Performance Evaluation of Digital Control Algorithms for A DC Motor System

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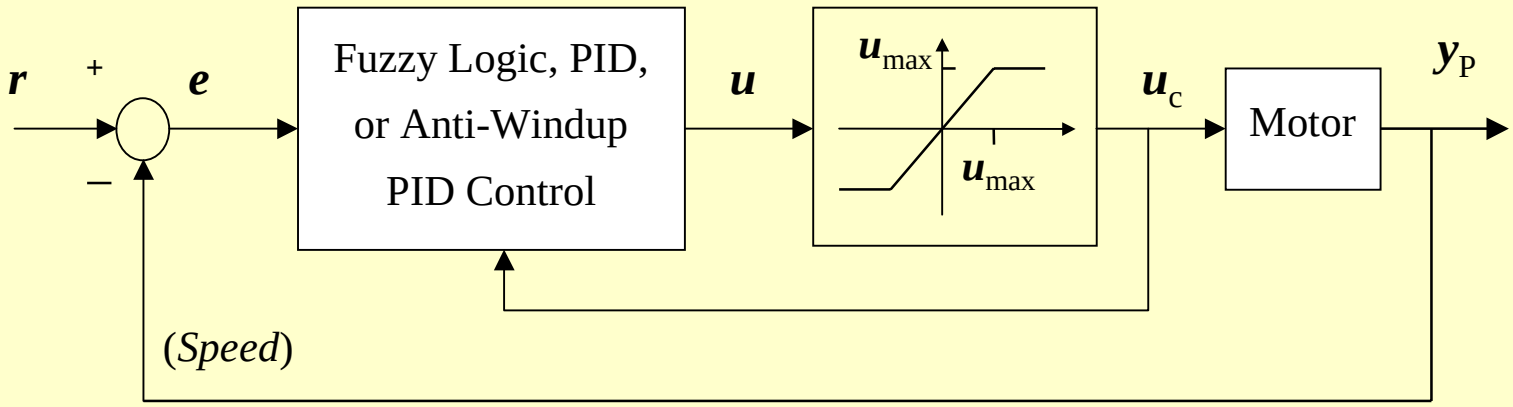
DC Motor Control Objectives

- Achieve fast and smooth speed response
- Robustness to load variations

- However, due to *saturation nonlinearity* in the speed control loop, windup effect degrades the performance of the PID controller.
- Input command to the motor is saturated because of the magnetic saturation and motor overheating protection.

- Both anti-windup PID and fuzzy logic controllers achieve similar control performance.
- Improved performance includes small overshoot, short settling time, and robustness.

