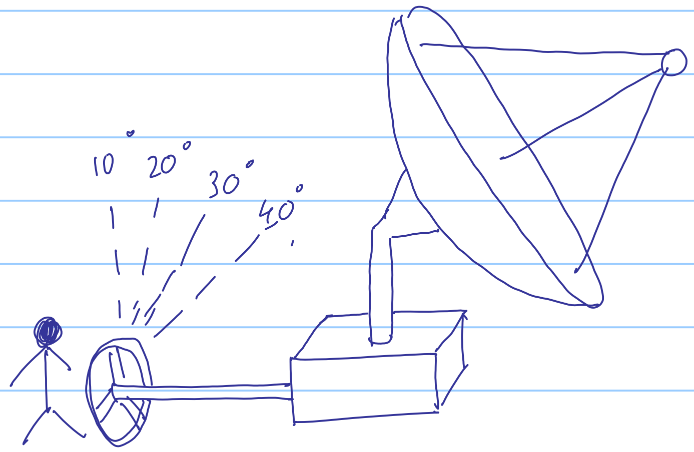
Chapter - 1

Control System / Feedback Examples

Note Title 21-12-2009

* What is a control system?
* Why control system?
* Feedback
* Examples.

Q) How to change the azimuth angle according to a given angle command?

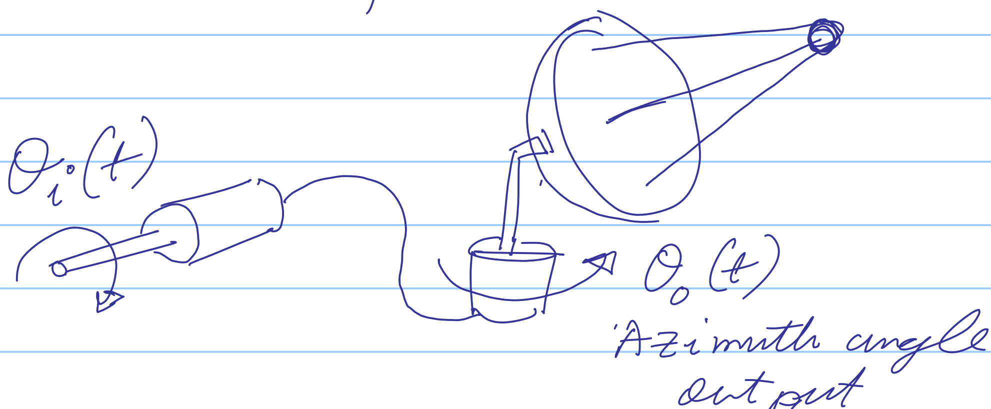


Attempt 1: Manually through gears
→ Too slow
→ Imprecise

Attempt 2: Use a motor to turn the heavy antenna

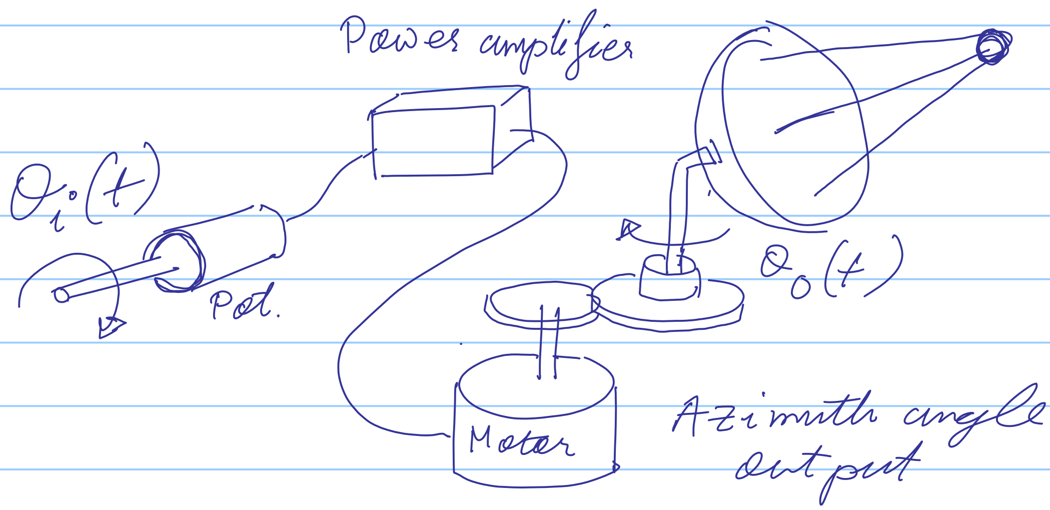
Q. How to convert an angle command into an electrical signal?

