CCD temperature control

CTIO 60 inches Echelle

ECH60HF-4.1

La Serena, December 09, 2009

Contents

Introduction

The goal of this brief report is to summarize the new CCD temperature control of the Echelle at the 60 inches telescope, as well as to set a baseline for future comparison. This document does not pretend to be a comprehensive study of the thermal control, but just a quick reference. All the following tests/tunings were done in the electronic lab. In La Serena

The temperature control is being done through an external, commercial temperature controller. All the internal cabling and sensor are the original ones in use with the old Arcon controller.

a) instrument**: Lakeshore 325** temperature controller
b) sensor: **silicon diode 1N914** at the detector mount
c) actuator: **bank of FETs** installed at the detector mount, driven by an analog output of the Lakeshore controller

Figure 1 shows a simple diagram of the control. The FETs are powered externally by a 5 Volts power supply, and the Lakeshore output controls the gate of the field transistors. The input for the control is the silicon diode installed at the mount

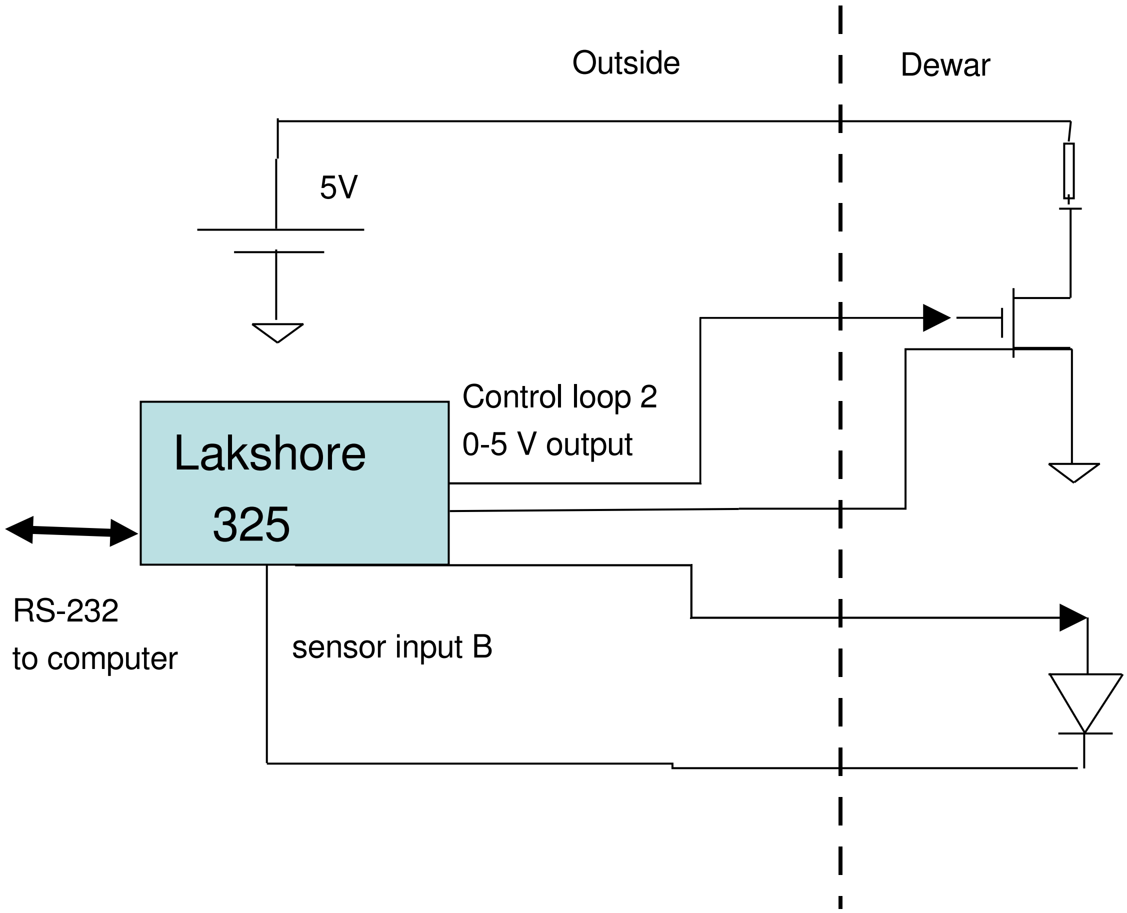

Figure 1: temperature control

Chapter 1: Control: Dynamic response

The Lakeshore 325 implements a PID algorithm for the control loop.
The curve for the diode was uploaded (custom), to make it consistent with other instruments on site. The actual polynomial used for the curve can be found in **appendix A**, along with the 70 points derived from it an uploaded to the instrument as custom **curve 21, DT-1N914**. As a reference, it was found that it made very little difference with the standard instrument curve **DT-500D**.

