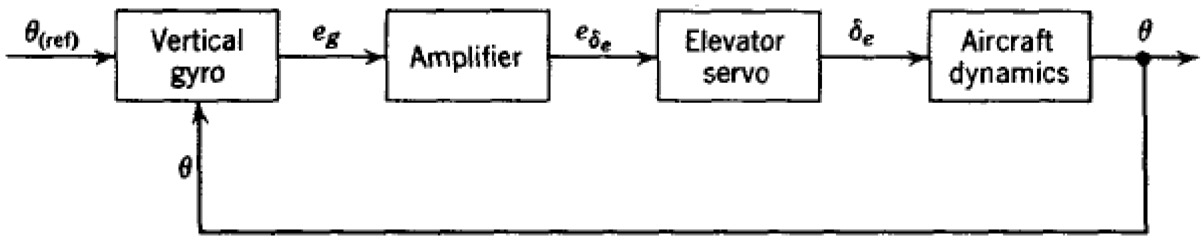
Longitudinal Autopilots

Displacement Autopilot:

The Simplest form of autopilot, 1st appeared and still being used

This autopilot was designed to hold the aircraft in straight and level flight with little or no maneuvering .



Displacement Autopilot without pitch rate feedback

The elevator servo can be electromechanical or hydraulic with an electrically operated valve.

Elevator servo can be represented by a gain multiplied by first order lag

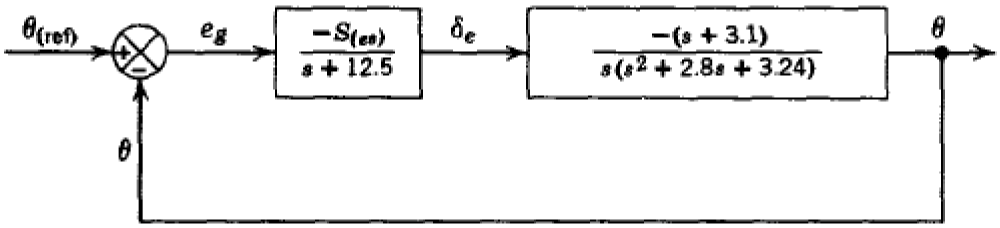
Time constant varies from 0.1 to 0.03 sec.

The transfer function used to represent the aircraft can be the complete 3 DOF longitudinal transfer function or the transfer function of the short period approximation.

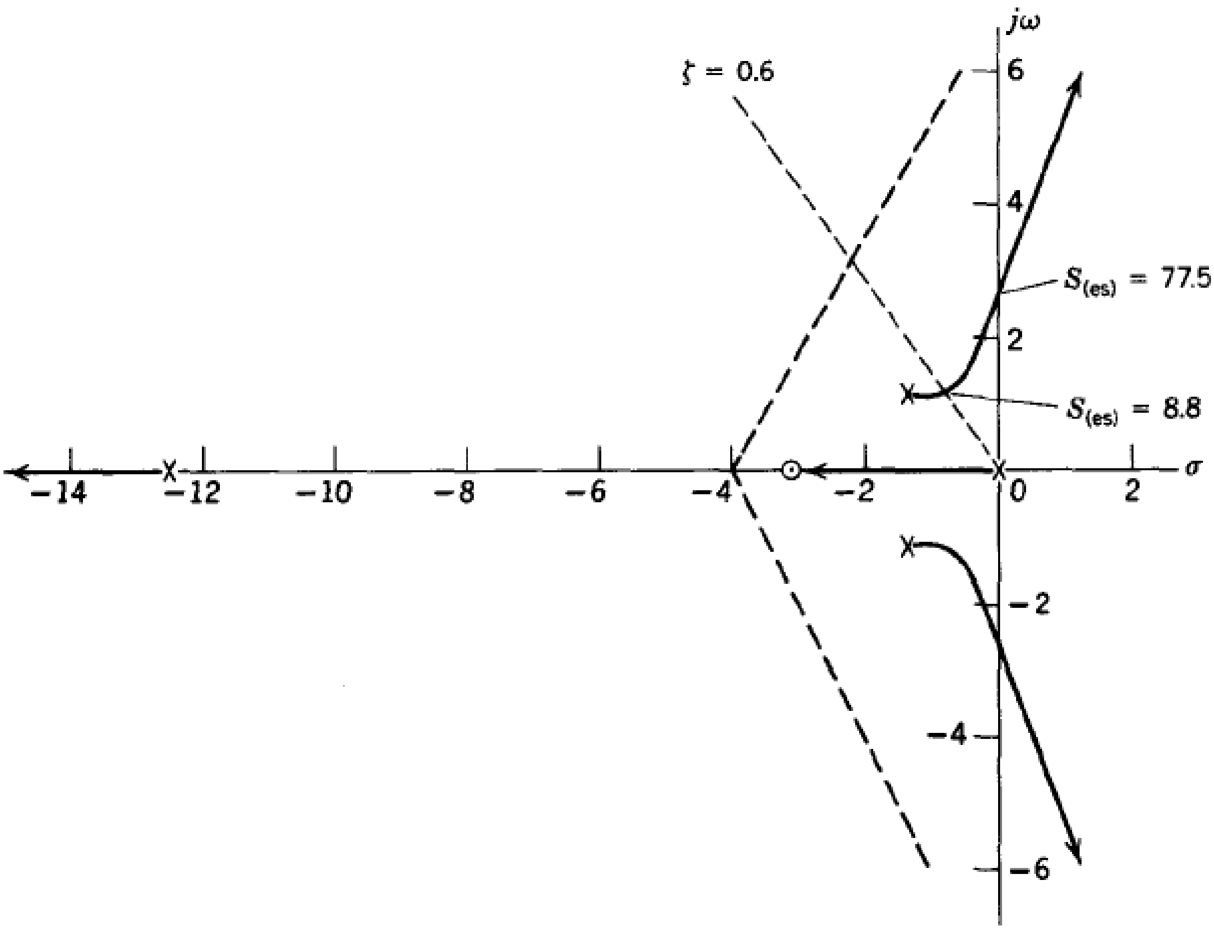
The system is type 0, i.e. there will be steady state error.

