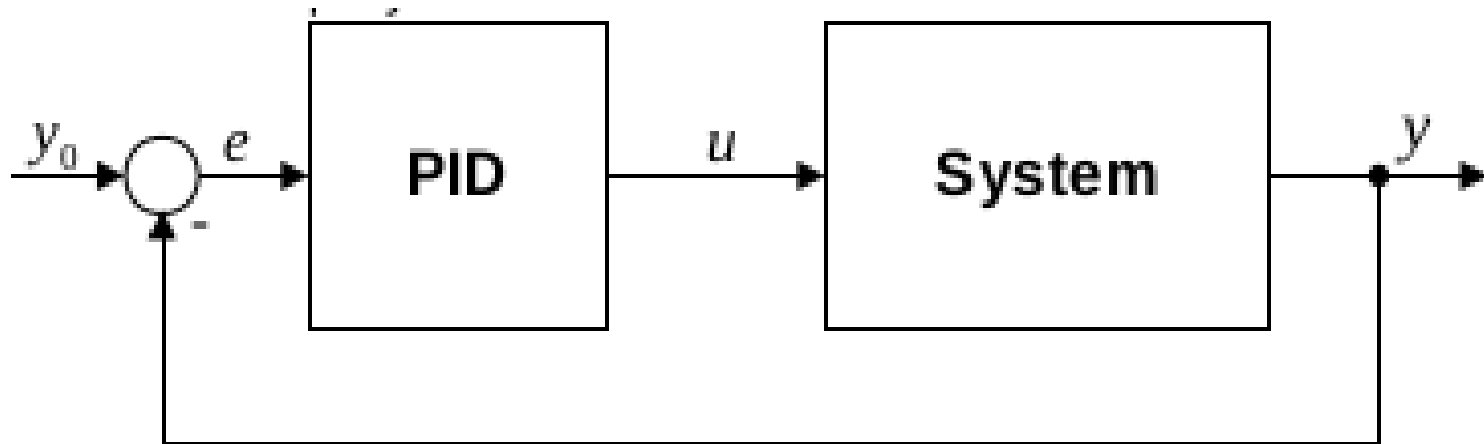


Temperature PID Control

A practical approach using Ziegler-Nichols

Caramon Pi

Closed Loop System



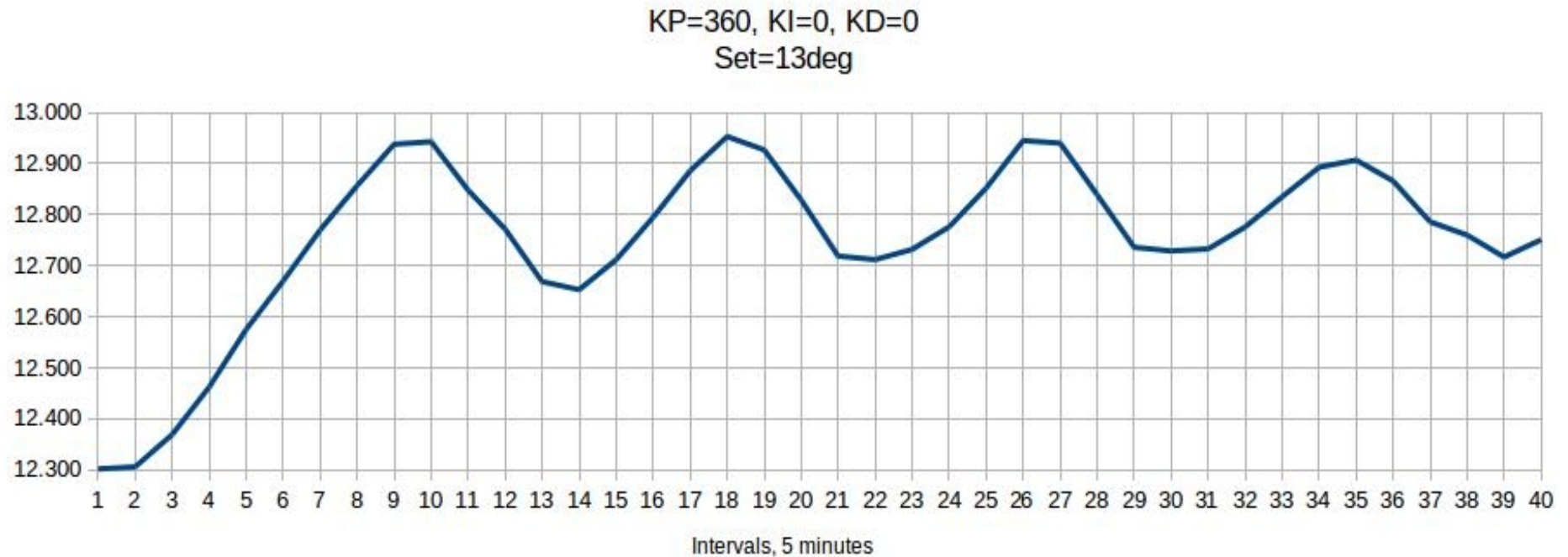
PID algorithm $u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}$

Discrete form $u(n) = K_p e(n) + K_i \sum_{k=0}^n e(k) + K_d (e(n) - e(n-1))$ $K_i = \frac{K_p T}{T_i}$ $K_d = \frac{K_p T_d}{T}$

Improved controller, by basing the derivative term on the process value only

$$u(n) = K_p e(n) + K_i \sum_{k=0}^n e(k) + K_d (y(n) - y(n-1))$$

Ziegler-Nichols



Closed-loop tuning method

Ultimate gain, $K_u=360$

Ultimate period, $P_u=35$ minutes = 2100 sec

Sample time, $T_s = 10$ minutes = 600 sec

	Kp	Ti	Td
P	$K_u / 2$	-	-
PI	$K_u / 2.2$	$P_u / 1.2$	-
PID	$K_u / 1.7$	$P_u / 2$	$P_u / 8$

Controller Parameters

Ku	360
Pu [s]	2100
Ts [s]	600



Z-N

	Kp	Ti [s]	Td [s]
P	180.00	-	-
PI	163.64	1750	-
PID	211.76	1050	262.50



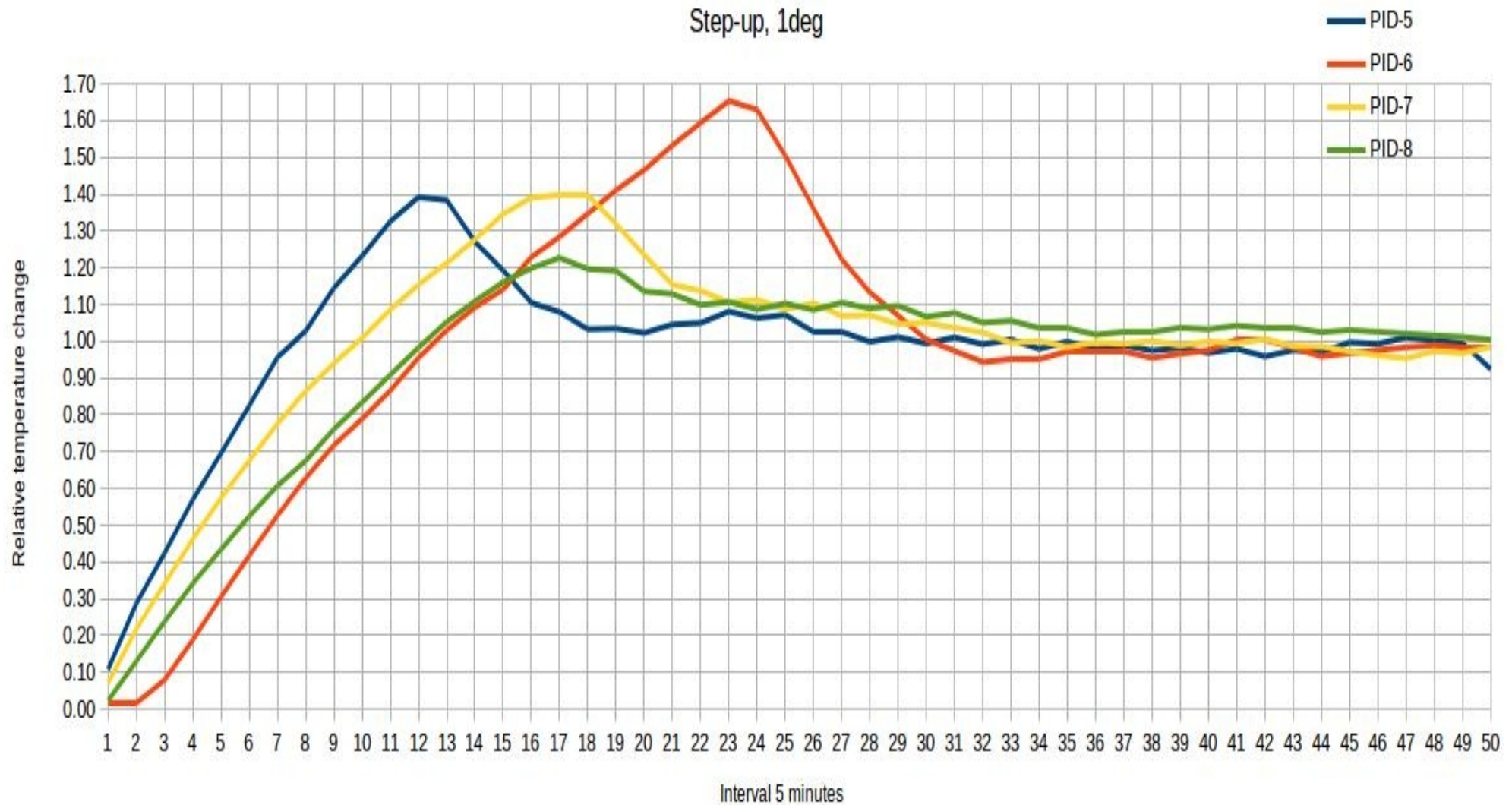
$$K_i = (K_p \times T_s) / T_i$$

$$K_d = (K_p \times T_d) / T_s$$

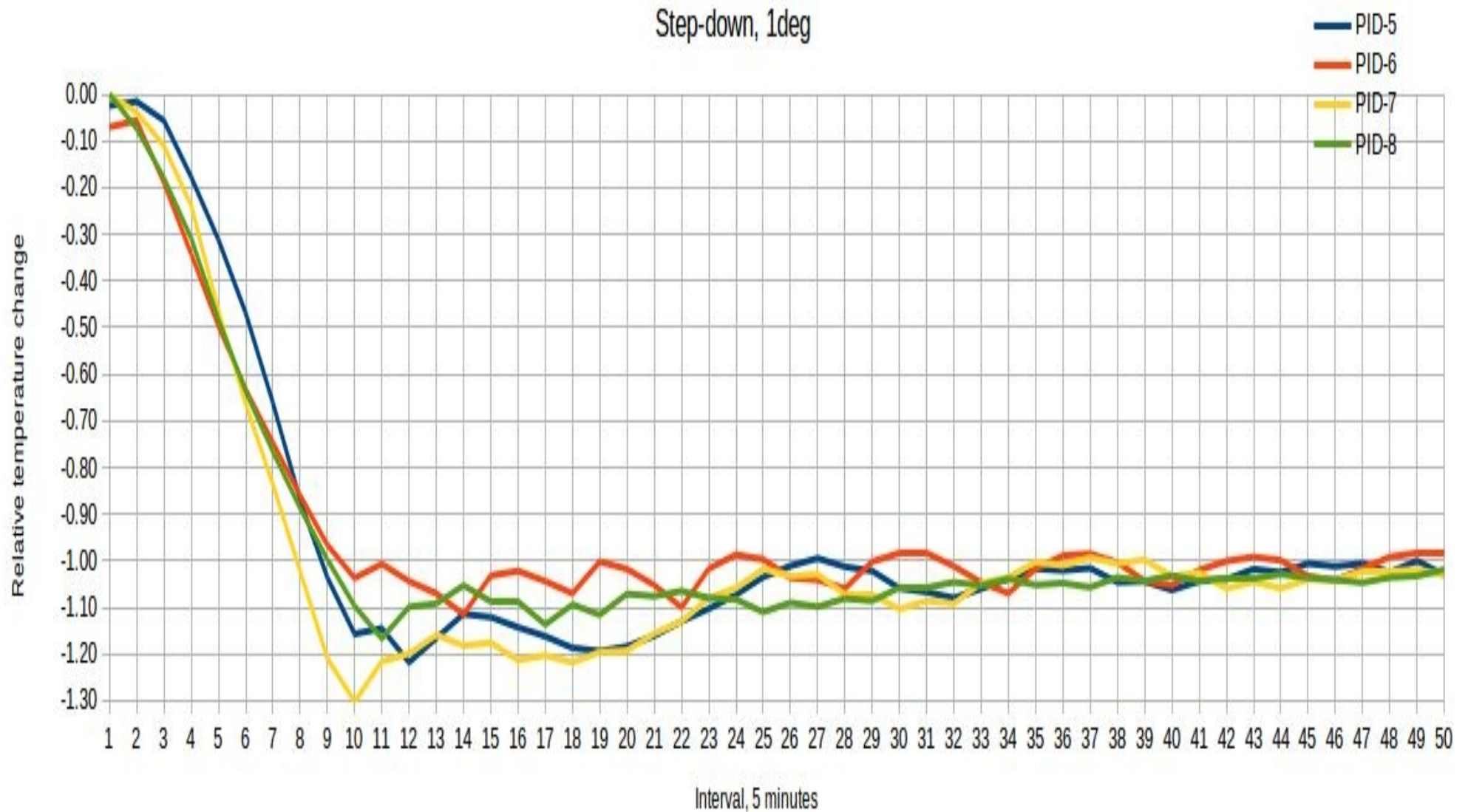


	Kp	Ki	Kd	Comment
PID-5	163.64	56.10	-	Z-N, PI
PID-6	211.76	121.01	92.65	Z-N, PID
PID-7	163.64	42.10	-	PID-5, Ki decreased 25%
PID-8	163.64	28.05	-	PID-5, Ki decreased 50%

