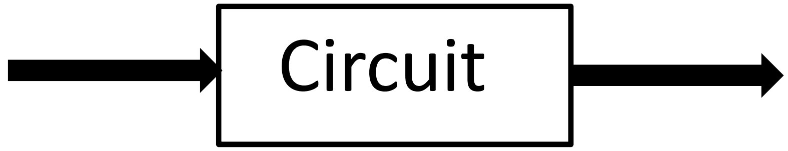
$V_{in} = 4$

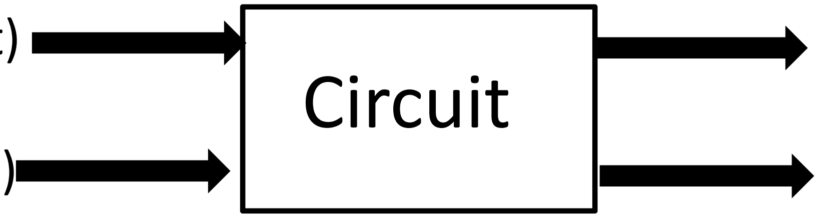


$V_{out} = 4*3 = 12$

Gain = 3

$V_{in1}(t) = 4\cos(10kt)$

$V_{in2}(t) = 4\cos(20kt)$



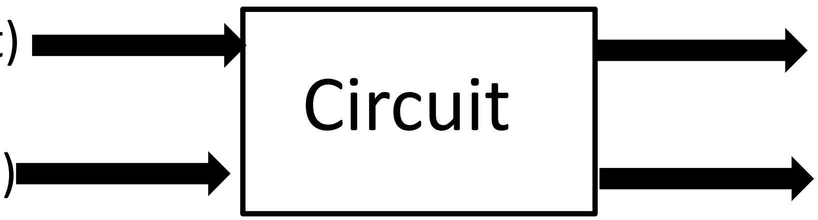
$V_{out1}(t) = 12\cos(10kt)$

$V_{out2}(t) = 12\cos(20kt)$

Gain = 3

$V_{in1}(t) = 4\cos(10kt)$

$V_{in2}(t) = 4\cos(20kt)$



$V_{out1}(t) = 12\cos(10kt)$

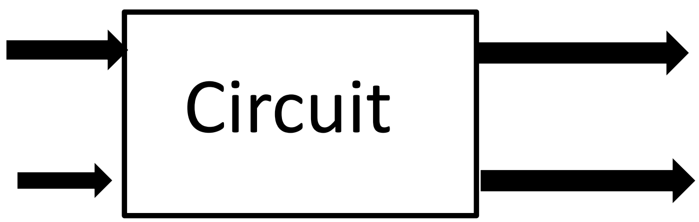
$V_{out2}(t) = 20\cos(20kt)$

@10k Gain = 3

@20k Gain = 5

$V_{in1}(t) = 4\cos(10kt-10^o)$

$V_{in2}(t) = 4\cos(20kt-30^o)$



$V_{out1}(t) = 12\cos(10kt+20^o)$

$V_{out2}(t) = 20\cos(20kt-70^o)$

@10k Gain = 3, phase shift = 30^o

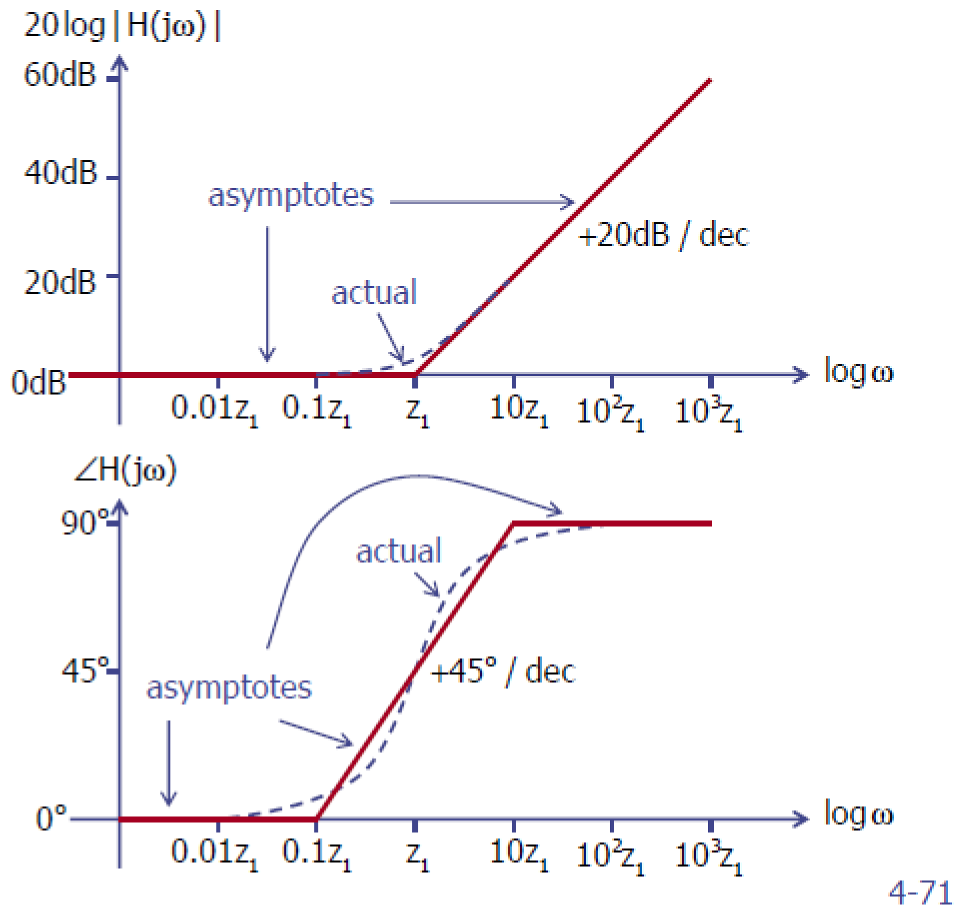
@20k Gain = 5, phase shift = -40^o

Magnitude and Phase Plots of Real Zero

$$H(s) = 1 + \frac{s}{z_1}$$

Magnitude plot:

Phase plot:



Magnitude and Phase of Real Zero