→ Ans: Use a potentiometer to convert position into voltage



Q) What can we change / add to the system such that the objective is attained?

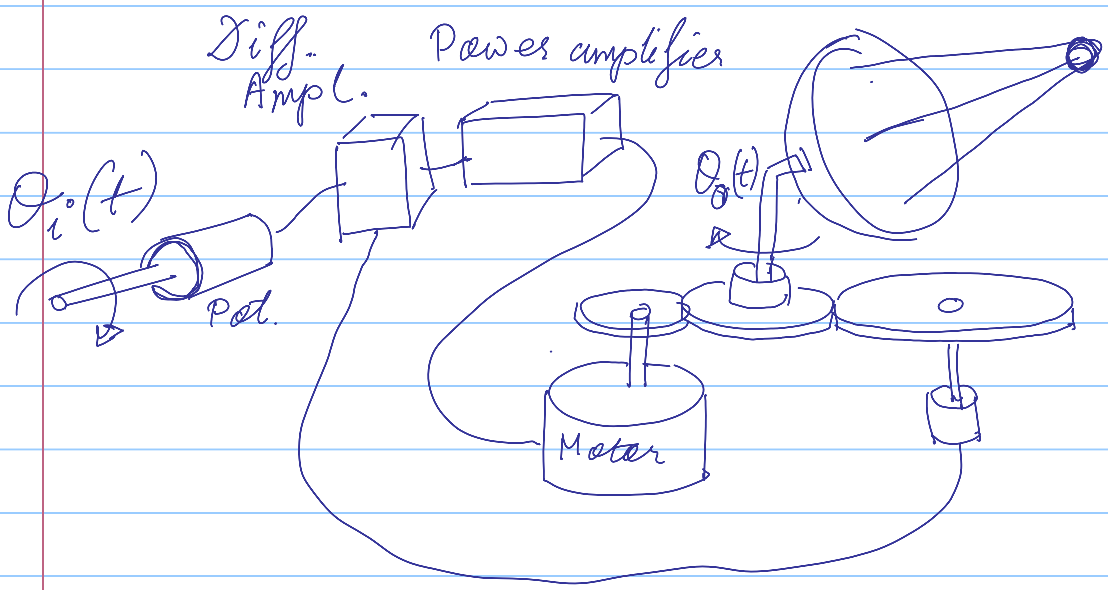
* The pot. output voltage is low but the antenna is heavy
  → Power amplifier
  → Motor



* Still there will be inaccuracies and disturbances (e.g. wind)

→ Feedback

* Add another gear/pot. to get voltage prop to output angle.
* Compare with $\theta_i(t)$
* Use the error $[\theta_o(t) - \theta_i(t)]$ to drive the system.



Advantages with this setup:

1) Power amplification
2) Remote control
3) Convenience of input form
4) Compensation for disturbances

