ECEN 4797/5797

Introduction to Power Electronics

Lecture #29

Friday, October 30, 2009

- "algebra on the graph" example
- Measurement of ac transfer functions
- Introduction to converter control systems
- Sections 8.4-8.5, 9.1-9.2

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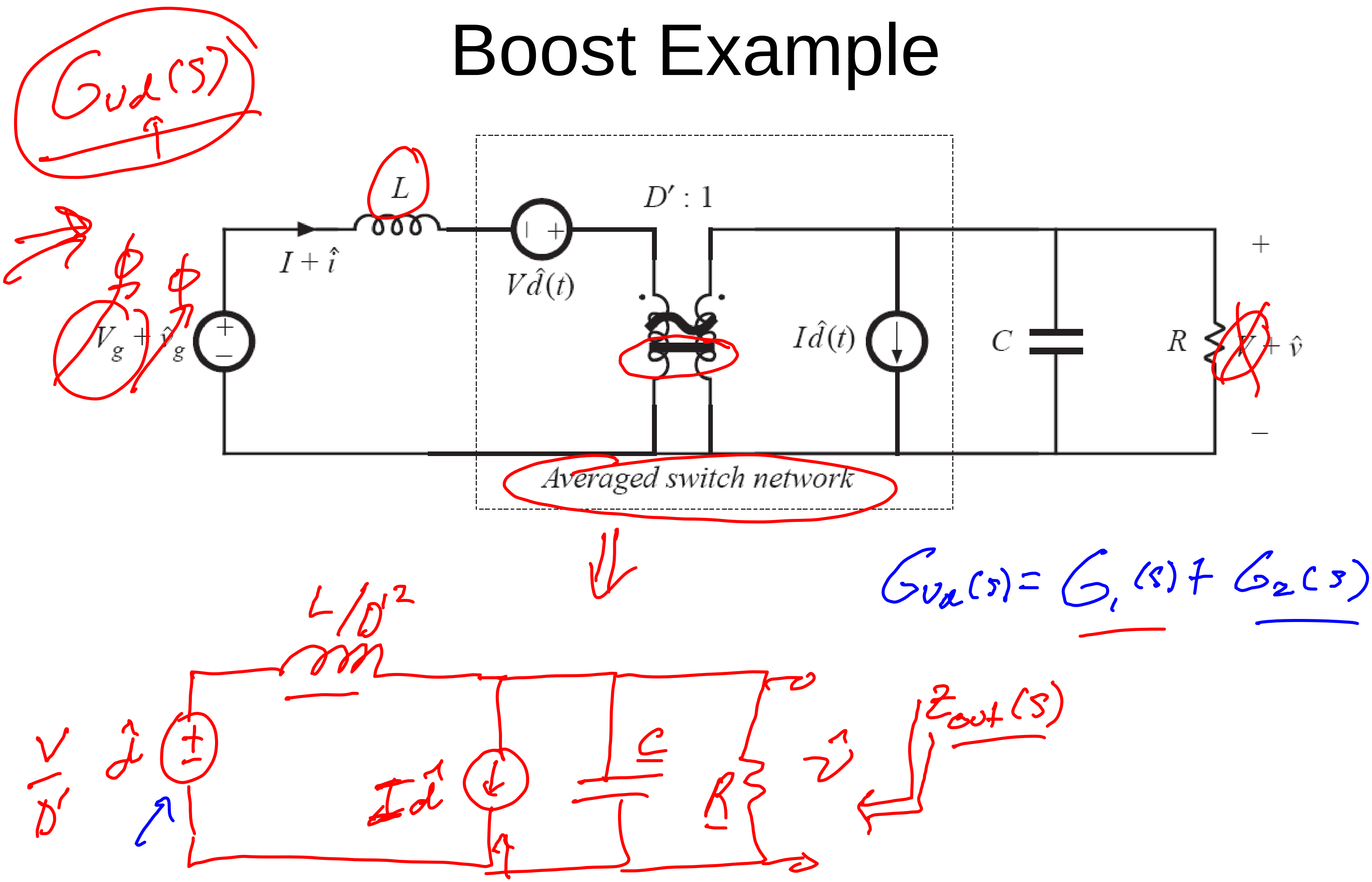
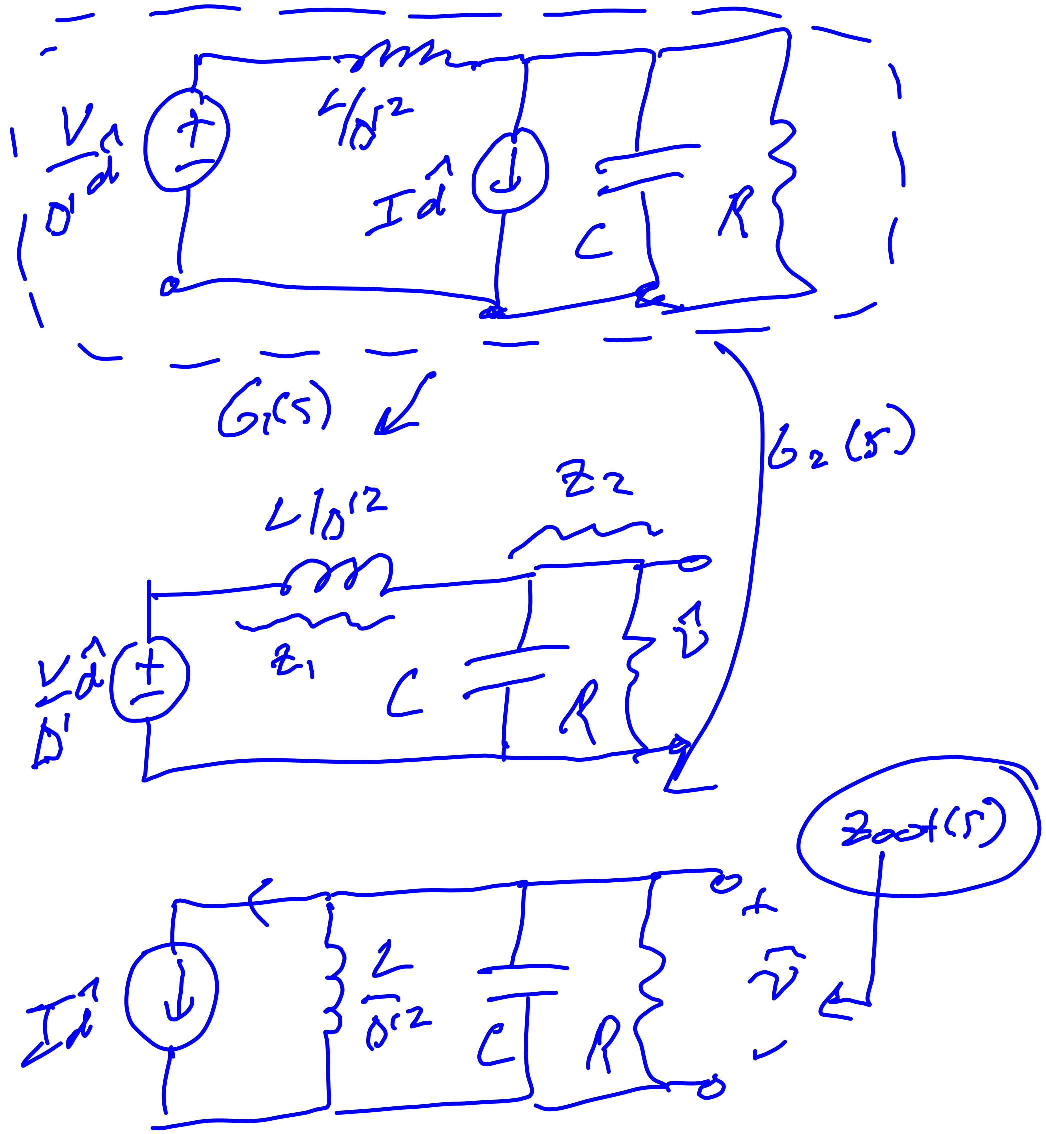
Boost Example