Comparison, Step-up



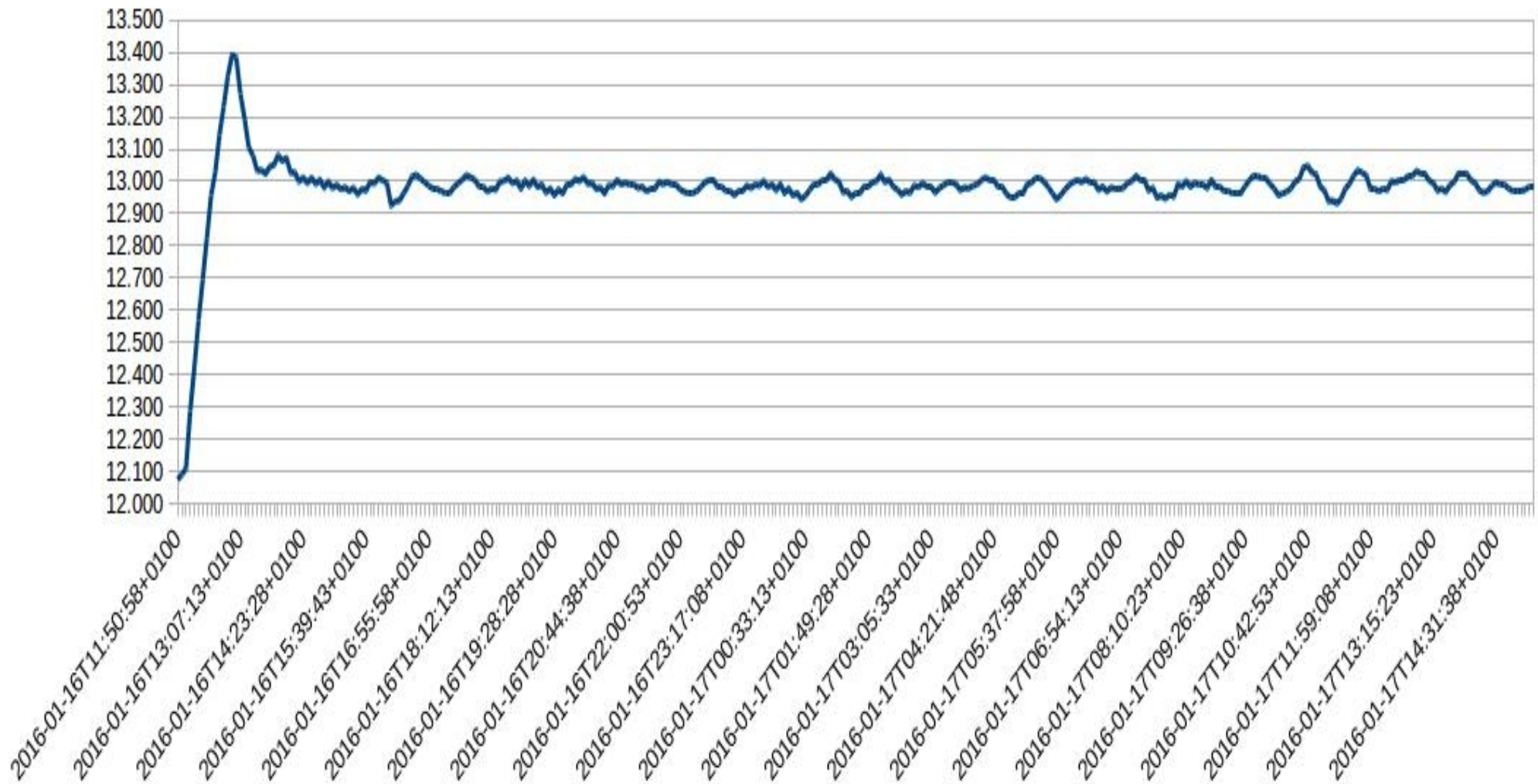
Comparison, Step-down



PID-5, Step-up

KP=163.64, KI=56.10, KD=0, Set=13deg

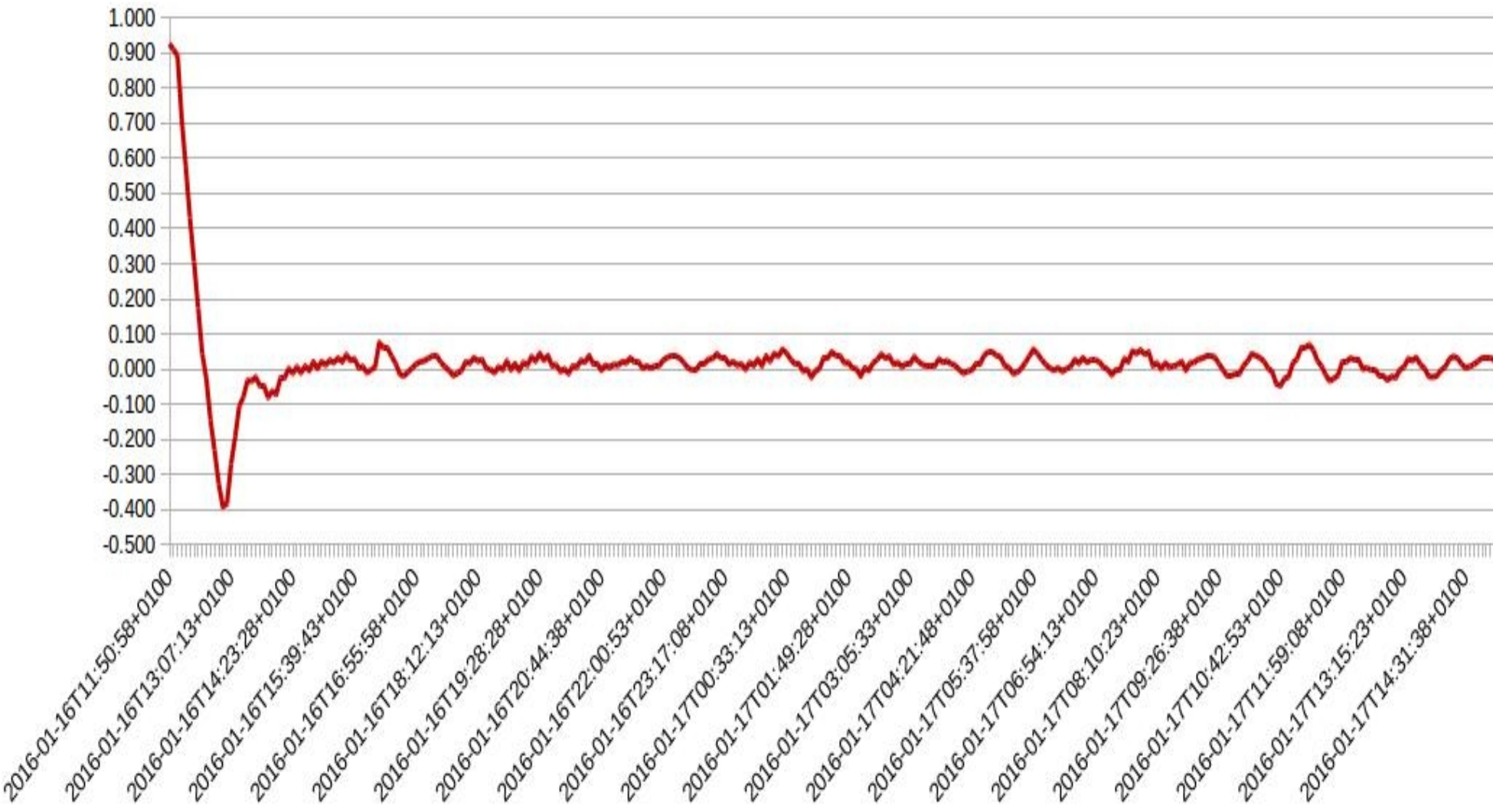
Actual Temperature



PID-5, Step-up

KP=163.64, KI=56.10, KD=0, Set=13deg

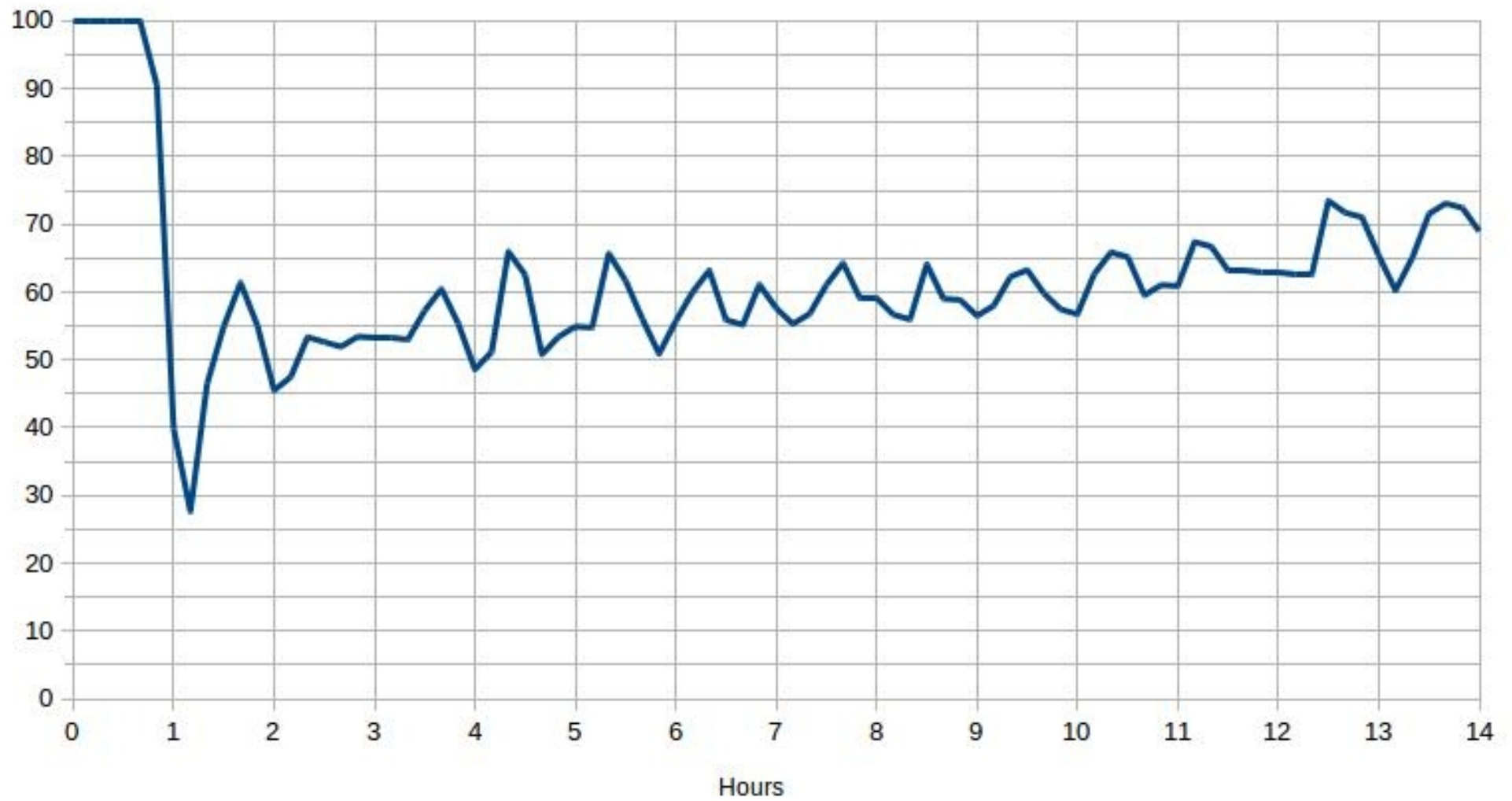
Error



PID-5, Step-up

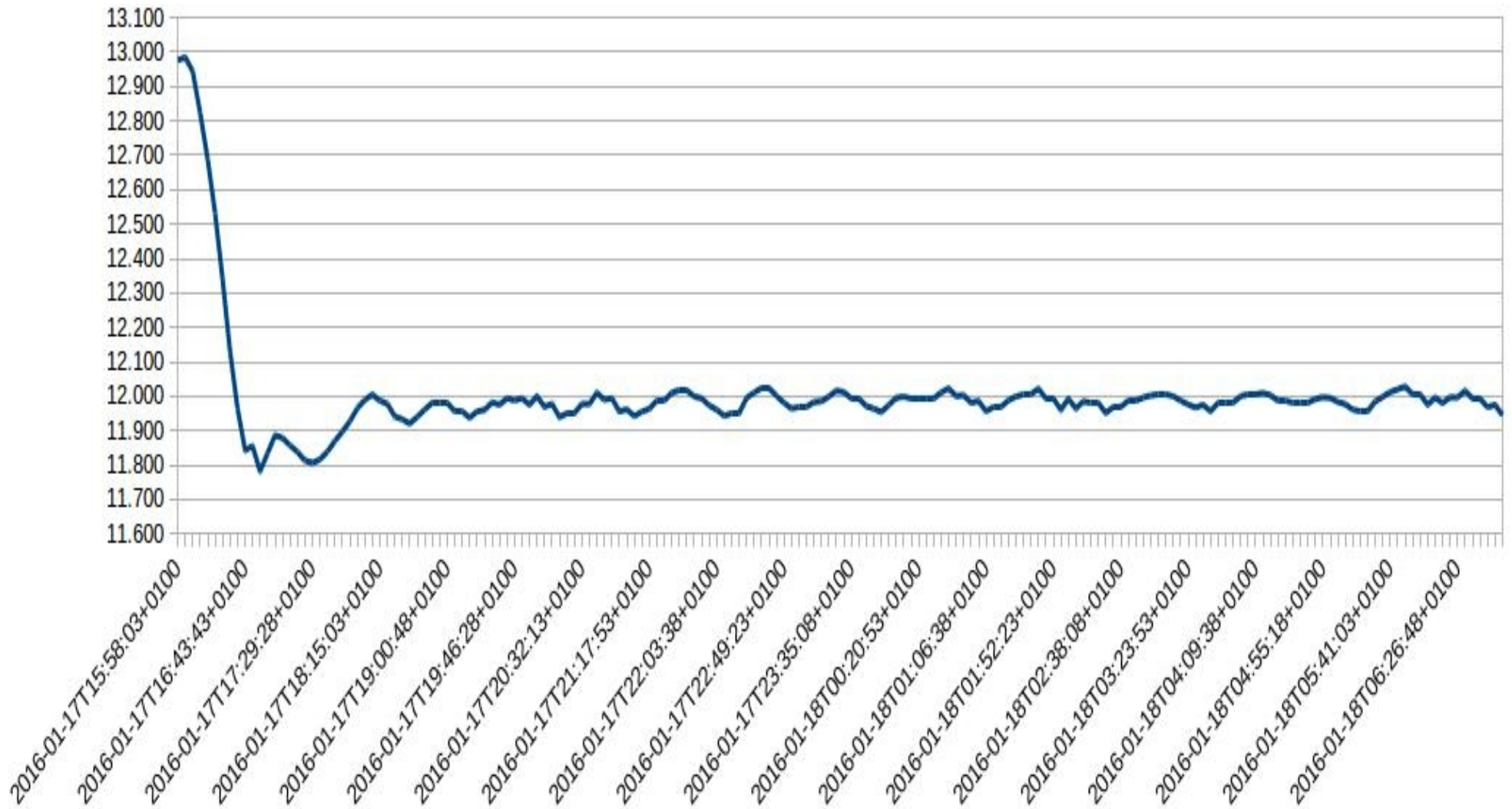
KP=163.64, KI=56.10, KD=0, Set=13deg

Duty



PID-5, Step-down

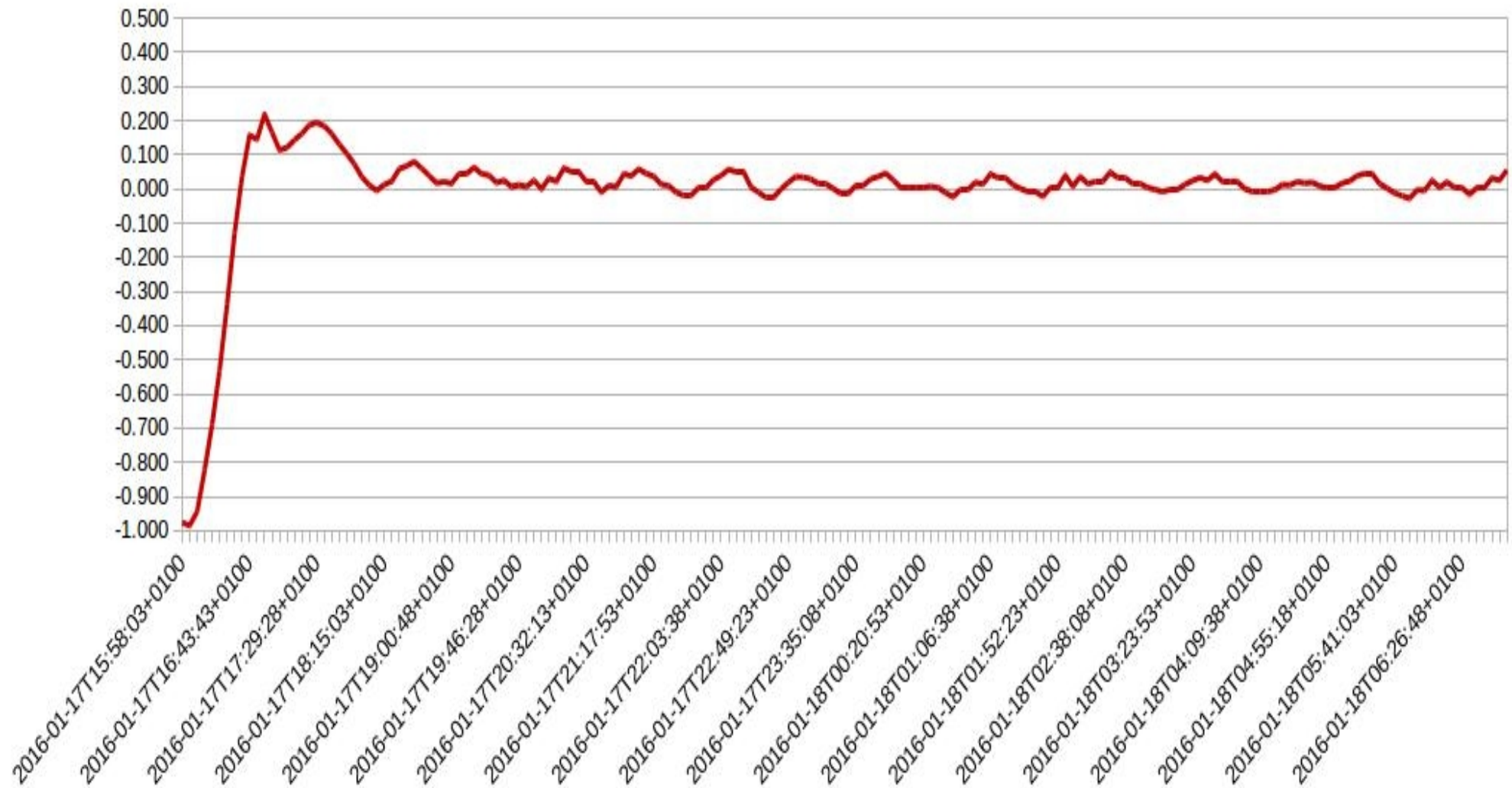
KP=163.64, KI=56.10, KD=0, Set=12deg
Actual Temperature