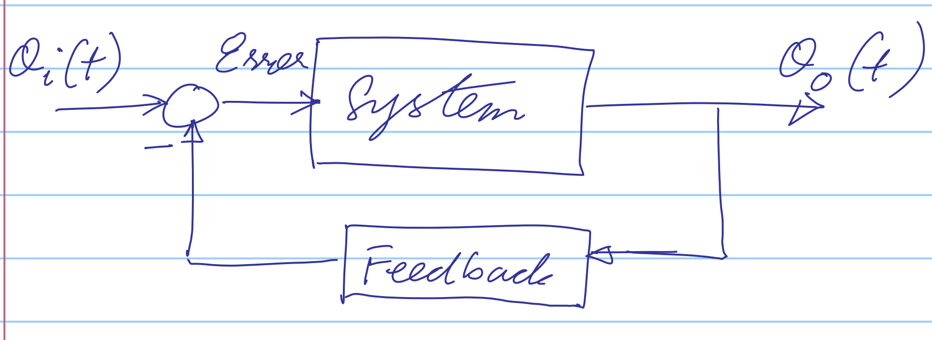
* These are the reasons why a control system is built.

Two Levels of Design

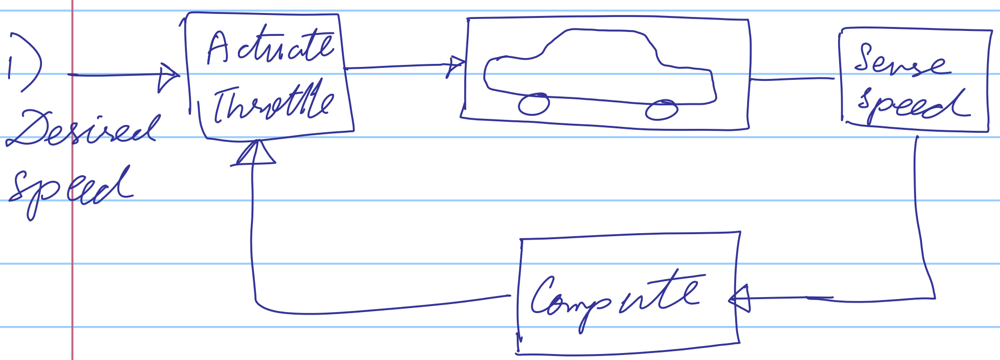
* Obeying domain constraints we can re-design the "system"
e.g. we can change the mass, diameter etc of the antenna as long as its primary objectives are satisfied. (Rarely happens)

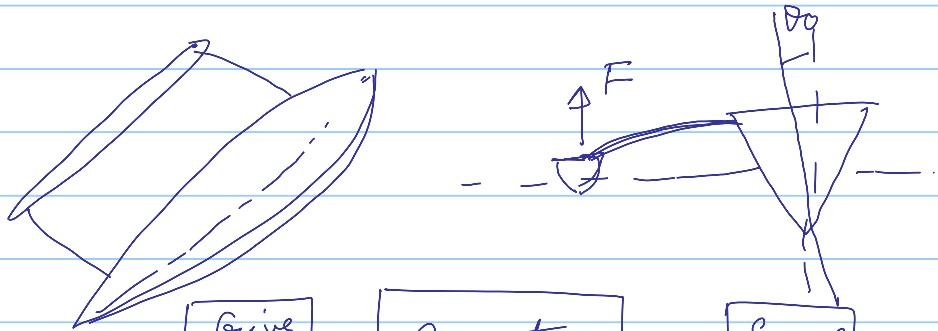
* We can add anything "around" the "system" to make $\theta_i(t) = \theta_o(t)$. (This is control eng. domain)

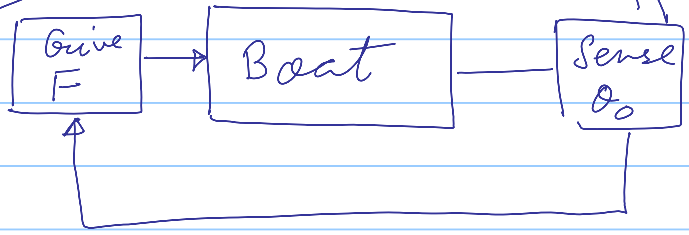
The Feedback Structure – an amazingly versatile idea



Familiar Examples

1) 