Control Block Diagram



$$e(k) = r(k) - y_p(k)$$

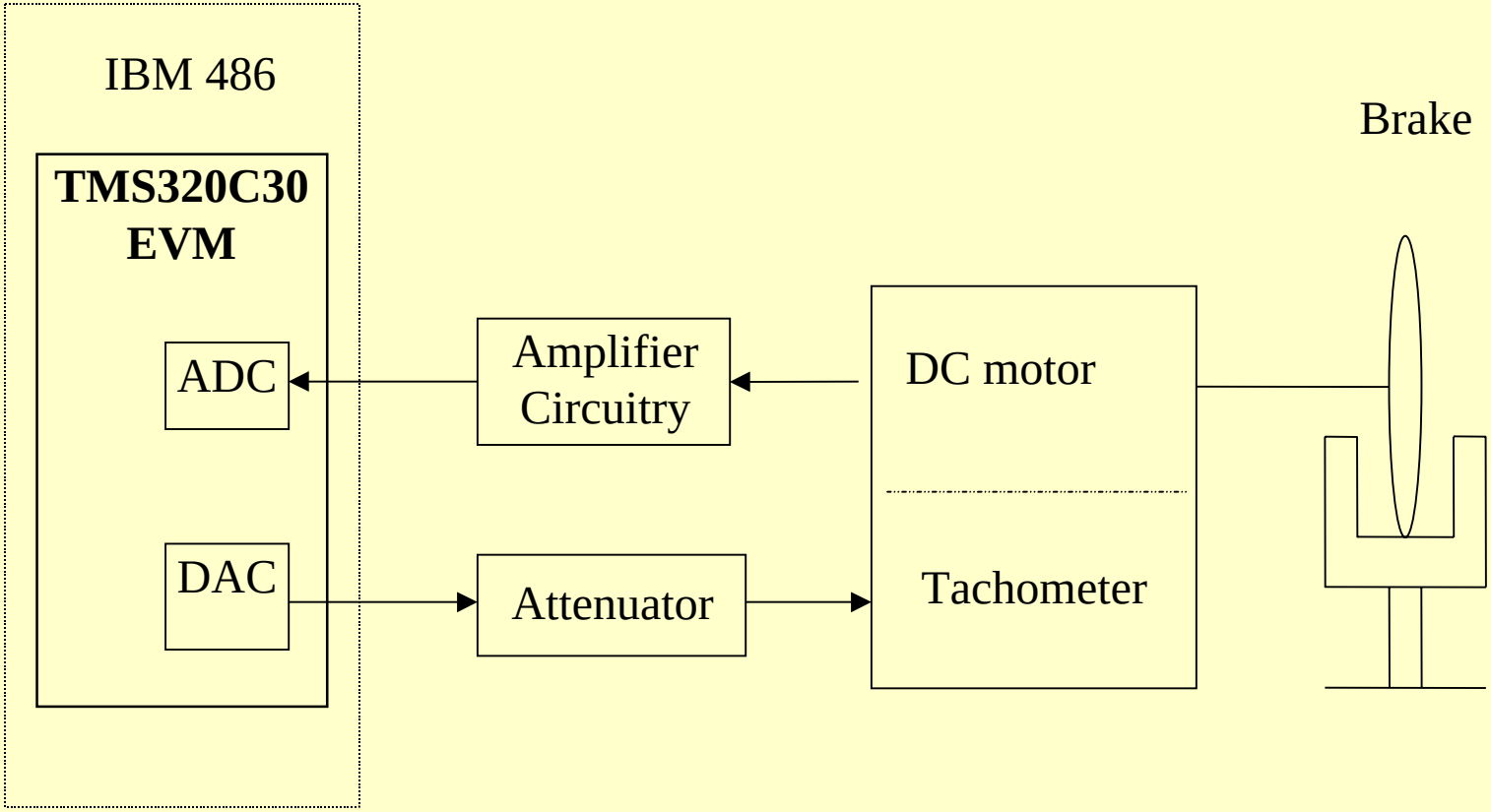
$$\Delta e(k) = e(k) - e(k\text{-}1)$$

$$u_c(k) = N_u F[N_e e(k), N_{\Delta e} \Delta e(k)]$$

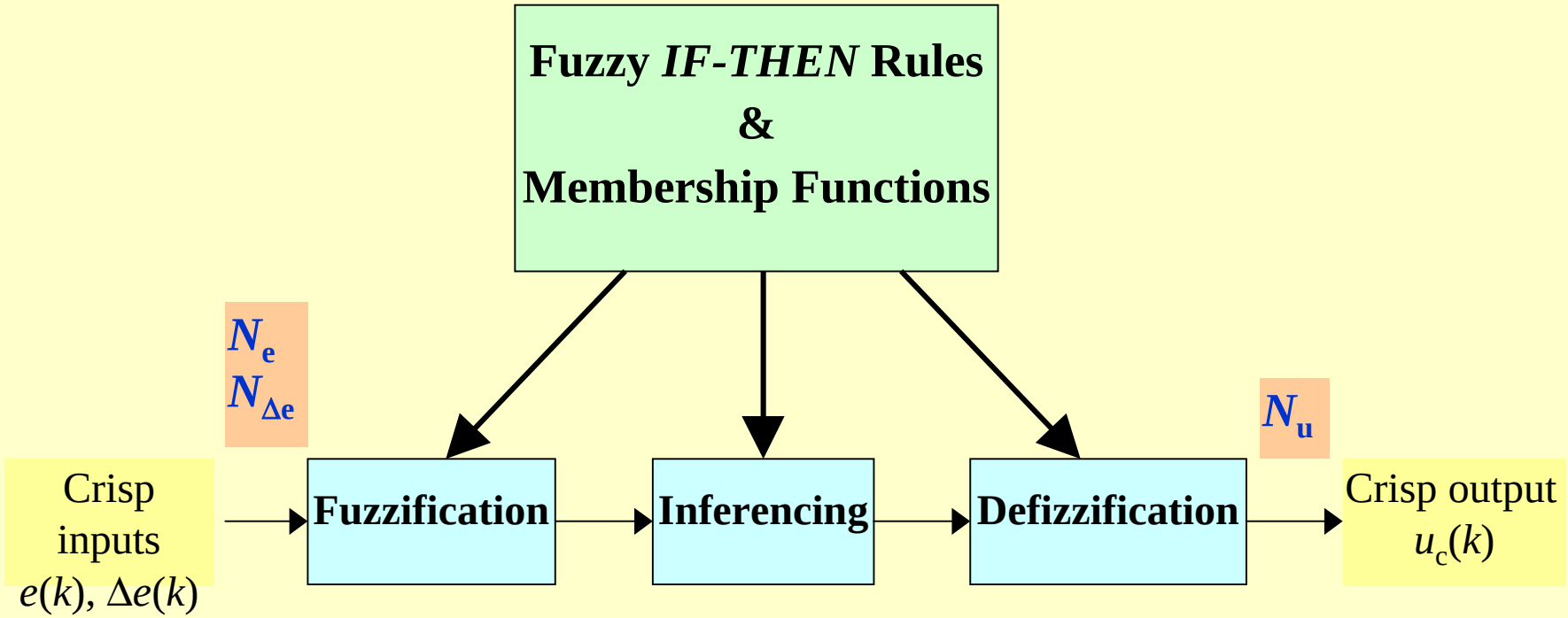
- N_e, $N_{\Delta e}$, and N_u are scaling factors
- $e(k)$ and $\Delta e(k)$: the error and change of error of dc motor speed
- F represents the FLC operation

◆ Scaling factors are tuned according to hardware specification and system response