PID-5, Step-down

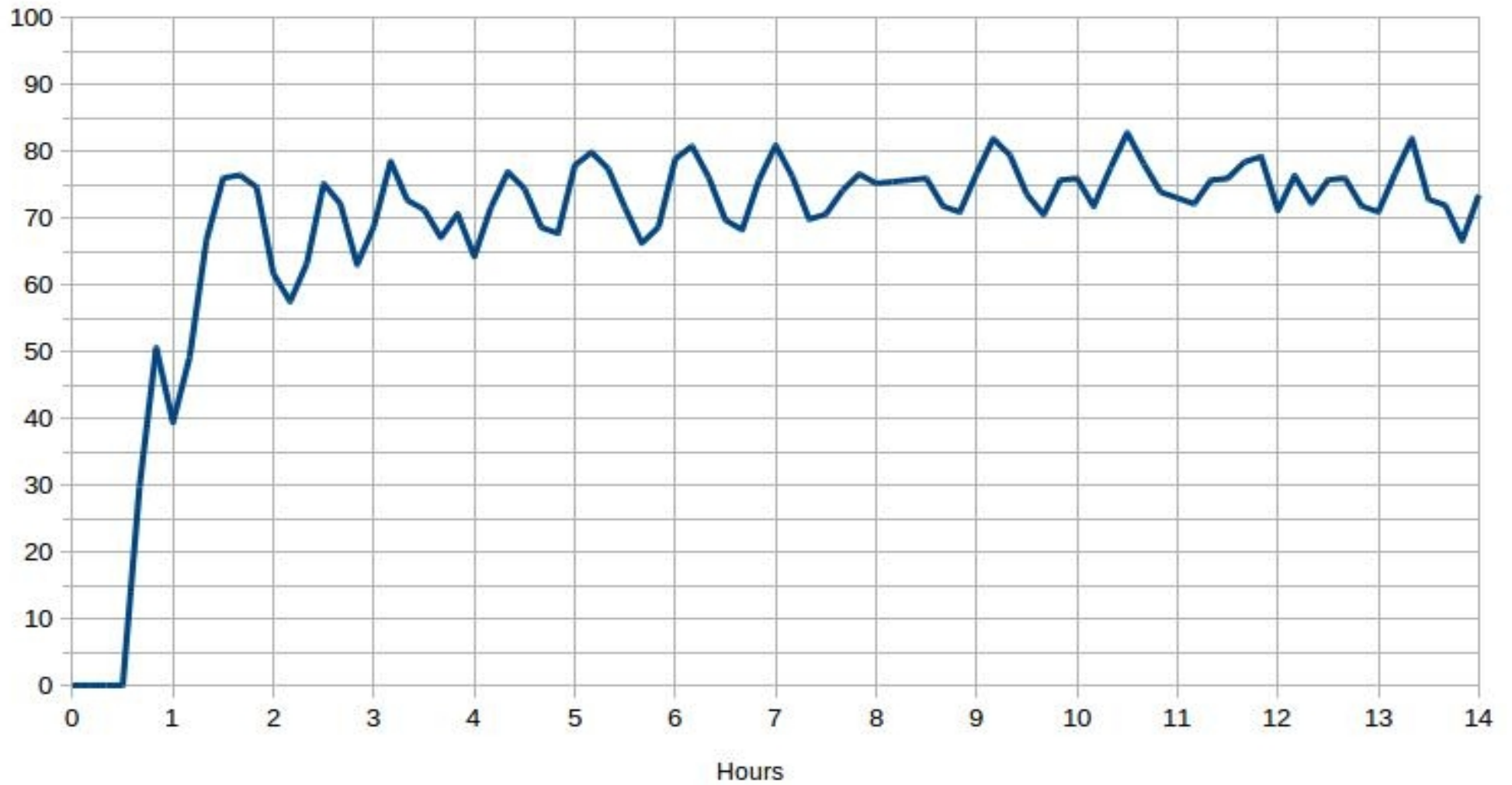
KP=163.64, KI=56.10, KD=0, Set=12deg

Error



PID-5, Step-down

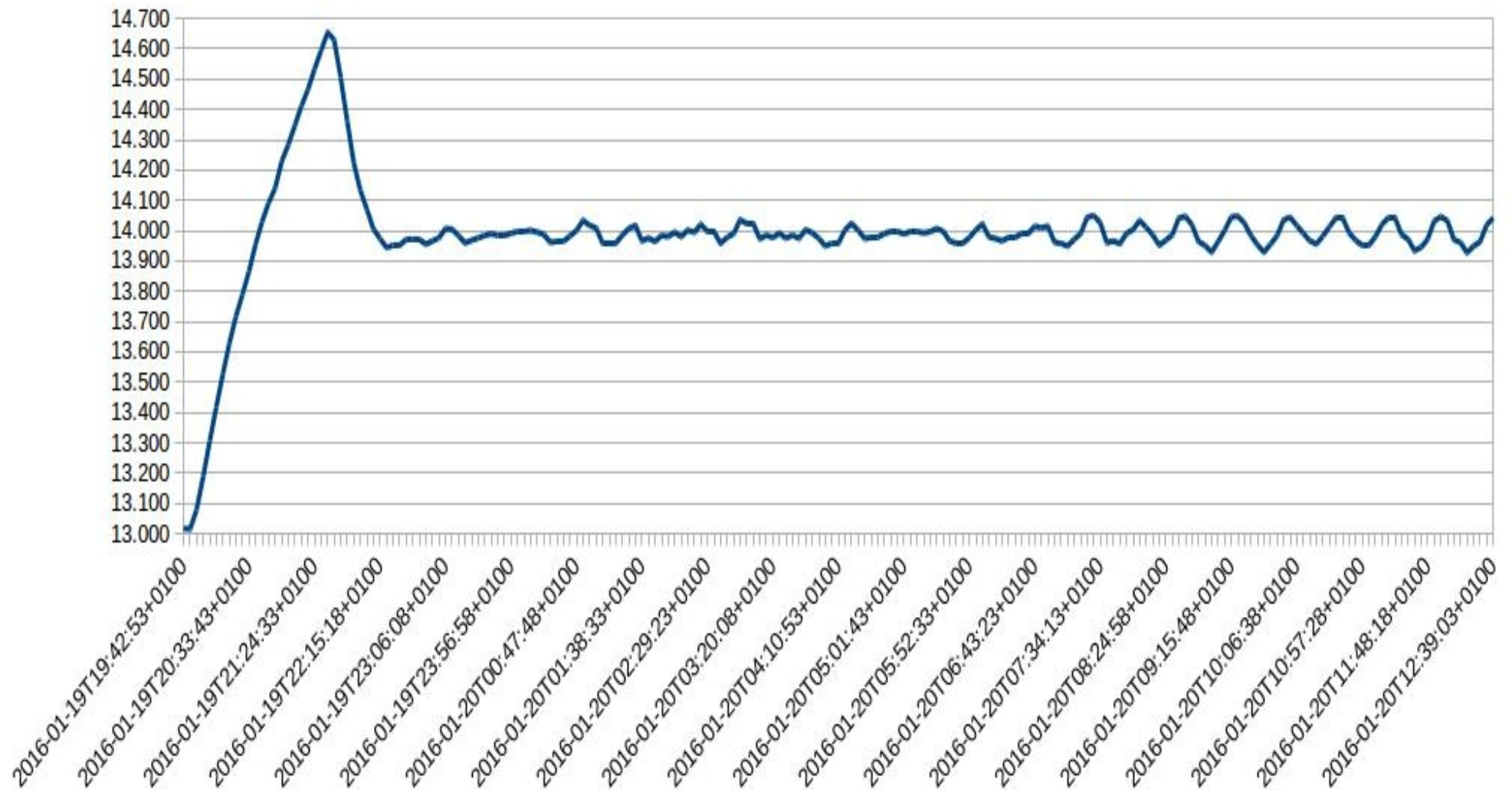
KP=163.64, KI=56.10, KD=0, Set=12deg
Duty



PID-6, Step-up

KP=211.76, KI=121.01, KD=92.65, Set=14deg

