Ferroelectric measurement

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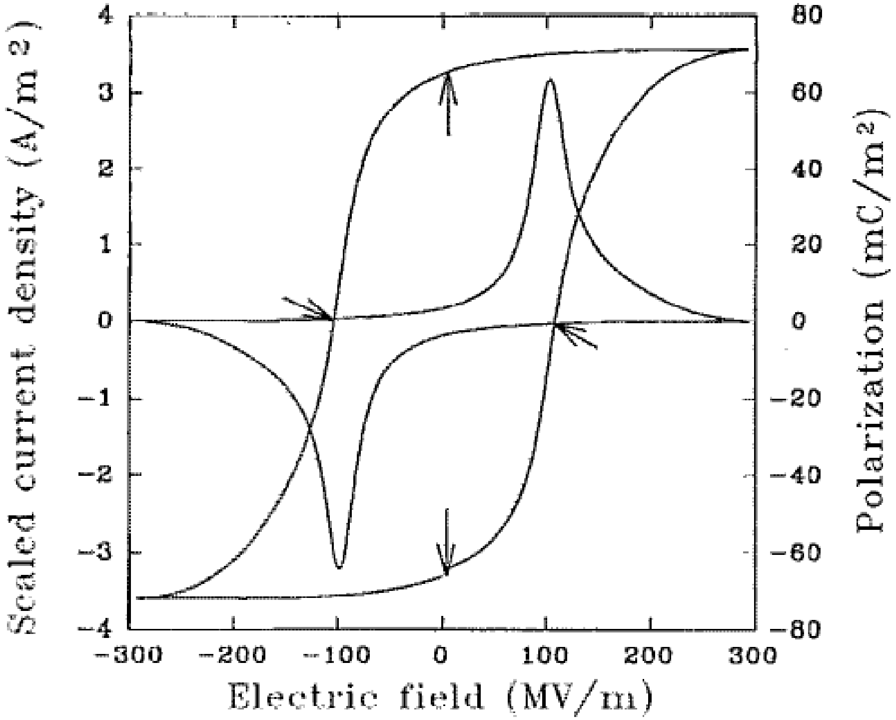
Prof. Xu's Group meeting

Direct I-V measurement



$$i = icap + ip + icond = Cs\frac{dV_s}{dt} + As\frac{dP_s}{dt} + \frac{V_s}{R_s}$$

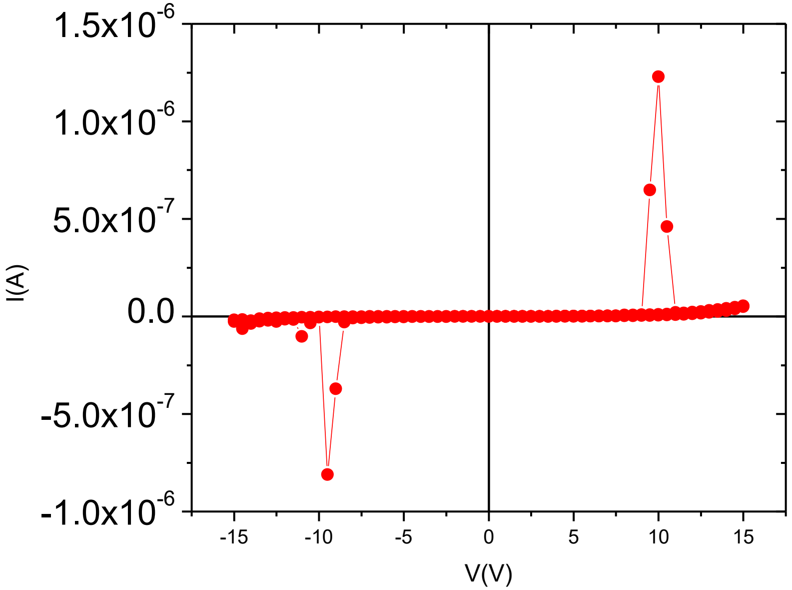
There are three instantaneous current components in the series circuit, polarization current (i_p), conductive current ($I_{cond,}$ if sample is lossy) and current due to stray linear capacitances (I_{Cap}).

