Dynamics & Control

lessons learned from optical disc drives …

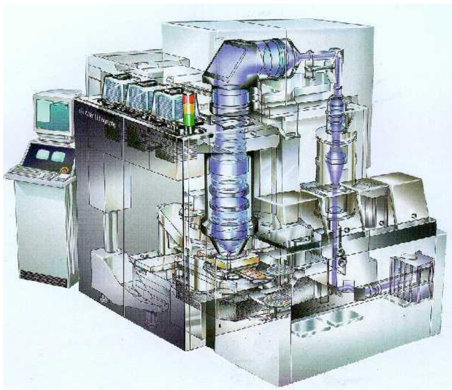
and many other (former) Philips applications

Adrian M. Rankers

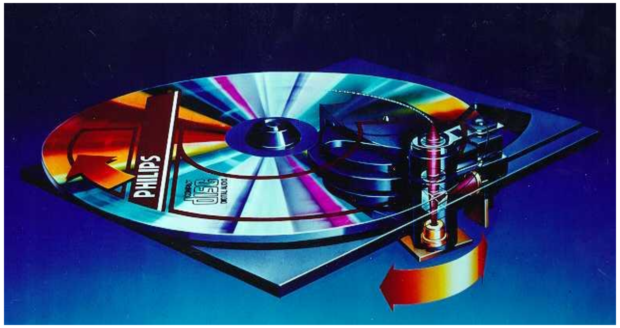
10.Tagung “Feinwerktechnische Konstruktion“
Dresden, 22-23 September, 2016

PHILIPS & spin-outs

ASML

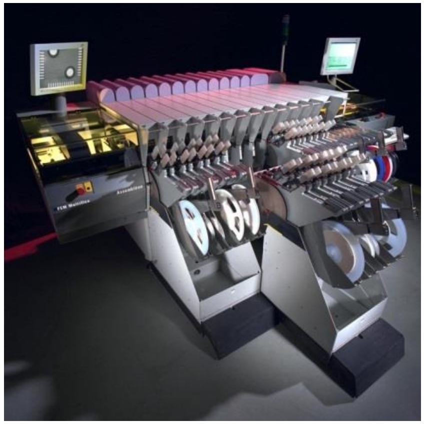


NXP



PHILIPS

FEI™



Kulicke & Soffa®

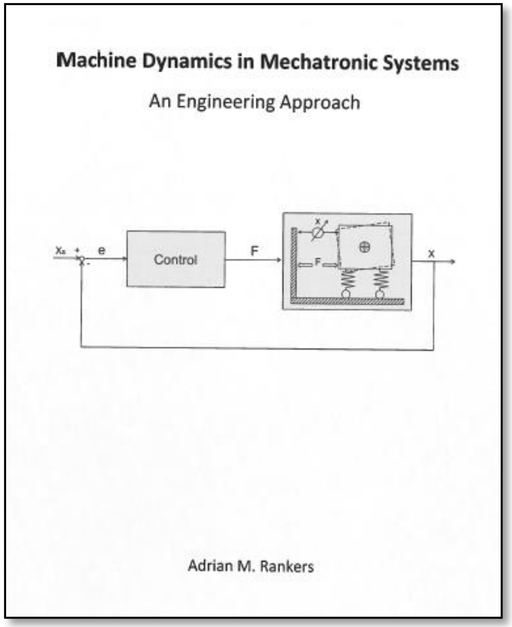
Preface

- Just a glimpse of some of the lessons learned
- Focus on Dynamics & Control
- Examples from Optical Disc Drives
- Lessons Learned:
  - Contents
  - Way of Explaining & De-mystifying

More details ...

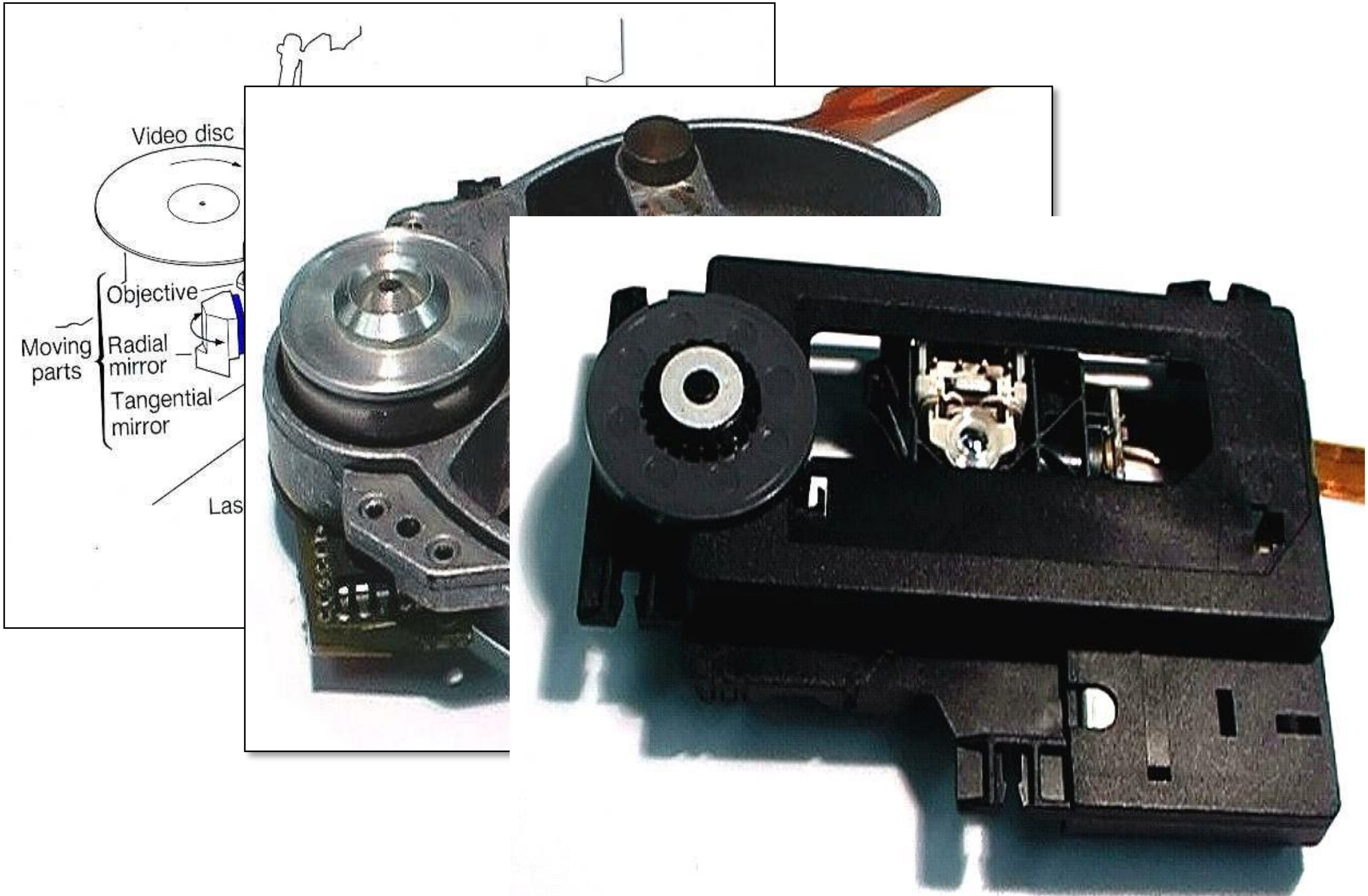
High Performance Mechatronics
Robert Munnig Schmidt, Georg Schitter, Adrian Rankers, Jan van Eijk