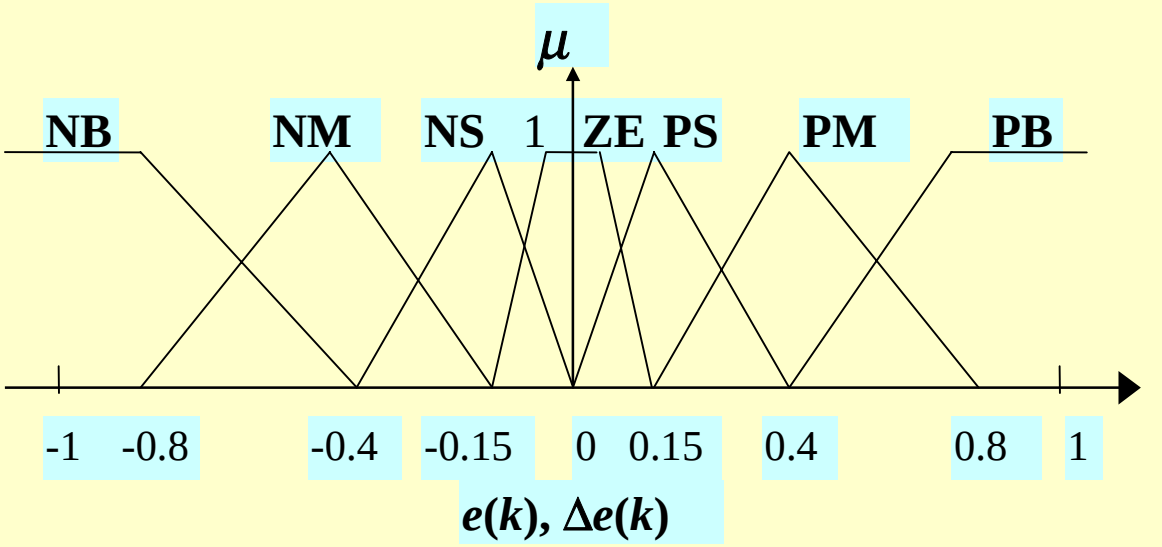
Experimental Setup

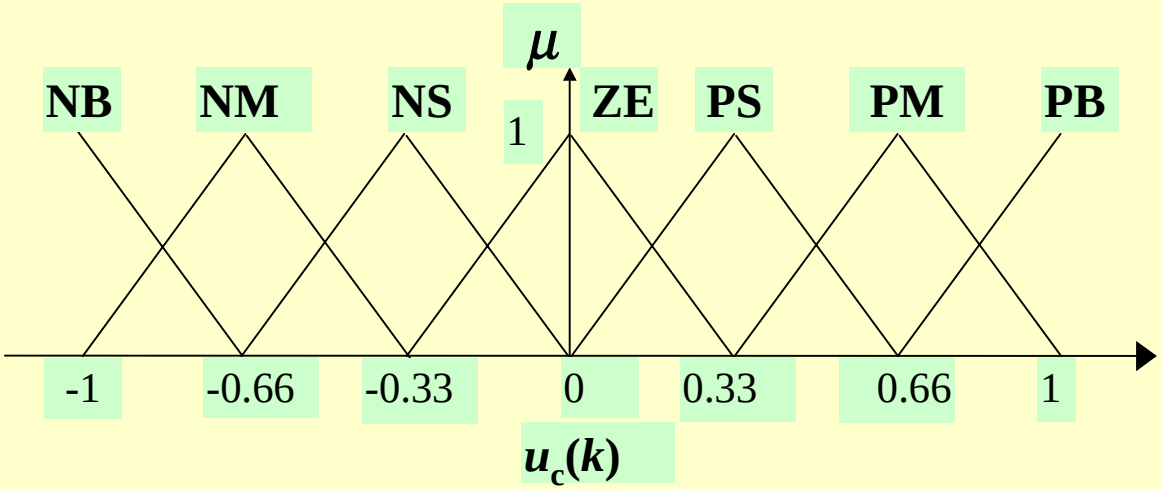


Fuzzy Logic Control Scheme



Membership Functions





Fuzzy Logic Rules

Fuzzy *IF-THEN* rules are derived from heuristics and knowledge of the system response.

IF $e(k)$ is L_1 AND $\Delta e(k)$ is L_2 , *THEN* u is U_1

$e(k)$ / $\Delta e(k)$	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB				NB	NB		
NM	NB			NB	NB		
NS	NB			NM	NM	NM	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM		PS	PS	PM		
PM				PM	PB	PB	
PB			PM	PM	PB		

PID Control

Continuous-time:

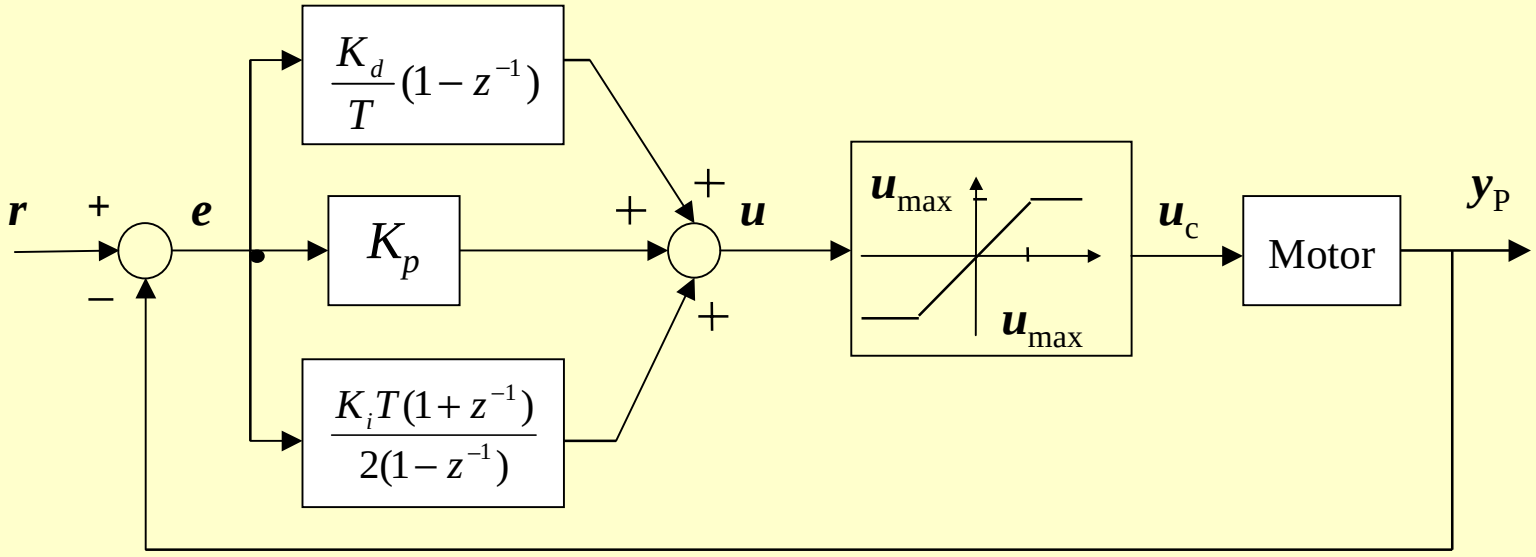
$$u(t) = K_p e(t) + K_i \int e(\tau)d\tau + K_d \frac{de(t)}{dt}$$

Discrete-time:

$$u(k) = + (0.5K_i T - K_p - 2K_d / T)e(k-1) + (K_d / T)e(k-2)$$

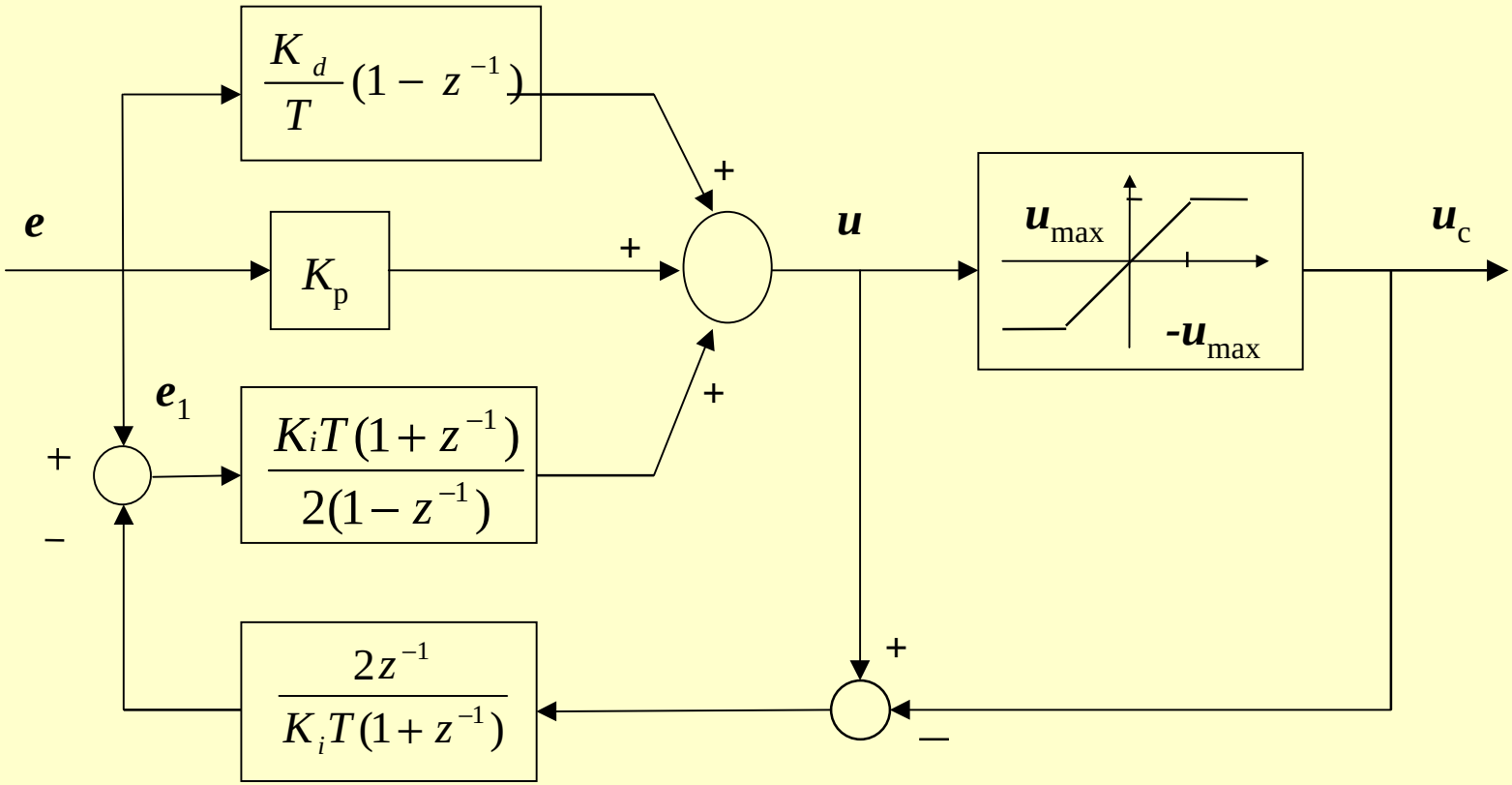
$$K_p = 50, K_i = 0.2, and\ K_d = 0.05$$