Figure 2 shows the step response of the closed control loop after the final tuning of the PID parameters. The final values are stated on table 1.

The working temperature was chosen to be close to **-110 C** (163 K) because this is about the usual working temperature of the system. Note that the response of the system is pretty fast, and both under and overshoot are reasonably small. The heater power was measured at the Lakeshore side, simply by requesting the % of the maximum power. It is important to note that with the heater load settings for Loop 2 (see ***Appendix B***) the maximum output voltage is **5 V**, and the maximum power is 1 W.

However, since in this case we are controlling the gate of a FET, the actual current from the Lakeshore is negligible (just the leakage current of the FET's gate), so the "power %" we here state really refers only to the **% over 5 V of output**. The actual power is being provided through the 5 V external power supply, which provides the FET's S-D current.

Parameter	**Value**
overshoot	400 mK
undershoot	200 mK
Recovery	<50 secs inside 10 mK target
P	400
I	120
D	0

Table 1: PID control response for 1 K step @ 163 K (-110 C)

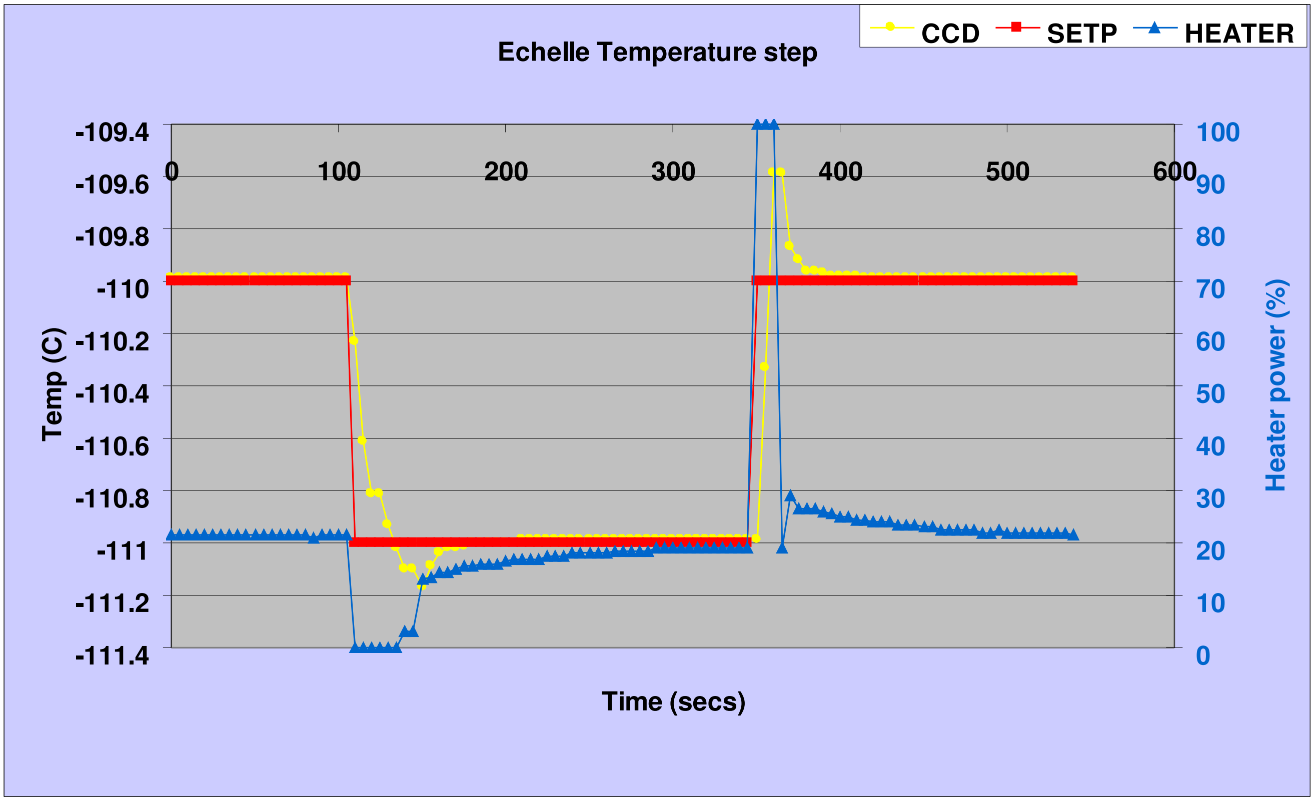

Figure 2: Step response after tuning

Chapter 2.:Control stability

Figure 3 shows the long term control stability. The graph shows a period of about 7 hours. Note that the CCD temperature (yellow) does not move at all during the time period. This is just due to the resolution of the curve. So, this curve is just tell us that the CCD temperature is stable to at least 10 mK.