Consider $H(s) = 1 + s/z_1$.

$H(j\omega)$	$\|H(j\omega)\|$	$20\log\|H(j\omega)\|$	$\angle H(j\omega)$
$H(j0)$	$=1$	0dB	0^o
$H(jz_1/100)$	$\sqrt{1+0.01^2} \approx 1$	0dB	0^o
$H(jz_1/10)$	$\sqrt{1+0.1^2} \approx 1$	0dB	5.7^o
$H(jz_1/3)$	$\sqrt{1+0.333^2} = 1.054 \approx 1$	0dB	18.4^o
$H(jz_1)$	$\sqrt{1+1} = \sqrt{2} \approx 1.414$	3dB	45^o
$H(j3z_1)$	$\sqrt{1+3^2} = \sqrt{10} \approx 3.162$	10dB	71.6^o
$H(j10z_1)$	$\sqrt{1+10^2} = \sqrt{101} \approx 10$	20dB	84.3^o
$H(j10^2z_1)$	$\sqrt{1+100^2} \approx 100$	40dB	90^o
$H(j10^3z_1)$	$\sqrt{1+1000^2} \approx 1000$	60dB	90^o

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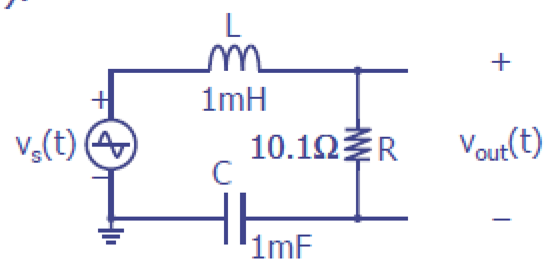
Example 4-27

Example 4-27: Consider an RLC circuit with its input connected to a signal generator that generates sine waves. Find the transfer function $H(s) = V_{out}(s)/V_{in}(s)$ and sketch the Bode plots of H(s).



