Calibración de transformadores de corriente

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Método Diferencial

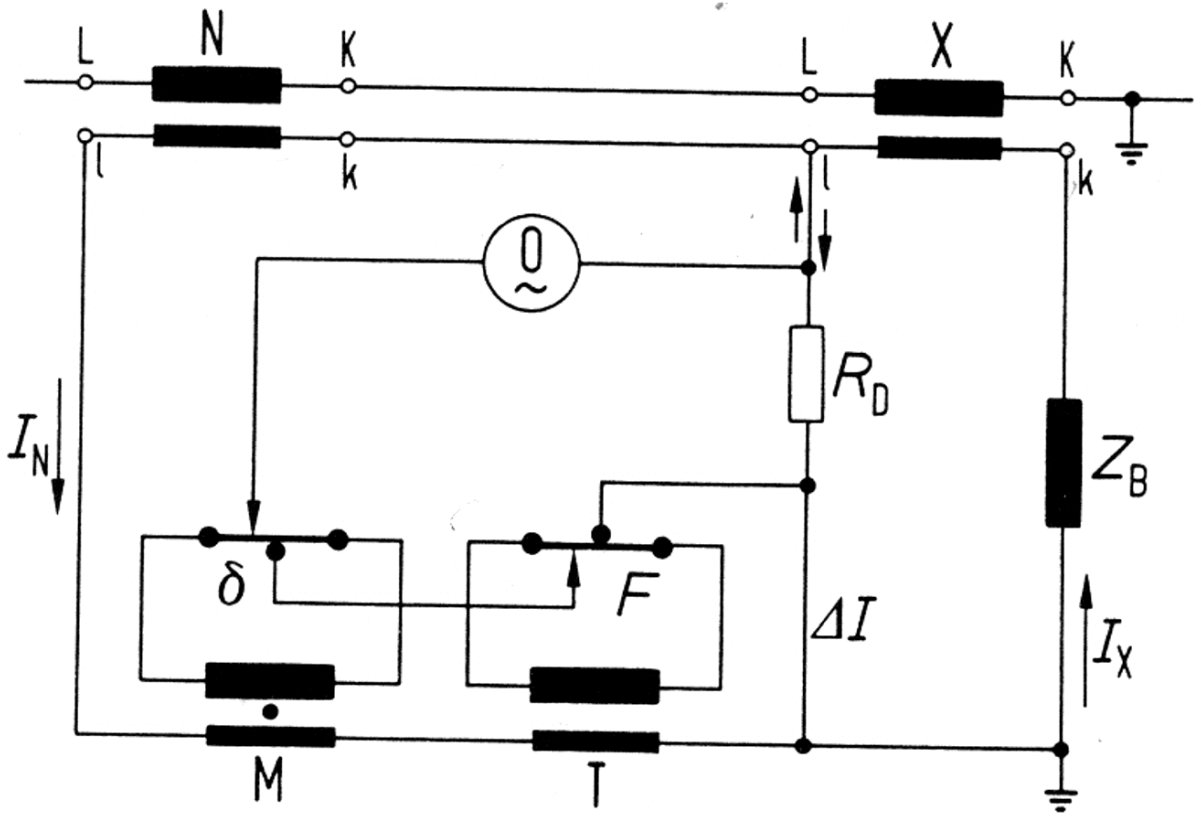
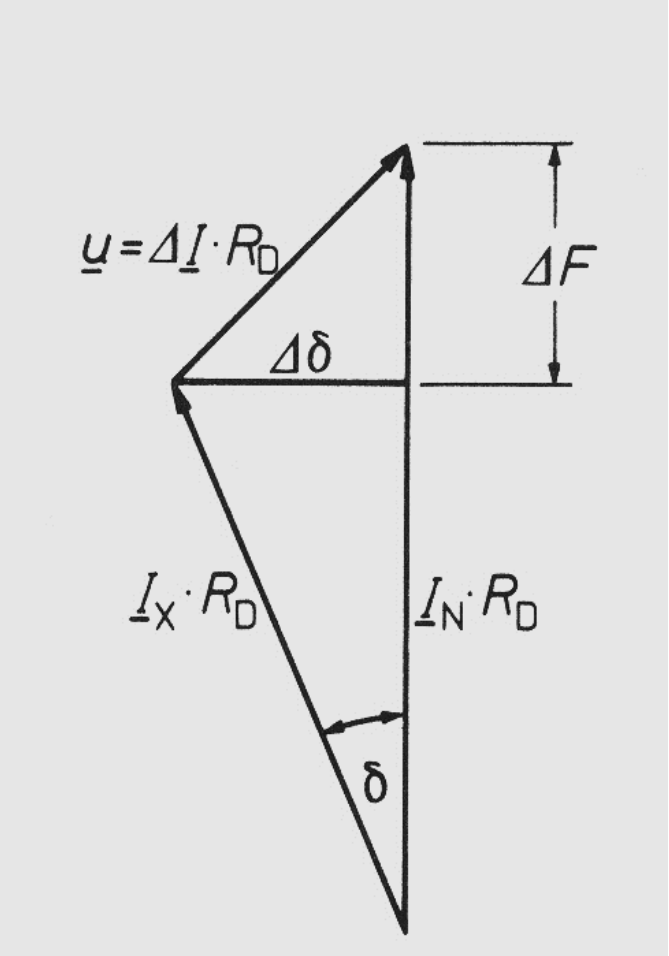


