UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

FACULTAD DE INGENIERÍA

Práctica: Simulación de circuitos con simulador

EQUIPO:

INTEGRANTES:

ASIGNATURA: Circuitos Integrados

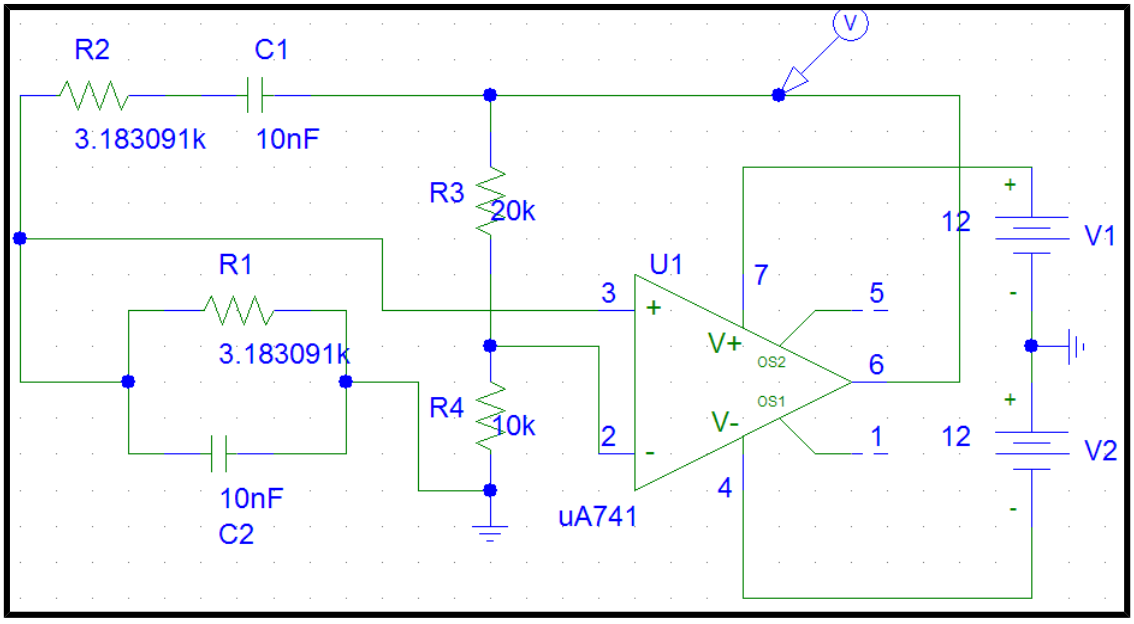
GRUPO: 1

05/05/2006, Ciudad Universitaria, México

SIMULACIÓN DE CIRCUITO GENERADOR DE ONDA TRIANGULAR

	F	C	R=1/(WC)
5KHz	5.00E+03	1.0000E-09	3.183E+04
	5.00E+03	**1.0000E-08**	**3.183E+03**
	5.00E+03	1.0000E-06	3.183E+01
10 Hz	1.00E+01	1.00E-09	1.592E+07
	1.00E+01	1.00E-06	1.592E+04
	1.00E+01	**2.20E-06**	**7.234E+03**
100KHz	**1.00E+05**	**1.00E-09**	**1.592E+03**
	1.00E+05	1.00E-06	1.592E+00
	1.00E+05	2.20E-06	7.234E-01
1MHz			**1.591546E+0**
	1.00E+09	**1.00E-12**	**5**

1nF	1.00E-09
10nF	1.00E-08
1uF	1.00E-06
2.2uF	2.20E-06
10uF	1.00E-05
47uF	4.70E-05
1pF	1.00E-12
1nF	1.00E-09