Discrete-Time PID Control



Discrete-Time Anti-Windup Control

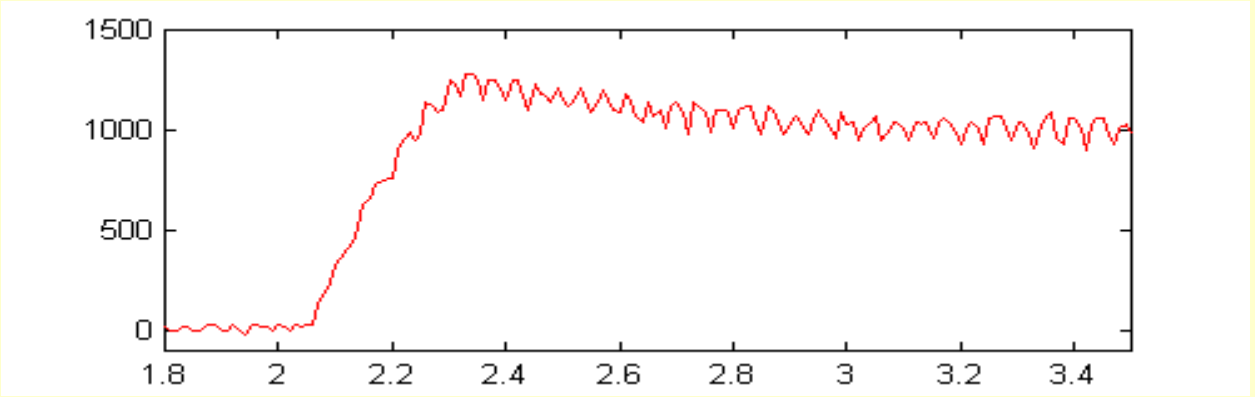
K_a was chosen large enough so that the anti-windup compensation is capable of following e to keep the output from saturating