Fig.11

Diagrama Vectorial



Puente diferencial Laboratorio de UTE

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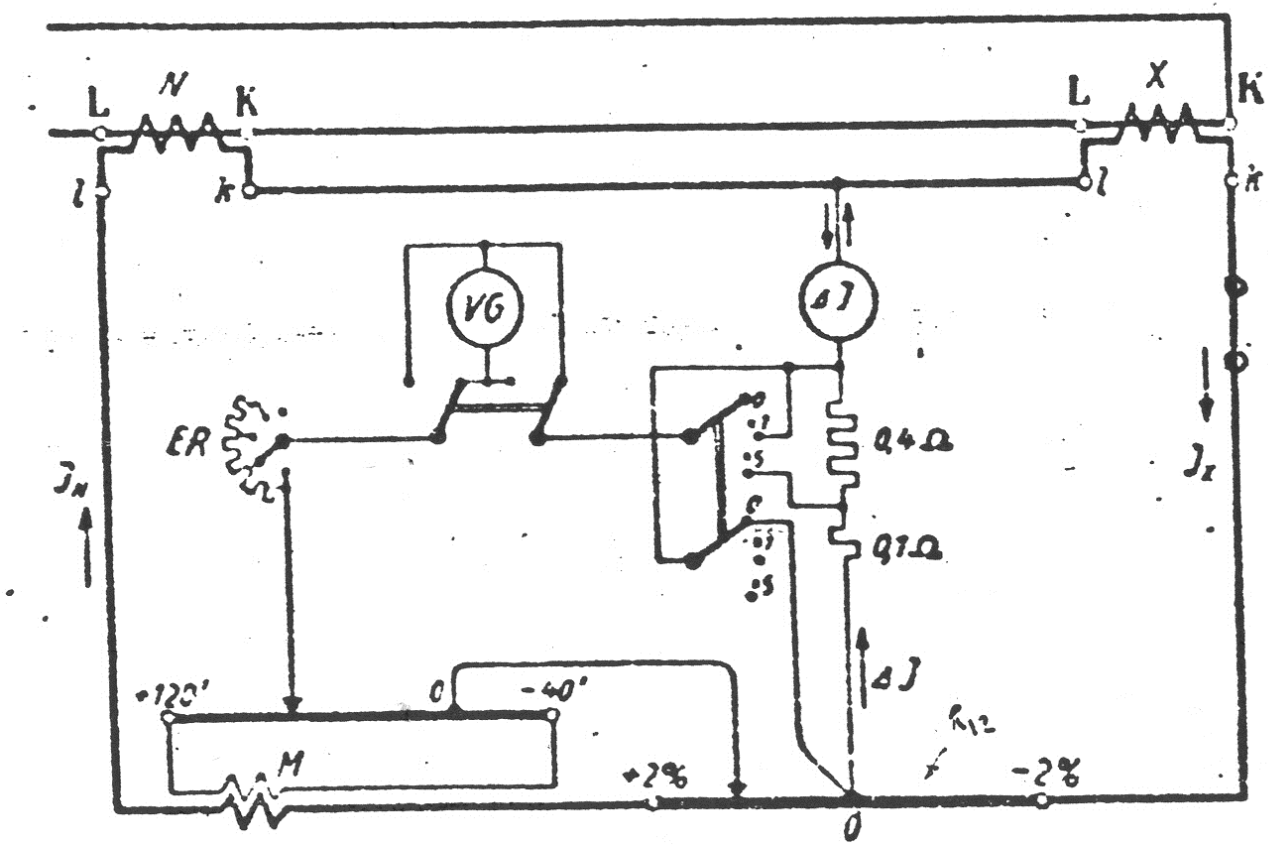
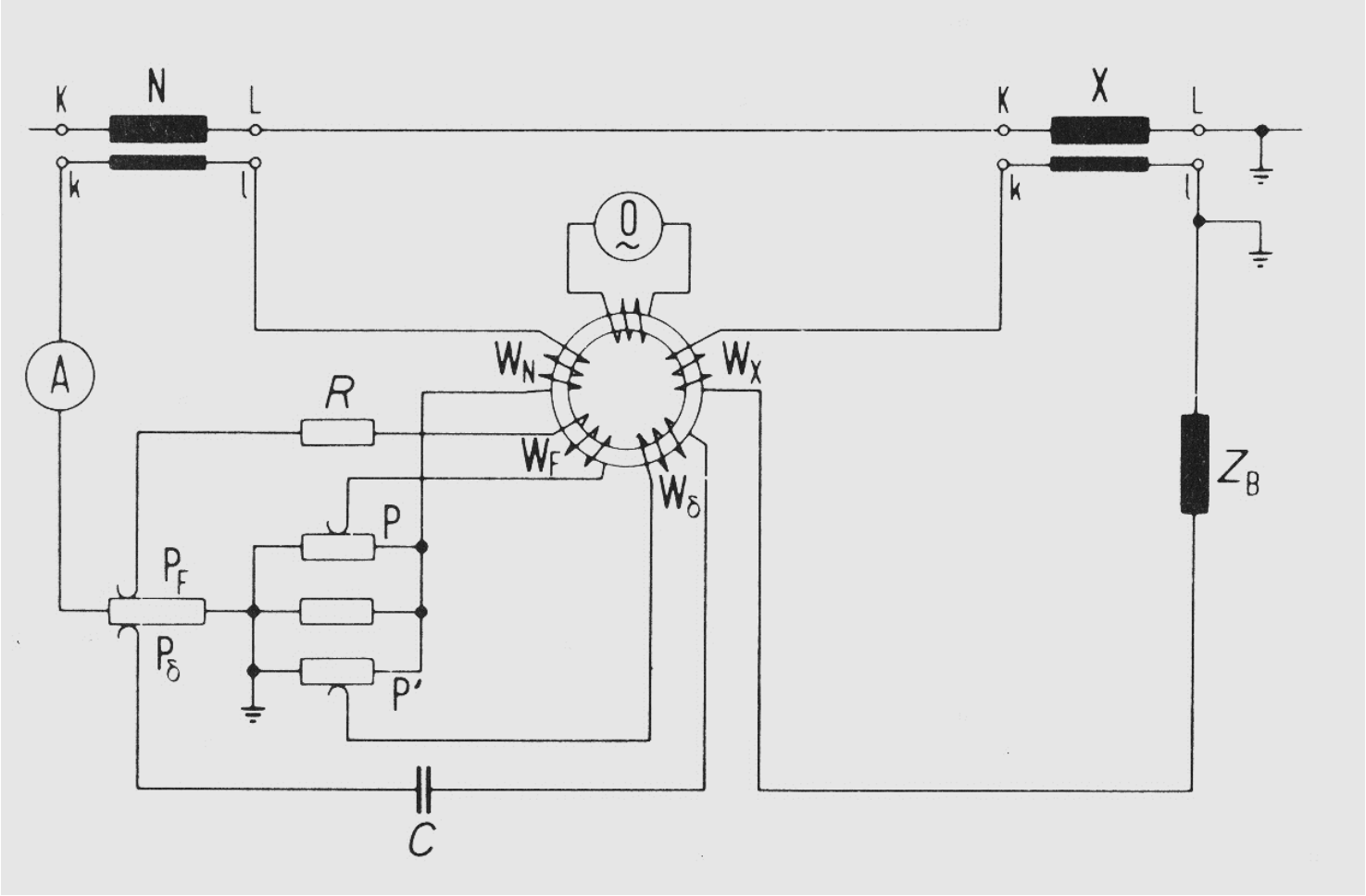
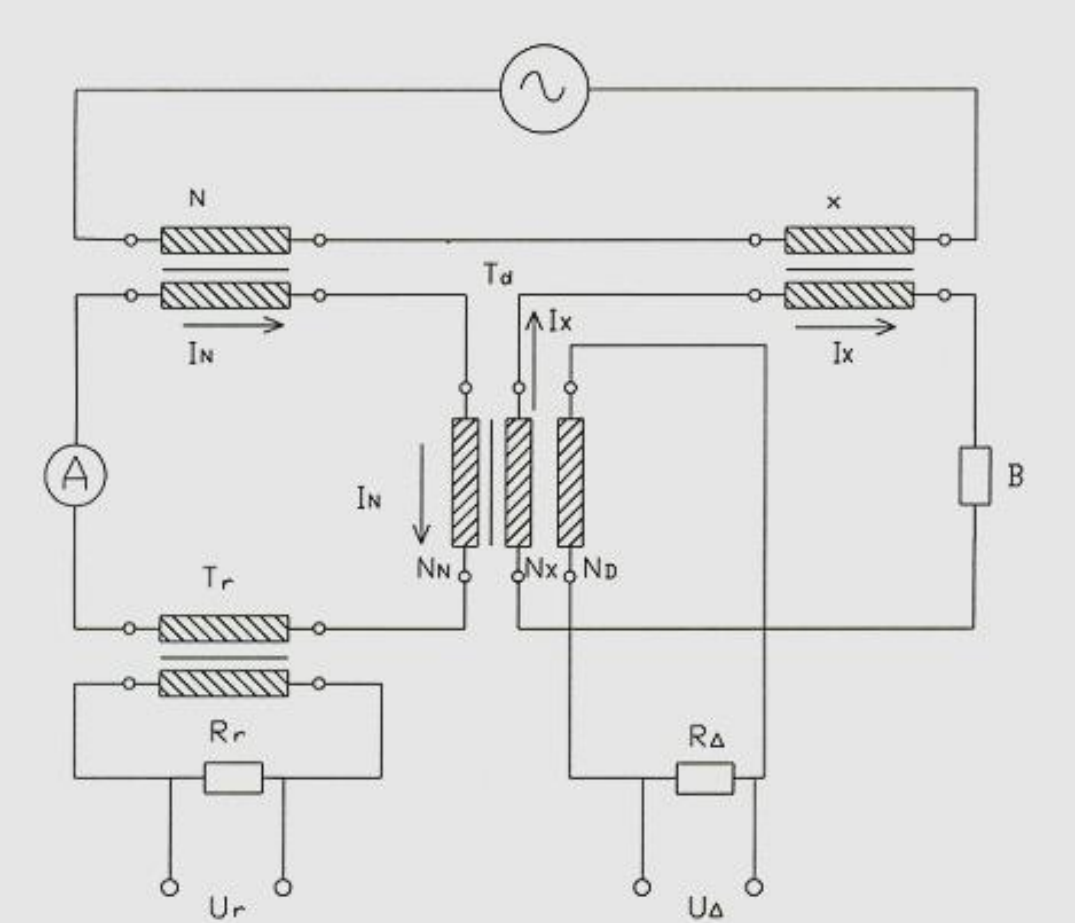