ISBN 978-1-61499-367-4

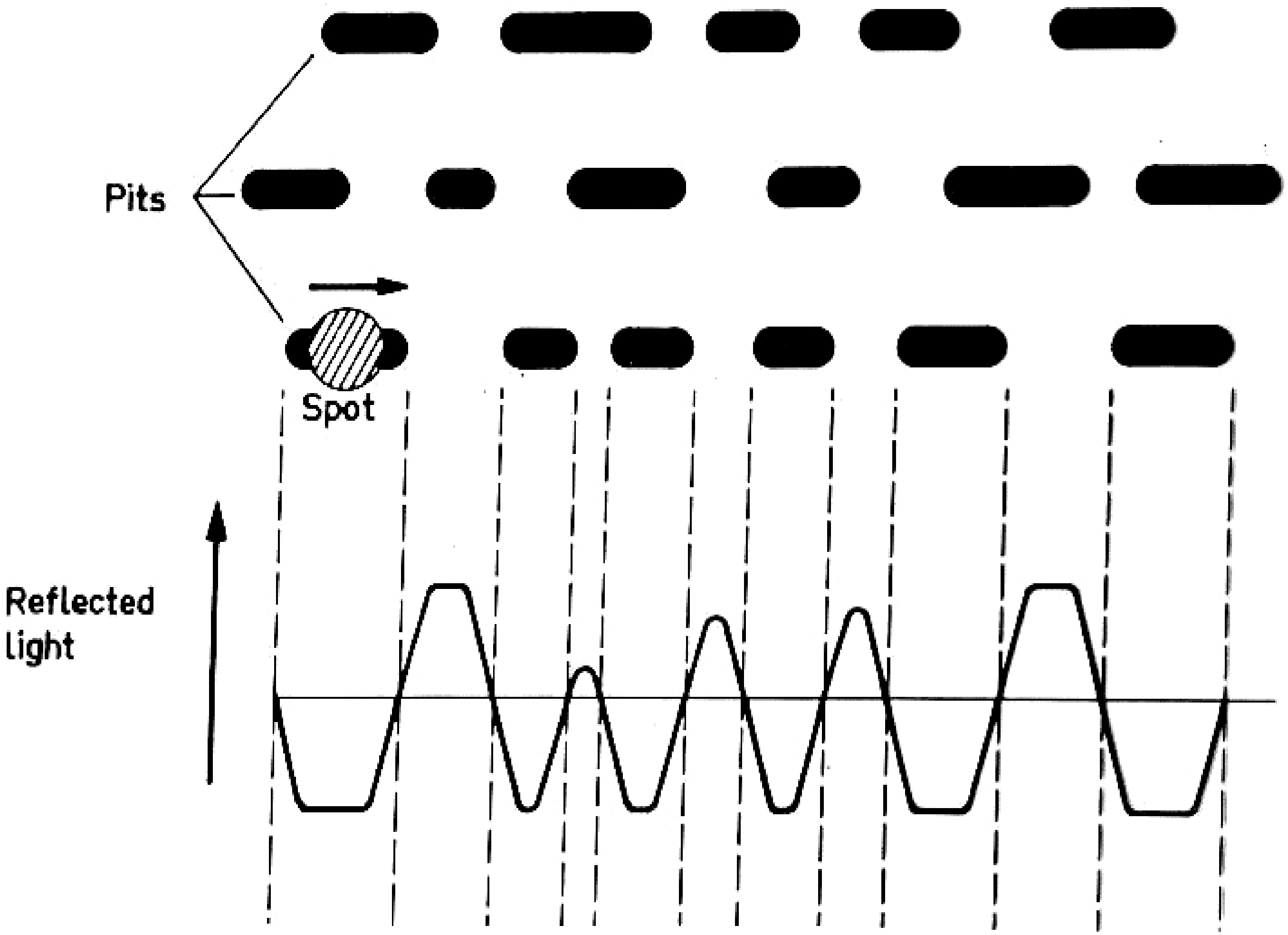


Machine Dynamics in Mechatronic Systems
(available as PDF via **www.mechatronics-academy.nl**)

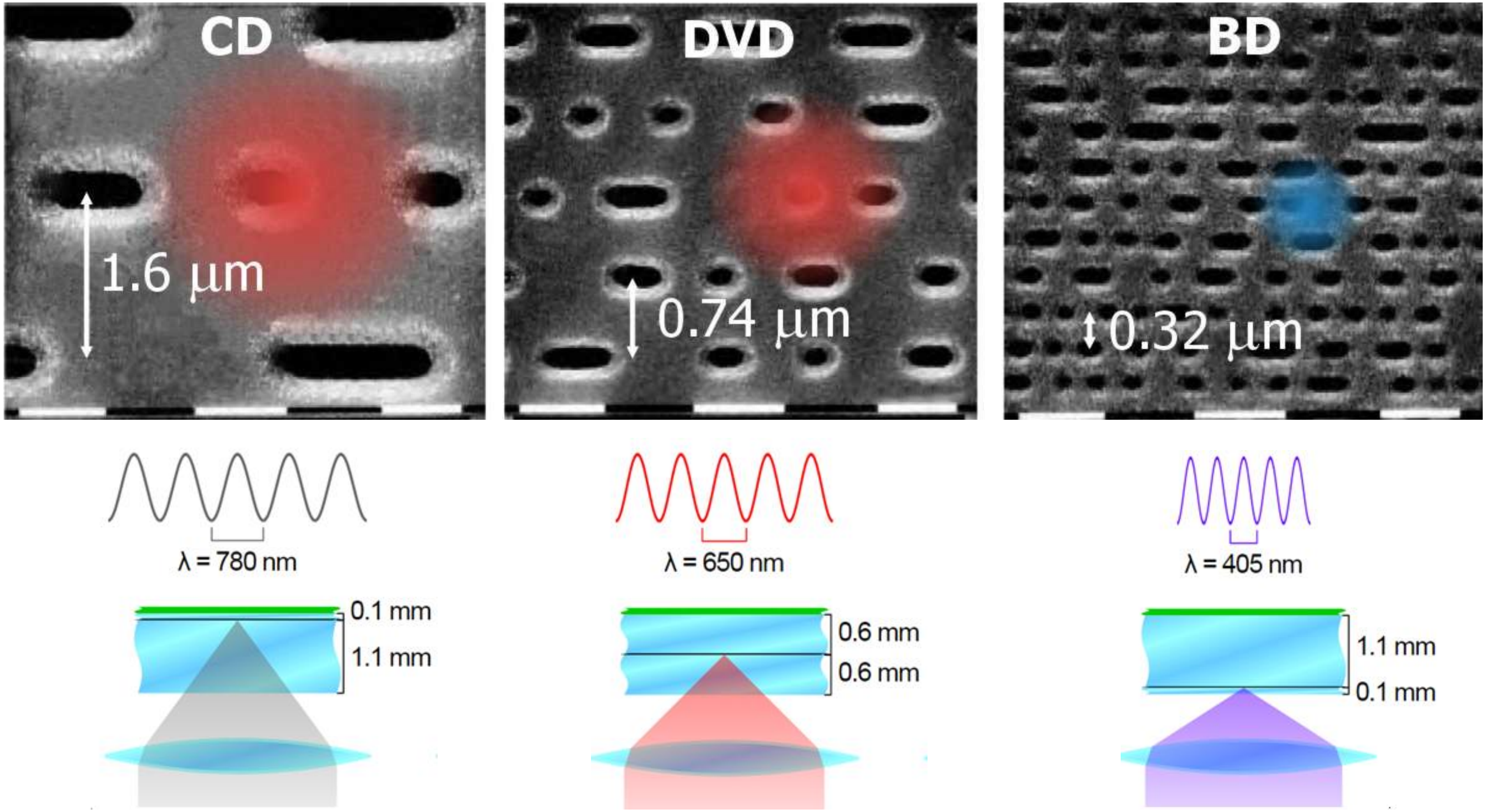
Optical Disc Drives



Music is decoded as pits

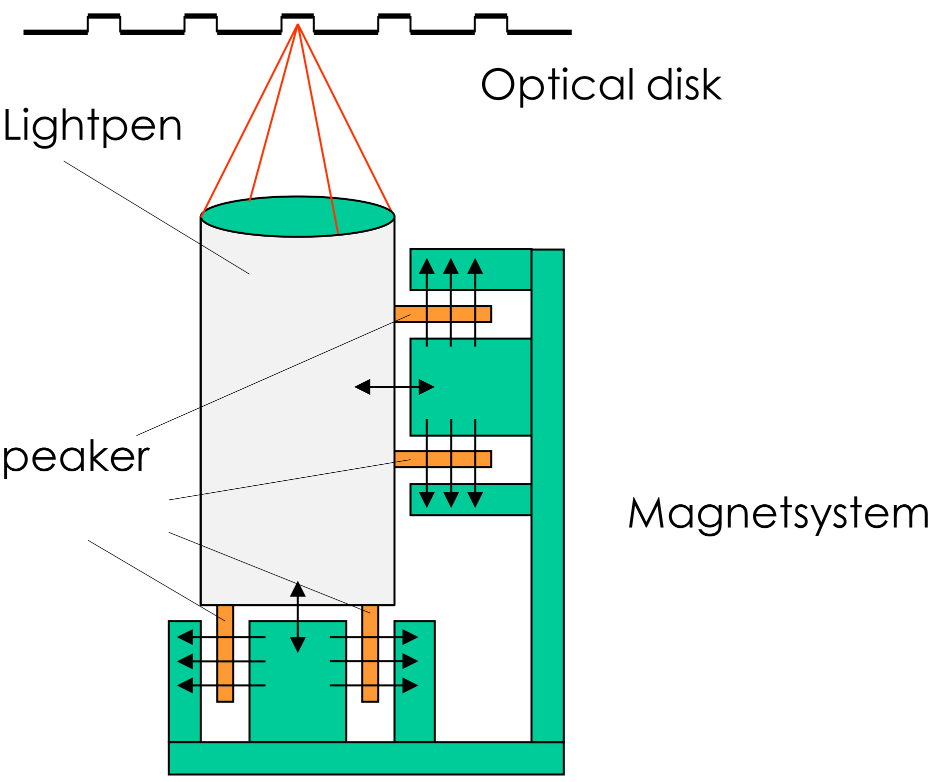


Evolution of Optical Disc Standards



Source: www.wikipedia.org/wiki/Compact_disc

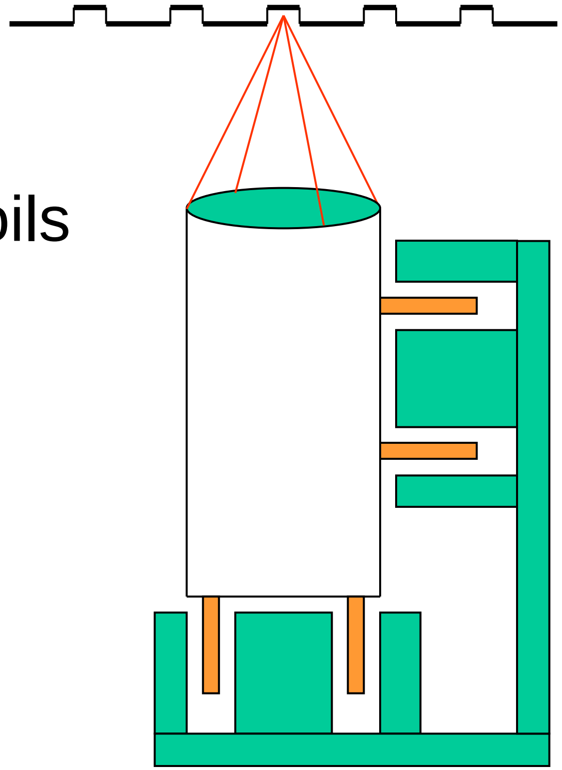
Non-contact pickup



Sensing of position error between light spot & compact disc track:

- Radial: Diffraction based (VLP/Japanse: 3-spot sensing)
- Focus: Foucault knife

Non-contact pickup



Current in the coils gives a force

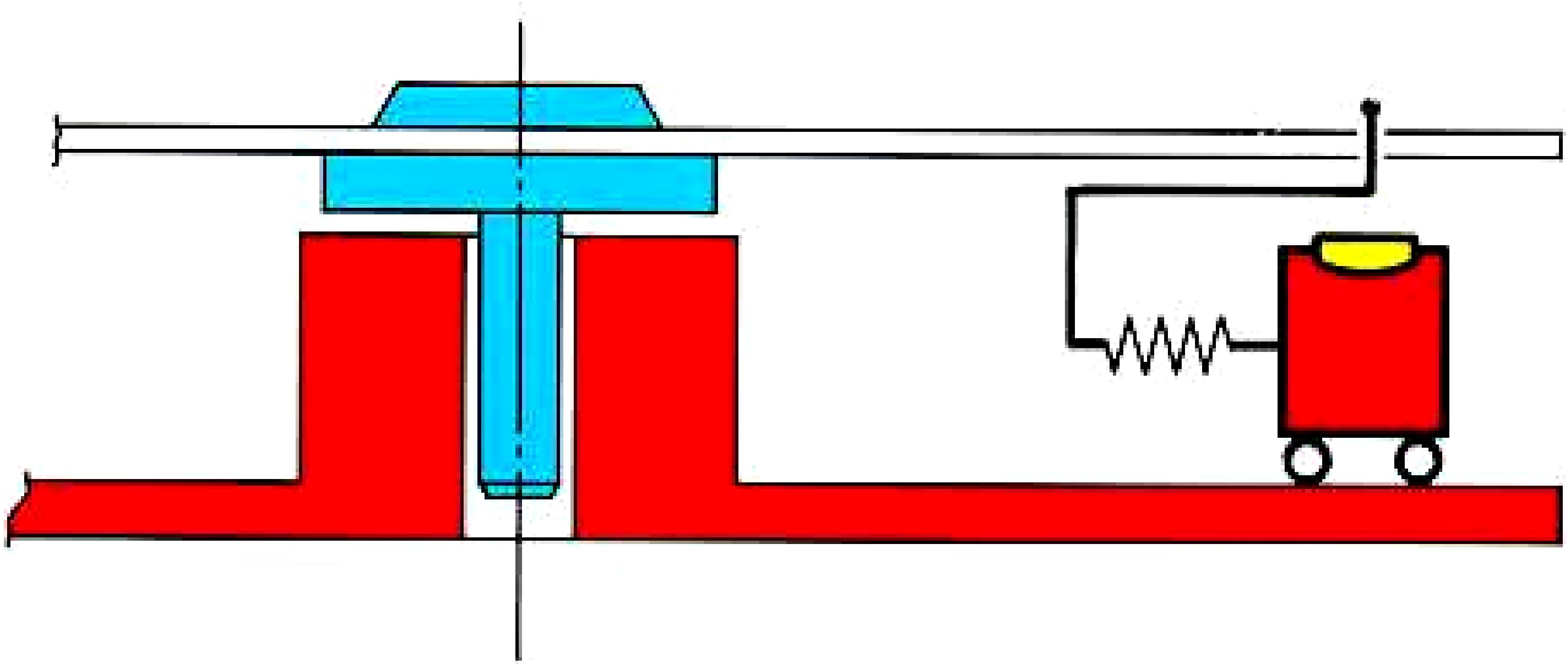
Forces on the coils move the pickup

CD specifications

- Specifications
  - Focus error 1 μm
  - Radial error 0.2 μm

- Disturbances:
  - Eccentricity 200 μm @10Hz
  - Shocks 200 μm @25Hz

Compact Disc Model



Required Servo Stiffness & Servo Bandwidth ?

Mechanical Equivalent

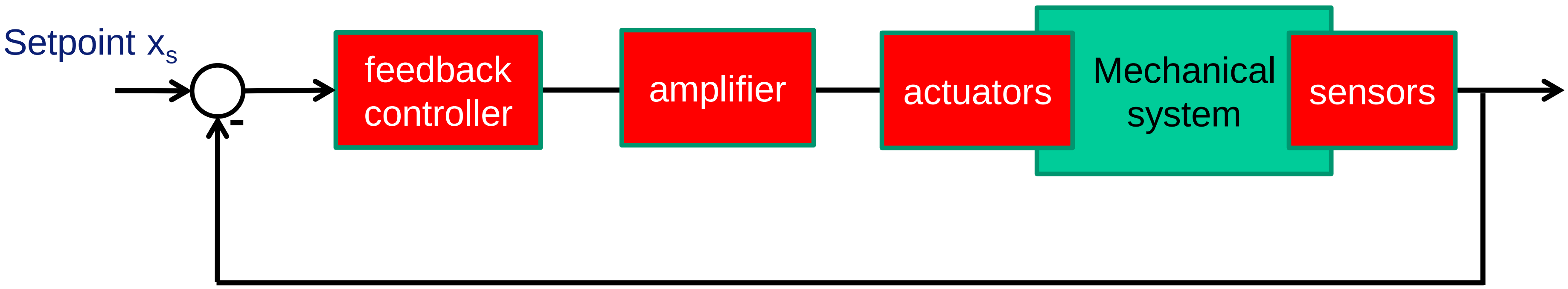
$200\ \mu m\ @25Hz \rightarrow \ddot{x} = 4\ m/s^2$

$m = 10\ gr \rightarrow F = 0{,}04\ N$

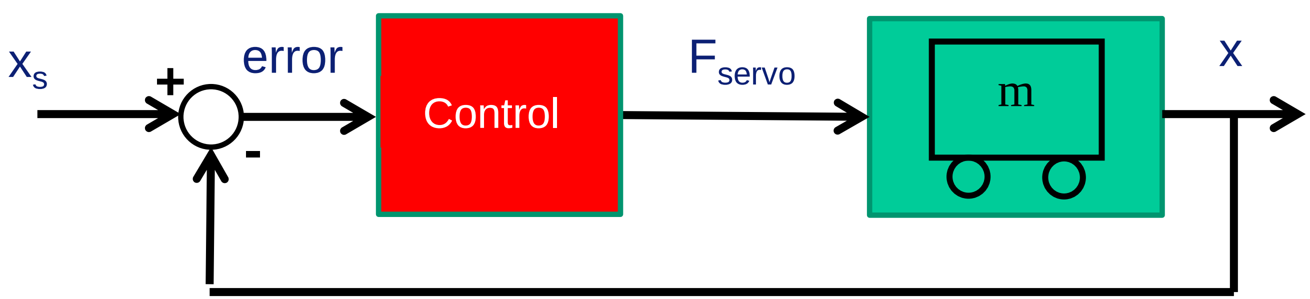
$\Delta x = 0{,}2 \cdot 10^{-6}\ m \rightarrow k = 2 \cdot 10^{5}\ N/m$

$f_{bw} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \rightarrow f_{bw} \cong 750\ Hz$

Elements of feedback loop



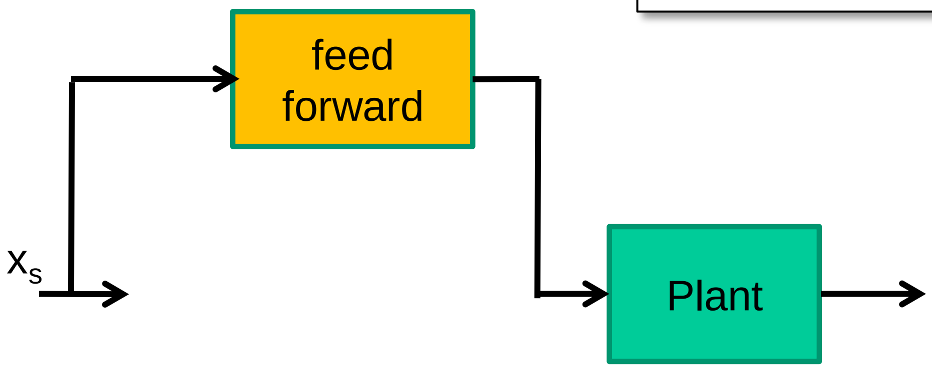
An error is required to generate a servo force.



