Implementation of Conventional and Neural Controllers Using Position and Velocity Feedback

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Summary

- Design and Compare Conventional and Neural Controllers for a Small Robot Arm
- Position and Velocity Feedback Design
- User Friendly Interface Design

Previous Work

- Quanser Consulting
  - Provided Software for Use with the Robot Arm, A/D, D/A Converters
- Dr. Dempsey
  - Research on different Velocity Algorithms
  - Neural Network Architecture

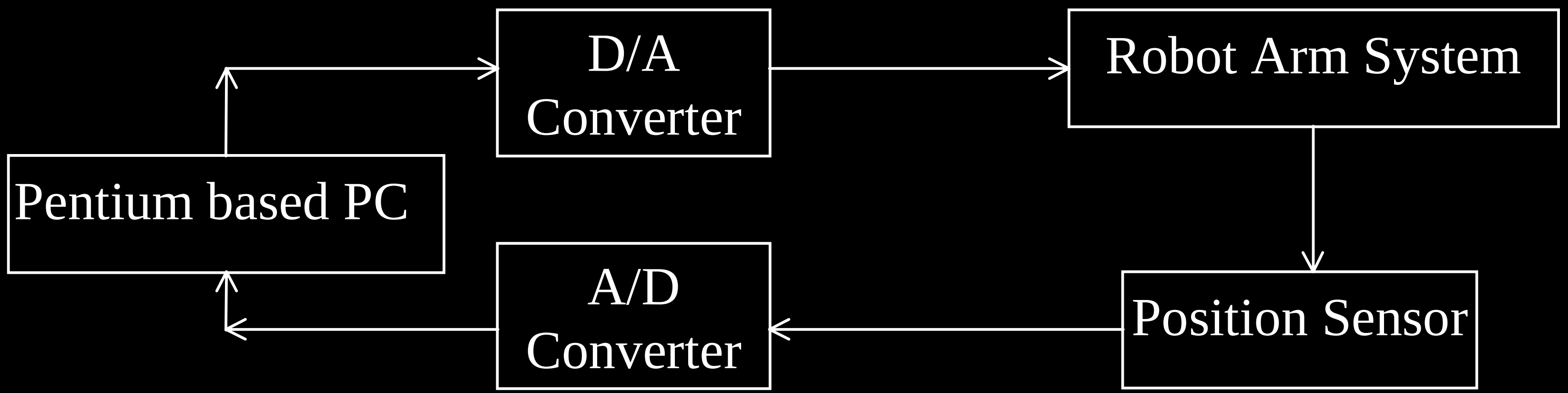
Modes of Operation

- Default
  - Computer Generates the Command Signal
  - User Set the Final Position of the Robot Arm
- Joystick
  - Connects to A/D Channel
  - Generates Command Signal by the Movement of the Joystick

Preliminary Design Work

- High Level Block Diagram
- Control Block Diagram
- Software
- Velocity Algorithms
- Neural Networks

