Double stage TIA

2024/06/03 Kojima Hikaru

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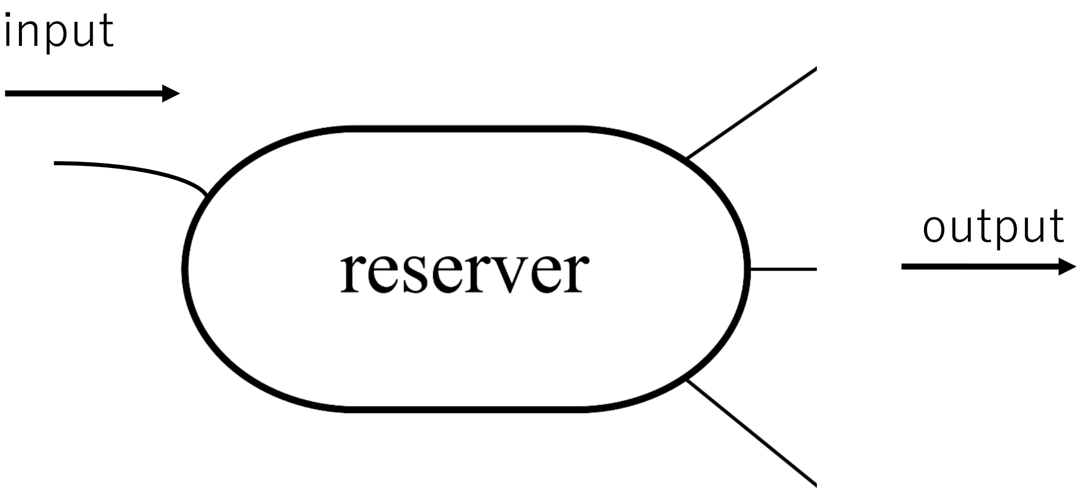
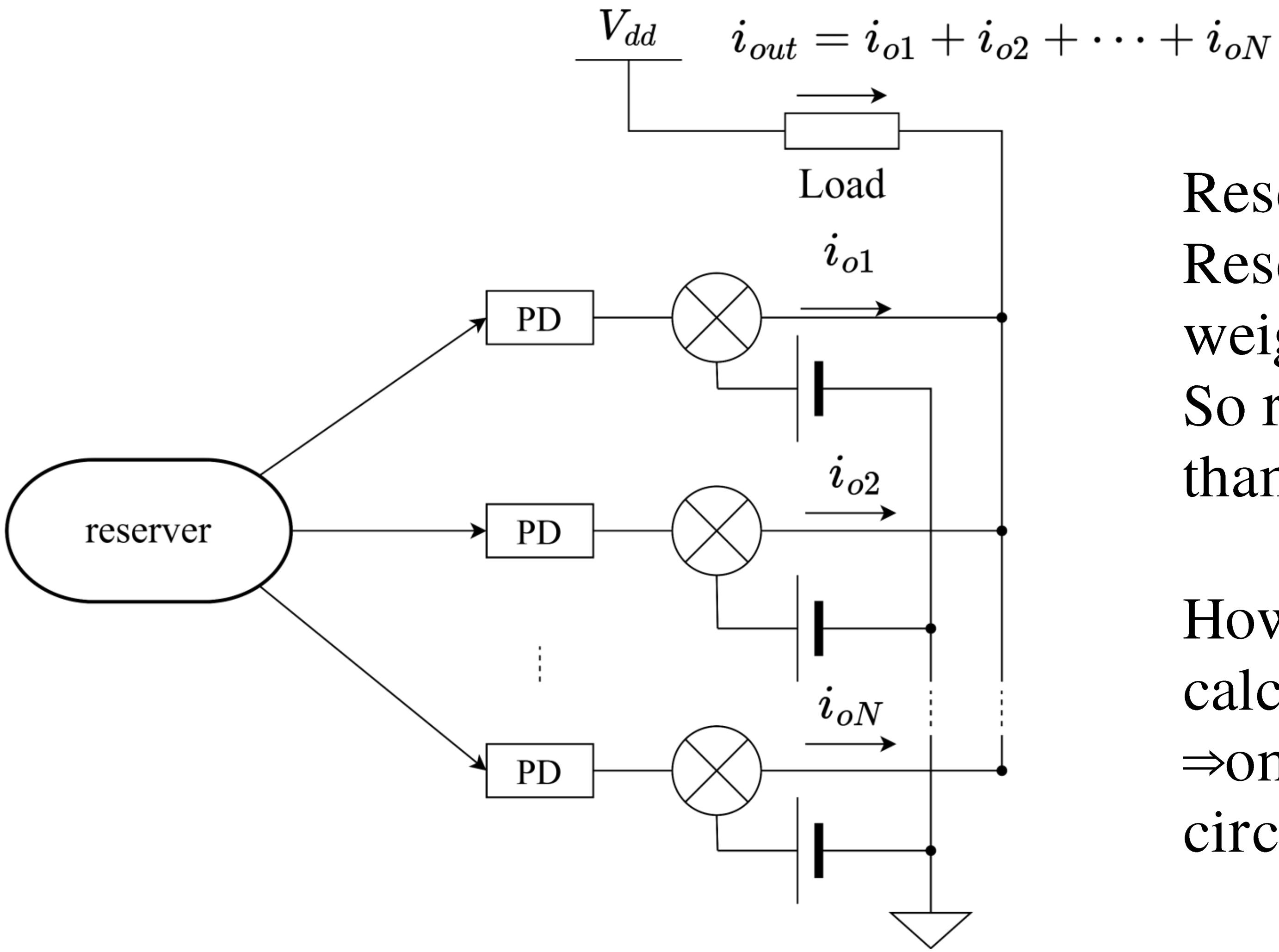
Background



- Reserver is a device that work as a neural network by physical phenomenon.
- Reflecting and interfering input light in the photonic reserver made that it store the state of a short time ago.

It seems that photonic reserver can predict chaotic-signal and real-time graphic processing.