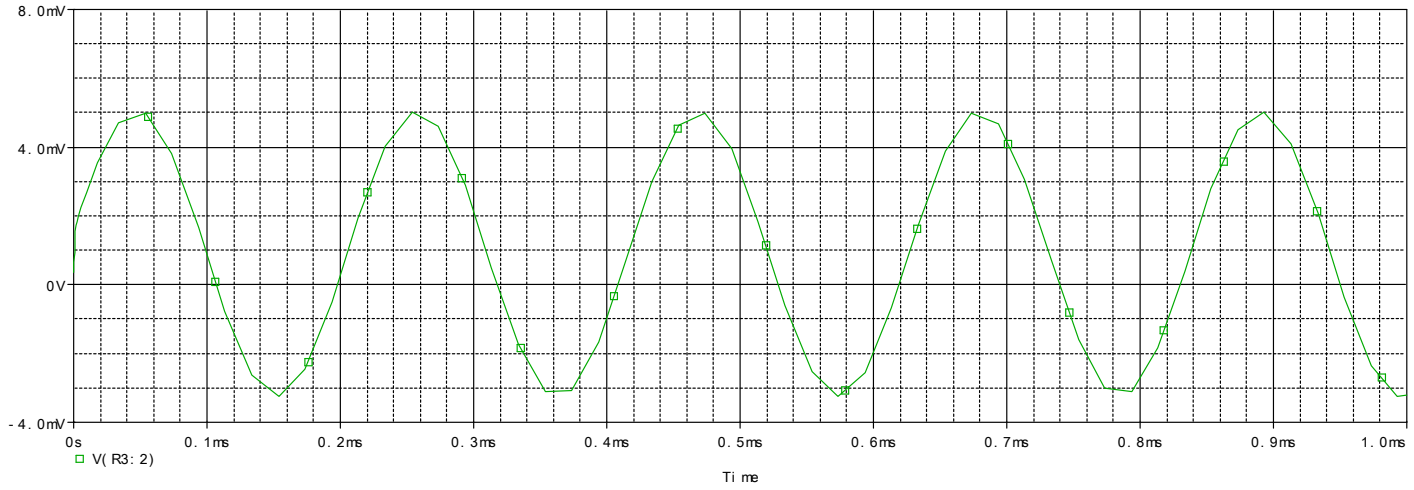


K=(1+R3/R4)=3

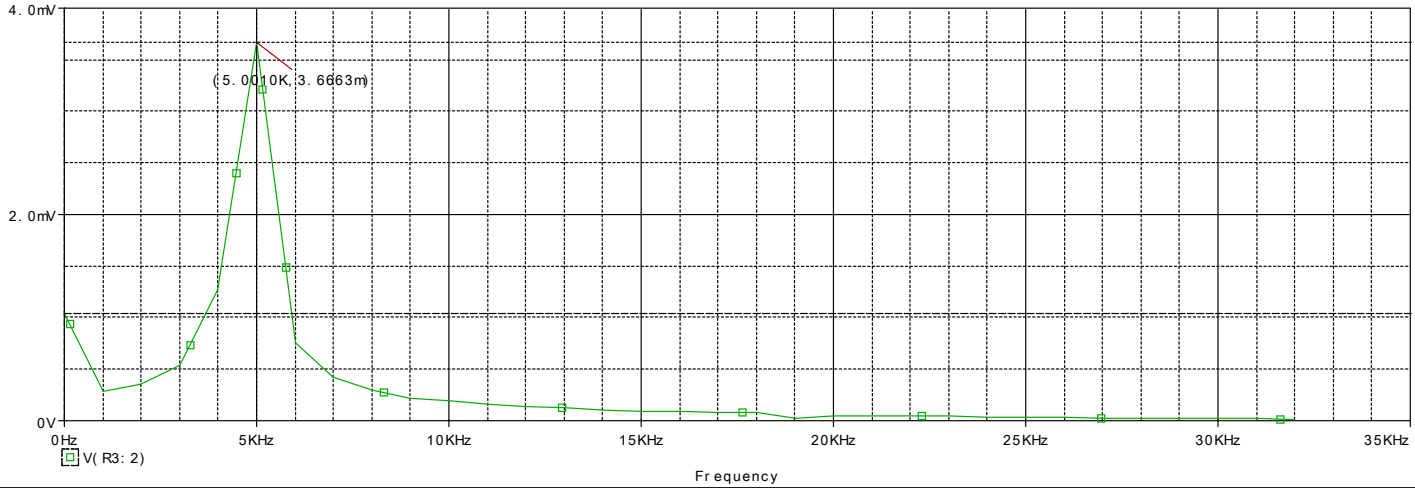
R3=2*R4