$$G_{vd}(s) = G_1(s) + G_2(s)$$

$$G_1(s) = \left(\frac{Z_2}{Z_1 + Z_2}\right)\frac{V}{D'} = \frac{V}{D'}\left(\frac{Z_1 Z_2}{Z_1 + Z_2} \cdot \frac{1}{Z_1}\right) = \frac{V}{D'}\frac{Z_{out}}{Z_1}$$

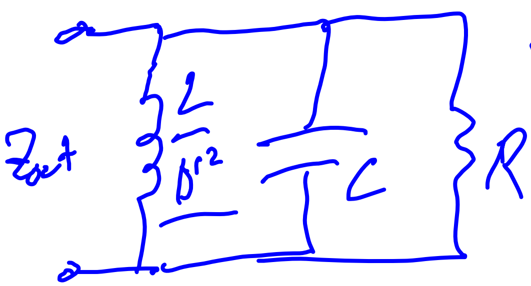
$$\boxed{G_1(s) = \frac{V}{D'} \cdot Z_{out}/Z_1}$$

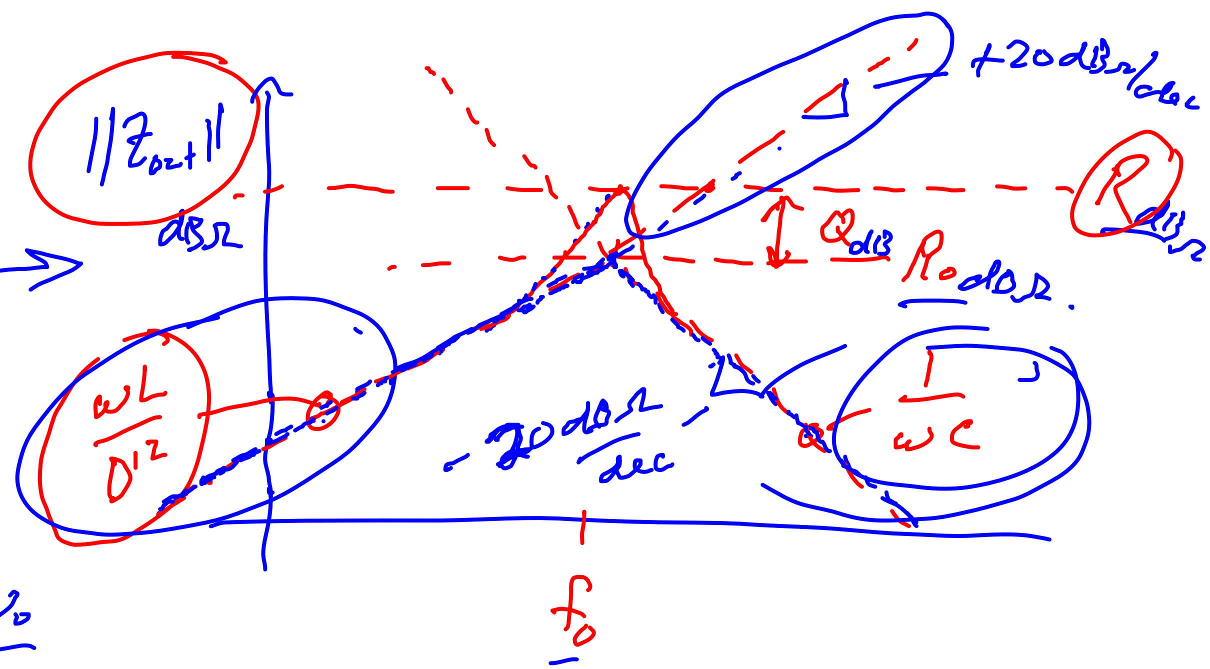
$$G_2(s) = -I \cdot Z_{out}(s)$$

$$Z_{out} = \frac{sL}{D'^2} \,\|\, \frac{1}{sC} \,\|\, R$$

$$G_{vd}(s) = \left.\frac{\hat{v}(s)}{\hat{d}(s)}\right|_{\hat{v}_g \to 0} = G_1 + G_2$$

$Z_{out}(s)$:



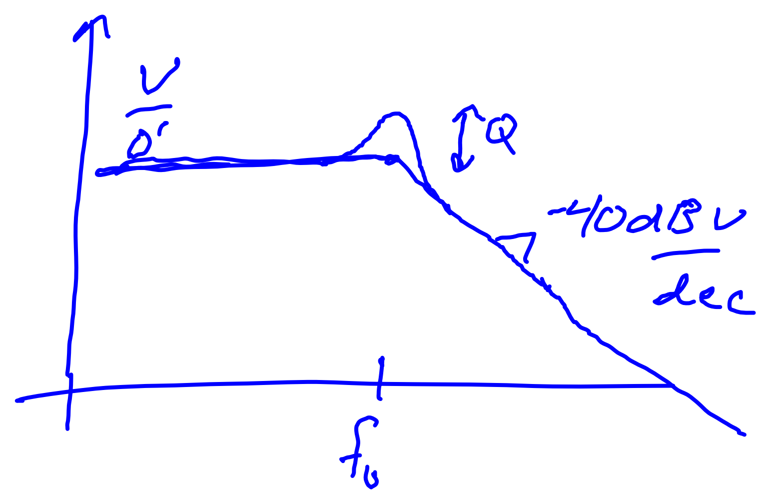


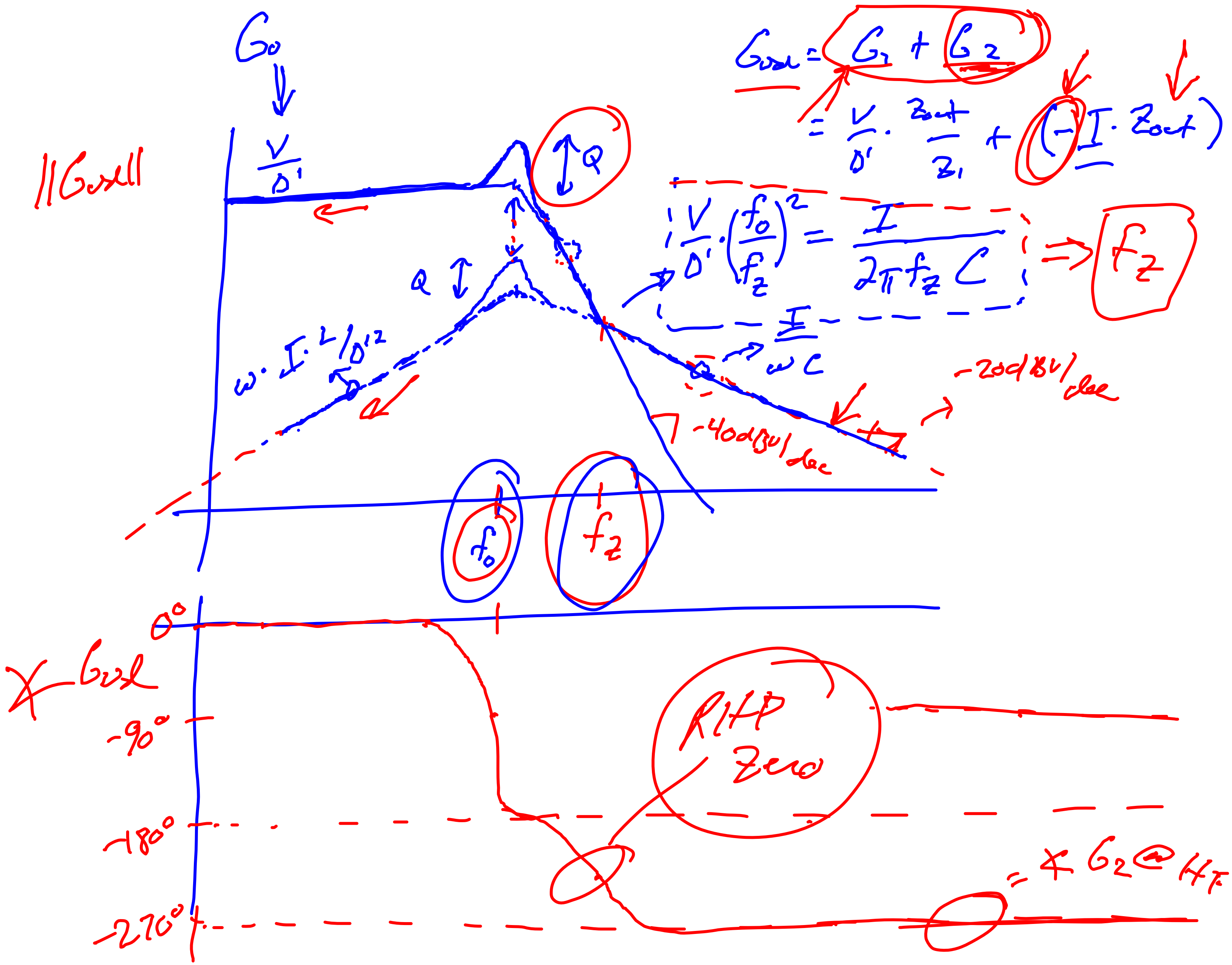
$$f_0 = \frac{D'}{2\pi\sqrt{LC}} = \frac{\omega_0}{2\pi}$$

$$R_0 = \frac{1}{\omega_0 C} = \frac{\sqrt{LC}}{C D'} = \frac{1}{D'} \cdot \sqrt{\frac{L}{C}}$$

