Quantum Design

Application Note 1070-301

Using Pot-Fill Mode and CLTC to Control Low Temperatures in the PPMS

The Quantum Design PPMS offers two unique modes for controlling low temperatures in the sample chamber: Continuous Low-Temperature Control (CLTC) and pot-fill. Since January 1998, the PPMS has included both of these modes for low-temperature control, with CLTC shipped as the default mode. Earlier model PPMS systems included only the pot-fill mode, but owners of such systems can add the CLTC option.

The two modes for controlling low-temperature are reviewed below. Both modes can reduce the temperature to about 1.9 K, so if you have both you can select the one that best fits your experiment. How to use the MultiVu application (or the Mon6000 utility) to set your low-temperature control mode is explained in the last section. For a more detailed description of temperature control in the PPMS, see the *Physical Property Measurement System: Hardware Manual*.

Continuous Low-Temperature Control (CLTC)

The system uses the Continuous Low-Temperature Control (CLTC) option to regulate temperatures below about 4.2 K by drawing cold helium gas through a carefully tuned flow impedance that restricts the gas flow. The helium gas is then drawn through the annulus to cool the sample chamber. The system heaters warm the gas and the sample chamber directly. CLTC mode includes a pre-cooling phase[1] that begins when the temperature in the sample chamber is about 11 K. The pre-cooling ensures that the temperature of the chamber smoothly transitions through 4.2 K and that the unit can indefinitely maintain temperatures below 4.2 K. The pre-cooling method uses aggressive feedback on multiple parameters. This might cause a temporary loss of temperature control, reflecting processes that prevent liquid helium from collecting in the annulus while the neck is cooled.

Pot-Fill Mode

In pot-fill mode, the system initiates a pot fill at about 4.2 K, when it fills the cooling annulus with a controlled amount of liquid helium and manipulates the boiling point of the helium. The liquid helium is drawn through the impedance tube, with the impedance heater off. When the annulus is almost full, which takes about 45 minutes, the impedance heater is turned on, warming the impedance tube until the helium pressure inside prevents liquid helium from entering either end of the tube. This state is commonly called "on the pot." When the system is "on the pot," it controls temperature increases and decreases by opening and closing the flow-control valve in the Model 6000 and by using the heaters. The system can maintain temperatures as low as about 1.9 K for 30 minutes to 1.5 hours, with the length of time depending on the temperature that you have set. The liquid helium bath around the sample chamber provides a uniform, stable thermal environment.

In pot-fill mode, temperature control is temporarily lost after the liquid helium has completely boiled out from the cooling annulus. During this time, the system will turn off the impedance heater and refill the annulus with liquid helium. Note that it will take up to about 45 minutes to empty the cooling annulus if you change the temperature setpoint from below 4.2 K to above 4.2 K.

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[1] The amount of pre-cooling required depends on the recent temperature history of the sample chamber. For example, a rapid change from room temperature to 2 K will cause wild temperature oscillations for some time, while a slow change might require little-to-no pre-cooling.

Selecting the Low-Temperature Control Mode

You will usually use CTLC or pot-fill mode according to your experimental needs and the characteristics of the temperature-control mode. Table 1 summarizes the general characteristics and advantages of each mode.

Important: Because the two control modes are so different, sometimes you can use pot-fill mode to cool the chamber when CLTC mode is not bringing temperatures below 4.2 K. Rather than stopping the experiment to investigate the cooling problem, you can switch to pot-fill mode and attempt to bring the unit to your target temperature. If the unit cools successfully when you use pot fill, you might be able to complete the experiment before you fix the cooling problem.

Table 1. Characteristics of low-temperature control modes

CONTROL METHOD	CHARACTERISTICS	ADVANTAGE
CTLC	• Begins a pre-cooling phase at about 10 K • Reaches low temperatures without collecting liquid helium around the sample chamber	• Will hold temperature indefinitely • Smooth temperature control going through 4.2 K helium boiling point • Temperature increases are smooth and fast
Pot-fill mode	• Takes over control at about 4.2 K • Fills cooling annulus with liquid helium and manipulates boiling point of helium.	• Uniform thermal environment for the sample chamber • Quiet thermal environment for sample chamber • Best absolute temperature accuracy • Sometimes cools when CLTC does not

Setting the Low-Temperature Control Mode

If your PPMS has the capability for both low-temperature control modes, you can change from CLTC to pot-fill mode (or vice versa) by using the MultiVu **Utilities** dropdown menu or the Mon6000 utility, which is often located in C:QDPPMS\Tools. Instructions are included for both utilities. To determine if you have the CLTC option, follow the MultiVu instructions through Step 4.