High Level Block Diagram



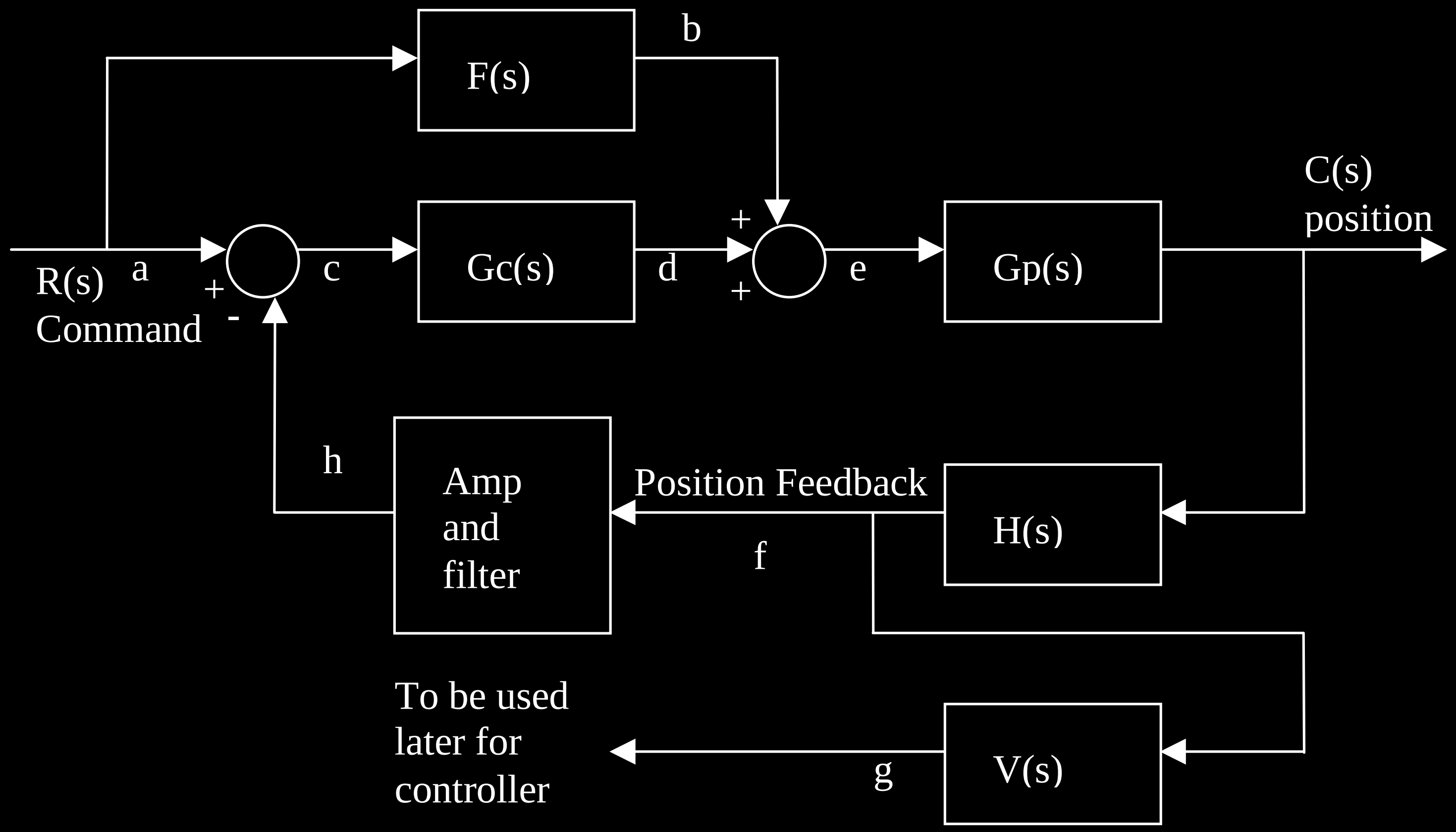
High Level Block Diagram

- Pentium Based PC
  - Generates Command Signal if Joystick is not Present
  - Implementation of Controllers
  - Generates Real-Time Graphs
  - Display the User Interface

High Level Block Diagram

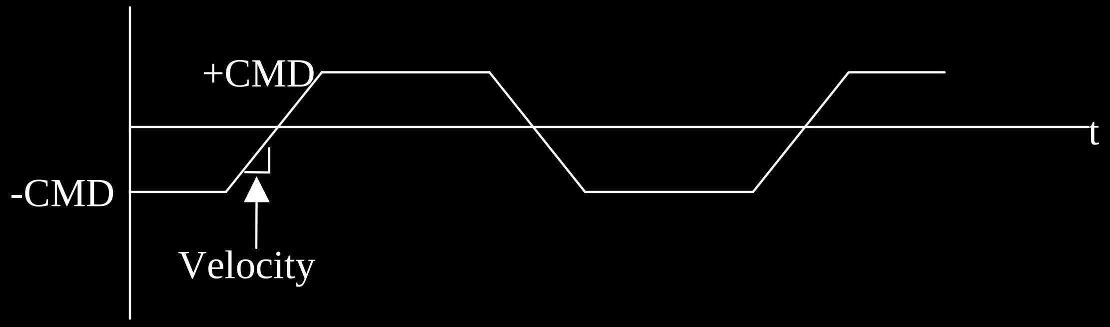
- Robot Arm System
  - Power Amplifier
  - DC Motor Assembly
  - Gear Trains
  - Load
    - The Robot Arm

Control Block Diagram



Input And Outputs of System

- A) R(s) is the Command Signal



$$|CMD| \leq 90^{\circ}$$

$$VELOCITY_{MAX} = 45 \,{}^{\circ}\!/_{sec}$$

Inputs and Outputs

- C(s) is the Position of the Robot Arm
  - Percent Overshoot(%O.S.) = 5%
  - Time To first Peak (tp) = 3s
  - Magnitude of Peak in Frequency Domain (Mp) = 1.32dB
  - Frequency of Peak In frequency Domain (wp)=170mHZ

Inputs and Outputs

  - Bandwidth Closed Loop (BW) = 290mHz
  - Phase Margin (PM) = 50deg
  - Gain Margin (GM) = 6dB
  - Steady State Error = 2deg
- Output should be the same as input

Subsystems

- F(s)
  - Feed-Forward Compensator
  - Neural Network if Implemented
  - Implemented in Software
- Gc(s)
  - Plant Controller
  - A PID-type controller
  - Implemented in Software