Soln.: $$V_{out}(s) = \frac{R}{sL + R + \frac{1}{sC}} V_{in}(s) = \frac{sRC}{s^2LC + sRC + 1} V_{in}(s)$$

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{sRC}{s^2LC + sRC + 1} = \frac{s(10.1)(10^{-3})}{s^2(10^{-3})(10^{-3}) + s(10.1)(10^{-3}) + 1}$$

$$= \frac{1.01\times10^{-2}s}{1 + 1.01\times10^{-2}s + 1\times10^{-6}s^2} = \frac{s}{99(1+s/100)(1+s/10^4)}$$

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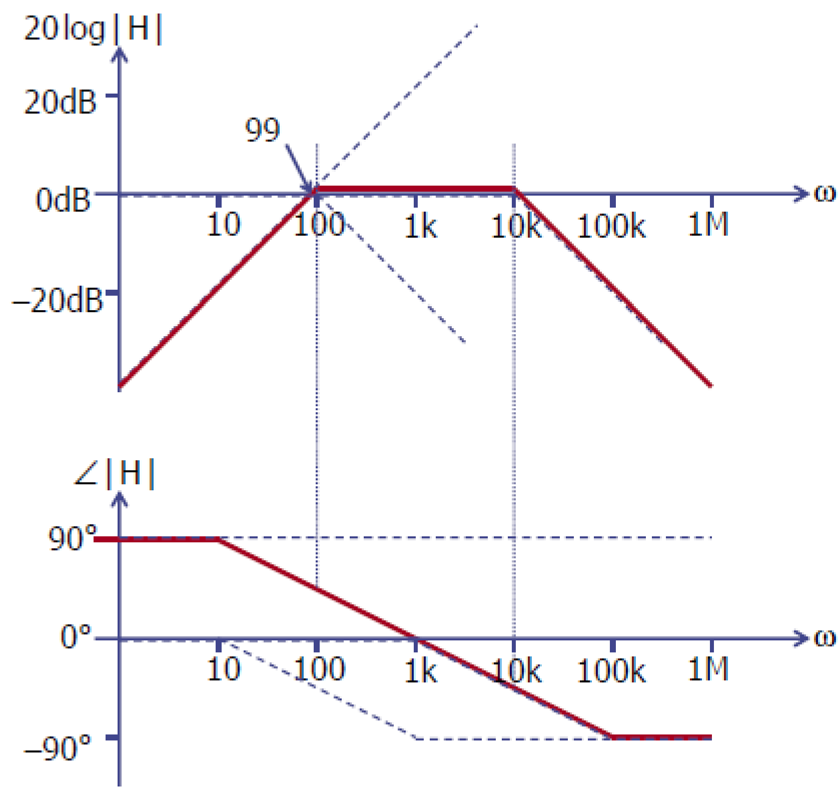
Example 4-27 (cont.)

$$H(s) = \frac{s}{99(1+s/100)(1+s/10^4)}$$



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Standard Form of Transfer Function

Recall a transfer function is written as

$$H(s) = H_1 \frac{(s+z_1)(s+z_2)\ldots(s+z_m)}{(s+p_1)(s+p_2)\ldots(s+p_n)}$$

For convenience in working out Bode plots, it is better to write the transfer function as

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = H_o \frac{(1+s/z_1)(1+s/z_2)\ldots(1+s/z_m)}{(1+s/p_1)(1+s/p_2)\ldots(1+s/p_n)}$$

where $H_o = H(j0)$ is the DC gain.