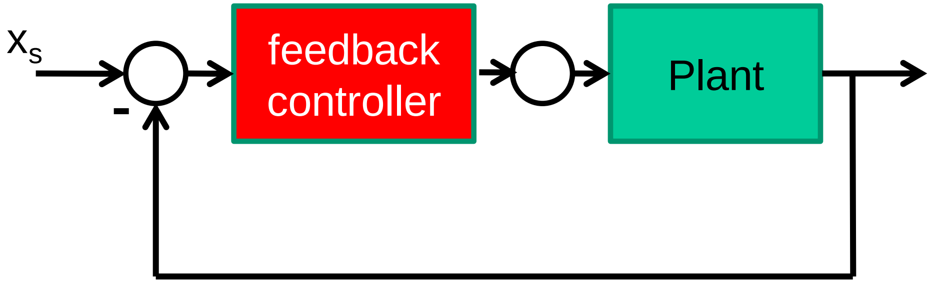
Feedforward complements feedback

- Velocity, Acceleration, Jerk, Snap
- Iterative Learning Control
- Repetitive Control

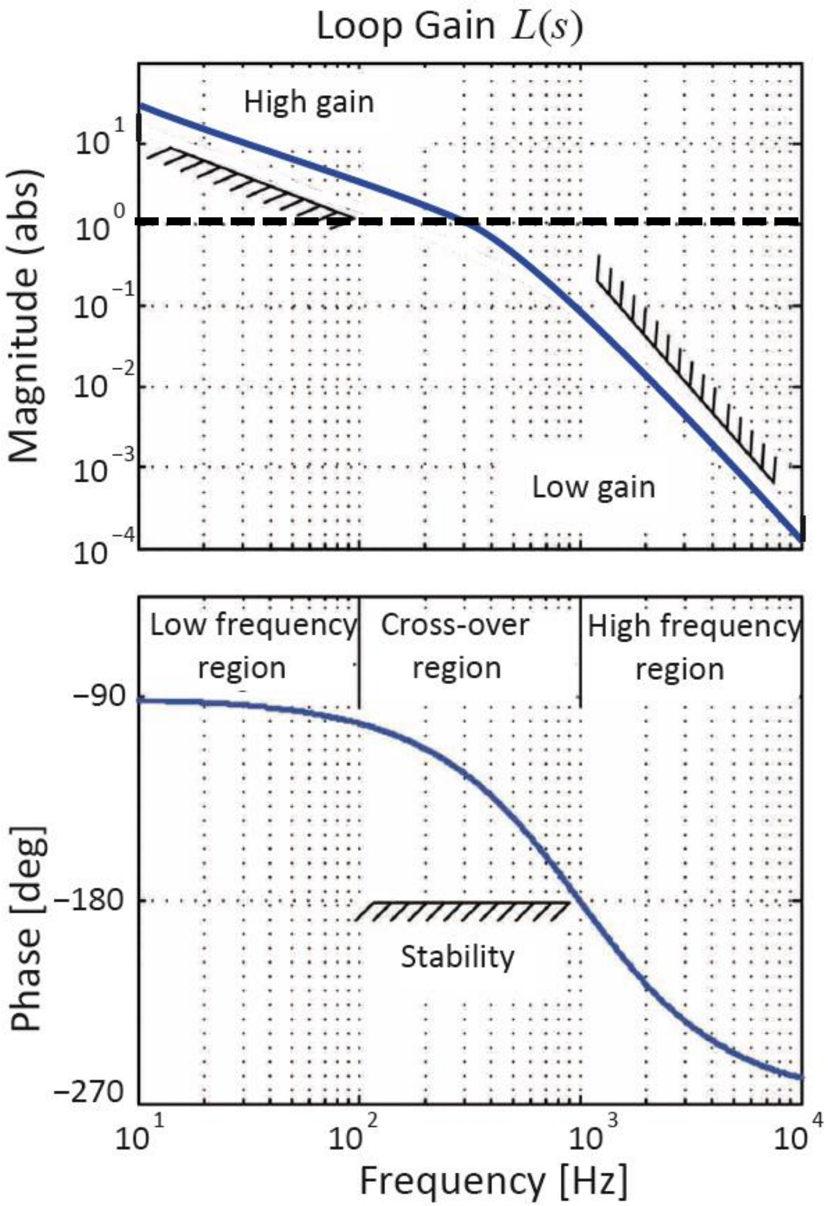
feedforward ...

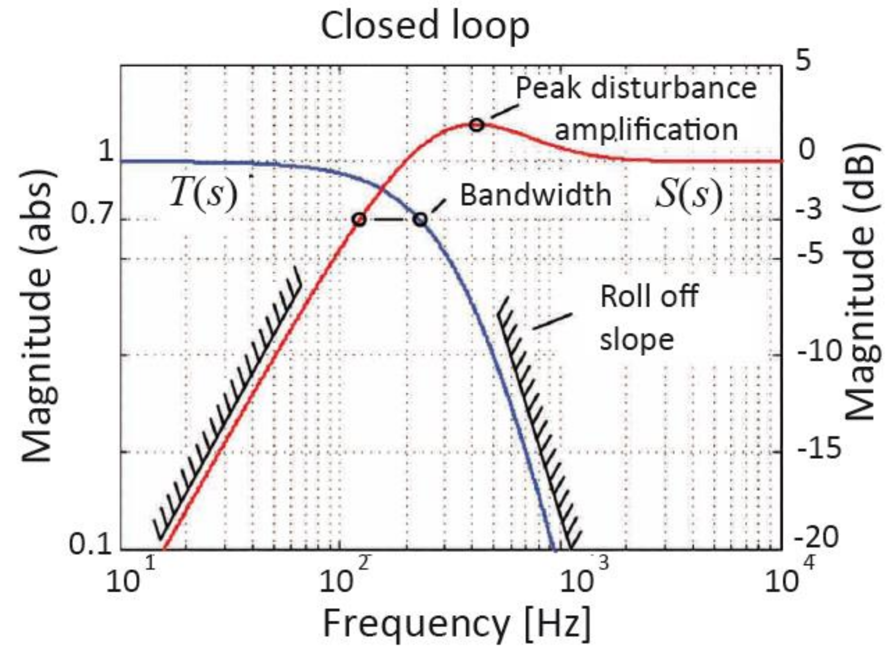


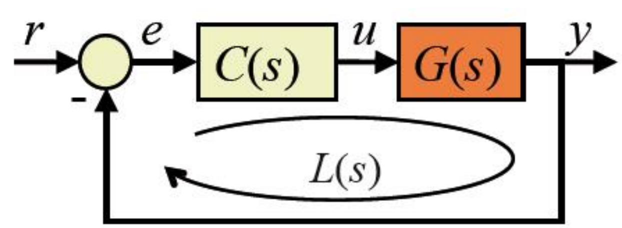
feedback ...



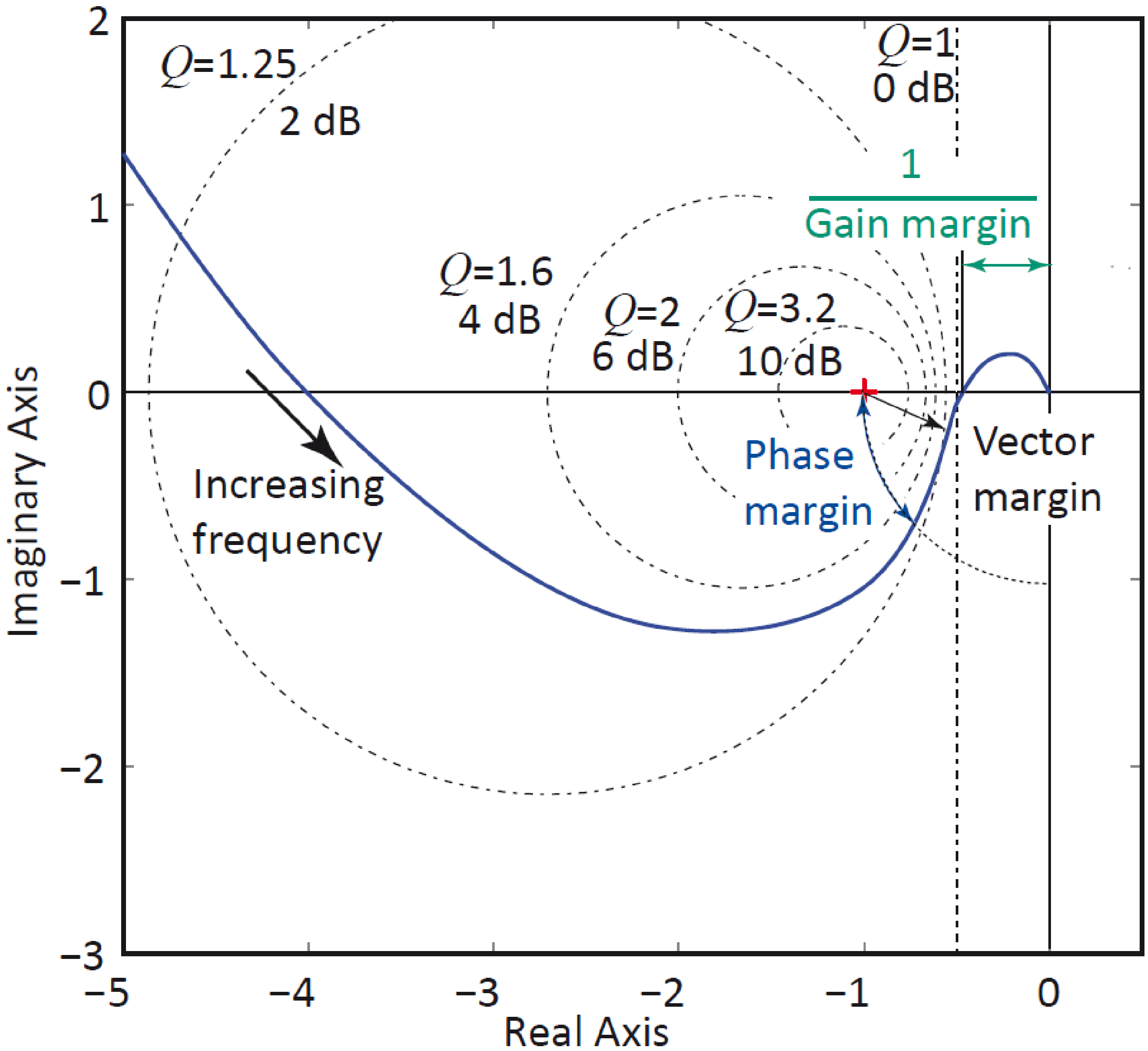
Tuning the feedback loop (performance + stability)