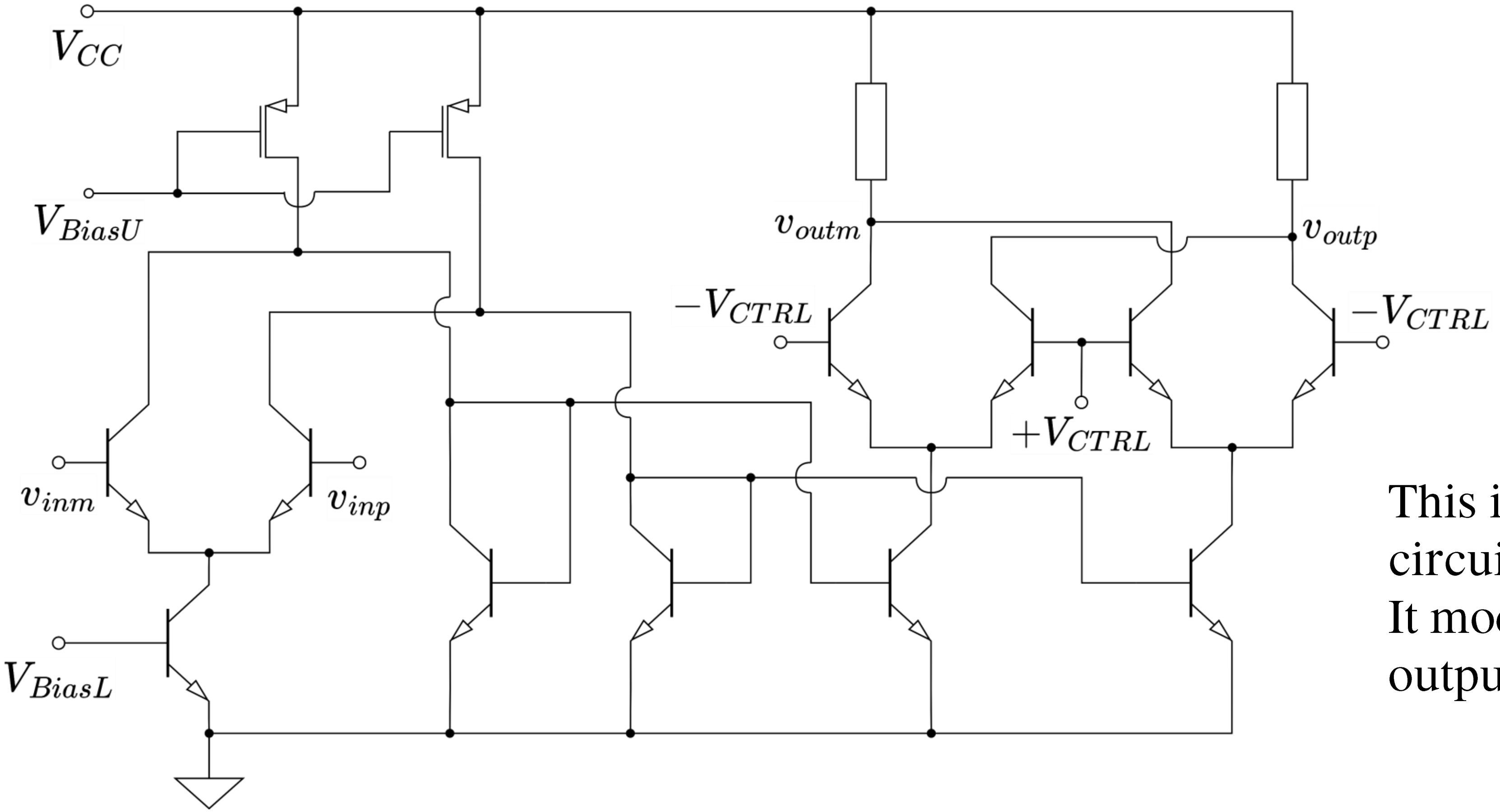
Background



Reserver's output is sum-of-product.
Reserver's learning is only learning of weight of sum-of-product.
So reserver's learning cost is fewer than machine learning.

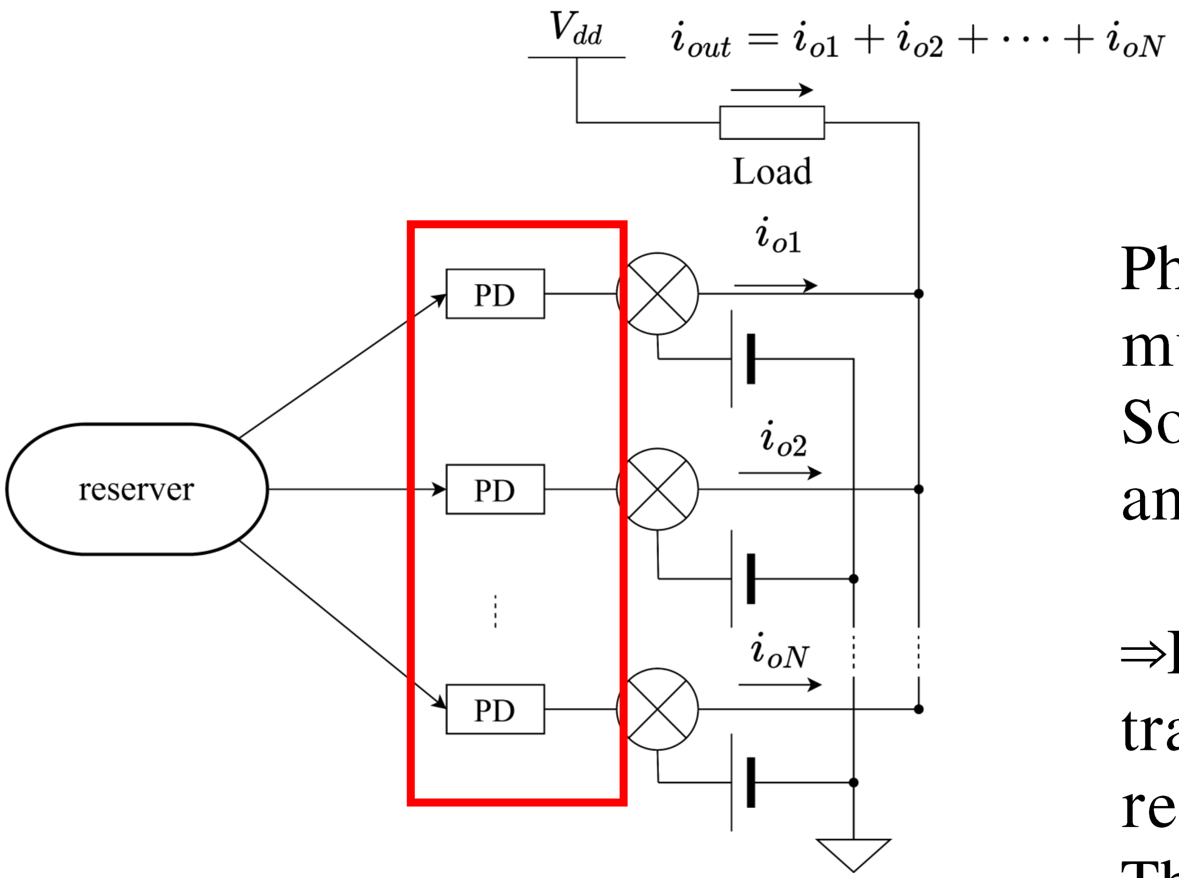
However, it is difficult for light to calculate sum-of-product.
⇒only this part, calculate in electronic circuits.

