Two-Thomas Filter (TT) LTspice Simulation

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Contents

Motivations

The report gives a general overview Two-Thomas General Circuit analysis, followed by detailed discussions of low-pass , including design information, and Simulations.

Introduction

Tow–Thomas second-order filter is two alternative generation methods of the Tow–Thomas filter are discussed. The first is a generation method from the second-order passive RLC filter and the second is from the multiple feedbacks inverting low-pass filter using a single op amp.

Generalized Circuit Analysis

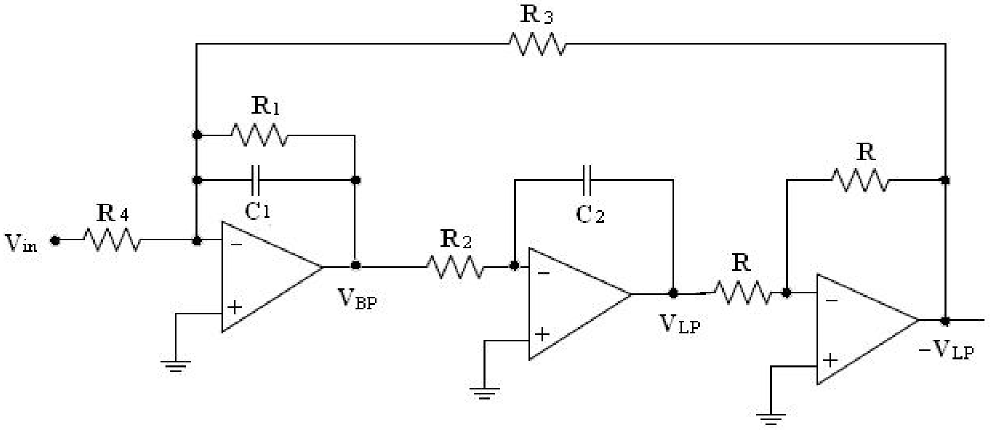


Fig. 1

TT realize both LPF & BPF having these Transfer Functions

$$\frac{V_o^{LP}(s)}{V_{in}(s)} = -\frac{\frac{R_6}{R_1R_4R_5C_1C_2}}{s^2+\frac{s}{R_3C_1}+\frac{R_6}{R_2R_4R_5C_1C_2}}$$

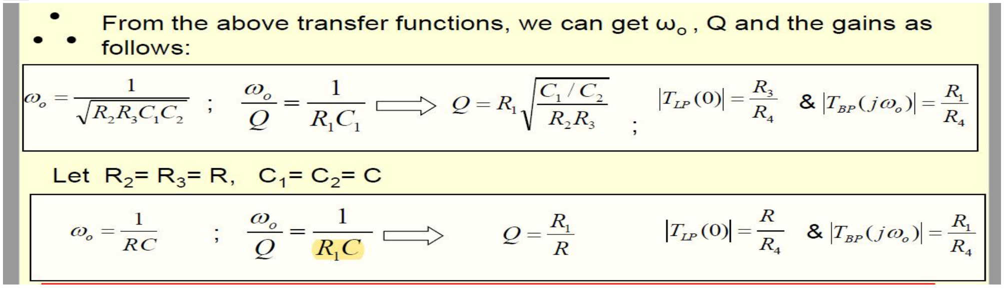
$$\frac{V_o^{BP}(s)}{V_{in}(s)} = -\frac{s\frac{1}{R_1C_1}}{s^2+\frac{s}{R_3C_1}+\frac{R_6}{R_2R_4R_5C_1C_2}}$$

Check your results in (iii) and (iv) by simulating the filter

(iii) The above filter is used to realize a maximally flat ($Q = 1/\sqrt{2}$) LPF with f_o=10 KHz and K_o=10 (V/V). The following design equations are used: R_2=R_3=R=1KΩ, C_1=C_2=C, **Find C, R_1, and R_4.**

