Control

MIEET 1º ano

UAlg UNIVERSIDADE DO ALGARVE

30 anos 1979 | 2009

Peter Stallinga, UAlg 2011

MIEET. The levels of knowledge

Physics

Electronics

Sensors and Actuators

Systems

Control

Digital Electronics

Integrated Circuits

Micro Assembler

Machine Language

Macro Assembler

High Level Programming Languages

Object-oriented Programming

Distributed Programming

Information Processing

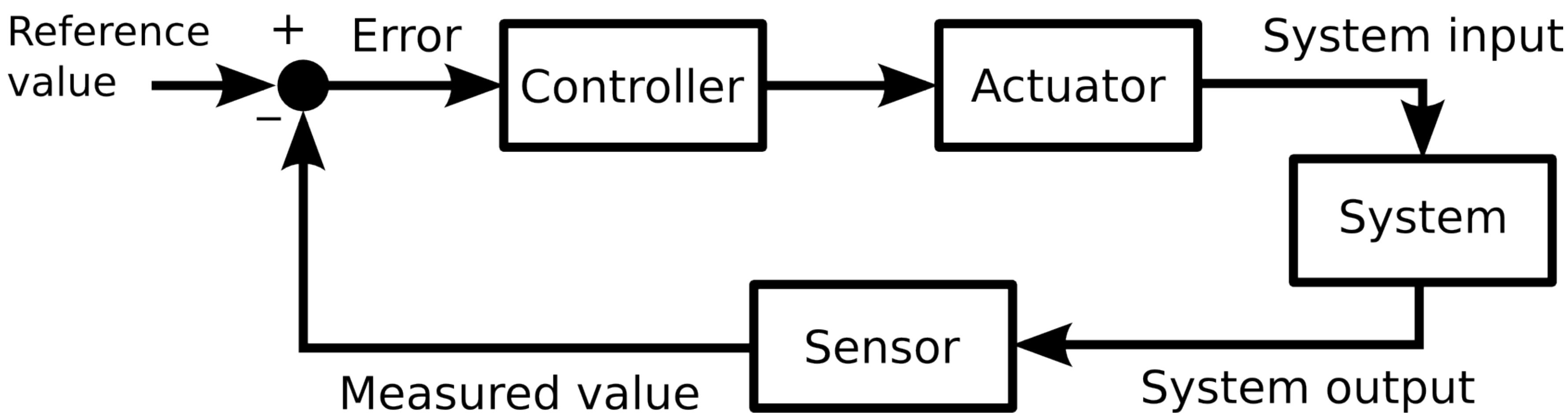
Optics / EM Waves

Telecommunications

Internet

Today
IALP
MIEET

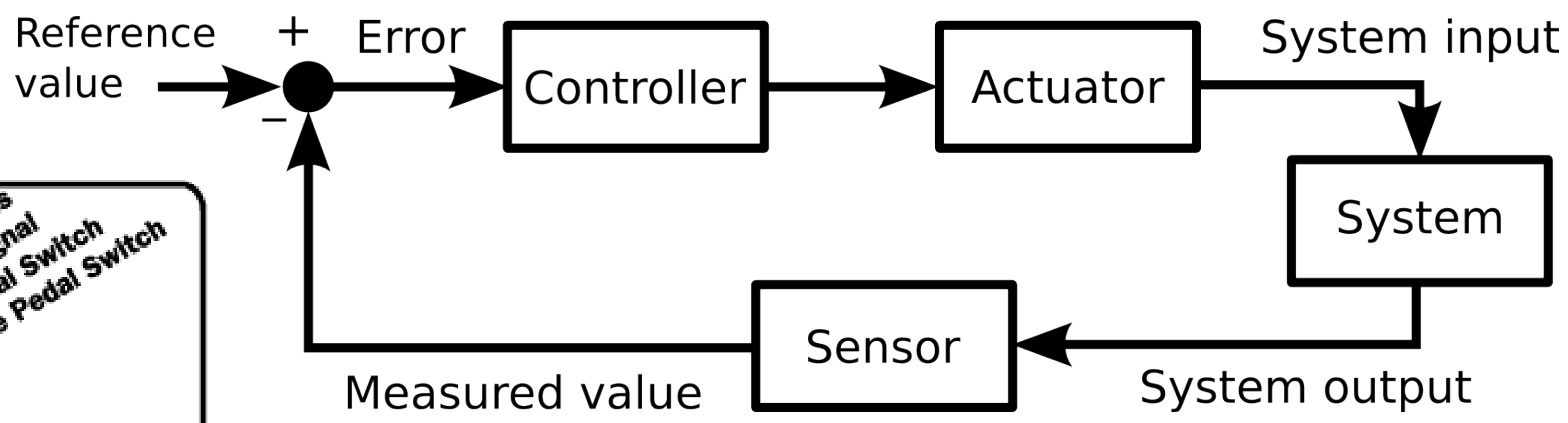
Control theory

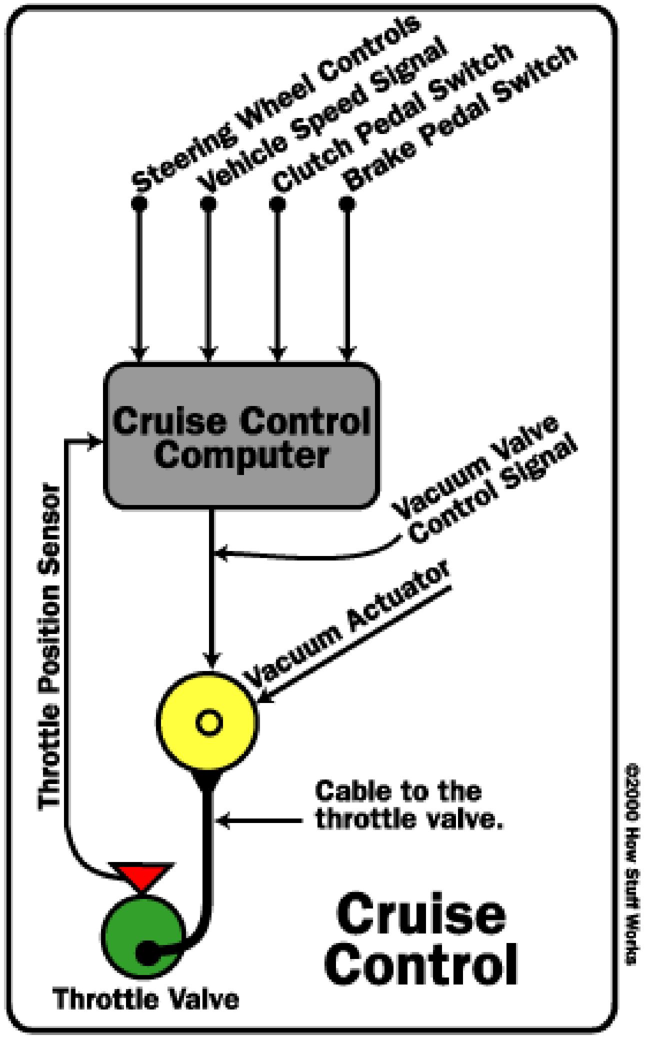


Cruise Control Symbol

Distance Control (Adaptive Cruise Control)

