# Temperature PID Control

A practical approach using Ziegler-Nichols

Caramon Pi

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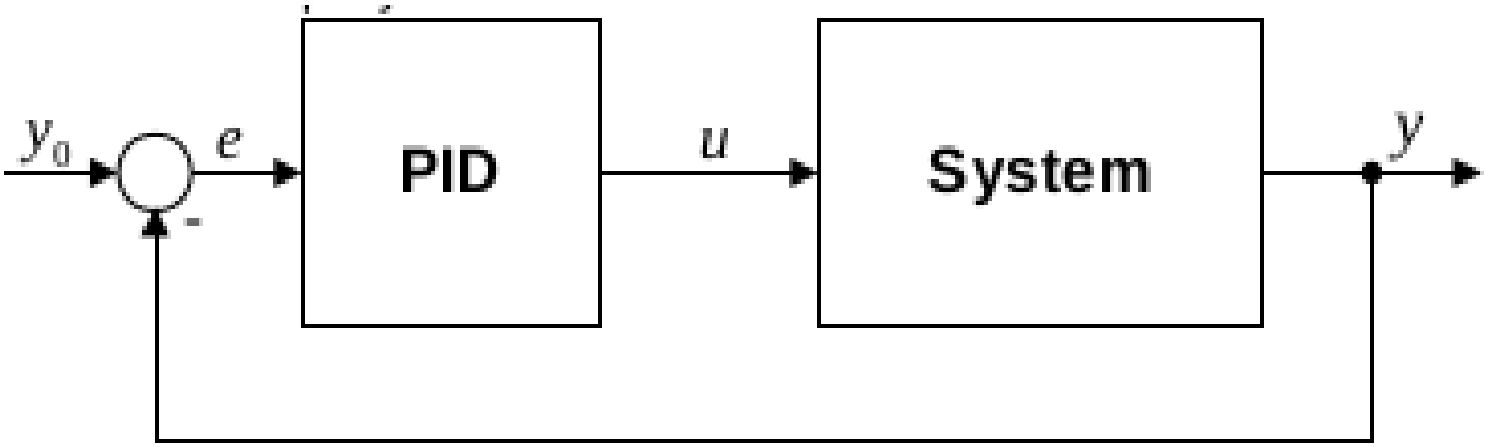
# Closed Loop System



