Instructions for the Heater Controller (made by LBNL ~ March 2014)

1. Introduction

The heat controller is a two channel PID-controlled thermostat. It is suitable for low voltage (60 V max.) DC-heating applications. It has two modes of operation (i.e. internal and external), which may be used simultaneously. Per channel it provides an internal heating current of up to 5 A. It also has an analog control voltage 0-5 V for external power supplies. The output current can be limited hardware-wise using the digital trimmer on the front panel. It is intended as a safety precaution to ensure that the current supported by the heating element is not exceeded.

2. Hardware

The inside of the box consists of:

- Two PID-controllers (4B63)
- Two Heater Controller Boards (printed circuit boards)
- A large 60 V power supply
- A smaller 12 V power supply

The front panel accommodates:

- Display screen/monitor of PID controllers, labeled meter 1 and meter 2 in the actual device
- Two big switches(labeled heater controller) for switching on the internal (60 V/5 A max.) output current for each channel
- Two small switches (labeled control out) for turning the analog control output on
- Two digital trimmers (labeled current limit), those act as hardware current limit.
- And two LEDs (labeled thermal status) that indicate malfunction (overheating) of the high current/60 V output. The LEDs are also on when the 60 V output is disabled.

3. Setting up the box for operation

1. All switches should be in the ‘off’ position.
2. Set the current limit to zero on both channels (i.e. by setting digital trimmer to 00).
3. Connect the AC-in and turn the power on. The PID-controllers should now light up.
4. Consult the PID-manual for programming instructions. Or consult the quick setup guide (next section). You are free to choose from a variety of PID-programs. The “PID” procedure is probably the most suitable program to start with. The temperature is maintained at a set point (i.e. the number displayed in SV in PID monitor). In the “manual” mode you can manually set the output current/power as percentage of the maximum output current. In this mode the heater acts as a simple power supply, where the output current can be controlled.
5. Connect the thermocouple and mount it to the object to be heated.
6. Connect the heating current through the large 60 V burndy outputs to the load resistor.
7. Alternatively connect the analog control output (only in case of external mode) to an external power supply.
8. Using the digital trimmer on the front panel, raise the current limit to the desired level. The numerical display gives a percentage of 5 A. I.e. 50 corresponds to a maximum output current of 2.5 A (there may be an offset).
9. Make sure that the control voltage generated by the PID controller is deactivated (see point 6. in the quick setup for the PID-controller).
10. Enable the 60V or analog control output. You can also enable the analog control output simultaneously with the 60V to monitor the control voltage.
11. When turning on the 60V output for either cannel, both fans (at the heat sinks) should start spinning. If they don’t, disable the output.

12. Start the heating program on the PID-Controller (see point 6. in the quick setup for the PID-controller). **It is very important to start any automatic program such as the PID after enabling the output (i.e. either turning on 60V for internal OR the control out for external mode)!** If the program does not sense any change when increasing the control voltage, it will set the control voltage to the maximum. When you enable the output now it will be the maximum output (where you set the limit on the dial).

4. Quick setup for the PID-controller

FRONT KEY FUNCTIONS
Key functions are as follows:

INDEX: Pressing the INDEX key advances the display to the next menu item.

UP ARROW: Increments a value or changes a menu item. If pressed during the **Operation Mode**, the set point value will be increased.

DOWN ARROW: Decrements a value or changes a menu item. If pressed during the **Operation Mode**, the set point value will be decreased.

ENTER: Stores the value or item change. If not pressed, the previously stored value or item will be retained. When pressed during the **Operation Mode, the** controller switches to the **Regulation Mode**. If held for more than 3 seconds during the **Operation Mode**, the controller switches to the **Initial Setting Mode**. If pressed during the **Regulation Mode** or **Initial Setting Mode**, the controller will return to the **Operation Mode**.