Hand Analysis

1-



From the above transfer functions, we can get ω_o , Q and the gains as follows:

$$\omega_o = \frac{1}{\sqrt{R_2R_3C_1C_2}} \quad ; \quad \frac{\omega_o}{Q} = \frac{1}{R_1C_1} \Longrightarrow Q = R_1\sqrt{\frac{C_1/C_2}{R_2R_3}} \quad ; \quad |T_{LP}(0)| = \frac{R_3}{R_4} \ \& \ |T_{BP}(j\omega_o)| = \frac{R_1}{R_4}$$

Let R_2= R_3= R, C_1= C_2= C

$$\omega_o = \frac{1}{RC} \quad ; \quad \frac{\omega_o}{Q} = \frac{1}{R_1C} \Longrightarrow Q = \frac{R_1}{R} \quad |T_{LP}(0)| = \frac{R}{R_4} \ \& \ |T_{BP}(j\omega_o)| = \frac{R_1}{R_4}$$

2- **For LPF**

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From this equations

→ $Q = \frac{R_1}{R_1}$ ($\therefore R_1 = \frac{1}{\sqrt{2}} \times 1000 \simeq 707\ \Omega$)

→ $K_o = 10 = \frac{R}{R_4}$ ($\therefore R_4 = 100\ \Omega$)

→ $\frac{2\pi(10^4)}{1/\sqrt{2}} = \frac{1}{(707)\ C}$ $\therefore C \simeq 16.07\ n$

3- for BPF

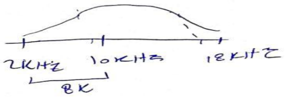
f_o v $_{BP}$

$T(j\omega_o) = \frac{R_1}{R_4}$; $Q = \frac{R_1}{R}$ $\therefore R_1 = 707\ \Omega$

$10 = \frac{707}{R_4}$ $\boxed{\therefore R_4 = 70.7}$ for BP

with Range 2K to 18K

centered f_o at 10KHz



3.**1-**

(iv) Repeat (iii) for K_o= 1, and 2.

