PH233 End-semester exam

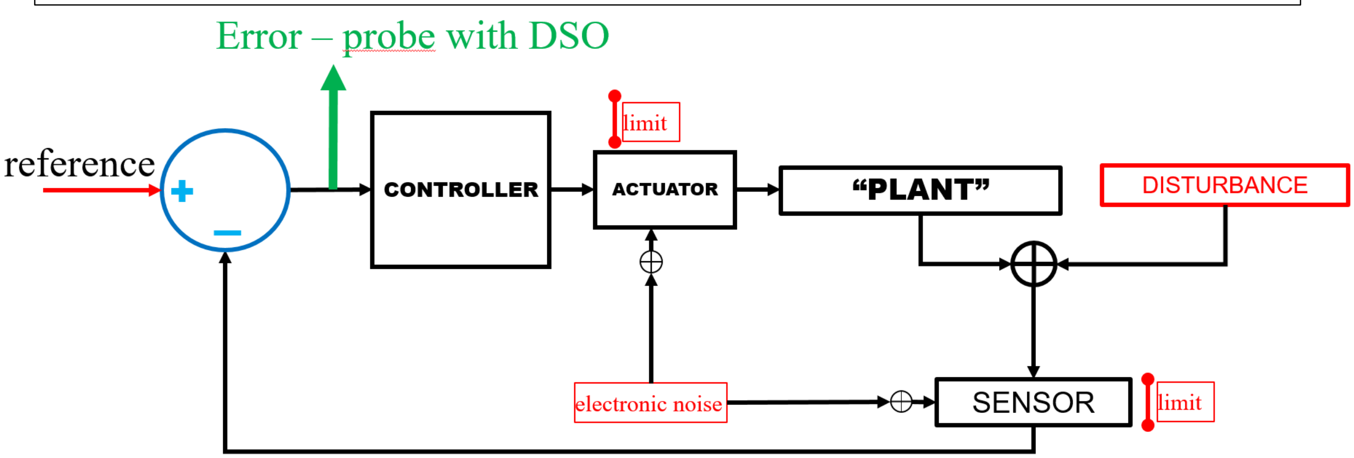
Conceptual introduction

Fig 1 shows the conceptual overview of a feedback system to control a real world 'PLANT'. In this assignment you will first setup and test each module of the feedback control system shown in Fig 1.

After designing and testing the entire system, every module behaves in a deterministic fashion, so all the signals circulating in the feedback loop are known: each can be measured and verified. EXCEPT THE EXTERNAL DISTURBANCE – that is a complicated combination of inputs from the external world with many unknown factors.

The grand objective is to use the fully assembled feedback control system to measure precisely the amplitude of a disturbance introduced in the system.

Fig 1: Overview of a feedback control system. All the "known" modules are colored black. There is one new difference amplifier block in blue. The unknown quantities to be determined are in **red**. Final measurement is in **green**.



PHYSICS CONTEXT of this problem: (simplified description)

The above scheme is similar to what the LIGO experiment uses for the detection of gravitational waves. For LIGO, the PLANT + SENSOR consists of a Michelson-Morley type light interferometer with the sensor focused on a dark fringe. The feedback controller is tuned precisely to reject ground based noise injected into the interferometer mirrors. i.e. the error in the feedback look is 0 in the steady state. Hence, any extra disturbance detected in this loop is inferred to be from the passage of gravitational waves which move the mirror mass distorting the interferometer arm lengths. We will setup a breadboard based simple system to mimic the conceptual basis of such a detection scheme using an LED + photo-transistor sensor.

Practical overview of this lab assignment

This document gives an overview of the lab assignment. The assignment is split in 5 modules as follows. Each module has its separate assignment sheet. Submit solutions to each module assignment separately. Modules need to be completed sequentially: Module E requires (D and C) requires B requires A.

Module A) Characterize the ACTUATOR: **10**

Setup a circuit for an LED whose brightness limits are to be determined with precise current control. I_{LED}→brightness mapping are to be experimentally determined

Module B) Characterize the PLANT: **10**

Setup a phototransistor as a light sensor. Determine the mapping of Incident light → output voltage sensitivity and limits. In this experiment the PLANT consists of the LED and phototransistor closely coupled to each other. Setup the plant on your breadboard and fine tune settings of actuator and sensor such that the sensitivities are well-matched and both actuator and sensor signals stay well within their respective limits.

Module C) Proportional Controller 20

For simplicity we will use only a proportional **(P)** controller. Note that this feedback system is configured as a disturbance-rejection network. Fine-tuning the gain constant K_P can be done by trial and error instead of rigorous tuning by the Zeigler-Nichols method. Our final goal is clear: in steady state, with the controller working properly the error probed at the input of the controller block in Fig 1 must be minimum and be able to tolerate small disturbance without the system breaking out into oscillation.

Module D) Difference amplifier 10

To close the feedback loop, you need the important difference amplifier block in the left of Fig 1 – this determines the difference between the reference and the sensor value. Build this difference amplifier block in Module D

Module E.1) Calibrate and test stability of P controller 20

Inject disturbance of known amplitude into your feedback control system – test that your system detects the disturbance correctly, and returns back to its stable point with error → 0. This will give you a calibration for your real disturbance measurement in the next step.

Module E.2) Final measurement of external, unknown disturbance 10

Apply an external disturbance light signal to your plant. One example of such a disturbance is to switch on an overhead tube-light which flickers at 100Hz.

Circuit board Layout:

In this lab you will NOT use the FG. So it's a good idea to disconnect it completely from the power $\pm V_{CC}$ rails to avoid spurious transients.
For the final solution, you will need a total of FOUR opamps + circuit for the phototransistor sensor. So please plan your photogenic layout on the breadboard to accommodate 4 opamps with clear connections. Leave plenty of clear space at one end of the breadboard to setup the plant neatly.