Galvanómetro eléctronico

Método con transformador comparador de corriente



Comparador de corriente sin realimentación



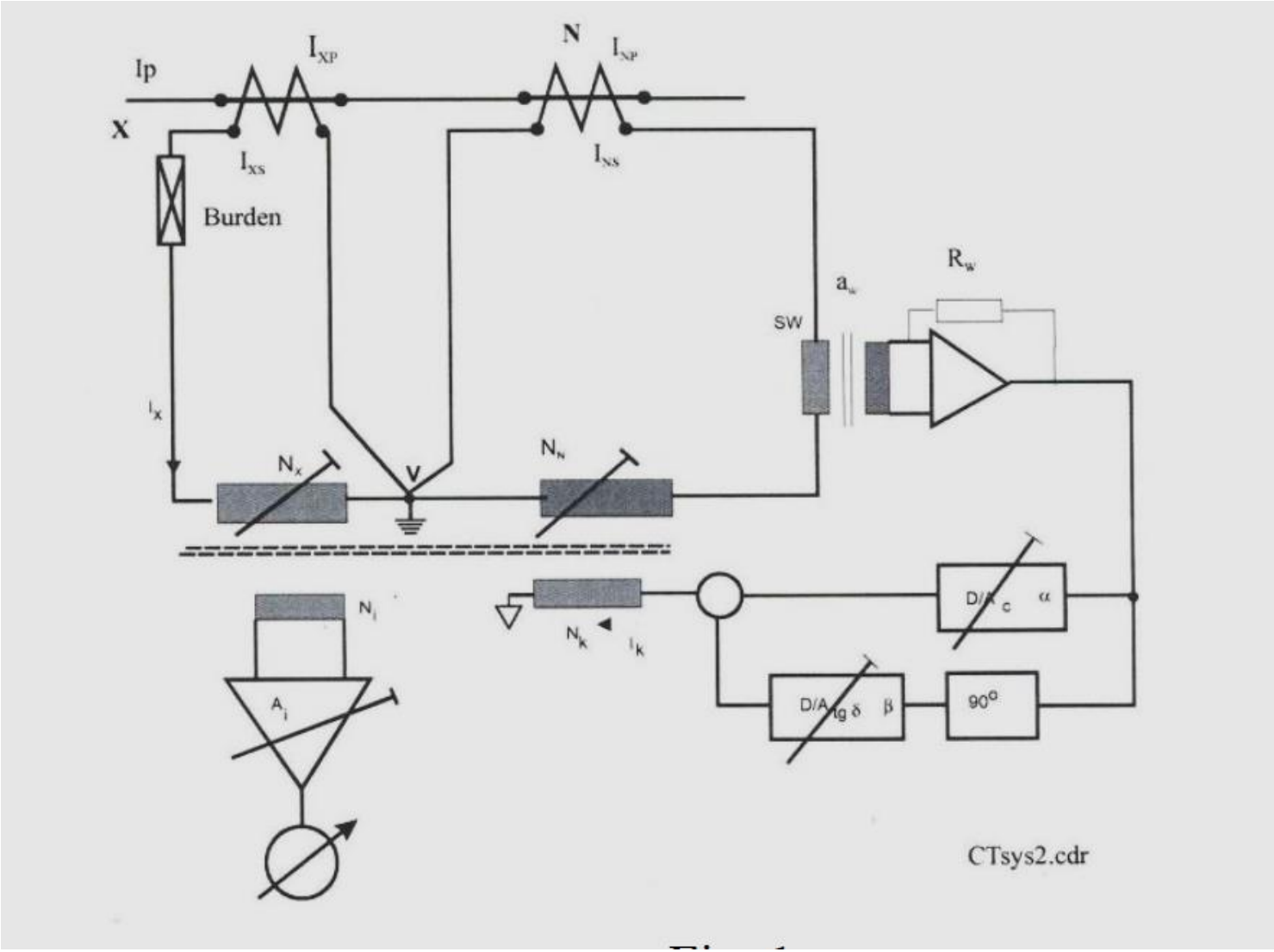
Ur: tensión proporcional a In

Ud: tensión proporcional a Ix/In

Error: proporcional a Ud/Ur

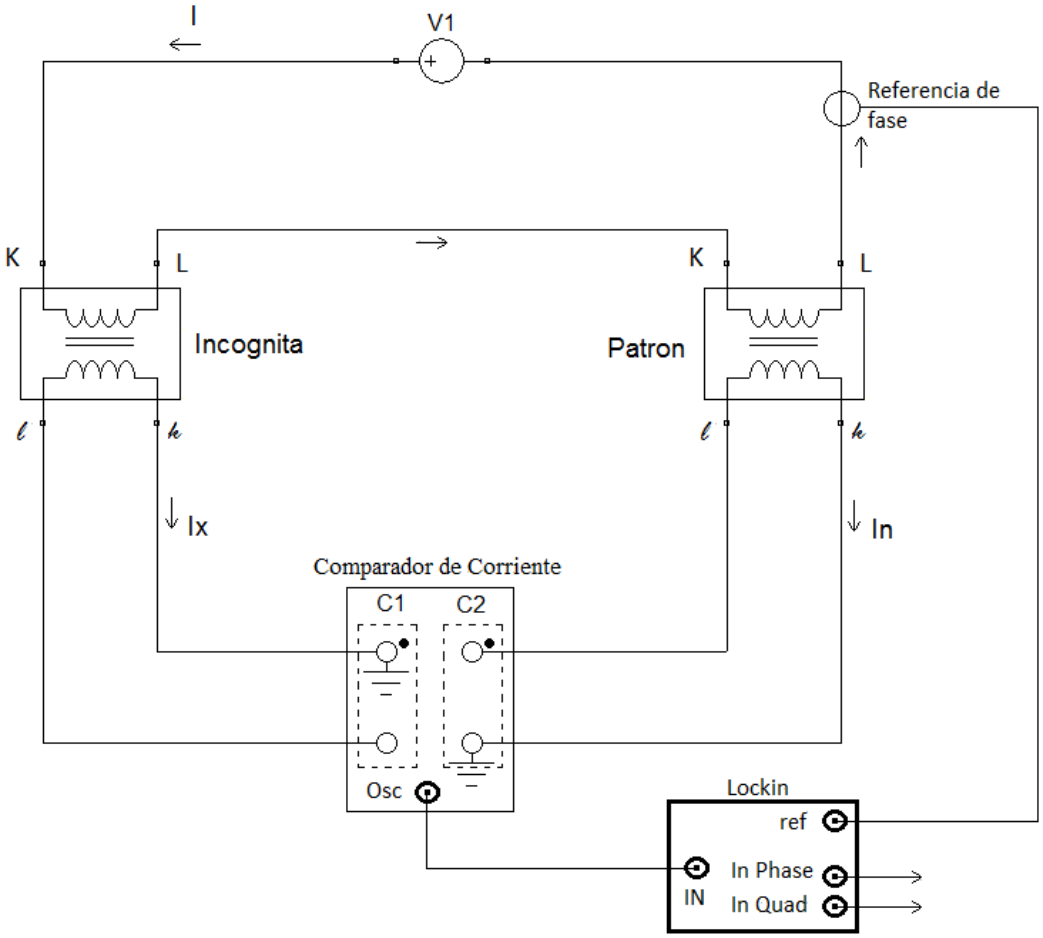
Ambas tensiones medidas como fasores (magnitud y fase).