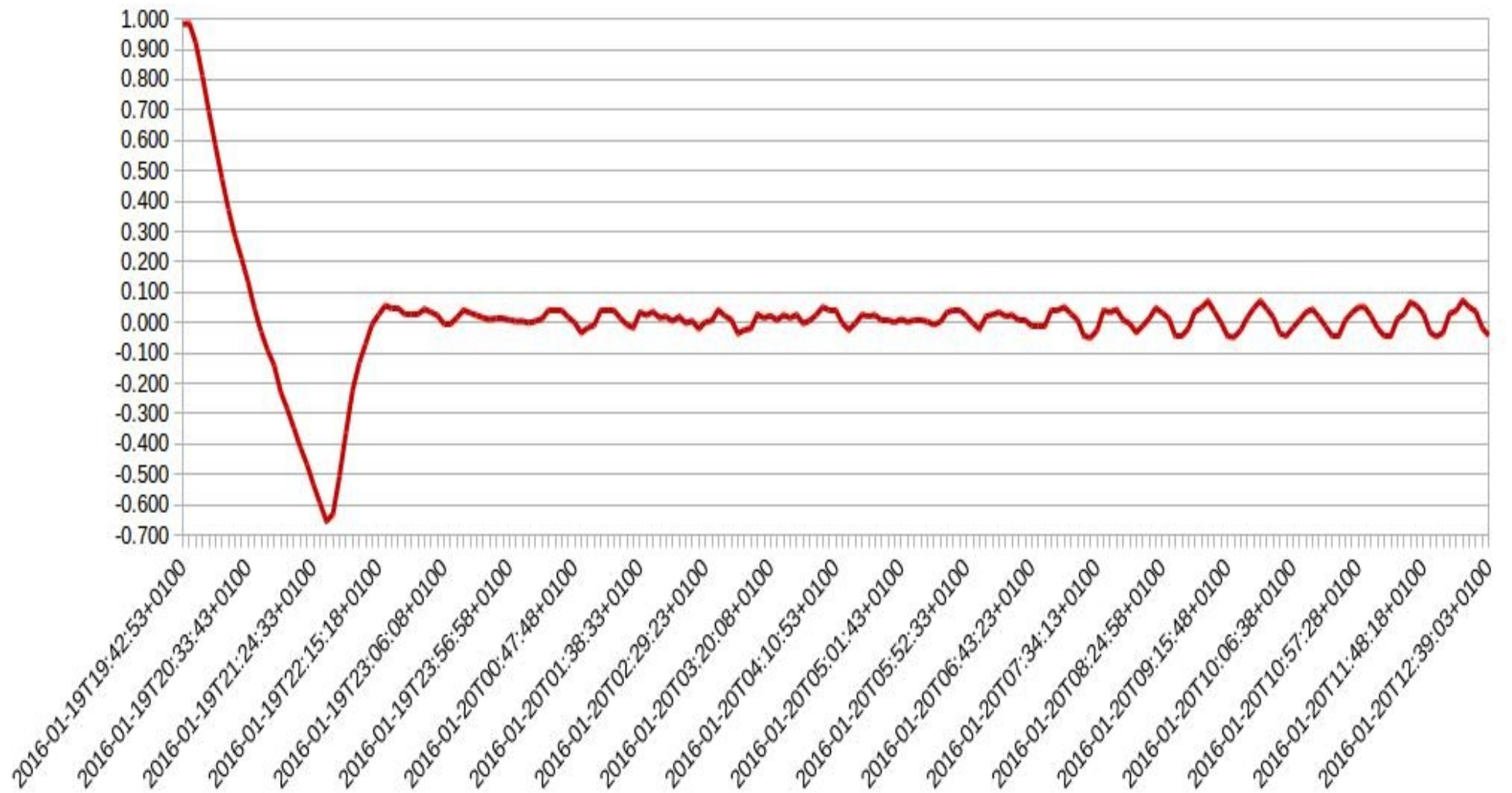
Actual Temperature



PID-6, Step-up

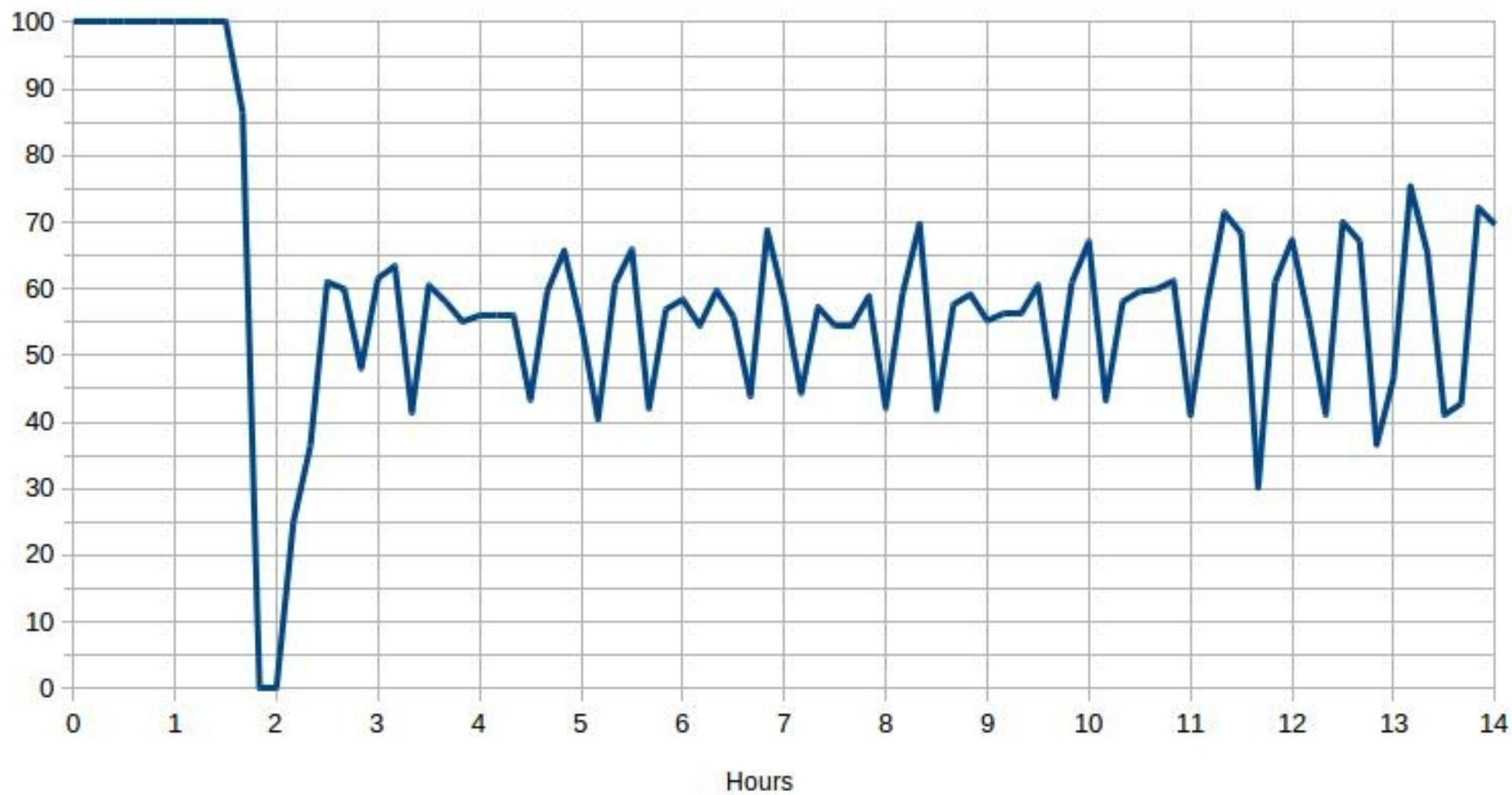
KP=211.76, KI=121.01, KD=92.65, Set=14deg

Error



PID-6, Step-up

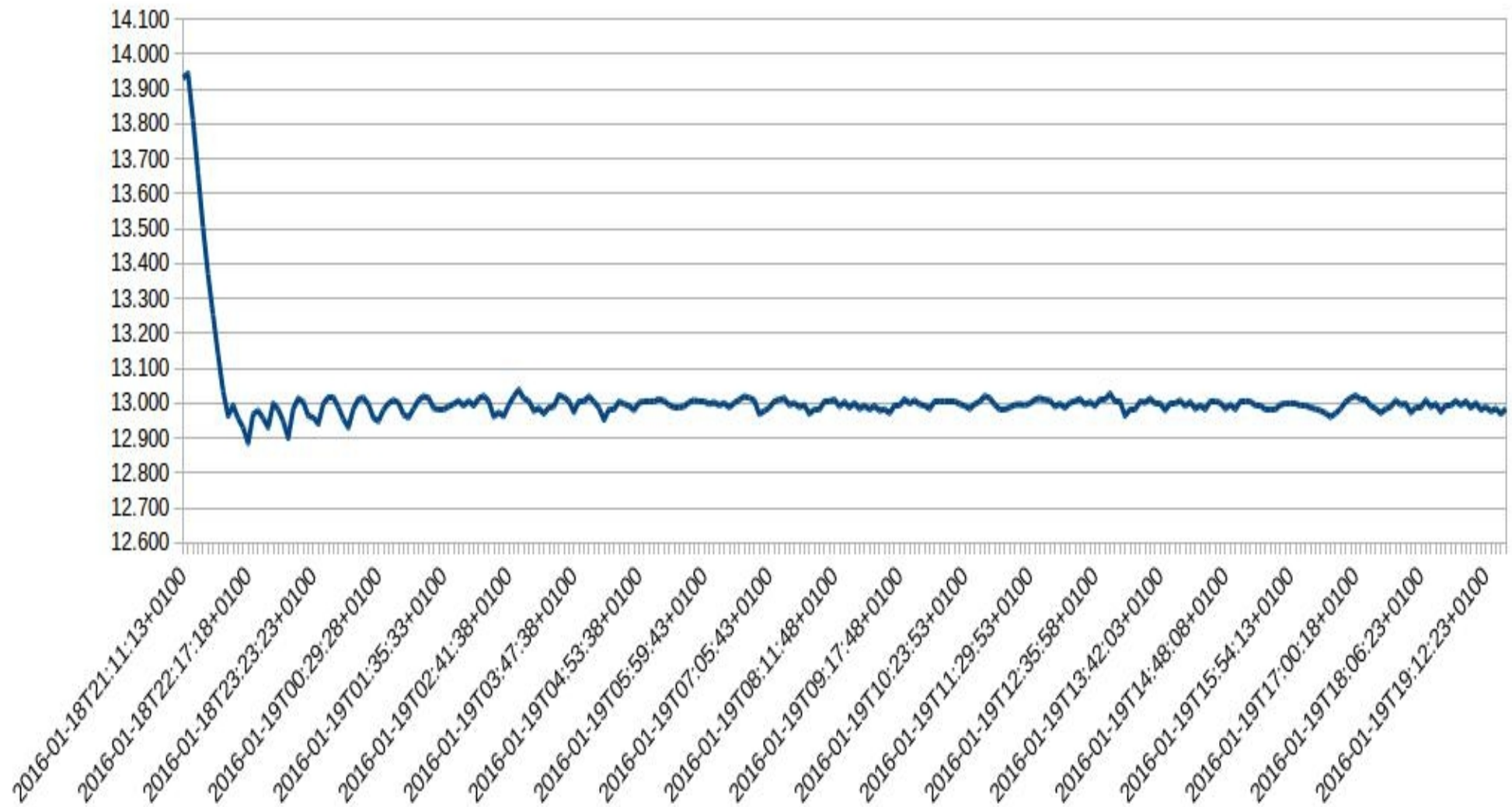
KP=211.76, KI=121.01, KD=92.65, Set=14deg
Duty