for $K_o = 1$

→ $1 = \frac{R}{R_4}$ $\therefore R_4 = 1000\ \Omega$

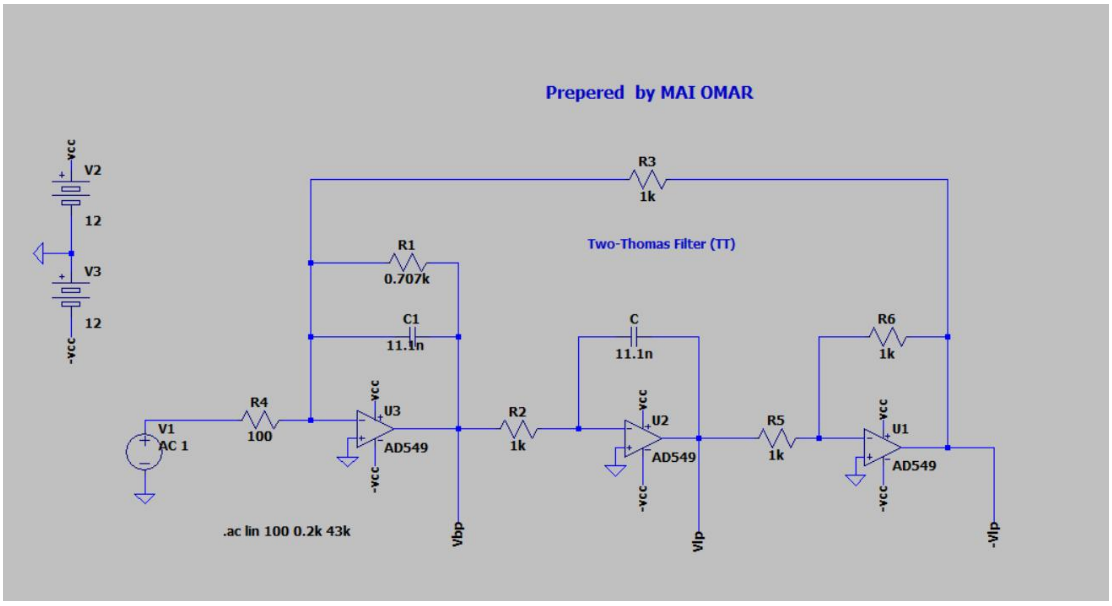
→ for $K_o = 2$

$2 = \frac{R}{R_4}$ $\therefore R_4 = 500\ \Omega$

→ all values Remains $R_1 = 707\ \Omega$
$C = 16.07\ n$

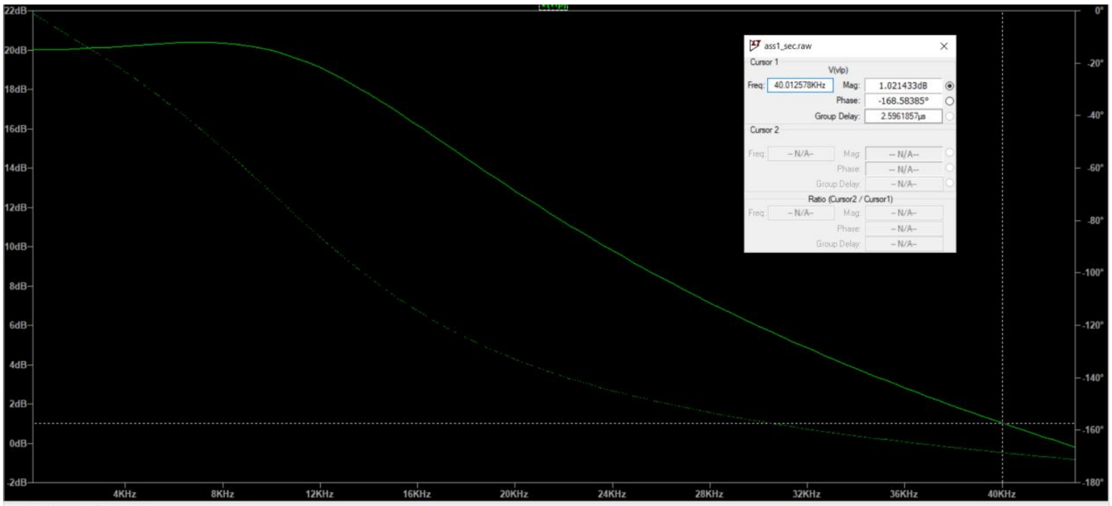
Simulation Results

1- Circuit