Background



This is a proposing analog multiplying circuit.
It modified gilbert multiplier for expand output amplitude.

Purpose



Photonic reserver output by light and multiplier's input is voltage.
So, we need photo-diode. But the output amplitude is smaller than multiplier's input.

⇒It is necessary to photonic-electronic translator and amplifier that have dimension of resister.
This name is TIA(Trans-Impedance Amplifier)

Single stage TIA

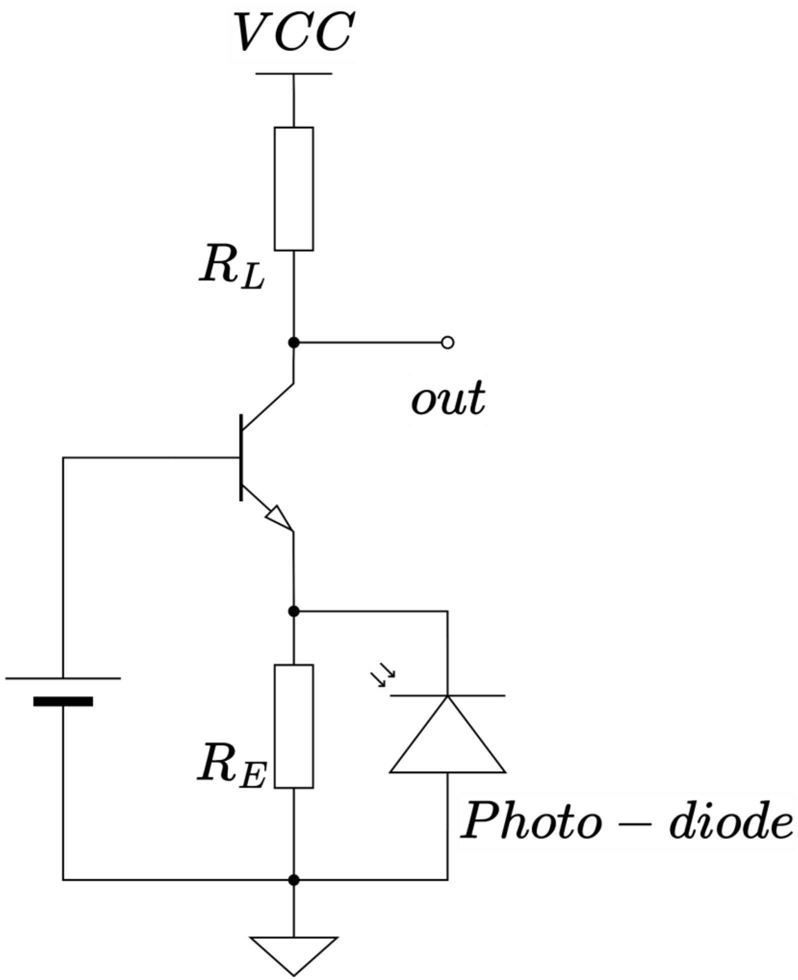
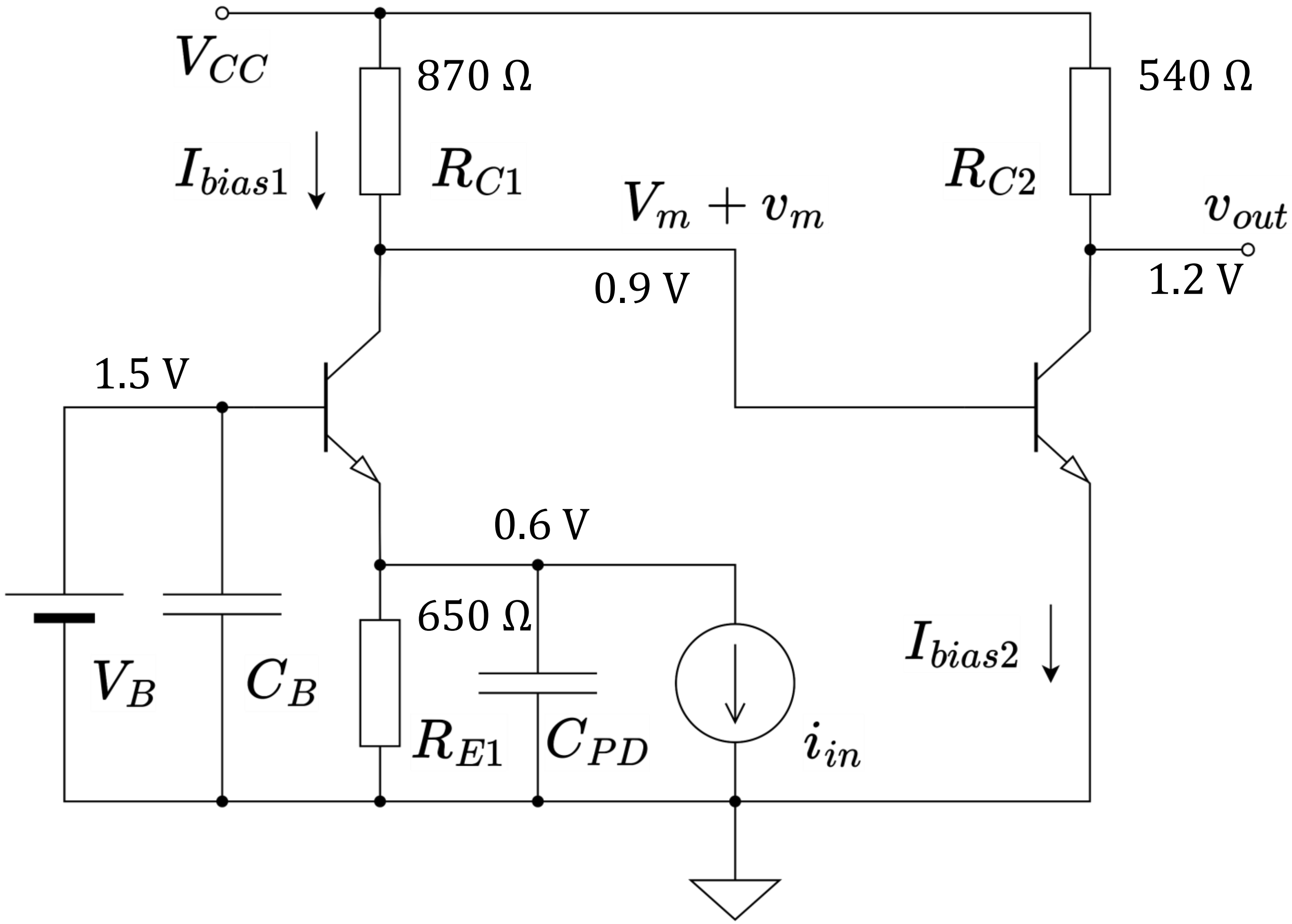


