Stability Analysis of Linear and PWM Power Amplifiers

Presented By:
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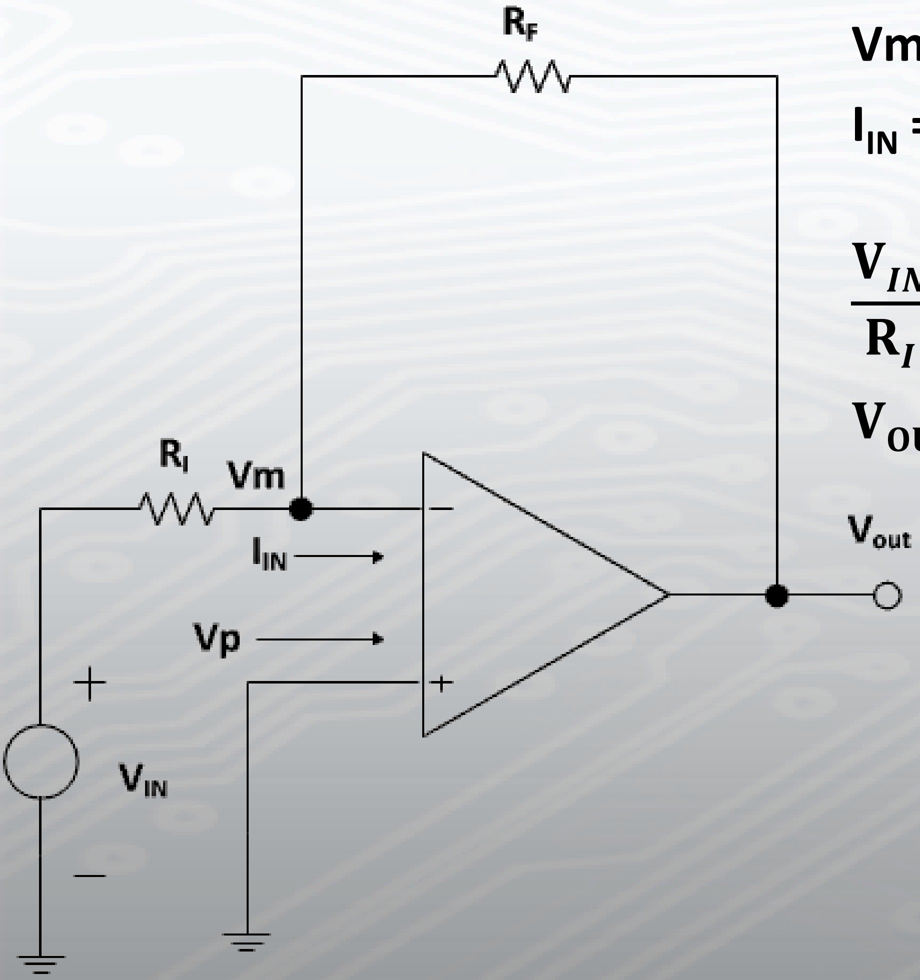
Topics of Discussion

- Operational Amplifiers
- PWM Amplifiers
- Stability Analysis
- Real Life Stability Tests
- Conclusion

Op Amps

Linear Operation Basics

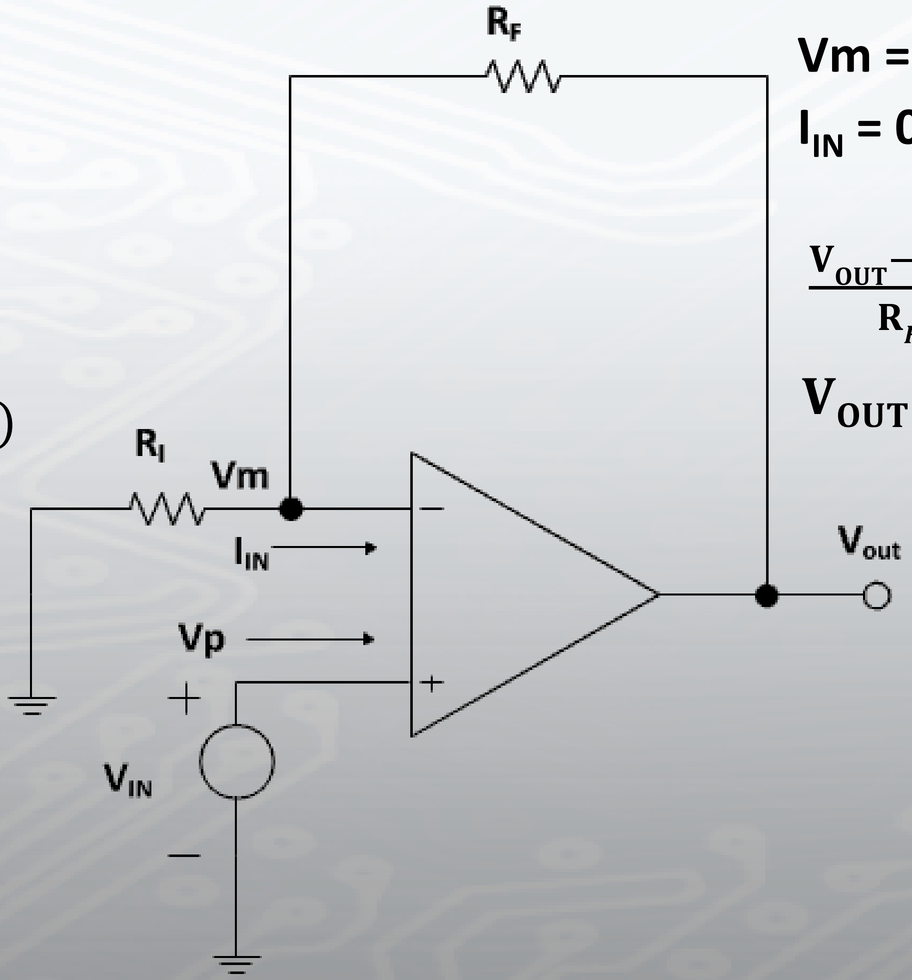


Vm = Vp = 0

I_{IN} = 0

$$\frac{V_{IN}}{R_I} + \frac{V_{OUT}}{R_F} = 0$$

$$V_{OUT} = -VIN\left(\frac{R_F}{R_I}\right)$$



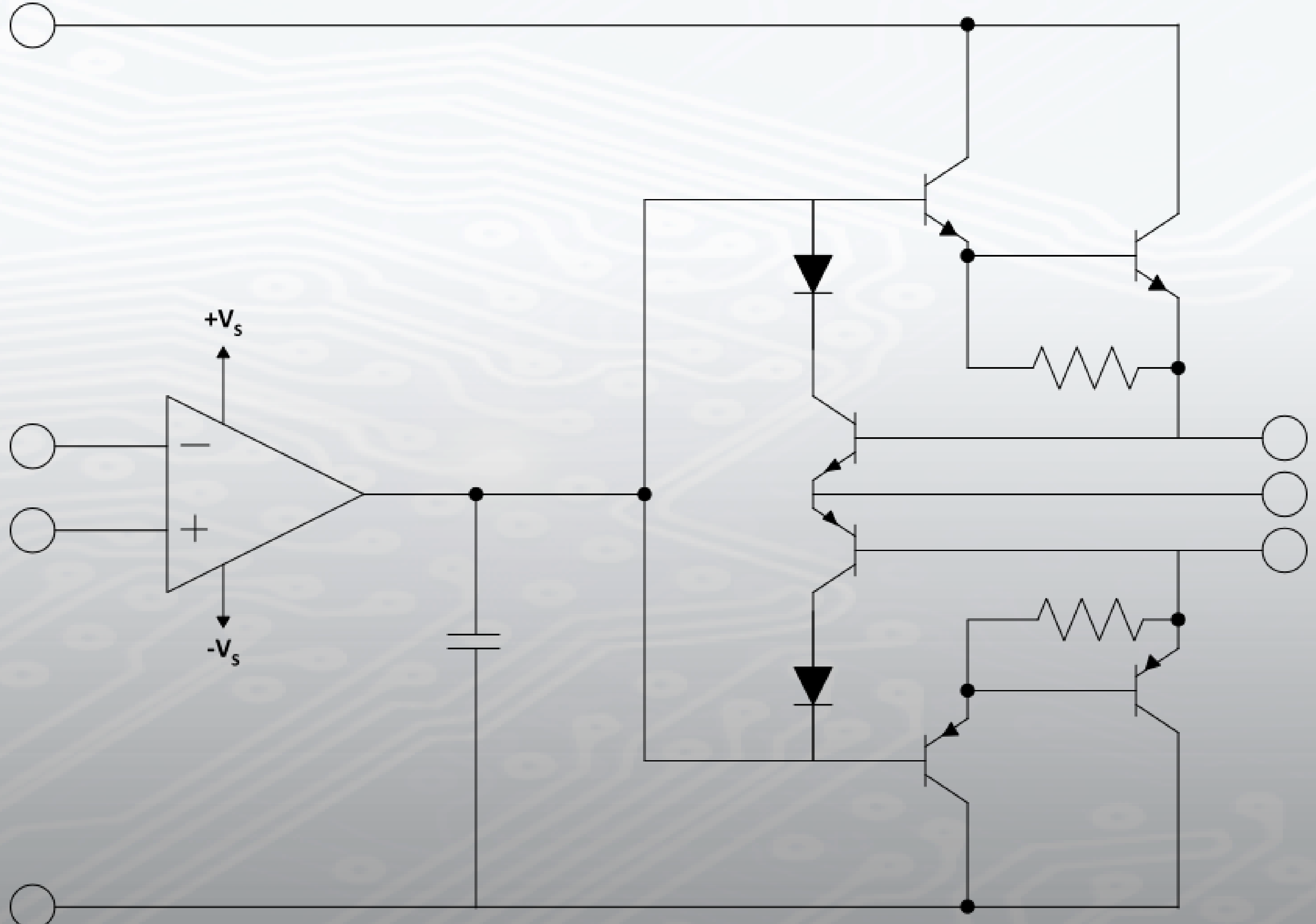
Vm = Vp = V_{IN}

I_{IN} = 0

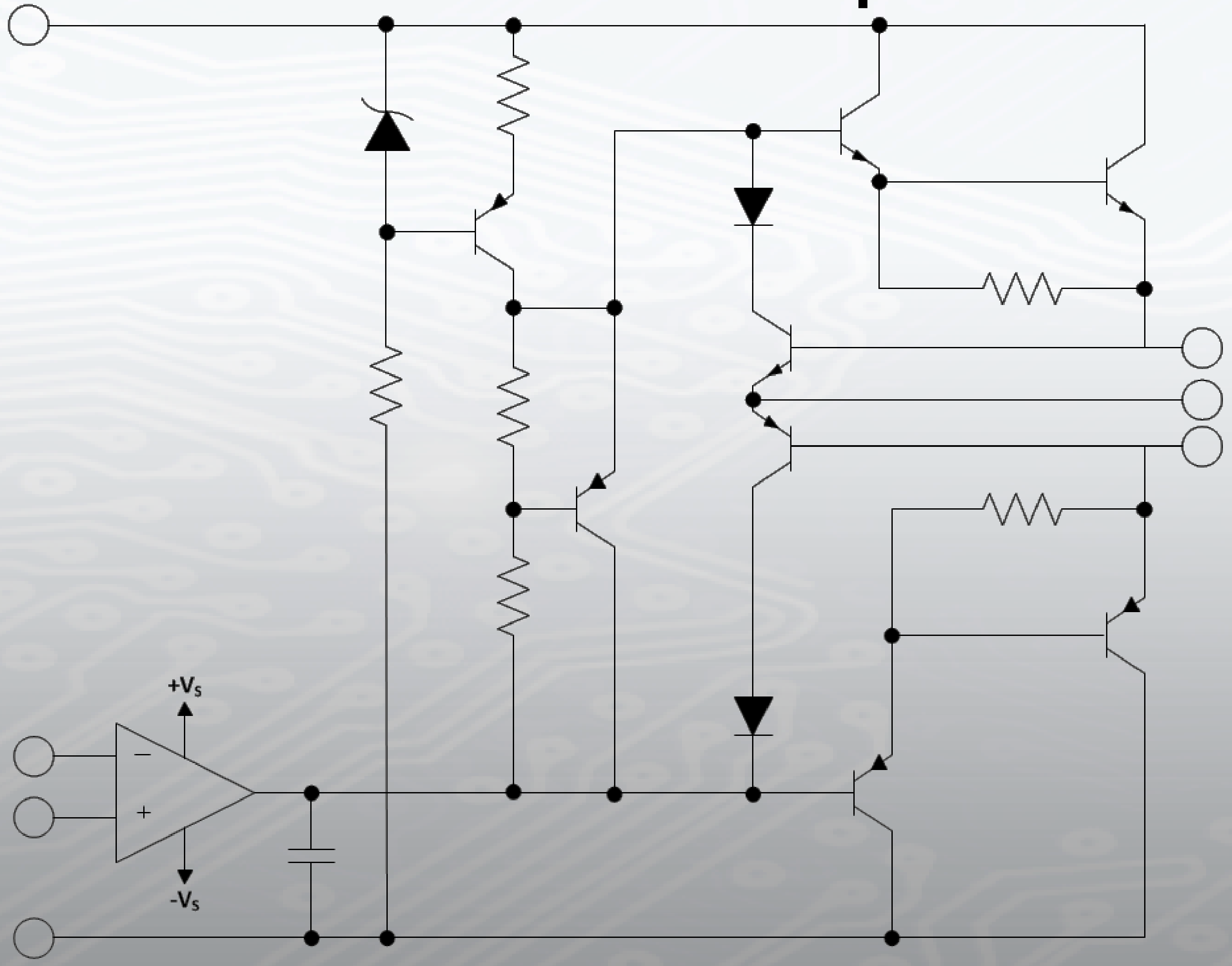
$$\frac{V_{OUT}-VIN}{R_F} + \frac{0-VIN}{R_I} = 0$$