R4=10k→ R3=20k

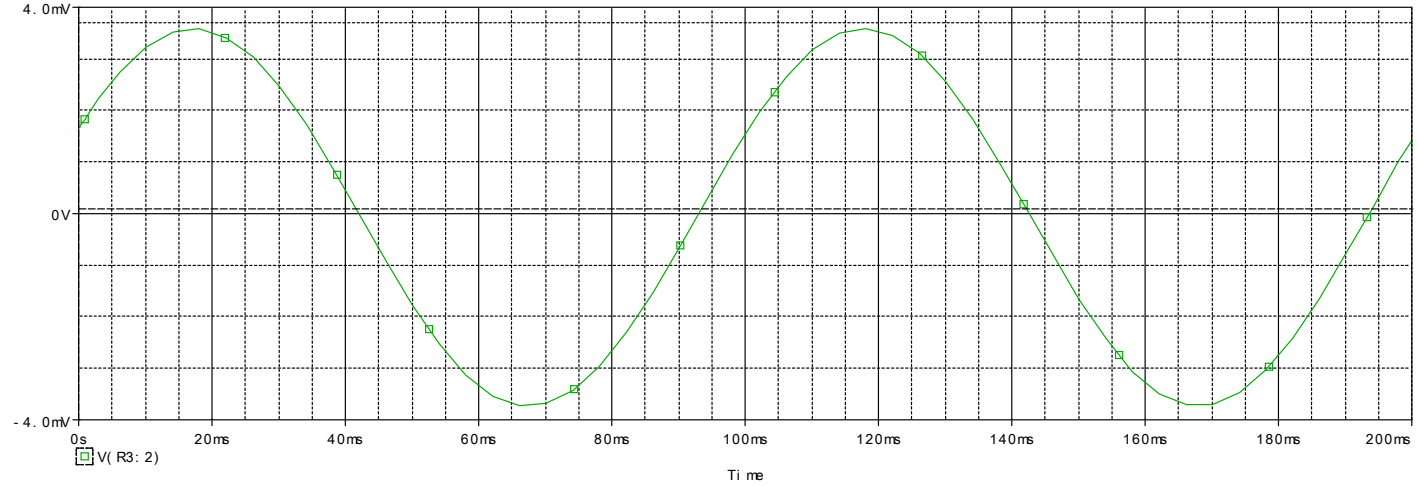
Simulación 5 [kHz] → oscilador diseñado en clase