PID-6, Step-down

KP=211.76, KI=121.01, KD=92.65, Set=13deg

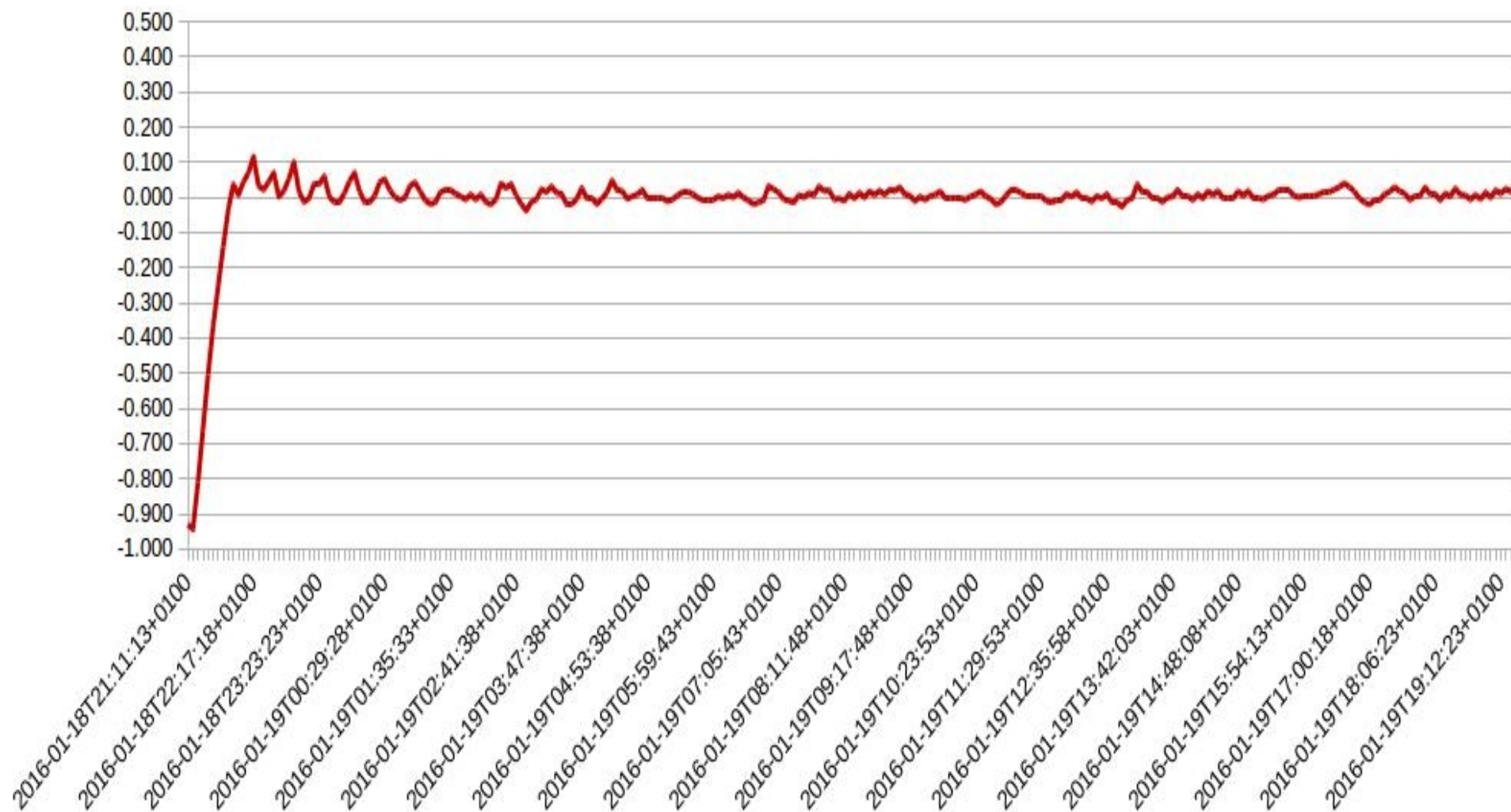
Actual Temperature



PID-6, Step-down

KP=211.76, KI=121.01, KD=92.65, Set=13deg

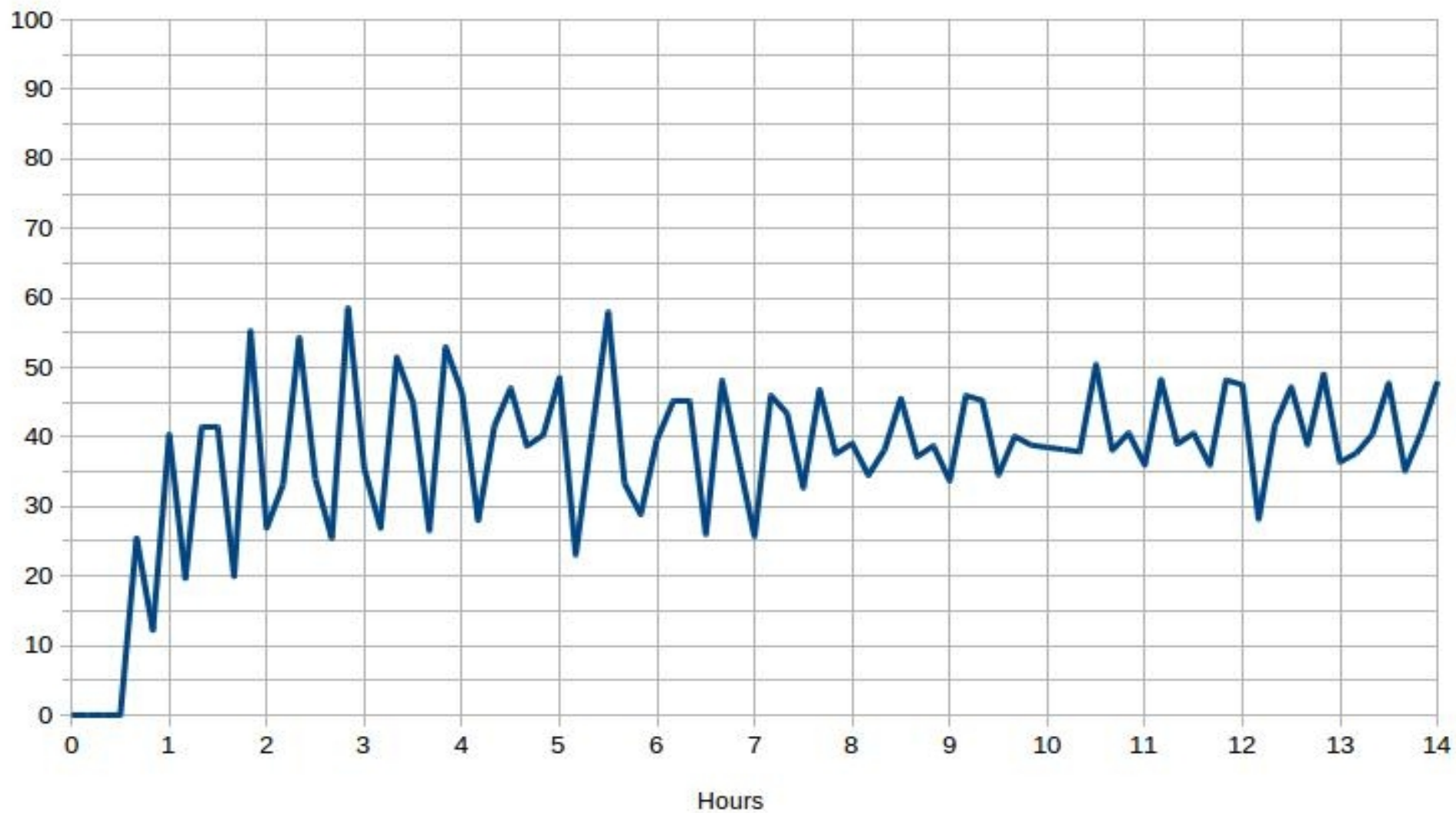
Error



PID-6, Step-down

KP=211.76, KI=121.01, KD=92.65, Set=13deg

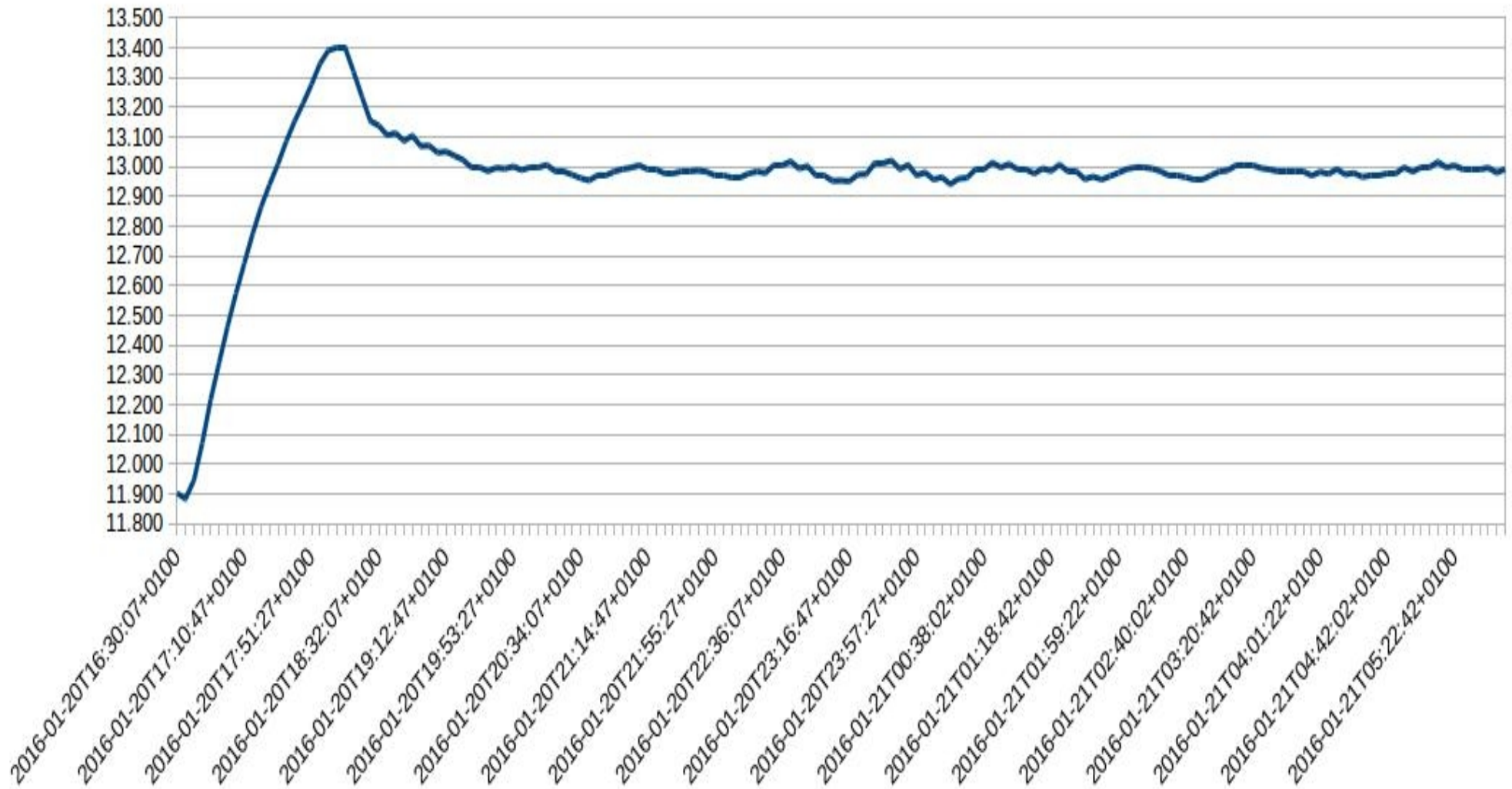