$$V_{OUT} = VIN\left(1 + \frac{R_F}{R_I}\right)$$

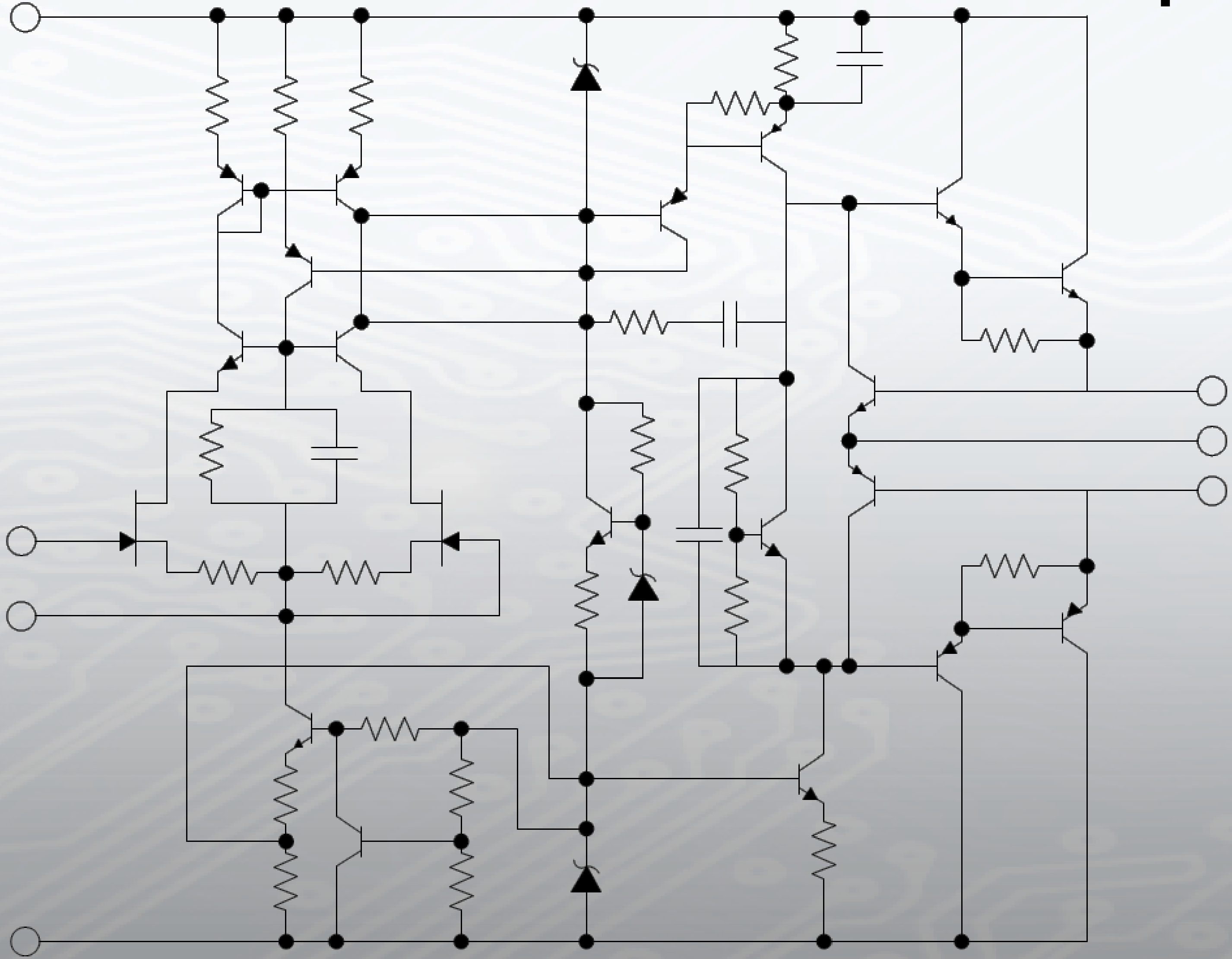
Class C Output Stages



Simple Class AB Outputs



Complex Amplifier



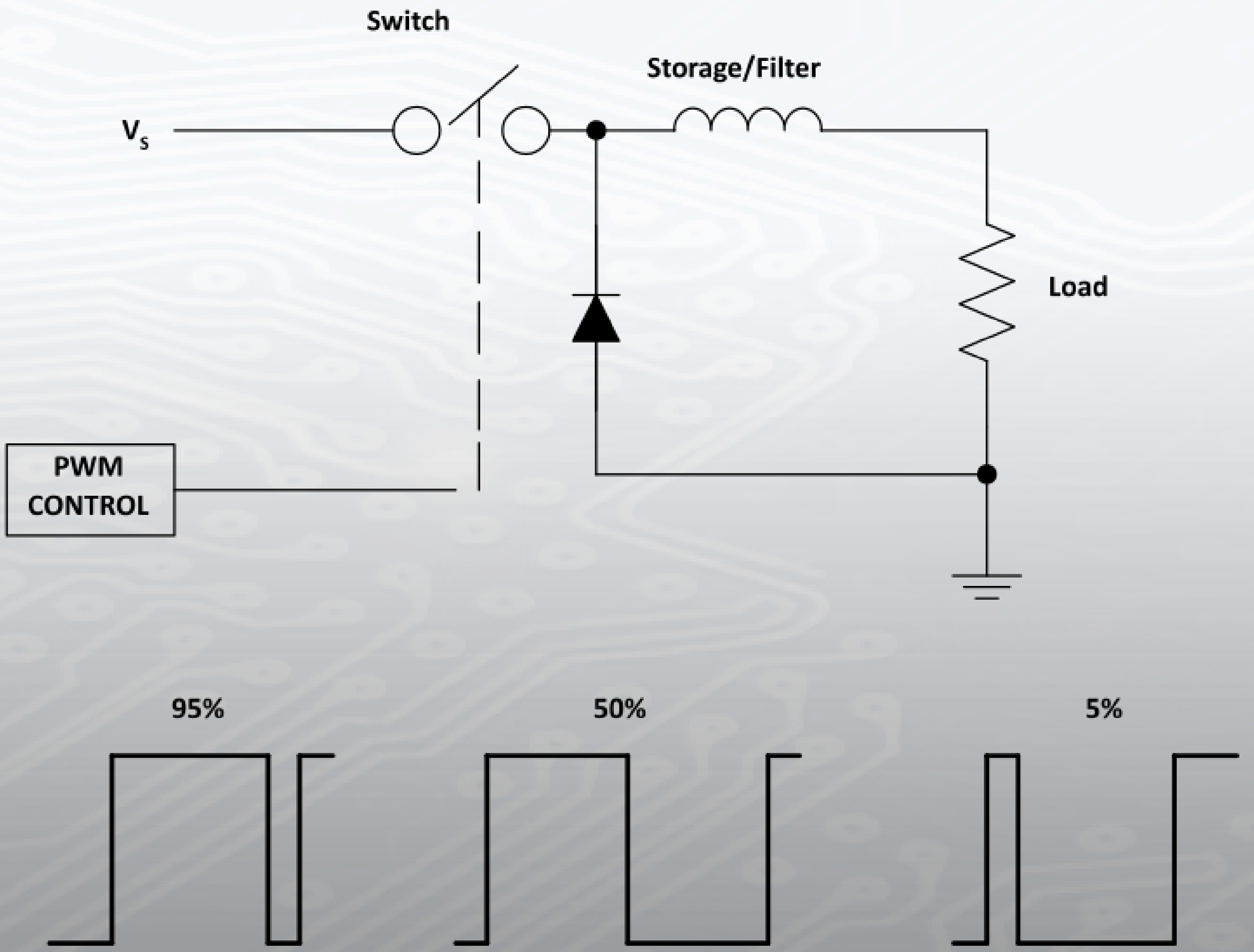
PWM Amplifiers

PWM

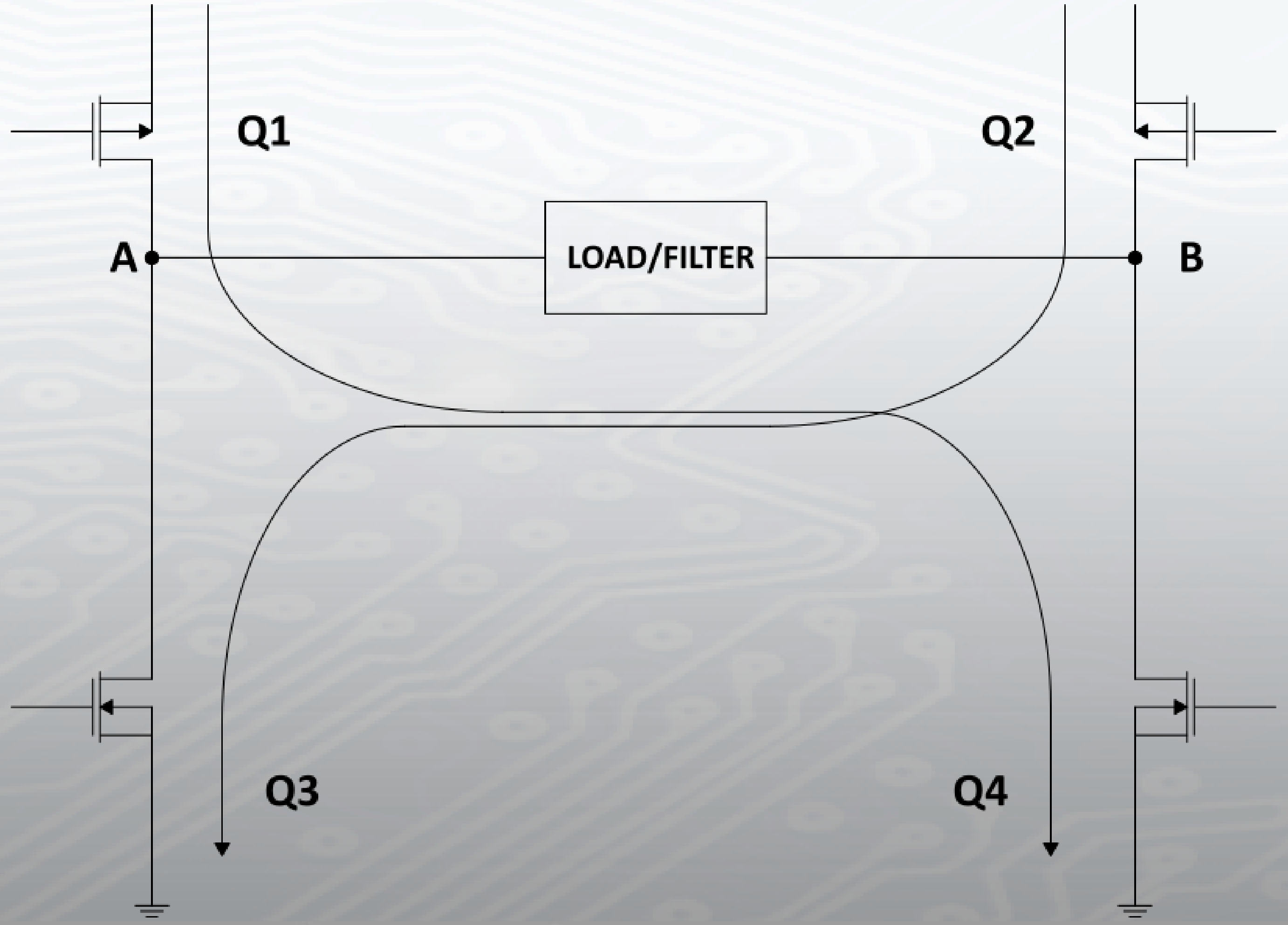
Pulse Width Modulation

- More Work
- Less Waste

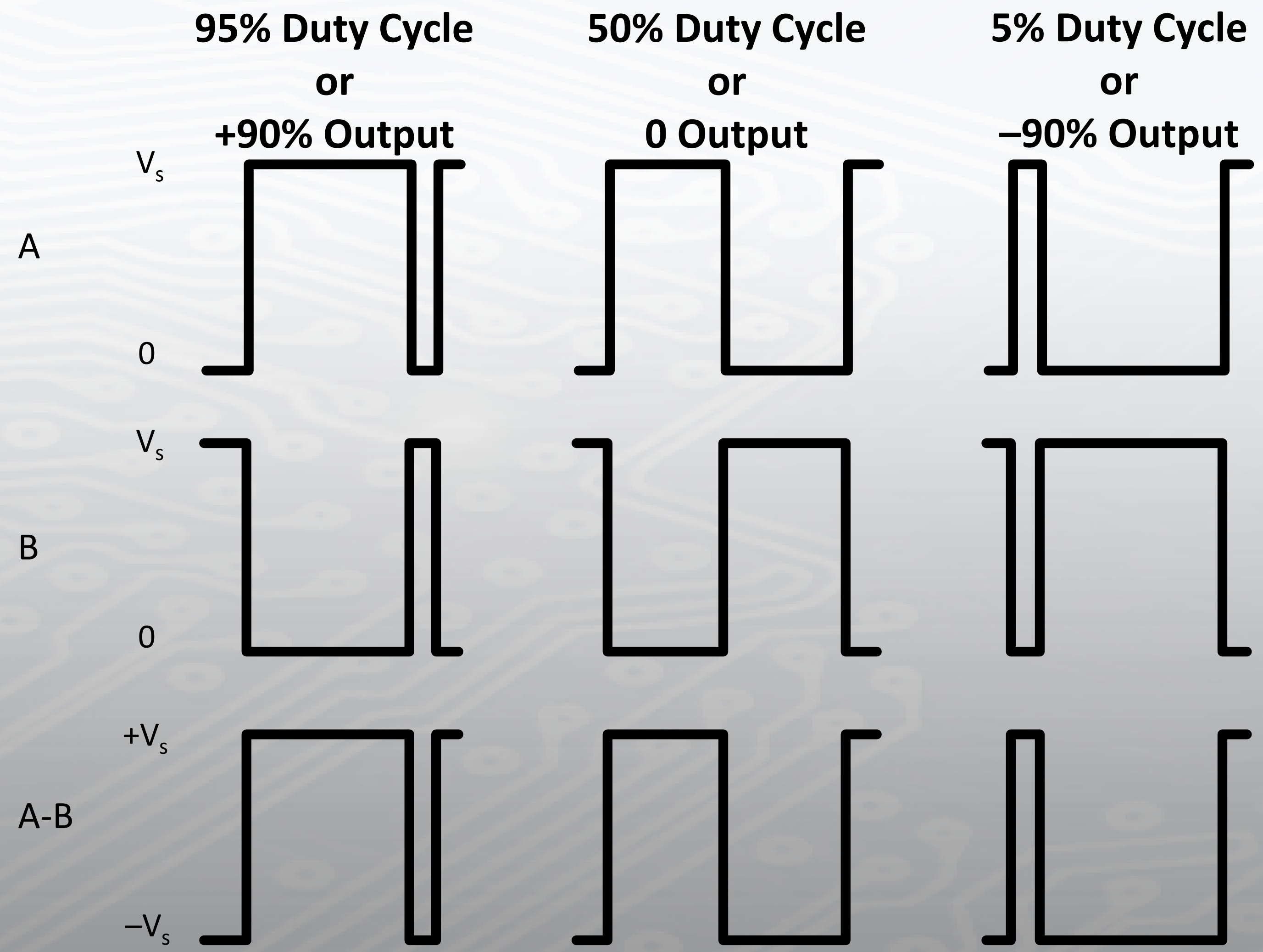
PWM Power Delivery



H-Bridge Providing Bipolar Output from a Single Supply



H-Bridge Waveforms



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STABILITY & COMPENSATION

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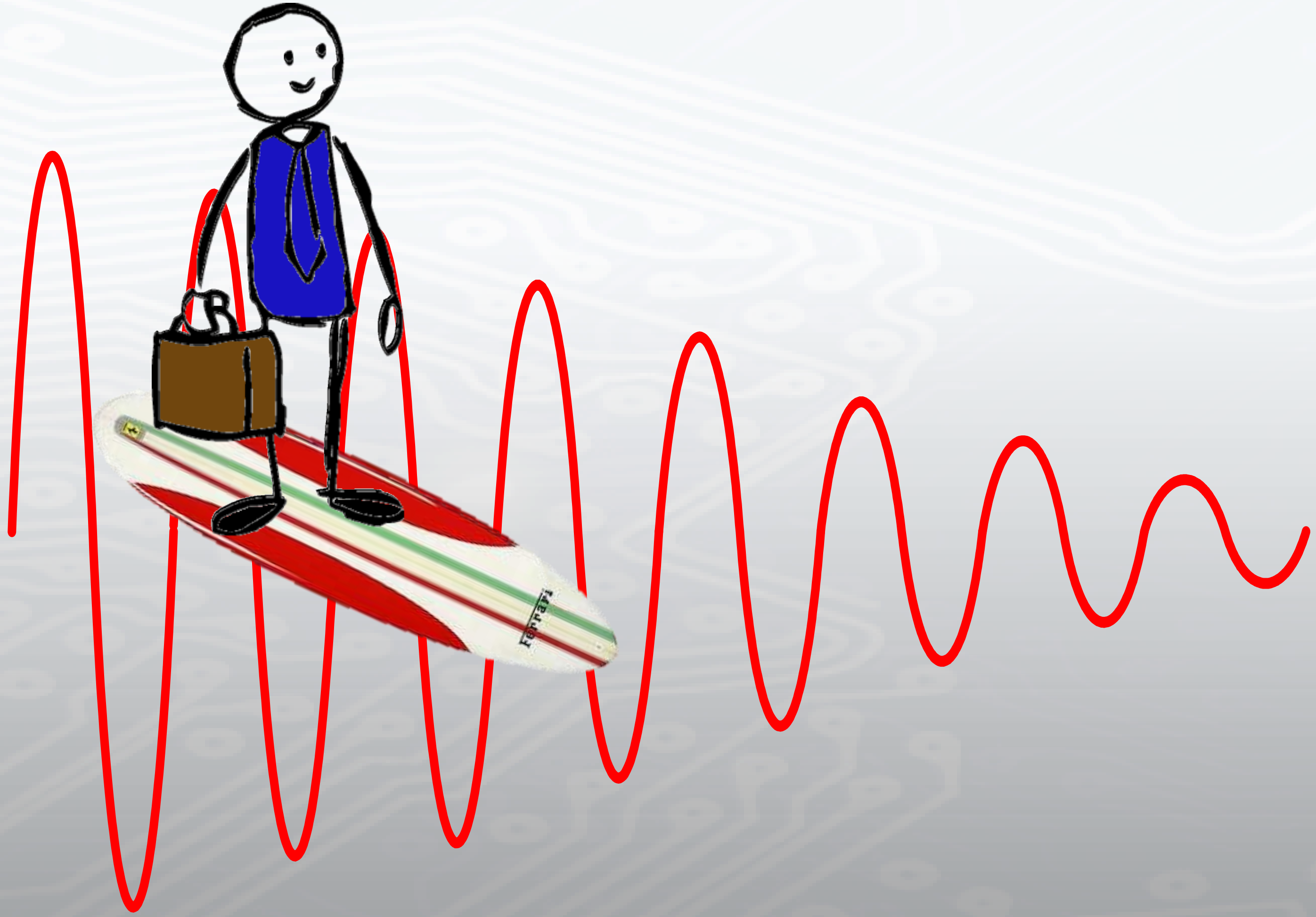
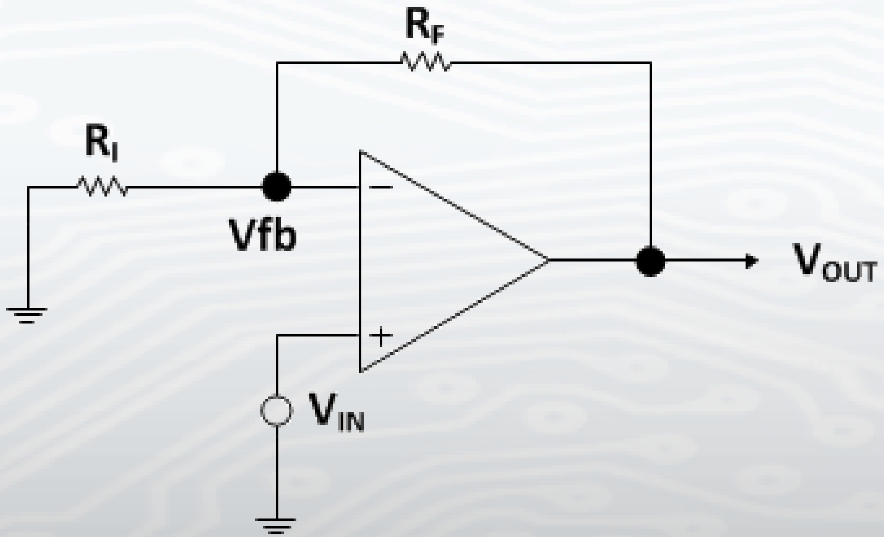
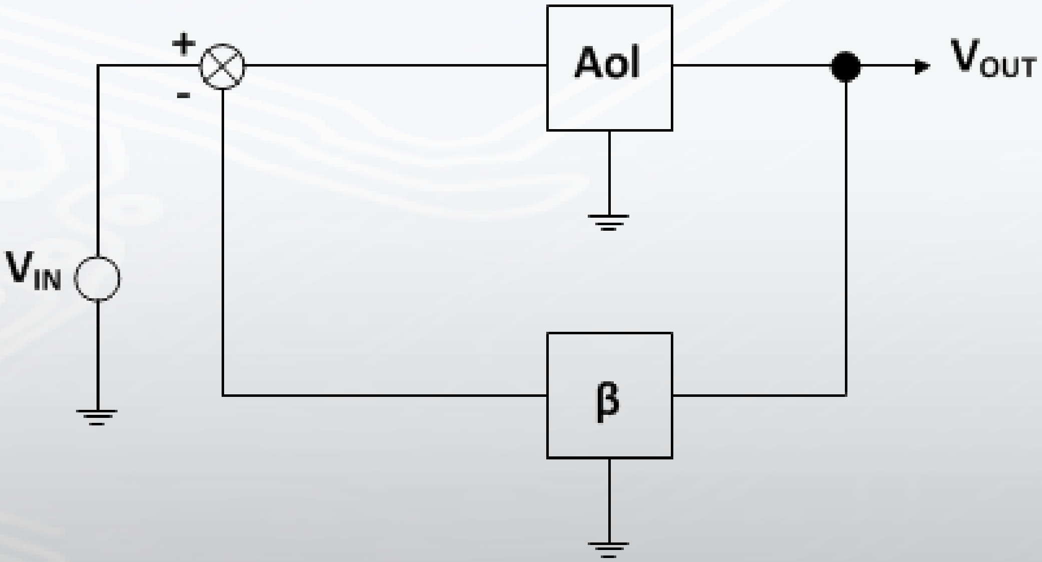
Loop Stability



