Research Migration Project

https://esim.fossee.in/research-migration-project

The Research Migration Project is an initiative of FOSSEE, IIT Bombay that promotes the use of eSim for reproducing published research circuits originally implemented using proprietary simulation tools. The objective is to migrate these validated designs to eSim to build an open source resource database.

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Title of the circuit :

Analog PID Controller for DC Motor Speed Control

Theory/Description :

This circuit uses operational amplifiers (Op-Amps) to build a continuous-time proportional-integral-derivative (PID) controller. The circuit comprises of three parallel signal processing stages: a Proportional amplifier (to enhance rising time), an Integrator (to minimize steady-state error), and a Differentiator (to reduce overshoot). These three signals are summed using an inverting adder to generate the control signal for the load (modelled as a DC Motor). The feedback loop creates the error signal, which the PID controller minimizes, by comparing the output speed (expressed as voltage) to a setpoint.

Reason to reproduce with eSim :

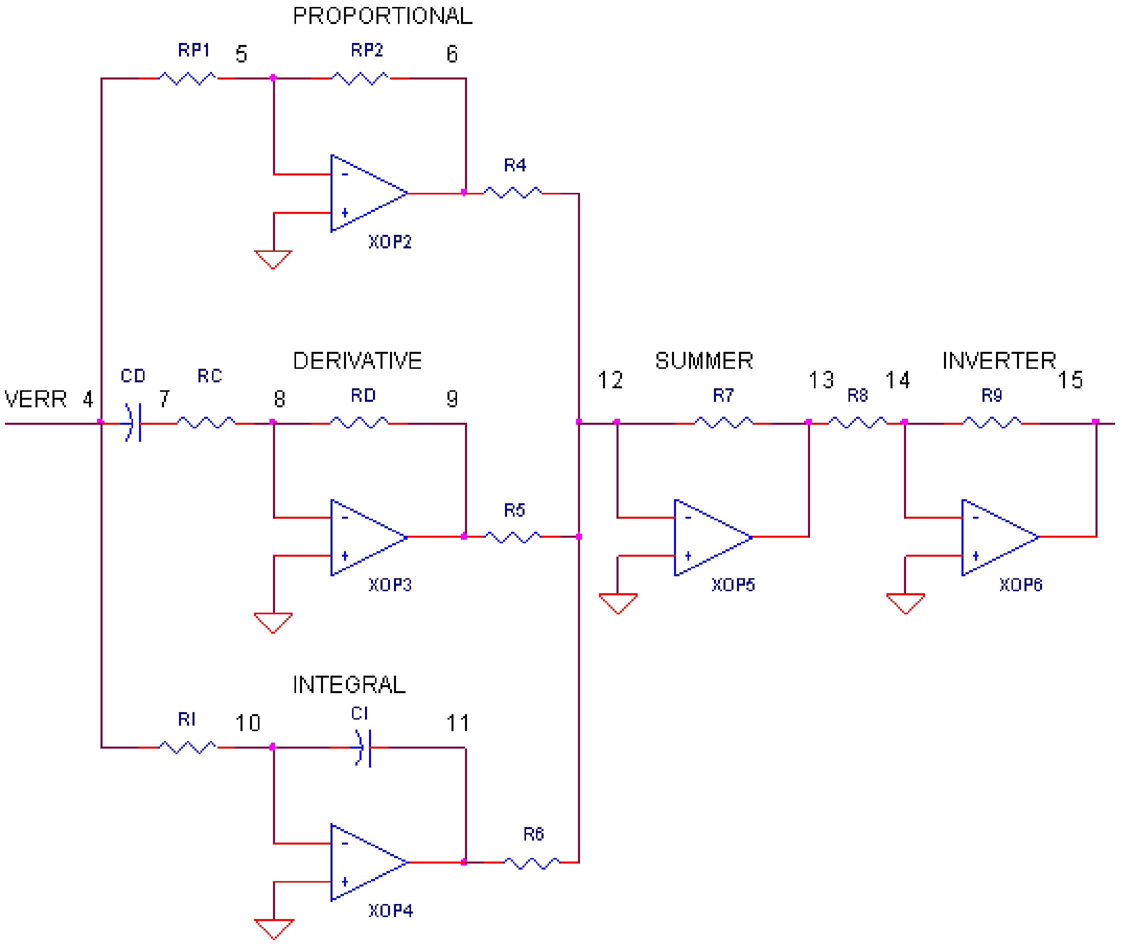
Reproducing this circuit in eSim (using the Ngspice engine) allows for the validation of control theory concepts in an open-source environment without relying on proprietary tools like MATLAB/Simulink. It demonstrates the capability of eSim to handle mixed-signal simulation and complex feedback loops. This project serves as an educational resource for students to visualize the transient response and stability of analog control systems cost-effectively.