Photo-diode is a device of current output and multiplier's input is voltage, so TIA needs current input and voltage output.
That is a reason why common-base amplifier is used for TIA.

But this topology is trade-off between trance-impedance and bandwidth.

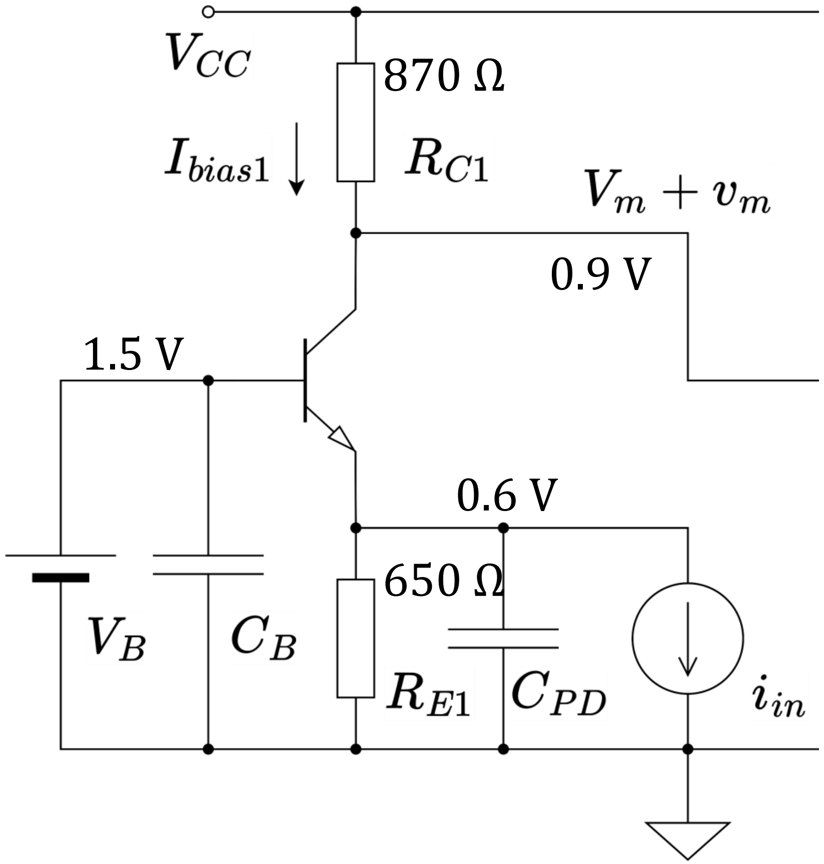
Double Stage TIA

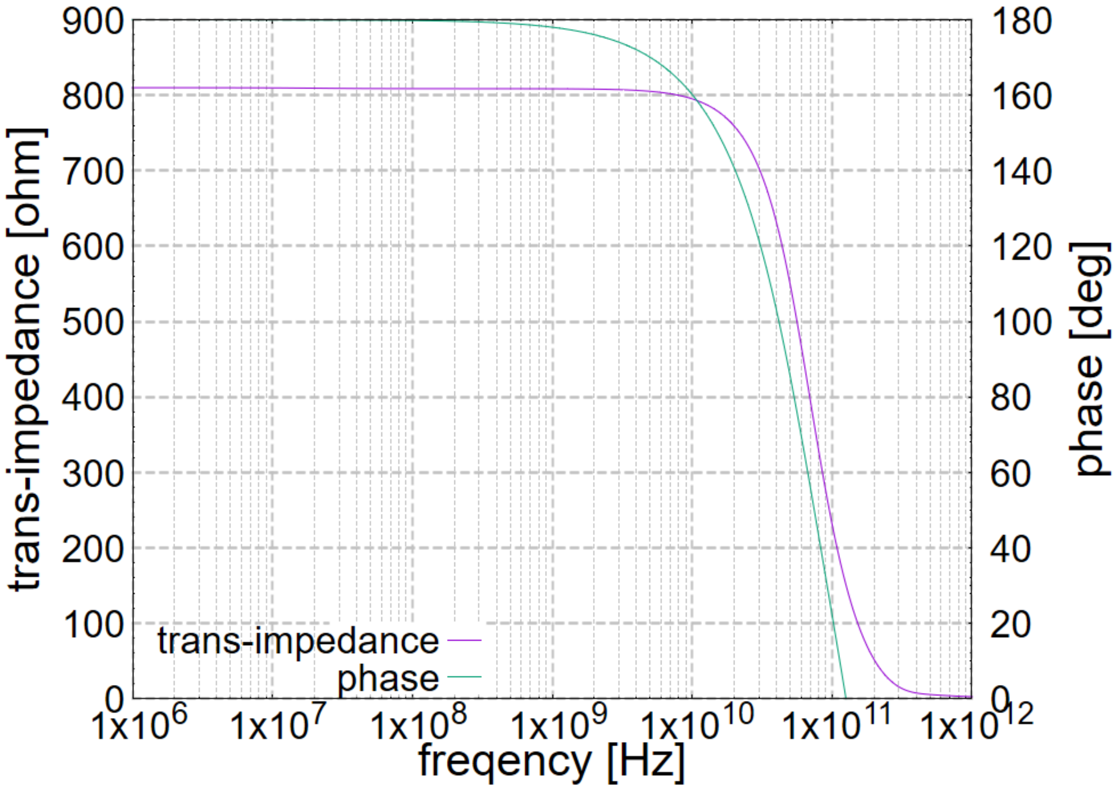


To avoid the tread-off, I examining double stage TIA.