2- Putting Vin =1 so gain = Vout(VLP) [Magnitude &Phase]

VLP



Cursor 1

V(vlp)

Freq: 40.012578KHz Mag: 1.021433dB ●

Phase: -168.58385° ○

Group Delay: 2.5961857µs ○

Cursor 2

Freq: -- N/A-- Mag: -- N/A-- ○

Phase: -- N/A-- ○

Group Delay: -- N/A-- ○

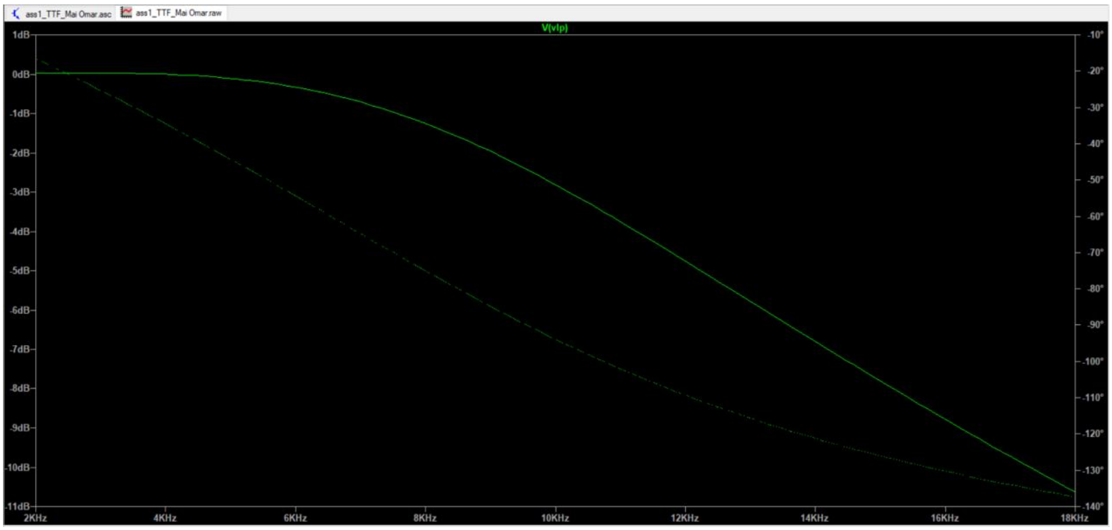
Ratio (Cursor2 / Cursor1)