Comparador de corriente con realimentación



Comparador de corriente automático

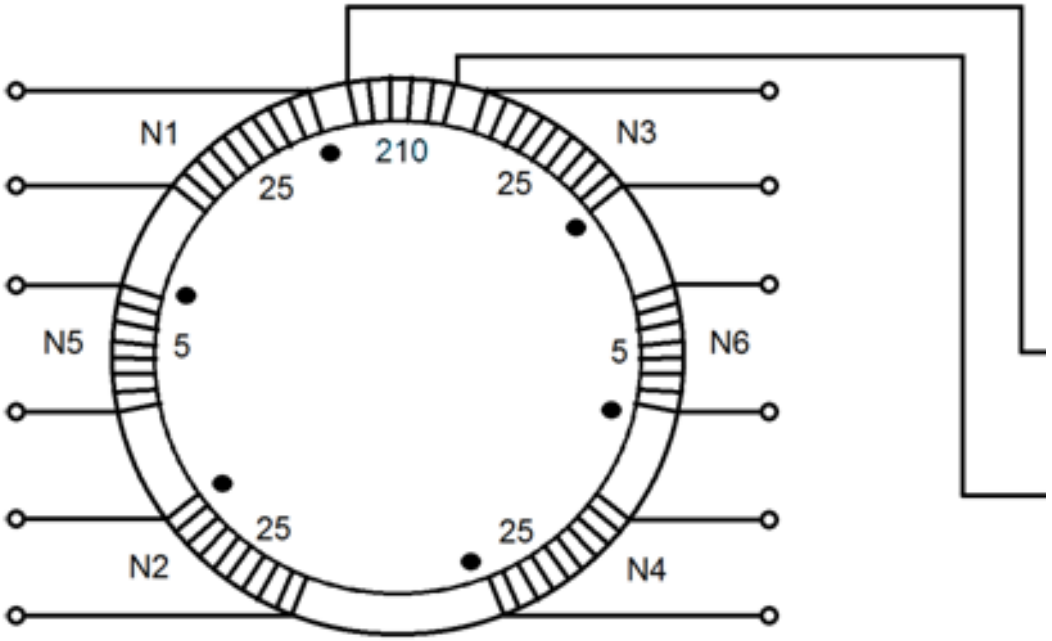
Comparador de corriente sin realimentación



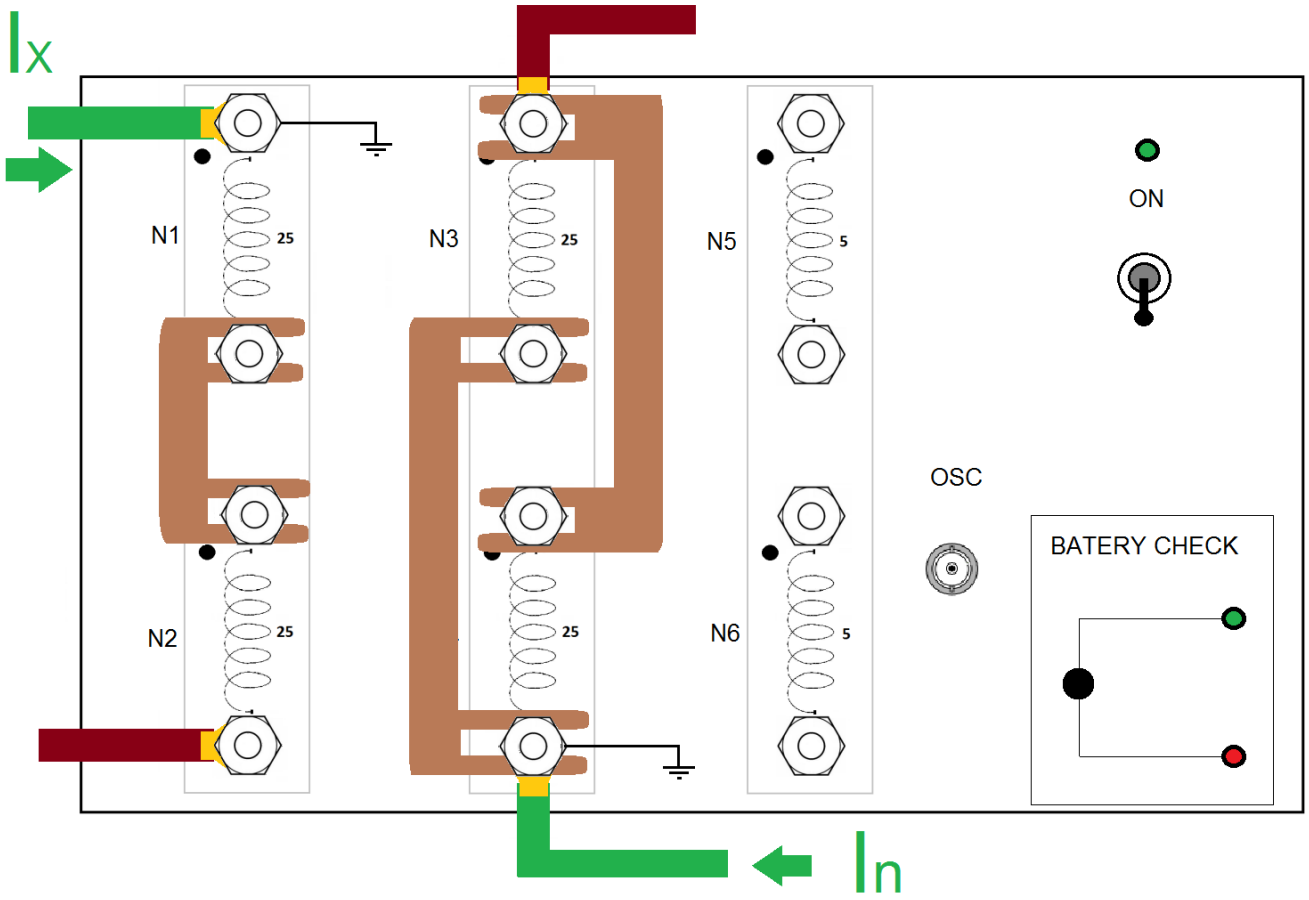
High-Precision Current Comparator for Current Transformer Calibrations, Daniel Slomovitz, Gonzalo Aristoy , Leonardo Trigo, Alejandro Santos, X SEMETRO, 2013.

Comparador de corriente UTE

- Toroidal mu-metal core with 6 identical primary windings (rope type).
- Each winding: 5 x 5 turns.