This topology dividing gain between two stage, I attempt high trans-impedance and large bandwidth.

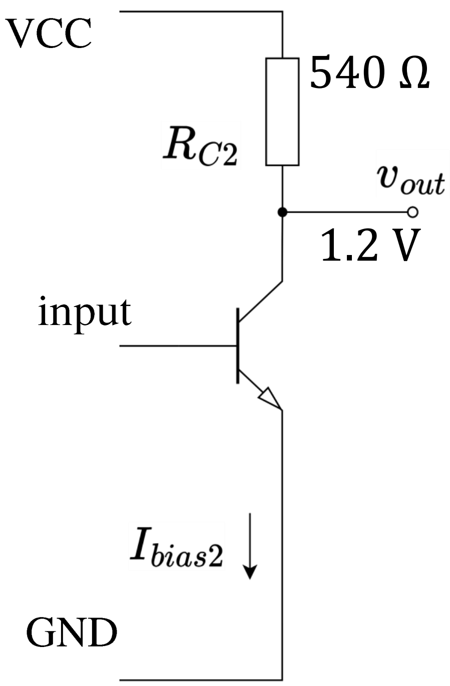
Double Stage TIA

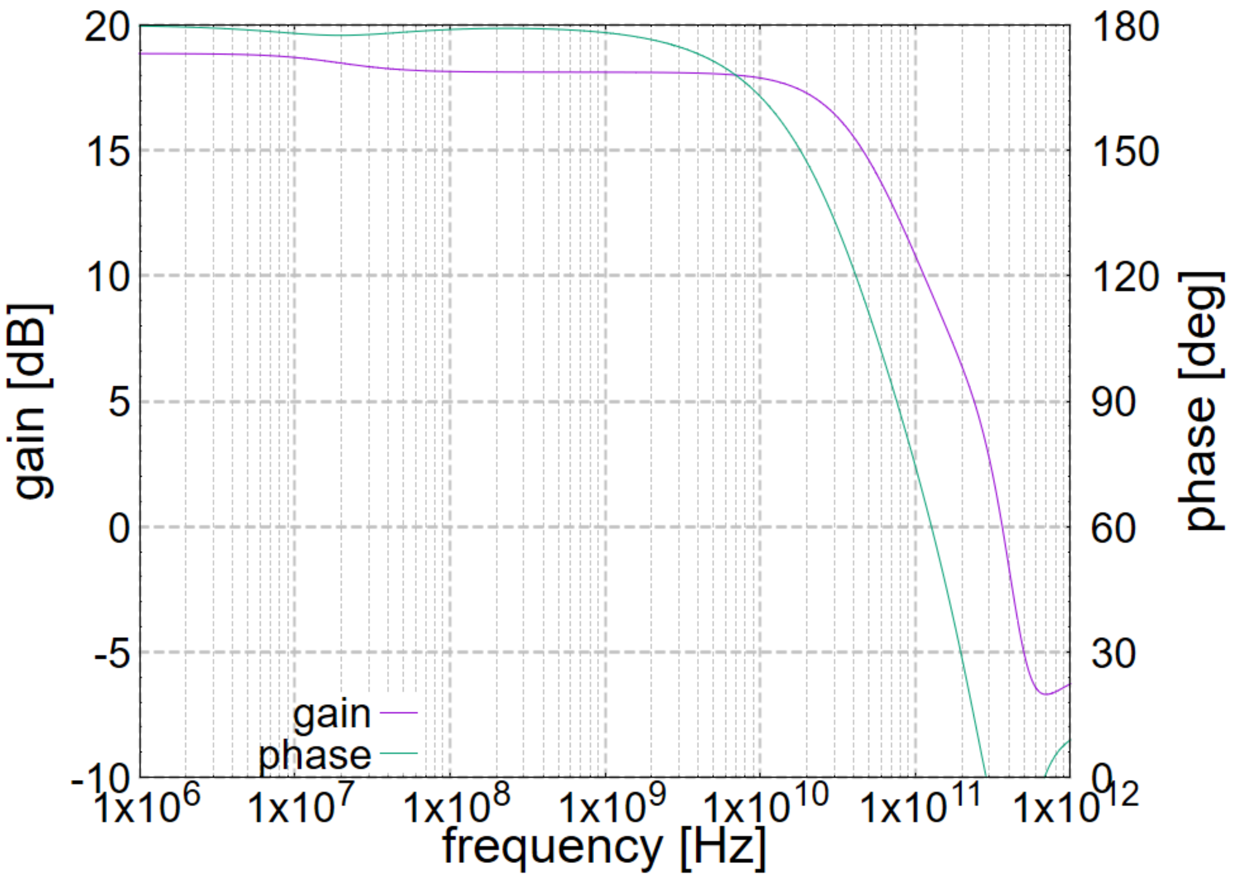




First stage of frequency characteristic.
This cutoff frequency is 10 GHz ordered.