Beta (β) – Feedback Factor





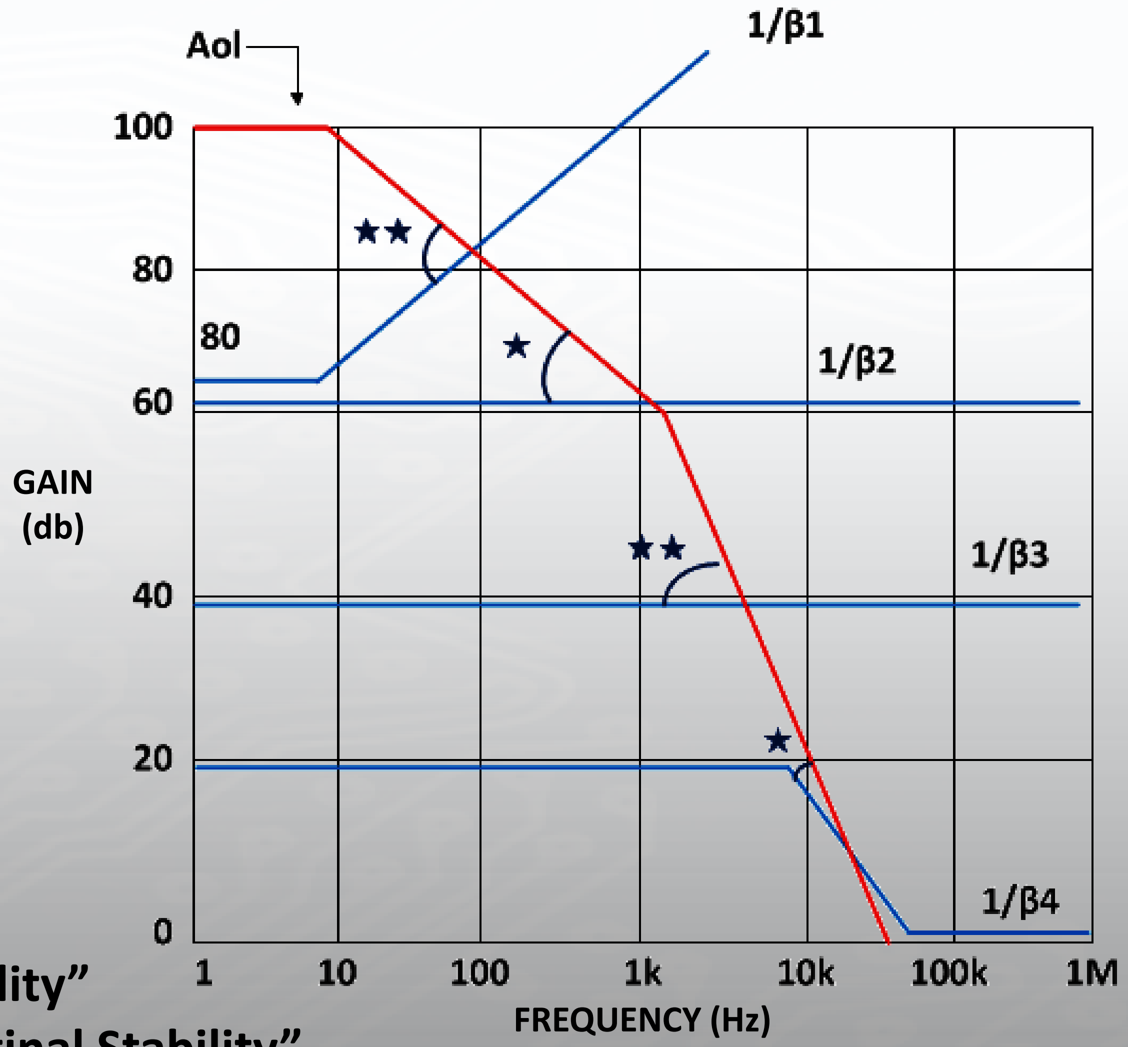
$$\beta = \frac{Ri}{Ri+Rf}$$

$$Vfb = \beta\ Vout$$

$$\frac{Vout}{Vin} = \frac{Aol}{1+Aol\beta} = \frac{1}{\beta}$$

(For Aol β >> 1)

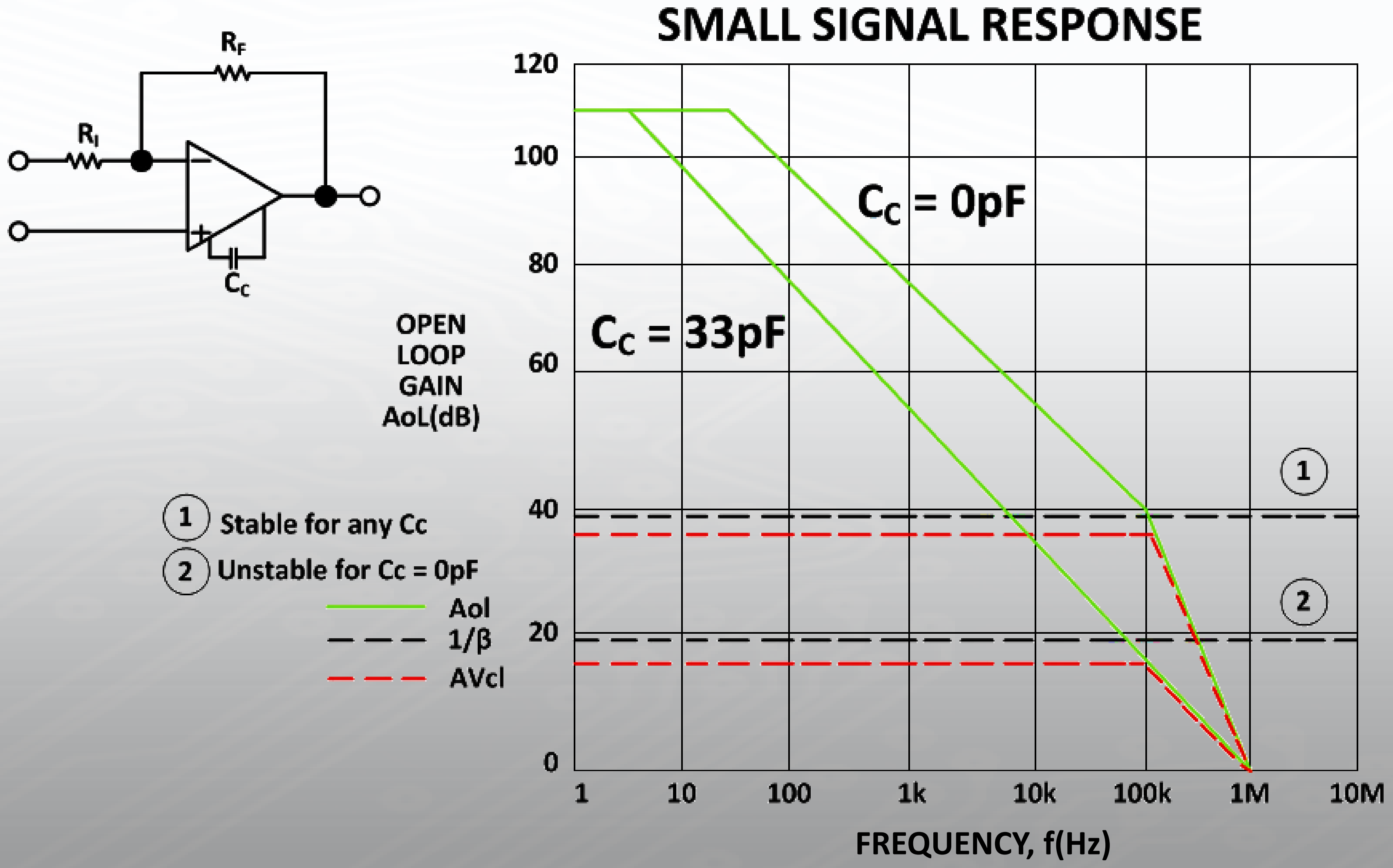
Rate of Closure & Stability



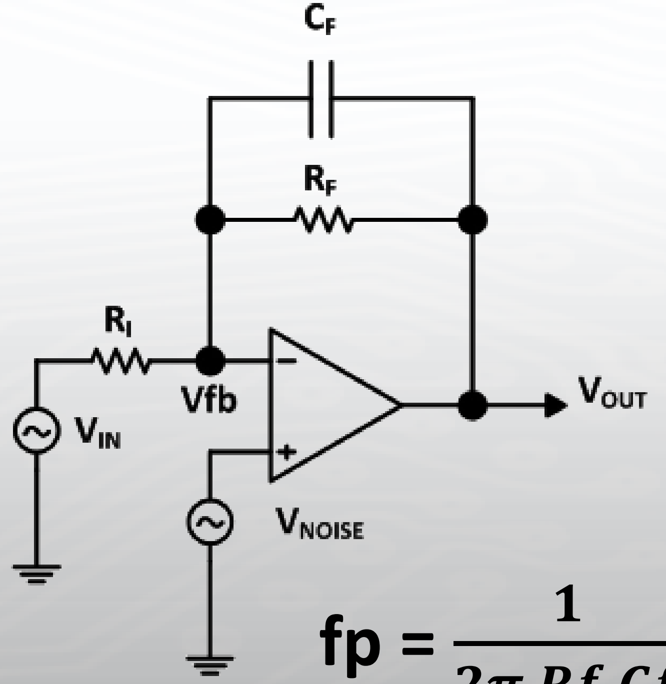
*20db/ decade Rate of Closure → "Stability"

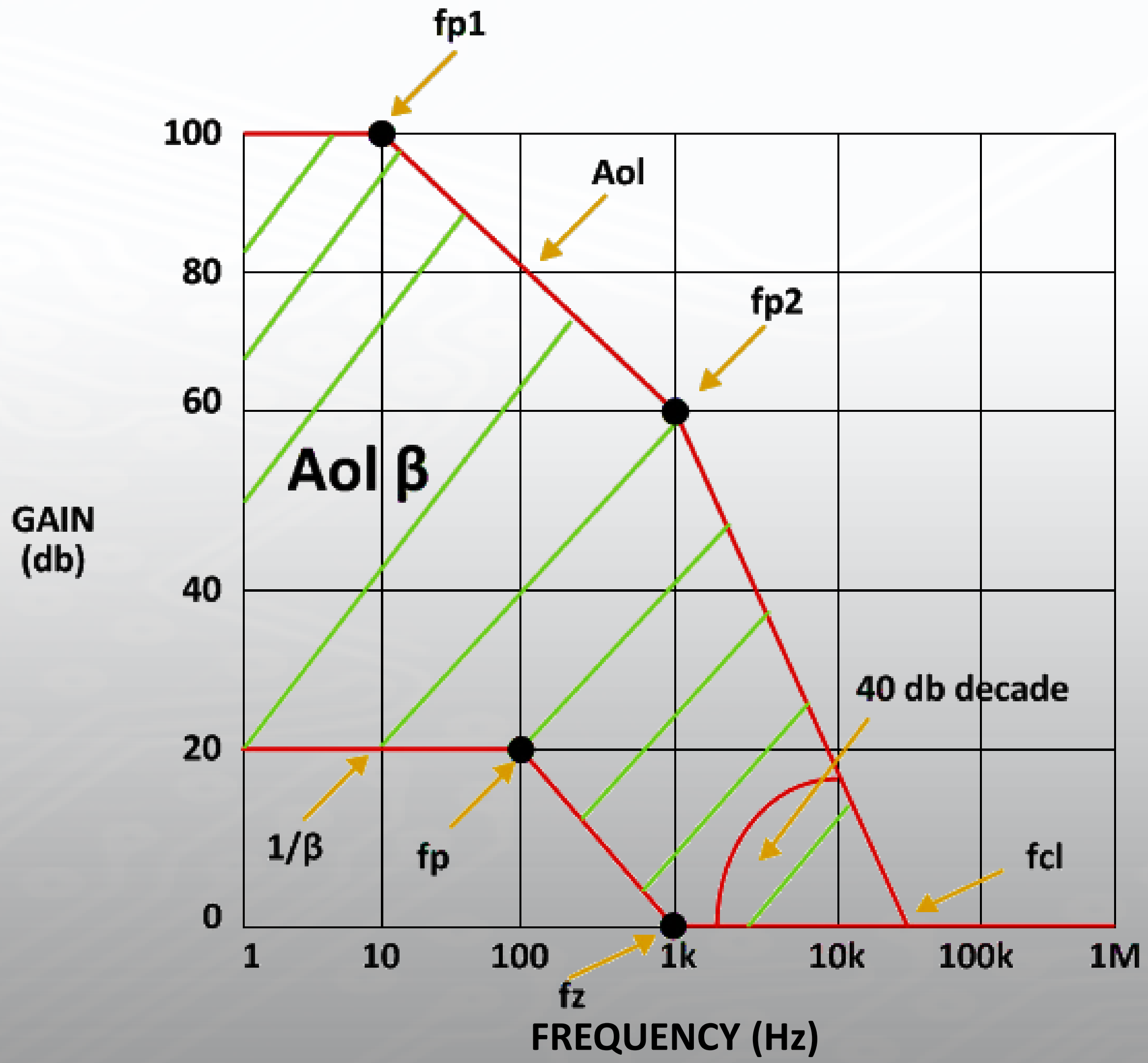
**40db/ decade Rate of Closure → "Marginal Stability"