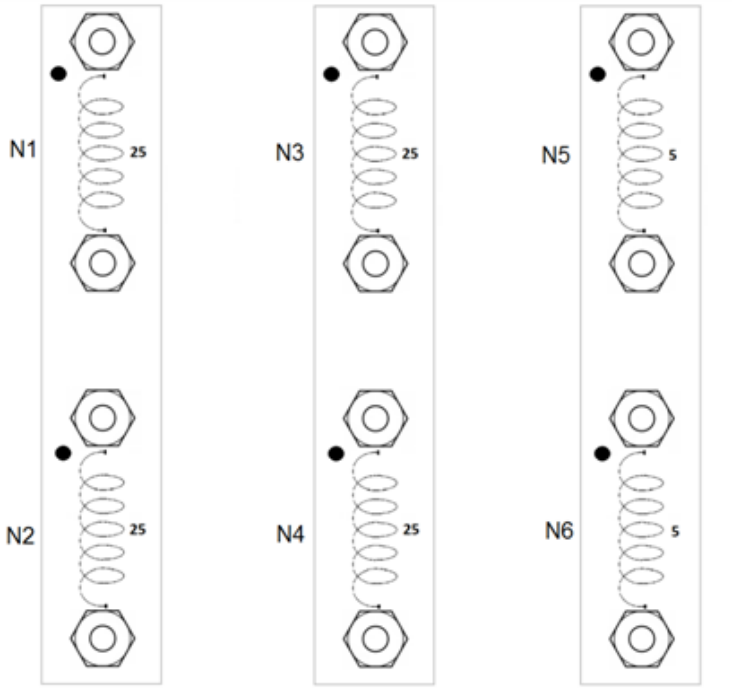


Series-parallel connections

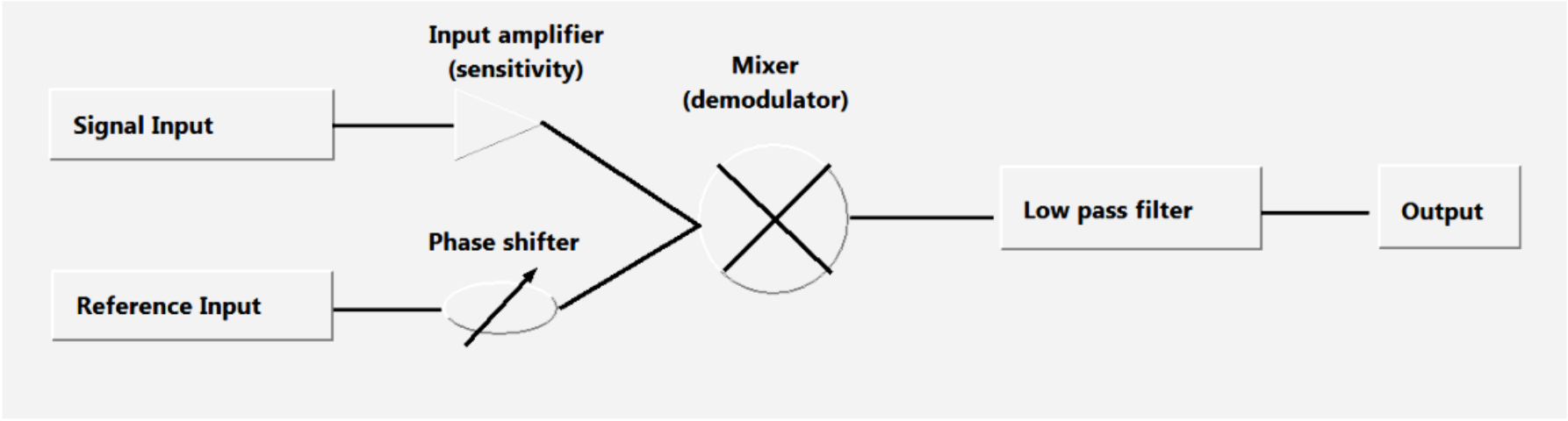


Ratios

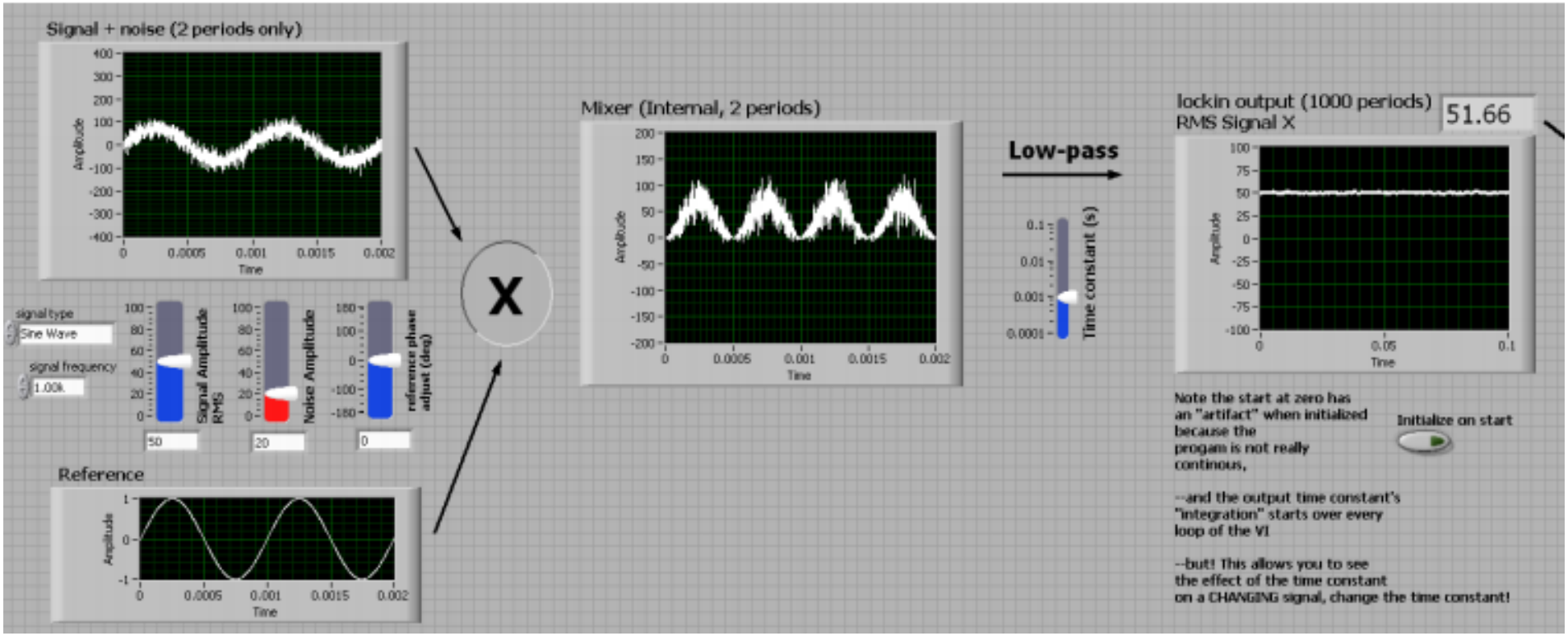
Ratio	s: series, p: paralell	Turns
1	N1 s N2 Vs N3 s N4 N1 p N2 Vs N3 p N4	50 Vs 50 25 Vs 25
2	N1 s N2 Vs N3 p N4 N1 p N2 Vs N3 s N4	50 Vs 25 25 Vs 50
2.5	N1 p N2 Vs N5 s N6 N3 p N4 Vs N5 s N6	25 Vs 10 25 Vs 10
5	N1 p N2 Vs N5 p N6 N3 p N4 Vs N5 p N6	25 Vs 5 25 Vs 5
10	N1 s N2 Vs N5 p N6 N3 s N4 Vs N5 p N6	50 Vs 5 51 Vs 5



Amplificador Lock-in



Amplificador Lock-in



Amplificador Lock-in

$$v_s = \sum A_k \cdot \operatorname{sen}(k\omega t + \varphi_k)$$

$$v_r = B \operatorname{sen}(\omega t)$$

$$\frac{1}{T}\int_0^T v_s \cdot v_r \, dt = \frac{B}{T}\int_0^T \operatorname{sen}(\omega t)\cdot \sum A_k \operatorname{sen}(k\omega t + \varphi_k)\, dt$$