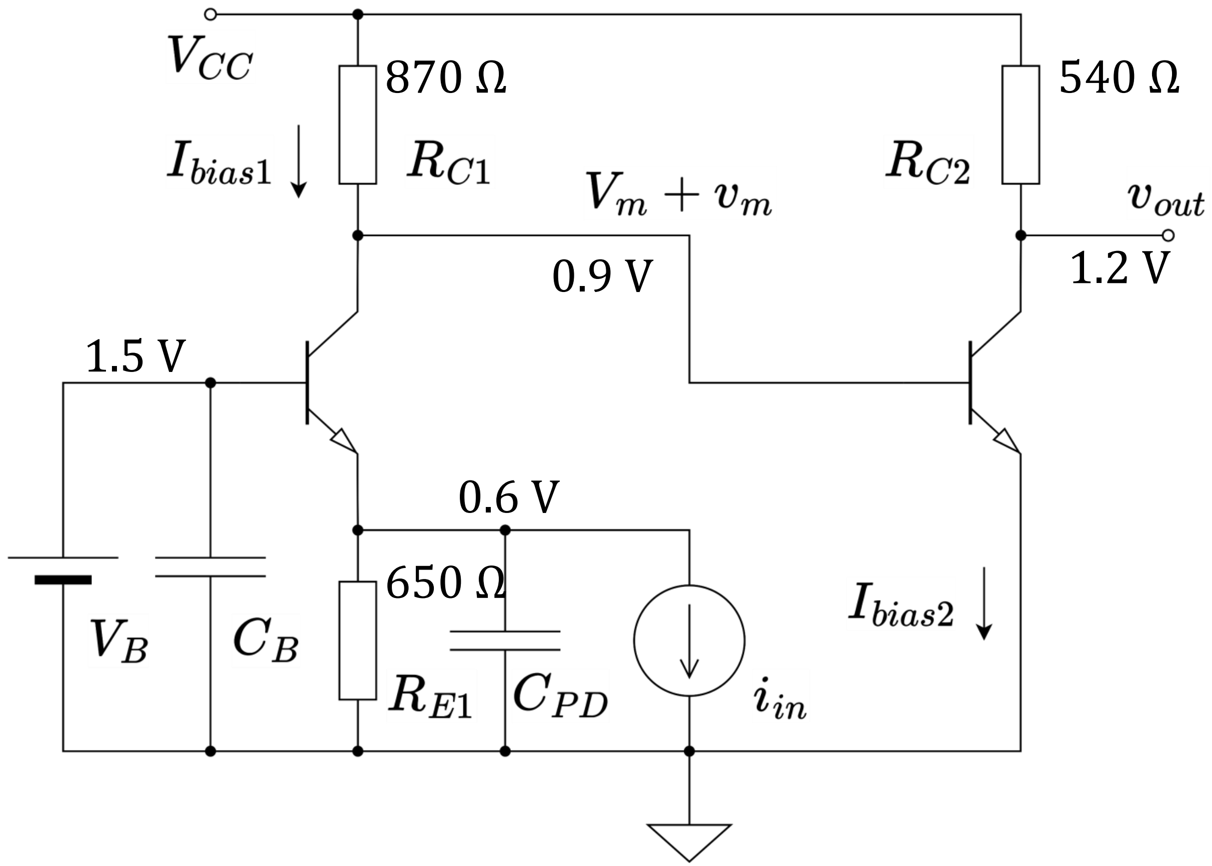
Double Stage TIA

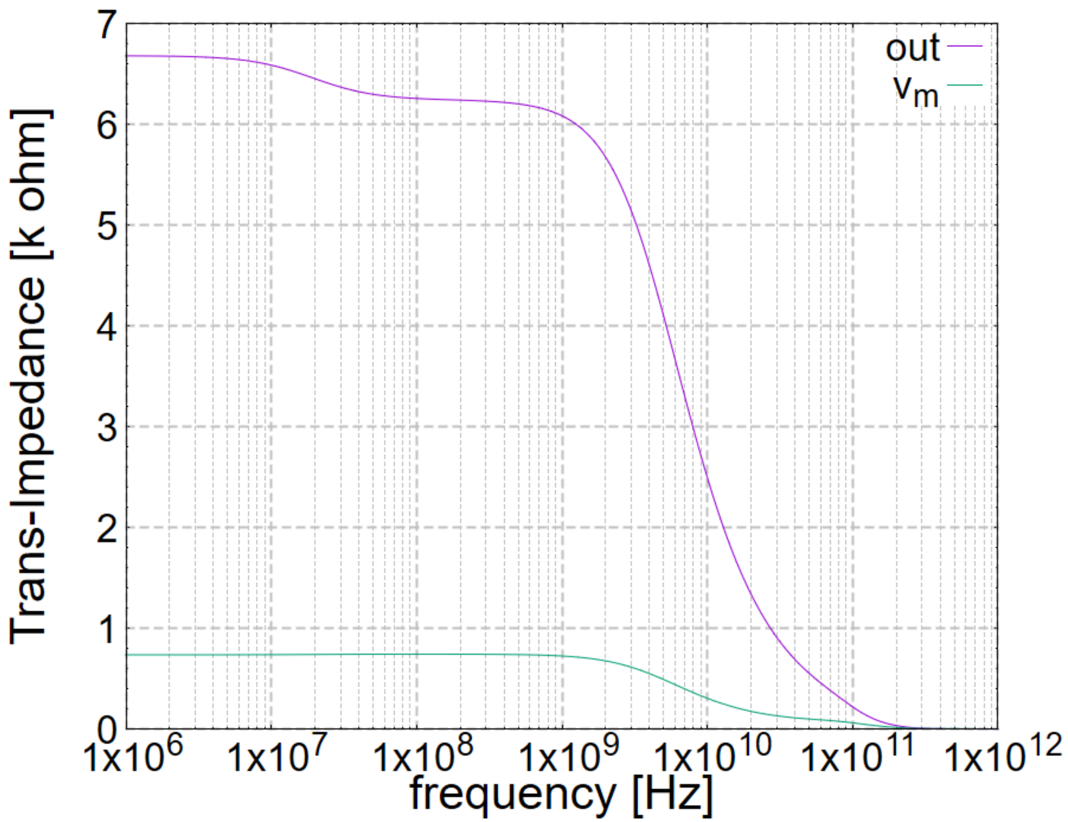




Second stage of frequency characteristic.
This cutoff frequency is 10 GHz ordered.