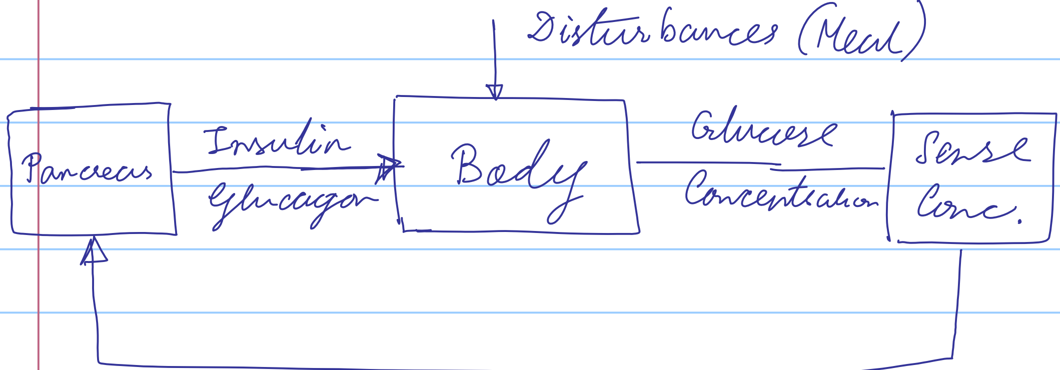
2) 



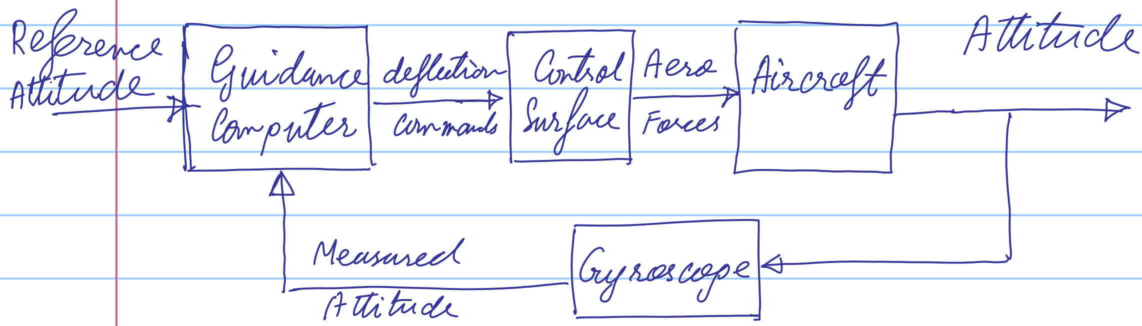
Regulation Example

Feedback within our body

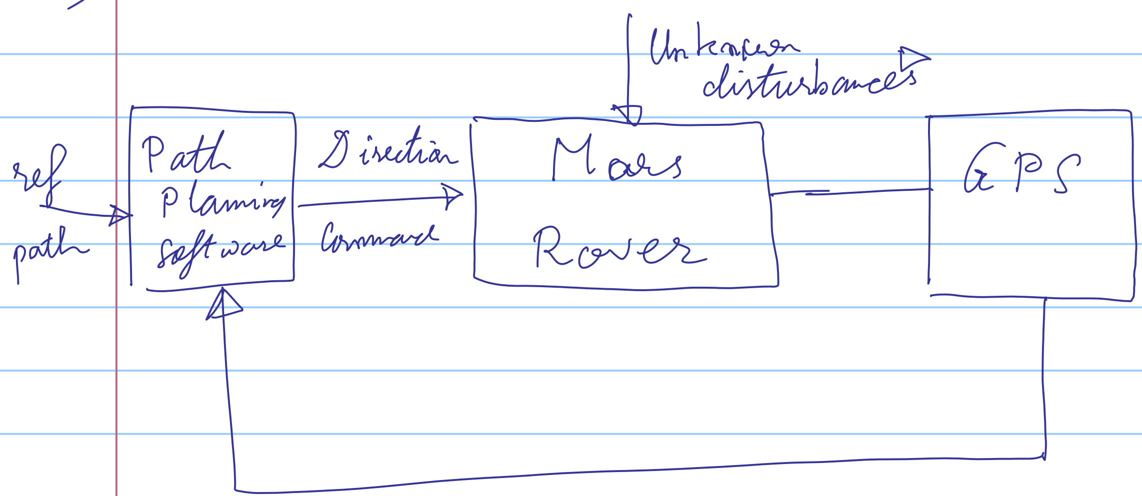
3) Blood - Glucose Control (Regulation)