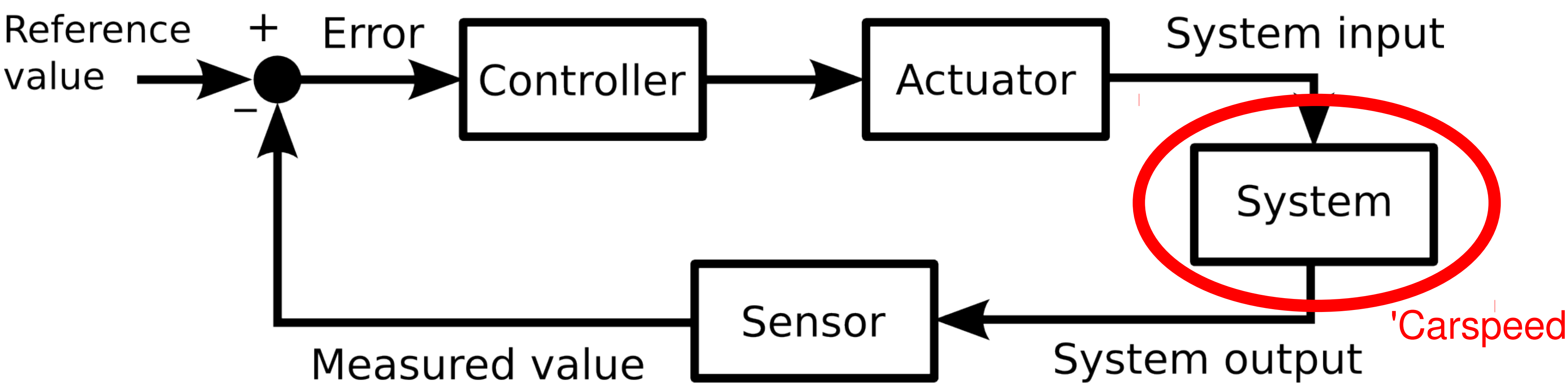
Control theory





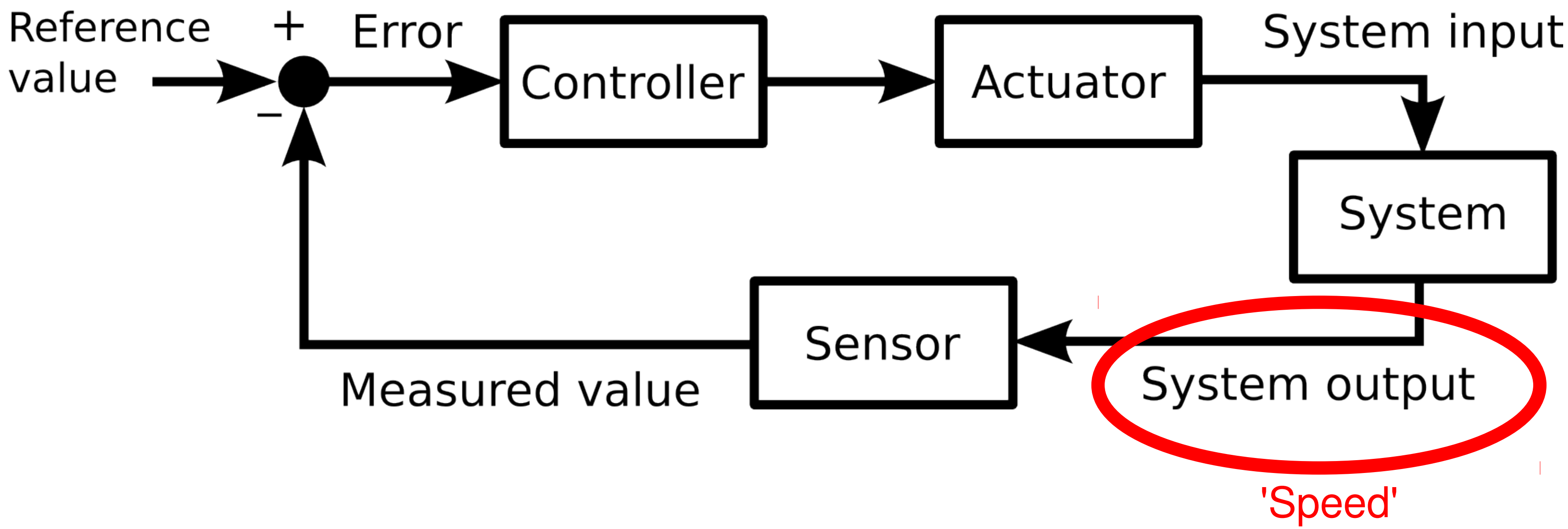
Example. Cruise control

1: The 'system' we want to control



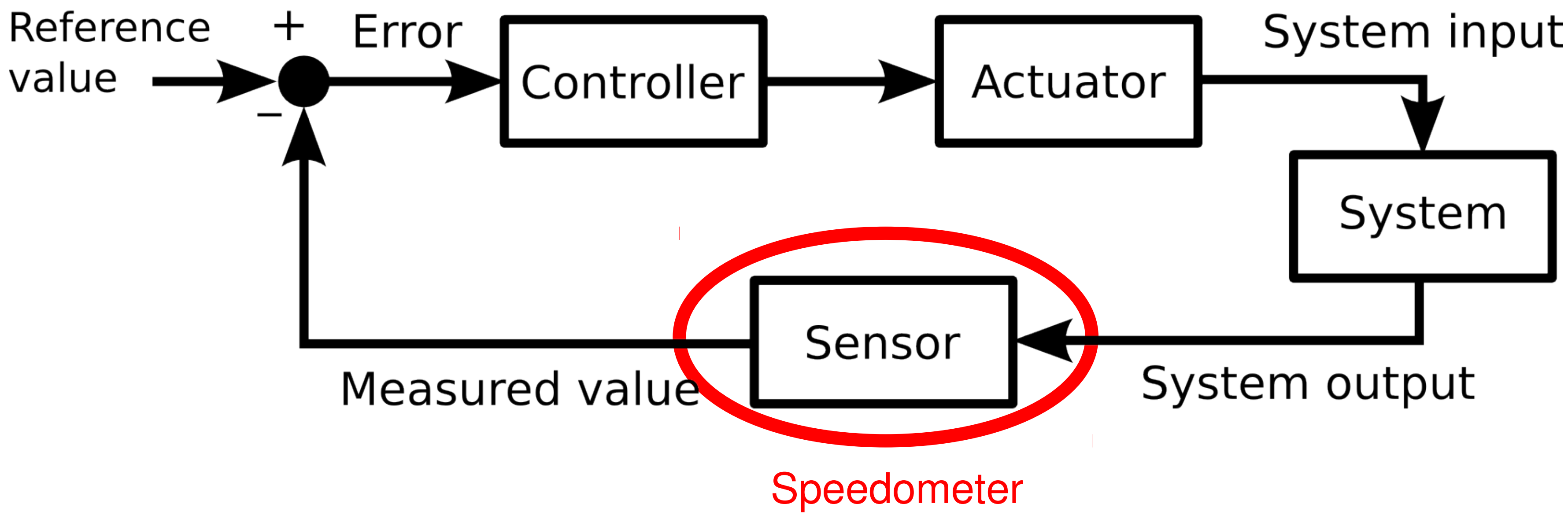
Example. Cruise control

2: The 'variable' we use to monitor the state of the system



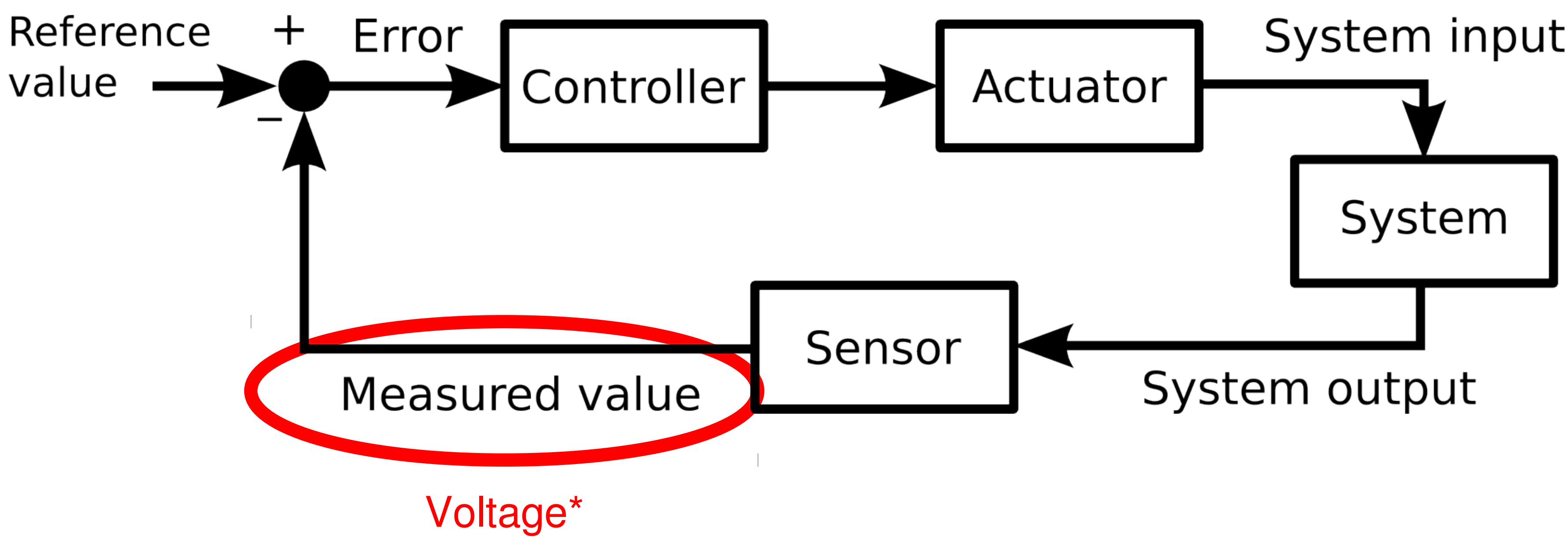
Example. Cruise control

3: The sensor we use to estimate the value of the variable