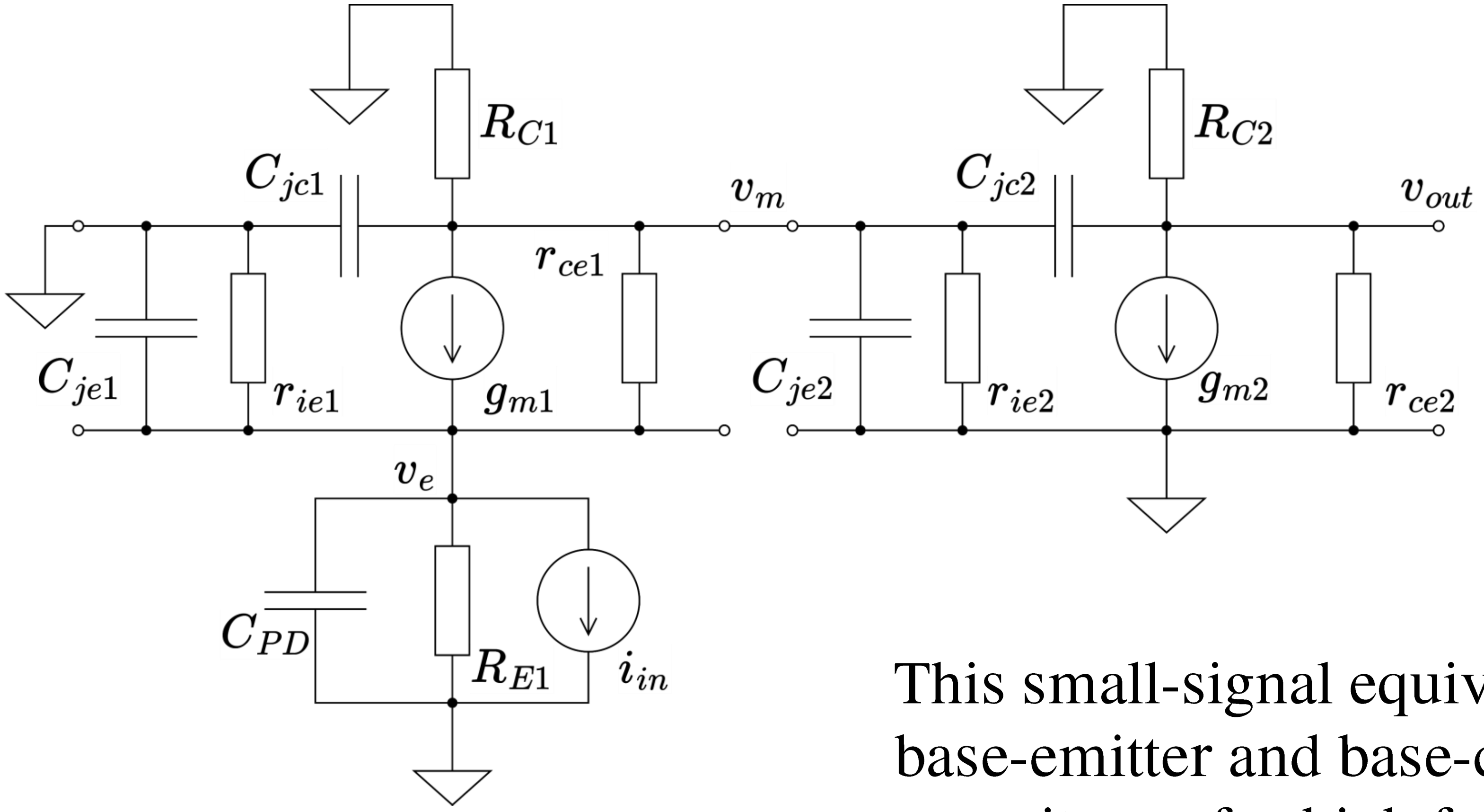
Double Stage TIA





Connected two stage of frequency characteristic.
This cutoff frequency is limited to a GHz ordered.

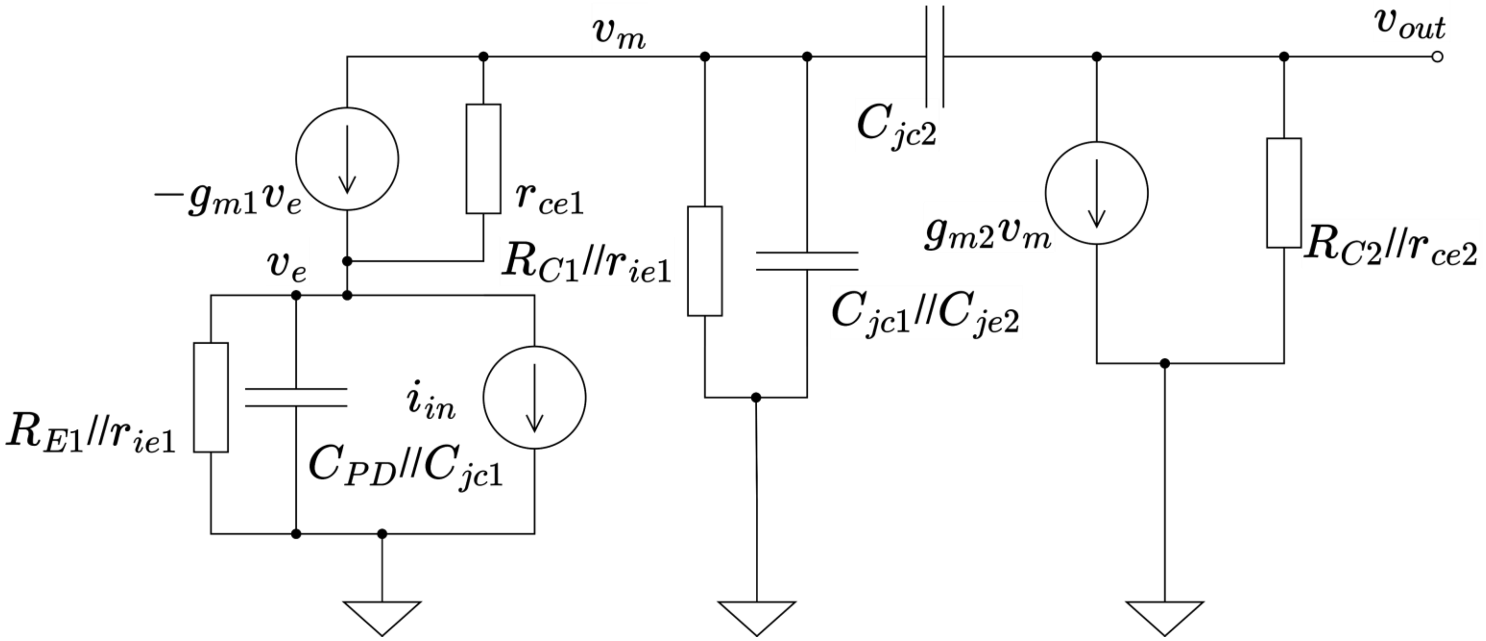
Small-signal analysis



This small-signal equivalent circuit is containing base-emitter and base-collector junction capacitance for high frequency response.