Subsystems

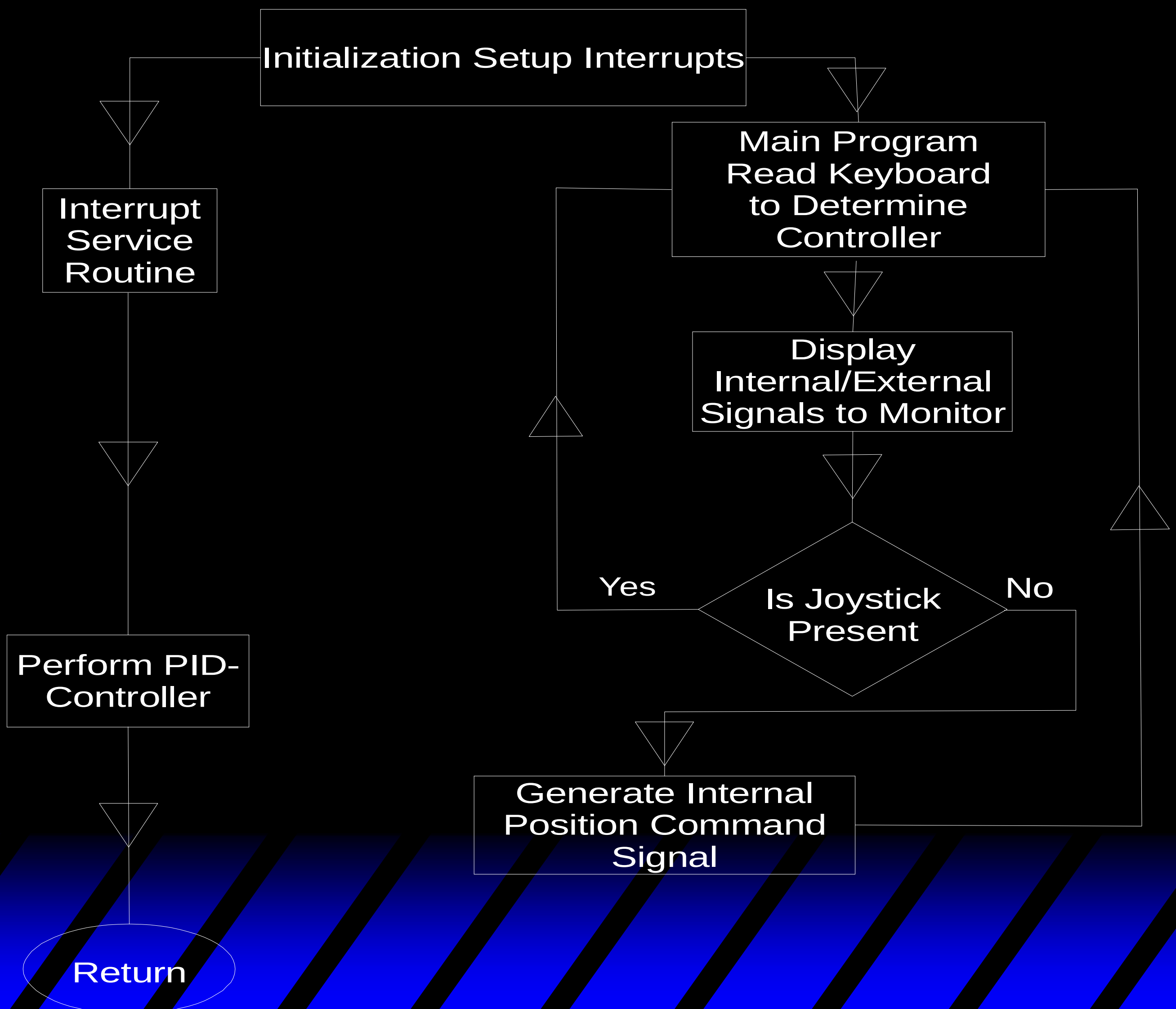
- Gp(s)
  - Plant or Robot Arm System
  - Hardware
- H(s)
  - Position Sensor
  - Hardware

Subsystems

- V(s)
  - Algorithm used for Velocity Feedback
  - To Be Determined
- Amp and Filter
  - Amplify signal
  - Filter out the noise

Software Flowchart

Pentium-based PC



Subsystems

- Initialization
  - Initializes the Interrupts to be set at 200Hz Sampling Rate (5ms)
- Main Program
  - Calculate the Values for the Display
  - Check the Keyboard and Joystick
  - If Present Read Joystick and Generate the Command Signal