As explained below, you will first verify the low-temperature control mode that is currently active, then you will issue the command to switch to the other mode.

MULTIVU

Verify Option and Control Mode

In MultiVu, you will use the **Send GPIB Commands** dialog to verify the mode that is being used.

1. Select **Utilities >> Send GPIB Commands** from the MultiVu dropdown menus (Figure 1).

2. The **Send GPIB Commands** dialog will open, as shown in Figure 2.
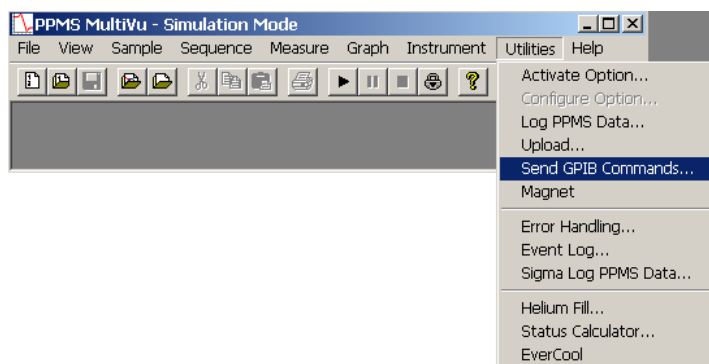

Figure 1. Opening the Send GPIB Command utility in MultiVu

In the **Send GPIB Commands** dialog, note the **Send:** text box at the top of the dialog, the **Response:** area in the middle of the dialog, and the **Send and Read** button at the bottom of the dialog. You will use these sections to verify the temperature-control mode.

3. In the text box next to **Send:** type the following:

   clt?

   (just as is shown in Figure 2). Then click on the **Send and Read** button.

Figure 2. Using the Send GPIB Command dialog to verify control mode

4. In the **Response:** area, the utility will report two numbers (e.g., "**0,1**" as shown in Figure 2).

The first number indicates the active temperature control mode and the second indicates if the CLTC option has been installed. For example, the first number in Figure 2 is **"0,"** indicating that the system is using pot-fill mode, but the second number is **"1,"** indicating that the CLTC option has been installed. A **"0,0"** report would indicate that pot-mode is being used but there is no CLTC option, and a "**1,1**" report would indicate that low temperatures are being controlled by the CLTC option.

Change Control Mode

To use MultiVu to change the low-temperature control mode, you will issue a command to shut down the PPMS, along with a number specific to the control mode that you want to be activated.

The example below uses the commands that activate CLTC.

1. In the **Send:** text box type the following:

   shutdown 2 (just as is shown in Figure 3). Then click on the **Send and Read** button.

Figure 3. Switching from pot-fill mode to CLTC

2. To verify which temperature mode the system has activated, type **clt?** again and click on the **Send and Read** button.