Duty



PID-7, Step-up

KP=163.64, KI=42.10, KD=0, Set=13deg

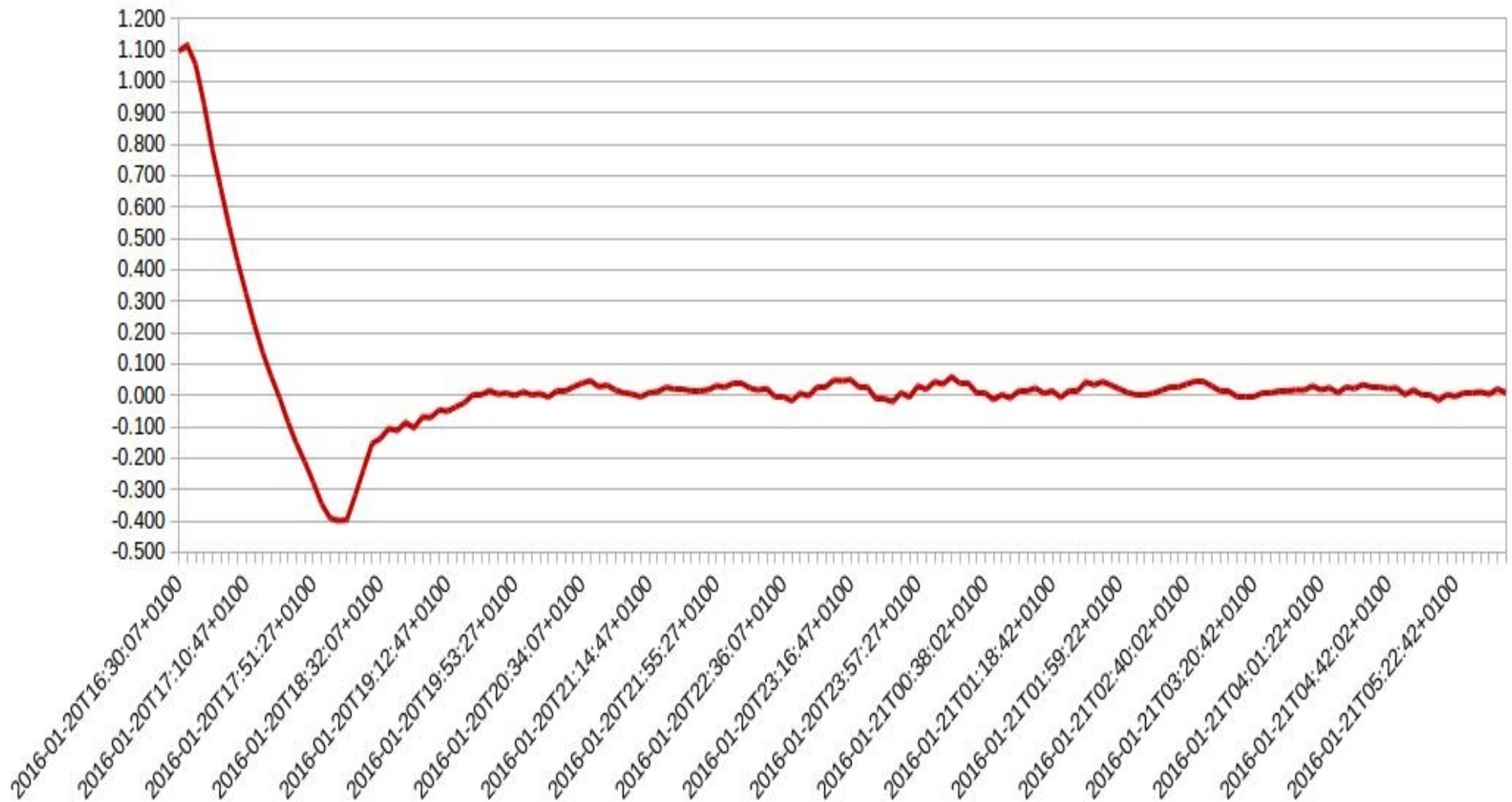
Actual Temperature



PID-7, Step-up

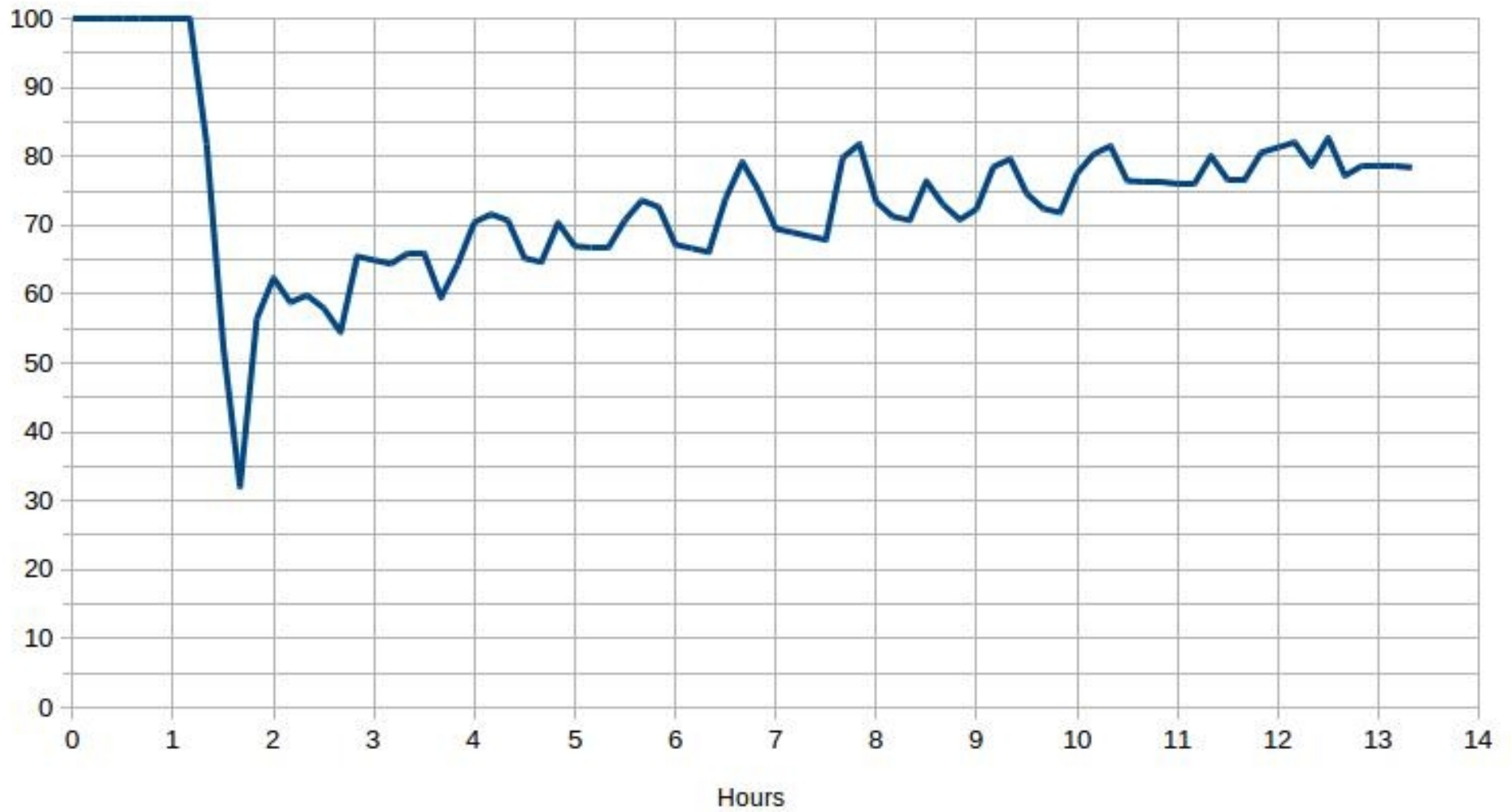
KP=163.64, KI=42.10, KD=0, Set=13deg

Error



PID-7, Step-up

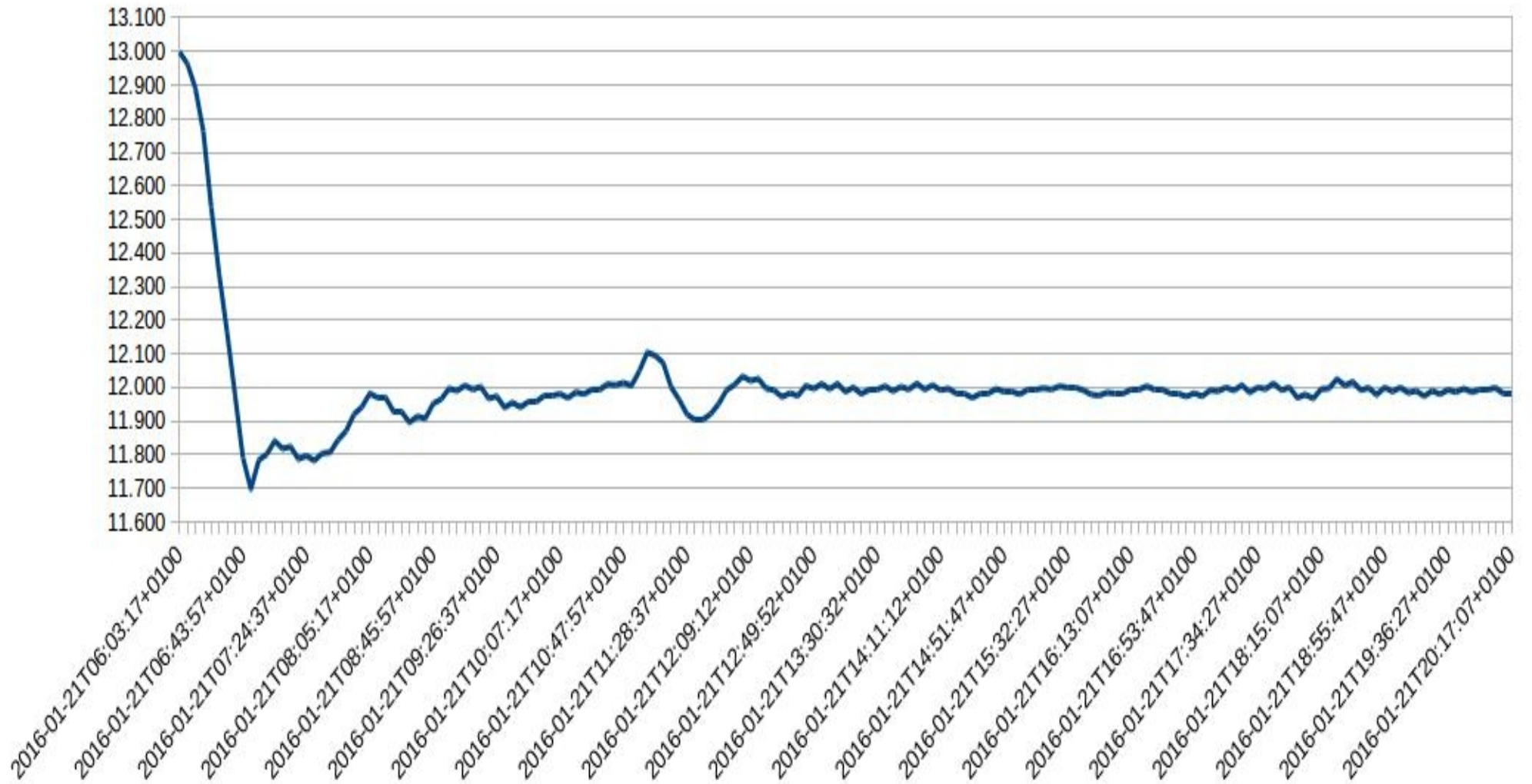
KP=163.64, KI=42.10, KD=0, Set=13deg
Duty