External Phase Compensation



Stability – Rate of Closure

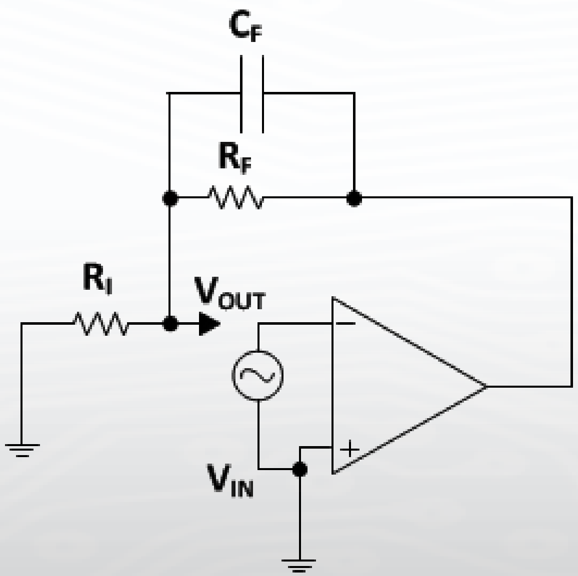




$$fp = \frac{1}{2\pi\, Rf\, Cf}$$

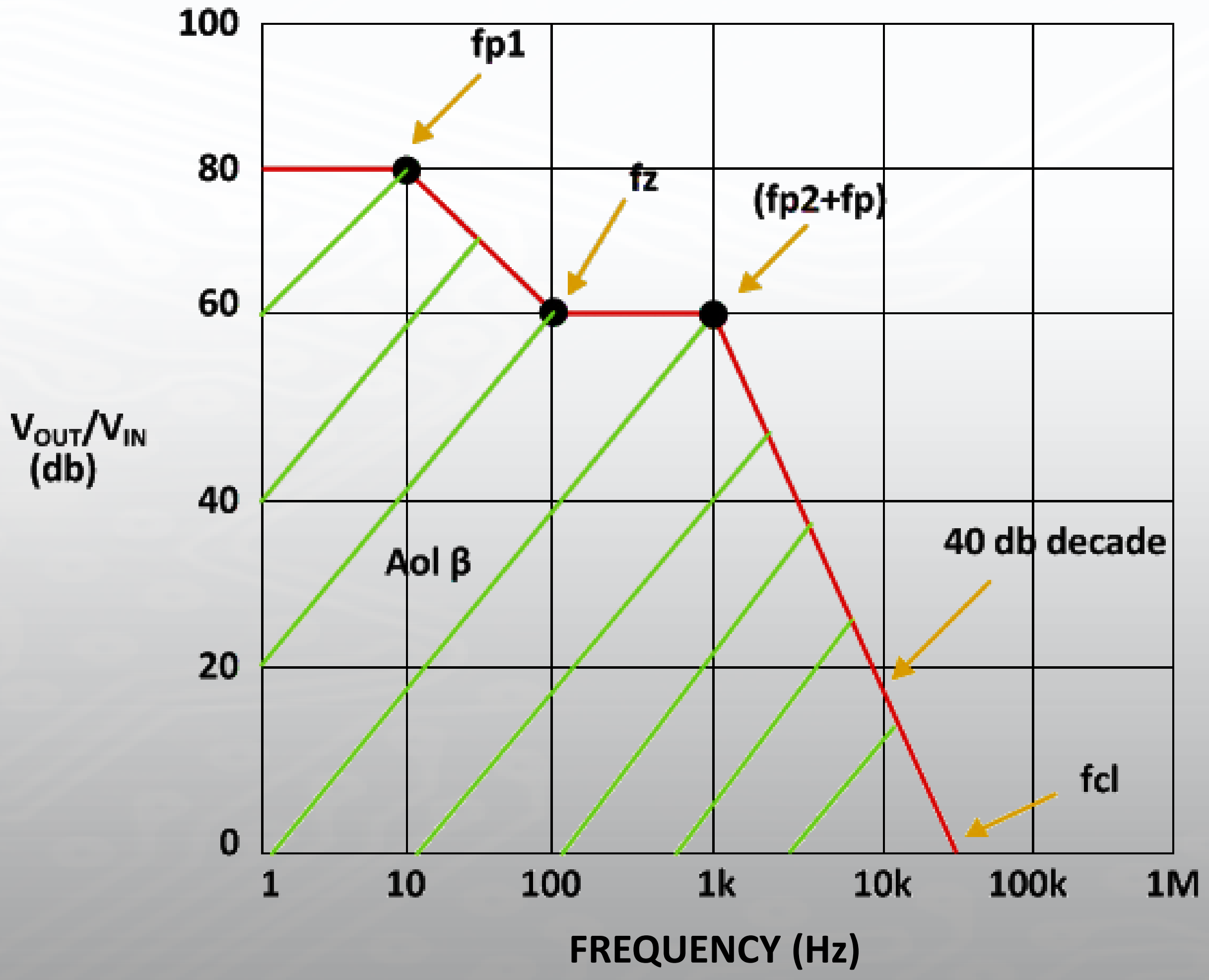
$$fz = \frac{Ri + Rf}{2\pi\, Ri\, Rf\, Cf}$$

Stability – Open Loop

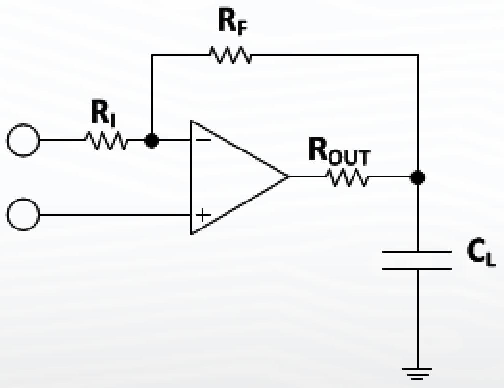


$$fz = \frac{1}{2\pi\, Rf\, Cf}$$

$$fp = \frac{Ri+Rf}{2\pi\, Ri\, Rf\, Cf}$$

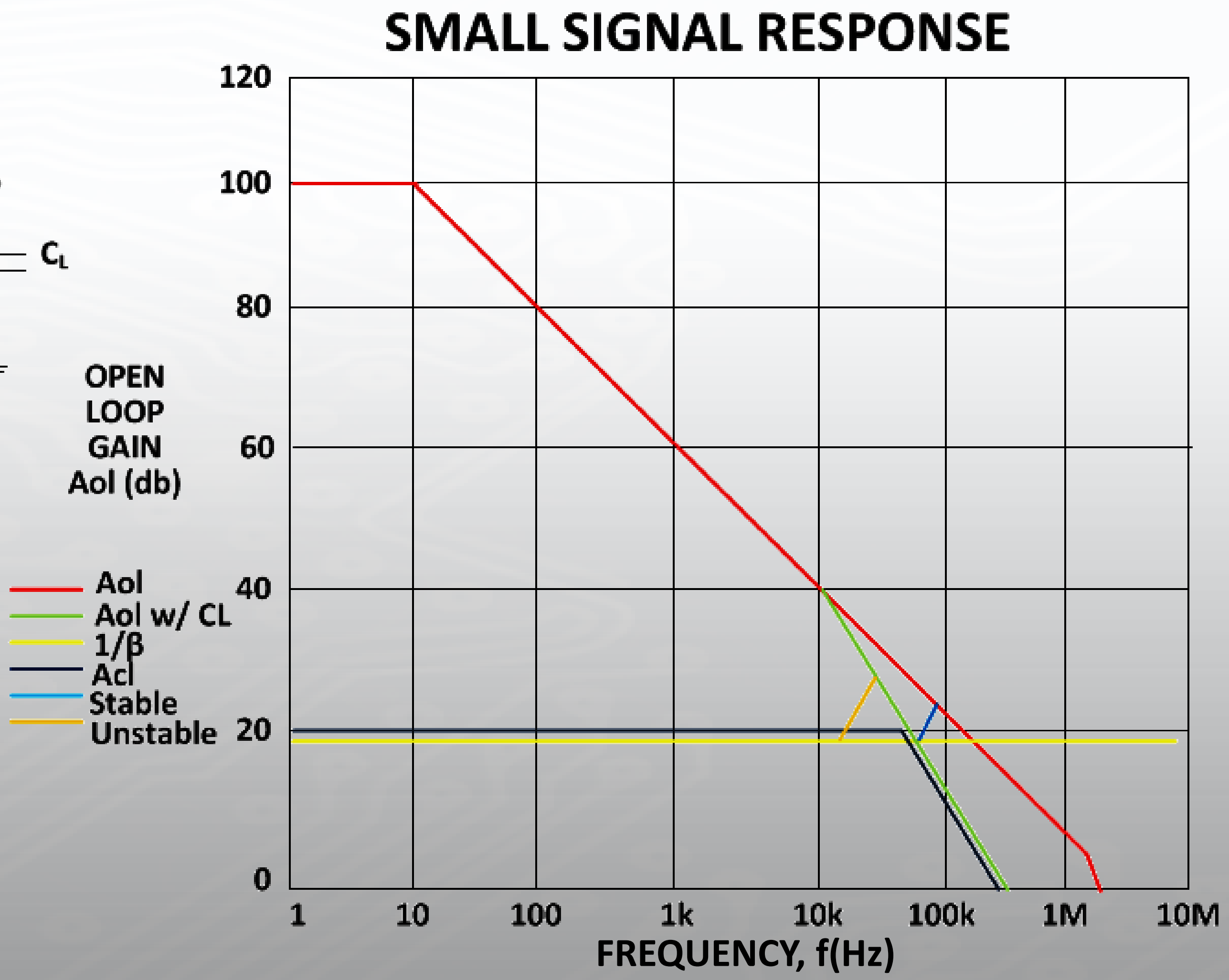


Capacitive Loading

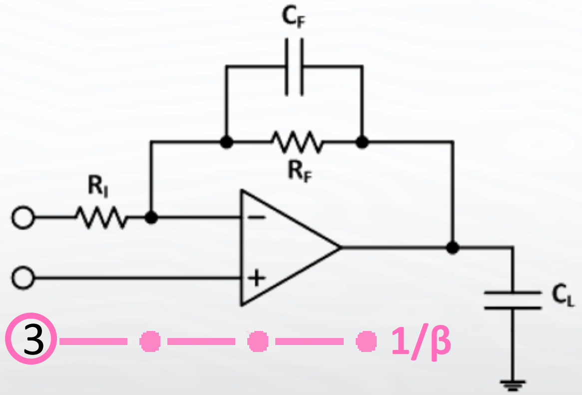


Unity Gain
Stable Amplifier

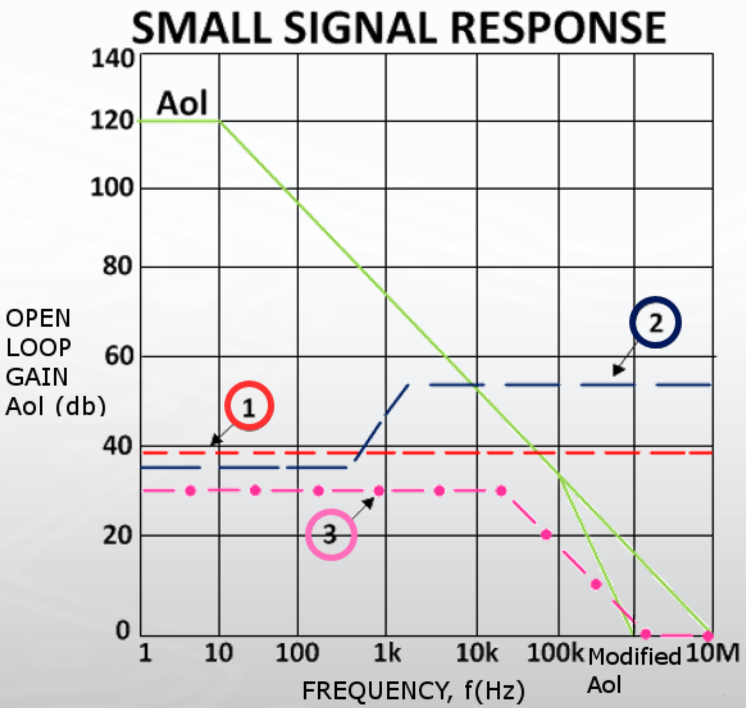
Unstable
40db/decade
with CL

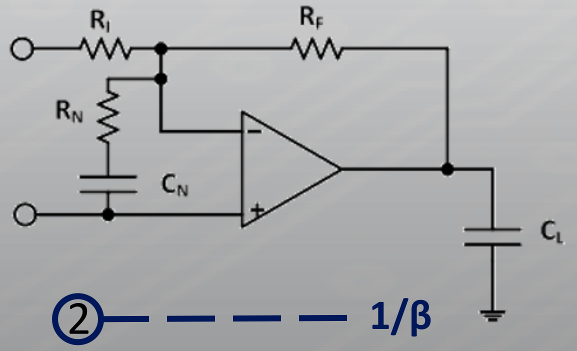


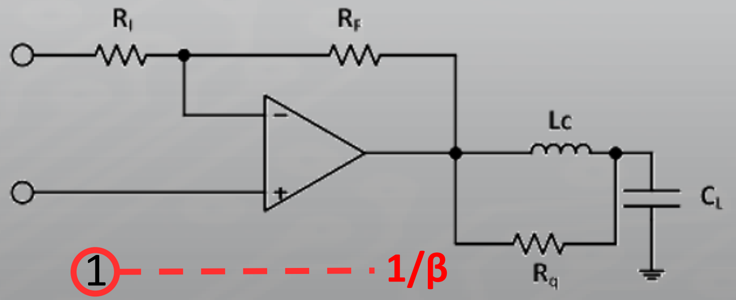
Capacitive Load Compensation



REQUIRES UNITY
GAIN STABLE AMPLIFIER







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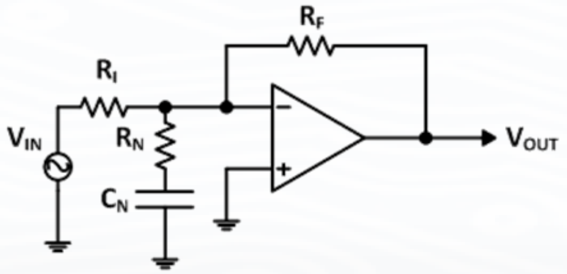
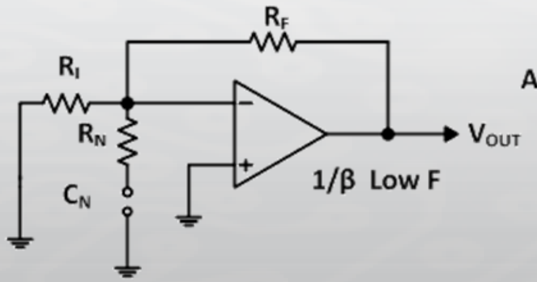
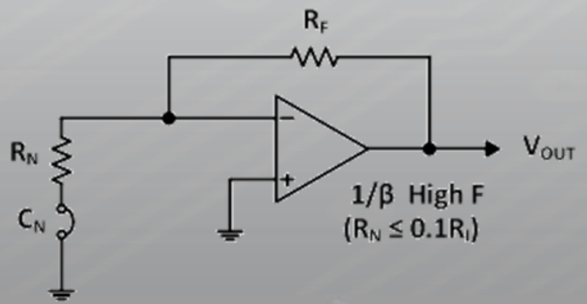
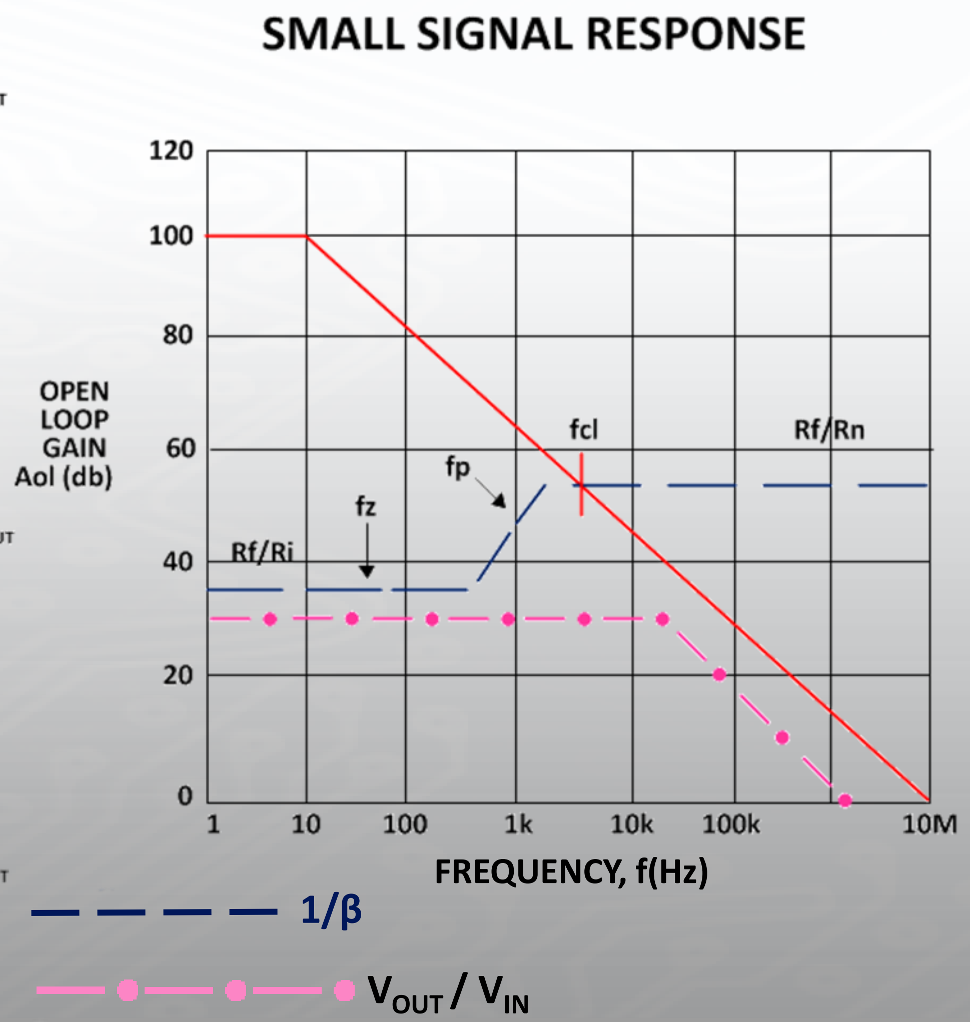
Noise-Gain Compensation