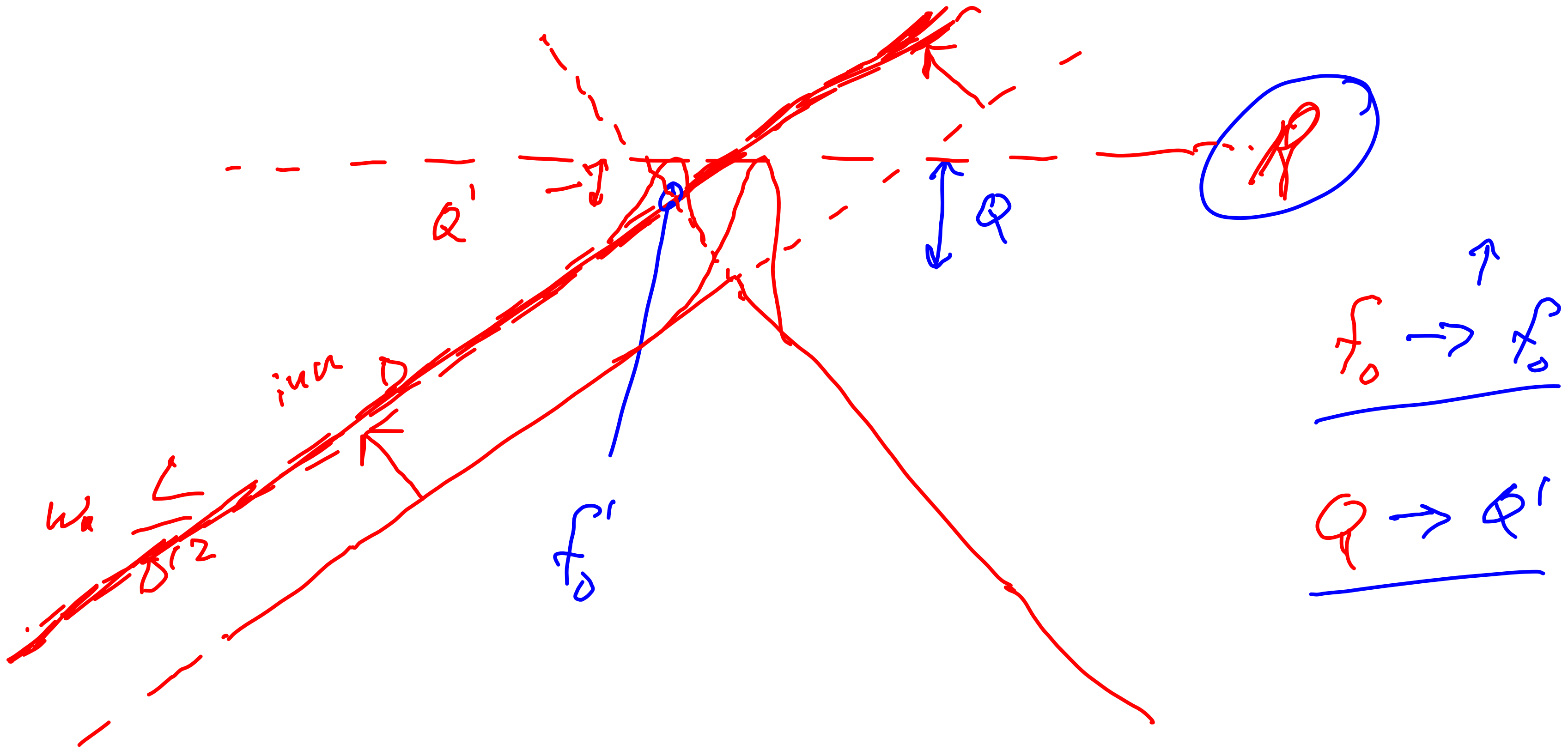
$$\underline{Q} = \frac{R}{R_0} = D' R \cdot \sqrt{\frac{C}{L}}$$