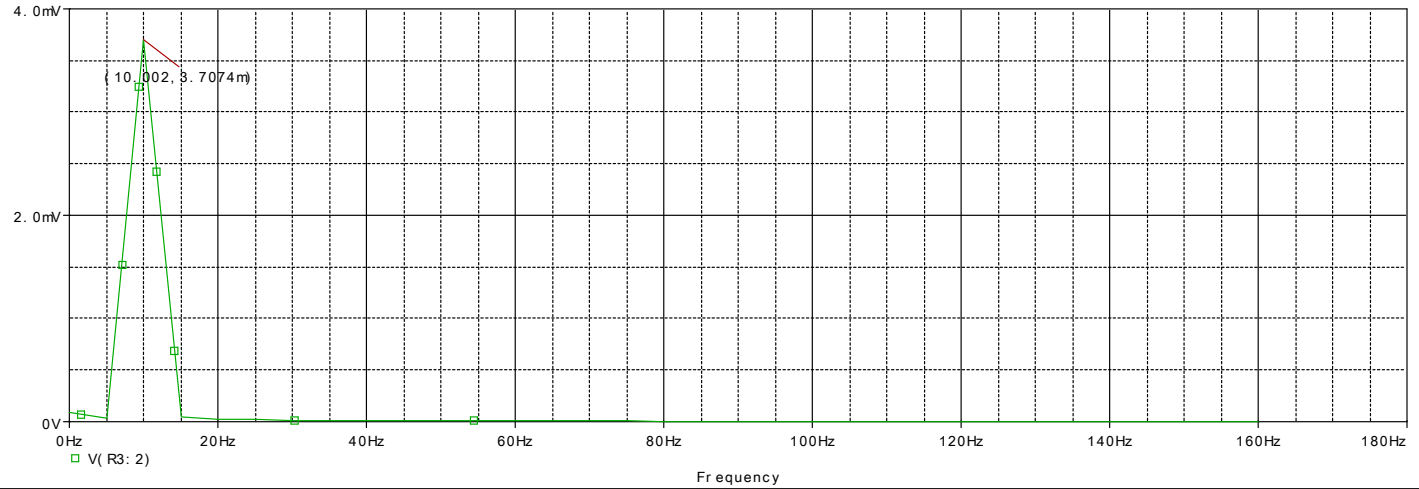
Espectro en frecuencias



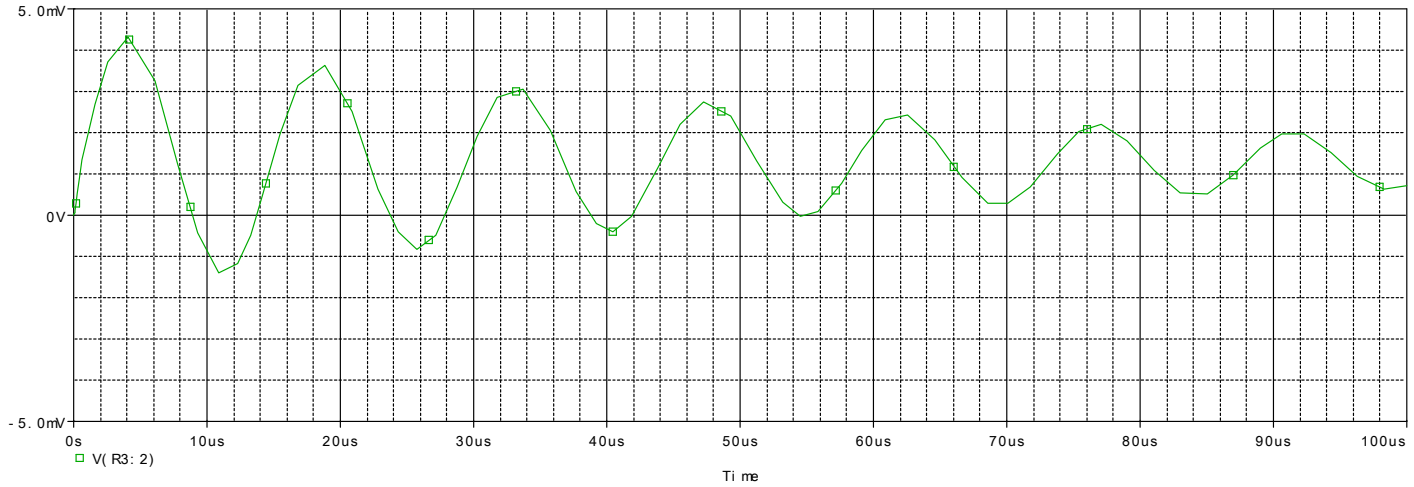
Simulación 10 [Hz]