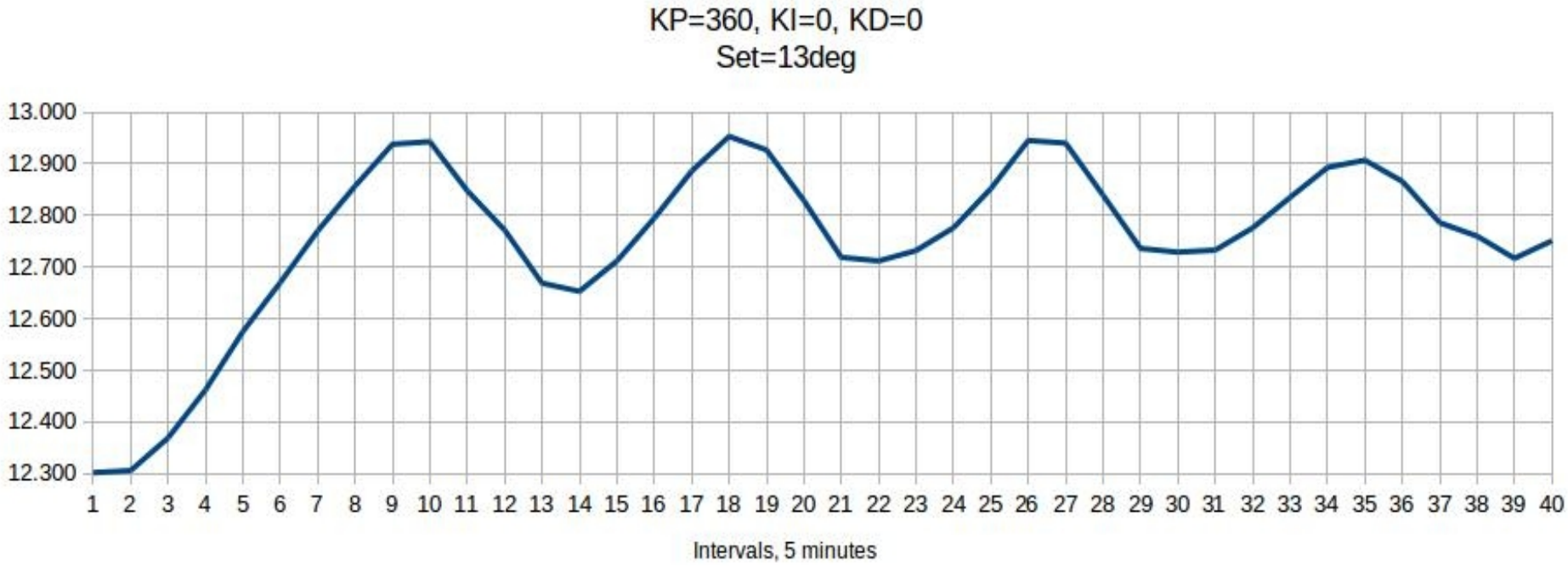

PID algorithm $$\mathrm{u}(t) = \mathrm{MV}(t) = K_p e(t) + K_i \int_0^t e(\tau)\,d\tau + K_d \frac{de(t)}{dt}$$

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

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

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

# Ziegler-Nichols




Closed-loop tuning method

Ulitmate gain, Ku=360

Ultimate period, Pu=35 minutes = 2100 sec

Sample time, Ts = 10 minutes = 600 sec (*)

**(*) Values measured 2016 using CMON R1Axx**

| | Kp | Ti | Td |
|---|---|---|---|
| P | Ku / 2 | - | - |
| PI | Ku / 2.2 | Pu / 1.2 | - |
| PID | Ku / 1.7 | Pu / 2 | Pu / 8 |

# Controller Parameters

| | |
|---|---|
| Ku | 360 |
| Pu [s] | 2100 |
| Ts [s] | 60 |

Z-N

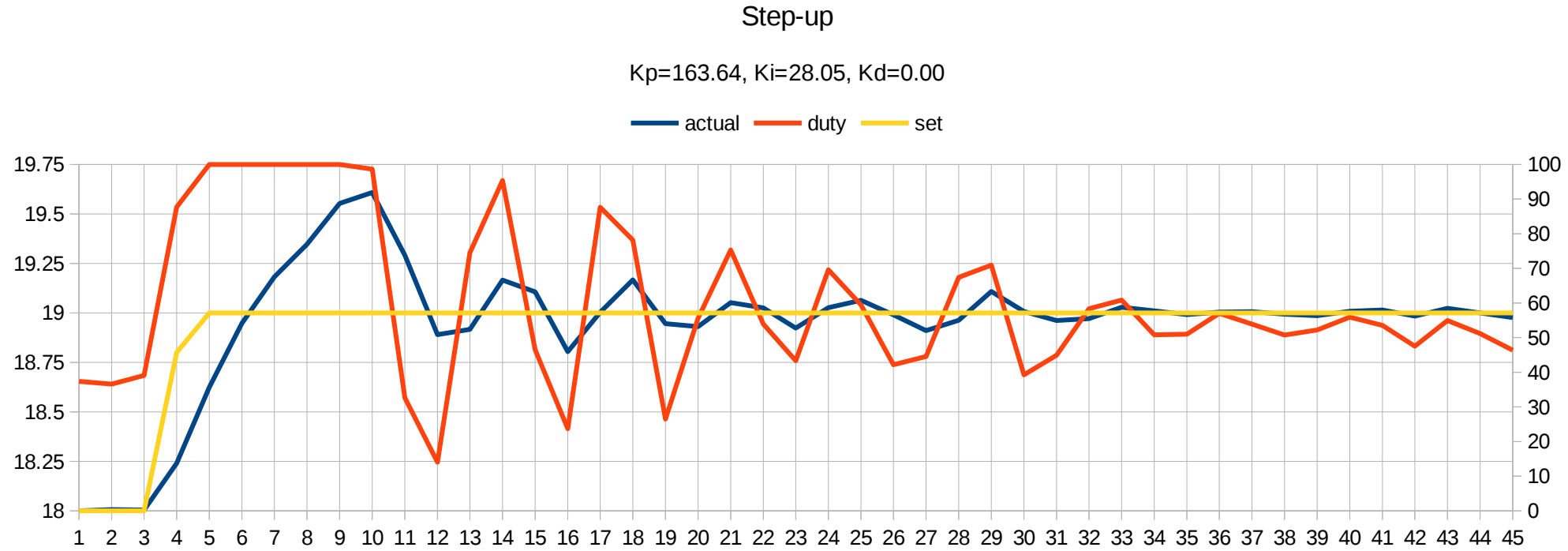
| | Kp | Ti [s] | Td [s] |
|---|---|---|---|
| P | 180.00 | - | - |
| PI | 163.64 | 1750 | - |
| PID | 211.76 | 1050 | 262.50 |

