```
*  
*  
If YN <> 7 Then Call Error_Codes  
End If  
Call Inject_Current_In_Thermocouple (1, 6.5)  
Call Rest State  
*  
*
```

Read_Filtered_Volts (NChan, TimeConstant, Voltage)

This routine autoranges and filters voltage readings on AD channel NChan. The length of time the measurements are linearly averaged is user set by the variable TimeConstant. The units for Timeconstant are seconds and must be positive. This routine checks if the board is set for unipolar or bipolar operation and converts to voltage accordingly. The voltage measured is returned in Voltage. Nchan is an integer, TimeConstant is single and Voltage is double precision.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:


```

*
*
Call Delay(5)
'
' Here we measure the filtered voltage.
'
Call Read_Filtered_Volts(0, 20, Voltage)
ZeroOffset = Voltage / PreampGain
X! = Voltage / PreampGain
*
*

```

Read_Volts (NChan, Voltage, GainUsed)

This routine autoranges one voltage reading on AD channel nChan. It checks if the board is set for unipolar or bipolar operation, and converts to voltage accordingly. The voltage measured is returned in Voltage, and the gain that was selected by this routine-is returned in GainUsed. Nchan and GainUsed are integers and Voltage is double precision.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
DELAYLOOPRFV2: If DelayEnd > Timer Or ODATE$ =
Date$
Then
    Call Read_Volts(TNChan, TVoltage, TGainUsed)
    Voltage = Voltage + TVoltage
*
*

```

Reset_Multiplexer

This routine resets (opens) all of the latching relays of the BC-MPNV100 unit.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```
*  
*  
Sub Command4_Click ()  
RIndicator.ForeColor = &HFF&  
Call Reset_Multiplexer  
Indicator1.ForeColor = 0  
Indicator2.ForeColor = 0  
Indicator3.ForeColor = 0  
*  
*
```

Rest_State

This routine sets the digital circuits in the BC-MPNV100 to their rest or neutral state.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```
*  
*  
End If  
Call Delay(TogLength!)  
Call Rest_State  
End Sub  
*
```

*

Set_Inject_Current_In_Thermocouple (NRelay)

This uses the digital outputs to set the 7th latching relay and the relay specified in NRelay to inject cooling current into thermocouple #NRelay. The current is injected indefinitely until cleared by another routine like Stop_Inject_Current_In_Thermocouple. NRelay is an integer.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
X0! = CoolTime
  EndCoolRead = EndPreRead + CoolTime / PointInterval
  Call Set_Inject_Current_In_Thermocouple(NRelay)
  For DCounter = EndPreRead To EndCoolRead
    Call Read_Filtered_Volts(0, PointInterval, Voltage)*
  
```

*

Set_Multiplexer_Channel (NRelay)

This routine sets the relay specified by NRelay. NRelay can be the 7th relay if need be. NRelay is an integer variable.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
  End If

```

```

Call Delay(TogLength!)
Call Set_Multiplexer_Channel (1)
End Sub
*
*
```

Short_Amplifier_and_Thermocouple (NRelay)

This routine closes the latching relay Nchan of the BC-MPNV100 unit while simultaneously closing the 7~ relay (shorting relay if the CUR/SHORT switch is set to SHORT). The net result is that both the selected thermocouple and the amplifier input are shorted.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
End If
Call Delay(TogLength!)
Call Short_Amplifier_and_Thermocouple (1)
End Sub
*
*
```

Short_Amplifier_Input

This routine closes the 7th latching relay (shorting relay if the CUR/SHORT switch is set to SHORT) of the BC-MPNV100 unit.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
End If
Call Delay(TogLength!)
Call Short_Amplifier_Input
End Sub
*

```

Stop_Inject_Current_In_Thermocouple (NRelay)

This routine shuts off the cooling current turned on by Set_Inject_Current_In_Thermocouple. The subroutine leaves NRelay set, so that voltage measurements can be started immediately. NRelay is an integer.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
If ActiveFlag = False Then Exit Sub
Next DCounter
Call Stop_Inject_Current_In_Thermocouple(NRelay)
*
*

```

Toggle_Digital_Out (OLine_0, OLine_1, OLine_2, OLine_3)