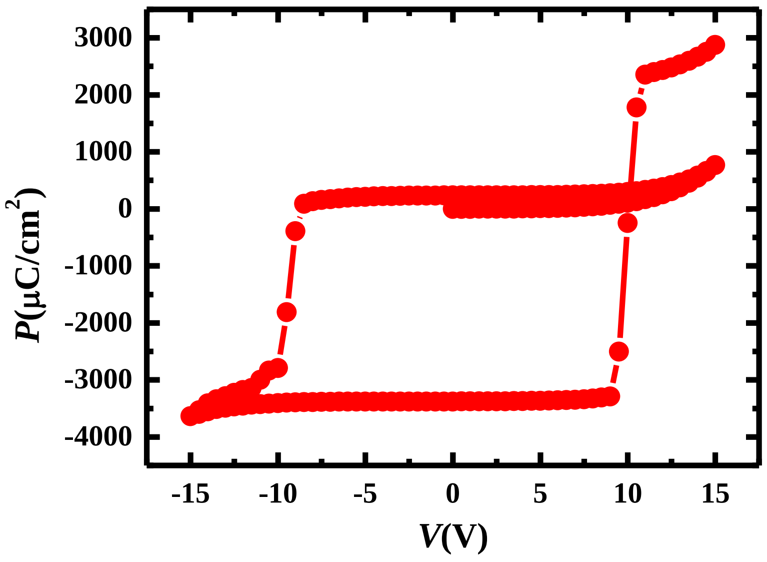
$$Q = \int I\,dt = \int 24I\,dV$$

$$\frac{dV}{dt} = 15V/6min \quad dt = 24dV(sec/Volt)$$

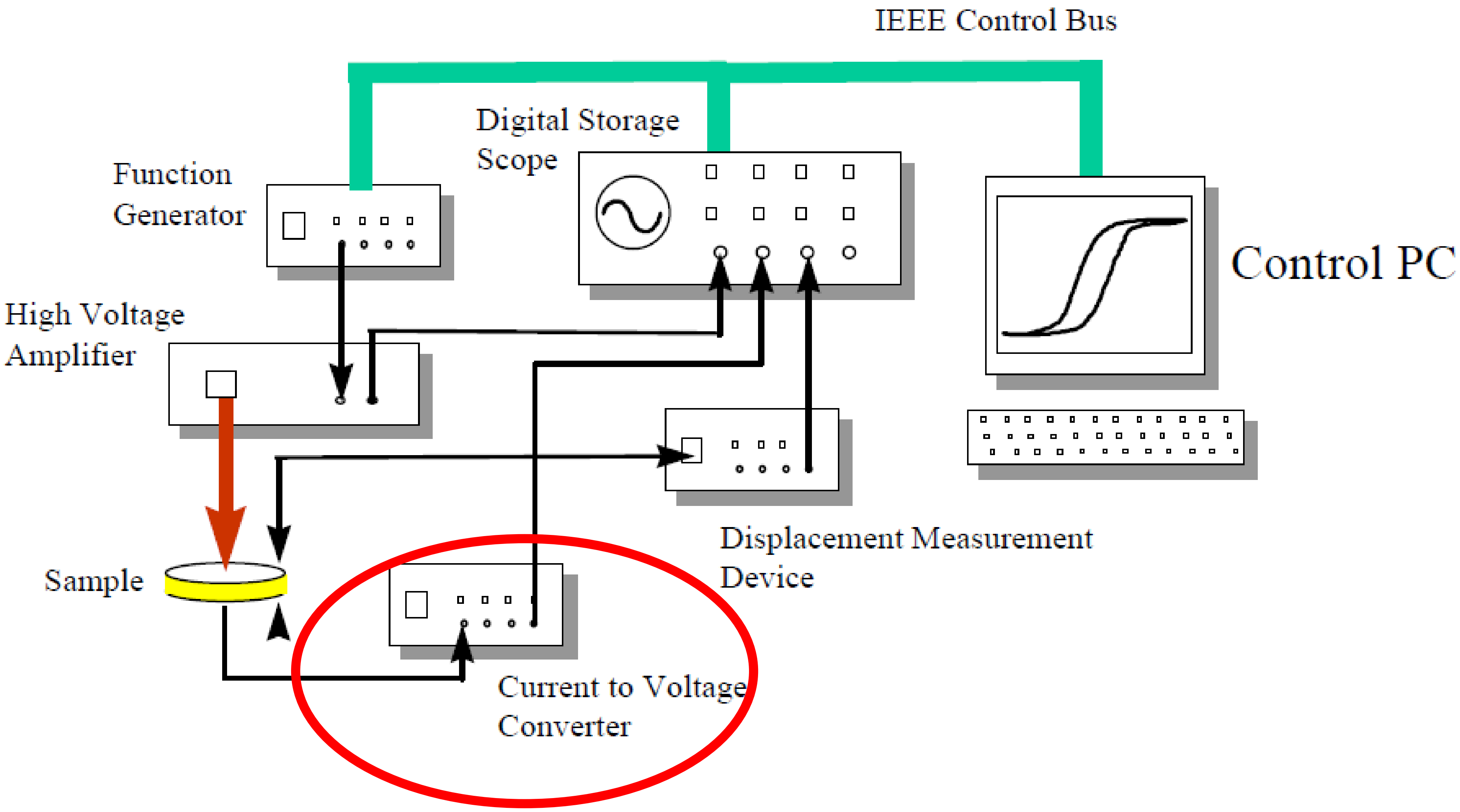
$$P = Q/A \qquad A \sim 0.005cm^2$$

The P is too large, cannot be real.



