OAK RIDGE National Laboratory

EPICS Database Exercises

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Many slides from Andrew Johnson, APS/ANL

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Extending “ramp_with_limit.db” further

```
# A ramp from 0 to 'limit', were limit

# can be configured via a separate record

record(ao, "$(S):limit")

{

   field(DRVH, "100")

   field(DOL,  "10")

   field(PINI, "YES")

}



record(calc, "$(S):ramp")

{

   field(SCAN, "1 second")

   field(INPA, "$(S):ramp")

   field(INPB, "$(S):limit")

   field(CALC, "A<B ? A+1 : 0")

}
```

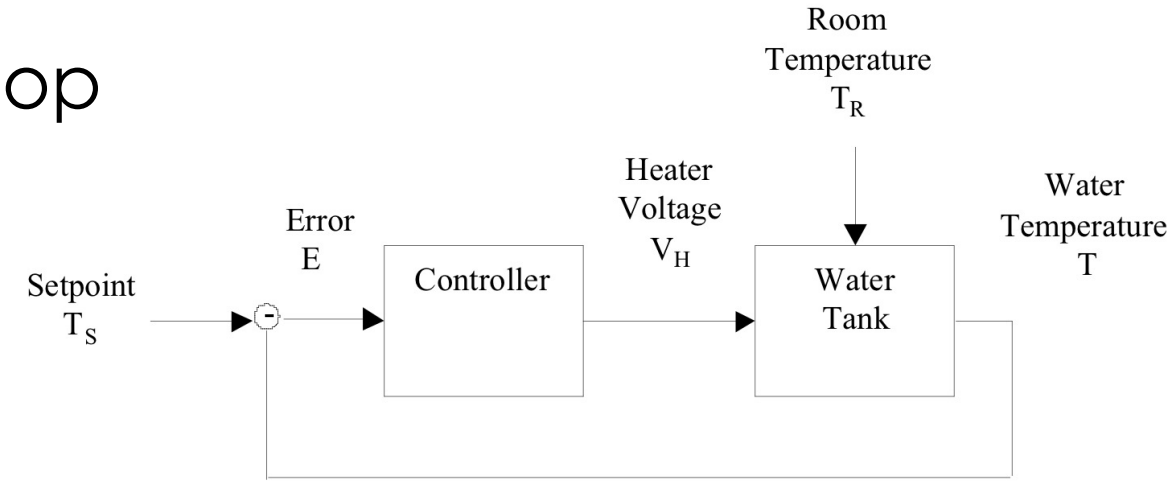
1. Add a “$(S):step” record and use it in the CALC to allow stepping the ramp in increments between 0.1 and 5.
2. Create a display for all 3 records.
3. Make the “..ramp” display units of “a.u.” and have it show 2 digits after the decimal point
4. Add a widget to the display that allows controlling the rate at which the logic processes
5. Configure the “..ramp” to generate an alarm when the value is above 8
6. Configure the “..ramp” to only send values to an archive when the value changes by 2 or more
7. Add an analog output record which, when processed, resets the “..:limit” to 10. Add a button to the display which triggers this reset.

Binary records

1. Create a BO with values “Normal” and “Doubled”, add to display
2. Use in the “..:ramp” to double the effective step size
3. Configure the BO such that when setting it to “Doubled”, it will revert to “Normal” after 5 seconds