Example. Cruise control

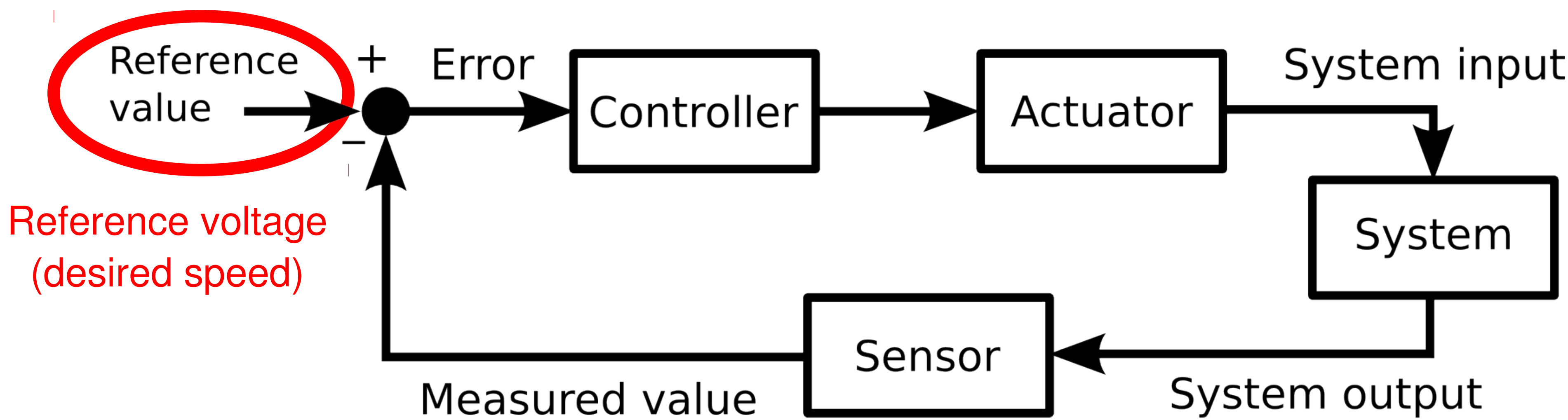
4: The (electronic) signal containing the value of the variable



*: Or other electronic signal unit

Example. Cruise control

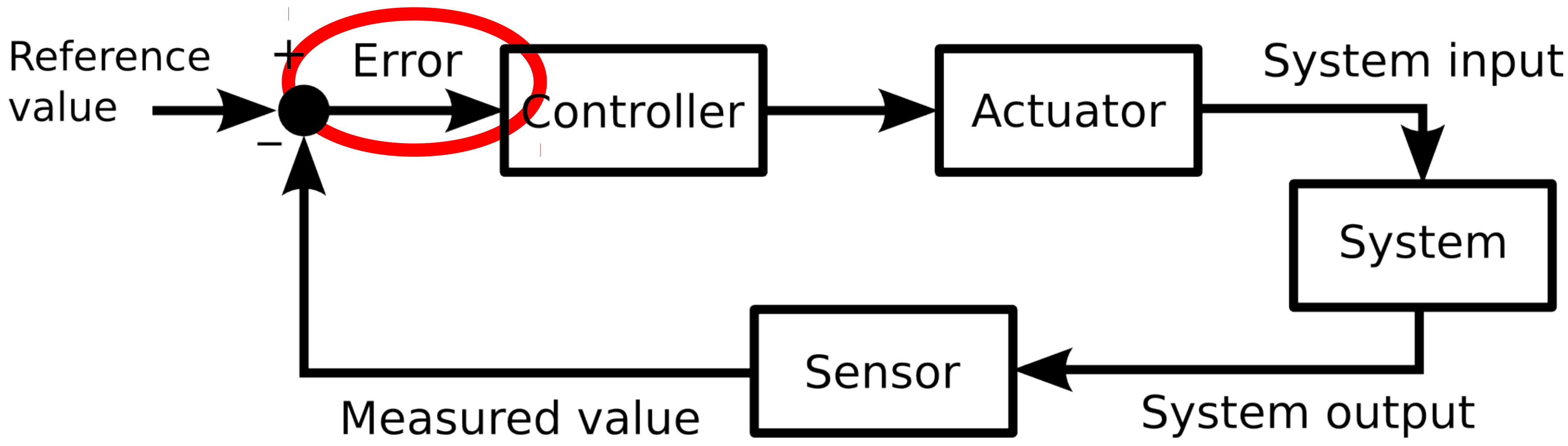
5: The desired value of the signal



Example. Cruise control

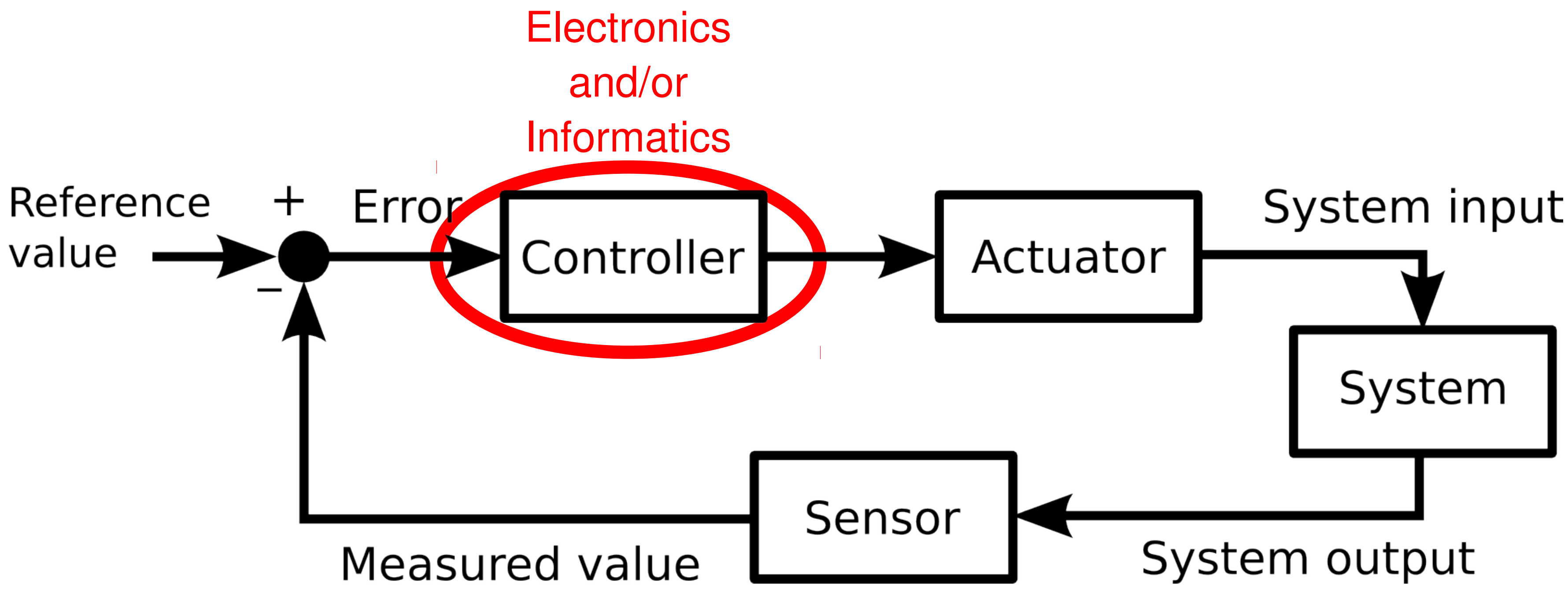
6: The difference between desired and actual value

Desired speed minus measured speed (in volts)