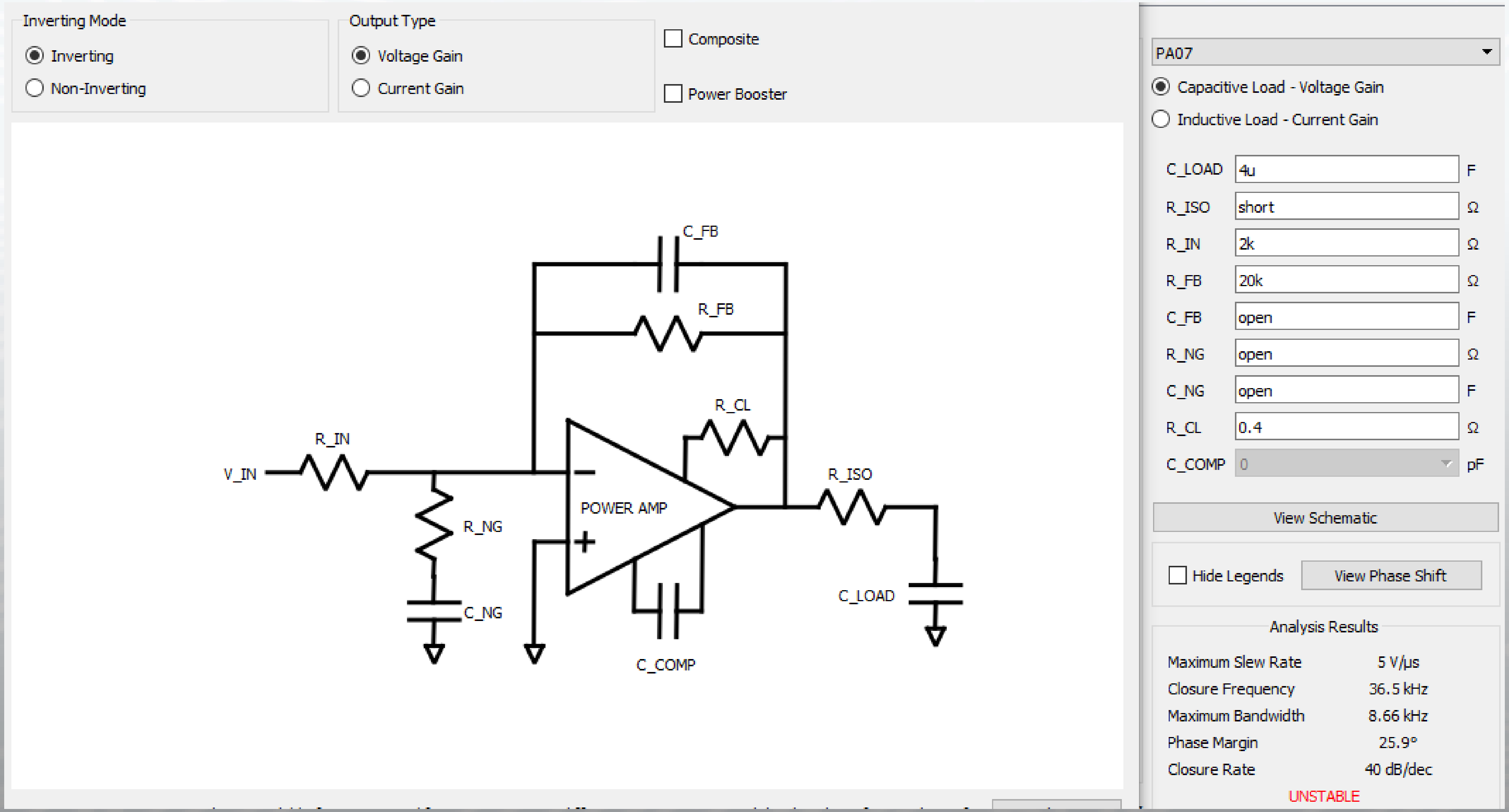




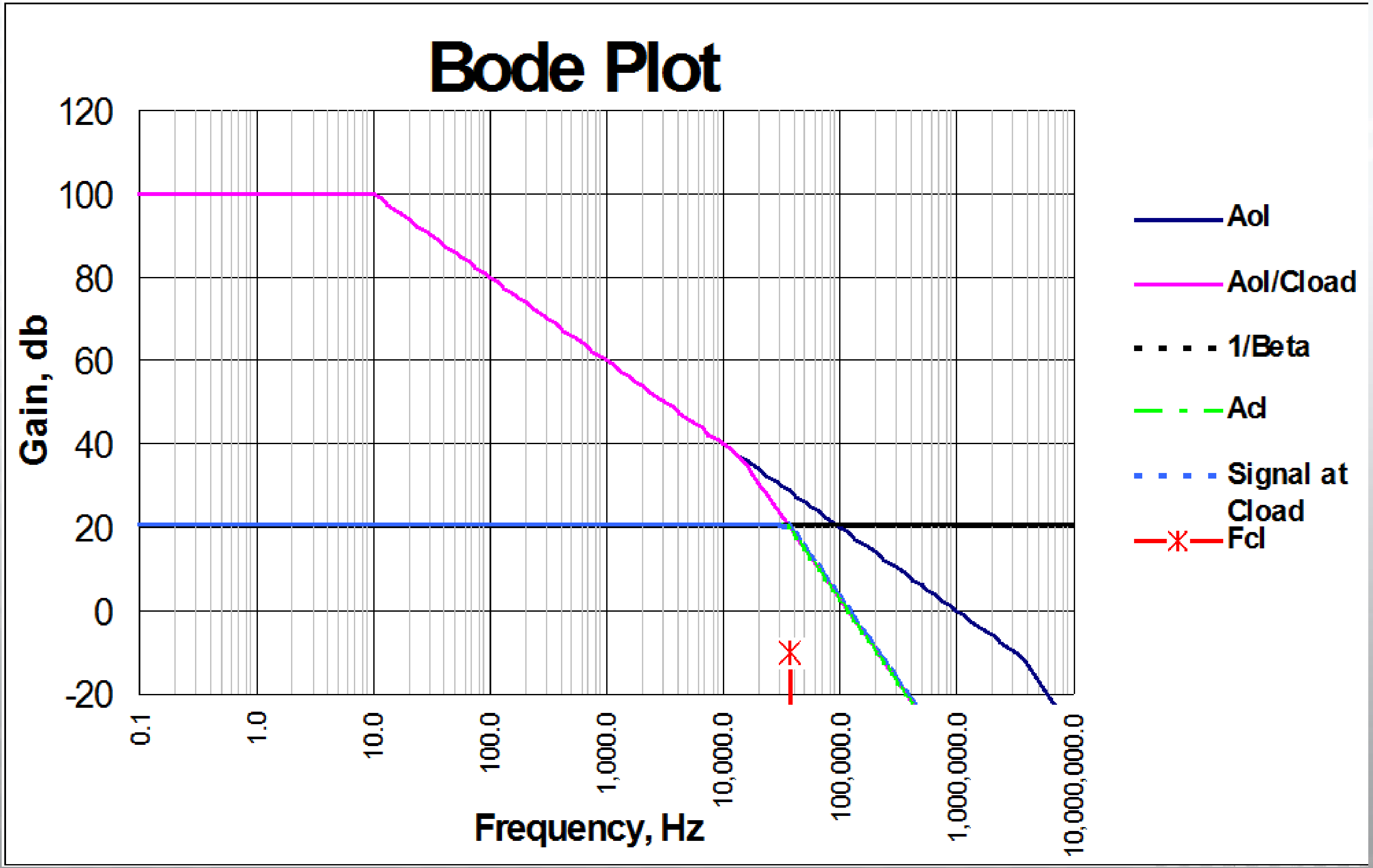




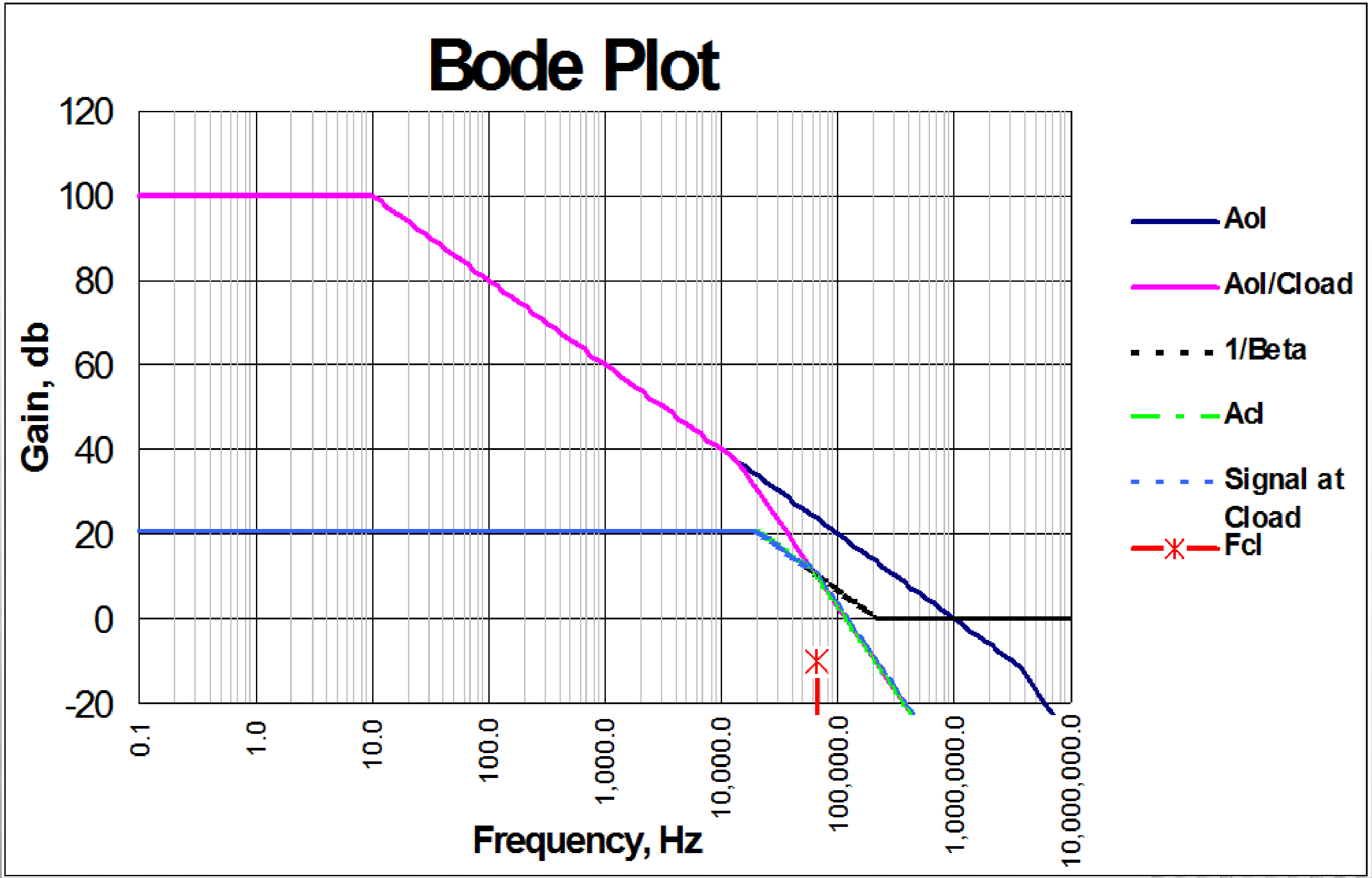
PowerDesign Cload



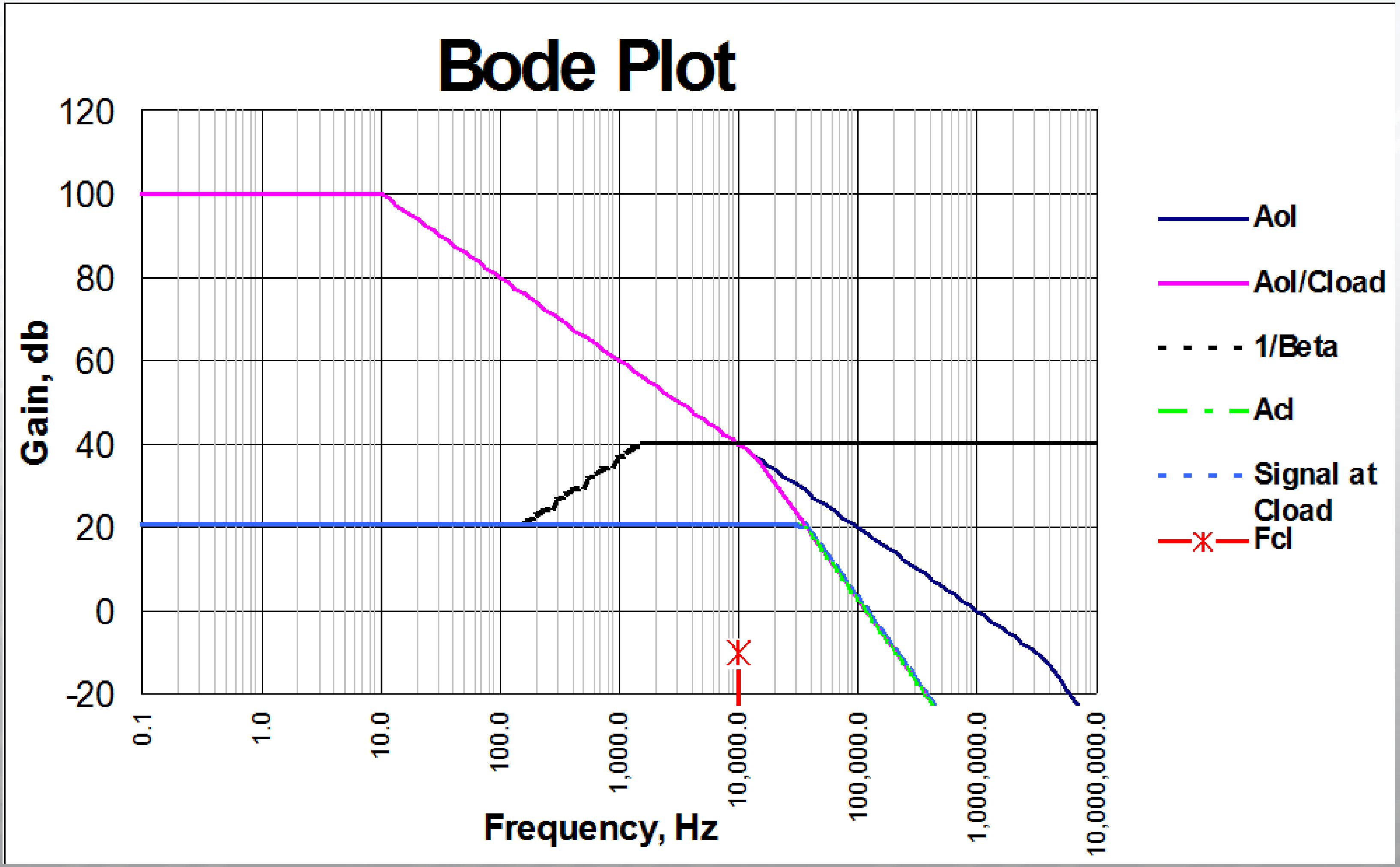
PA07/Cload Problem



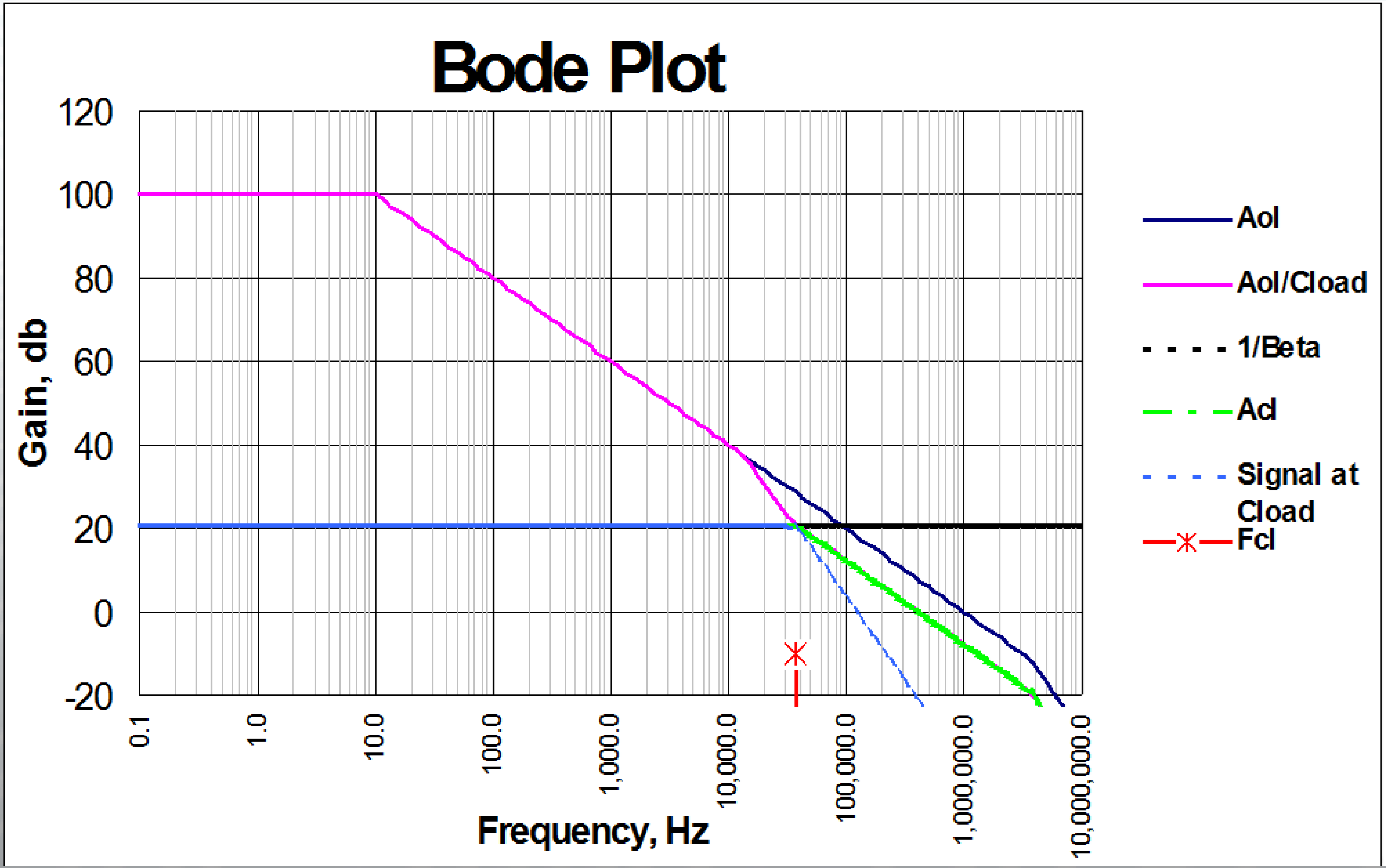
PA07/Cload Cf Solution



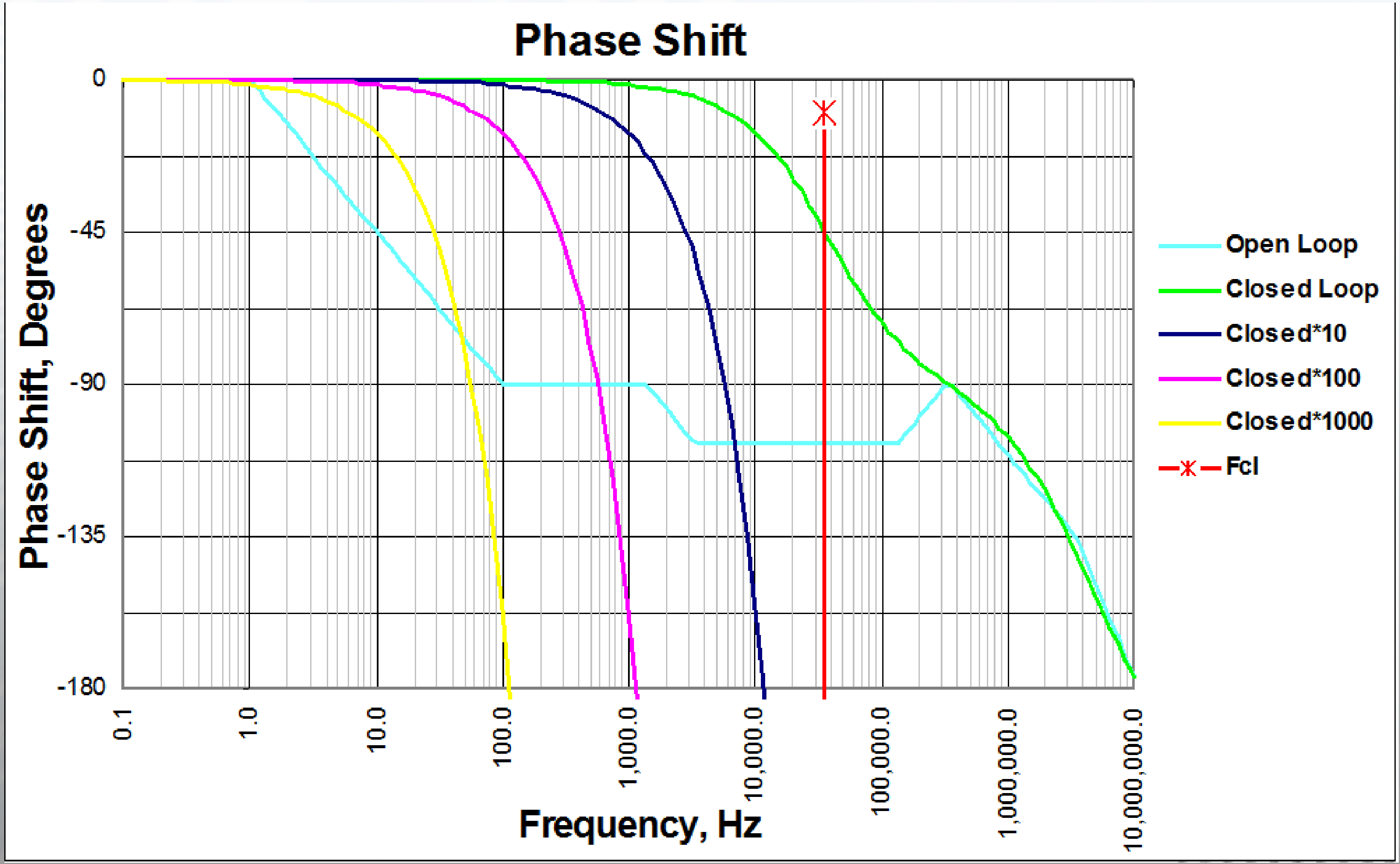
PA07/ Cload Noise Gain Solution