Heater Control Simulation

- Typical control loop



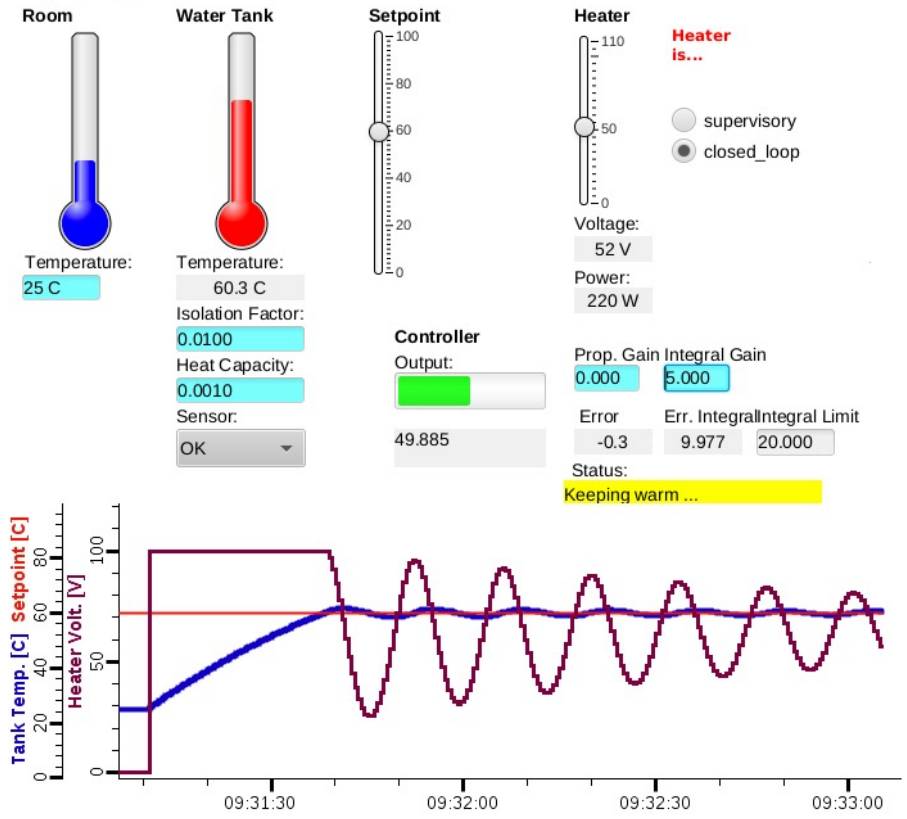
- PID Controller

$$O(n) = K_P\ E(n) + K_I \sum_i E(i)\ dT + K_D\ [E(n)-E(n-1)]/dT$$

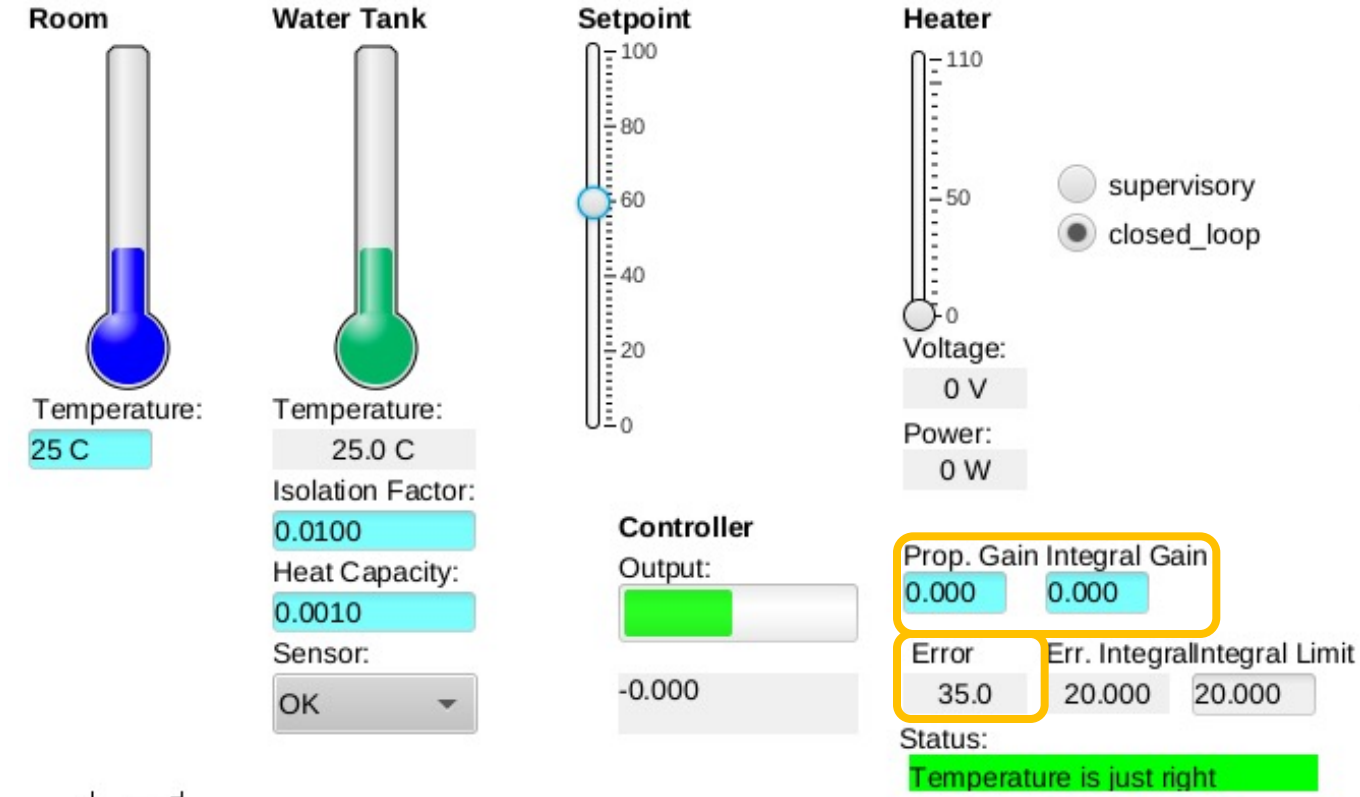
  - Update period dT
  - Error readings $E(n)$
  - Output $O(n)$
  - Proportional Gain K_P, Integral K_I, Derivative K_D