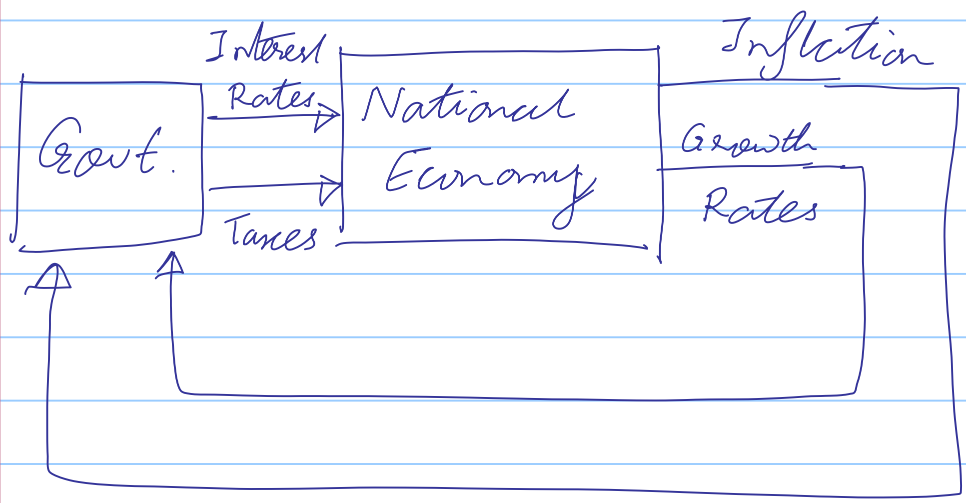
4) Attitude Control



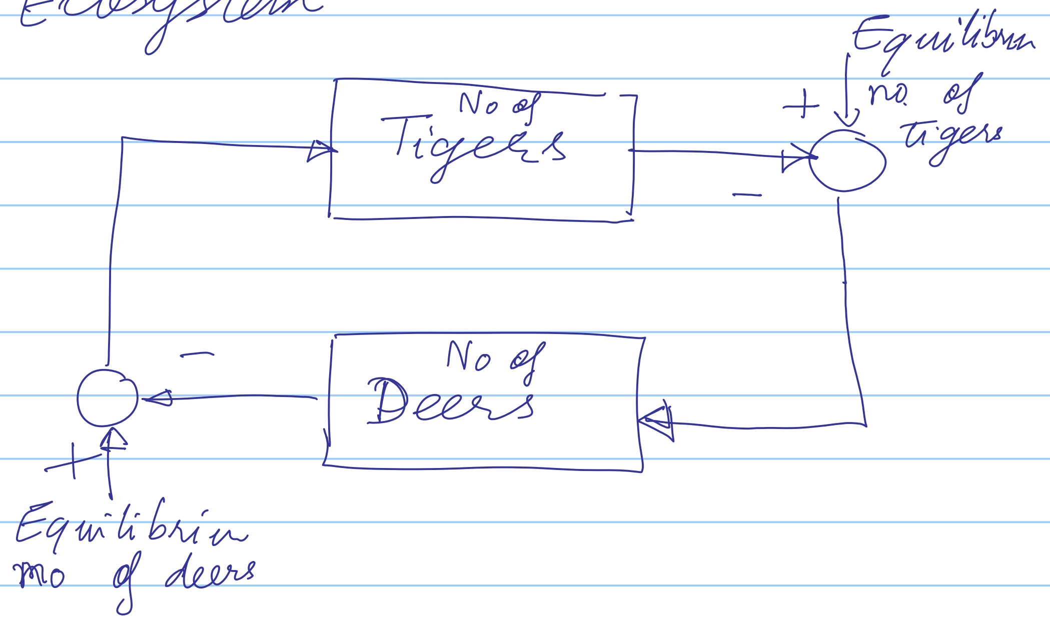
5) Feedback in Robotics



6) Feedback in Macroeconomics



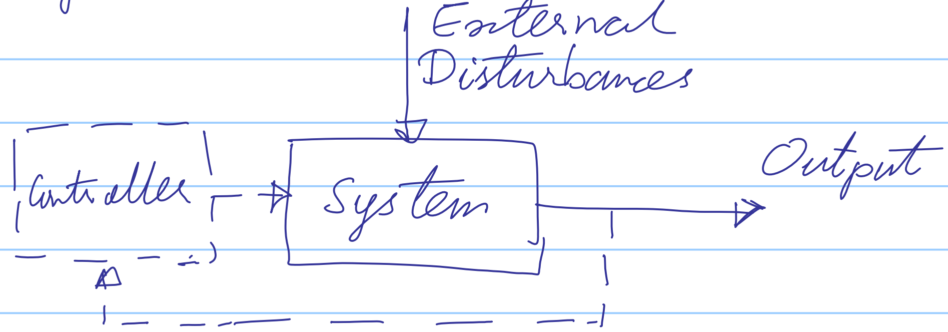
7) Ecosystem



Not well understood — multiple levels of feedback complicate matters.

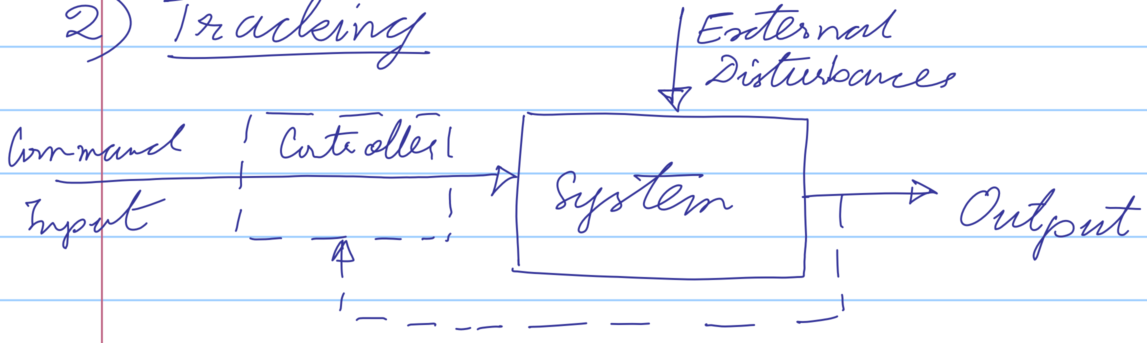
Control systems have two basic Objectives: (from the examples above)

1) Regulation



Objective: Desired Output is zero.

2) Tracking



Objective: Output should follow input.

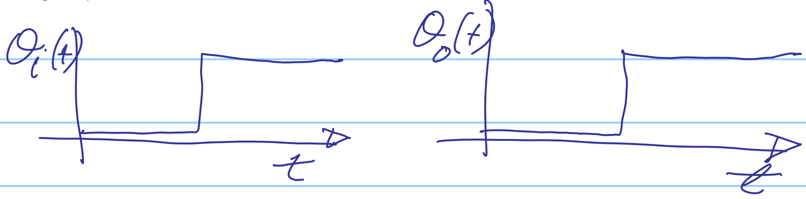
* Clearly our antenna control system is a Tracking system.

* We will see that these two control objectives are fundamentally similar.