PID-7, Step-down

KP=163.64, KI=42.10, KD=0, Set=12deg

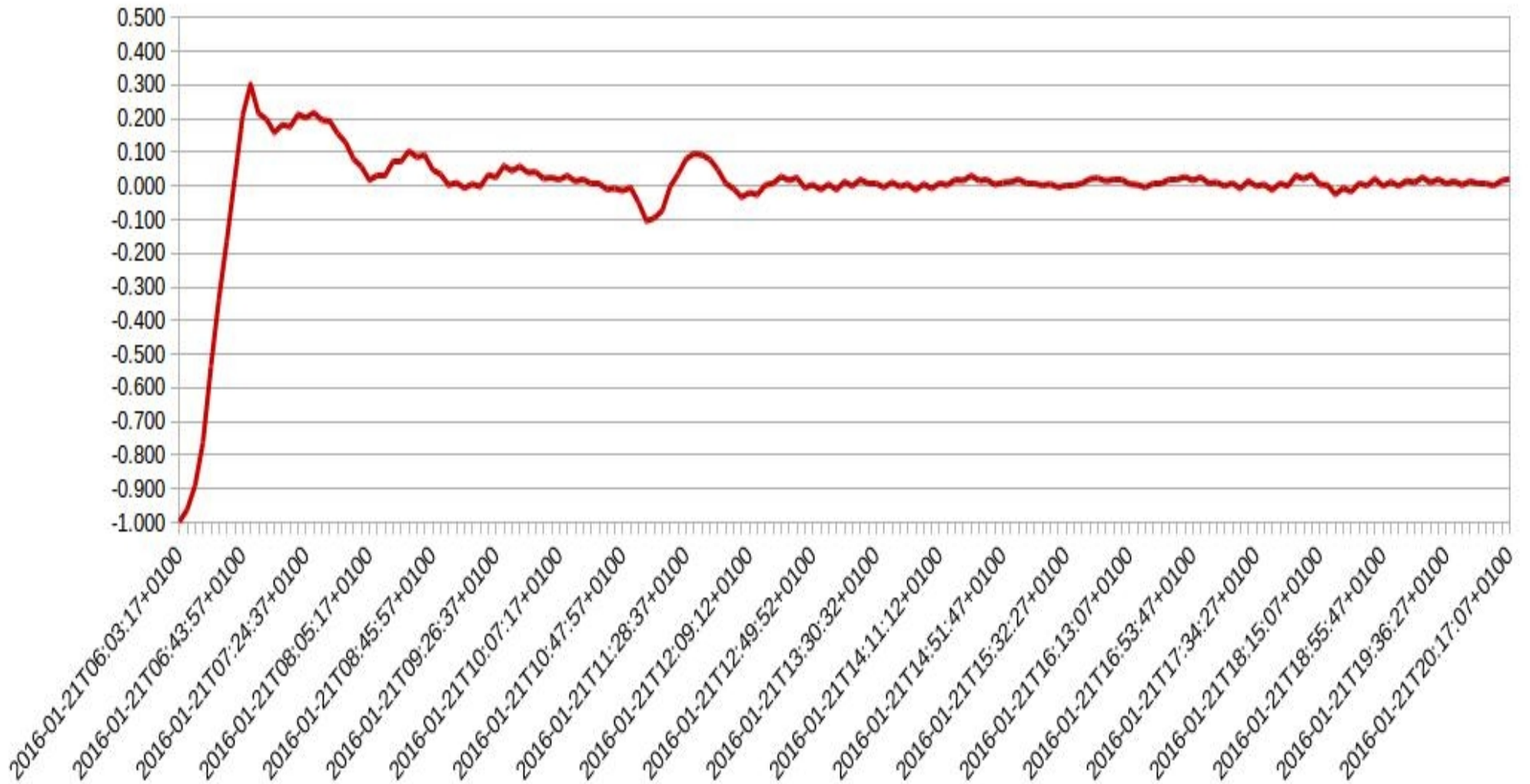
Actual Temperature



PID-7, Step-down

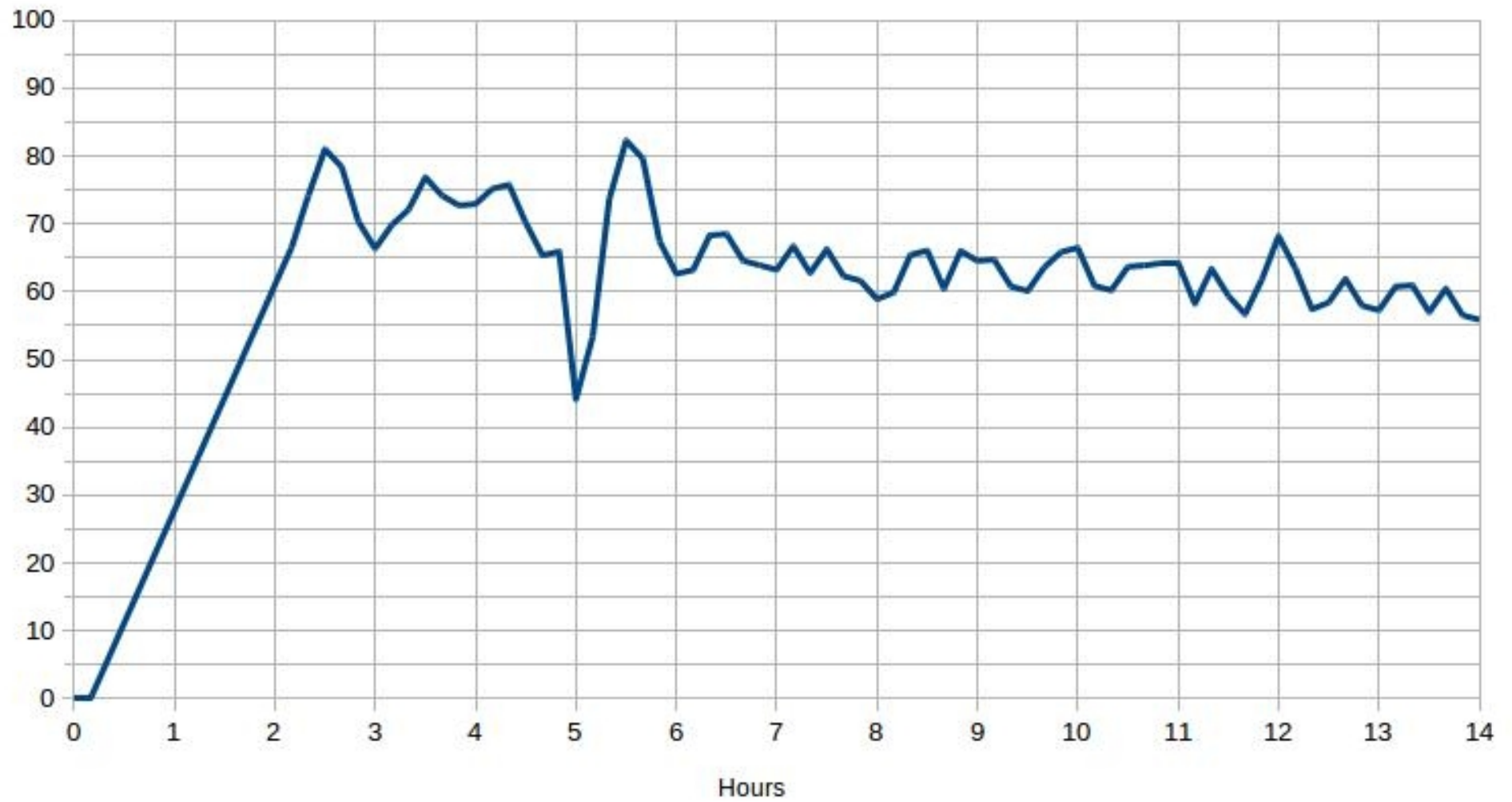
KP=163.64, KI=42.10, KD=0, Set=12deg

Error



PID-7, Step-down

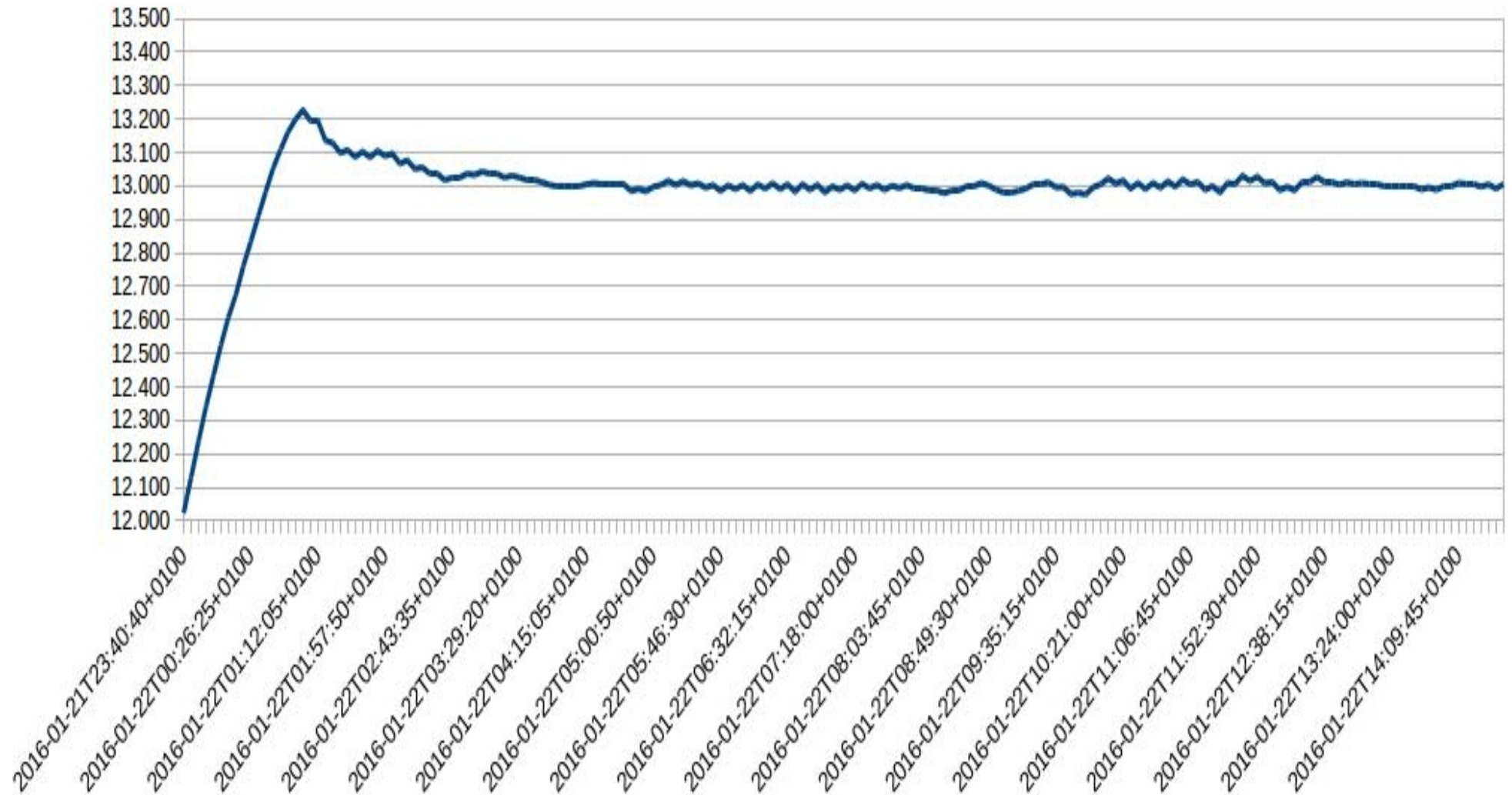
KP=163.64, KI=42.10, KD=0, Set=12deg
Duty