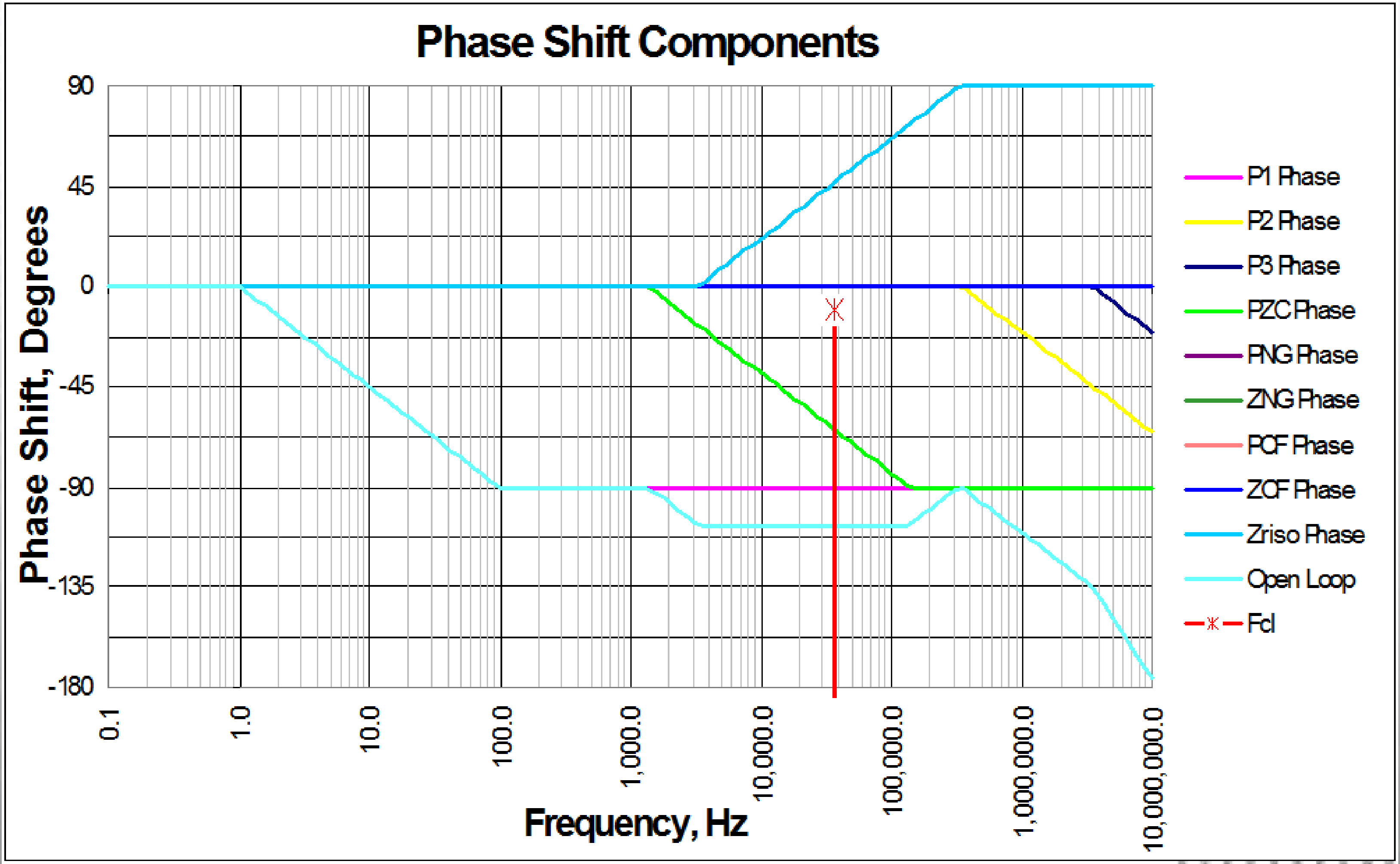
PA07/Cload Riso Solution



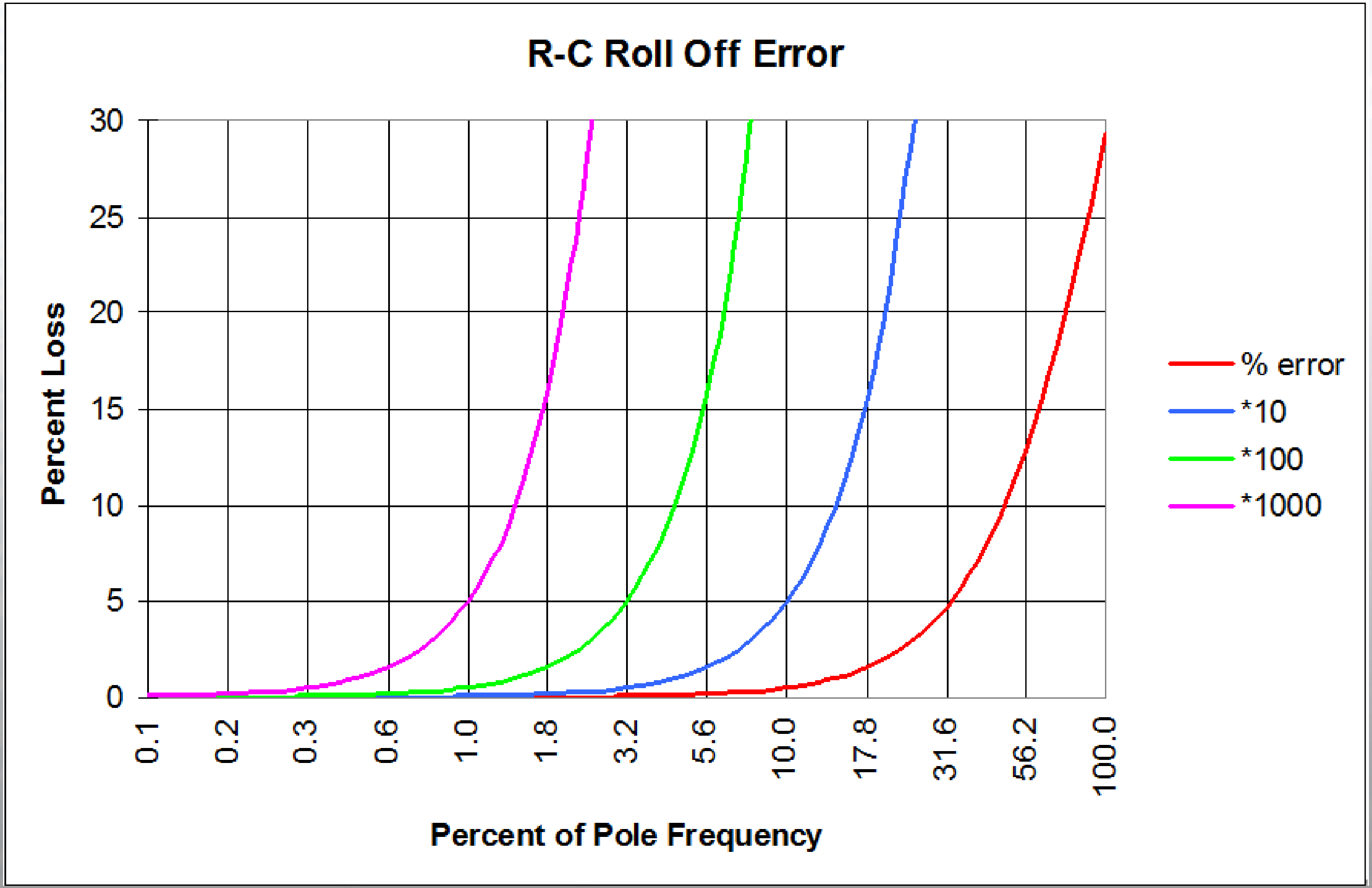
PA07/Cload Riso Phase



PA07/Cload Riso Phase Components



Errors of Straight Lines



Stability and Compensation

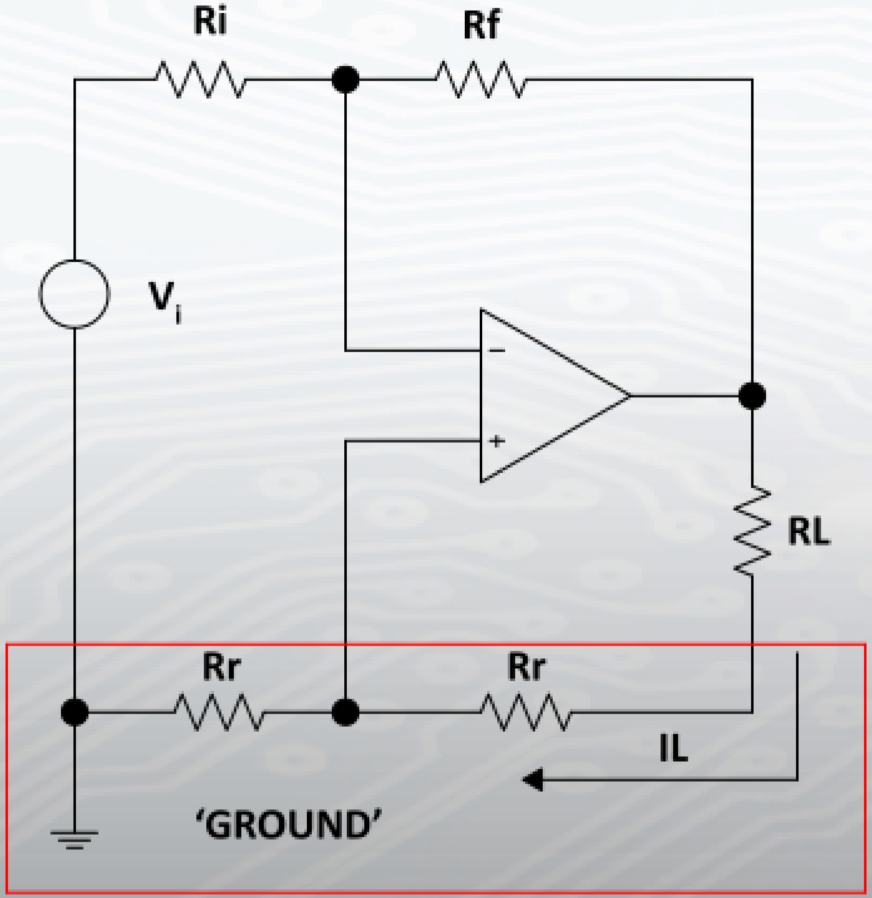
- Ground Loops
- Supply Loops
- Local Internal Loops
- Coupling: Internal and External
- Aol Loop Stability