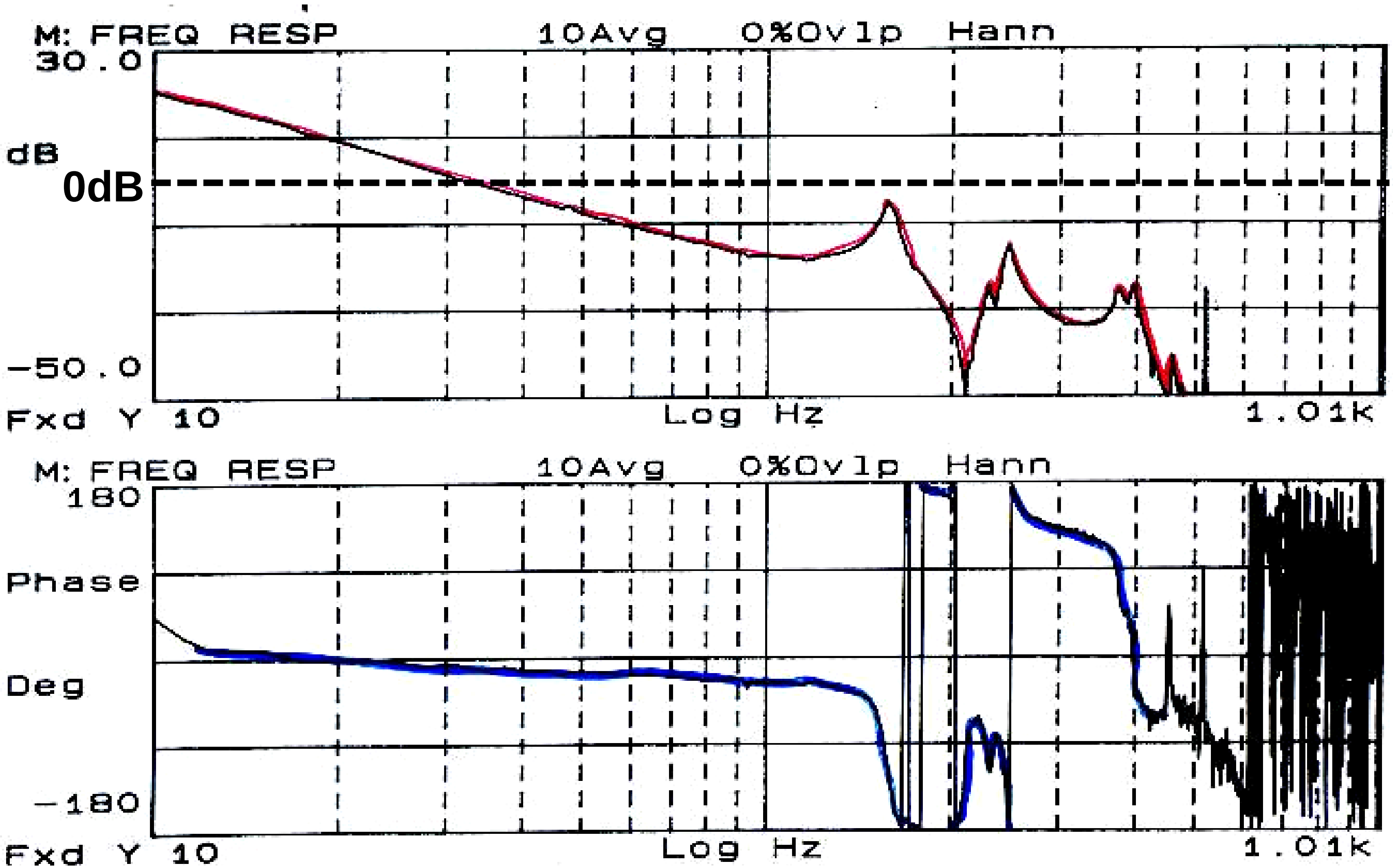




Nyquist Plot of open-loop transfer



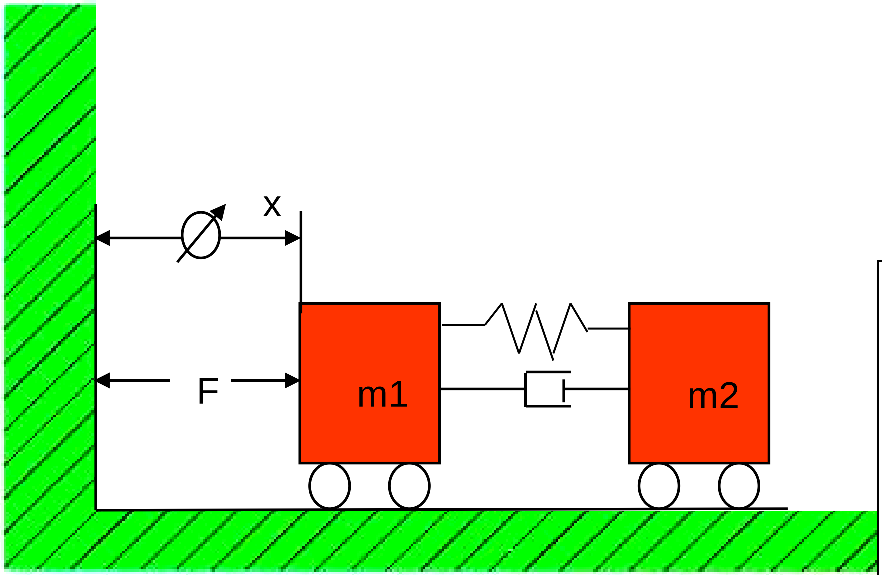
Real Mechanics

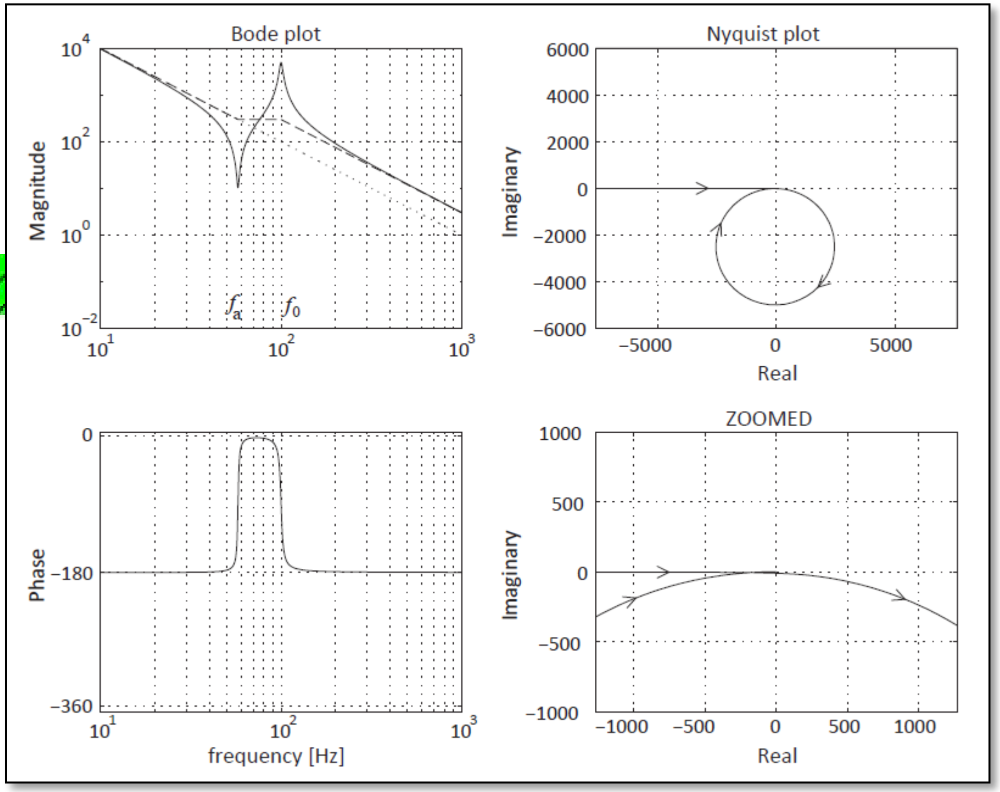


Three main dynamic effects

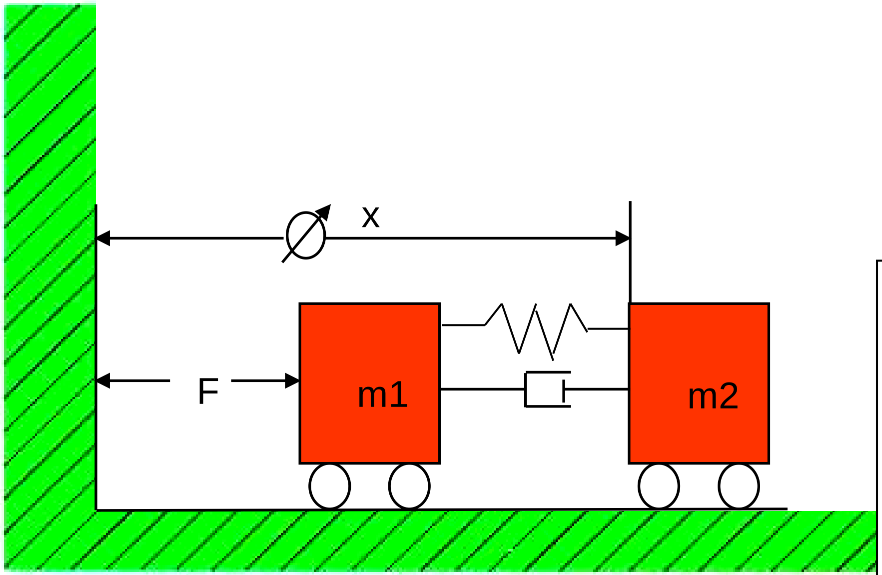
- Actuator Flexibility
- Guiding System Flexibility
- “Non-Rigid” Foundation