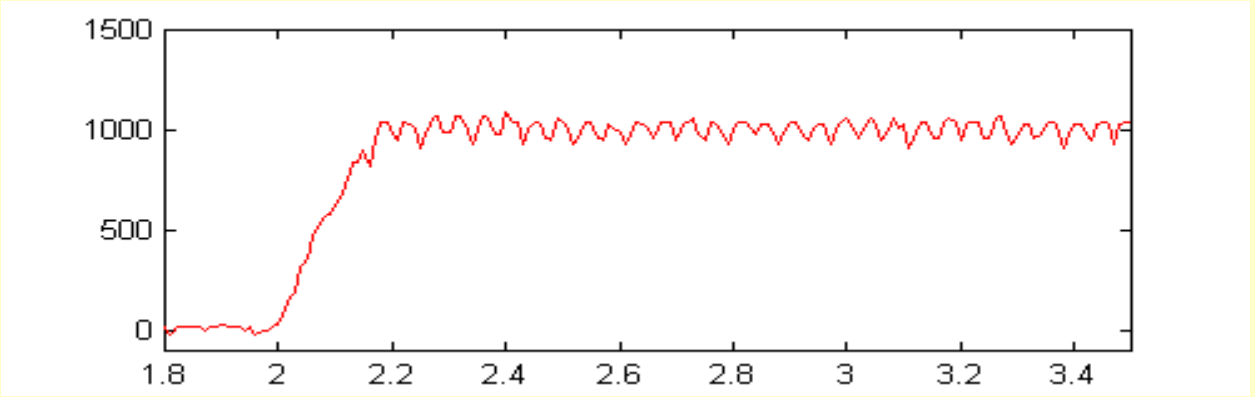
rpm

Step response with load

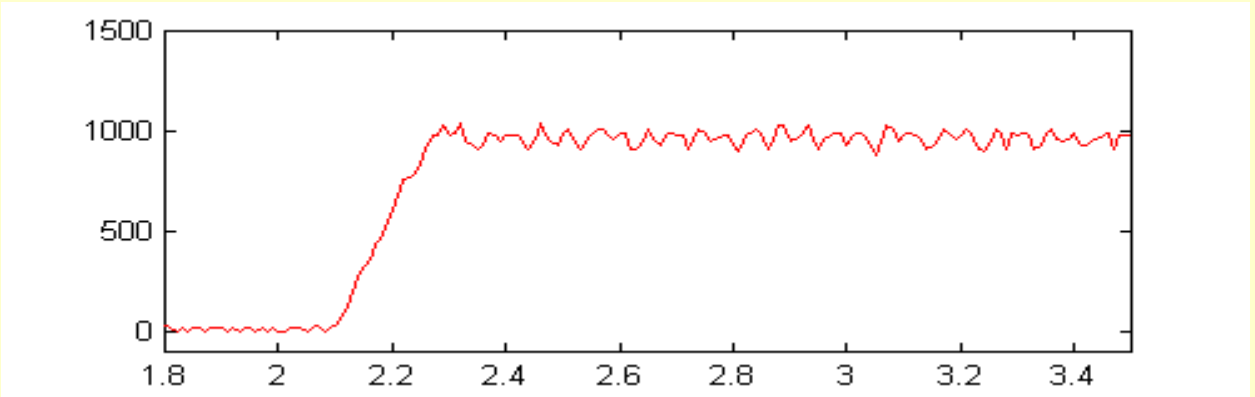
PID Control



PID Anti-Windup Control



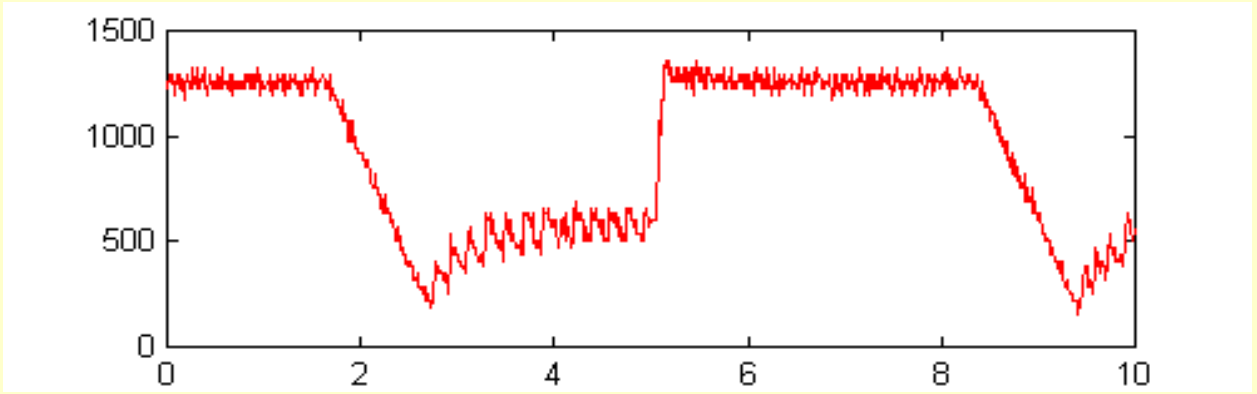
Fuzzy Logic Control