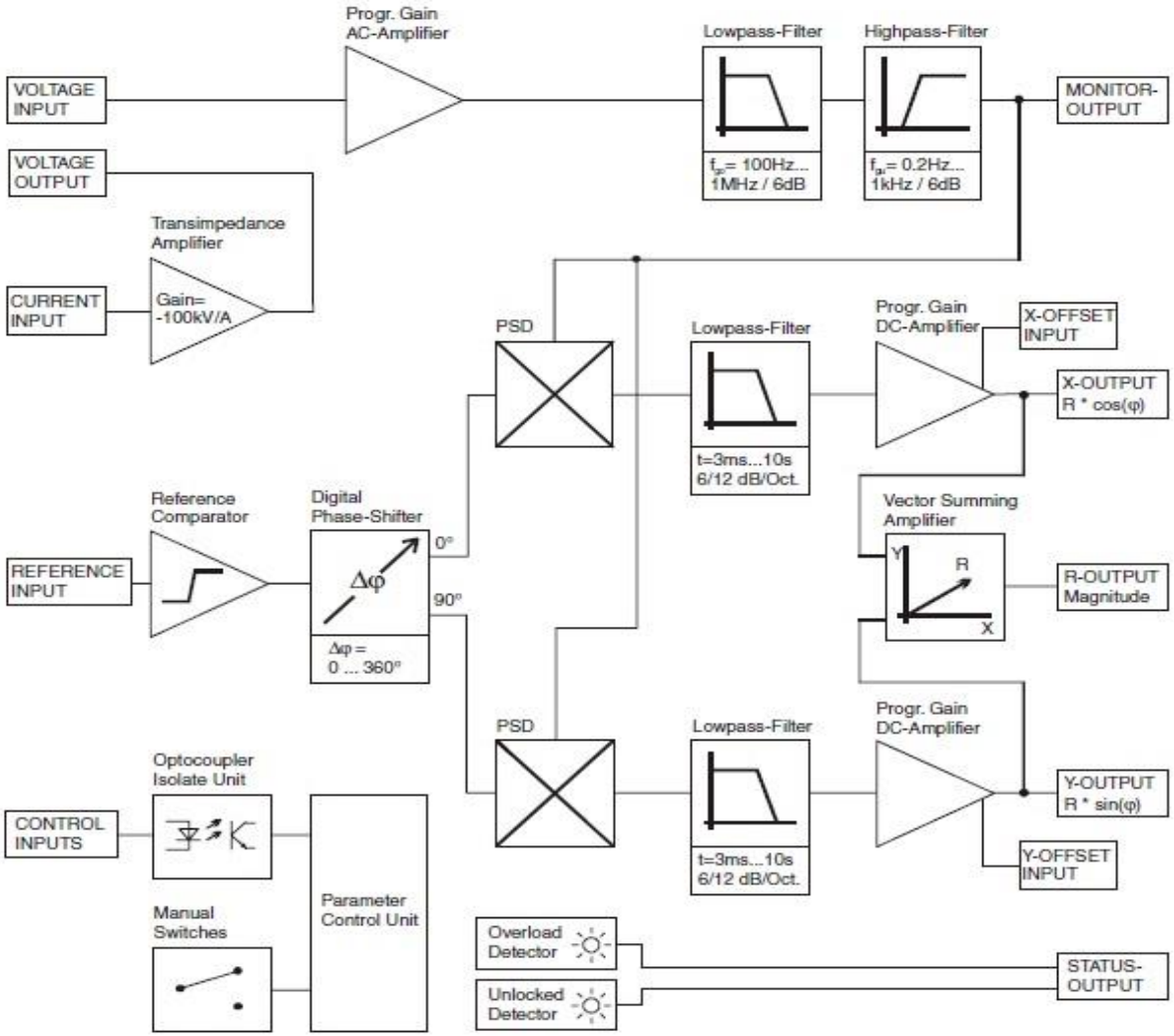
$$= \frac{B}{T}\int_0^T \operatorname{sen}(\omega t)\, A_1 \cdot \underbrace{\operatorname{sen}(\omega t + \varphi_1)}_{\operatorname{sen}(\omega t)\cos(\varphi_1) + \cos(\omega t)\operatorname{sen}(\varphi_1)}\, dt$$

$$= \frac{B}{T}\int_0^T [\operatorname{sen}^2(\omega t)\cos(\varphi_1) + \underbrace{\operatorname{sen}(\omega t)\cos(\omega t)\operatorname{sen}(\varphi_1)}_{\to 0}]\, dt$$

$$= \frac{BA_1}{T}\cos(\varphi_1)\underbrace{\int_0^T \operatorname{sen}^2(\omega t)\, dt}_{1/2} = \frac{BA_1}{2}\cos\varphi_1$$

t/2-sen(2t)/4

Amplificador Lock-in comercial



Uncertainty budget

Factor	Contribution $x10^{-6}$
Uncertainty type A	0,03
External Magnetic field	0,10
Shunt resistor	0,03
Stray capacitances	0,01
Magnetizing impedance	0,00
Electronic amplifiers	0,02
Multimeters	0,03
Combined unc. k=2	0,23

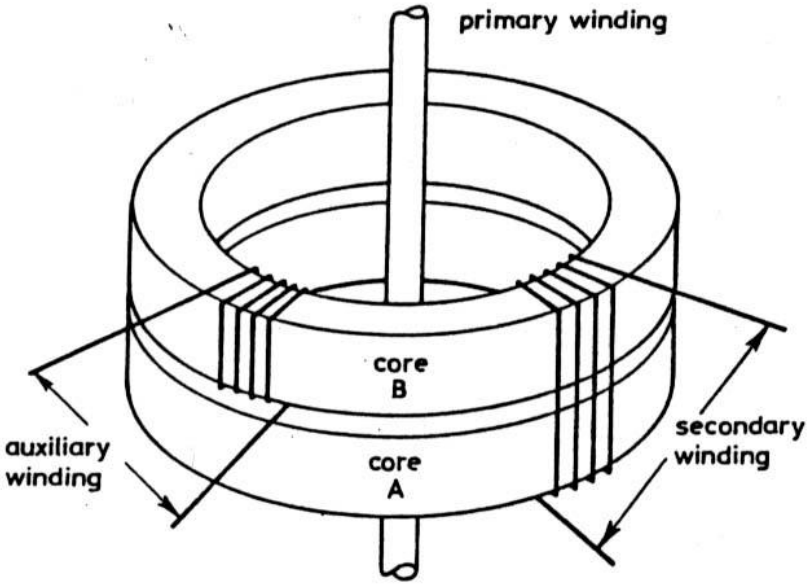
Transformadores patrones

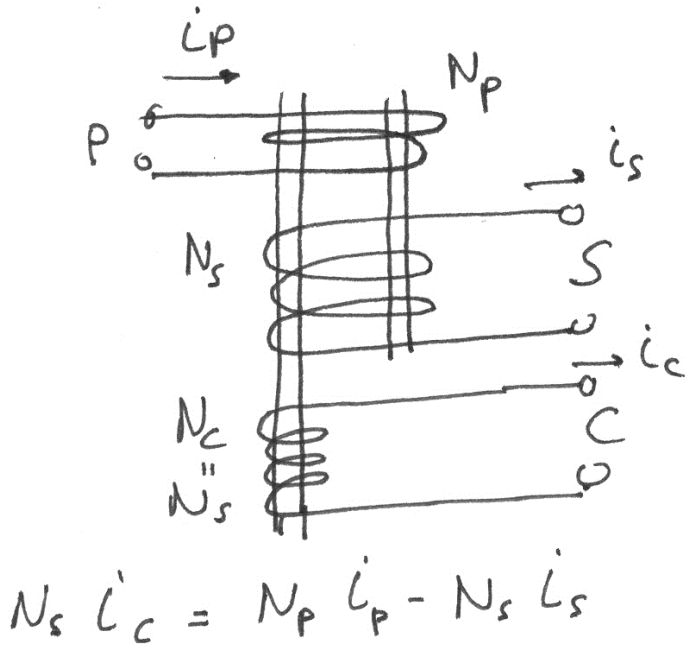
- Rangos de corriente
- Clase de precisión
- Potencia de precisión