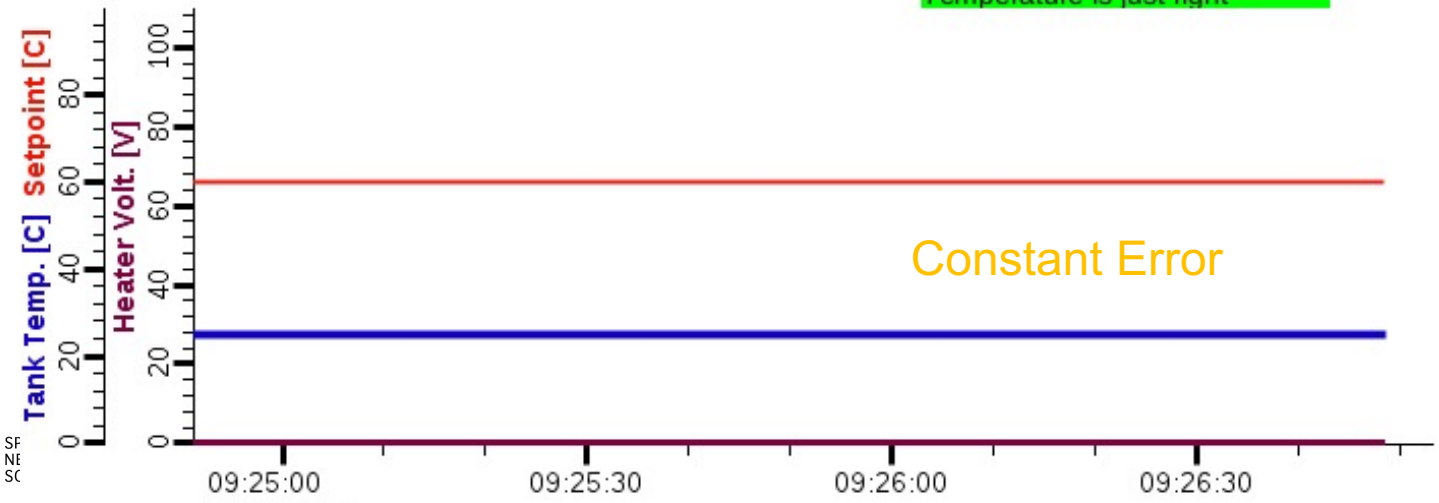
Study the "fishtank" example

1. Go to examples/*fishtank
2. Start IOC: ./st.cmd
3. Open heater.bob



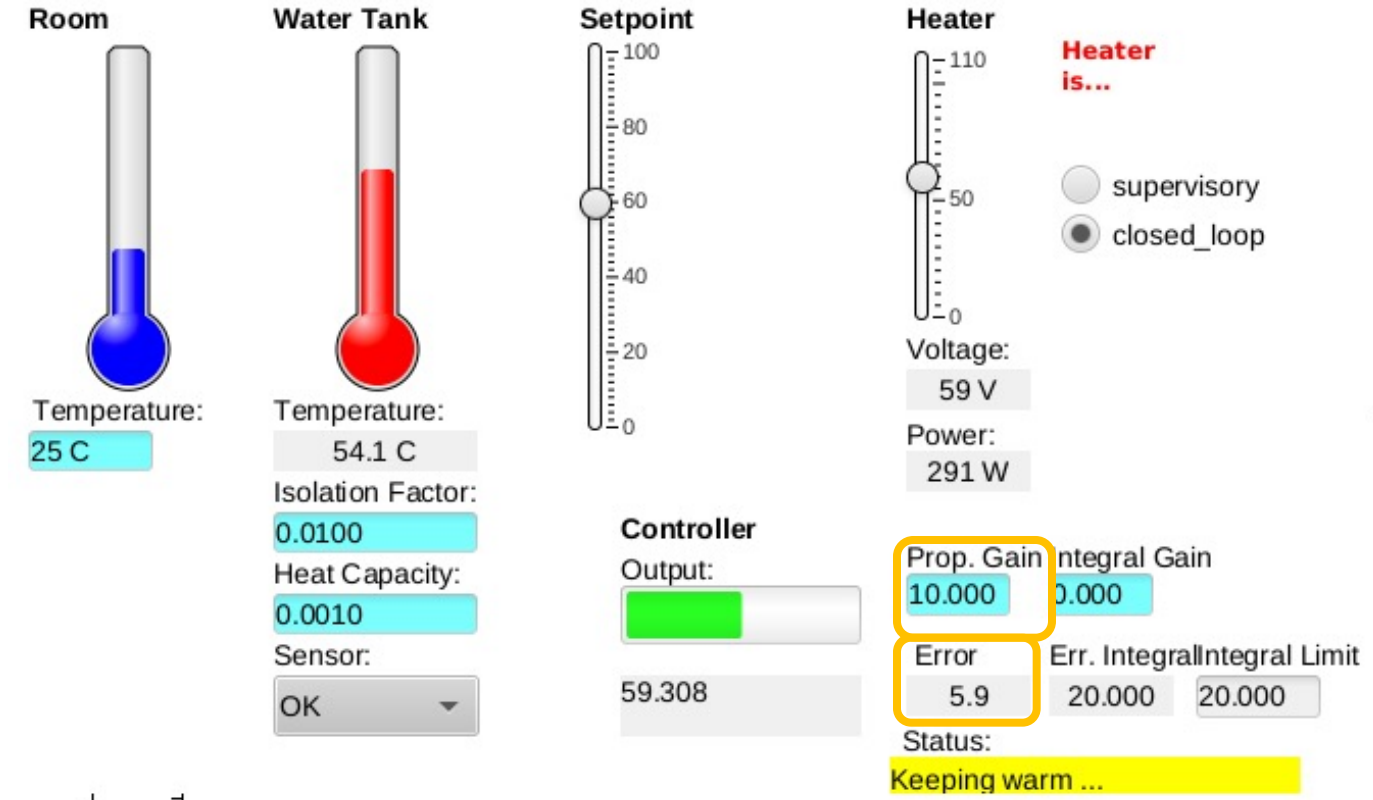