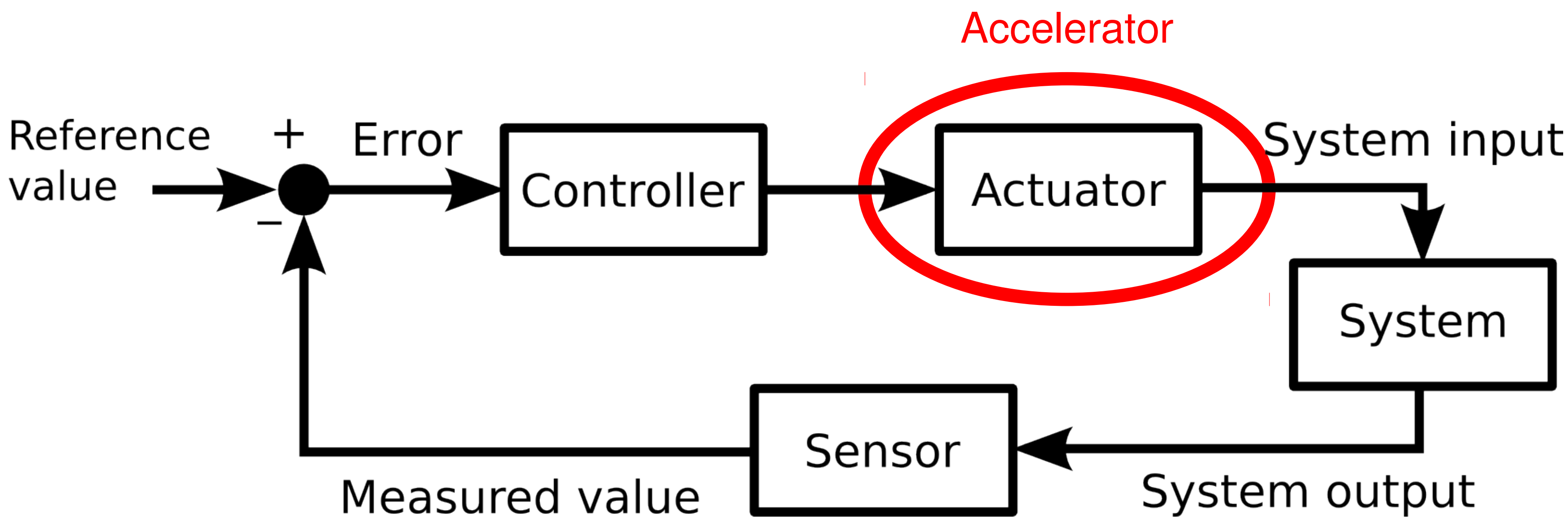
Example. Cruise control

7: The controller processing the signal and taking decisions



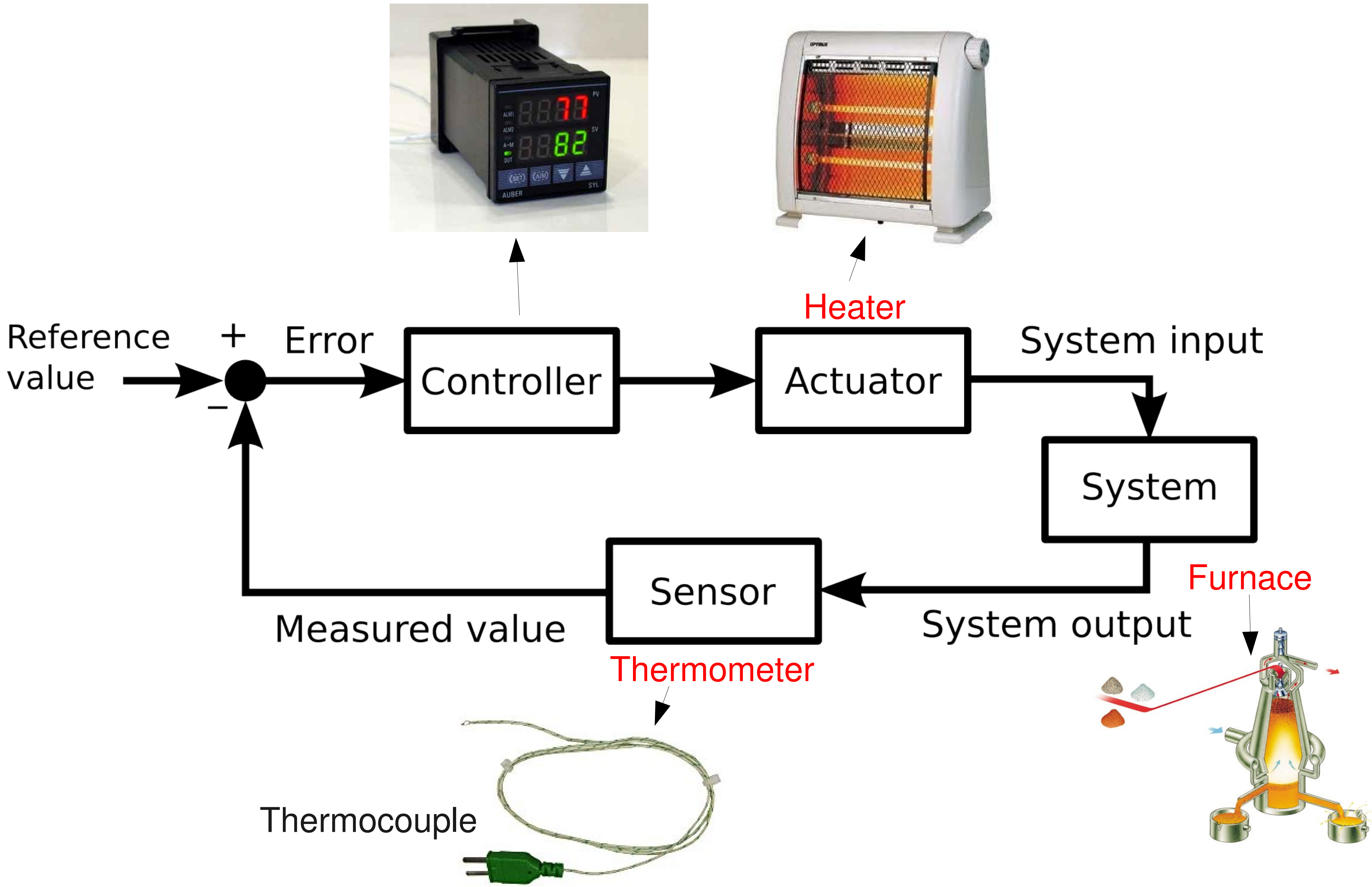
Example. Cruise control

8: The transducer translating the 'decision' into an 'action'

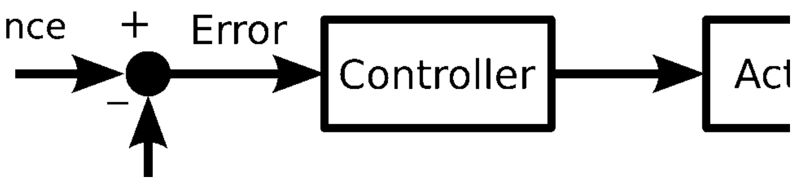


Note: system input is not same domain as system output
In this case: acceleration (m/s^2) vs. speed (m/s)

Example: Temperature control



ON/OFF. Air conditioning

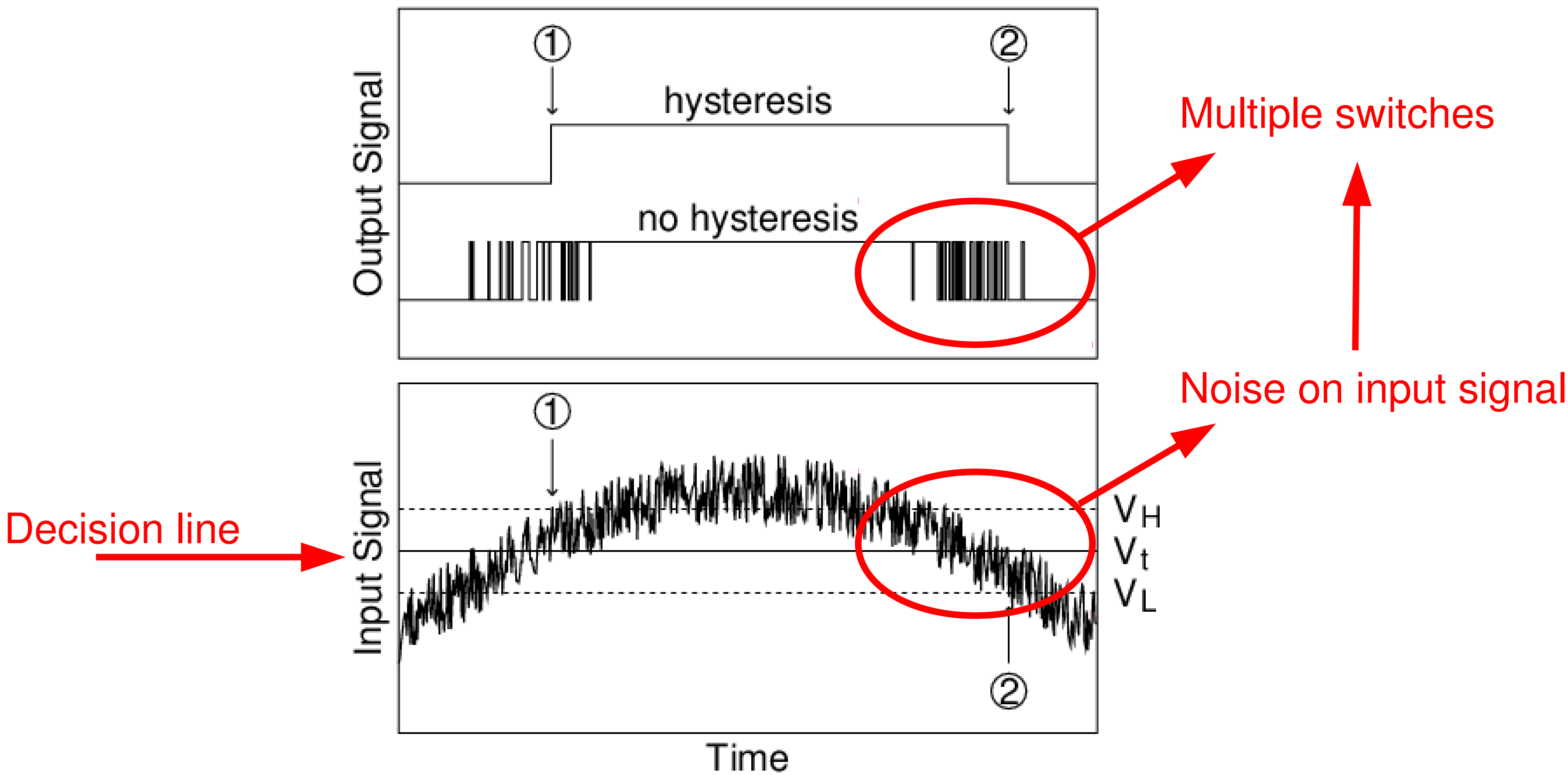


Simplest controller algorithm: ON/OFF:

- Switch **on** air-conditioning when it is too warm, *Error*(*t*)>0
- Switch **off** when it is too cold, *Error*(*t*)<0

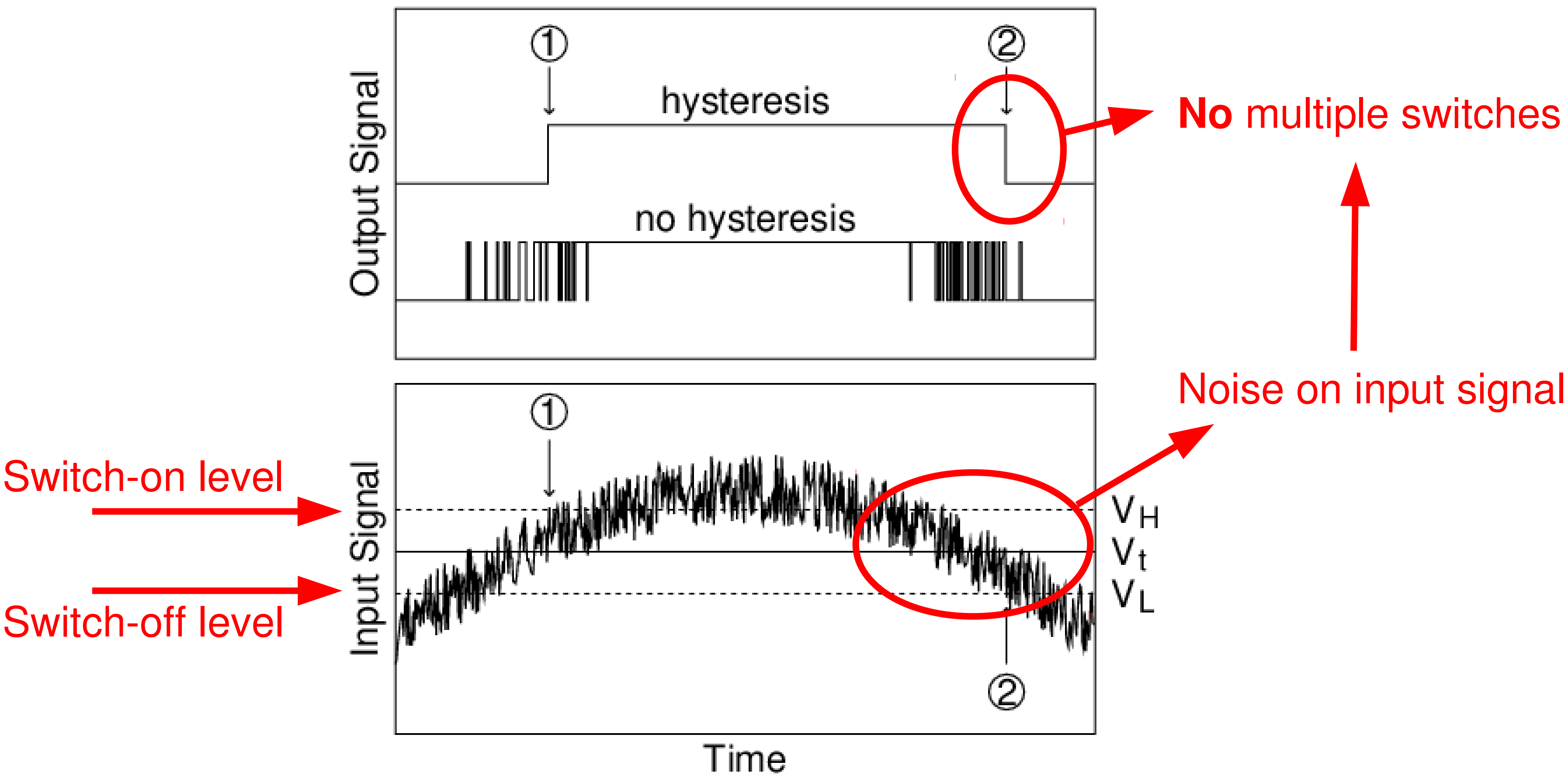
ON/OFF. Multiple switches

Simplest control algorithm: ON/OFF
Will cause 'switching effects':



ON/OFF. Hysteresis

Avoid multiple switches by introducing hysteresis:



PID

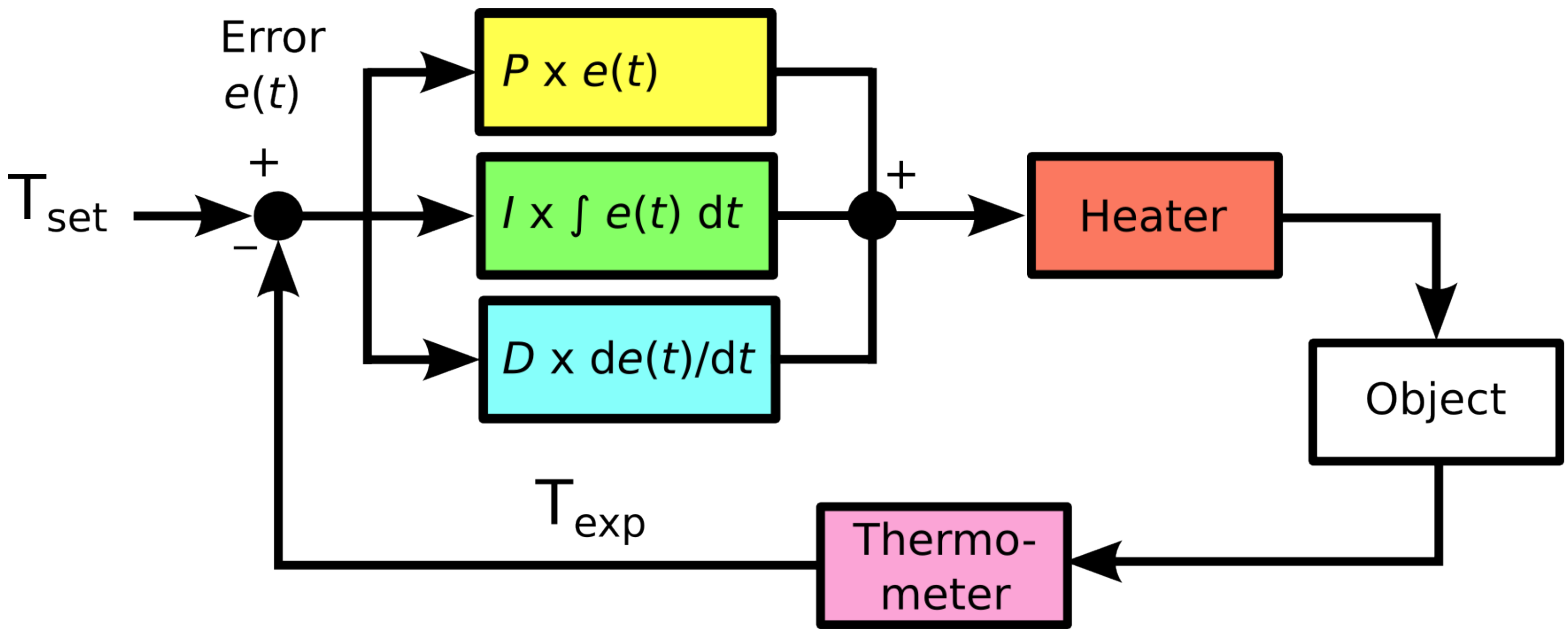
Advanced control system: PID

- **P**roportional
- **I**ntegral
- **D**ifferential

Not simple on/off binary output, but **analog scale output**

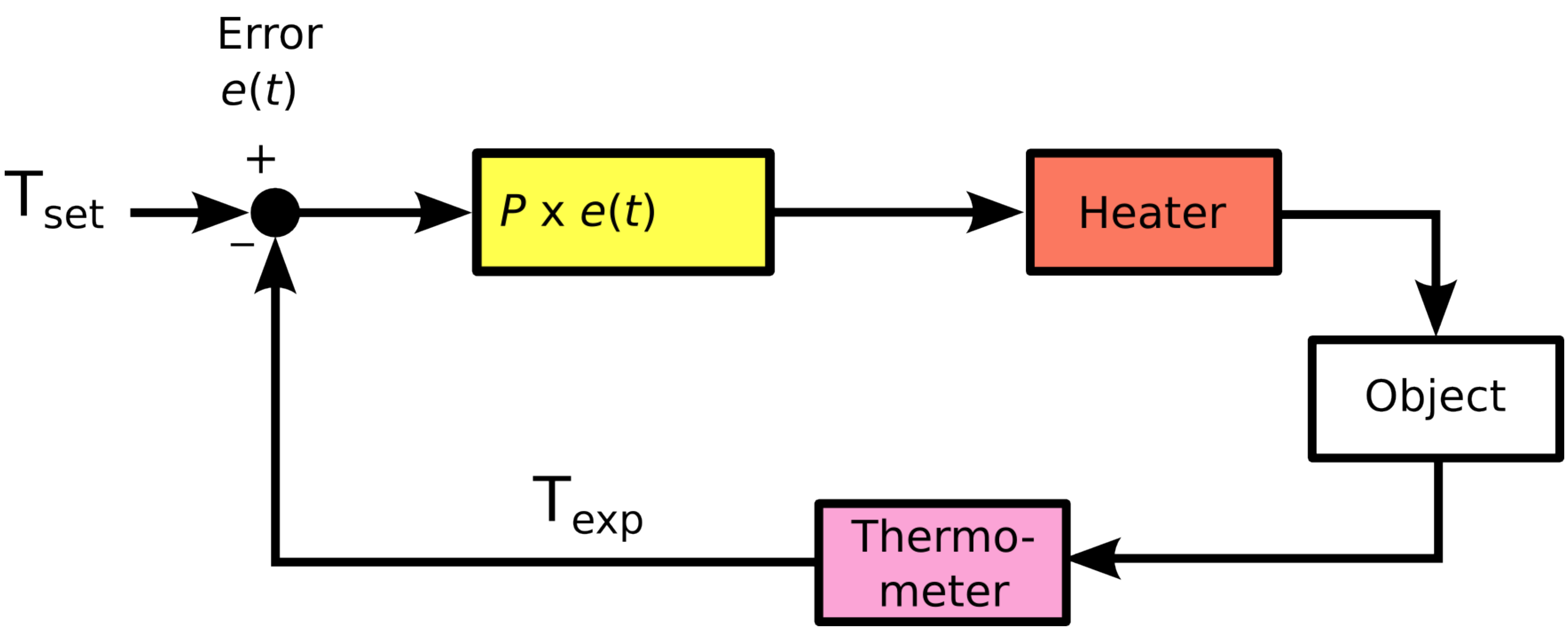
PID

The most famous control 'algorithm/system' is PID (proportional, integral, differential). For example to control the temperature:



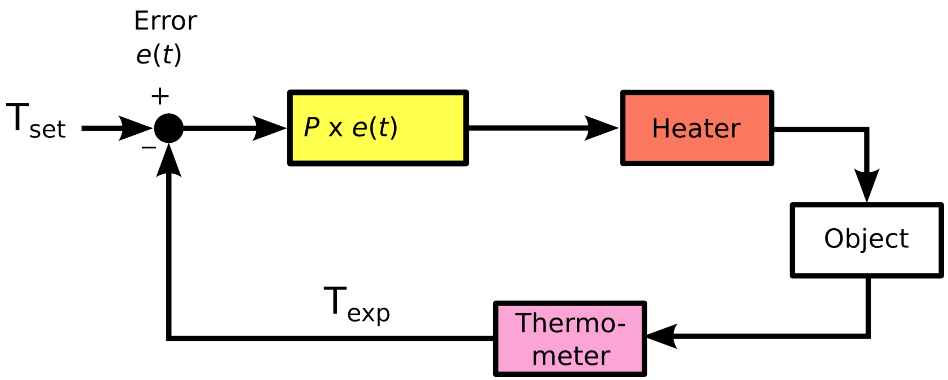
PID: P only

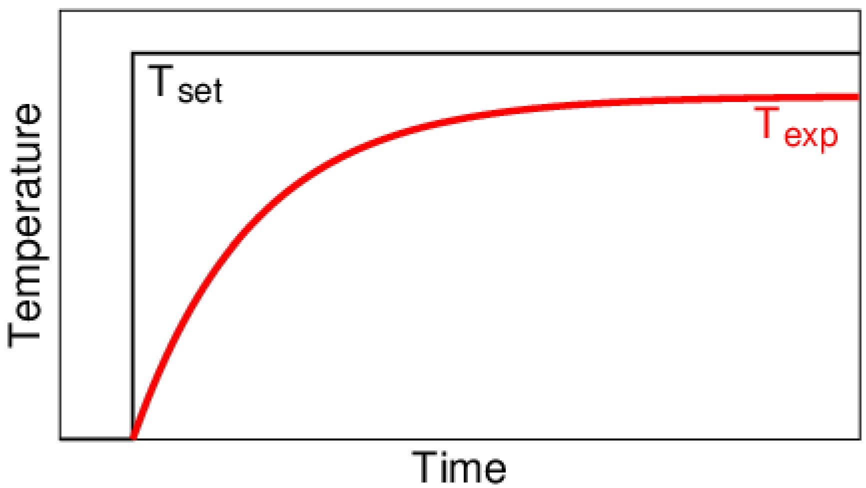
P: Heater power proportional to error $e(t) = \Delta T = T_{set} - T_{exp}$



PID: P only

P: Cannot **ever** reach desired value T_{set} !





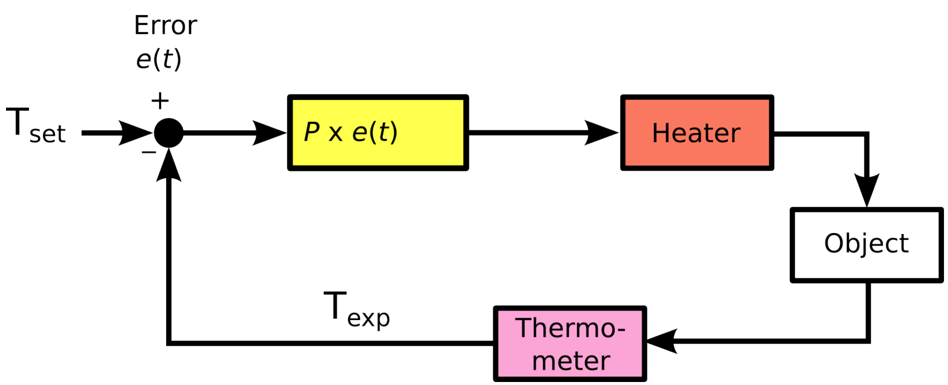
At end, 'steady state': Heater power is equal to heat loss

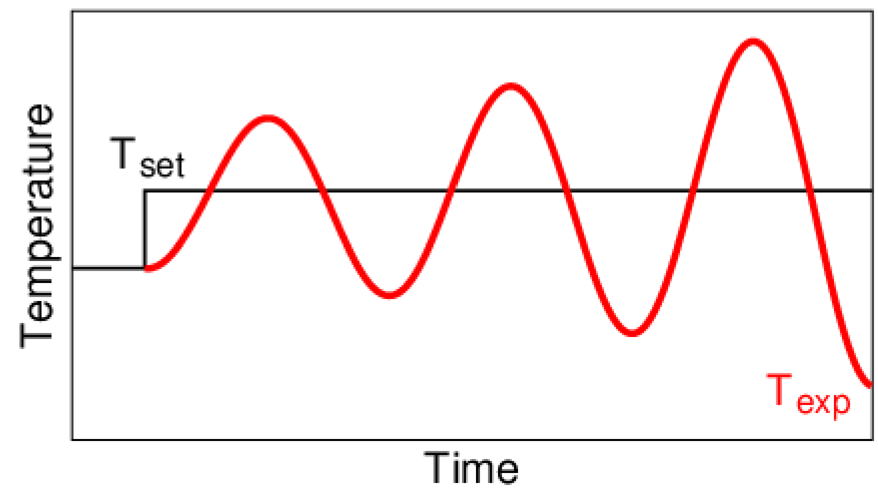
$$P_{loss} = P_{heat} = P \times e = P \times (T_{set} - T_{exp})$$

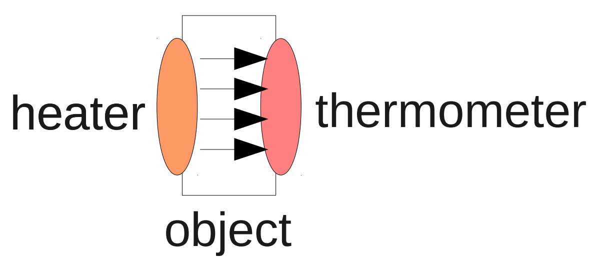
$$\rightarrow \quad T_{exp} = T_{set} - P_{loss}/P$$