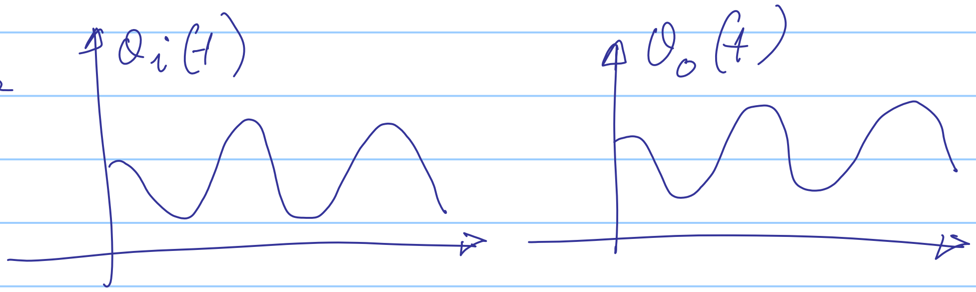
Antenna Control Objective

$\theta_o(t) = \theta_i(t)$ whatever $\theta_i(t)$ we choose.

e.g.



or

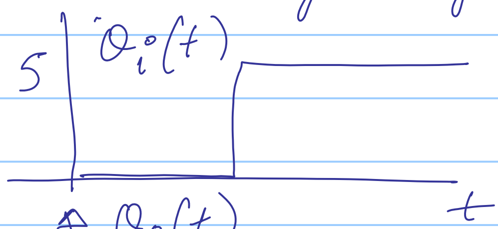


* It is "obvious" that the step input is one of the "hardest" inputs for any system to follow:

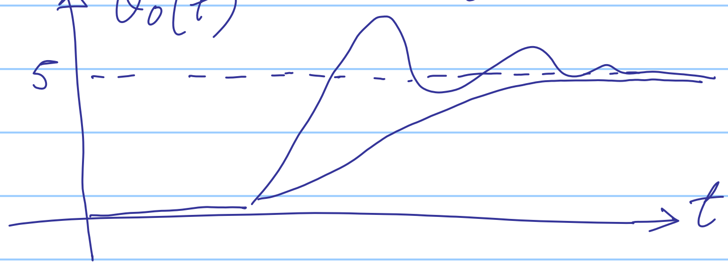
→ So "step" input is one of the most popular test signals

Q) Does our antenna control (feedback) system satisfy the objective?

Unfortunately, no. E.g. in response to a step input



the output behaves like



So we re-define our objectives:

New objectives:

1) Transient response –
→ output should rise fast
→ not overshoot too much
→ not oscillate for too long

2) Steady state response
→ there should not be big differences between θ_o & θ_i after considerable amount of time.

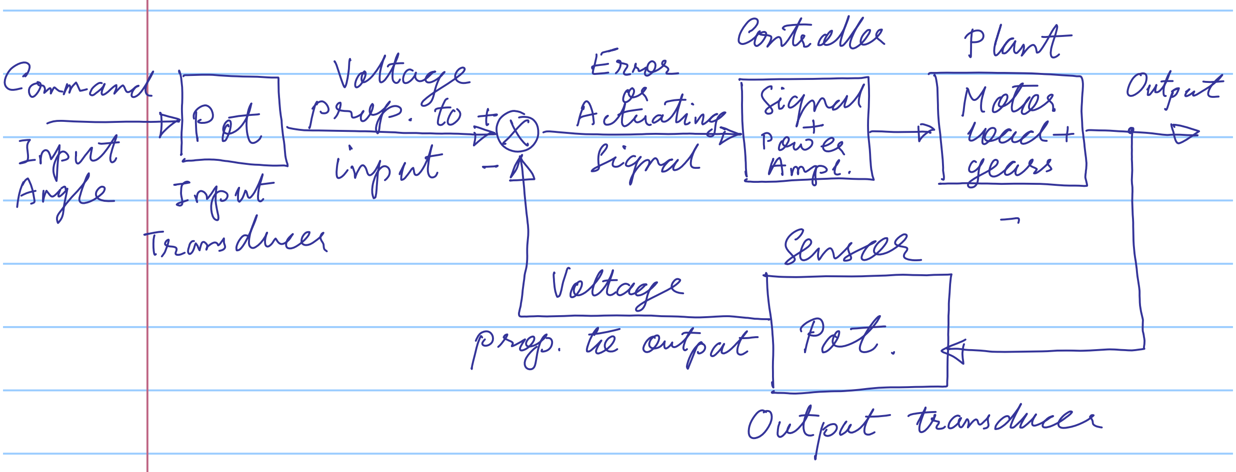
3) Stability → Output should not grow without bound / saturate

Steps of Design

1) Determine physical system & specs from requirement

Example: ◦ Get weight dimension of antenna, descriptions of motor, potentiometer, differential ampl., power amplifie
◦ Depending on the purpose of the antenna get control specs such as desired transient behaviour & steady state error requirements.