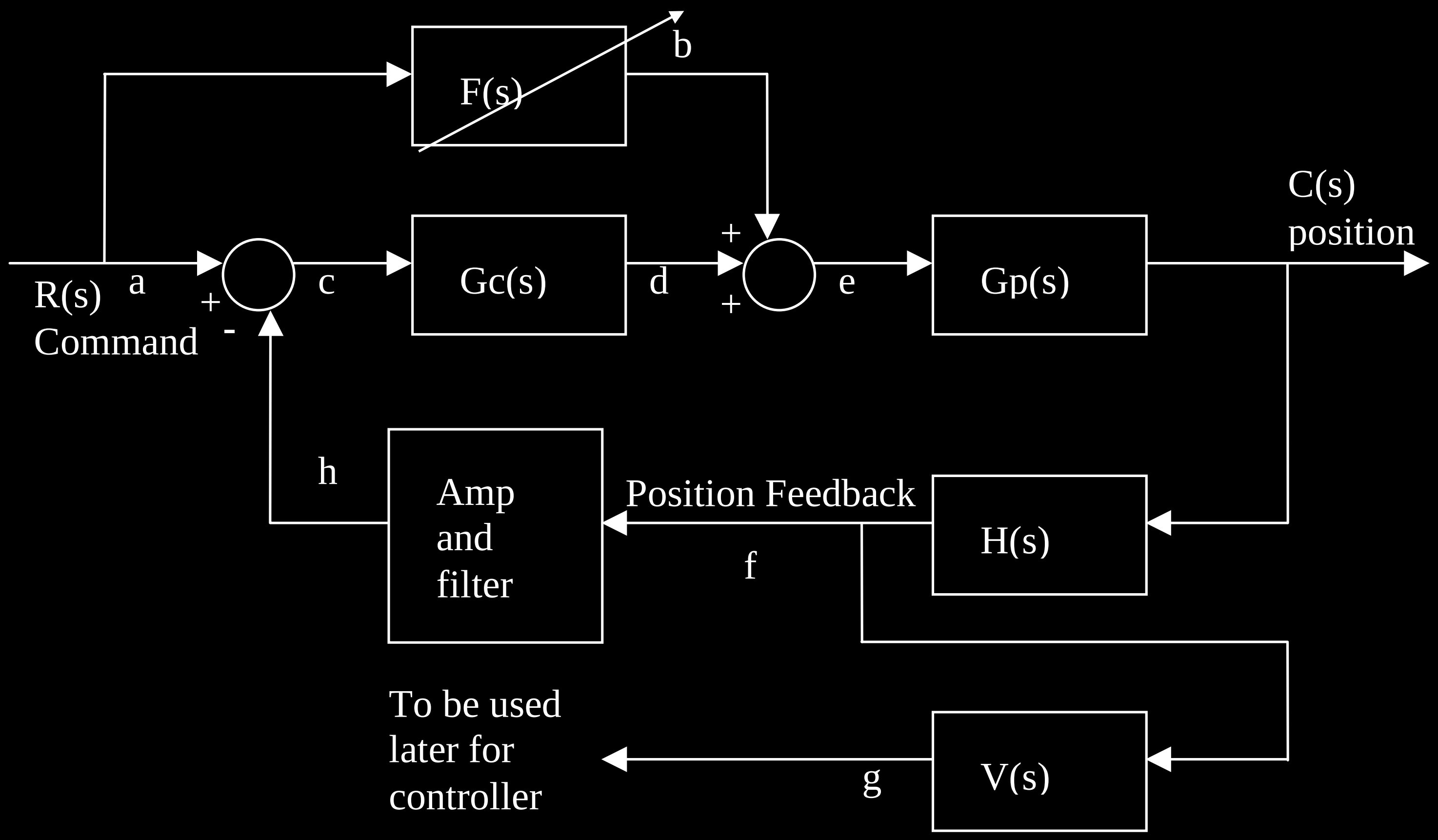
Subsystems

- Interrupt Service Routine and Performing of PID Controller
  - Send Signal form Calculated Values of Main Program and Interrupt Service Routine to the Robot Arm
  - Signals also Sent to the Monitor at User Specified Times

Velocity Algorithms

- Design S-Plane Lead Network use Tustin Method(Bilinear Transformation)
- Use Polynomial Curve Fit Algorithm to Calculate Velocity

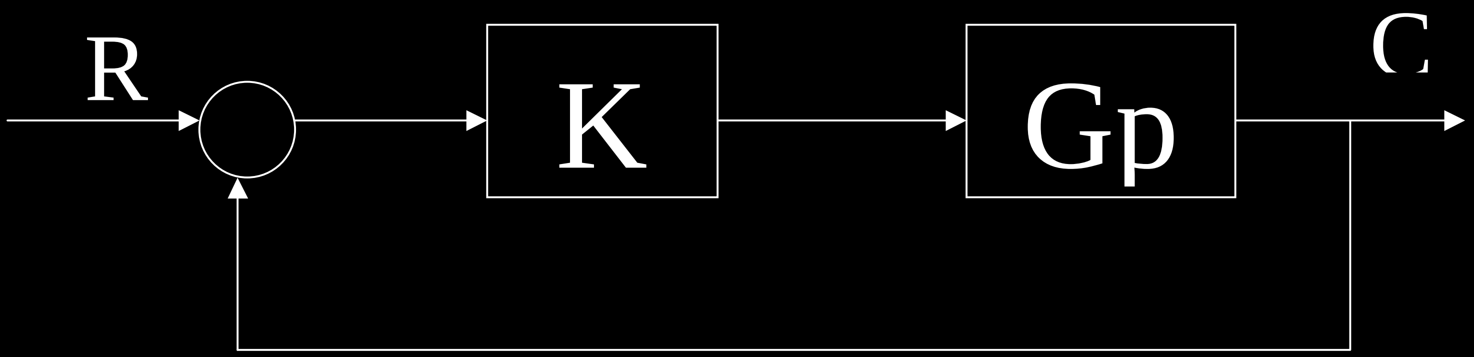
Neural Network



Preliminary Lab Work

- P Controller Design and Testing
- C-Code
  - Filter Design using Tustin Method
  - Filter Testing
  - Improvement of Display