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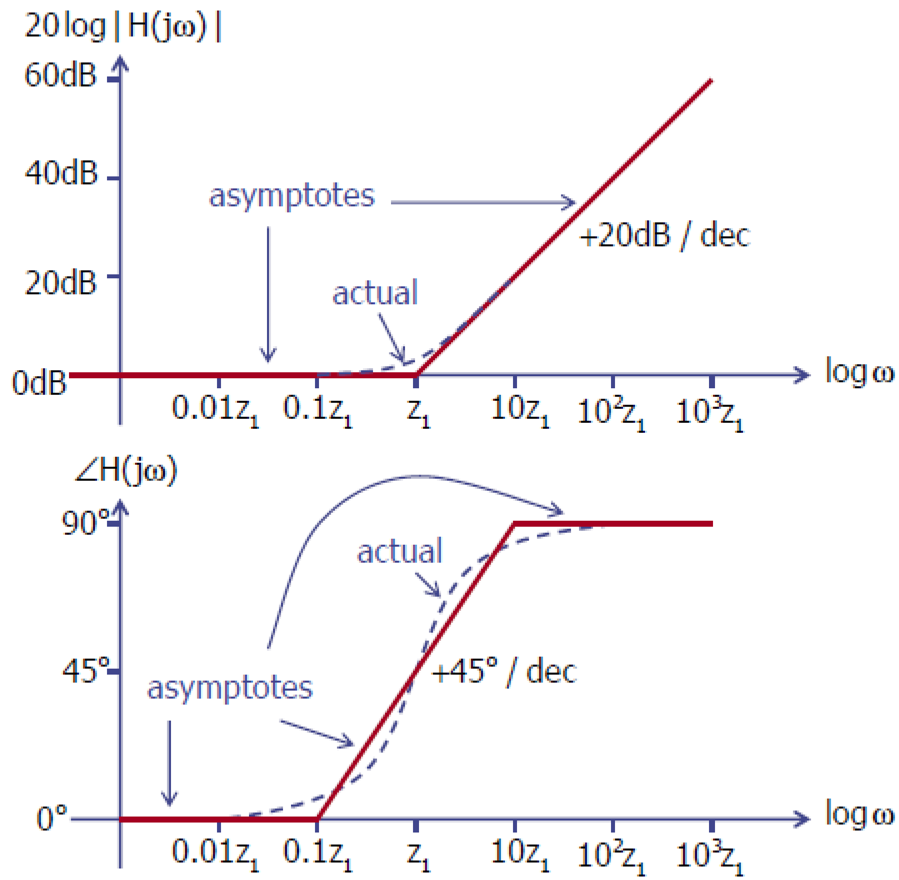
Magnitude and Phase Plots of Real Zero

$$H(s) = 1 + \frac{s}{z_1}$$

Magnitude plot:

Phase plot:



4-71

Magnitude and Phase Plots of Real Pole

$$H(s) = \frac{1}{1 + \frac{s}{p_1}}$$

Let

$$H'(s) = 1 + \frac{s}{p_1}$$

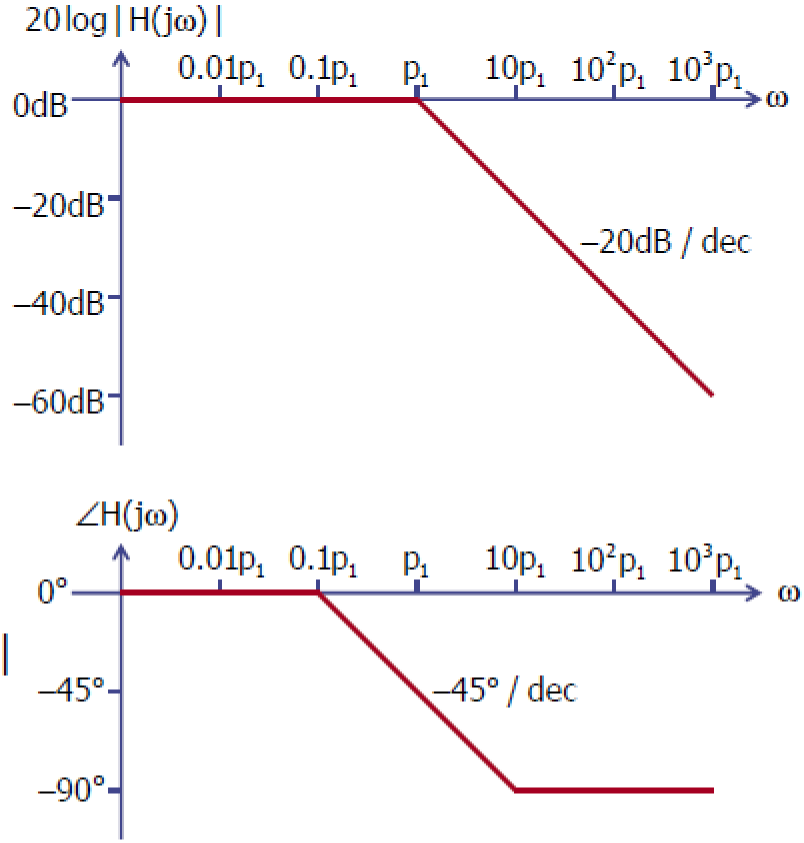
then

$$H(s) = \frac{1}{H'(s)}$$

and

$$20\log|H(j\omega)| = -20\log|H'(j\omega)|$$

$$\angle H(j\omega) = \angle H'(j\omega)$$



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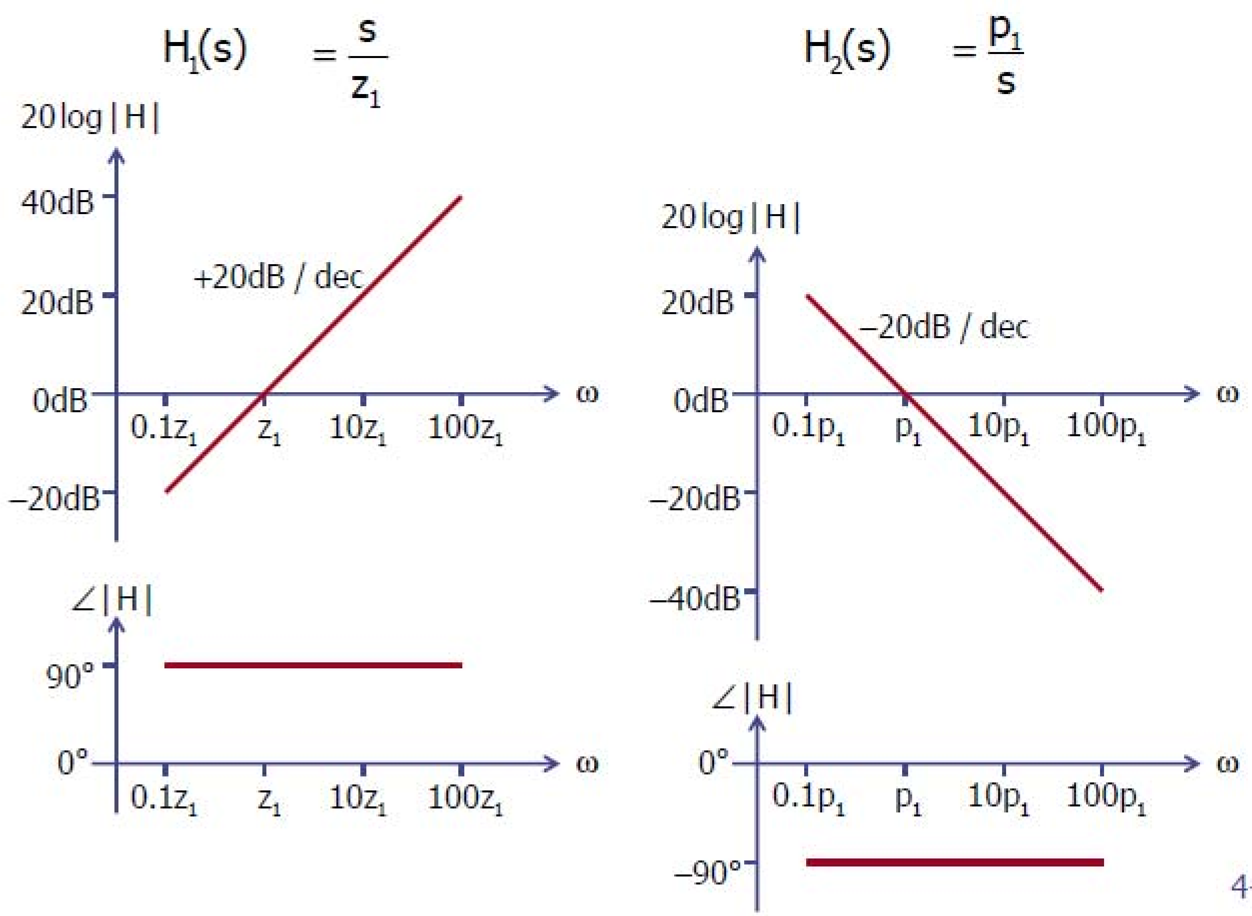
Bode Plots of s/z_1 and p_1/s (cont.)