Freq: -- N/A-- Mag: -- N/A--

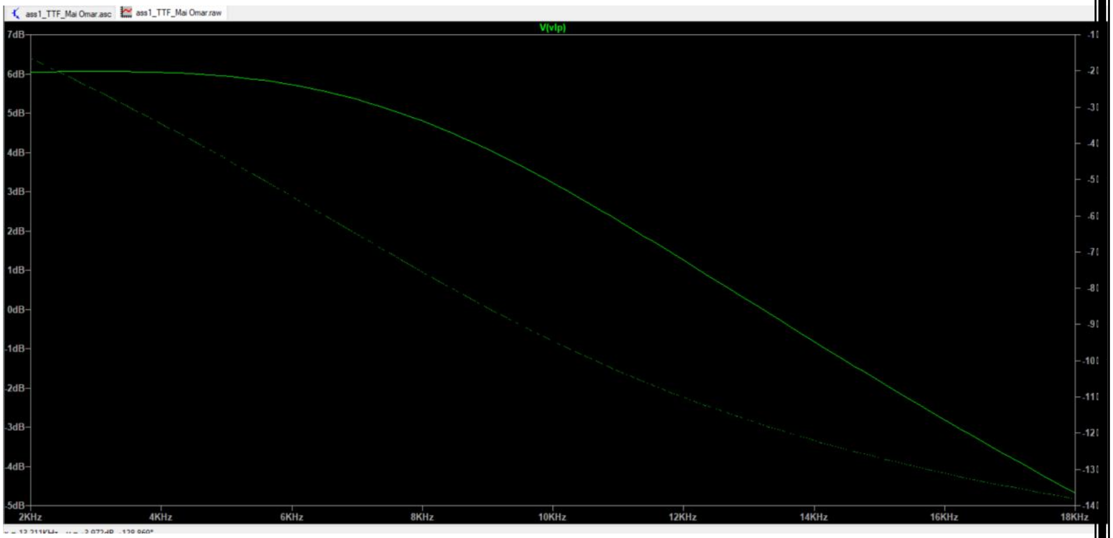
Phase: -- N/A--

Group Delay: -- N/A--

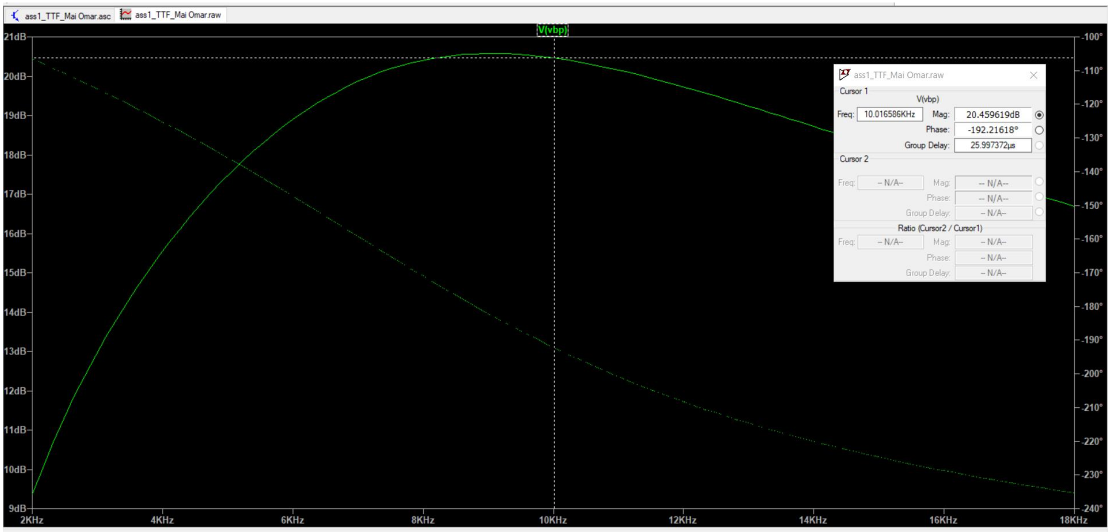
2-for K=1 →R4=1k



3-for k=2 → R4=500



3- for BPF(K=10) → R4=70



Cursor 1

V(vbp)

Freq: 10.016586KHz Mag: 20.459619dB ●

Phase: -192.21618° ○

Group Delay: 25.997372µs

Cursor 2

Freq: -- N/A-- Mag: -- N/A--

Phase: -- N/A--

Group Delay: -- N/A--

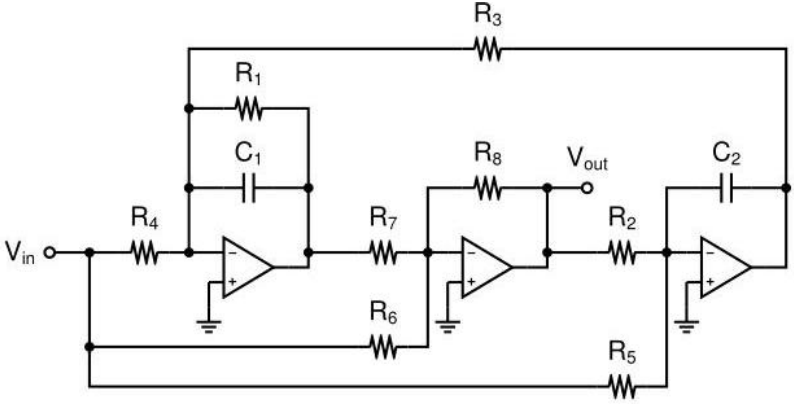
Ratio (Cursor2 / Cursor1)

Freq: -- N/A-- Mag: -- N/A--

Phase: -- N/A--

Group Delay: -- N/A--

Two-Thomas Biquad(KHN)



1-Hand Analysis

→ let R = 1K ; $f_o = 10K$ ∴ $f_o = \frac{1}{2\pi(1K)C}$

$\boxed{C = 15.9 \, nF}$

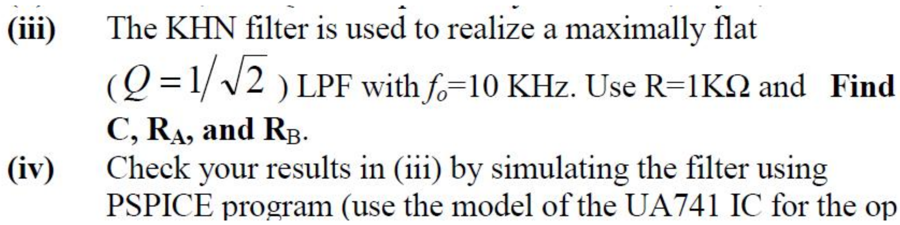
→ $Q = \frac{R_A + R_B}{3R_B} = \frac{1}{3}\left(1 + \frac{R_A}{R_B}\right)$