The autopilot will be examined for two aircrafts

The Conventional Transport aircraft and Jet Transport aircraft



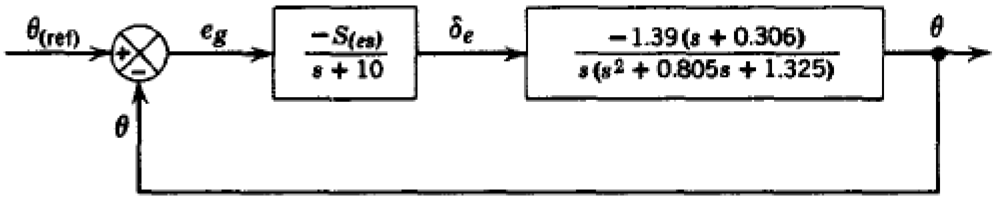
Block Diagram for the conventional transport and autopilot



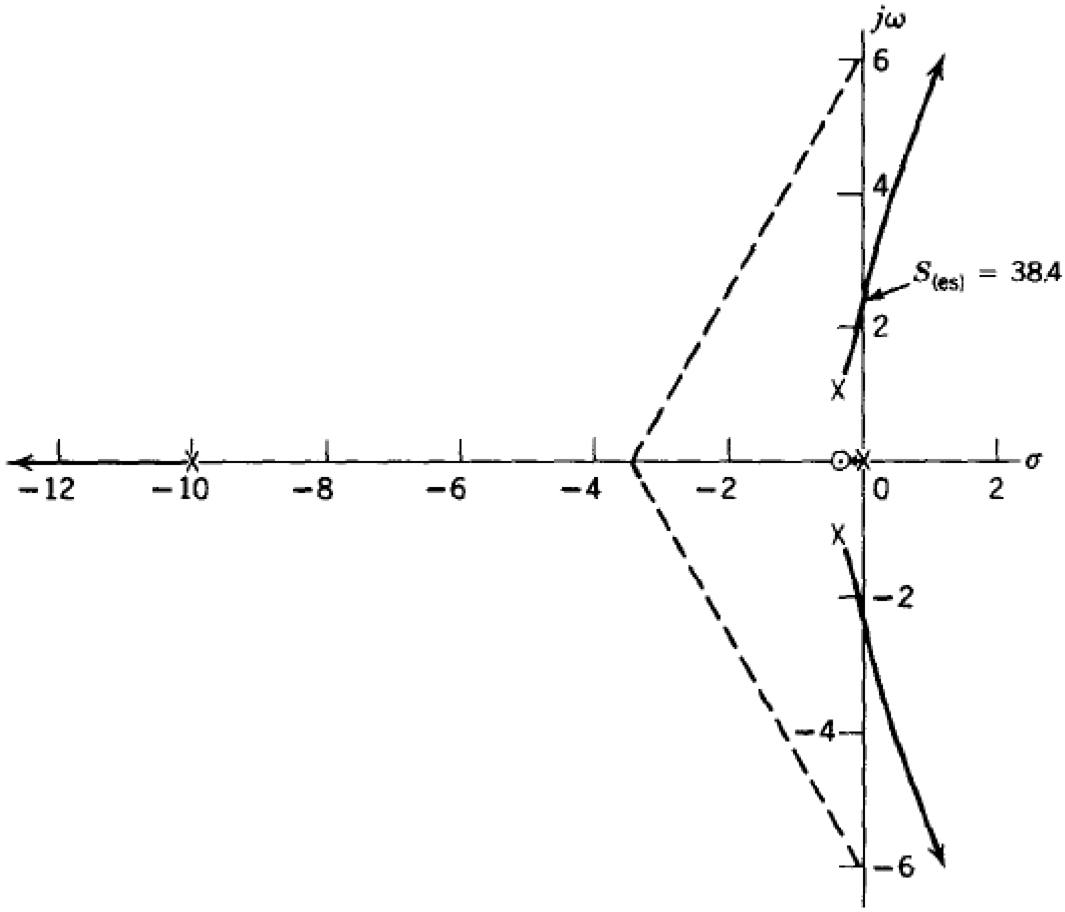
Root Locus for conventional transport and autopilot

Information:

Open loop poles: 0 , -12.5 , -1.4 ± j 1.1314
Open loop zeros: -3.1
Asymptote: center -4.067 , angle 60,-60, 180
Breakaway (Breakin): No
Intersection with Imag. Axis: 2.742
Best ζ = 0.77
Gain for critical stability = 74.5
For gain =12   poles -1.02, -12.55, -0.867 ± j 1.1 ζ = 0.62
Gain margin = 6.2