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Example 4-24

Example 4-24: Sketch the Bode plots of

$$H(s) = \frac{1000(s+10)}{(s+1)(s+1000)}$$

Soln.:

The magic of Bode plots is that if we have a complicated transfer function as the one given above, we can break it down into smaller pieces, and add up all the pieces together one by one.

(1) First of all, write H(s) in the standard form, i. e.,

$$H(s) = \frac{1000 \times 10(1+s/10)}{(1+s)\times 1000 \times (1+s/1000)}$$

$$= \frac{10(1+s/10)}{(1+s)(1+s/1000)}$$

(2) Identify all corner frequencies: z_1=10 rad/s, p_1=1 rad/s, p_2=1000 rad/s.

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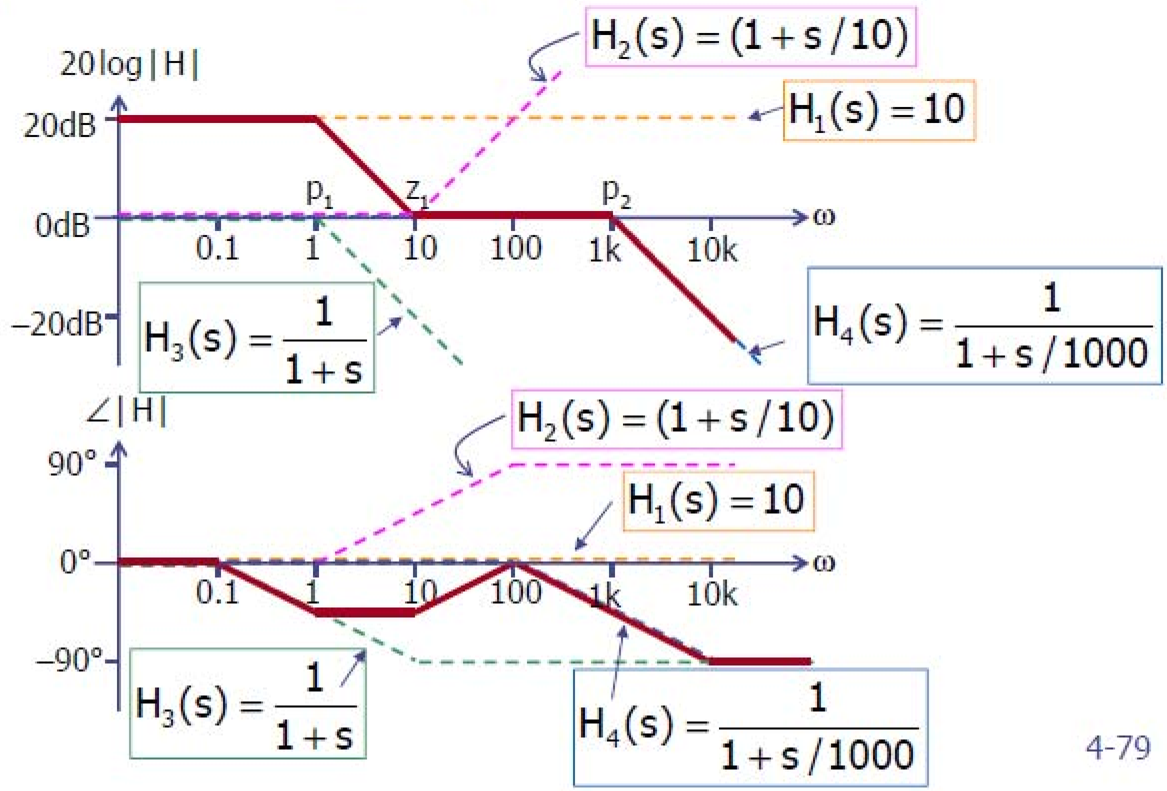
Example 4-24 (cont.)

(3) Draw Bode plots of individual factor, and start adding the Bode plots from low to high frequency.



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