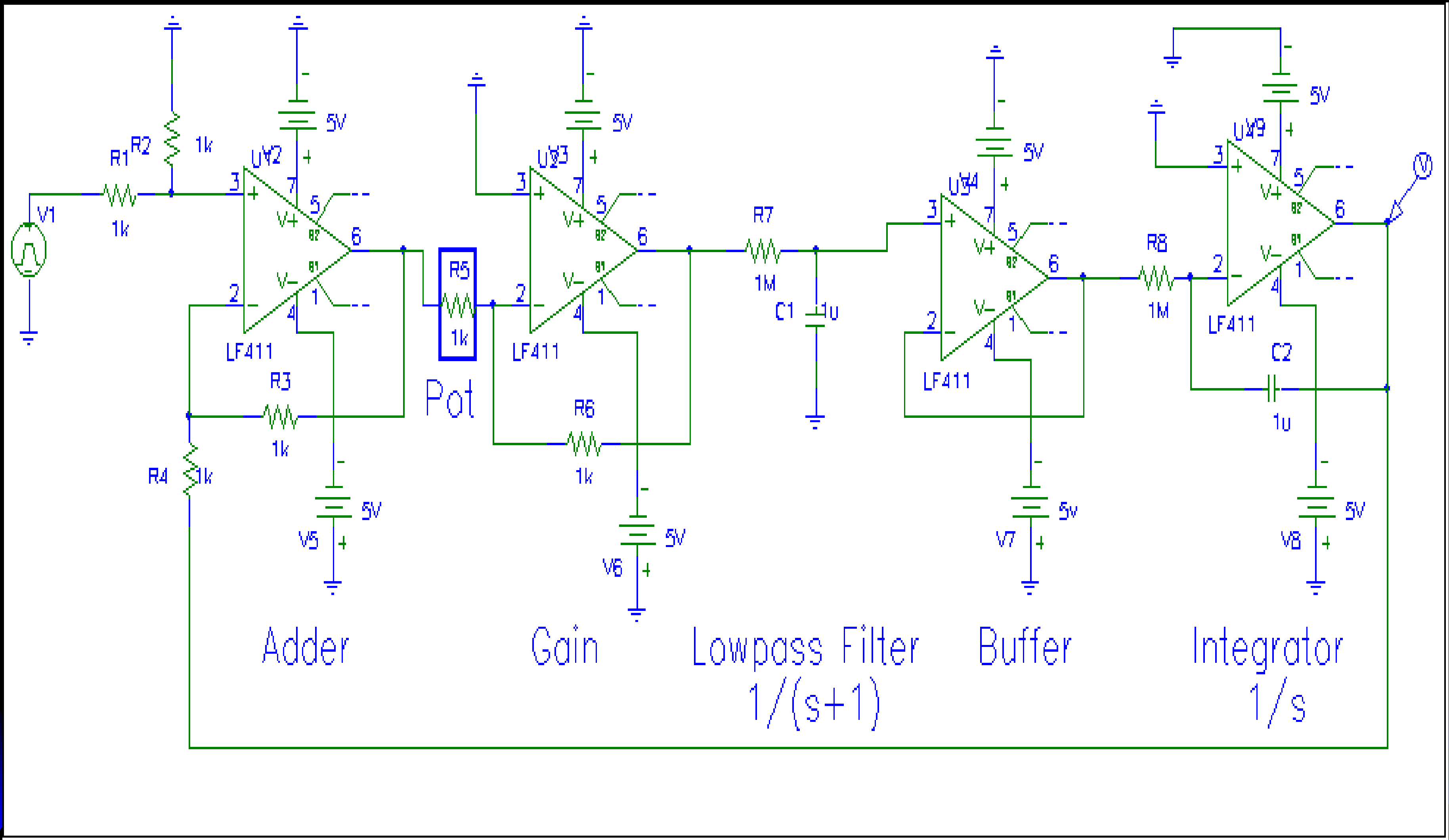
P Controller Design



Calculation Results

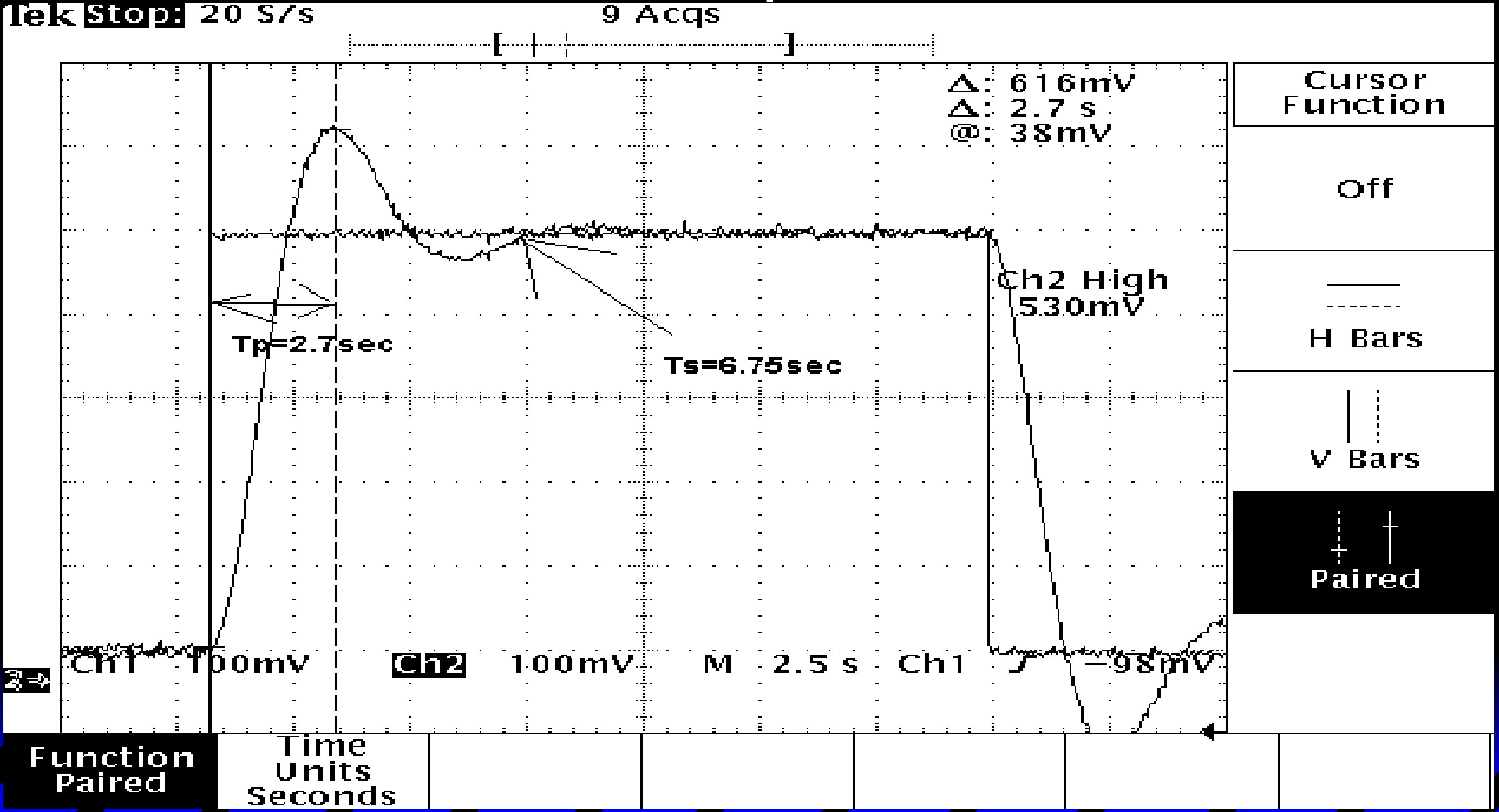
◆ For 0% OS	k=0.25	
	Ts=11.7sec	Tp=Infinity
◆ For 5%OS	k=0.525	
	Ts=8.4sec	Tp=6sec
◆ For 25%OS	k=1.534	
	Ts=6.78sec	Tp=2.76sec

Circuitry Used



Measurement 25% OS

- Ts=6.75 Tp=2.7



Calculation Vs. Measurement

Calculation		Measurement	
◆ 0%	Ts=11.7sec	◆ 0%	Ts=12.5sec
◆ 5%	Ts=8.4sec	◆ 5%	Ts=7.4sec
	Tp=6sec		Tp=5.75sec
◆ 25%	Ts=6.78sec	◆ 25%	Ts=6.75sec
	Tp=2.76sec		Tp=2.7sec
	BW=290mHz		BW=270mHz
	fpeak=175mHz		fpeak=161.8mHz
	Mp=1.32 norm.		Mp=1.354 norm.