2) Draw a functional block diag.
→ diag. of component parts and their interconnection



3) Create a schematic

→ ~~Choose the correct~~ amount of information to get a representation that is just enough for getting the objective.

→ Neglect unnecessary details.

__Example:__

__Potentiometer__ → just a gain

__Neglected:__ friction, inertia, the dynamic characteristics (voltage does not rise instantly with angle change)

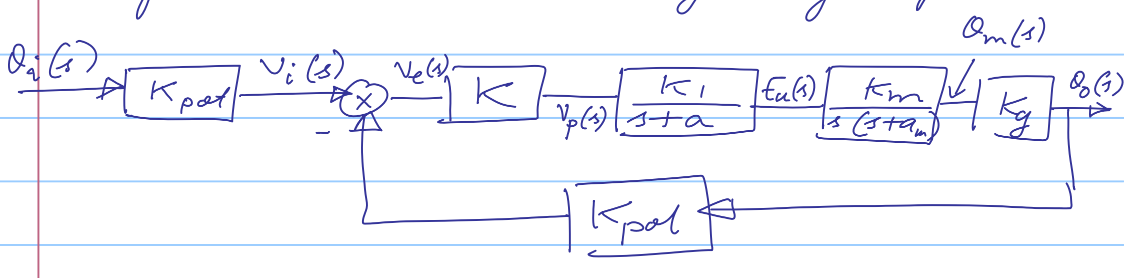
__Differential Ampl + Power Ampl__ → just gain

→ Dynamics neglected

__DC motor:__ Motor dynamics + load is modelled

→ Armature inductance is neglected

⇒ These decisions can be made with experience + knowledge of components.



4) Develop a mathematical model (block diagram)

→ Use physical/biological/economic laws to get mathematical model (e.g. Kirchoff's laws, Newtons laws etc)

→ Derived models may be complex (non-linear, time-varying, pde, high order)

→ Simplifying assumptions make them
ordinary diff eqns
& transfer functions
& state space models

5) Reduce block diag.: large block diagrams with many blocks become a single block.

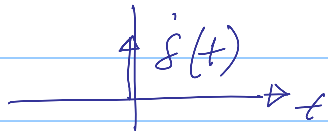
6) Analyze & design

We will learn about this in this course in details.

After each design the model is tested with various input signals

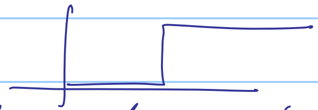
Some of the common test signals are:

1) Impulse



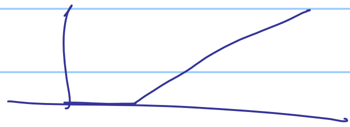
→ this is used to check transient response

2) Step →



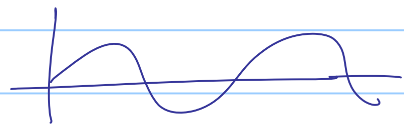
→ both for transient + steady state error

3) ramp →



→ steady state error

4) Sinusoidal inputs



→ Can be used to form mathematical models.

Summary:

* Control systems are used to
    - → keep output near zero
    - → make output follow input

Specific objectives are to make
- transient response better
- decrease steady state error
- stability

* Advantages include → power ampl., convenience of input form, remote control and disturbance rejection.

* Control systems usually use feedback

* Control system design involves a number of steps
* Any design is tested with a number of test input.

Reading Exercise: Disadvantages of Feedback.

Homework - 1

2, 6, 9, 12a-b, 15, 20.