- Relación de transformación: 5 . . . 1200 / 5 A
- Exactitud: ± 0,005 % ± 0,5’ para corriente comprendida entre el 1 % y el 120 % de I_n
- Carga sobre el bobinado principal: 5 VA (Bornes S)

Two-stage standard transformer

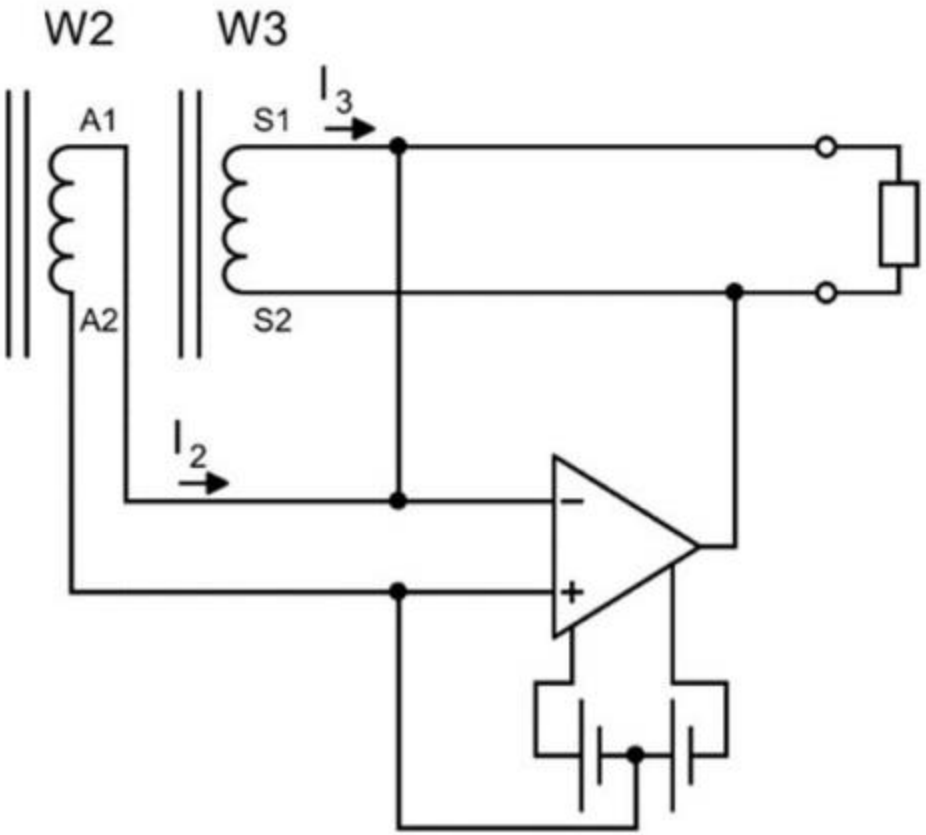
(Betts, 1983)





- Errors lower than 10 μA/A and 10 μrad can be achieved.
- Using only one stage, errors increase up to 350 μA/A and 500 μrad.

Transformador doble etapa

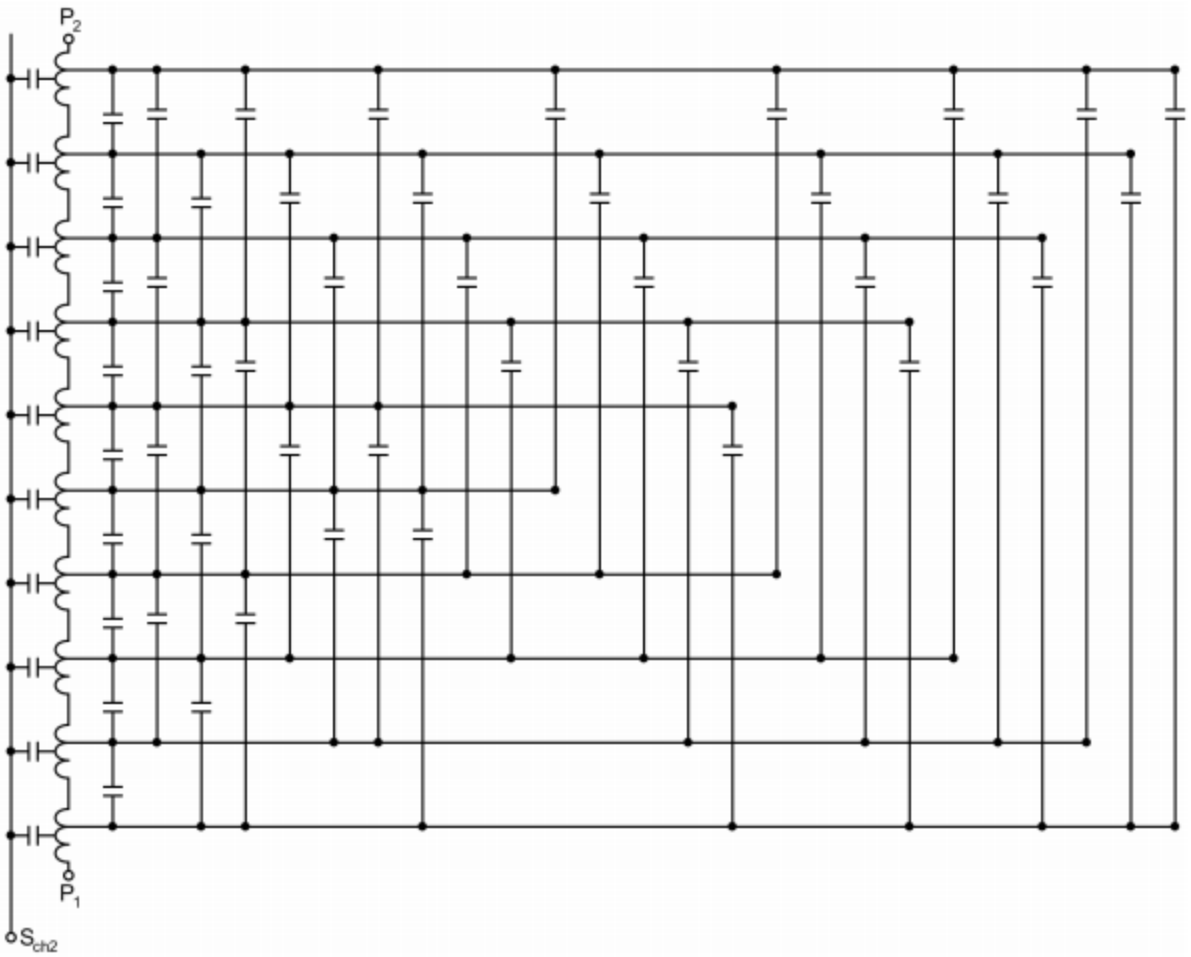


Sumador electrónico de corriente de compensación.