Block Diagram for the jet transport and autopilot

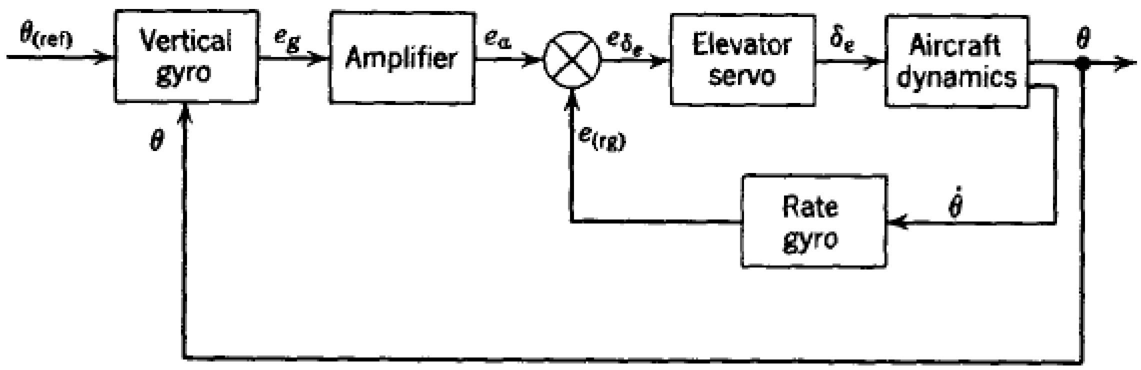


Root Locus for jet transport and autopilot

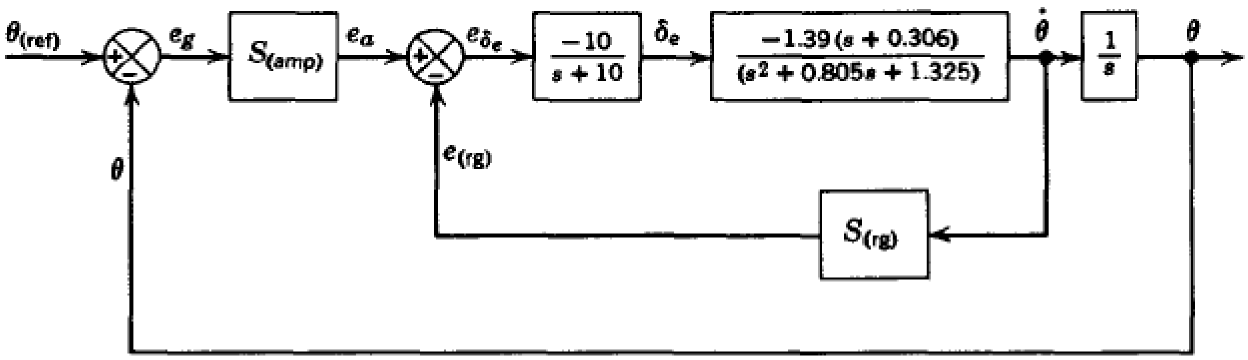
Information:

Open loop poles: 0 , -10 , -0.4025 ± j 1.784
Open loop zeros: -0.306
Asymptote: center -3.5 , angle 60, -60, 180
Breakaway (Breakin): No
Intersection with Imag. Axis: 2.584
Best ζ = 0.22