$$G_1(s) = \frac{Z_{out}}{Z_1}$$

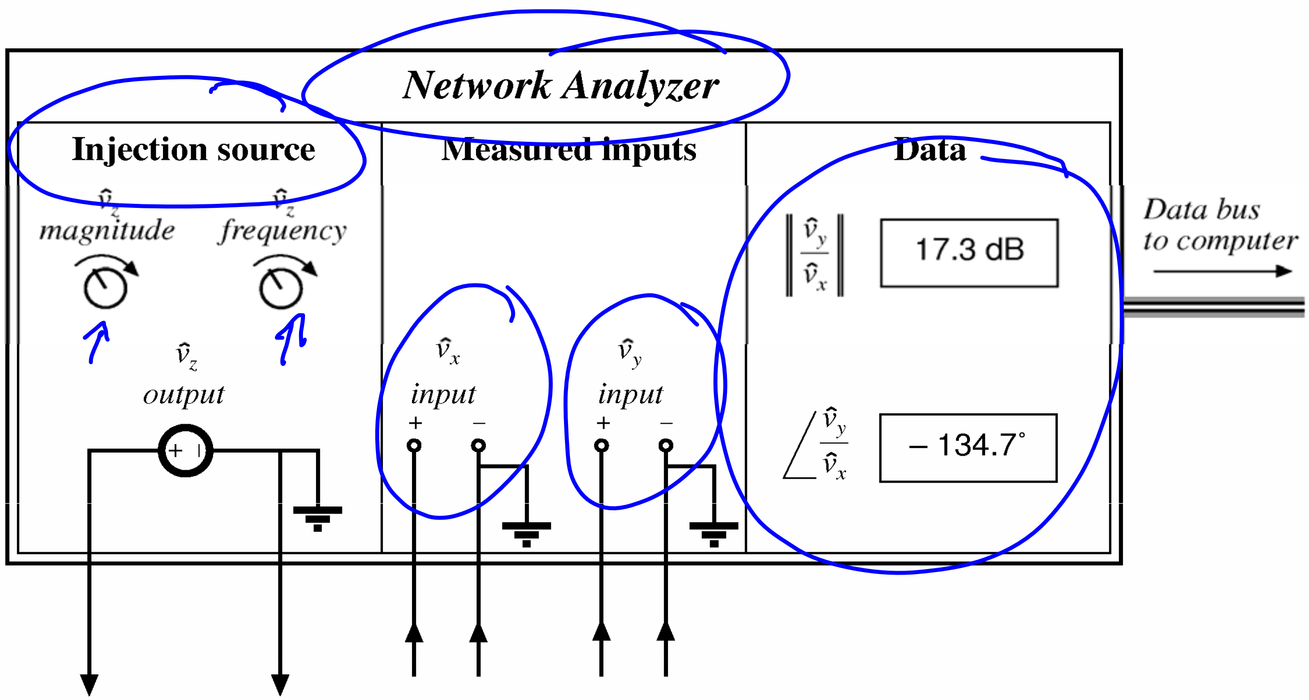




Go
V/D'
||Gvd||
Q
w · I · L/D'^2
V/D' · (f0/fz)^2 = I/(2π fz C)
fz
I/wC
-20dBV/dec
-40dBV/dec
f0
fz
Gvd = G1 + G2
= V/D' · Zout/Z1 + (- I · Zout)
0°
∠Gvd
-90°
-180°
-270°
RHP Zero
= ∠G2 @ HF


Q'
Q
inc
f_0'
$f_0 \rightarrow f_0'$
$Q \rightarrow Q'$

8.4. Measurement of ac transfer functions and impedances



Swept sinusoidal measurements

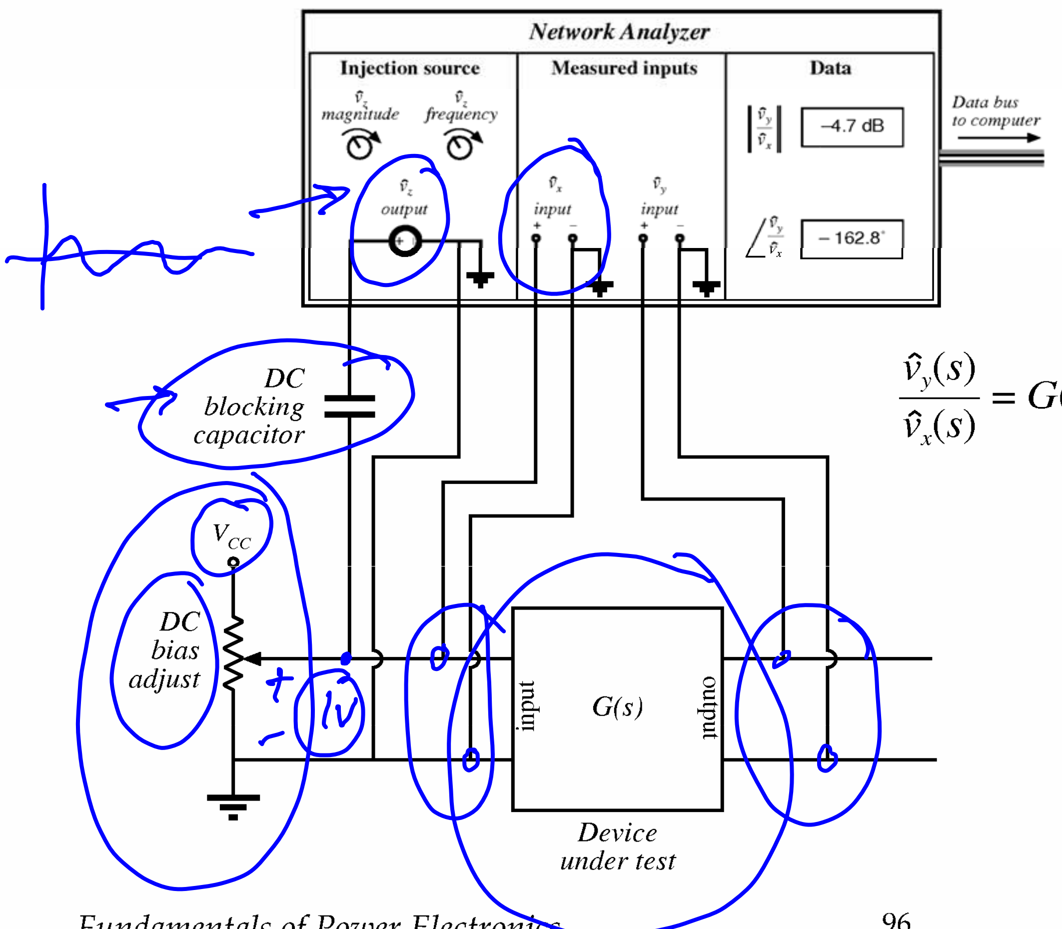
- Injection source produces sinusoid $\hat{v}_z$ of controllable amplitude and frequency
- Signal inputs $\hat{v}_x$ and $\hat{v}_y$ perform function of narrowband tracking voltmeter:

  Component of input at injection source frequency is measured

  Narrowband function is essential: switching harmonics and other noise components are removed
- Network analyzer measures

$$\left\| \frac{\hat{v}_y}{\hat{v}_x} \right\| \quad \text{and} \quad \angle \frac{\hat{v}_y}{\hat{v}_x}$$

Measurement of an ac transfer function

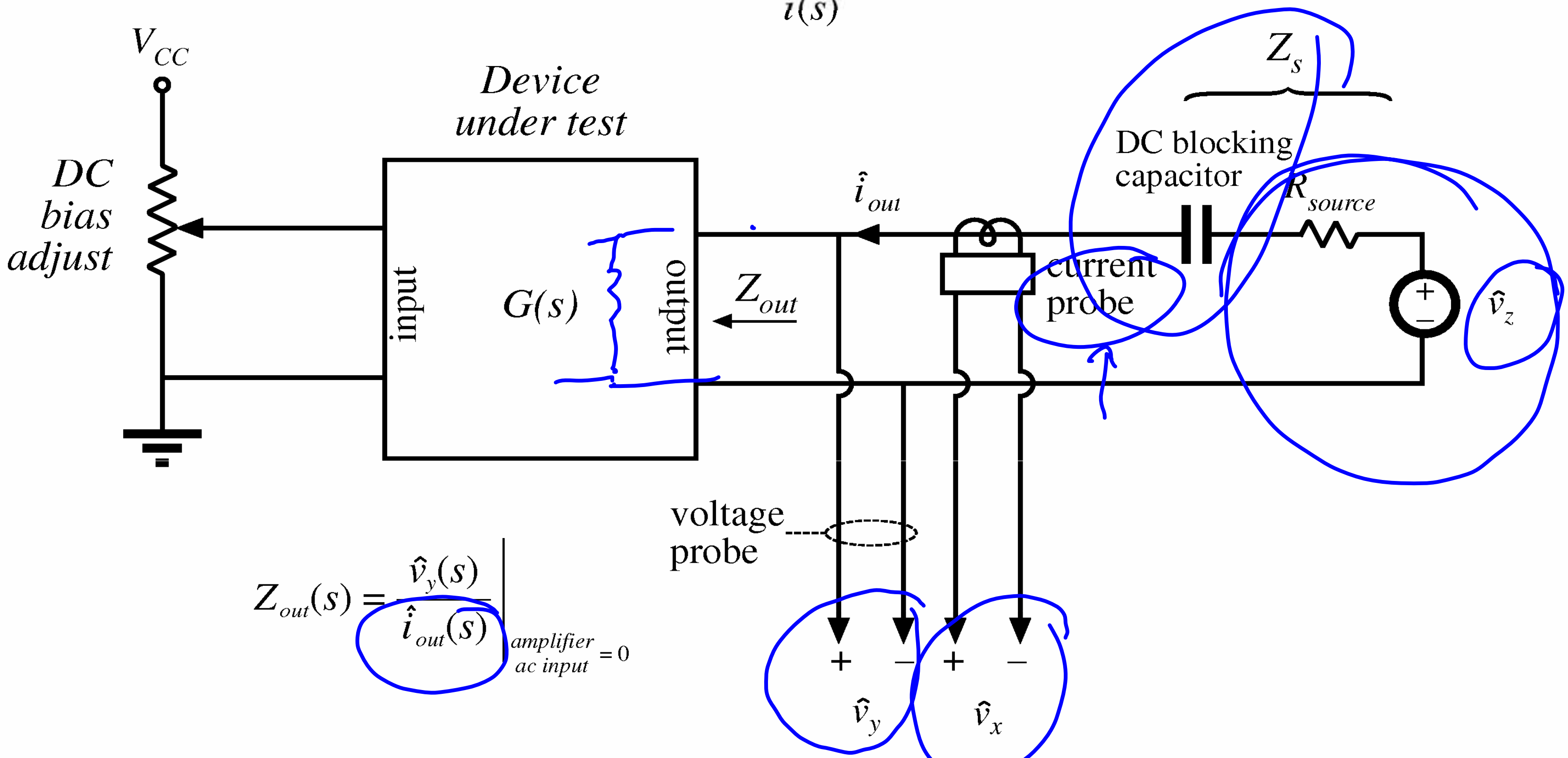


$$\frac{\hat{v}_y(s)}{\hat{v}_x(s)} = G(s)$$

- Potentiometer establishes correct quiescent operating point
- Injection sinusoid coupled to device input via dc blocking capacitor
- Actual device input and output voltages are measured as $\hat{v}_x$ and $\hat{v}_y$
- Dynamics of blocking capacitor are irrelevant