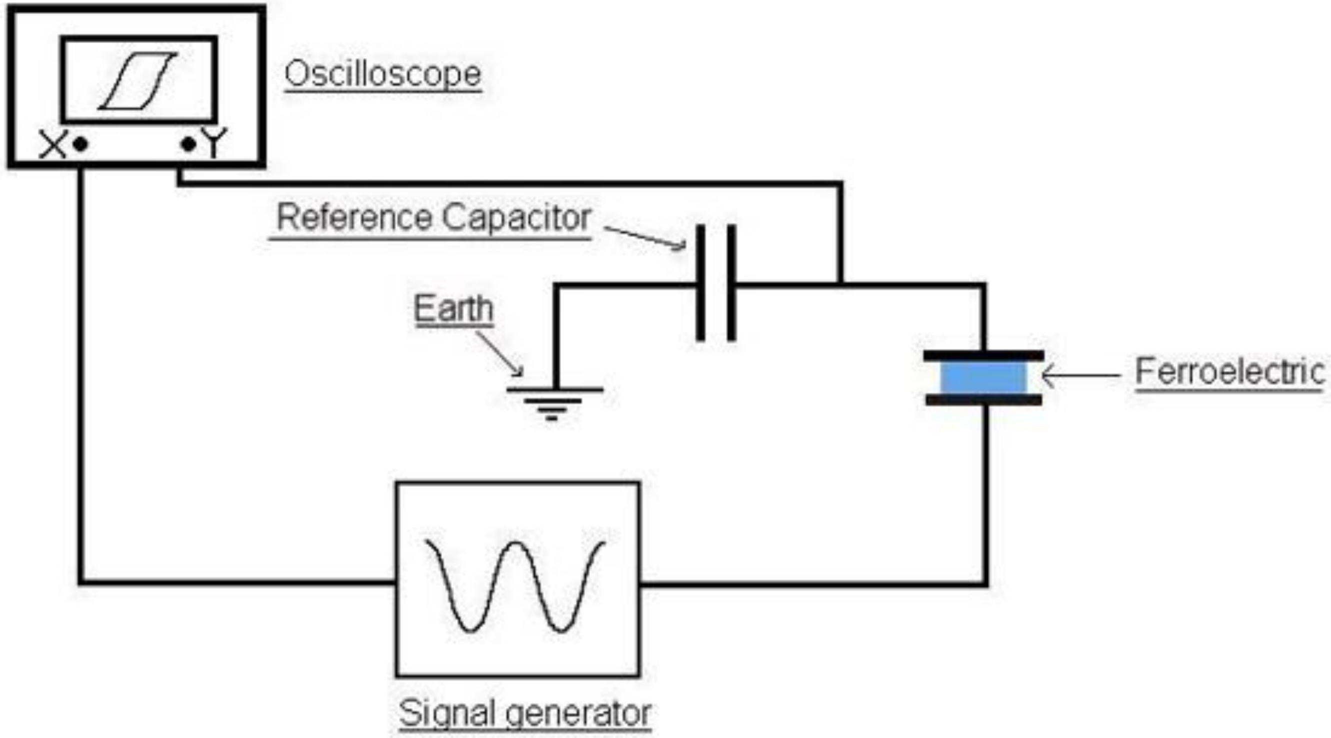


Ferroelectric measurement setup

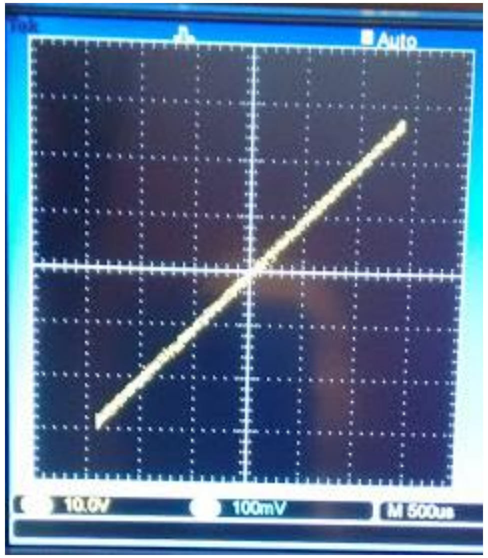


Sawyer-Tower (ST) circuit measurement

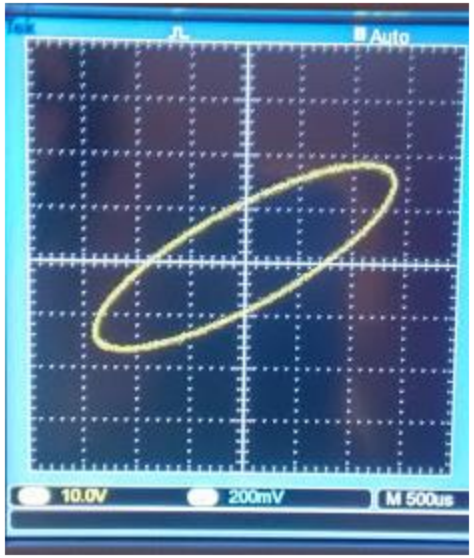
The circuit consists of two capacitors, one due to sample (C_x) and other one is a linear-known-valued sense-capacitor (C_{sense}). They are in series, where C_{sense} is chosen much greater than C_x so that voltage drop across C_{sense} is much less than that