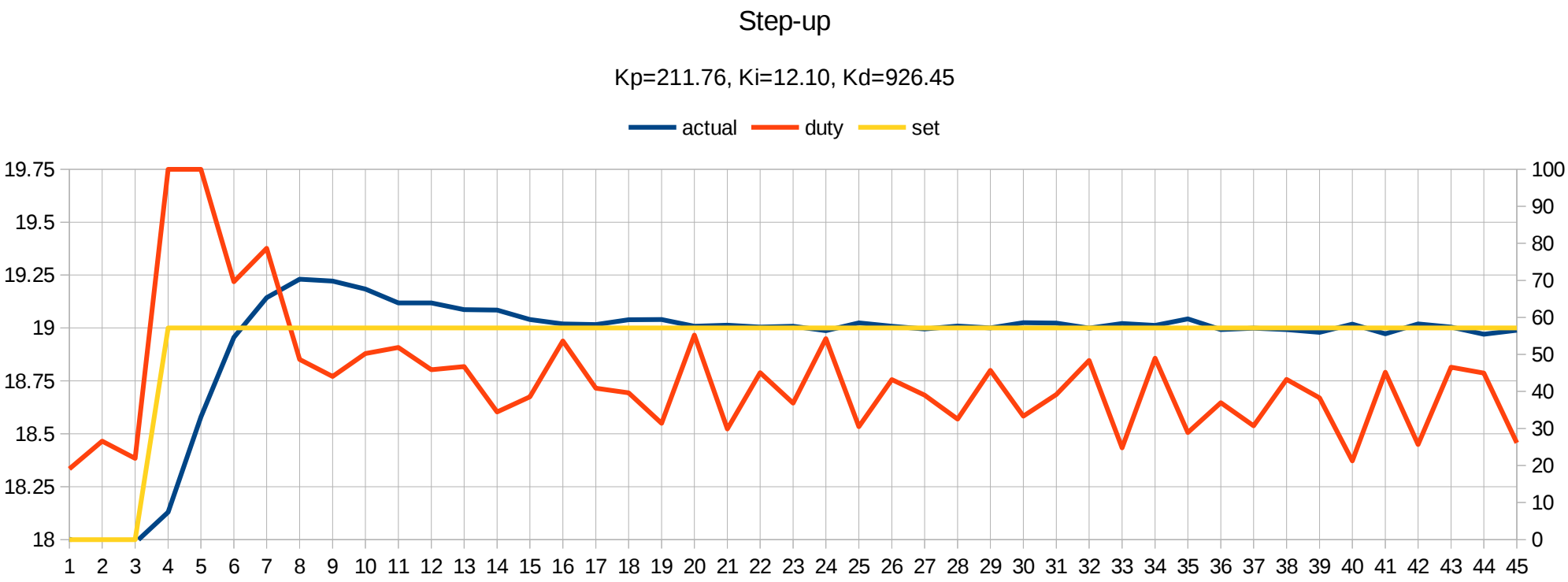
Sample time decreased from 600s to 60s.
Possible due to new hardware with SSR.