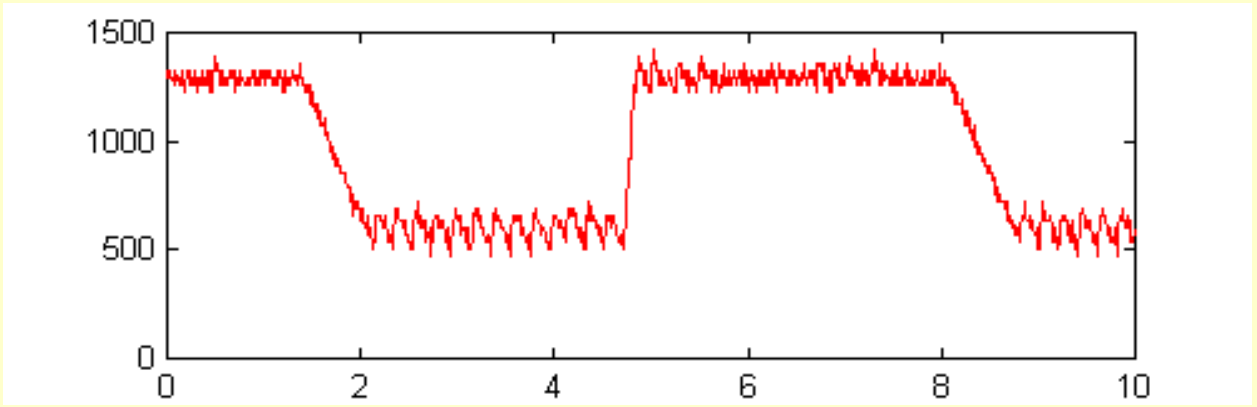
Speed response without load

rpm

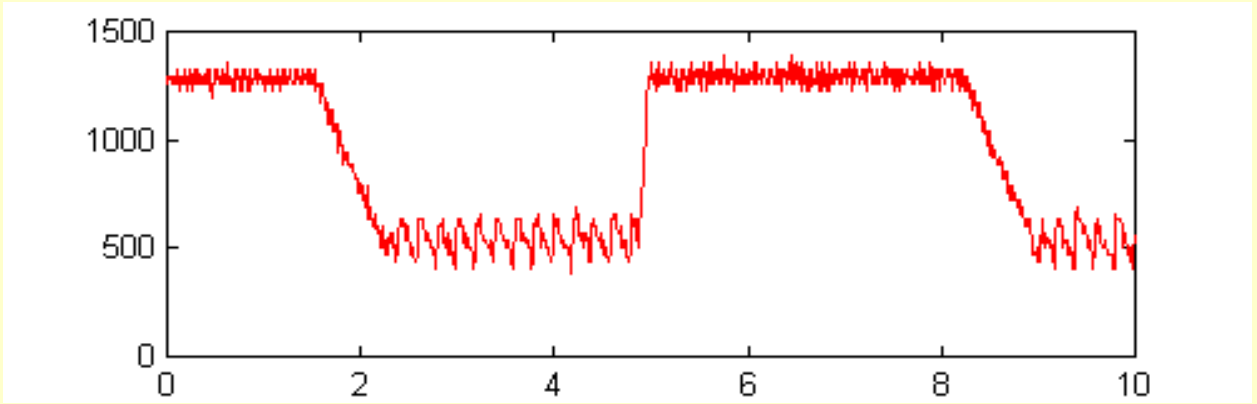
PID Control



PID Anti-Windup Control

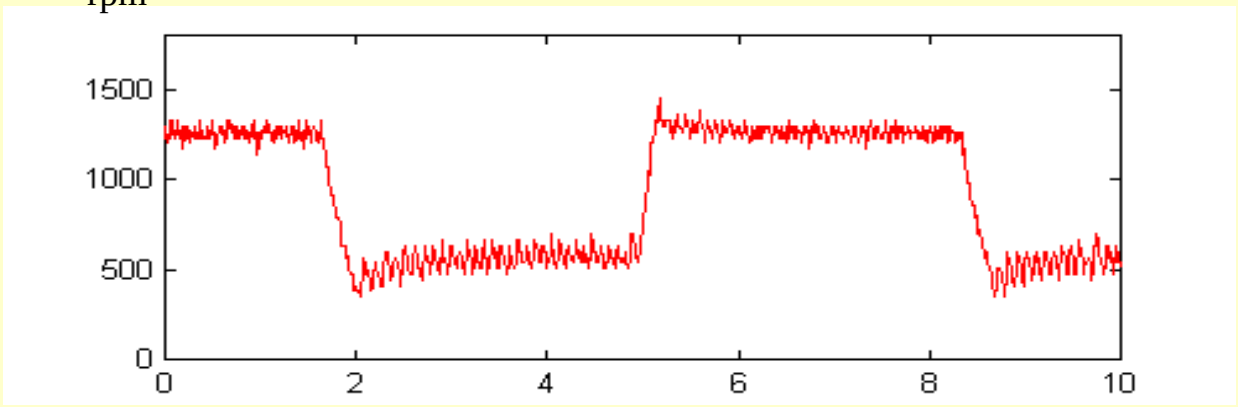


Fuzzy Logic Control

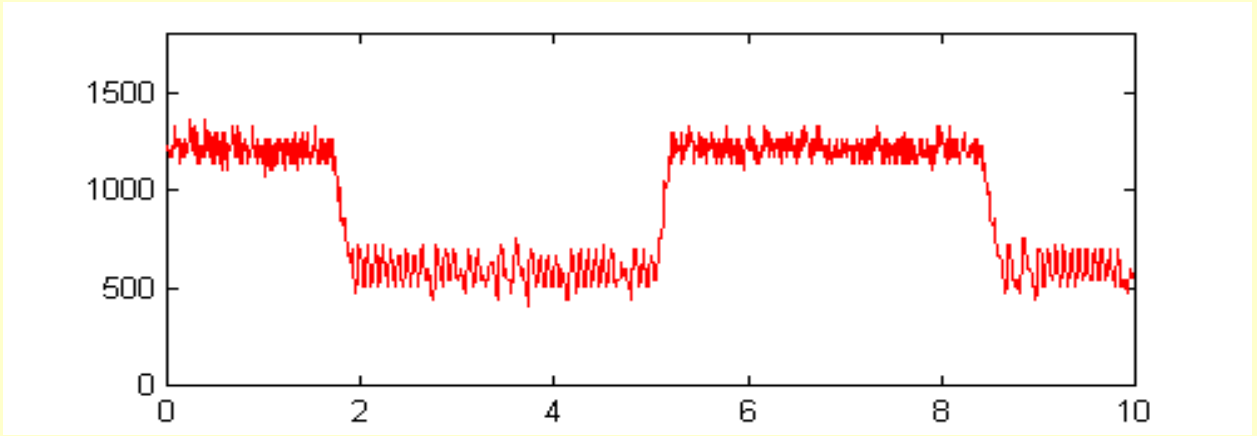