No Control

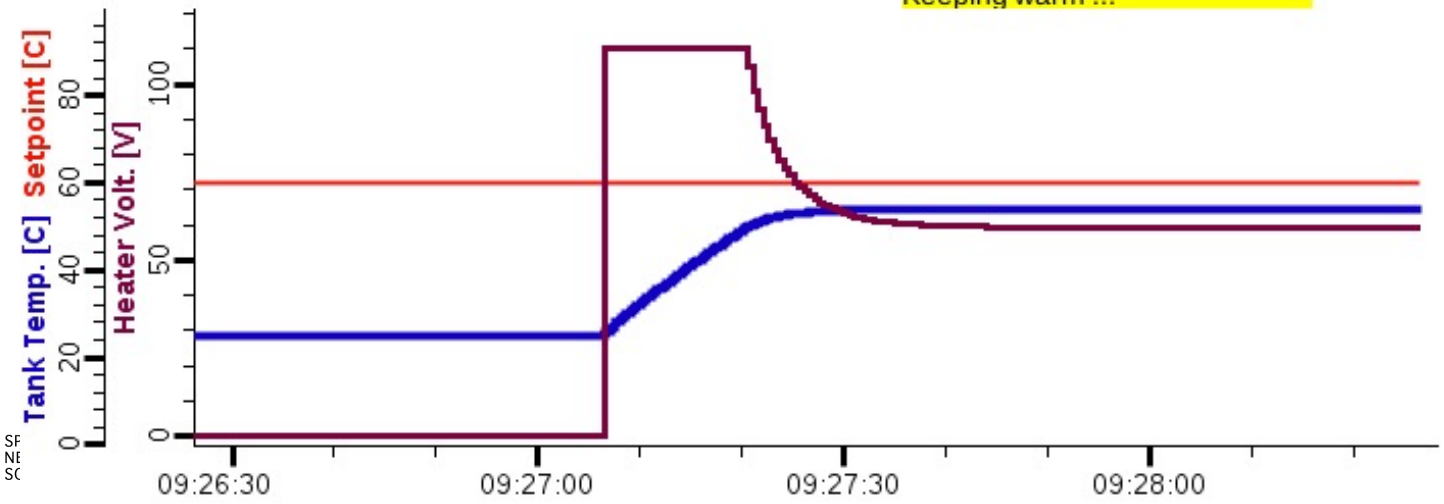




1. Set the Prop and Int. gain to zero
2. Verify that tank temperature ignores the Setpoint

Only Proportional Control