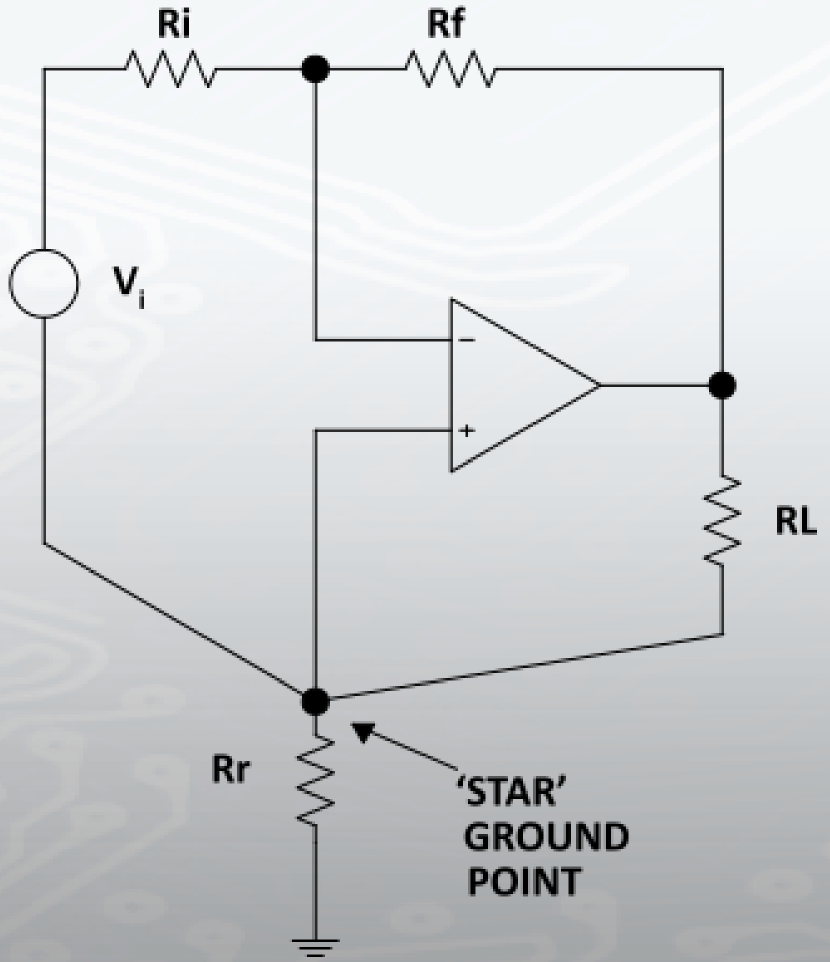
Eliminate Coupling

Internal and External

- ✓ Ground the Case
- ✓ Reduce Impedances
- ✓ Eliminate I_b Compensation Resistor on +IN
- ✓ Don’t Run Output Traces Near Input Traces
- ✓ Run I_{out} Traces Adjacent to I_{out} Return Traces

Ground Loops



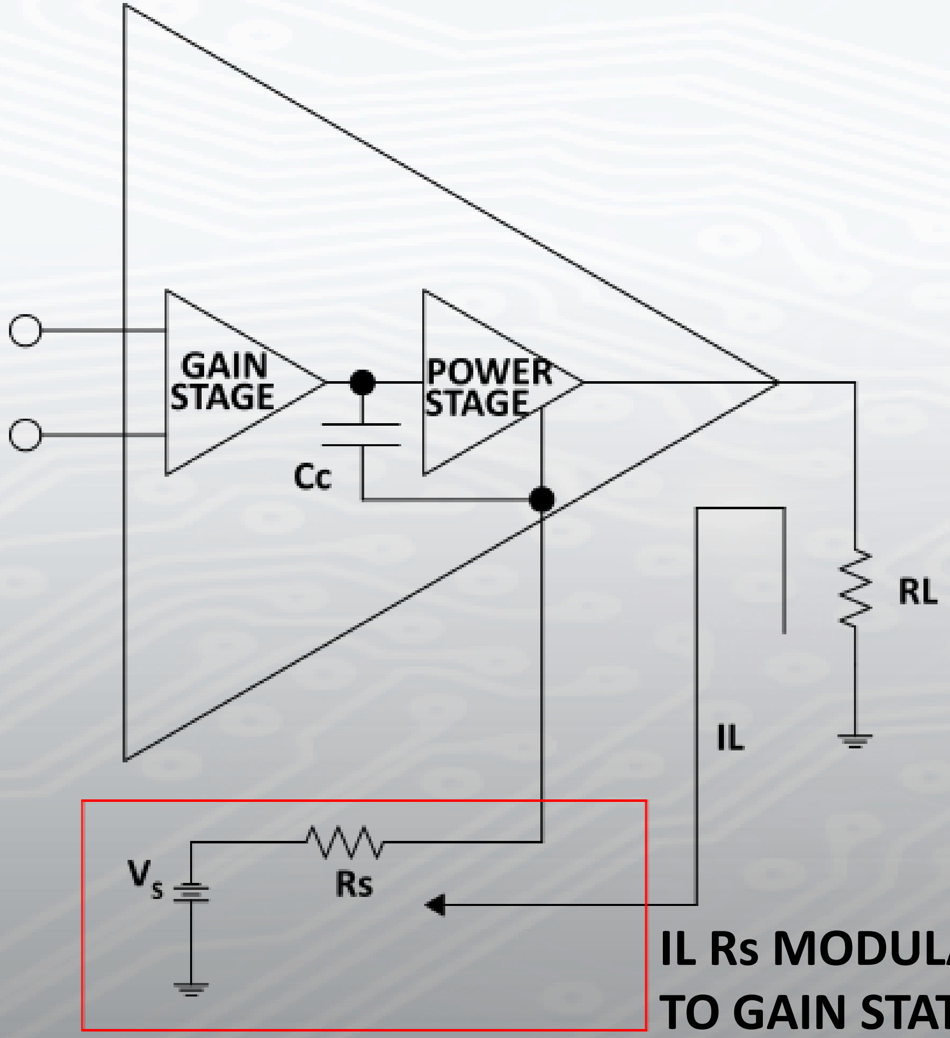


PROBLEM

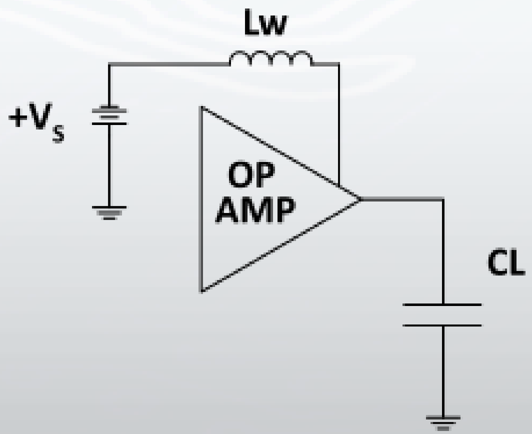
f(osc) = ≈ f(unity)

SOLUTION

Supply Line Modulation

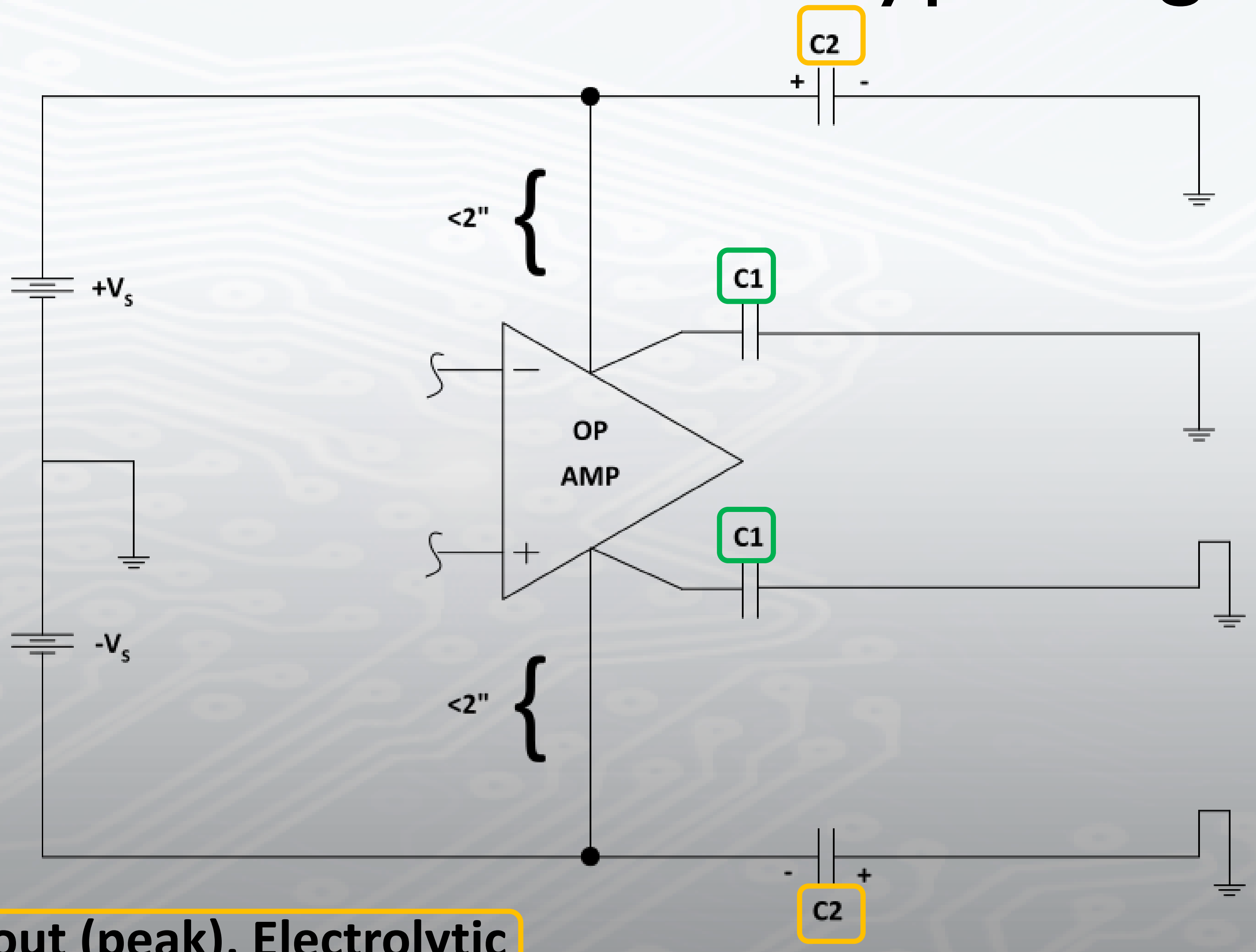


IL Rs MODULATION FEEDS BACK
TO GAIN STATE



Lw & CL FORM
"TANK"