$\boxed{\text{let } R_A = 10K} \longrightarrow \boxed{\therefore R_B = 8.9K}$

LPF & HPF with $K_o = 1$ ✓

$|T_{BP}(jW)| = Q$

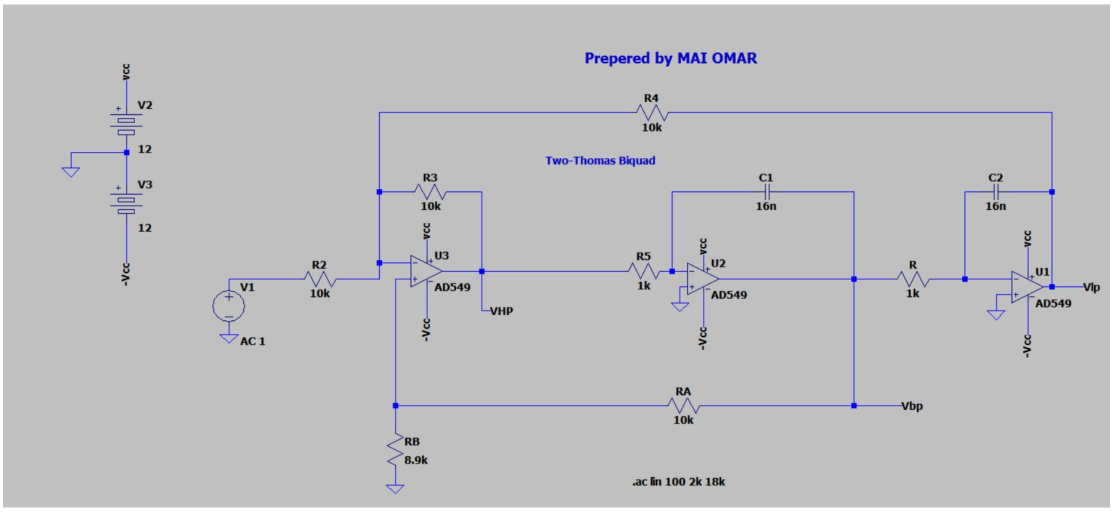
Simulation Results



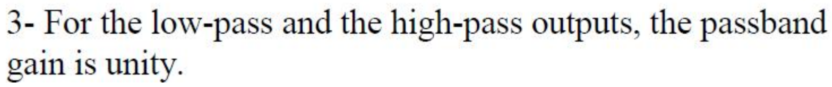
(iii) The KHN filter is used to realize a maximally flat ($Q = 1/\sqrt{2}$) LPF with f_o=10 KHz. Use R=1KΩ and **Find C, R_A, and R_B.**

(iv) Check your results in (iii) by simulating the filter using PSPICE program (use the model of the UA741 IC for the op