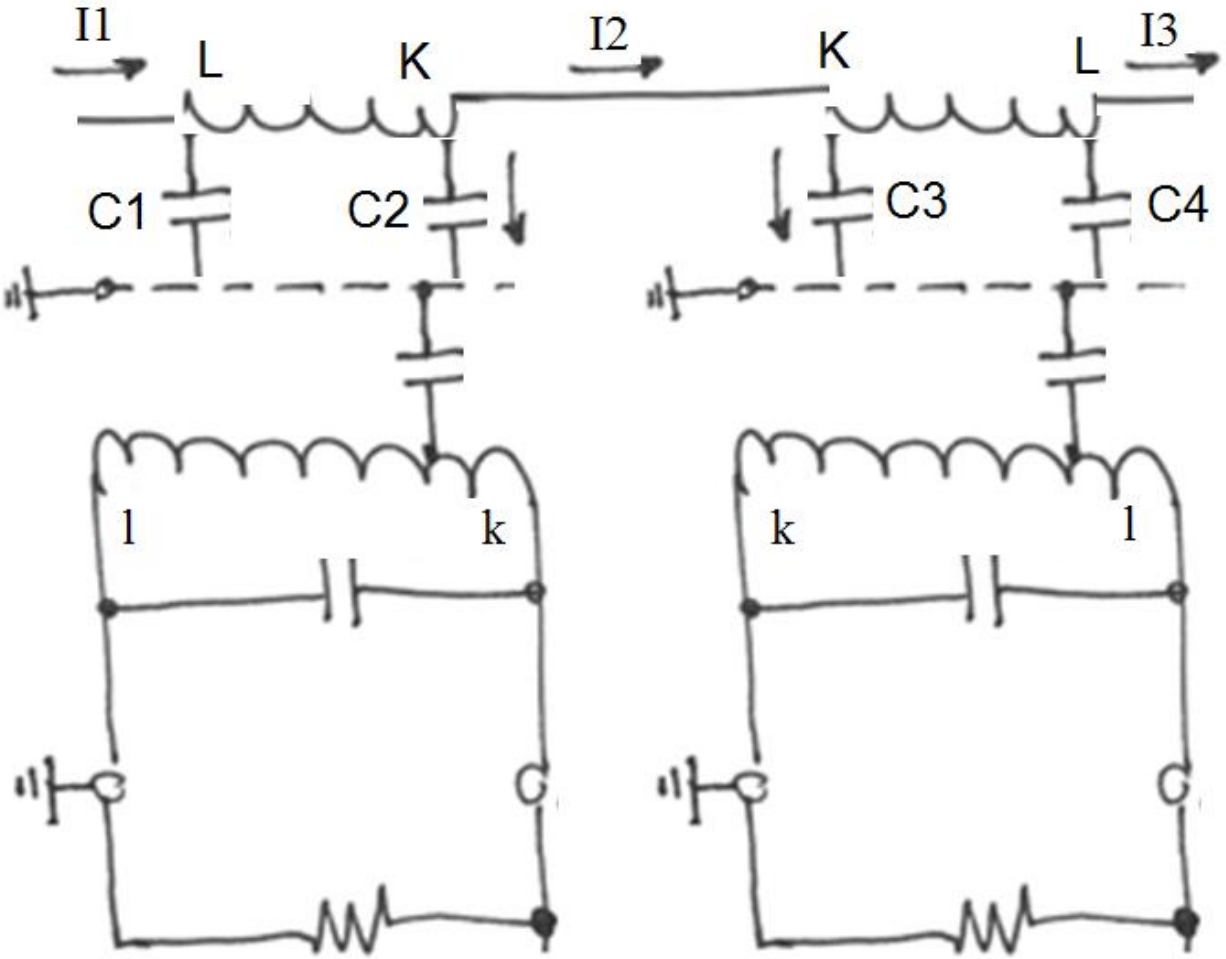
I3: corriente secundaria
I2: corriente de compensación.

D. Slomovitz, A. Santos, R. Sandler and G. Barreto, "High-Precision Self-Calibrating Current Transformer With Stray Capacitances Control," in *IEEE Transactions on Instrumentation and Measurement*, vol. 70, pp. 1-9, 2021

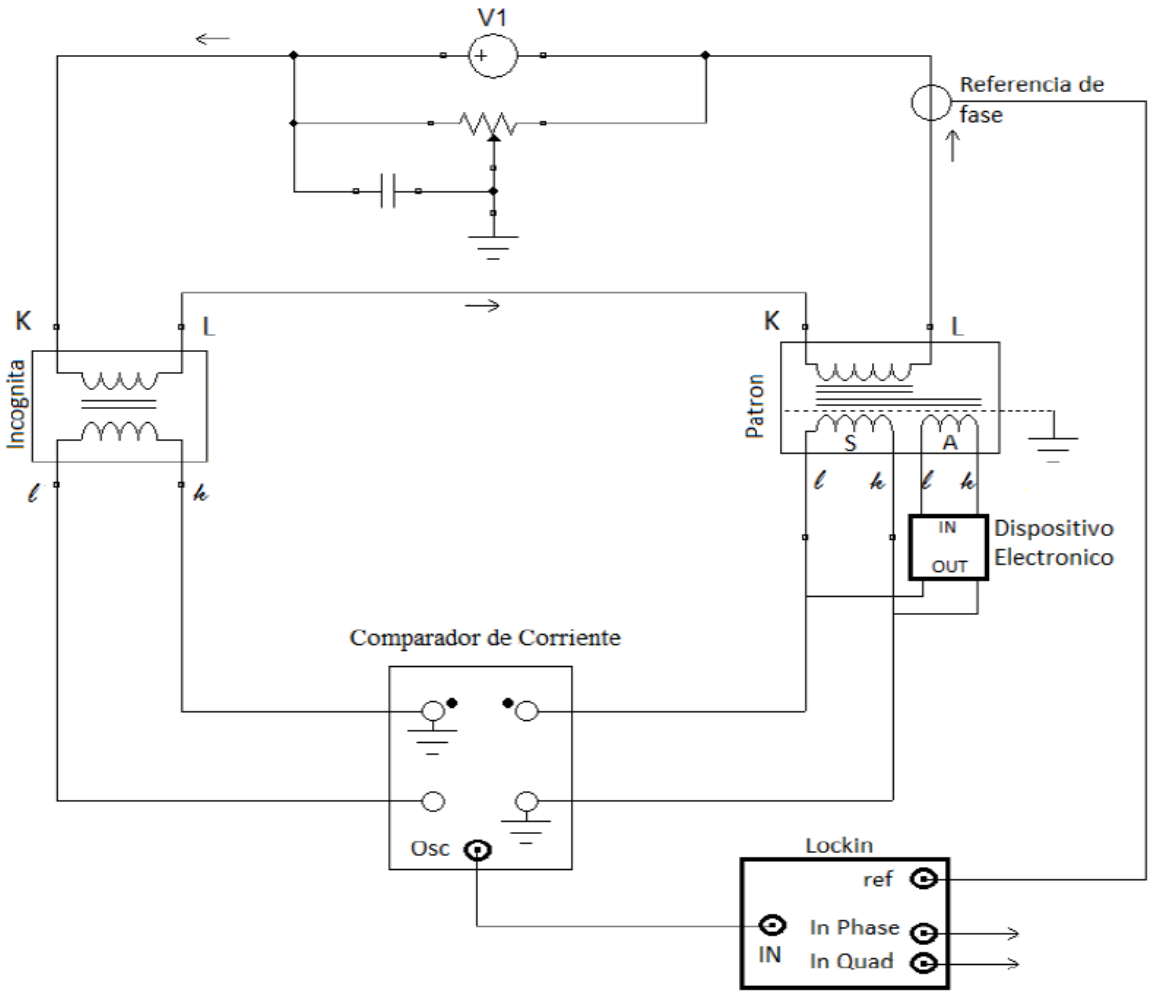
Capacidades parásitas



Capacidades parásitas



Tierra de Wagner



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