Expected Outcome/outputs :

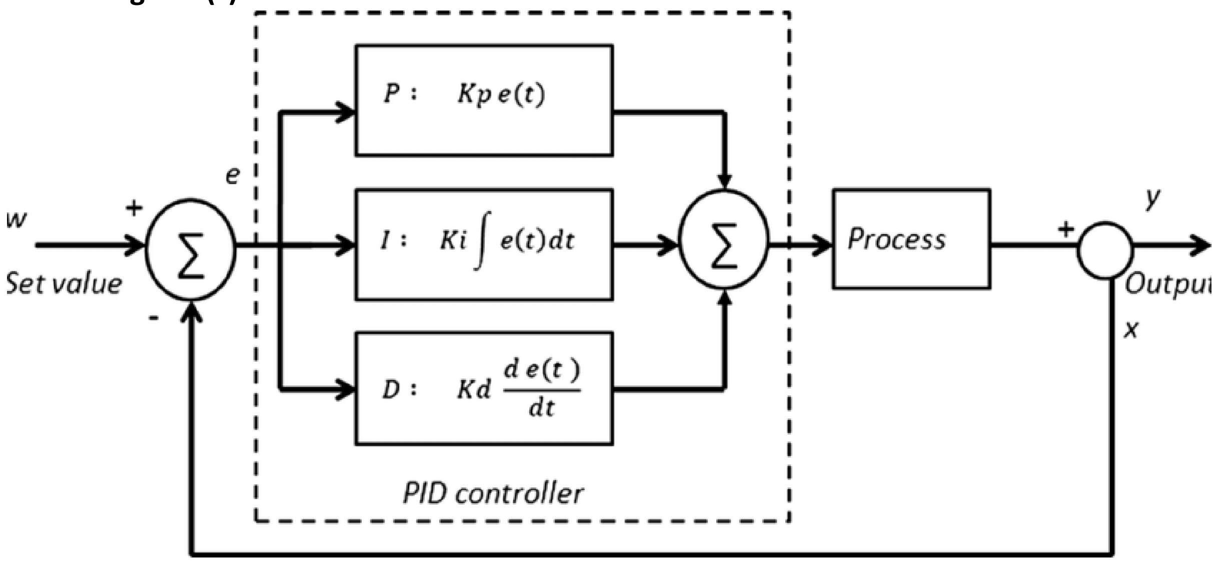
When simulated, the circuit is expected to show the following waveforms:

1. Transient Response: A plot of the Output Voltage (Motor Speed) rising and settling to the Setpoint Voltage with minimal overshoot and zero steady-state error.
2. Error Signal: A waveform showing the error voltage decaying to zero over time.
3. Control Signals: Individual waveforms for the P, I, and D outputs, allowing for the analysis of each component's contribution to the system stability.

Circuit Diagram(s) :



Block Diagram (s) :



Expected Results (Input, Output waveforms and/or Multimeter readings) :

1. Input Signal (Setpoint): A step voltage signal (e.g., 0V to 5V) will be applied as the reference input. This represents the desired motor speed changing instantaneously from "Stop" to "Full Speed".

2. Output Waveform (Transient Response): The output voltage (representing actual motor speed) is expected to rise towards the setpoint value. The waveform will exhibit:

- Rise Time: A smooth increase from 0V.
- Overshoot: A slight peak above 5V (depending on the Kp and Kd tuning) before correcting itself.
- Settling: The waveform will stabilize and flatten out exactly at the setpoint voltage (5V).

3. Error Signal Waveform: The error voltage (measured at the output of the difference amplifier) will start at a maximum value (5V) at t=0 and exponentially decay to 0V. This validates that the Integral (I) term is correctly accumulating and eliminating steady-state error.

4. Multimeter Readings: In steady-state simulation analysis:

- Input Node: 5.00V
- Output Node: 5.00V (demonstrating unity gain in closed loop)
- Error Node: 0.00V (demonstrating zero steady-state error)

Research Paper/Journal/etc. :

- Title: Op-Amps and Linear Integrated Circuits
- Author: Ramakant A. Gayakwad
- Page No.: Chapter 7 (General Linear Applications)
- Link: https://www.pearson.com/en-us/subject-catalog/p/op-amps-and-linear-integrated-circuits/P200000003206

Source/Reference(s) :

Ogata, K., "Modern Control Engineering", Pearson Education.

eCircuit Center, "Op-Amp PID Controller", Available: http://www.ecircuitcenter.com/Circuits/op_pid/op_pid.htm

ResearchGate (Block Diagram Source).