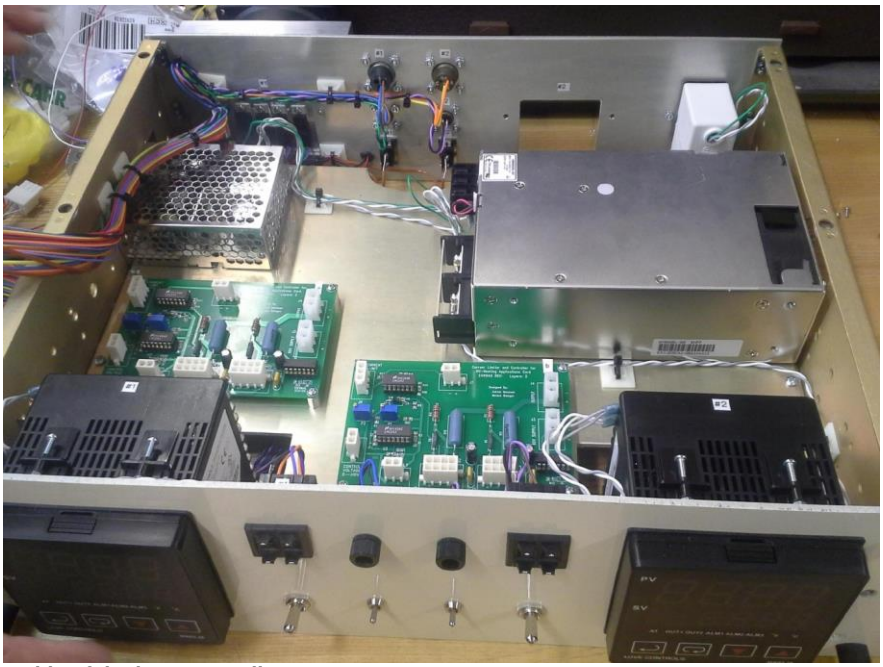
>>> When setting up the PID controller for the first time, follow these steps:

1. Press and hold the ENTER key for at least 3 seconds while at the Home Display in order to access the Initial Setting Menu. Pressing the INDEX key will cycle through the below menu items. The parameter will be displayed in the top display, while its value will be displayed in the bottom display. The UP and DOWN arrows change the values of the parameters. The ENTER key must be pressed after any changes.
2. inPt is the first menu item using the ARROW keys, scroll until you reach J. Select it by pressing ENTER. You have now selected a J-type thermocouple as temperature probe.
3. Scroll further down in the Initial Setting Menu using the INDEX key until you reach Ctrl. Using the ARROW keys select PID mode.
4. Enter the Operation Mode by pressing ENTER.
5. Press INDEX once. Here you can select the set point temperature (can set either in ^{O}C or ^{O}F).
6. The next menu item in the Operation Mode is r-S. Here you can (start) run or stop the heating process. Make sure you select „stop“. Select run and then press ENTER (Start the program) when you have reached point 11. In „Setting up the box foe operation“.

5. Components of the heat controller

The front panel accommodates:

- Two big switches for switching on the internal (60 V/5 A max.) output current for each channel
- Two small switches for turning the analog control output on
- Two digital trimmers, those act as hardware current limit.
- And two LEDs that indicate malfunction (overheating) of the high current/60 V output. The LEDs are also on when the 60 V output is disabled.



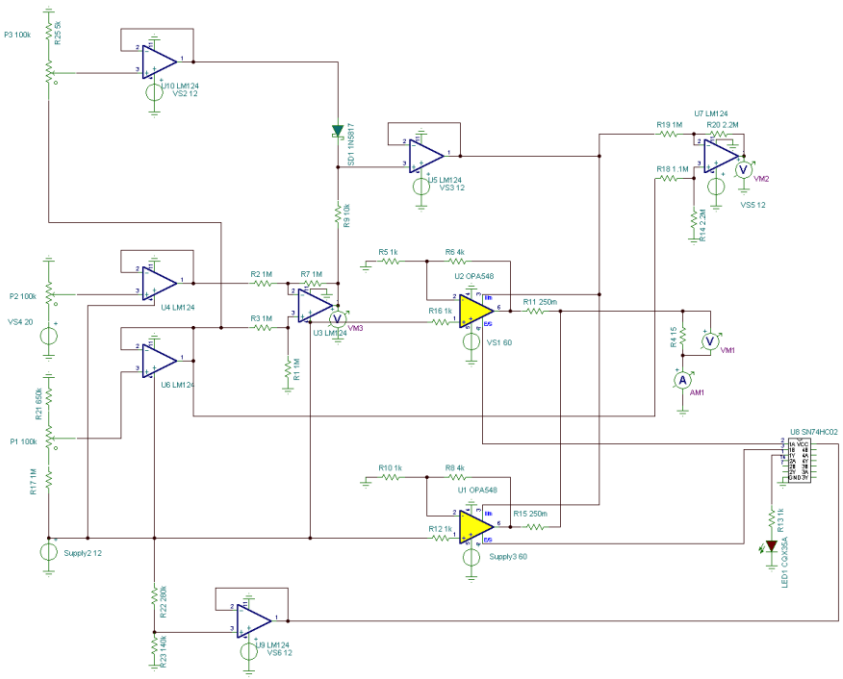
Inside of the heat controller

The back panel accommodates:

- Two 60 V outputs (labeled heater output) with large burndy connectors. (the other ends are BNC connectors)
- Two small (10V max, isn't it 5V??) analog control outputs (labeled analog output, connect to external power supplies, BK Precision black units).
- Two J-type thermocouple input (the other ends are BNC connectors)
- An AC-input 110-220 V (with an ON/OFF switch).
- Two heat sinks with fans.

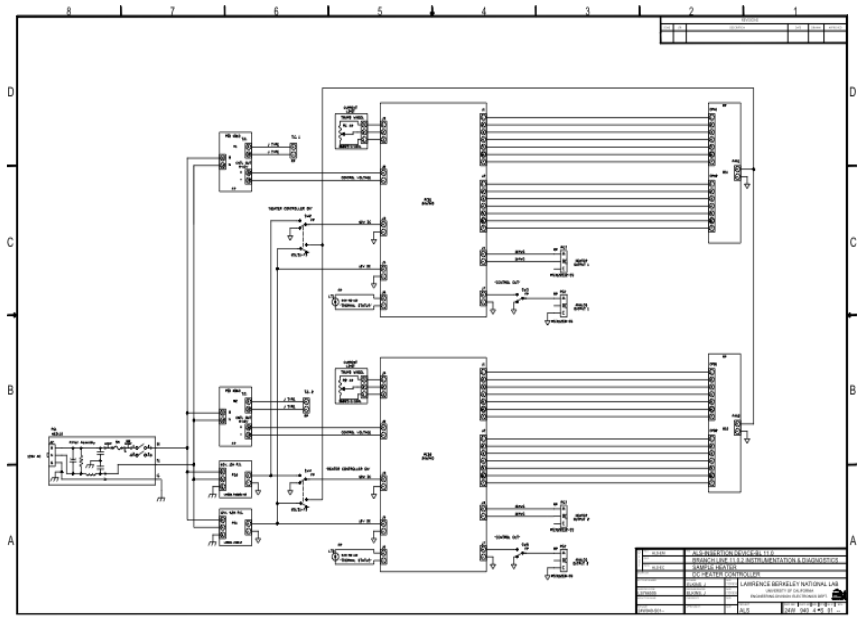
Backside of the heat controller

6. Electrical circuit schematics



Circuit diagram

R25 can be replaced with a 110 kOhm resistor. This increases the overall current limit to 10 A per channel. The number displayed on the current limiter dial on the front panel then corresponds to amperes. **However the maximum current that should go through a single channel is 5 A!** Also the internal power supply has a maximum output of 10 A.



Wiring
Specifications:
Max. voltage output: 60 V
Max. current output per channel: 5 A
Min. value for the load resistor: 8 Ohm
Total max. heating power: 600 W

7. Q&A

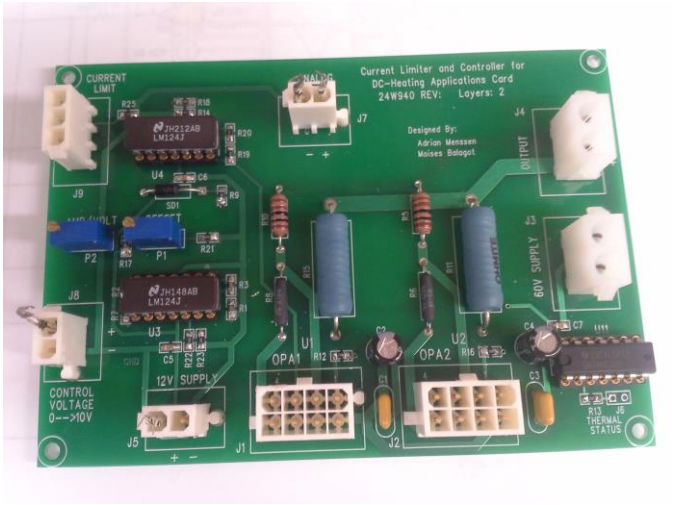
Q: Which value of resistance should I choose for the heating resistor?
A: It is best to choose the highest possible resistance.
Example: A heating wire supports a maximum of 2 A. Since the maximum voltage output is 60 V You should choose the resistance to be around 30 Ohms. The maximum power that is generated at the resistor is now 4*30 W=120 W.