3. If the system has switched to CLTC, the **Response** area should now display "**1,1**" (as is shown in Figure 4).

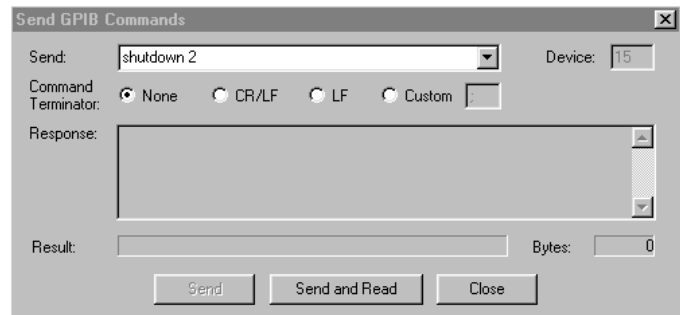Table 2 summarizes the shutdown commands and their meaning.
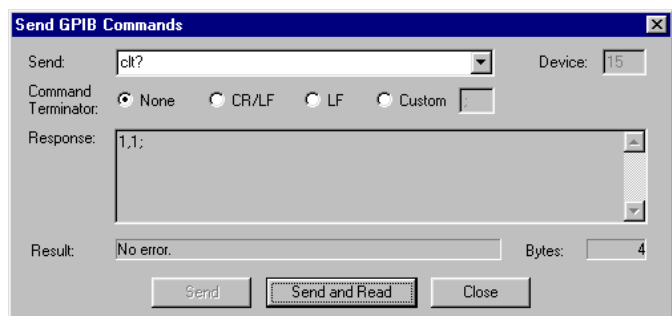
Figure 4. Verifying that CLTC is the low-temperature control mode

Table 2. Commands to shut down the PPMS and set temperature control modes

COMMAND	ACTION
shutdown 0	Shut down the PPMS but do not change the temperature control mode.
shutdown 1	Shut down the PPMS and set the temperature control mode to pot fill.
shutdown 2	Shut down the PPMS and set the temperature control mode to CLTC.

MON6000

The **Mon6000** dialog is set up somewhat differently than the **Send GPIB Commands** dialog in MultiVu, but you will use the same commands that you use with MultiVu (shown above) to verify or change the low-temperature control mode.

1. Open the **Mon6000** dialog:

    a. Locate the `Tools` subdirectory of the `QDPPMS` directory (the `QDPPMS` directory might be on your `C:` drive).

    b. Locate the program called `Mon6000.exe` and double click on it to open it.

2. When the **Mon6000** dialog opens (Figure 5), you will see separate text-entry panels titled "**Command To Send**" and "**Response Received**."
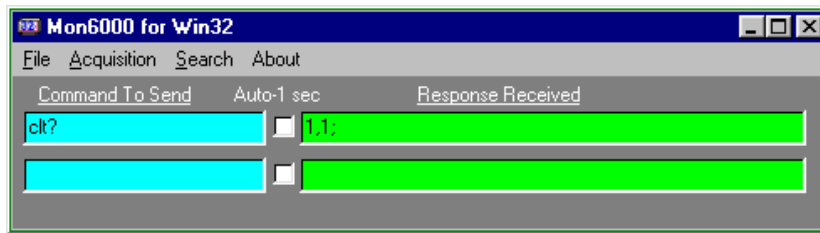

Figure 5. Checking the low-temperature control mode using the Mon6000 dialog

3. Use the **Command To Send** panel to enter your temperature-mode verification command (i.e., **clt?**).

    As shown in Figure 5, the **Response Received** panel will then display the active low-temperature regime. You can see that the CLTC option is installed and it is being used, because the **Response Received** panel displays "**1,1**" just as it would in MultiVu.

4. Use the shutdown command (**shutdown 1**) to shut down the PPMS and activate pot-fill mode (see Figure 6).
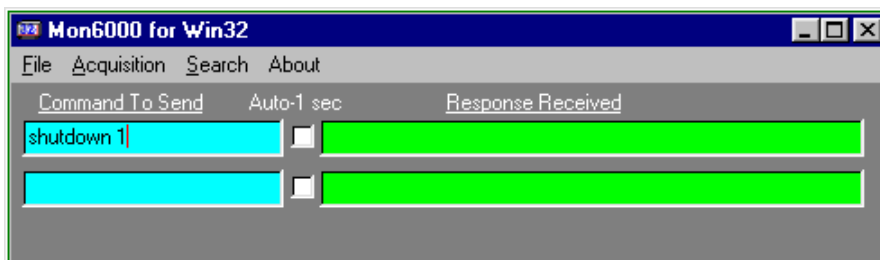

Figure 6. Switching low-temperature control modes using the Mon6000 dialog

5. You can verify that you have changed to pot-fill mode by typing "**clt?**" again in the **Command to Send** panel.

    The **Response Received** panel should display "**0,1**" if the system has changed successfully to pot-fill mode.

6. If you want to activate CLTC, type **shutdown 2** in the **Command to Send** panel.