This routine toggles the lines as specified in OLine_0 though OLine_3 for a period of about 0.1 seconds. The variables OLine_0 though OLine_3 are integers. The Toggle_Digital_Out and Variable_Toggle_Digital_Out automatically perform the bit 4 inversion so that relay 7 is on when the user sets bit 4 to 1, and off when the user sets bit 4 to 0.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
'
'   Now we decode NRelay into the digital lines and
'   toggle them in order to close the appropriate one.
'
If NRelay = 1 Then Call Toggle_Digital_Out(1, 0, 0, 1)
If NRelay = 2 Then Call Toggle_Digital_Out(0, 1, 0, 1)
If NRelay = 3 Then Call Toggle_Digital_Out(1, 1, 0, 1)
If NRelay = 4 Then Call Toggle_Digital_Out(0, 0, 1, 1)
If NRelay = 5 Then Call Toggle_Digital_Out(1, 0, 1, 1)
If NRelay = 6 Then Call Toggle_Digital_Out(0, 1, 1, 1)
*
*

```

Variable_Toggle_Digital_Out (OLine_0, OLine_1, OLine_2, OLine_3, TogLength!)

This routine toggles the lines as specified in OLine_0 though OLine_3 for a period of about TogLength! seconds. The variables OLine_0 though OLine_3 are integers, TogLength! Is single precision. The Toggle Digital Out and Variable Toggle Digital Out automatically perform the bit 4 inversion so that relay 7 is on when the user sets bit 4 to 1, and off when the user sets bit 4 to 0.

Additional Resources Required: Keithley Metrabyte DAS-1600/1400/1200 Series Function Call Driver package installed on the computer.

Usage example:

```

*
*
Call Delay(TogLength!)

```

Call Short Amplifier

Call Variable_Toggle_Digital_Out(0, 1, 1, 1)

*

*

VI. Troubleshooting and Getting Help

The BC-MPNV100 has been designed to be a trouble-free, easy to operate system for the amplification of low level signals from low source resistance sensors such as thermocouples. It is, however, a complex instrument incorporating ultra-low noise operational amplifier chips. The amplifier has been designed with two goals in mind: durability and precision. These goals are not necessarily complementary. It is possible that the operational amplifier chips, especially the ones at the front of the amplifier, may fail as they see the brunt of the influences from the outside world such as static discharges. In this case, Burns consulting will repair or replace, at our discretion, a defective BC-MPNV100 for a period of 1 year from the purchase of the BC-MPNV100.

It is possible that the troubles you are encountering are of a less catastrophic nature and can be remedied by corrective actions outlined in this section. In the following table, we outline some common difficulties along with recommendations. The suggested actions are listed in order of most common occurrence.

Symptom:	Action:
Amplifier output is zero all of the time.	<ol style="list-style-type: none"> 1. Check connections of cables to the amplifier input. 2. Check connections of cables to the output device. (chart recorder, datalogger, etc.) 3. Check connections of cables to the batteries. 4. Check settings on the output device. (chart recorder, datalogger, etc.) 5. Check the batteries. Both batteries should read approximately 12 volts.

Continued ...

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Symptom:	Action:
<p>Amplifier output is ± 12 volts¹³ all of the time on the 10^5 gain setting, near zero on the 10^4 gain setting. Seems to be ignoring input signals.</p>	<ol style="list-style-type: none"> 1. Adjust the "Zero Adjust" knob to bring the signal back within range. 2. The input protection diodes are latched from hooking up batteries one-at-a-time with power cable connected and power switch on. Momentarily ground the input to the battery ground. 3. The amplifier is latched from a static discharge. Momentarily ground the input to the battery ground.
<p>Zero adjust knob has no effect on the output. Amplifier output is ± 12 volts all of the time on the 10^5 gain setting, near zero on the 10^4 gain setting. Seems to be ignoring input signals.</p>	<ol style="list-style-type: none"> 1. Check that thermocouple is not grounded, especially to amplifier's power ground. 2. The input protection diodes are latched from hooking up batteries one-at-a-time with power cable connected and power switch on. Momentarily ground the input to the battery ground. 3. The amplifier is latched from a static discharge. Momentarily ground the input to the battery ground.
<p>Amplifier output shows excessive noise.</p>	<ol style="list-style-type: none"> 1. Check that isopiestic thermocouple is not grounded, especially to amplifier's power ground. 2. Remove temperature monitor thermocouple from system and replace BNC 50Ω terminator in BD-37 to DB-9 adapter.

Continued ...

¹³ ± 8 volts when the REGULATION switch of the shielded power filter and conditioner box is set to ON.

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Symptom:	Action:
Computer shut down while DB-9 and/or DB-37 connectors were plugged/unplugged.	1. Connect or disconnect the cables. To reboot the computer, you have to turn its front power switch off, and then back on. <i>And next time remember to turn the computer off before plugging/unplugging the DB-9/DB-37 connectors.</i> ¹⁴
Amplifier output drifts over the course of the day.	1. Check to see if amplifier is on a place warmed by sun. Thermally isolate amplifier. 2. Check to see if amplifier is being hit with draft from ventilation system. Thermally isolate amplifier.
Zero on amplifier seems unusually large.	1. Check that the REGULATION switch is set to the position that you normally use. 2. Check that the batteries are properly charged. 3. Check to see if amplifier is on a place warmed by sun. Thermally isolate amplifier. 4. Check to see if amplifier is being hit with draft from ventilation system. Thermally isolate amplifier. 5. Remove temperature monitor thermocouple from system and replace BNC 50Ω terminator in BD-37 to DB-9 adapter.

Important!!! Thermal emf's are usually in the range of 10's of $\mu\text{V}/^\circ\text{C}$. This means that you need to have the BC-MPNV100 (or any other nanovolt amplifier) as thermally stable as possible. For best results the amplifier should be placed out of the way for drafts and away from windows or direct sunlight.