Gain for critical stability = 42.36
For gain =12 poles -0.18, -10.17, -0.23 + ± j 1.66 ζ = 0.13
Gain margin = 3.53

Displacement Autopilot with pitch rate feedback:

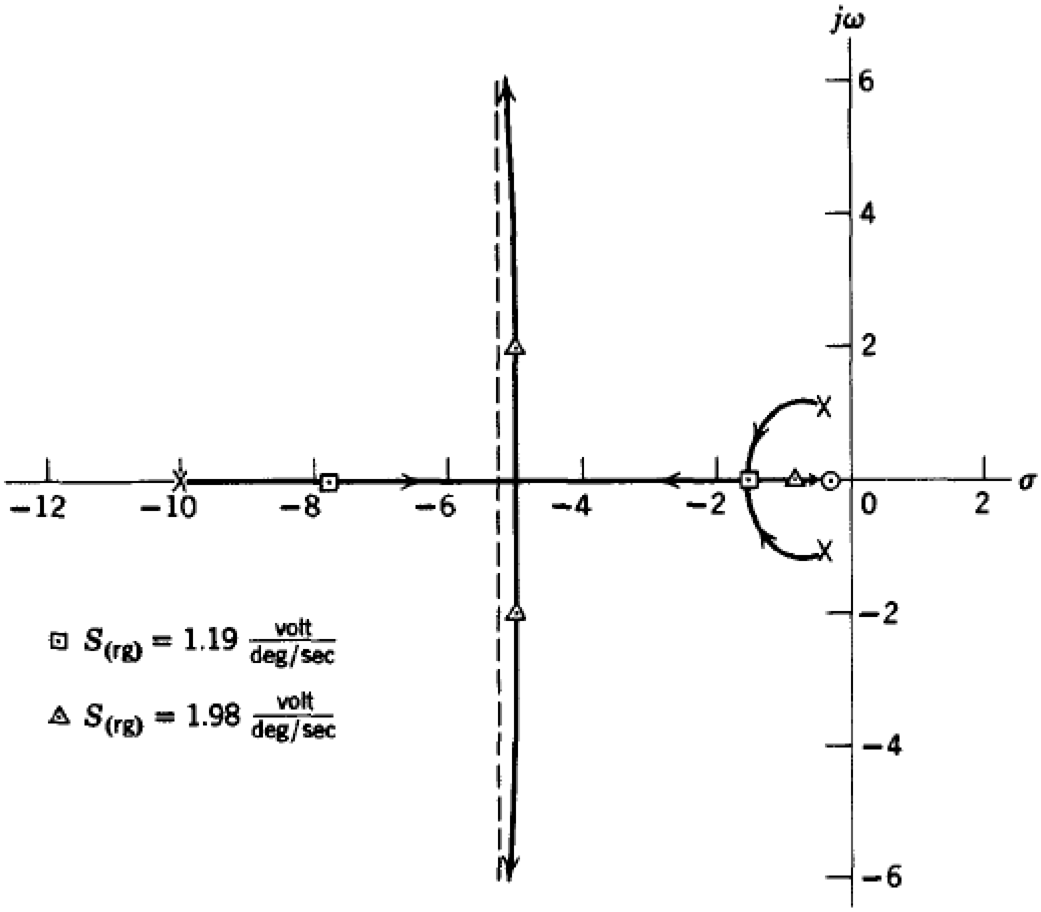


Displacement Autopilot with pitch rate feedback for damping



Block Diagram for the jet transport and displacement autopilot with pitch rate feedback added for damping