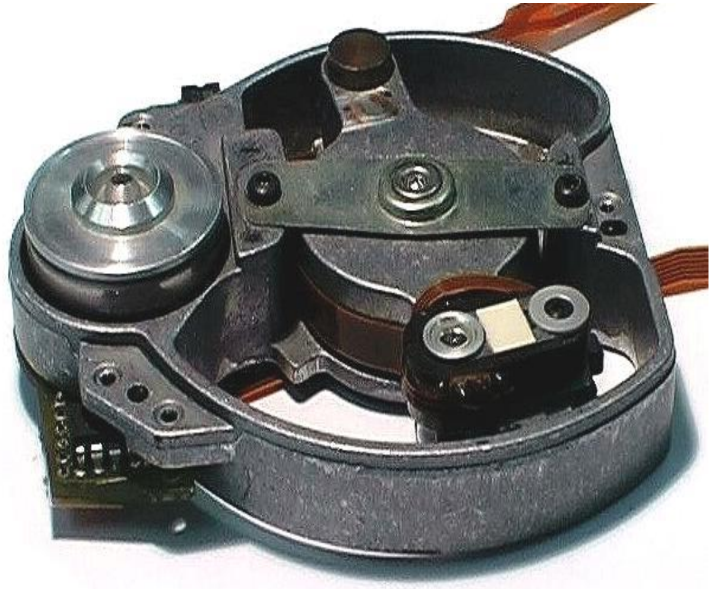
Actuator Flexibility (sensor at motor)

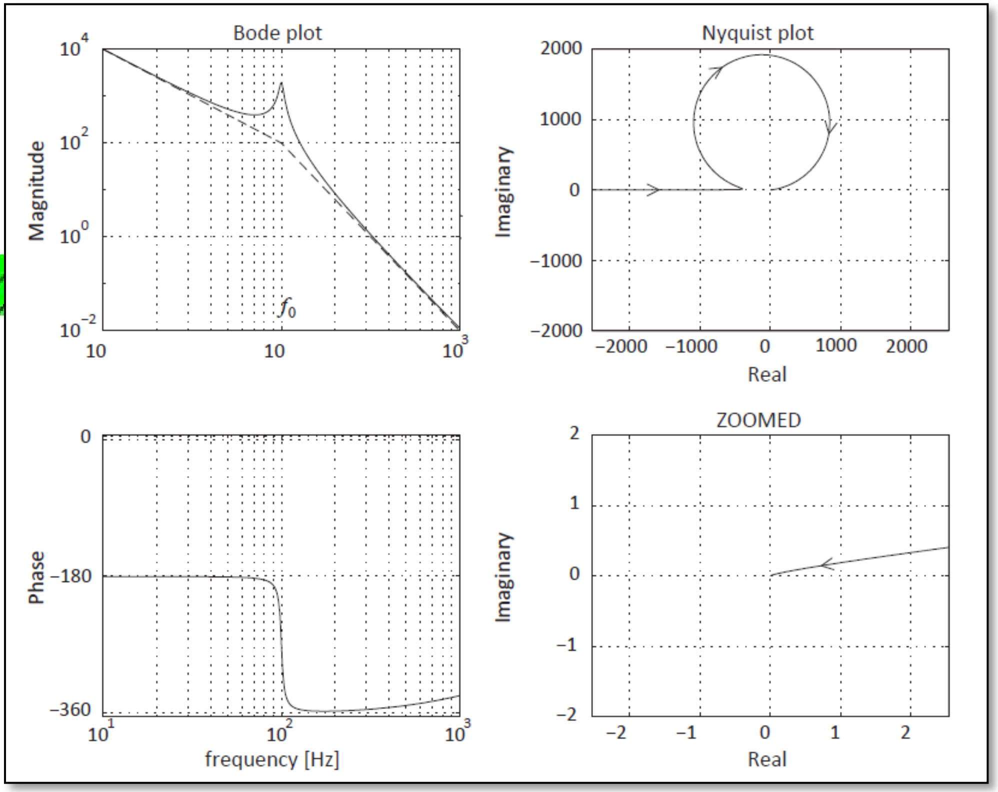




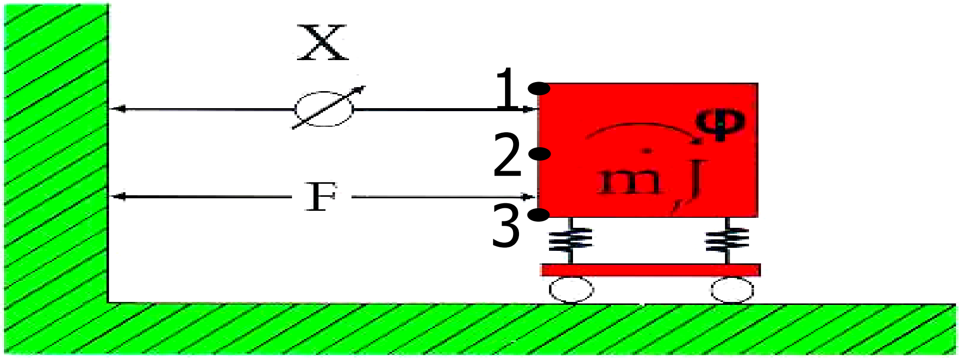
Actuator Flexibility (sensor at load)