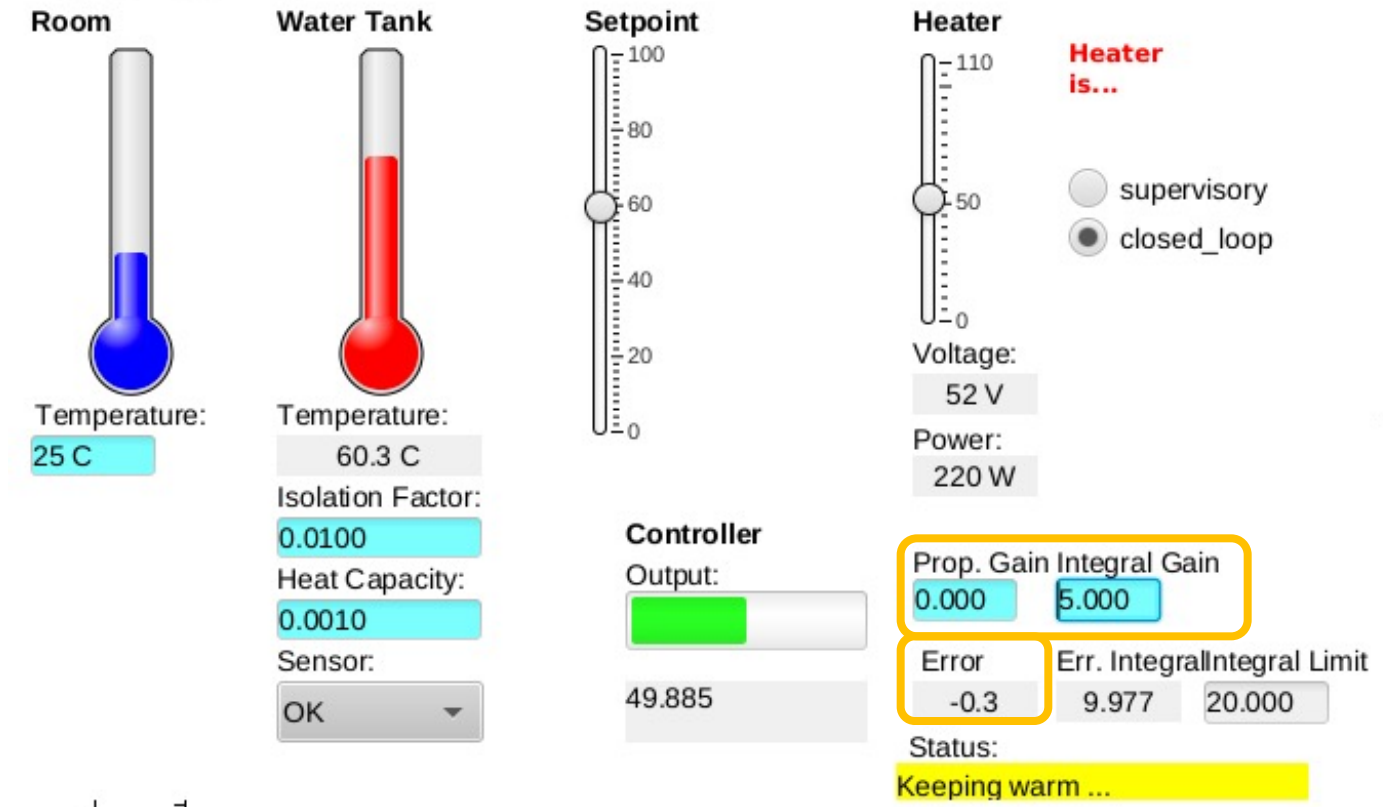


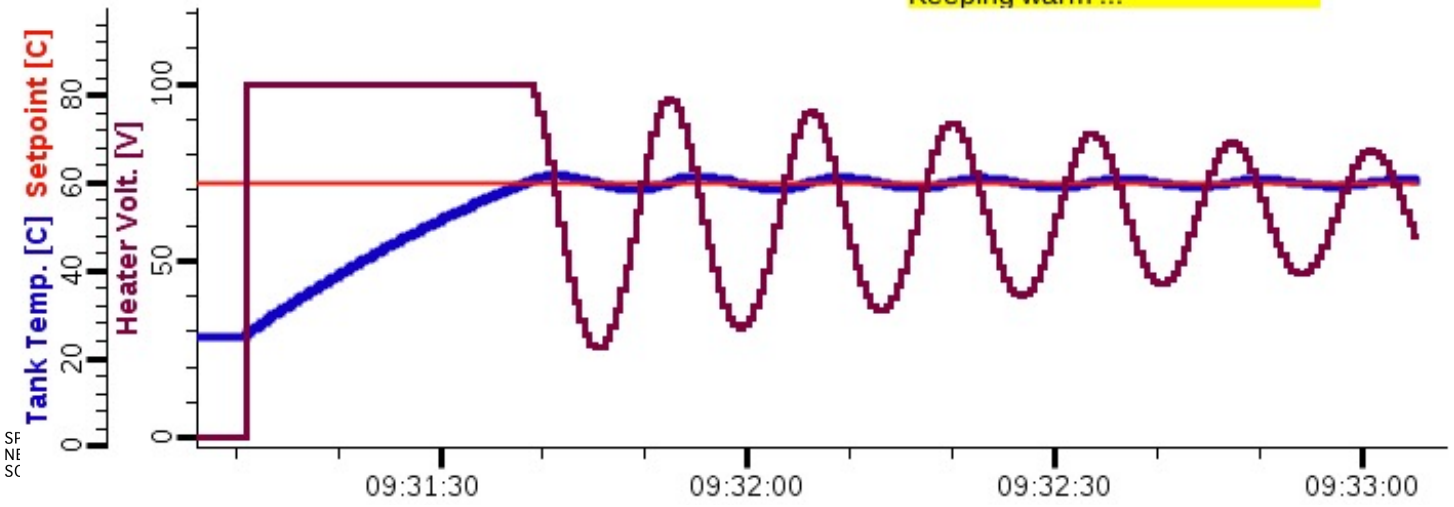


1. Set the Prop. gain
2. Verify that tank temperature reacts to setpoint, but doesn't quite reach it

Small residual Error

Only Integral Control





1. Set only the Integral gain
2. Verify that tank temperature reacts to setpoint. Can you find a good value for the int. gain?

Eventually, no Error!