Root locus for the inner loop:



Information:

Open loop poles: -10 , -0.4025 ± 1.0784

Open loop zeros: -0.306

Asymptote: center -5.25 angle 90 , -90

Breakaway (Breakin): -1.5, -5

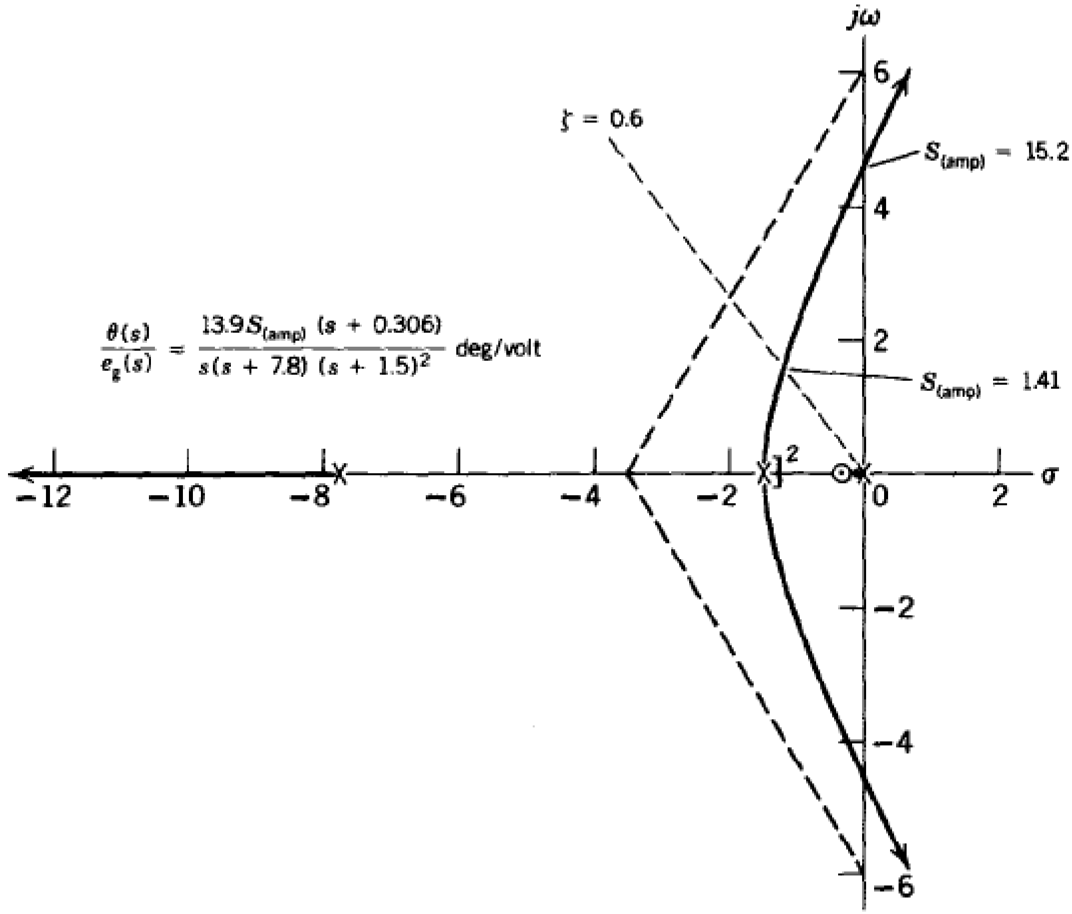
Intersection with Imag. Axis: No

ζ may assume any +ve value

Gain for critical stability K > 0

Let Srg = 1.19 and 1.98

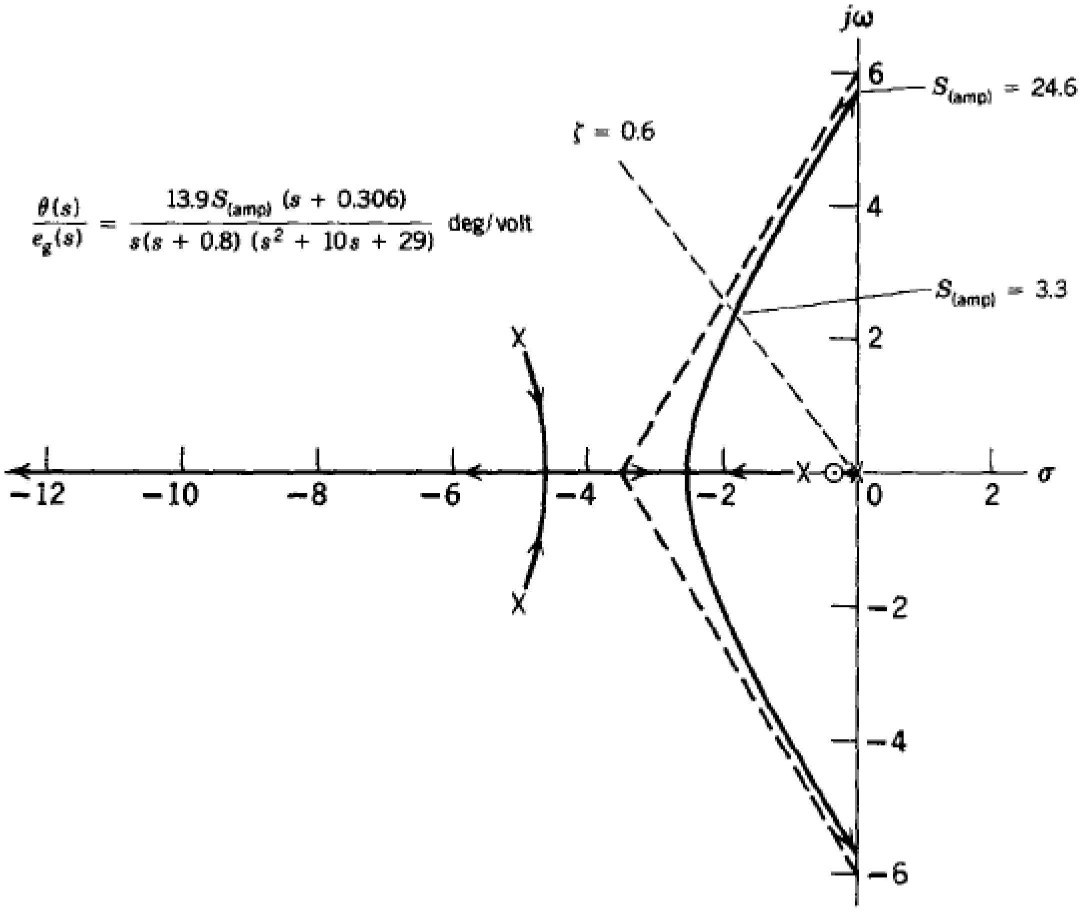
Root locus for the outer Loop: Srg = 1.19



Information:

- Open loop poles: -7.8 , -1.5 , -1.5
- Open loop zeros: -0.306
- Asymptote: center -3.5 , angle 60 , -60 , -180
- Breakaway (Breakin): -1.5
- Intersection with Imag. Axis: 4.781
- ζ may have any value
- Gain for critical stability = 15.2
- For Samp = 1.41 ζ = 0.6
- Gain margin =

Root locus for the outer Loop: Srg = 1.98



Information:

Open loop poles: 0 , -0.735 , -5.035 ± j 2.036

Open loop zeros: -0.306

Asymptote: center -3.5 angle 60,-60 , 180

Breakaway (Breakin): -4.476 , -2.605

Intersection with Imag. Axis: 5.813

ζ can bave any value

Gain for critical stability = 24.6

For Samp = 3.3 ζ = 0.63

Gain margin =

Conclusion:

The higher the gain of the inner loop, the higher the allowable gain for neutral stability for the outer loop.

However, too high an inner loop gain results in higher natural frequencies and lower damping as the inner loop poles moves out along 90 asymptote.

$S_{(rg)} \left(\frac{\text{volt}}{\text{deg / sec}} \right)$	$S_{(amp)}$ (volt / volt)	
	For $\zeta = 0.6$	For $\zeta = 0$
1.19	1.41	15.2
1.98	3.3	24.6