Speed response with load

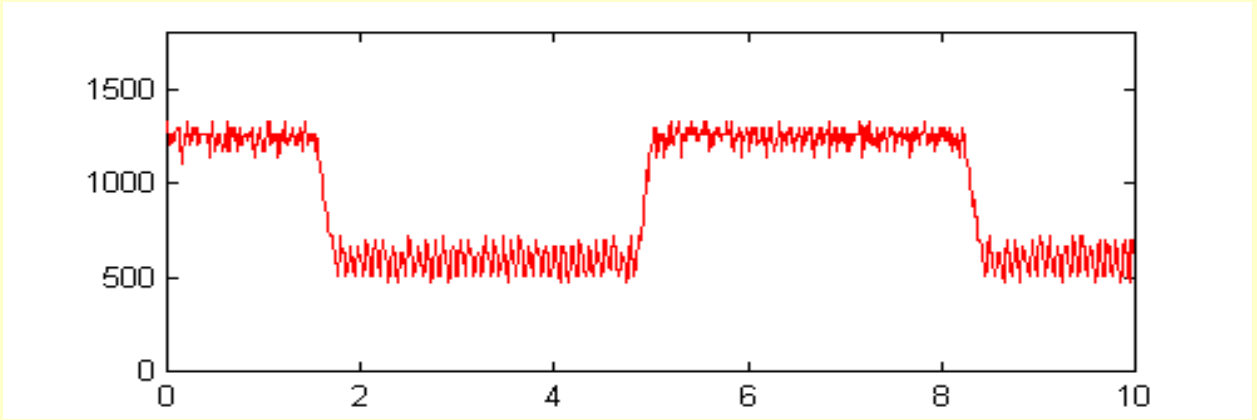
PID Control

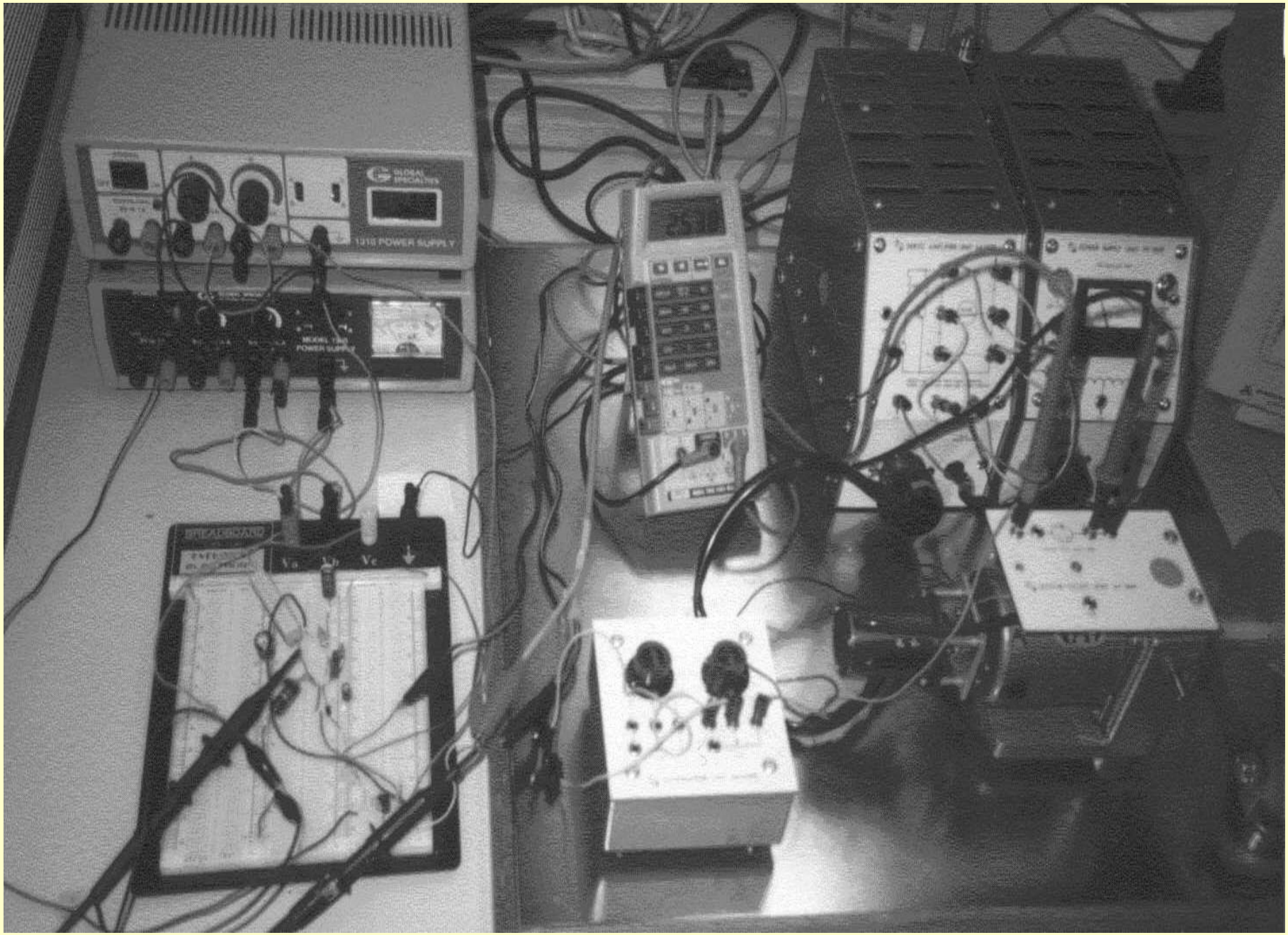


PID Anti-Windup Control



Fuzzy Logic Control

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