Q: What if the thermal status LED is on?
A: If the output is disabled the status LED should be on, as the chip is not operating. If the status LED is on when the 60V output is enabled, the operational amplifiers are overheating and/or are damaged. Check the temperature of the heat sink. The output being shortened out (less than 8 Ohm to GND) can cause overheating. If the overheating problem affects a single channel you may want to arrange the operational amplifiers such that for one channel the two OPAs are not on the same heat sink.

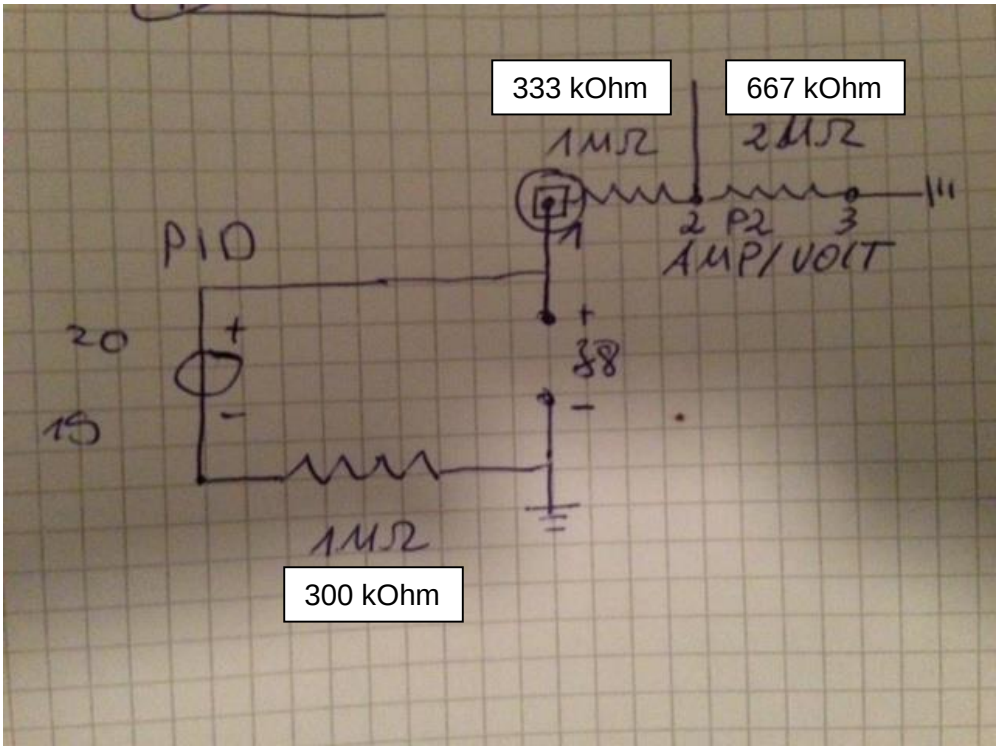
Q: The output exhibits strange behavior.
A: Strange output behavior may be caused by a damaged OPA. Both channels operate well with only a single OPA connected (however the output current is cut in half). Try to disconnect the OPAs alternately. You can disconnect all OPAs of the channel and still run in analog control mode with an external power supply as a backup option!

8. Appendix

Heater controller setup, test and troubleshoot
Before first use the heat controller needs to be set up for a linear response. The different analog outputs of two METERs is related to settings of POTI1 (offset) and POTI2 (AMP/VOLT) on the PCB as shown in the diagram below.



Both of the meters behave in a similar way; there is a temperature jump of up to 7 degree C when there is a contact to the ground. (Maybe a different impedance (outlined below) helps to solve this issue.)