Small-signal analysis

Given by KCL
$$\begin{cases} g_{ce1}(v_m - v_e) - g_{m1}v_e = i_{in} + \{G_{E1} + g_{ie1} + j\omega(C_{PD} + C_{jc1})\}v_e \\ j\omega C_{jc2}(v_m - v_{out}) = g_{m2}v_m + (G_{C2} + g_{ce2})v_{out} \\ g_{ce1}(v_m - v_e) - g_{m1}v_e + \{G_{C1} + g_{ie1} + j\omega(C_{jc1} + C_{je2})\}v_m + j\omega C_{jc2}(v_m - v_{out}) = 0 \end{cases}$$



Small-signal analysis

Low degree of omega is higher effect to trans-impedance.
So that, disregard arguments that have 3 or higher degree of omega.

$$X_t = \frac{\sum_{i=0}^{2} C_{1i} \cdot \omega^i}{\sum_{i=0}^{2} C_{2i} \cdot \omega^i}$$

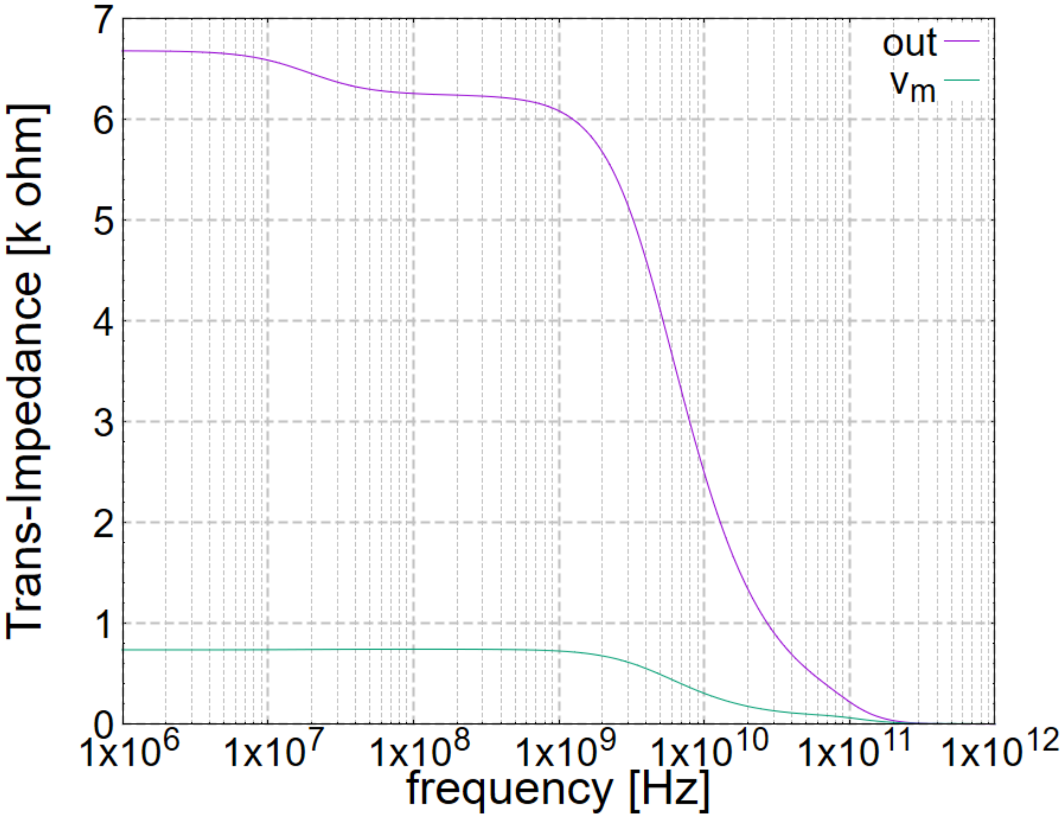
$$= \frac{\{(G_{c2} + g_{ce2})(G_1 G_2 - g_{ce1} G_2)\} + j\omega \left\{C_{jc2}(G_1 G_2 - g_{ce1} G_2) + (G_{c2} + g_{ce2})(G_1 C_2 + G_2 C_1 - C_2 gce1\,) + G_1 C_{jc2} g_{m2}\right\}}{g_{m1} g_{ce1}(G_{C2} + g_{ce2}) + j\omega C_{jc2} g_{m1} g_{ce1}}$$

$$- \frac{\omega^2 \left\{C_{jc2}(G_1 C_2 + G_2 C_1 - C_2 g_{ce1}) - C_1 C_2 (G_{C2} + g_{ce2}) + C_1 C_{jc2} g_{m2} - G_1 C_{jc2}^2\right\}}{g_{m1} g_{ce1}(G_{C2} + g_{ce2}) + j\omega C_{jc2} g_{m1} g_{ce1}}$$

$G_1 \coloneqq G_{E1} + g_{m1} + g_{ce1}$ $\quad$ $G_2 \coloneqq G_{C1} + g_{ce1} + g_{ie1}$ $\quad$ $C_1 \coloneqq C_{PD} + C_{je1}$ $\quad$ $C_2 \coloneqq C_{jc1} + C_{jc2} + C_{je2}$

	[mS]		[Ω]		[Ω]		[Ω]		[Ω]
g_{m1}	24.82	r_{ie1}	1.49529 M	$R_{C1}=1/G_{C1}$	870	C_{je1}	12.95 f	C_B	1 n
g_{m2}	25.96	$r_{ce1}=1/g_{ce1}$	2.658086 k	$R_{C2}=1/G_{C2}$	540	C_{jc1}	2.396 f	C_{PD}	16 f
		r_{ie2}	364.3157 k	$R_{E1}=1/G_{E1}$	650	C_{je2}	13.44 f		
		$r_{ce2}=1/g_{ce2}$	1.312616 k			C_{jc2}	772.6 a		

Small-signal analysis



Calculated low frequency gain ($\omega = 0$) from equation and table is about 0.232 Ω. But this conclusion is cleary incorrect.

Conclusion

In the end, I couldn’t find limit of frequency response.

I will continue to find the part of limitation.