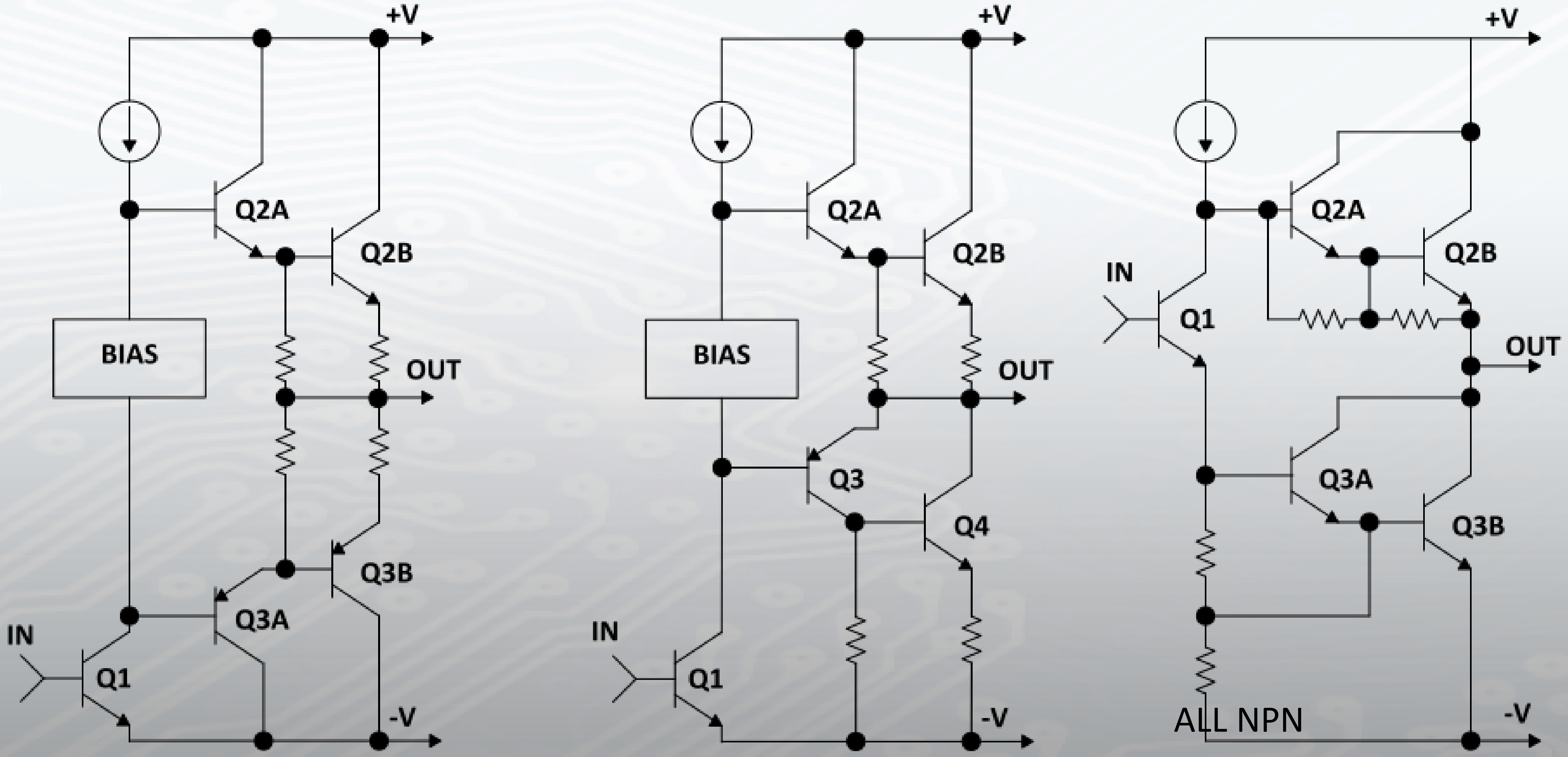
Bypassing Supply Lines



C1 = 0.1 to 1µF

C2 = 10µF/Amp out (peak), Electrolytic

Bipolar Output Stages

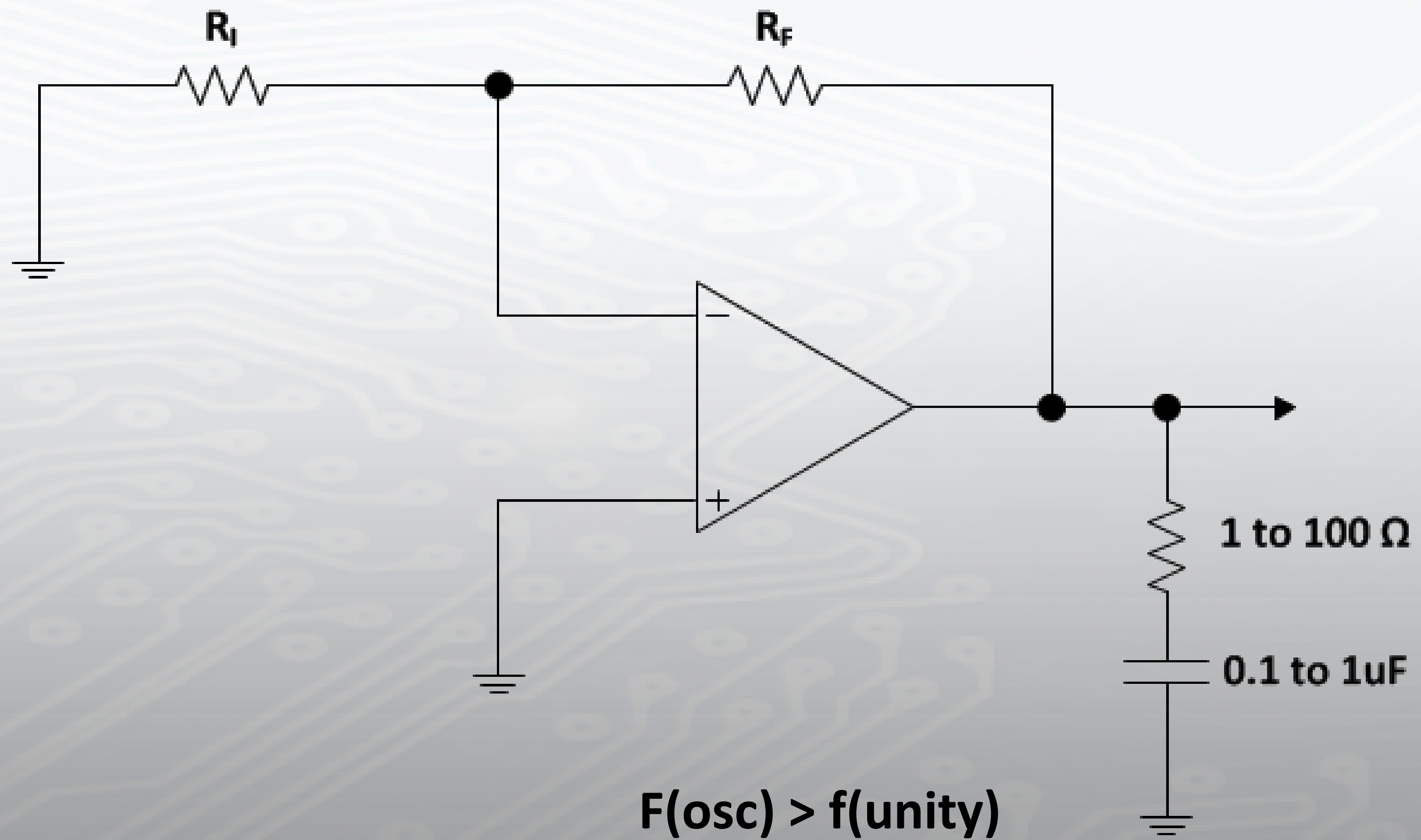


FULL COMPLEMENTARY

QUASI COMPLEMENTARY

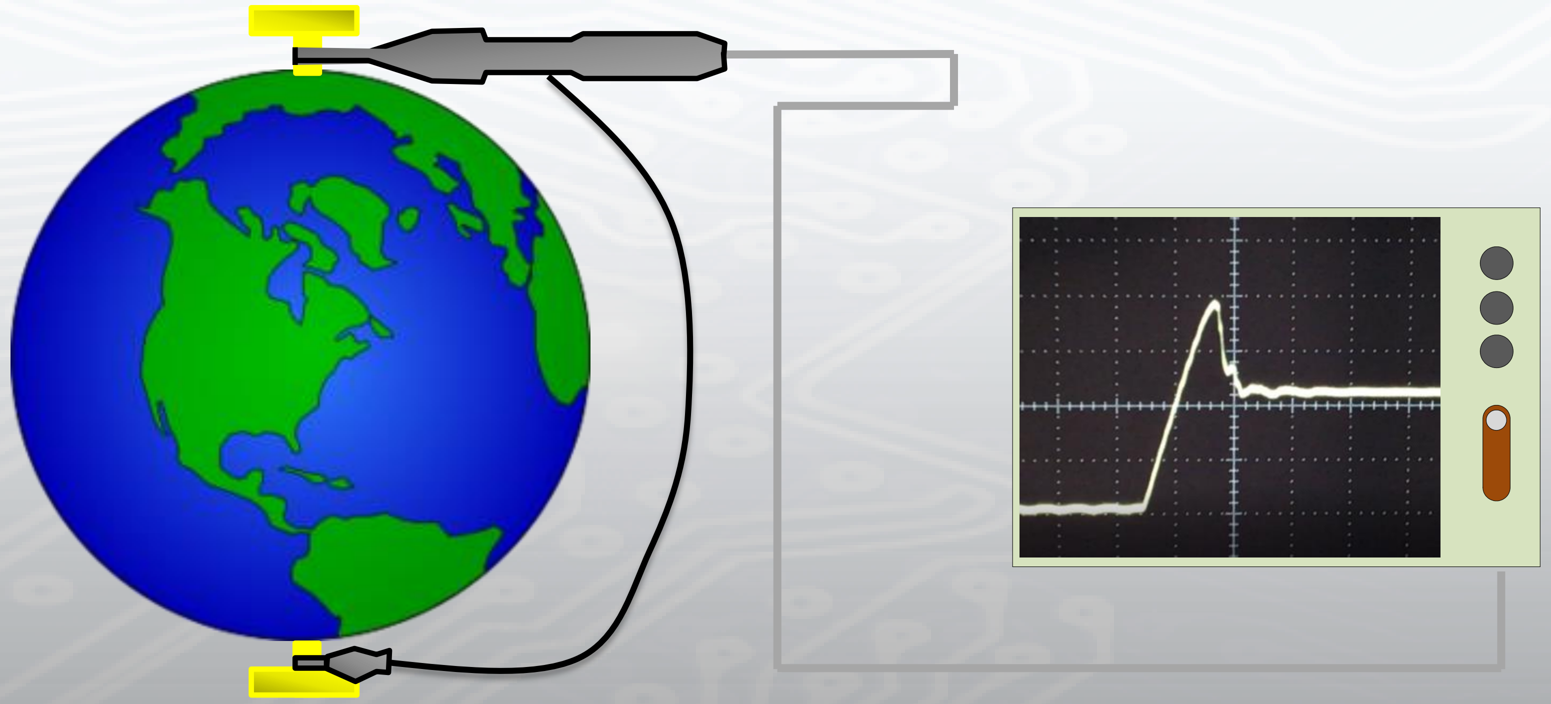
All NPN

Fixing Output Stage Oscillations

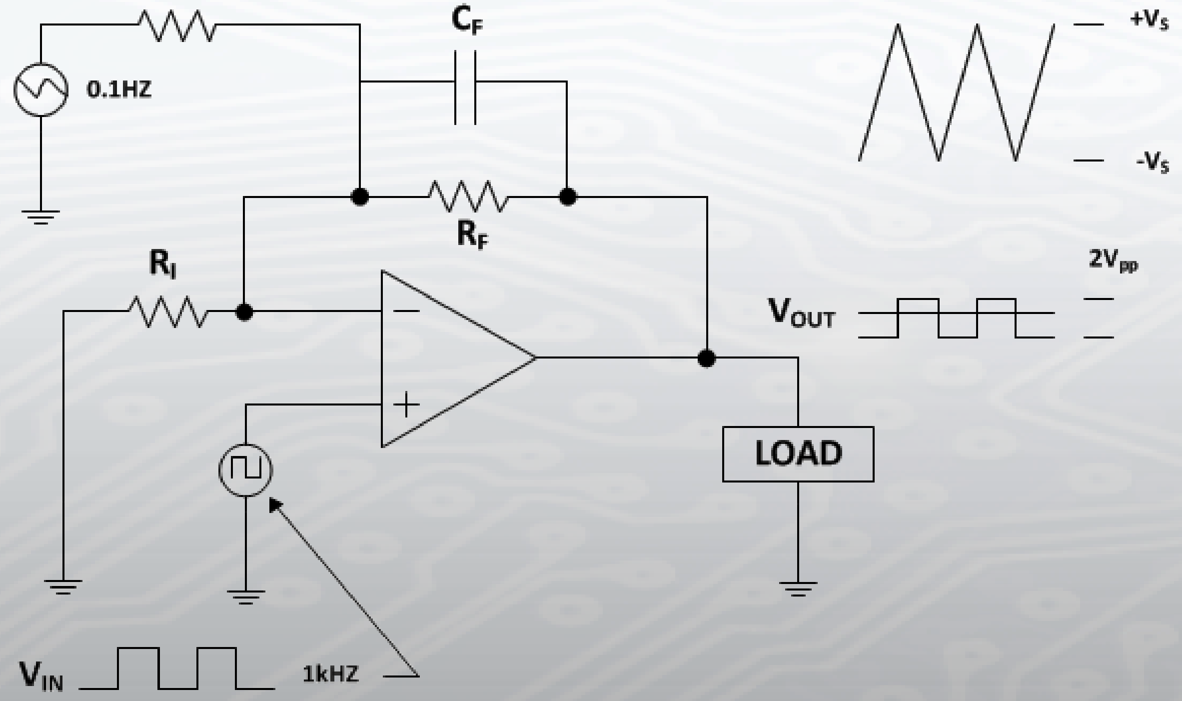


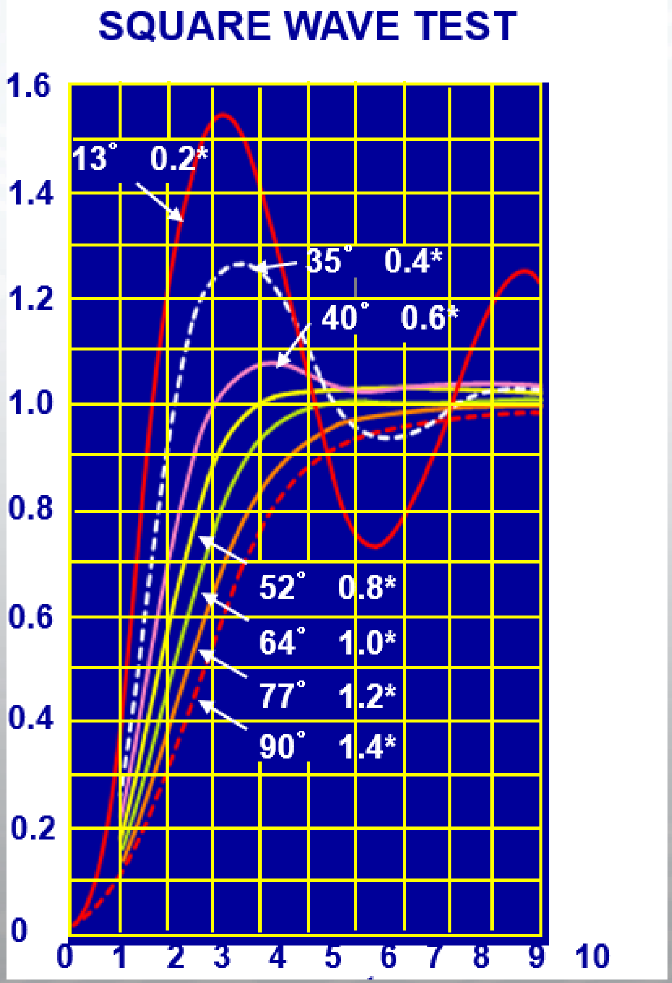
F(osc) > f(unity)

Real World Stability Tests

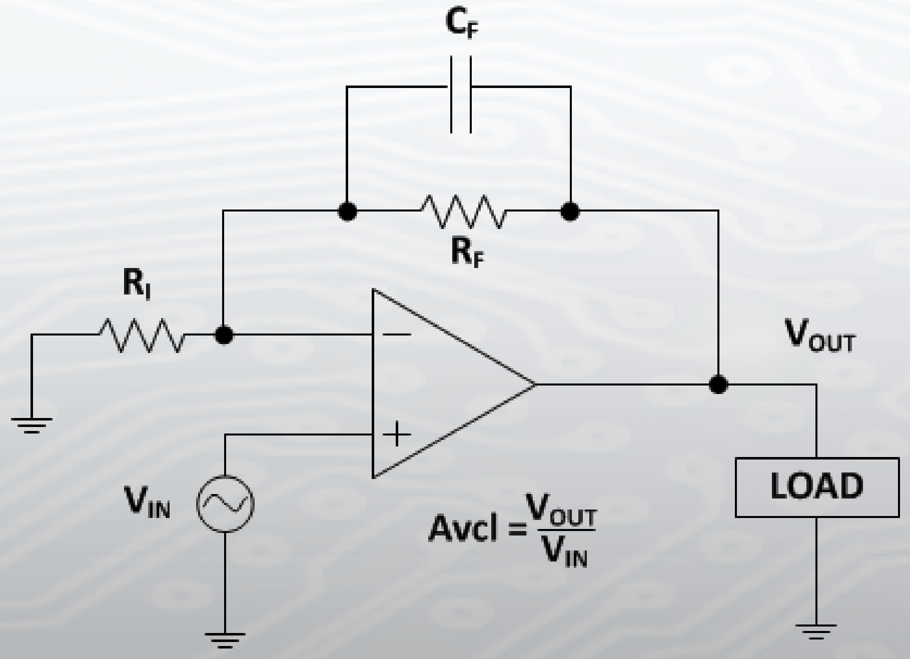


Square Wave Test



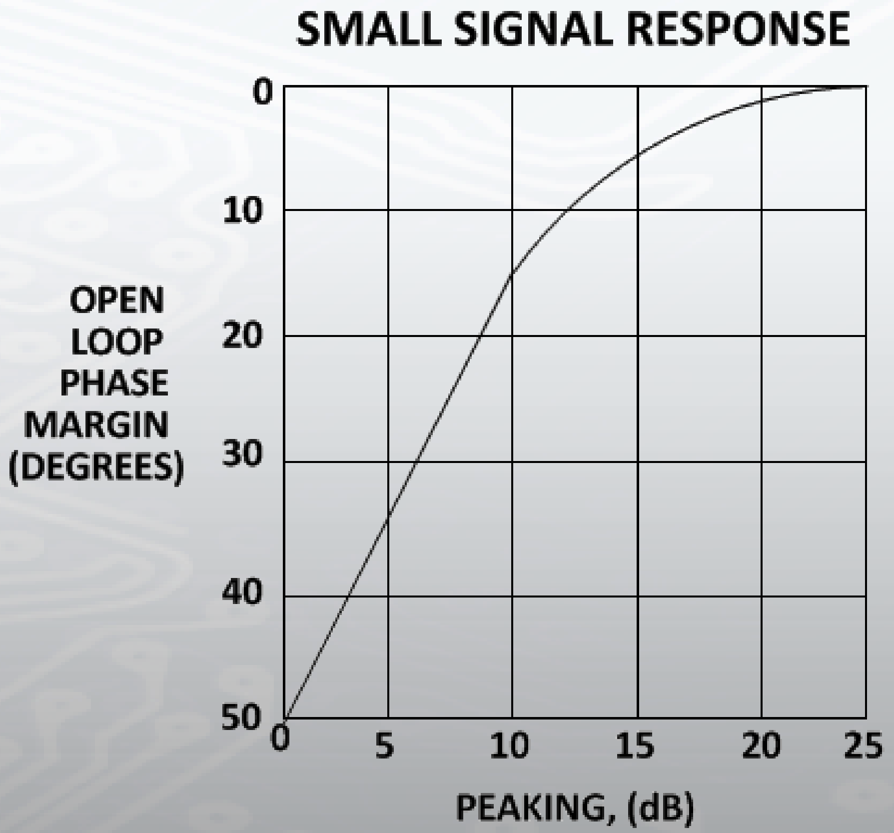


AVcl Peaking Test



PEAKING-MEASURED CLOSED LOOP

Avcl(dB) Peaking



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CONCLUSION

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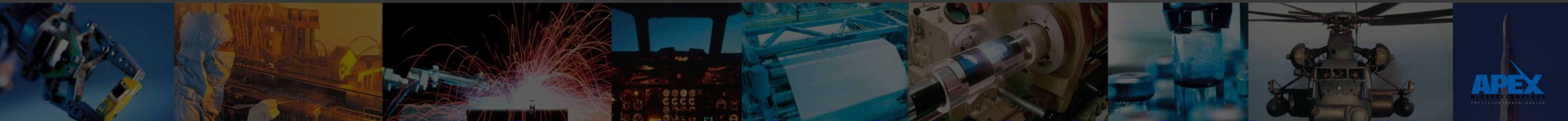

History Market-Position Device-Range Product-Portfolio Form-Factors Value-Added

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Thank you