Measurement of an output impedance

$$Z(s) = \frac{\hat{v}(s)}{\hat{i}(s)}$$



$$Z_{out}(s) = \left. \frac{\hat{v}_y(s)}{\hat{i}_{out}(s)} \right|_{\text{amplifier ac input} = 0}$$

Measurement of output impedance

- Treat output impedance as transfer function from output current to output voltage:

$$Z(s) = \frac{\hat{v}(s)}{\hat{i}(s)} \qquad Z_{out}(s) = \frac{\hat{v}_y(s)}{\hat{i}_{out}(s)}\Bigg|_{\substack{amplifier \\ ac\ input}=0}$$

- Potentiometer at device input port establishes correct quiescent operating point
- Current probe produces voltage proportional to current; this voltage is connected to network analyzer channel $\hat{v}_x$
- Network analyzer result must be multiplied by appropriate factor, to account for scale factors of current and voltage probes

Measurement of small impedances

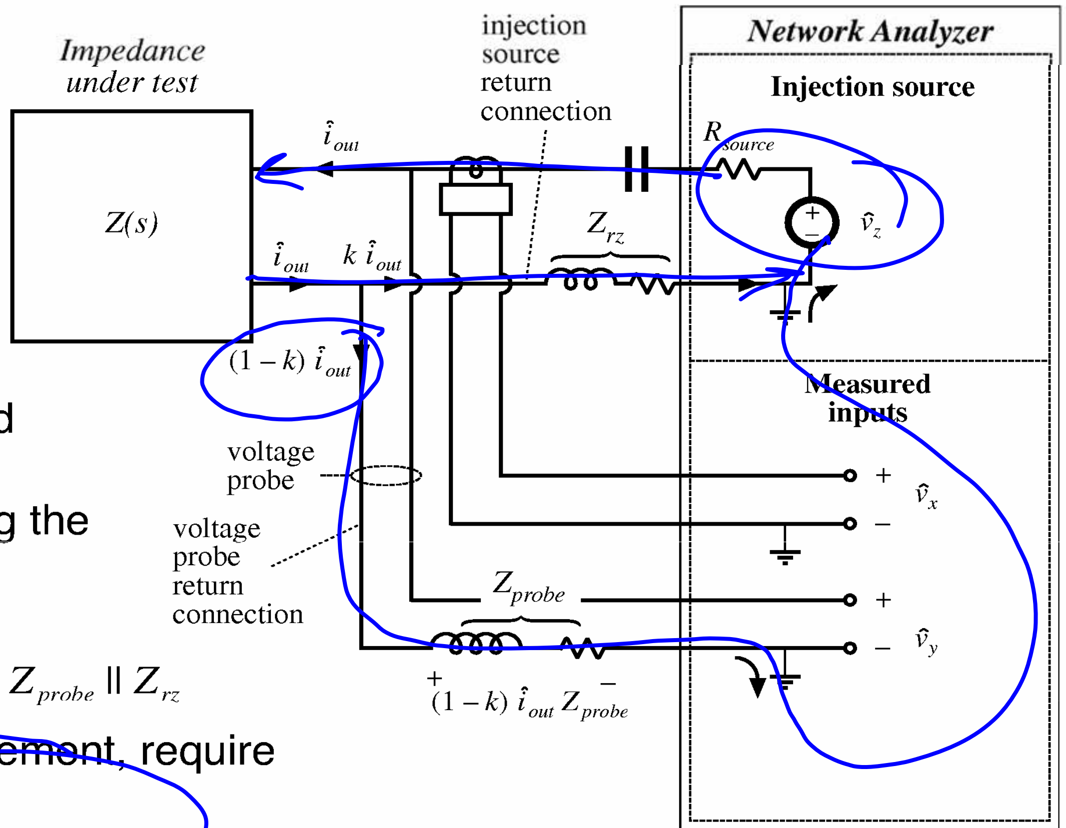
Grounding problems cause measurement to fail:

Injection current can return to analyzer via two paths. Injection current which returns via voltage probe ground induces voltage drop in voltage probe, corrupting the measurement. Network analyzer measures

$$Z + (1 - k)\, Z_{probe} = Z + Z_{probe} \parallel Z_{rz}$$

For an accurate measurement, require

$$\| Z \| >> \left\| \left(Z_{probe} \parallel Z_{rz} \right) \right\|$$



Improved measurement: add isolation transformer

Injection current must now return entirely through transformer. No additional voltage is induced in voltage probe ground connection