PID: P only

P: Delay can cause oscillations



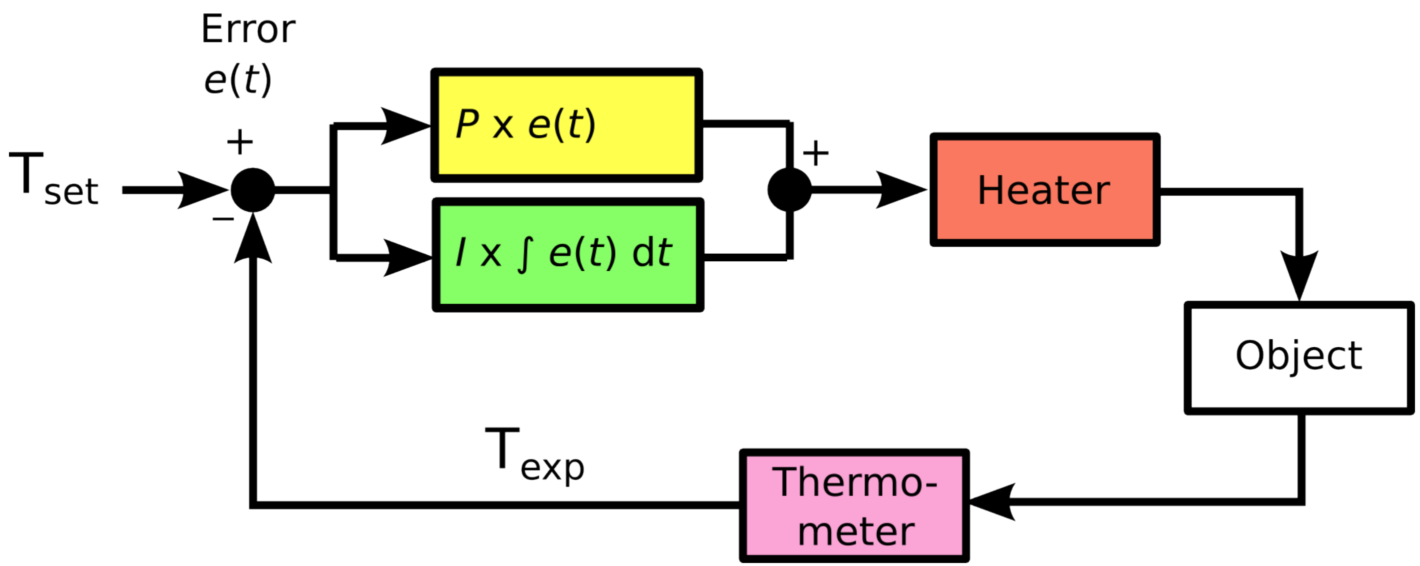




Delays (Δt of one loop): switches on/off the heater too late
Can cause a run-away situation!

PID: PI

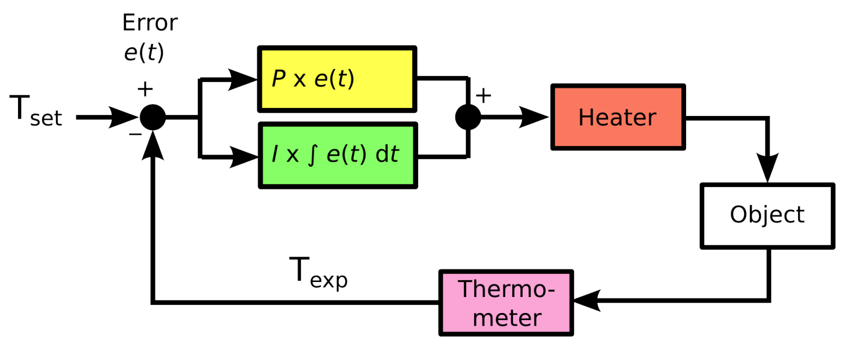
PI: **P**roportional and **I**ntegral

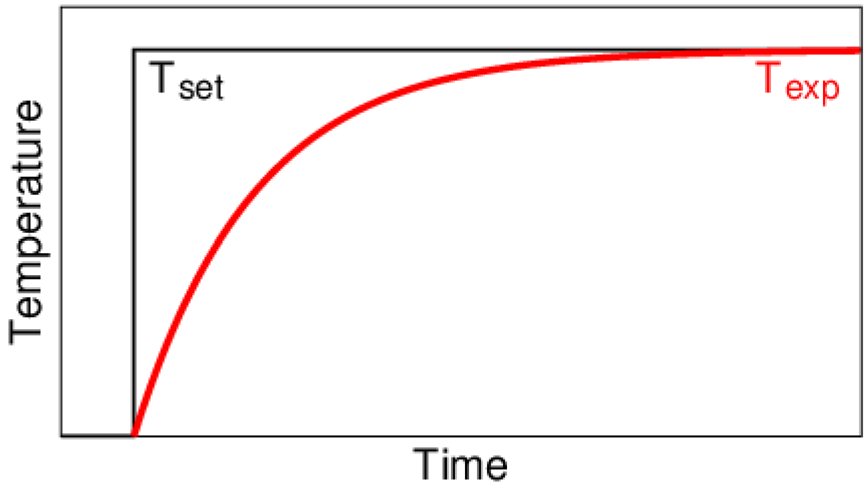


*: Or oscillations

PID: PI

PI: Persistent errors cannot exist



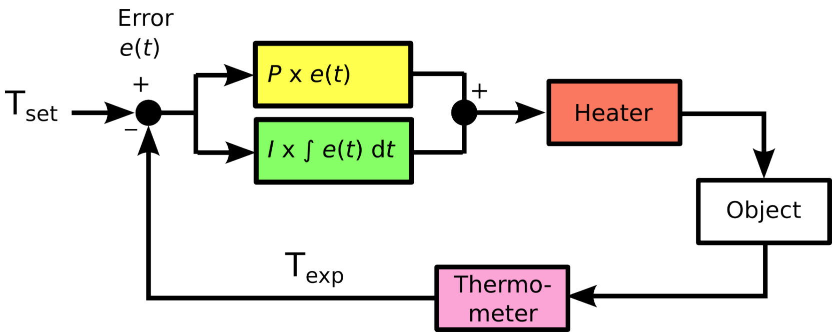


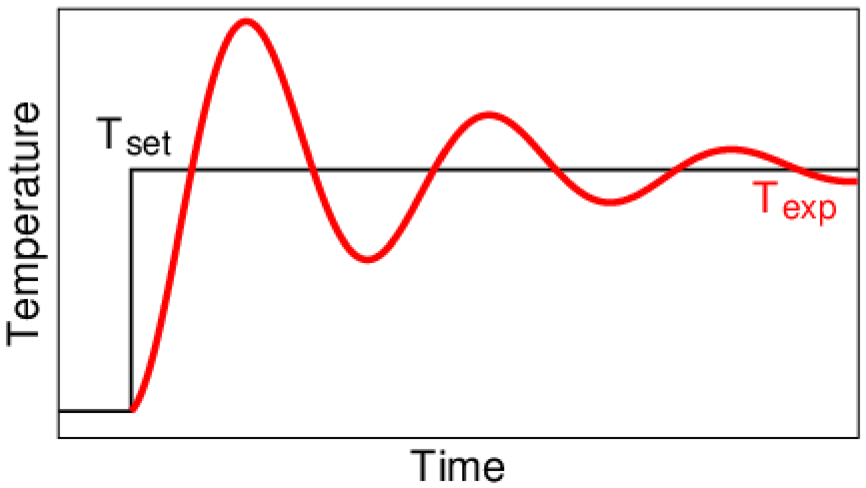
If persistent error $e(t) = e$, then (negative) $I(t) = \int e(t)\mathrm{d}t$ keeps growing constantly until e disappears. Ergo: final e **must** be 0*.

*: Or oscillations

PID: PI

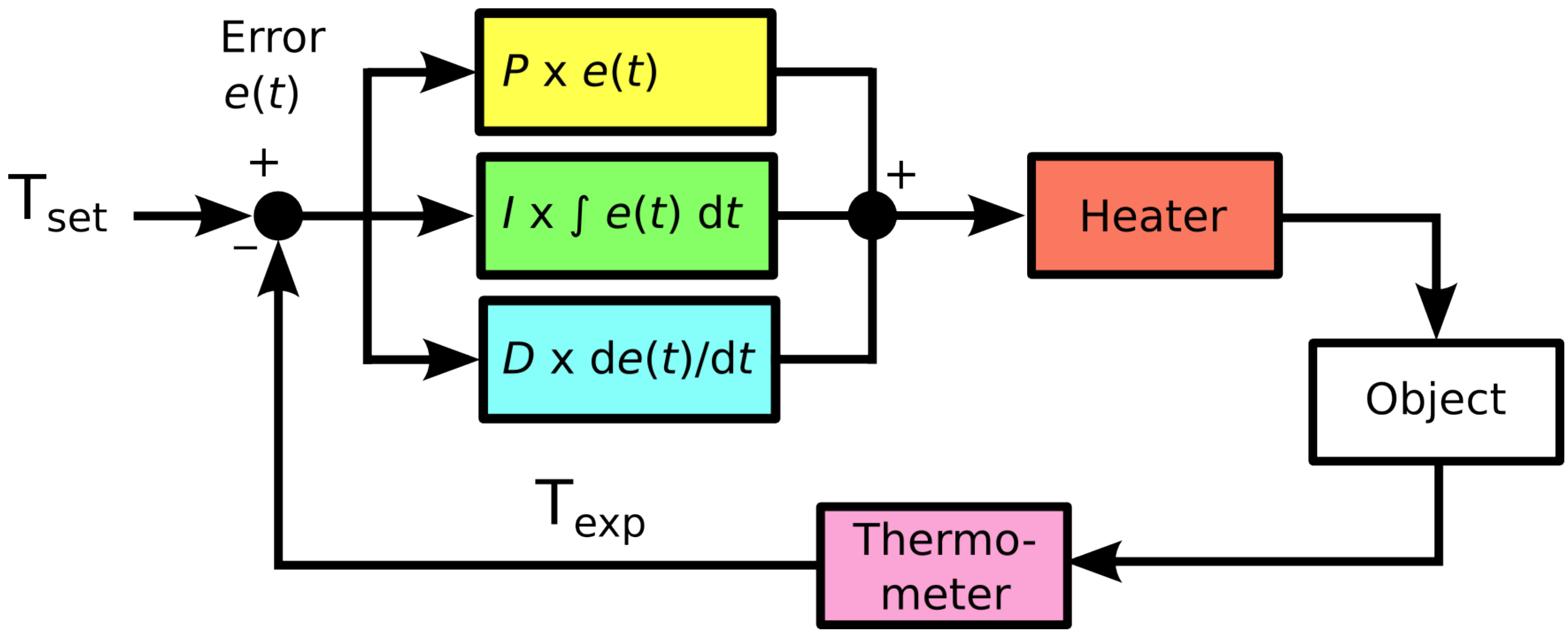
PI: can show severe '**overshoot**' effects