across C_x (sample). So the drive voltage V_d is almost equal to voltage across C_x. The voltage across C_{sense},which gives polarization of the sample, is applied to
vertical plates of the oscilloscope and the drive voltage after safe attenuation is applied to horizontal plates of the oscilloscope to measure electric field across the sample.



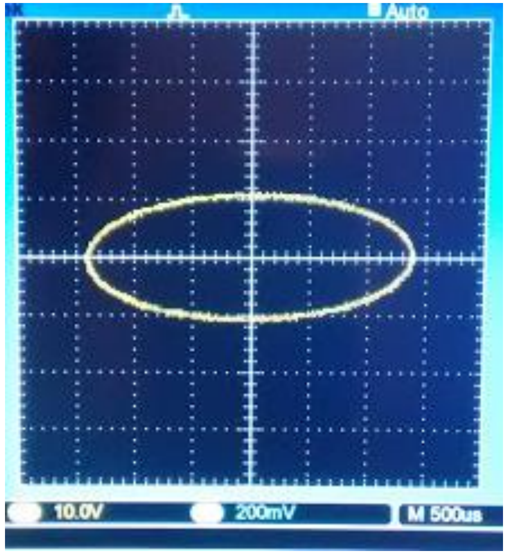
Lossy FE capacitor with leaky resistance and linear capacitance