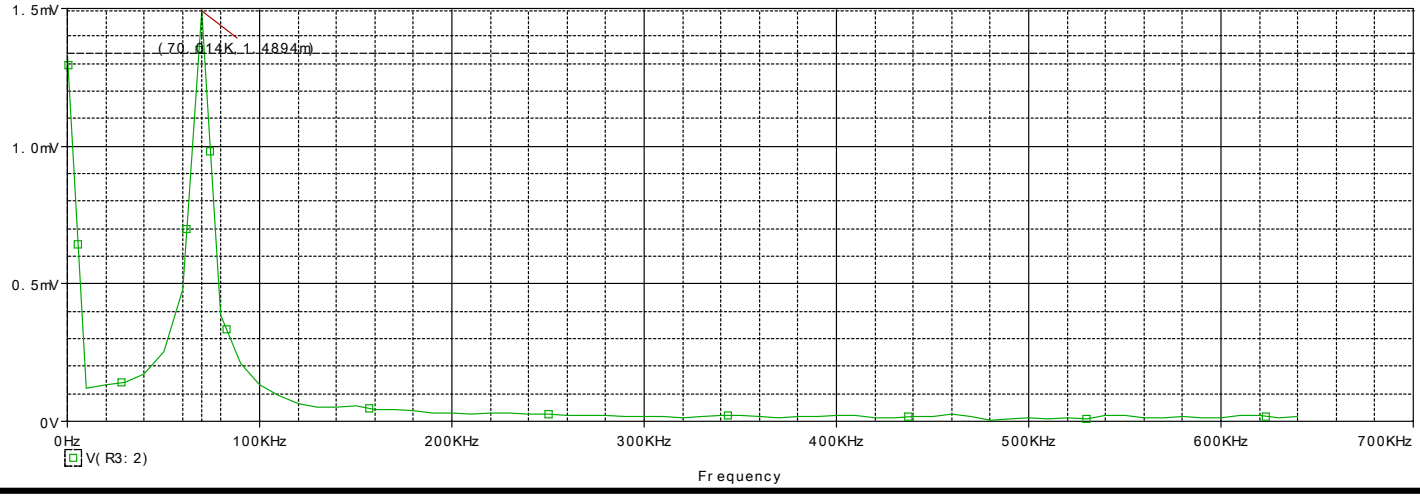
Espectro en frecuencias



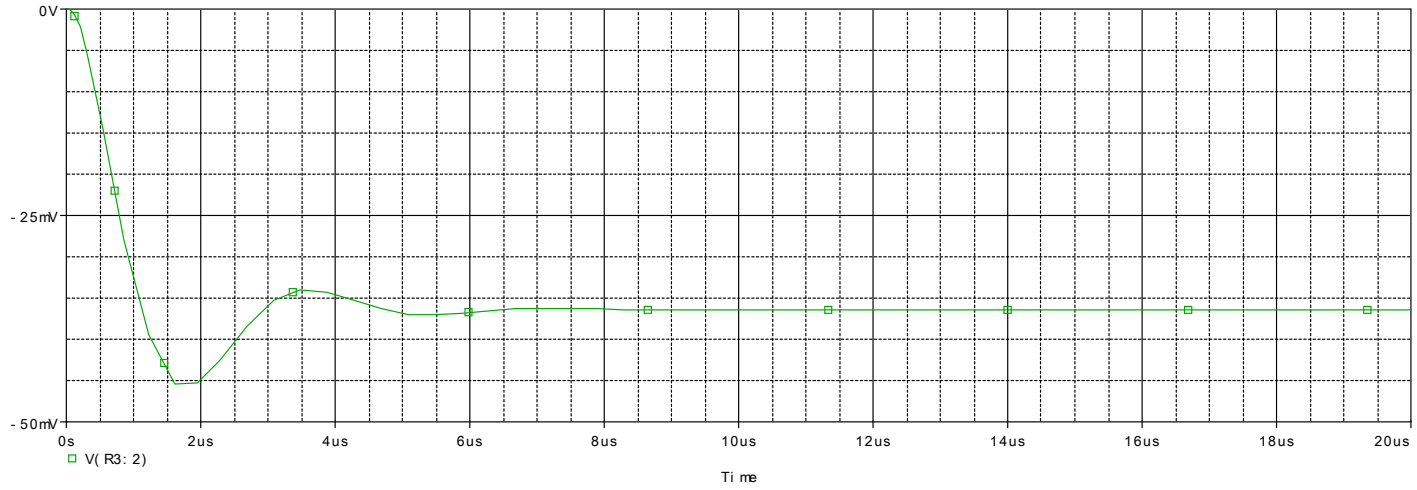
Simulación 100 [KHz]