A guide to set up a test bench can be found in the file “Testing Guide.pdf”

12/13/2013
Test of Analog out

METER 1			METER 2		
MODE ANALOG (OUTPUT 100%)			MODE ANALOG (OUTPUT 100%)		
ANALOG SWITCH	DIGITAL TRIMMER	ANALOG OUT (V)	ANALOG SWITCH	DIGITAL TRIMMER	ANALOG OUT (V)
OFF	00	0.0	OFF	00	0.0
ON	00	0.006	ON	00	0.006
ON	10	0.5	ON	10	0.506
ON	20	1.0	ON	20	1.04
ON	60	3.0	ON	60	3.14
ON	80	4.1	ON	80	3.98
ON	90	4.1	ON	90	4.0

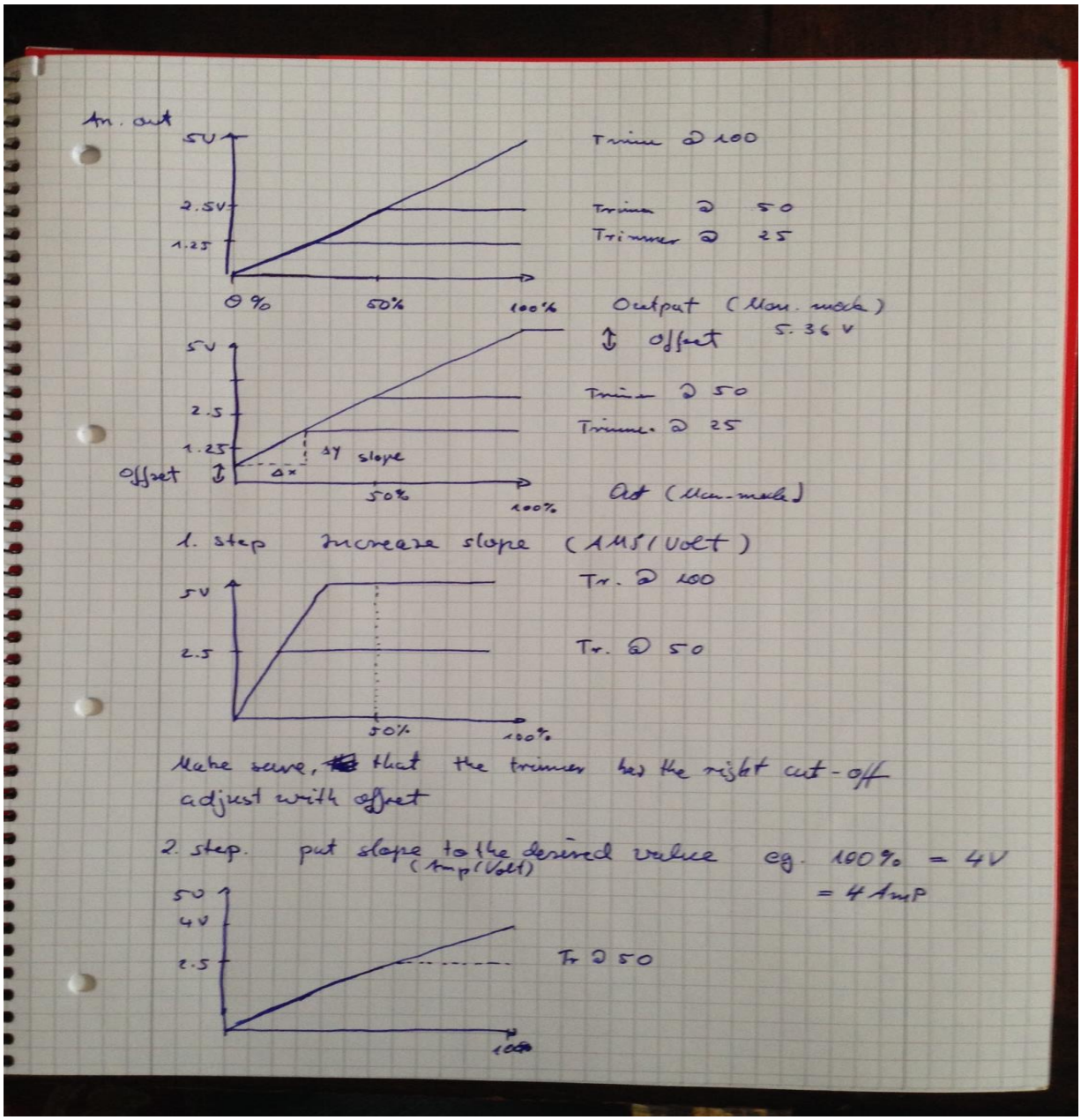
1/8/2014
Changes are made to the METER 2, 100 kOhm POTI2 (AMP/VOLT) on the PCB is replaced with a 1 MOhm POTI such that resistance between the pins 1 and 2, denoted by R12, is 330kOhm and that between pins 2 and 3 (i.e. R23) is 667kOhm. We have also added a 300 kOhm resistor between negative cables of J8 supply and pin 19 of the PID controller.