.. but Ringing

Study database: User Inputs to Simulation

- Note use of Macros
- Note use of Analog *Output* for user *Input* because of DRVL/DRVL

```
record(ao, "$(user):room")
{
    field(DESC, "Room Temperature")
    field(EGU, "C")
    field(HOPR, "40")
    field(LOPR, "0")
    field(DRVL, "0")
    field(DRVH, "40")
    field(DOL, "25")
    field(PINI, "YES")
}
```

```
record(ao, "$(user):setpoint")
{
    field(DESC, "Temperature Setpoint")
    field(EGU, "C")
    field(HOPR, "0")
    field(LOPR, "100")
    field(DRVL, "0")
    field(DRVH, "100")
    field(PREC, "1")
    field(DOL,  "30")
    field(PINI, "YES")
}
```

Simulated Tank Temperature

```
# supervisory: user can adjust voltage
# closed_loop: PID (in separate control.db) sets voltage
# When PID is INVALID, go back to 0 voltage
record(ao, "$(user):heat_V")
{
    field(DESC, "Heater Voltage")
    field(EGU, "V")
    field(DRVL,"0")
    field(DRVH,"110")
    field(DOL, "$(user):PID MS")
    field(OMSL,"closed_loop")
    field(IVOA, "Set output to IVOV")
    field(IVOV, "0")
}

# ~1100 Watt heater when run with 110V:
# P = U I = U^2 / R,  R~12 Ohm
record(calc, "$(user):heat_Pwr")
{
    field(DESC, "Heater Power")
    field(EGU, "W")
    field(INPA, "$(user):heat_V PP NMS")
    field(CALC, "A*A/12.1")
}
```

```
# Every second, calculate new temperature
# based on current temperature,
# room temperature and heater
#
# A - current temperature
# B - room temperature
# C - heater power
# D - isolation factor (water <-> room)
# E - heat capacity (would really depend on water volume)
#
# Very roughly with
# T(n+1) = T(n) + [Troom-T(n)]*Isolation_factor
#          + heater_pwr * heat_capacity
record(calc, "$(user):tank_clc")
{
    field(DESC,"Water Tank Simulation")
    field(SCAN,"1 second")
    field(INPA,"$(user):tank_clc.VAL")
    field(INPB,"$(user):room")
    field(INPC,"$(user):heat_Pwr PP NMS")
    field(INPD,"0.01")
    field(INPE,"0.001")
    field(CALC,"A+(B-A)*D+C*E")
    field(FLNK,"$(user):tank")
}
```

- What causes all these records to process?

PID (without D) Computation

```
# Error computation's SCAN drives the rest
record(calc, "$(user):error")
{
    field(DESC, "Temperature Error")
    field(SCAN, "1 second")
    field(INPA, "$(user):setpoint")
    field(INPB, "$(user):tank MS")
    field(CALC, "A-B")
    field(PREC, "1")
    field(FLNK, "$(user):integral")
}
# Integrate error (A) but assert that
# it stays within limits (C)
record(calc, "$(user):integral")
{
    field(DESC, "Integrate Error for PID")
    field(PREC, "3")
    field(INPA, "$(user):error PP MS")
    field(INPB, "$(user):integral")
    field(INPC, "20.0")
    field(CALC, "(B+A>C)?C:(B+A<-C)?(-C):(B+A)")
    field(FLNK, "$(user):PID")
}
```

```
# PID (PI) computation of new output
# A - Kp
# B - error
# C - Ki
# D - error integral
record(calc, "$(user):PID")
{
    field(DESC, "Water Tank PID")
    field(PREC, "3")
    field(LOPR, "0")
    field(HOPR, "110")
    field(INPA, "10.0")
    field(INPB, "$(user):error MS")
    field(INPC, "5.0")
    field(INPD, "$(user):integral MS")
    field(CALC, "A*B+C*D")
}
```