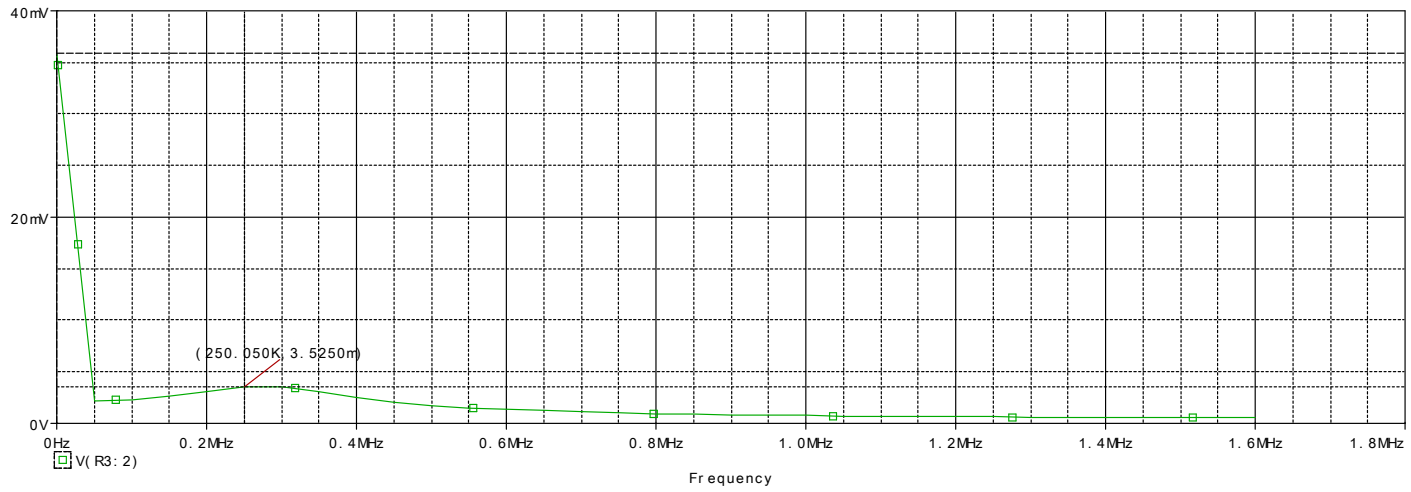
Espectro en frecuencias



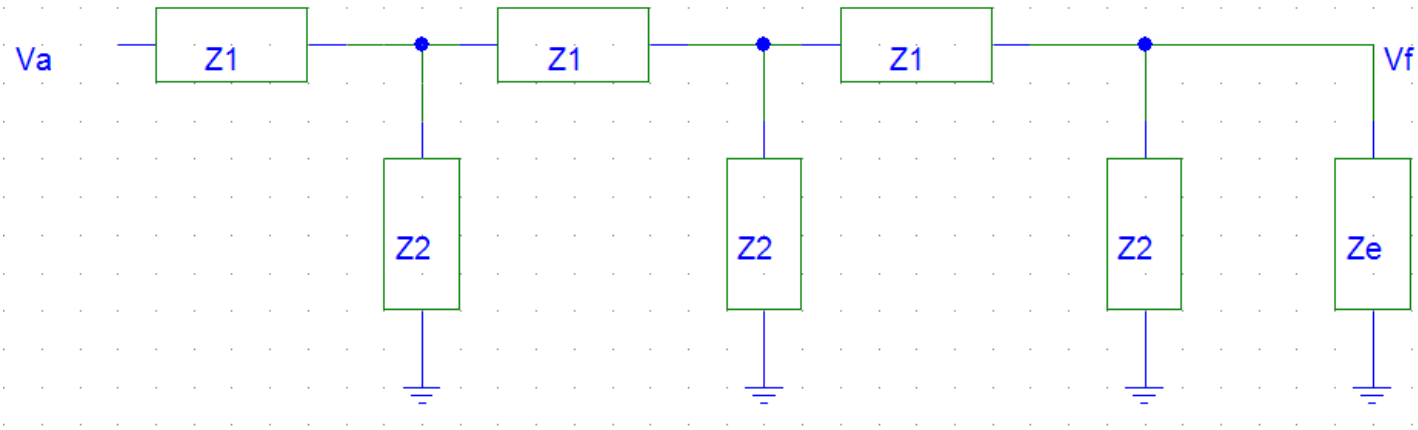
Simulación 1 [MHz]