C-Code Development

- Design of a digital filter @ 20Hz cutoff
- Changing Real-Time Display Mode

Filter Design

- Using Tustin Method
- With T=fixed sampling time=0.005sec

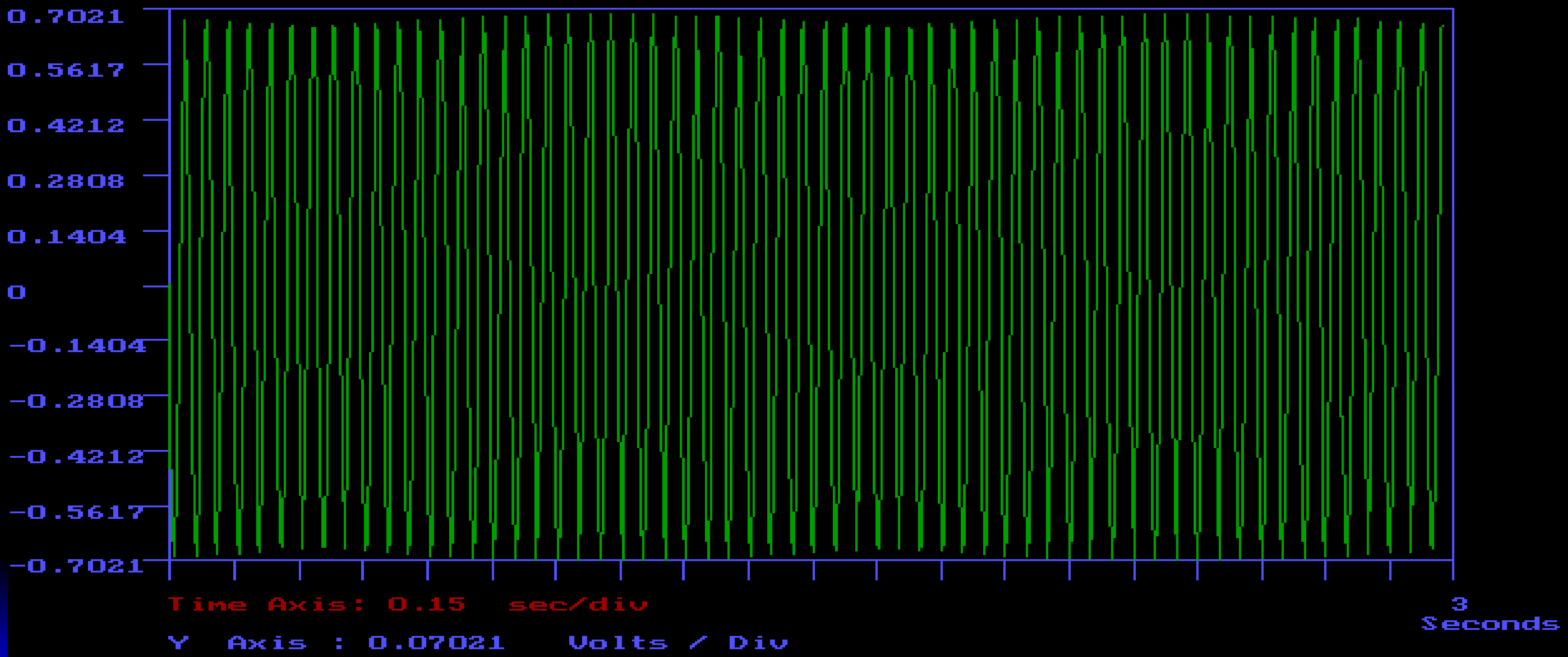
$$S = \frac{2}{T}\frac{z-1}{z+1}$$

- Filter Transfer Function to Obtain

$$G(s) = \frac{1}{1 + \dfrac{s}{20 * 2\pi}}$$

Filter Output on PC Screen

- Chose 1V@20Hz Input to see 3dB point



Changing Real Time Display

- Auto Scaling on y-Axis was given
- Problem: Plot off the Screen
- Improvement: now it takes the last highest value and adjusts it only by approximately 20% up or down

Equipment List
Hardware & Software

- 500MHz IBM compatible Pentium III PC
- *Quansar* Robot Arm System

  A/D & D/A converter card

  Amplifier
- Borland 4.5 C-Compiler
- Matlab 5.3
- WinCom V2.0 Real-Time Workshop

Schedule

Chris=C   Manfred=M   Dr.Dempsey=D

- 12 weeks available till Presentation at the Student Expo end of April

System Identification	C&M&D	3Weeks
Menu	C&M	1Week
P-Controller Design&Testing	C	1Week
Investigate&Implement Neural Network with P-Controller	M&D	1Week

Schedule

Chris=C   Manfred=M Dr.Dempsey=D

◆ Velocity Algorithm	C	1Week
◆ Two Loop Design		
With Neural Networks	M&D	1Week
◆ Redesign with Rotary Encoder	C&M	1Week
◆ Feed Forward Control & Implementation		
in Neural Networks	C&M&D	1Week
◆ Digital Control Analysis	C&M	2Weeks

Additional Work

- Presentation at Student Expo
  miss one Lab Period
- Expo Conference Report
- Presentation Board

The

End

Design Equations 1

$$\%OS = e^{-\zeta\pi / \sqrt{1-\zeta^2}}$$

$$W_n = \frac{1}{2\xi}$$

$$W_n = \sqrt{k}$$

Design Equations 2

- Vo/Vi= 1kΩ /Rpot=k => R=1000/k
- Transfer Function: 2nd order system

  C/R=wn^2/(s*s+2*zeta*wn+wn^2)=

  =k/(s*s+s+k)
- Ts=<2% from final value

Design Equations 3

- Tustin or Bilinear z-Transformation
- s=ln(z)*1/T~(2/T)*{(z-1)/(z+1)}
- Truncating Laurent Series Expansion

Calculation for Circuitry

- Chose 1μF Capacitor for Integrator & Filter

  →R=1MΩ for Integrator and Filter
- Chosen 1 kΩ Resistors for Gain & Summer

  →Rpot=1000/Gain

  →Rpot= 4 kΩ for 0%OS

  →Rpot= 1.905 kΩ for 5%OS

  →Rpot=652 Ω for 25%OS

Final C-code Function

- Output = 0.239*Input+
  +0.239*Past Input+
  +0.522*Past Output
- Past Input & Past Output had to be set zero to get started