¹⁴ Burns Consulting is not responsible for computer damage or data loss from the user manipulating cables to or from a powered computer.

What if it never looks right?

Your BC-MPNV100 has been tested before shipping and demonstrated acceptable characteristics within the designed specifications. It is possible that something may have gone wrong with the unit subsequent to its departure for our test bench. If all else fails, fax or email us and describe your problem.

Email:

We are anxious to help you make the most out of your BC-MPNV100 Nanovolt Amplifier. You can best talk to us by email. You can send questions regarding your BC-MPNV100 Nanovolt Amplifier to us at:

mjburns@ix.netcom.com.

When you do contact us, please send a description of the problem and what steps you have already taken to try to rectify the problem. Please allow at least 24 hours for a reply to your question.

Fax:

You can also reach us by fax at (818) 398-7607. When you do contact us, please send a description of the problem and what steps you have already taken to try to rectify the problem. Please allow at least 24 hours for a reply to your question.

VII. Technical Specifications

Amplifier Electronics:

Box: Extruded aluminum construction. 10.5 cm x 6.5 cm x 15 cm.

Power Supply: ± 12 or ± 8 volts @ 10 milliamperes supplied by two external (user supplied) batteries, and +5 volts supplied by the computer interface.

Input:	Type:	True differential.
	Differential input impedance:	250k Ω
	Impedance to ground:	15k Ω

Outputs:

10^4 gain setting:	1 volt/100 μ volts
10^5 gain setting:	1 volt/10 μ volts

Amplifier (for zero source resistance)¹⁵:

Voltage Gain (selectable): $\times 10328 (10^4)$ and $\times 100050 (10^5)$

Frequency Response: dc to 10Hz

Zero Adjust Span (referred to input): $\pm 500\mu V$

Drift (referred to input): 70nV/ $^{\circ}C$

Noise Specifications (Battery Operation Only):

1/f Corner Frequency: ~ 3 Hz

Total Input Noise Voltage (referred to input):

5.7 nV rms (Without digital filtering)

Continued ...

¹⁵ The BC-MPNV100 will function best with source resistances less than 400 Ω . The BC-MPNV100 will function with any source resistance, however the noise performance will degrade with increasing source resistance. For source resistances above 400 Ω , other amplifier designs will offer lower noise performance than the BC-MPNV100. For low-noise amplifiers for signal sources or sensors with source impedances greater than 400 Ω , contact Burns Consulting.

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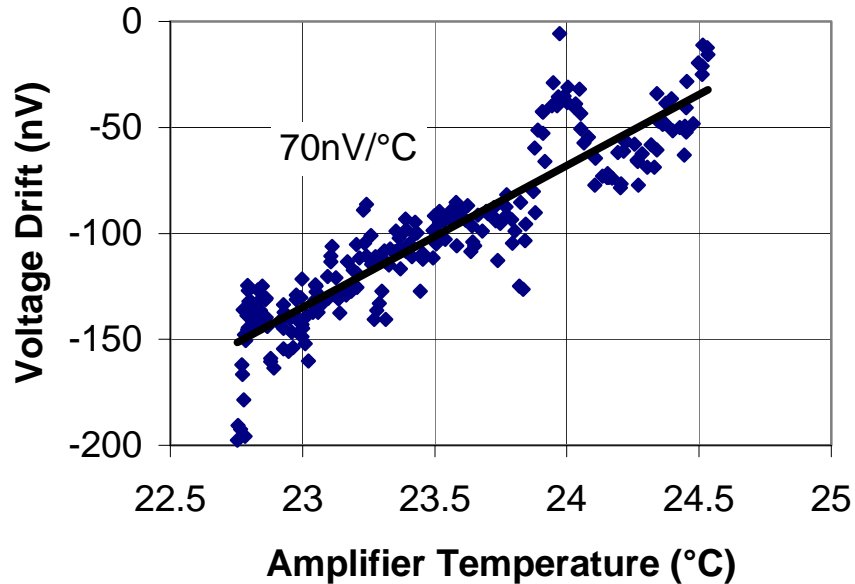


Figure VII.1 – Voltage drift (referred to input) of the BC-MPNV100 under battery operation, zero source resistance, zero-adjust setting of 5.0 and gain setting of 10^4 is approximately $70\text{nV}/^\circ\text{C}$. $1\text{nV}=10^{-9}\text{V}$. It should be noted that the thermocouple's voltage drift is approximately $40000\text{nV}/^\circ\text{C}$.

Power Conditioner Electronics:

Box: Cast aluminum construction. 9.2 cm x 3.8 cm x 2.7 cm.

Input Power Supply: ± 12 -8 volts supplied by two external (user supplied) batteries.

Output Power: ± 12 volts unregulated up to ~ 1 amp or ± 8 volts regulated up to ~ 1 amp.

RFI Filter: Each of the three power lines contains a 72kHz low-pass 22nf/110 μH π -filter followed by a 150kHz low-pass 5nf/110 μH π -filter.

Continued ...

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DB-9 Radio Frequency Interference Filter Module:

Spectrum Control, Inc.¹⁶ model number SCI-56-705-005-LI Electromagnetic Interference Connector Adapter. 9-pin DB plug/receptacle with each line containing a 800kHz low-pass 4000pf/5 μ H π -filter.

DB-9 Pin Numbers	Function
1	Digital Ground
2	Digital +5 Vvolts
3	Digital Bit 0
4	Digital Bit 1
5	Digital Bit 2
6	Digital Bit 3
7	Analog Ground
8	Amplifier - Output
9	Amplifier + Output

DB-9 Amplifier Connector¹⁷:

DB-9 Pin Numbers	Function	Wire Color	DAS 1600/1400 Designation
1	Digital Ground	blue	POWER GND
2	Digital +5 Vvolts	brown	+5 V PWR
3	Digital Bit 0	light blue	OP 0
4	Digital Bit 1	green	OP 1
5	Digital Bit 2	orange	OP 2
6	Digital Bit 3	gray	OP 3
7	Analog Ground	yellow	LL GND
8	Amplifier - Output	black	Ch0 LO IN
9	Amplifier + Output	red	Ch0 HI IN

Continued ...

¹⁶ Spectrum Controls, Inc. 2185 West Eighth Street, Erie PA 16505, U.S.A., (814) 455-0966

¹⁷ Never connect the DB-9 connector of the BC-MPNV100 unit to a computers serial port (DB-9 connector on a computer or terminal). Doing so may damage the BC-MPNV100 unit or the computer or both. Burns Consulting will not be responsible for damage to any equipment including the BC-MPNV100 unit, resulting from such misuse.

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DB-9 to DB-37 Adapter Cable:

DB-9 Pin Numbers	Function	Wire Color	DAS 1600/1400 Designation	DB-37 Pin Numbers
1	Digital Ground	blue	POWER GND	7