Espectro en frecuencias



Resolver:



$$Z_{eq} = Z_2 \parallel Z_e = \frac{Z_e Z_2}{Z_e + Z_2} \text{ ----------(1)}$$

$$\frac{v_a - v_x}{Z_1} = \frac{v_x - 0}{Z_2} + \frac{v_x - v_y}{Z_1} \text{ ----------(2)}$$

$$\frac{v_x - v_y}{Z_1} = \frac{v_y - 0}{Z_2} + \frac{v_y - v_f}{Z_1} \text{ ----------(3)}$$

$$\frac{v_y - v_f}{Z_1} = \frac{v_f - 0}{Z_{eq}} \text{ ----------(4)}$$

De (4)

$$\frac{v_y}{Z_1} - \frac{v_f}{Z_1} = \frac{v_f}{Z_{eq}}$$

$$\frac{v_y}{Z_1} = \frac{v_f}{Z_{eq}} + \frac{v_f}{Z_1}$$

$$\frac{v_y}{Z_1} = v_f\left(\frac{1}{Z_{eq}} + \frac{1}{Z_1}\right)$$

$$v_y = v_f Z_1\left(\frac{1}{Z_{eq}} + \frac{1}{Z_1}\right) \text{ ----------(5)}$$

(5) en (3)

$$\frac{v_x - v_f Z_1\left(\frac{1}{Z_{eq}} + \frac{1}{Z_1}\right)}{Z_1} = \frac{v_f Z_1\left(\frac{1}{Z_{eq}} + \frac{1}{Z_1}\right) - 0}{Z_2} + \frac{v_f Z_1\left(\frac{1}{Z_{eq}} + \frac{1}{Z_1}\right) - v_f}{Z_1}$$

$$\frac{v_x - v_f Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_1} = \frac{v_f Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_2} + \frac{v_f Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - v_f}{Z_1}$$

$$\frac{v_x}{Z_1} - v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) = v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1}$$

Despejando Vx

$$v_x = Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right] \text{----------(6)}$$

(6) en dos

$$\frac{v_a - v_x}{Z_1} = \frac{v_x - 0}{Z_2} + \frac{v_x - v_y}{Z_1}$$

$$v_y = v_f Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)$$

$$\frac{v_a}{Z_1} - \frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1} = \frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_2}$$

$$+ \frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1} - \frac{v_f Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_1}$$

$$\frac{v_a}{Z_1} - \frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1} = \frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_2}$$

$$+ \frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right) - \frac{v_f}{Z_1} + v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1} - \frac{v_f Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_1}$$

$$\frac{v_a}{Z_1}=\frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{v_f}{Z_1}+v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_2}$$

$$+\frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{v_f}{Z_1}+v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1}-\frac{v_fZ_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_1}+\frac{Z_1\left[v_f\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+v_f\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{v_f}{Z_1}+v_f\right.}{Z_1}$$

factorizando vf

$$\frac{v_a}{Z_1}=v_f\left\{\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_2}\right.$$
$$\left.+\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1}-\frac{Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_1}+\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1}\right\}$$

$$\frac{v_a}{Z_1\left\{\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_2}\right.}=v_f$$
$$\left.+\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1}-\frac{Z_1\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}{Z_1}+\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_1}\right\}$$

$$\frac{1}{Z_1\left\{\frac{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]}{Z_2}\right.}=\frac{v_f}{v_a}$$
$$\left.+\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]-\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]\right\}$$