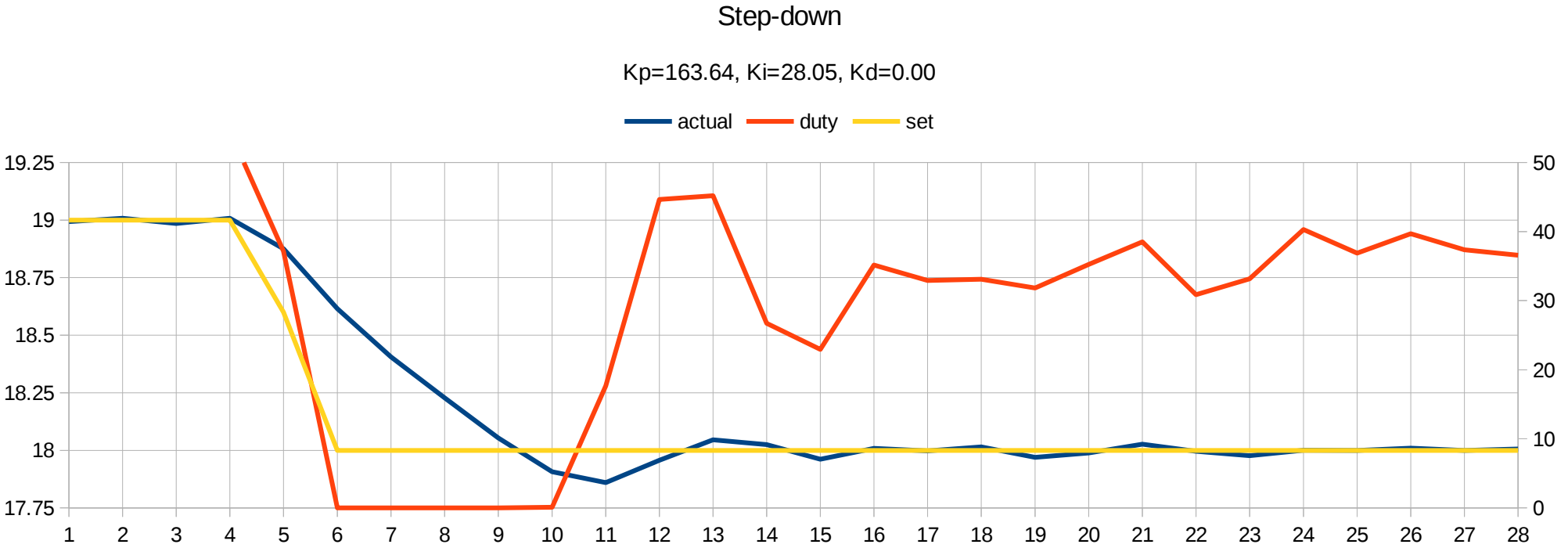
Ki = (Kp x Ts) / Ti

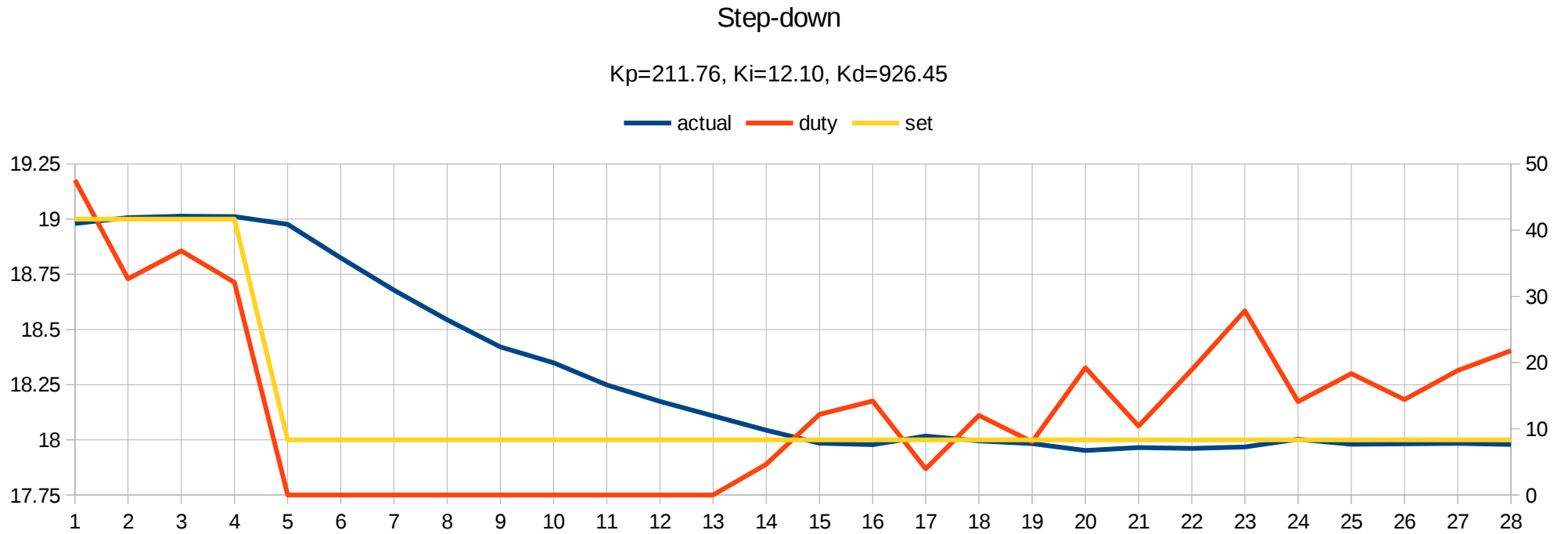
Kd = (Kp x Td) / Ts

| | Kp | Ki | Kd | Comment |
|---|---|---|---|---|
| PID-1 | 163.64 | 5.61 | - | Z-N, PI |
| PID-2 | 211.76 | 12.10 | 926.45 | Z-N, PID |
| PID-3 | 163.64 | 28.05 | - | PID from CMON R1Axx |


Step-up
Kp=163.64, Ki=28.05, Kd=0.00
actual
duty
set
19.75
19.5
19.25
19
18.75
18.5
18.25
18
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45


Step-up
Kp=211.76, Ki=12.10, Kd=926.45
actual
duty
set
19.75
19.5
19.25
19
18.75
18.5
18.25
18
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45


Step-down
Kp=163.64, Ki=28.05, Kd=0.00
actual
duty
set
19.25
19
18.75
18.5
18.25
18
17.75
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28


Step-down
Kp=211.76, Ki=12.10, Kd=926.45
actual
duty
set
19.25
19
18.75
18.5
18.25
18
17.75
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

# Conclusions

- PID-2 is a “true” ZN PID using Ts=60s.
- PID-3 was derived 2016 using Ts=600s.
  Not fitted for the new hardware using SSR and with less Ts.
  Is a PI and not PID.
- PID-2 has less overshot compared to PID-3.
- PID-2 settles faster than PID-3.
- PID-2 seems less “aggressive” on step-up.
- Both PIDs perform well on step-down.
- The slower decrease of temperature on step-down for PID-2 can be explained by the fact that outdoor temperature was higher during this experiment.
- Some questions can be raised about using the old values for Ku and Pu, as they were derived using Ts=600s. It could be necessary to perform new experiments using the new hardware with Ts=60s.