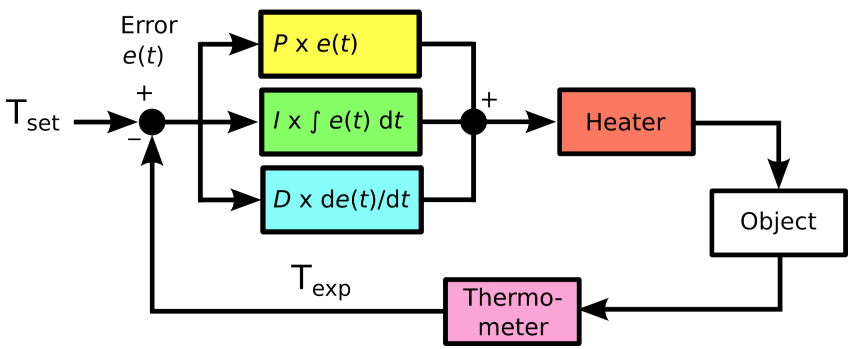
PID. The full Monty

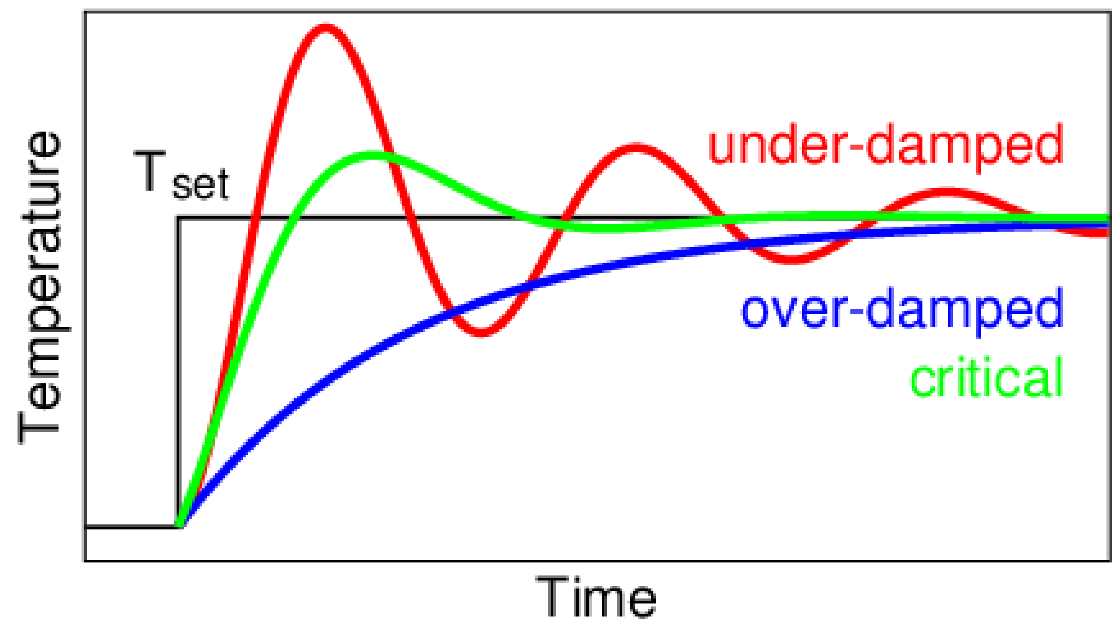
The full Monty



PID. Critical parameters

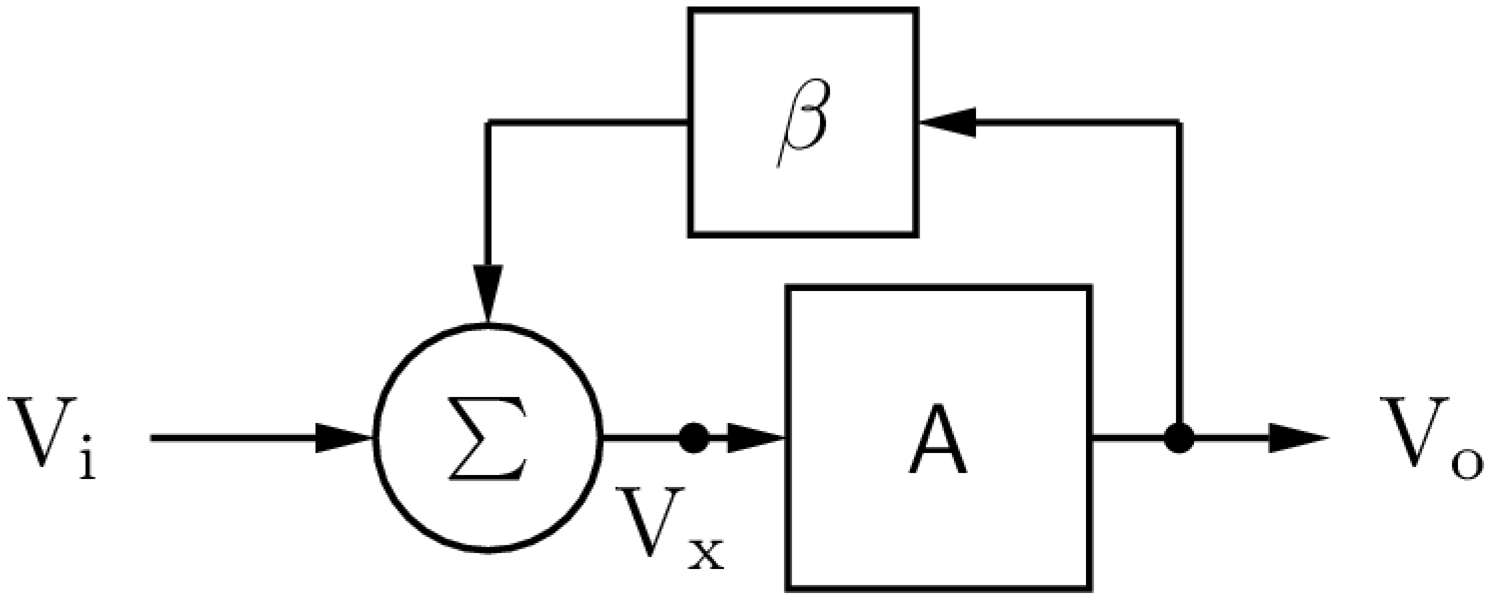
PID. By correct choice of parameters *P*, *I* and D, we can have a system that rapidly goes to desired value





Feedback

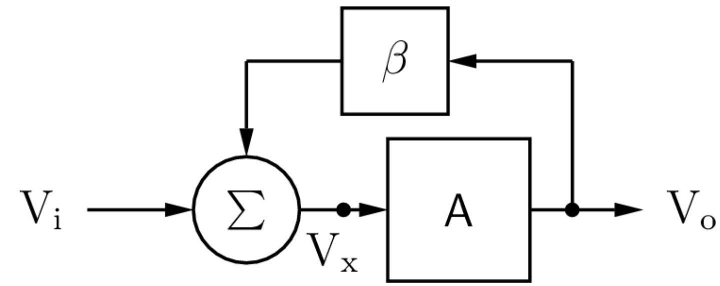
PID and control in general is a system of feedback:
Part (β) of output signal V_o is fed back (added) to input V_i



Such systems can have very many aspects
- Stability (will our temperature be stable?). Positive feedback is normally unstable (oscillations or runaway signal)
- Gain V_o/V_i
- Frequency response

Etc. (→ Electronics II)

Control/Feedback



Such systems find applications in many areas

- **Engineering**. Controlling temperature
- Managing the **economy** (viz. Keynes vs. Friedman, i.e., the phase of the feedback factor β)
- Personal **finance**. Spend less when you have less money.
- **Sociology** (a.k.a. 'training'). Put 'bad elements' in prison
- **Pedagogy** (a.k.a. 'learning'). Higher marks motivate students
- **Climatology**. Positive feedback: polar caps melt → darker → more heat absorption → hotter → etc. Negative feedback: Hotter Earth radiates more heat

Etc.