2	Digital +5 Vvolts	brown	+5 V PWR	1
3	Digital Bit 0	light blue	OP 0	23
4	Digital Bit 1	green	OP 1	4
5	Digital Bit 2	orange	OP 2	22
6	Digital Bit 3	gray	OP 3	3
7	Analog Ground	yellow	LL GND	19
8	Amplifier - Output	black	Ch0 LO IN	18
9	Amplifier + Output	red	Ch0 HI IN	37
	BNC - Input		Ch1 LO IN	17
	BNC + Input		Ch1 HI IN	36

VIII. Electrical connections for psychrometer sensors

Psychrometers from Isopiestic Company:

OMEGA Connector	Psychrometer Wire Color
+	gray with red (copper)
-	gray (copper)

The Psychrometers from Wescor including models C-52, C-30, L-51, L-51A, PCT-55 and PST-55:

OMEGA Connector	Psychrometer Wire Color
+	black (copper)
-	red (copper)
not connected	blue (constantan)
not connected	bare (copper)

Psychrometers from J.R.D. Merrill Specialty Equipment including model 75-2C:

OMEGA Connector	Psychrometer Wire Color
+	white (copper)
-	blue (copper)
not connected	red (constantan)
not connected	bare (copper)

IX. Sources for Psychrometer Sensors

Psychrometric mode¹⁸ sensors available from:

Wescor
459 South Main Street
Logan, UT 84321
(801) 752-6011
<http://www.wescor.com>

J.R.D. Merrill Specialty Equipment
R.F.D. Box 104A
Logan, Utah 84321
(801) 752-8403

Isopiestic mode psychrometer sensorss are available from:

Isopiestic Company
2 Harborview Road
Lewes, DE 19958
(302) 645-4014

¹⁸ Psychrometric mode is also know as the "Wet Bulb" or "Peltier" mode.

X. Suggested Reading on Psychrometer Sensors and Methods

For further information on measuring water potential (psychrometry), please see:

- "Measuring the Water Status of Plants and Soils, 2nd Edition", John S. Boyer, (Academic Press, New York, 1995)
- "Thermocouple Psychrometers for Water Potential Measurements", Ralph D. Briscoe, From the Proceedings of the NATO Advanced Study Institute on "Advanced Agricultural Instrumentation", II Ciocco (Pisa), Italy, May 27-June 9, 1984 (reprints available from Westcor, Logan Utah,)
- "Plant Physiological Ecology, Field Methods and Instrumentation" Edited by R.W. Pearcy, J. Ehleringer, H.A. Mooney, and P.W. Rundel (Chapman and Hall, London, 1989)

These books may be ordered through your local bookstore, or may be ordered over the World Wide Web from virtual bookstores such as Amazon.com Inc.¹⁹ at <http://www.amazon.com/>

¹⁹ Burns Consulting is not affiliated with Amazon.com, Inc.

XI. Customer Service and Guarantee Information

Customer Service

Email:

We are anxious to help you make the most out of your BC-MPNV100 Nanovolt Amplifier. You can best talk to us by email. You can send questions regarding your BC-MPNV100 Nanovolt Amplifier to us at:

mjburns@ix.netcom.com.

When you do contact us, please send a description of the problem and what steps you have already taken to try to rectify the problem. Please allow at least 24 hours for a reply to your question.

Fax:

You can also reach us by fax at (818) 398-7607. When you do contact us, please send a description of the problem and what steps you have already taken to try to rectify the problem. Please allow at least 24 hours for a reply to your question.

Guarantee

Your BC-MPNV100 is warranted free from defects for a period of one year from the date of purchase. Burns Consulting will repair or replace at its option any piece of defective equipment returned during this period. This service does not apply to apparatus subjected to excessive physical abuse or products that have been modified in any way. This amplifier is not to be used in any system for use with human subjects and the manufacturer will not be responsible for the results of such misuse. To return equipment for repair or replacement, email us at mjburns@ix.netcom.com, fax us at (818) 398-7607, or contact us through our Web page (<http://ourworld.compuserve.com/homepages/mjburns/>) to receive a return authorization number.

Prices

Prices are effective January 1, 1997 and supersede any previously published prices. Prices do not include any federal, state or local taxes and are subject to change without notice.

Shipping

Goods are shipped F.O.B. Altadena, California. Shipping charges are prepaid and billed with the goods. If special shipping instructions are required by the purchaser, they must be specified in writing on the customer's purchase order or letterhead.

Minimum Order

A minimum order of \$50.00 is required. Orders less than \$50.00 are subject to a \$10.00 service charge.

Specifications

Specifications on all products are subject to change without notice. Burns Consulting reserves the right to make improvements to the products without incurring any obligation to incorporate these changes in products previously sold.

Return of Materials

To return equipment for repair or replacement, email us at mjburns@ix.netcom.com or fax us at (818) 398-7607 to receive a return authorization number.