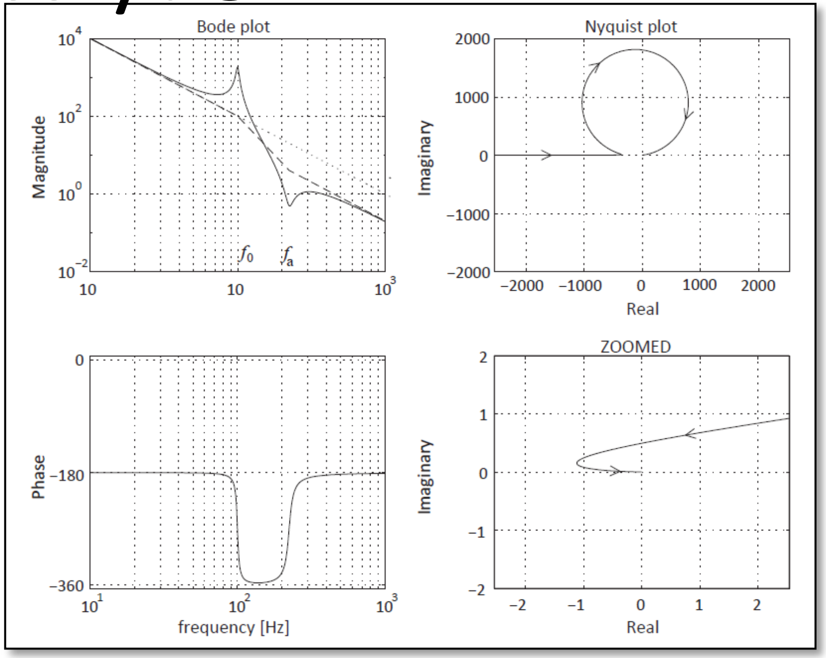




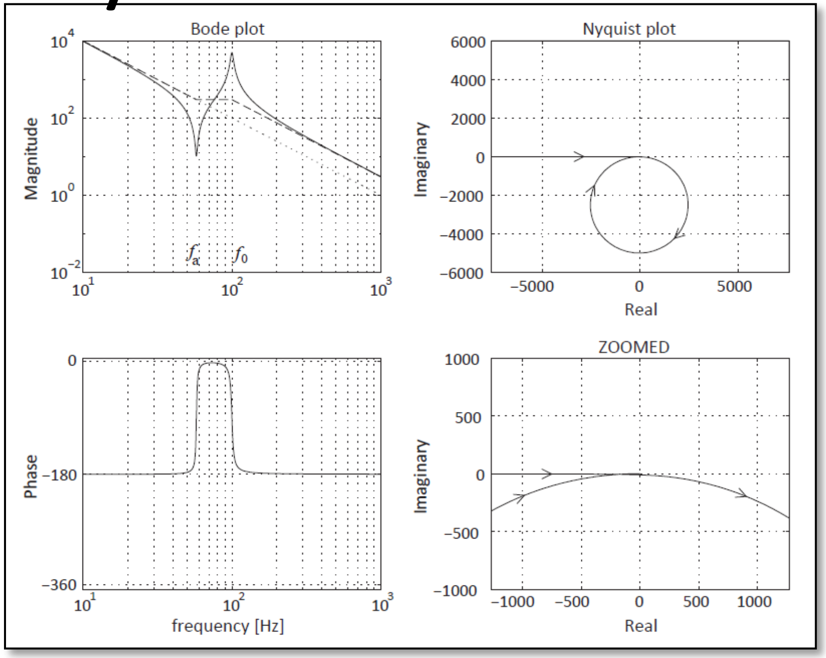
Guiding System Flexibility



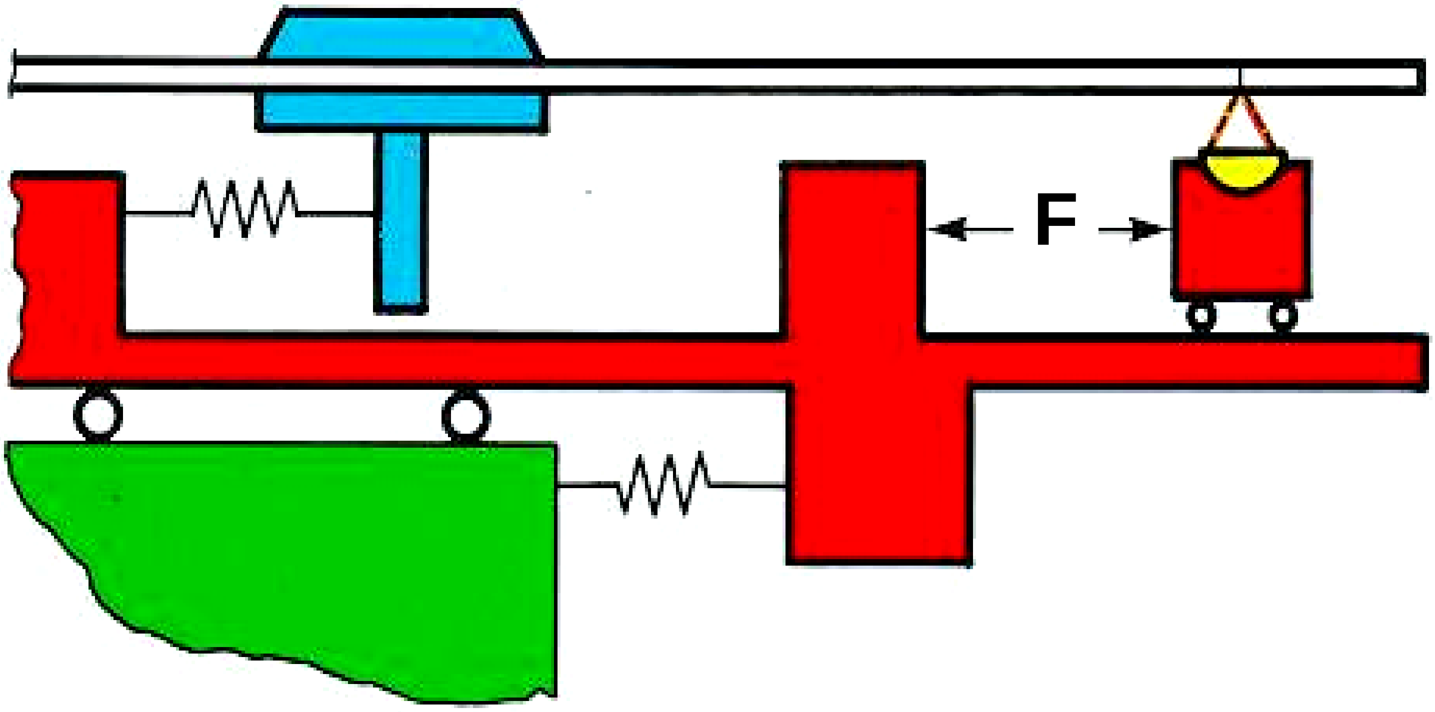
X1/F3



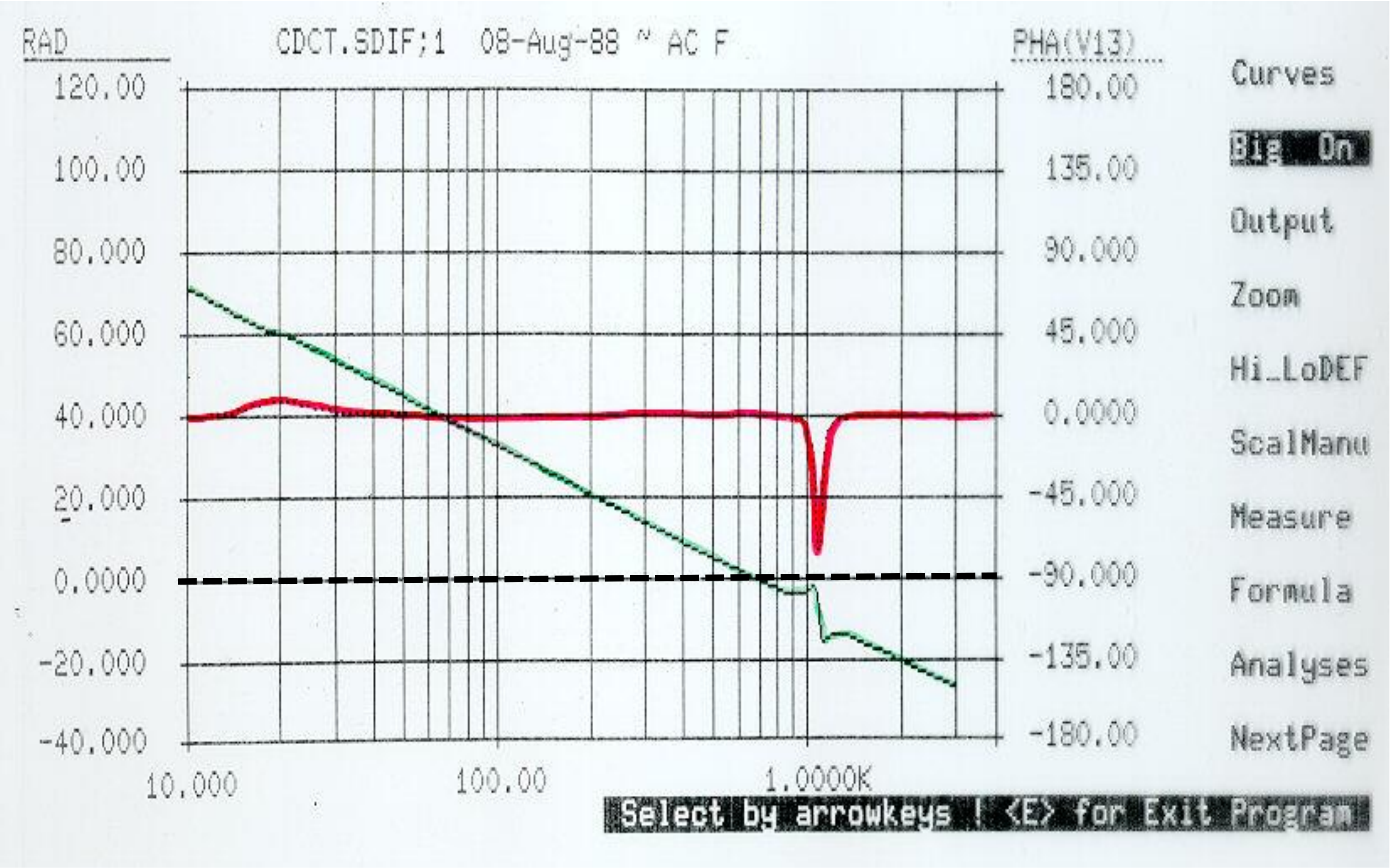
X3/F3



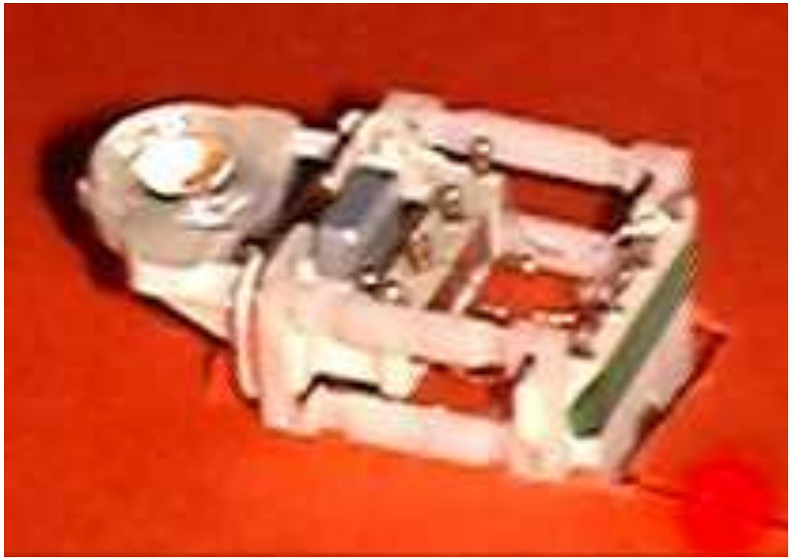
“Non-Rigid” Foundation

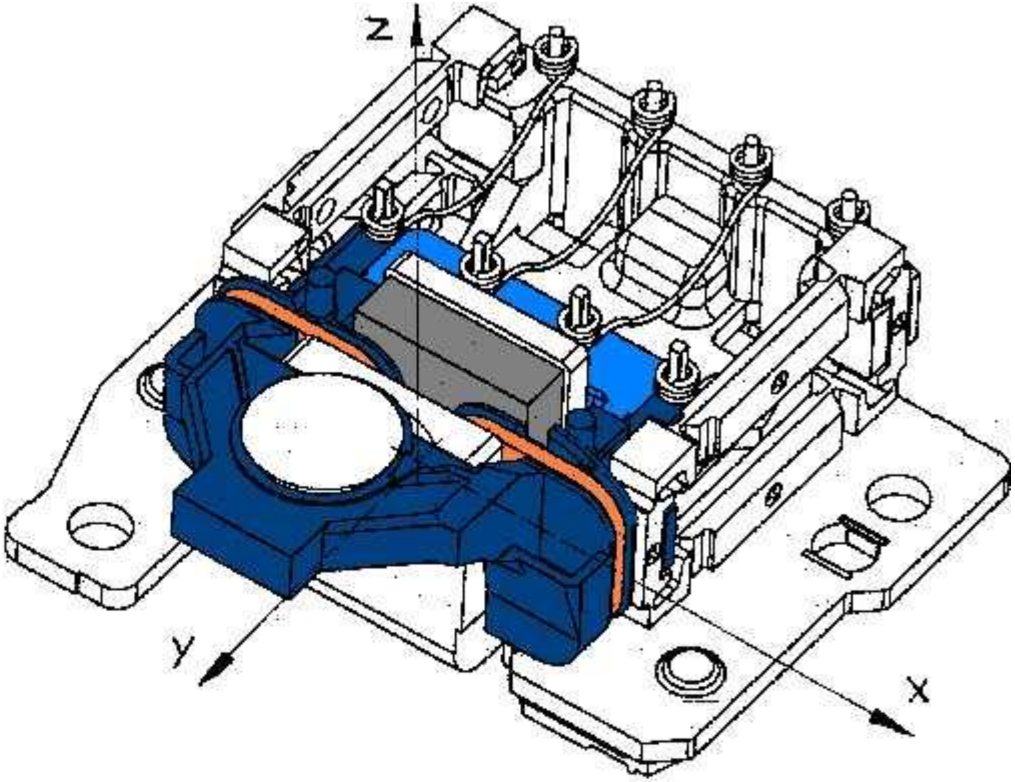


“Non-Rigid” Foundation



Optical Disc - Structural Modification





Long stroke – short stroke

Mode Shape Modification

- Non Controllable
- Non Observable

Predictive Modelling

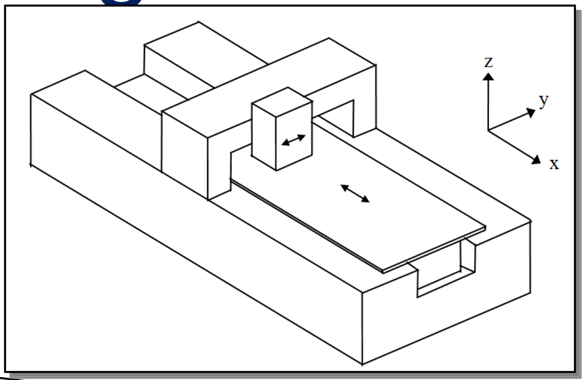
Critical Success Factors in an industrial setting

- Speed
- Usefulness of results

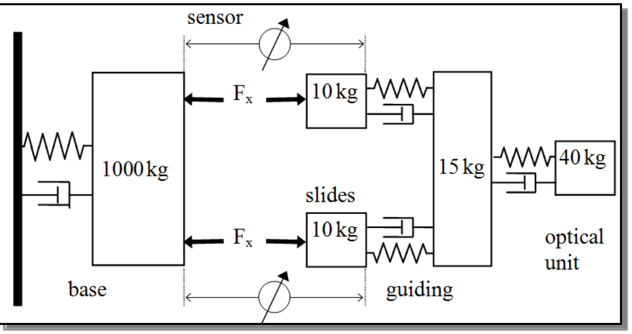
Industrial Approach

- Balance between accuracy and speed
- Support of design decisions & risk reduction
- **Quick rejection of unsuitable proposals**

Predictive Modelling

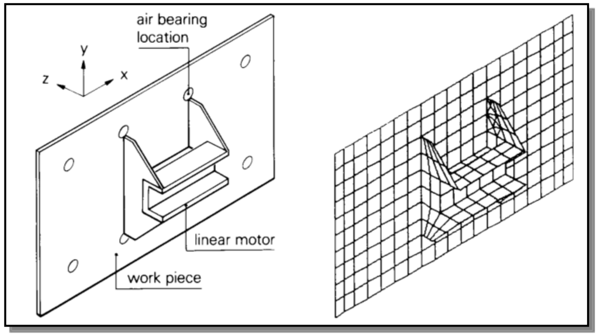


Concept evaluation
Rejection of non-working concepts
Selection of most suitable design(s)



System evaluation
2D/3D Effects, actuator/sensor choice, cooling strategies

Component evaluation