Note how the heater power changes to compensate for temperature variations that we are unable to see due to the resolution. Note also that the stable heater power is only of about **23%**

What is important to note/explain is the apparent offset between the requested setpoint (**-108.00**) and the measured, stable temperature (**-107.99**). This difference is due to the conversion between actual sensor units (volts) and temperature using the conversion curve given. The instrument does the real control using sensor units, so it passes the requested setpoint in temperature to a requested value in volts and closes the loop there. The sensor value is converted back to temperature for the user to see. Depending on the resolution of the ADC converter, the resolution of the given curve, the way the instrument makes the interpolation/conversion, and the way the instrument do the back conversion (truncation, etc) it is reasonable to expect some “apparent” offset. As a simple example, if we take the two closest points to our -108 C (165 K) setpoint on the curve in Appendix A, we have:

54 0.7450 165.7773
55 0.7475 164.8758

If we do a simple linear interpolation to get our setpoint (165 K) in volts, we would get 0.74711 V. So, if we assume the instrument truncates to 4 decimal places, the voltage setpoint would be 0.7471 V. If we now take this value back to temperature, it would give us 165.0036 K, or -107.996 C. This example is just to illustrate that the offset is really apparent; the real setpoint is 0.7471, and the sensor is really tied to this value -in Volts-
It would of course be very simple to show all this by showing the real response in sensor units rather than in temperature; however, that long exceeds the purpose of this document.
For the instrument that will use this control system the precision/stability shown is way better than really required.