Add Differential Control

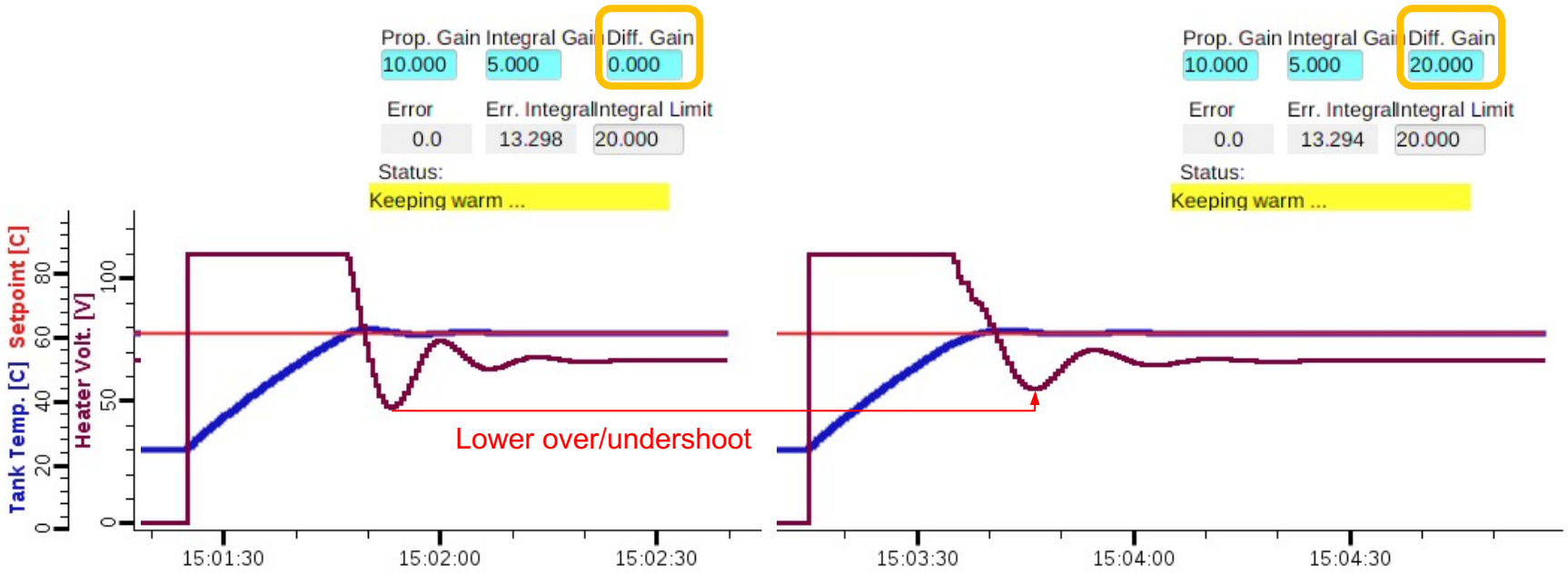
- **"Patch" database**
- **How does it change the processing of records?**

```
# Update 'error':
# Make passive (now triggered by new 'error_diff'
record(calc, "$(user):error")
{
    field(SCAN, "Passive")
}

# New computation of change in error triggers
# the error computation
record(calc, "$(user):error_diff")
{
    field(DESC, "Temperature Difference")
    field(SCAN, ".5 second")
    field(INPA, "$(user):error")
    field(INPB, "$(user):error MS PP")
    field(CALC, "(B-A)/0.5")
}

# Every second, calculate new heater voltage via PID (PI)
# A - Kp
# B - error
# C - Ki
# D - error integral
# E - Kd
# F - error differential
record(calc, "$(user):PID")
{
    field(INPE, "0.0")
    field(INPF, "$(user):error_diff MS")
    field(CALC, "A*B+C*D+E*F")
}
```

Adding Differential Control



Things to try

- Build a simple on/off fish tank controller
  - Simulate the heater
    - ‘bo’ record to turn on/off
  - Simulate the water temperature
    - ‘calc’ record(s):
      - Temperature rises when heater is on
      - Temperature drops to room temperature when heater is off
  - Add controller
    - ‘ao’ record to allow entering the desired temperature
    - ‘calc’ record(s) to turn heater on/off, automagically keeping water temp. close to setpoint

OK to take inspiration from Heater Control Simulation example

- But don’t copy anything without understanding it
- Compare behavior of the P-I controller with on/off controller