Optimal design of critical components



System verification
Fine tuning of models & learning

Technical lessons learned

- Motion Control
  - Important to have Feedback (FB) and Feedforward (FF)
  - Industrial FB is PID+ and mimics a servo spring+
  - FB is judged in frequeny domain
  - Challenge = Performance + Stability

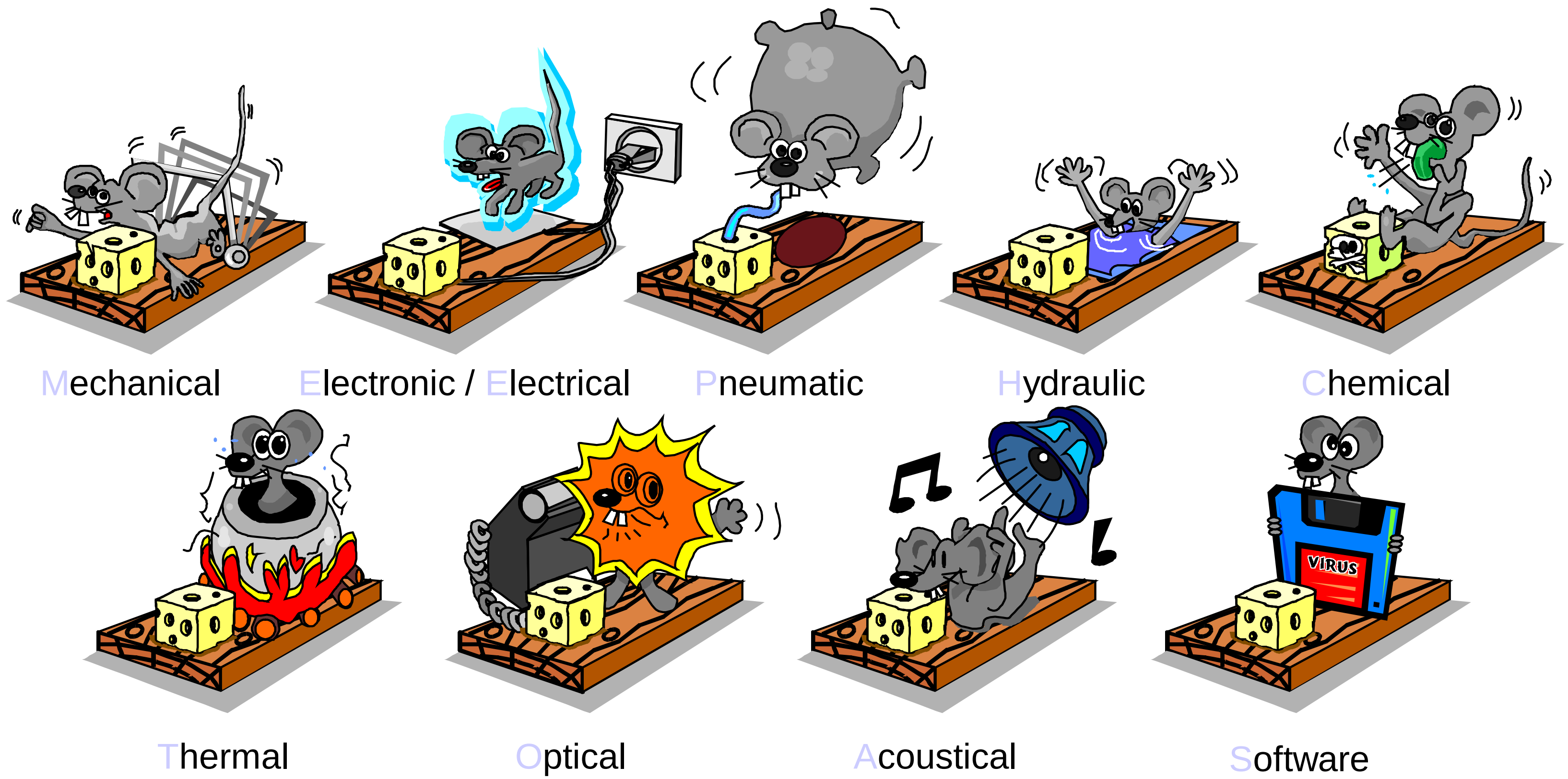
- Dynamics
  - Location of actuator/sensor determines impact on FRF
  - 3 Basic Dynamic Effects
  - Modal Decomposition helps to understand complex dynamics

- Predictive Modelling
  - Phased approach in line with Product Creation Process
  - Essentially risk reduction
  - One can only model what one understands !

The biggest challenge ???

Cooperation of People & Disciplines !!!

Key to success = team members with…



- *Expert Knowledge* in one or more disciplines
- *Basic Knowledge of* all modern disciplines/technologies
- Attitude & Soft Skills to work out system solutions in a team

Attitude / Soft Skills

- Communication
- Respect
- Curiosity
- Sharing Knowledge

}

Way of Working

End of Presentation

Thank you for your attention