1-Circuit

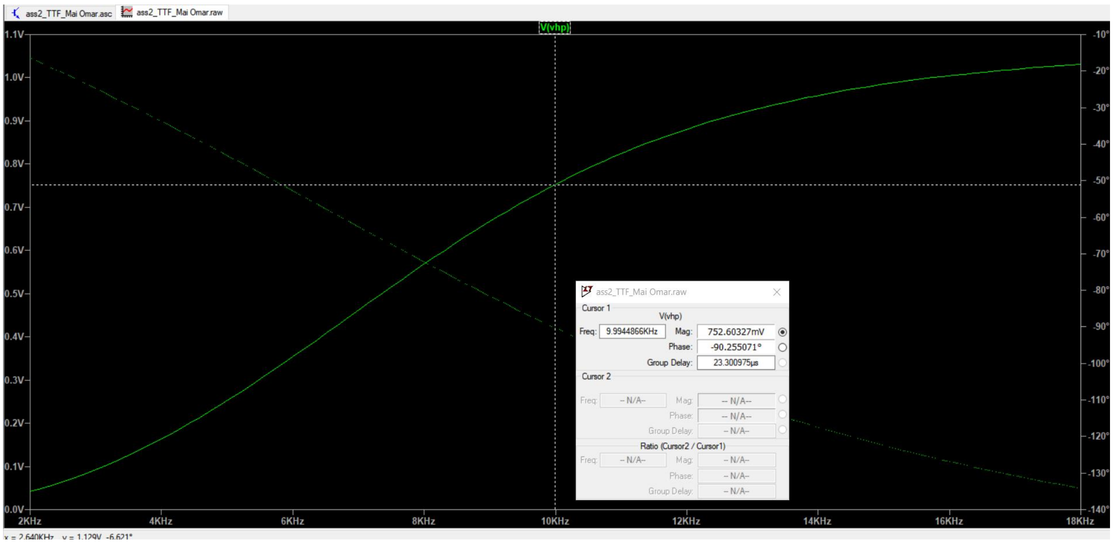


2- Putting Vin =1 so gain = Vout(VHP | VLP) [Magnitude &Phase]



3- For the low-pass and the high-pass outputs, the passband gain is unity.

For VHP as Mentioned it’s unity gain (K0=0db=1v)



Cursor 1

V(vhp)

Freq: 9.9944866KHz Mag: 752.60327mV ●

Phase: -90.255071° ○

Group Delay: 23.300975µs ○

Cursor 2

Freq: -- N/A-- Mag: -- N/A-- ○

Phase: -- N/A-- ○

Group Delay: -- N/A-- ○

Ratio (Cursor2 / Cursor1)

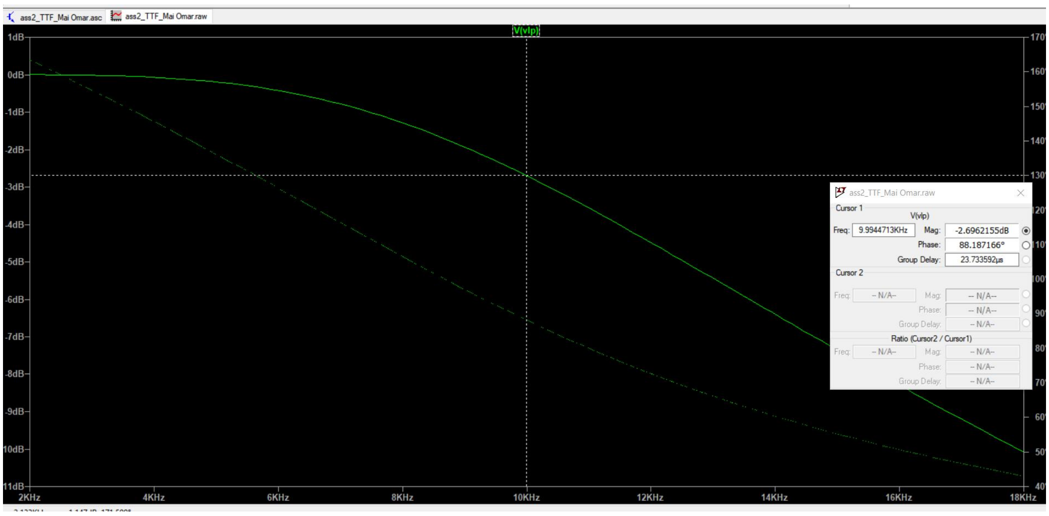
Freq: -- N/A-- Mag: -- N/A--

Phase: -- N/A--

Group Delay: -- N/A--

x = 2.640KHz y = 1.129V -6.621°

VLP



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Cursor 1

V(vlp)

Freq: 9.9944713KHz Mag: -2.6962155dB ●

Phase: 88.187166° ○

Group Delay: 23.733592µs ○

Cursor 2

Freq: -- N/A-- Mag: -- N/A-- ○

Phase: -- N/A-- ○

Group Delay: -- N/A-- ○

Ratio (Cursor2 / Cursor1)

Freq: -- N/A-- Mag: -- N/A--

Phase: -- N/A--

Group Delay: -- N/A--