Table 2 shows the parameters derived from the graph

Parameter	Value
stability	Better than 10 mK
heater power	23 %

Table 2: Long term stability parameters

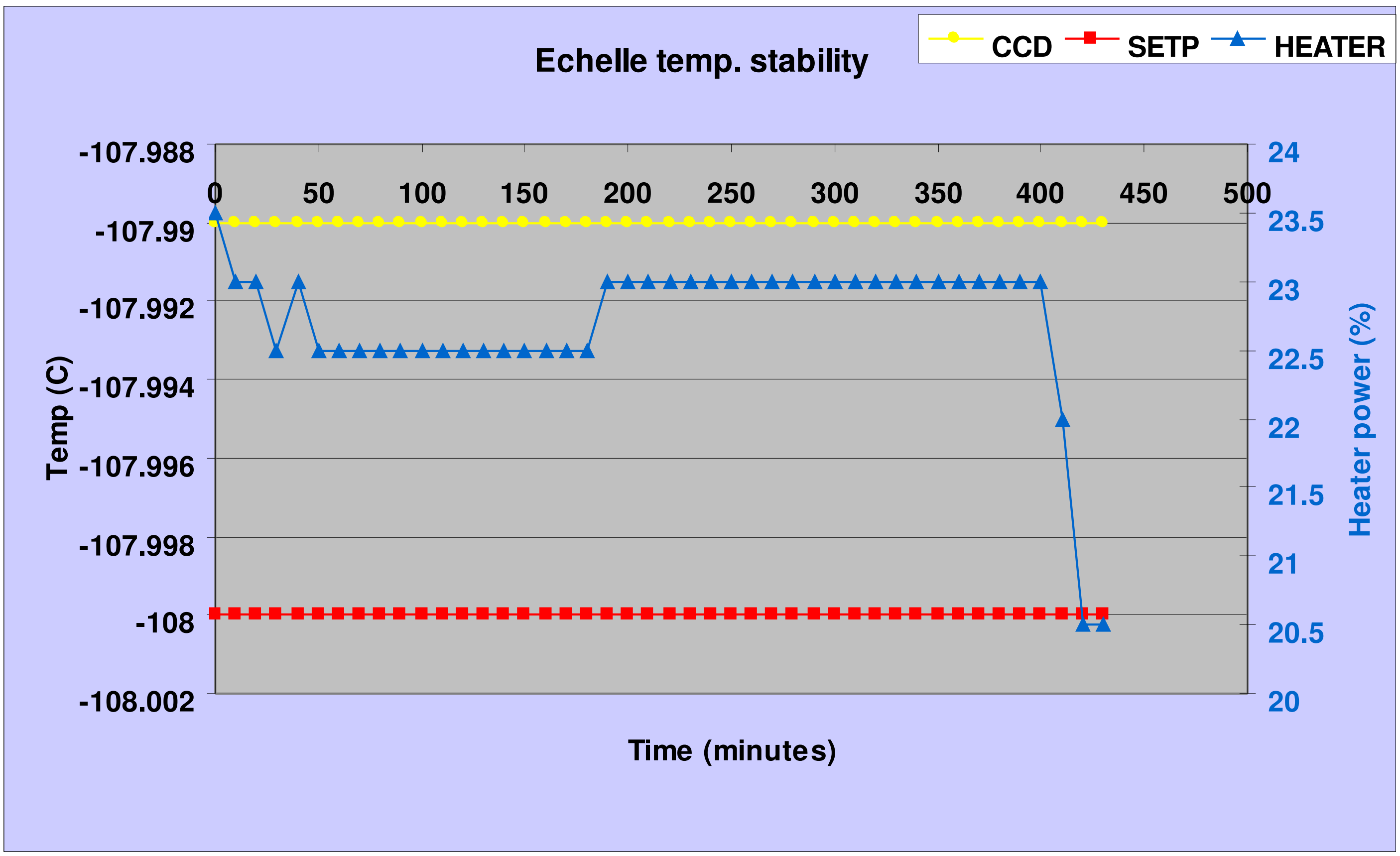

Figure 3: Long term temperature stability

Conclusion / General notes

- The temperature control system of the new Echelle works in a way suitable for the application
- All the Lakeshore settings are stored in the instrument's non-volatile memory, so there is no need for any parameter upload or handling at startup (power-up). The instrument has no need of any external intervention
- The actual control loop has been set so it also starts when the Lakeshore is powered (See ***Appendix B***)
- The computer that is usually attached to the Lakeshore's serial port is used only to monitor/graph/log the data periodically, but it is not required for the temperature control.

Appendix A: Diode curve

Name on instrument: DT-1N914

Loaded at: user curve 21

Polynomial:

$$T(V) = -219.7996 * V^{5} + 628.3720 * V^{4} - 786.8676 * V^{3} + 558.4024 * V^{2} - 581.5675 * V + 471.3507$$

File: 1N914_noao.325

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Sensor Model:   DT-1N914
Serial Number:  STANDARD
Data Format:    2     (Volts vs. Kelvin)
Setpoint Limit: 310.     (Kelvin)
Temperature coefficient: 1 (Negative)
Number of Breakpoints: 70

No.   Units      Temperature (Kelvin)

1      0.3800299.1722
2      0.3900295.3501
3      0.4000291.5441
4      0.4100287.7535
5      0.4200283.9775
6      0.4300280.2153
7      0.4400276.4663
8      0.4500272.7298
9      0.4600269.0051
10     0.4700265.2917
11     0.4800261.5890
12     0.4900257.8965
13     0.5000254.2136
14     0.5100250.5400
15     0.5200246.8750
16     0.5300243.2183
17     0.5400239.5695
18     0.5500235.9280
19     0.5600232.2935
20     0.5700228.6656
21     0.5800225.0438
22     0.5900221.4278
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23	0.6000217.8171
24	0.6100214.2113
25	0.6200210.6099
26	0.6300207.0127
27	0.6400203.4190
28	0.6500199.8285
29	0.6600196.2407
30	0.6700192.6550
31	0.6800189.0709
32	0.6900185.4879
33	0.6925184.5923
34	0.6950183.6967
35	0.6975182.8010
36	0.7000181.9054
37	0.7025181.0098
38	0.7050180.1142
39	0.7075179.2185
40	0.7100178.3229
41	0.7125177.4271
42	0.7150176.5313
43	0.7175175.6355
44	0.7200174.7395
45	0.7225173.8435
46	0.7250172.9474
47	0.7275172.0511
48	0.7300171.1548
49	0.7325170.2583
50	0.7350169.3616
51	0.7375168.4648
52	0.7400167.5678
53	0.7425166.6707
54	0.7450165.7733
55	0.7475164.8758
56	0.7500163.9780
57	0.7525163.0800
58	0.7550162.1818
59	0.7575161.2832
60	0.7600160.3845
61	0.7625159.4854
62	0.7650158.5860
63	0.7675157.6863
64	0.7700156.7863
65	0.7725155.8860
66	0.7750154.9853
67	0.7775154.0842
68	0.7800153.1827
69	0.7825152.2809
70	0.7850151.3786

Appendix B: Lakeshore 325 settings

Sensor Input:

***Input Setup* Key**

Input Setup: B
Type: Silicon diode
Curve: DT-1N914 (user curve 21)
Filter: off

Control Loop 2:

***Control Setup* Key**

Input: B
Unit: Celsius
Control Mode: Closed
Power-on: enabled *(control starts when powered)*
Heater load: 25 Ohms *(this reduces the nominal 0-10 V to 0-5 V)*
Setpoint ramp: off

Auto Tune Key

Tune mode: manual PID
P=400
I=120
D=0

***Heater Range* Key**

Heater Range: on