Test of Analog out

METER 1			METER 2		
MODE PID (OUTPUT 100%)			MODE PID (OUTPUT 100%)		
ANALOG SWITCH	DIGITAL TRIMMER	ANALOG OUT (V)	ANALOG SWITCH	DIGITAL TRIMMER	ANALOG OUT (V)
OFF	00	0.0	OFF	00	0.0
ON	00	0.0064	ON	00	0.012
ON	10	0.49	ON	10	0.55
ON	20	1.03	ON	20	1.08
ON	50	2.61	ON	50	2.7
ON	70	3.62	ON	70	3.76
ON	80	3.98	ON	80	4.33
ON	90	4.02	ON	90	4.86
ON	95	4.02	ON	95	5.13
ON	99	4.02	ON	99	5.34

- The analog outputs for the 2 units are now different. For METER1 the analog output is still at maximum of 4V (DIGITAL TRIMMER 99) as expected since no changes are made. For METER 2 the maximum output is 5.34V (DIGITAL TRIMMER 99).
- In case of the 100 kOhm POTI we took out the resistances were different, R12 (80.3 kOhm) and R23 (19.88 kOhm).
- The problem related to the jump in the temperature when grounding the thermocouple is solved for METER2 and still exist for METER1 (since no changes to METER1)

1/9/2014
The different analog outputs of two METERs is related to settings of POTI1 (offset) and POTI2 (AMP/VOLT) on the PCB as explained in the diagram below.



Further troubleshoot revealed that the 300 kOhm resistor between negative of J8 and pin 19 of the PID controller is not the best choice, it provides a large offset voltage at the control output (analog output). So we changed it to 100 Ohm resistor and the grounding offset problem of the thermocouple is reduced to very little (if any).
Since the AMP/VOLT POTI is different and additional 100 Ohm resistor in combination provides different impedance, so the slope and the offset of the analog output have to be tuned. Below is the table with the analog output for both units after many hours of tuning.

1/10/2014

MANUAL MODE			
	DIGITAL	ANALOG OUT (V)	ANALOG OUT (V)

OUTPUT (%)	TRIMMER	METER 1	METER 2	METER 1	METER 2
0.0	99	6.1×10^{-3}	6.1×10^{-3}		
10.0	00	6.2×10^{-3}	6.2×10^{-3}		
	10	236.0×10^{-3}	236.0×10^{-3}		
	50	288.3×10^{-3}	288.3×10^{-3}		
	99	291.3×10^{-3}	291.3×10^{-3}		
50.0	00	6.1×10^{-3}	6.1×10^{-3}	6.0×10^{-3}	6.1×10^{-3}
	10	0.459	0.459	0.47	0.475
	50	2.362	2.362	2.369	2.345
	99	2.491	2.491	2.484	2.419
100.0	00	6.1×10^{-3}	6.1×10^{-3}	5.9×10^{-3}	7.3×10^{-3}
	10	0.507	0.507	0.514	0.518
	50	2.539	2.539	2.548	2.549
	99	4.96	4.96	4.97	4.94

1/14/2014

Setting up the heating test conditions as indicated below:

Meter 1 and 2, Manual mode: the resistance is a series combination of the 10 Ohm load resistor (borrowed from the ALS EM shop) and the sample wire piece (5 Ohm) wrapped around a stainless steel tubing to mimic the gas line inside the COLTRIMS chamber. R_{total} is 15 Ohm.

OUTPUT (%)	DIGITAL TRIMMER	Voltage across R_{total} (V)	
		METER 2	METER 1
50.0	00	3.9	4.2
	10	12.1	11.7
	20	19.2	18.2
	30	25.8	23.4
100.0	00	4.5	
	10	12.6	
	20	19.9	
	30	26.7	

This table already indicates that the current offset is different for the two meters; we don't know the reason why…

MANUAL MODE									
OUT-PUT (%)	DIGITAL TRIM-MER	METER 1				METER2			
		Time	V_{Rtotal}	Temp 1	Temp 2	Time	V_{Rtotal}	Temp 1	Temp 2
100.0	30								