Simplificando

$$\frac{1}{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]\left\{\frac{Z_1}{Z_2}+1-\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+1\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{Z_1\left[\frac{Z_1}{Z_2}\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\frac{1}{Z_1}+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right]\left\{\frac{Z_1}{Z_2}+1-\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+1\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{\left[\frac{Z_1}{Z_2}\left(\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_1}\right)+\left(\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_1}\right)-\frac{Z_1}{Z_1}+\left(\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_1}\right)\right]\left\{\frac{Z_1}{Z_2}+1-\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+1\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{\left[\left(\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_1}\right)\left\{\frac{Z_1}{Z_2}+1+1\right\}-\frac{Z_1}{Z_1}\right]\left\{\frac{Z_1}{Z_2}+1-\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)+1\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{\left[\left(\frac{Z_1}{Z_{eq}}+1\right)\left[\frac{Z_1}{Z_2}+2\right]-1\right]\left\{\left[\frac{Z_1}{Z_2}+2\right]-\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{\left\{\left(\frac{Z_1}{Z_{eq}}+1\right)\left[\frac{Z_1}{Z_2}+2\right]\left[\frac{Z_1}{Z_2}+2\right]-\left(\frac{Z_1}{Z_{eq}}+1\right)\left[\frac{Z_1}{Z_2}+2\right]\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\left(\frac{Z_1}{Z_{eq}}+1\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{\left\{\left(\frac{Z_1}{Z_{eq}}+1\right)\left[\frac{Z_1}{Z_2}+2\right]\left[\frac{Z_1}{Z_2}+2\right]-\left(\frac{Z_1}{Z_{eq}}+1\right)\left[\frac{Z_1}{Z_2}+2\right]\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\left(\frac{Z_1}{Z_{eq}}+1\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)\right\}}=\frac{v_f}{v_a}$$

$$\frac{1}{\left(\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_2}+2\right)\left[\frac{Z_1}{Z_2}+2\right]-\left(\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+\frac{Z_1}{Z_2}+2\right)\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\left(\frac{Z_1}{Z_{eq}}+1\right)+\left(\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)}=\frac{v_f}{v_a}$$

$$\frac{1}{\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+4\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_2}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_2}+4-\left(\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{1}{Z_{eq}}+\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{1}{Z_1}+\frac{Z_1}{Z_2}\frac{1}{Z_{eq}}+\frac{Z_1}{Z_2}\frac{1}{Z_1}+\frac{1}{Z_{eq}}+\frac{1}{Z_1}\right)-\left(\frac{Z}{Z}\right.}$$

$$\frac{1}{\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+4\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_2}\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_2}+2\frac{Z_1}{Z_2}+4-\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{1}{Z_{eq}}-\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{1}{Z_1}-\frac{Z_1}{Z_2}\frac{1}{Z_{eq}}-\frac{Z_1}{Z_2}\frac{1}{Z_1}-\frac{1}{Z_{eq}}-\frac{1}{Z_1}-\frac{Z}{Z}}$$

$$\boxed{\frac{1}{\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{Z_1}{Z_2}+4\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}+3\frac{Z_1}{Z_{eq}}+\frac{Z_1}{Z_2}\frac{Z_1}{Z_2}+4\frac{Z_1}{Z_2}+4-\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{1}{Z_{eq}}-\frac{Z_1}{Z_{eq}}\frac{Z_1}{Z_2}\frac{1}{Z_1}-\frac{Z_1}{Z_2}\frac{1}{Z_{eq}}-\frac{Z_1}{Z_2}\frac{1}{Z_1}-1}=\frac{v_f}{v_a}}$$