Subsystems

- Keyboard
  - Gives the User a Choice of Which Signals are to be Displayed and Controller type
  - Command Signal Parameters
- Display
  - Will Show all Internal and External Signals Chosen by the User

Subsystems

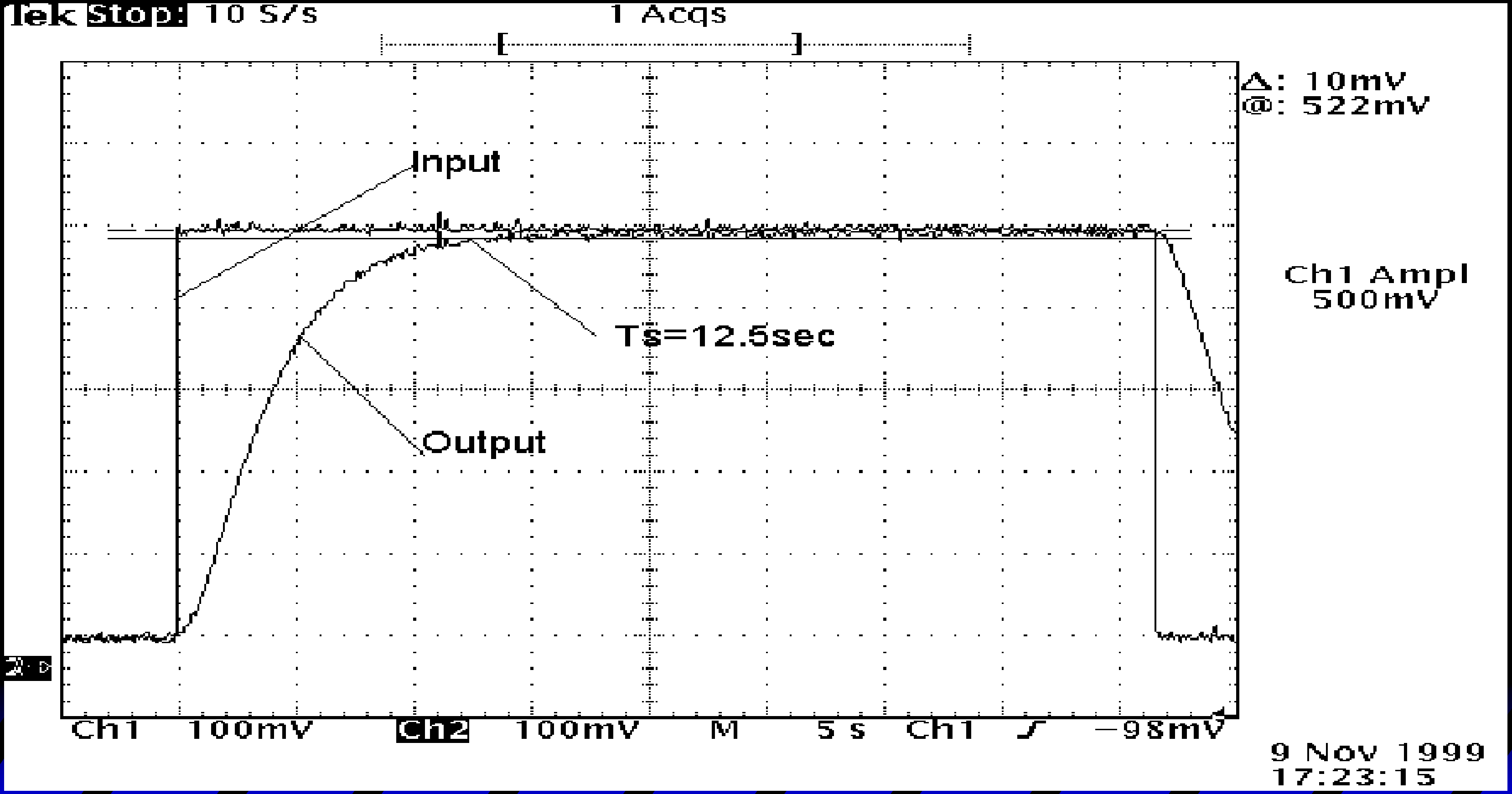
- Joystick Check
  - If Present Joystick Position will be Read and Sent to the Interrupt Service Routine
  - If not the PC will Generate the Command Signal
- Generate Command Signal
  - This Option Occurs if the Joystick is not Present.
  - PC Performs the Calculations for the Command Signal

How Measurement was Obtained

- Input Square Wave Chosen at Least Double the Settling Time
- Potentiometer was Adjusted to Get %OS Wanted
- Read Results from Scope
- Frequency Domain: Swept from 1mHz till Sine Wave to get BW(3dB) and Mp

Measurement 0% OS

- Ts=12.5sec



Measurement 5% OS

- Ts=7.4 sec   Tp=5.75sec