PID-8, Step-up

KP=163.64, KI=28.05, KD=0, Set=13deg

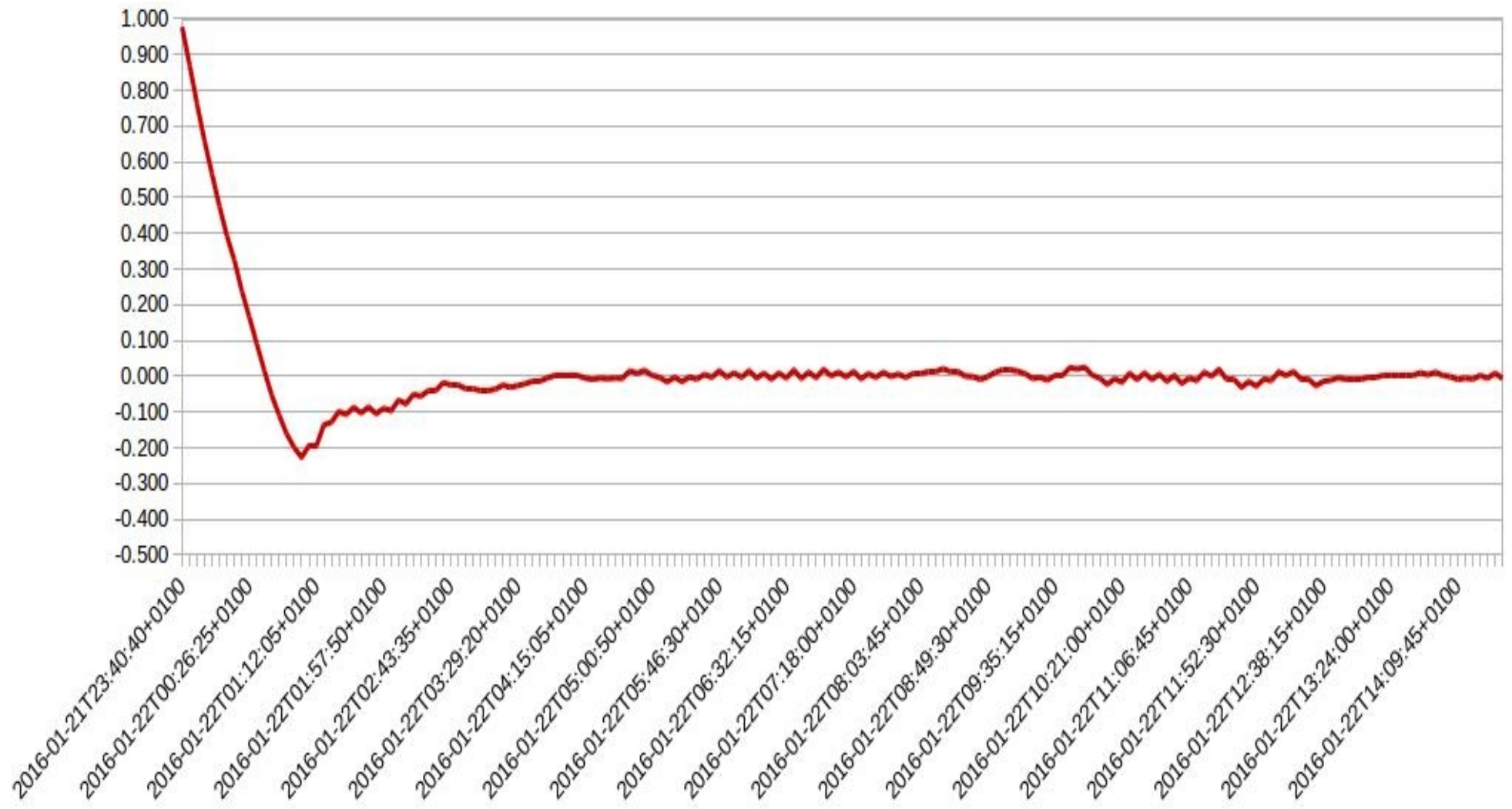
Actual Temperature



PID-8, Step-up

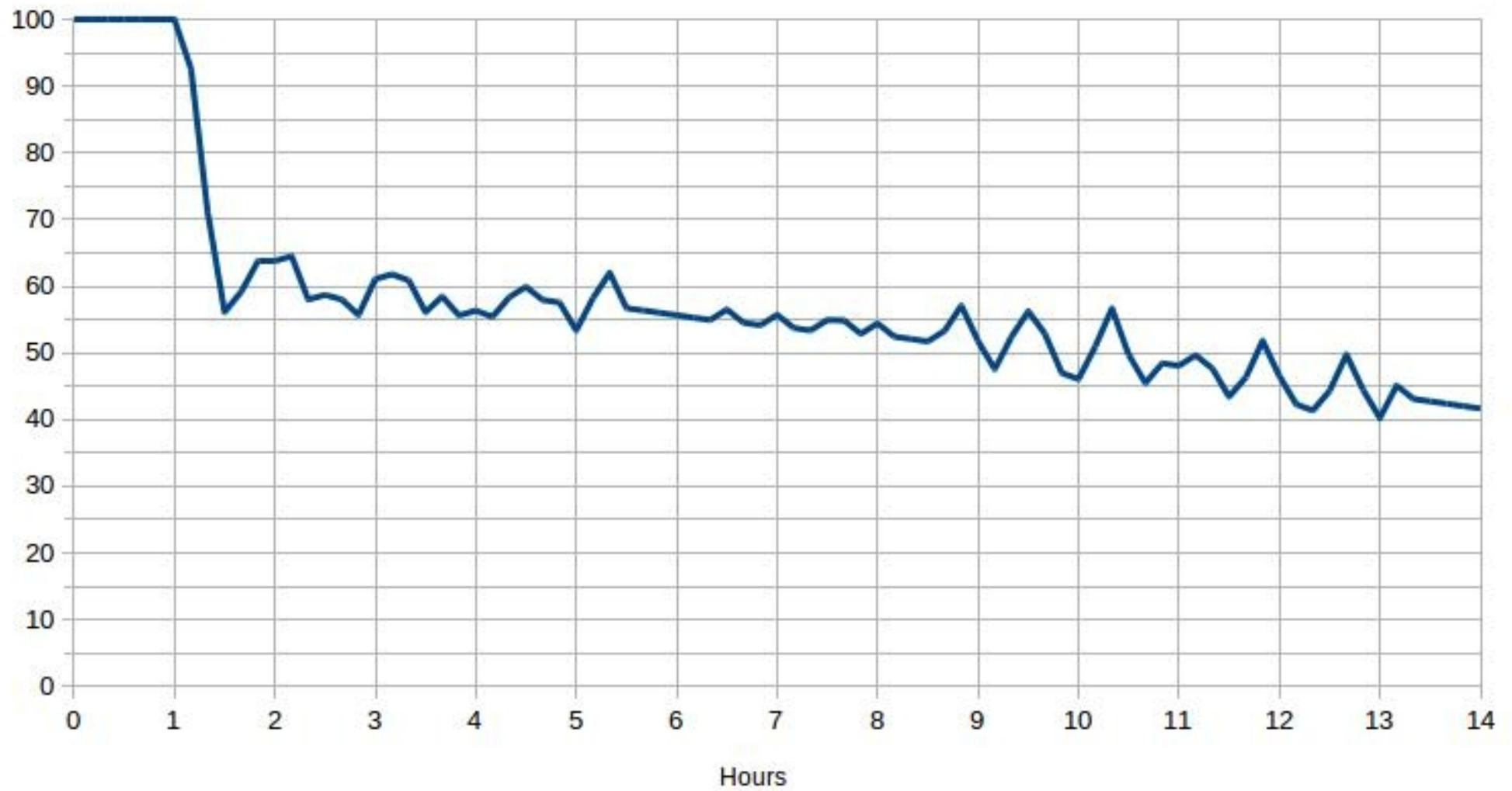
KP=163.64, KI=28.05, KD=0, Set=13deg

Error



PID-8, Step-up

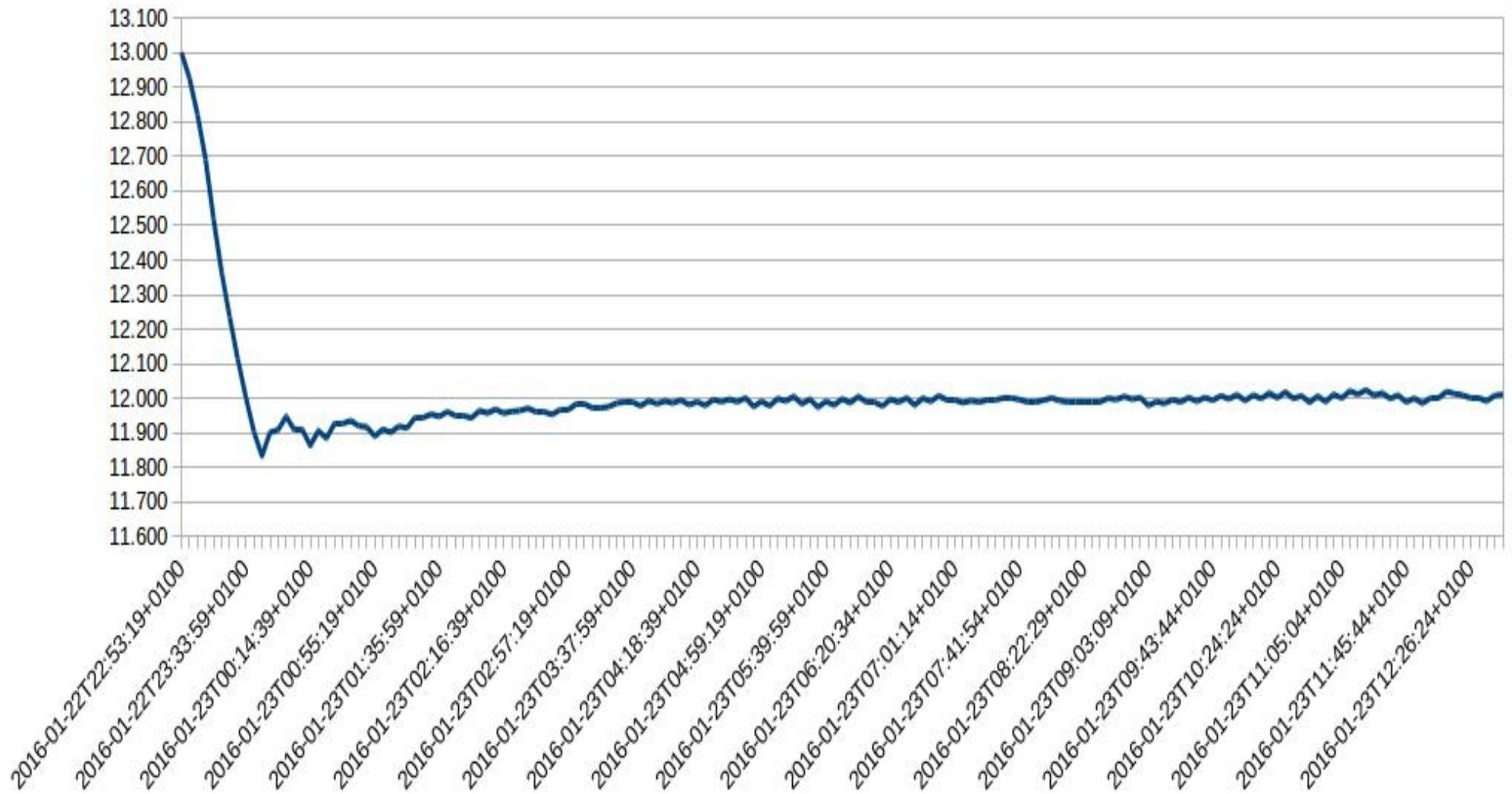
KP=163.64, KI=28.05, KD=0, Set=13deg
Duty



PID-8, Step-down

KP=163.64, KI=28.05, KD=0, Set=12deg

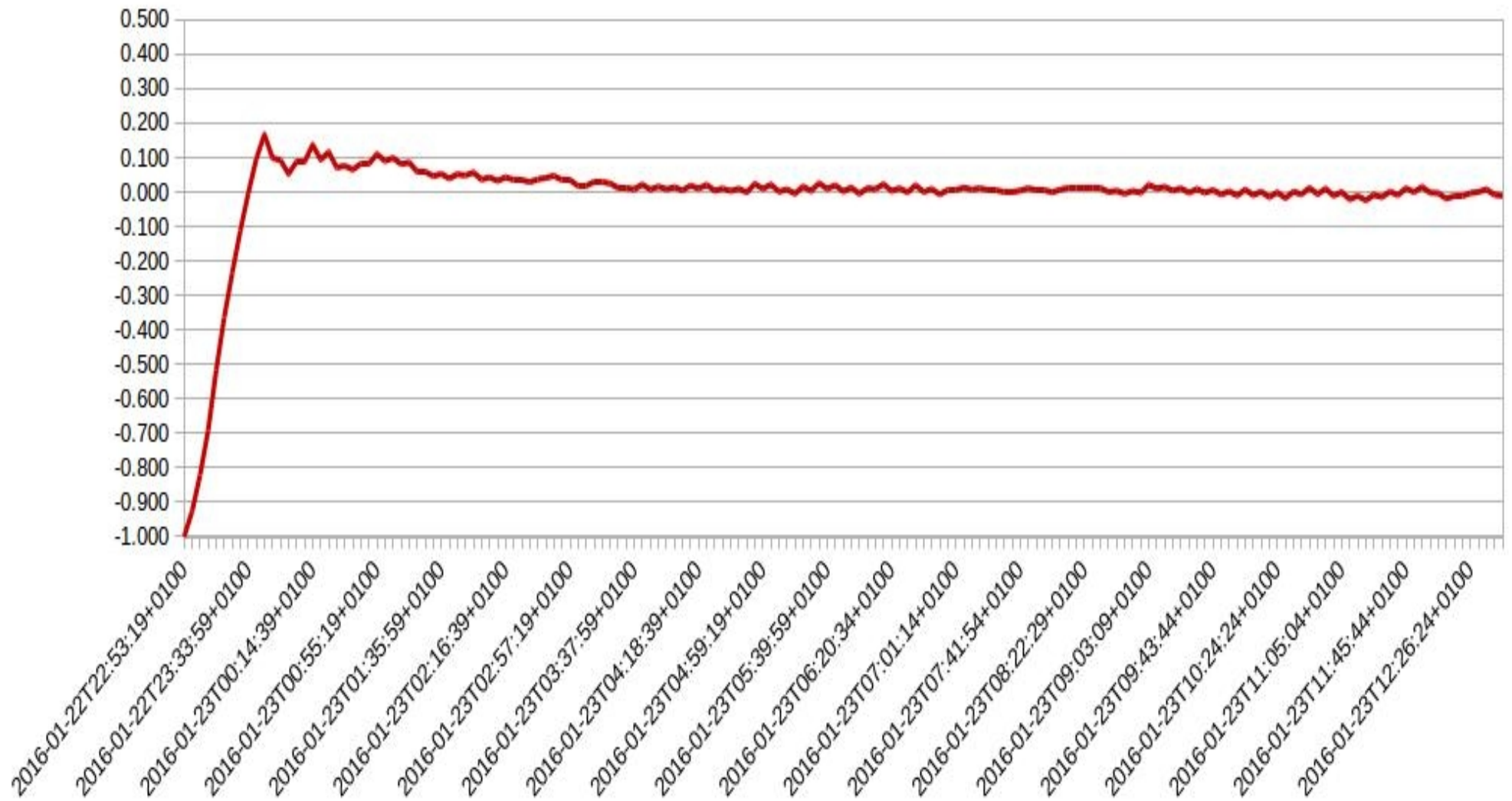
Actual Temperature



PID-8, Step-down

KP=163.64, KI=28.05, KD=0, Set=12deg

Error



PID-8, Step-down

KP=163.64, KI=28.05, KD=0, Set=12deg
Duty