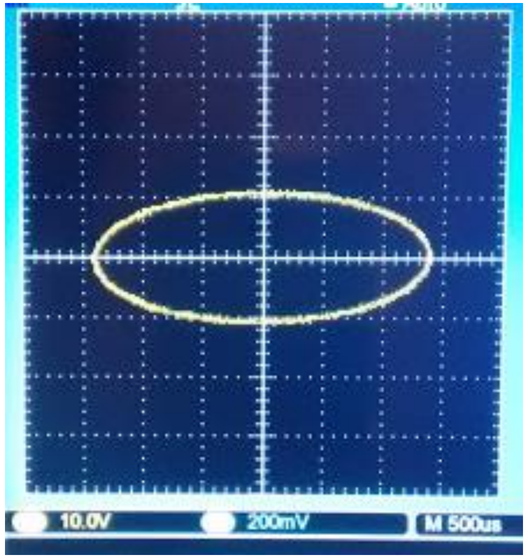
Ideal linear capacitor
0.1nF



Lossy capacitor
0.1 nF+2MOhm



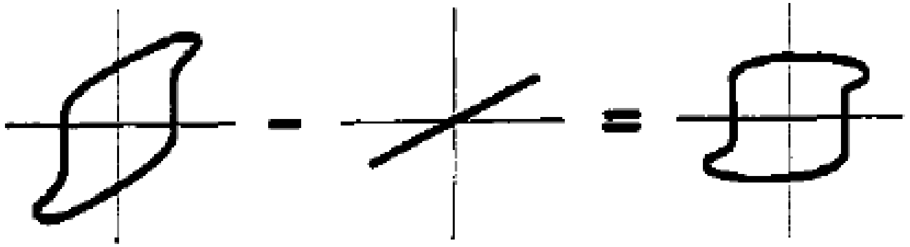
More lossy capacitor
0.1 nF+100 kOhm



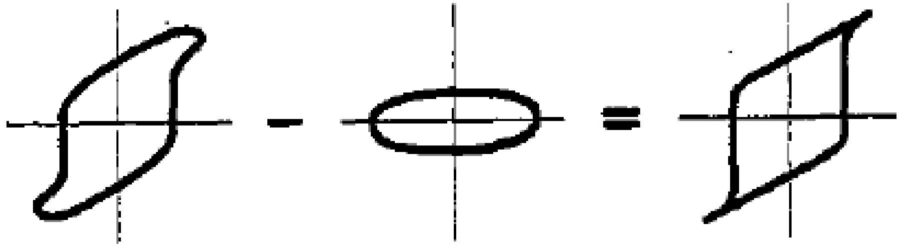
Ideal resistor
2MOhm

C_{sense}=10nF

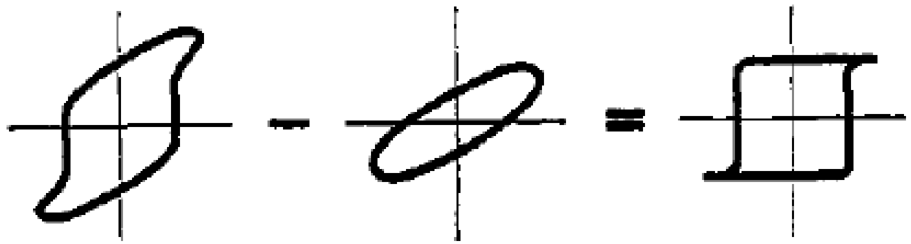
Compensate for the linear capacitance and lossy resistance



The linear capacitance can be compensated for by subtracting from the loop a straight line with the correct slope.

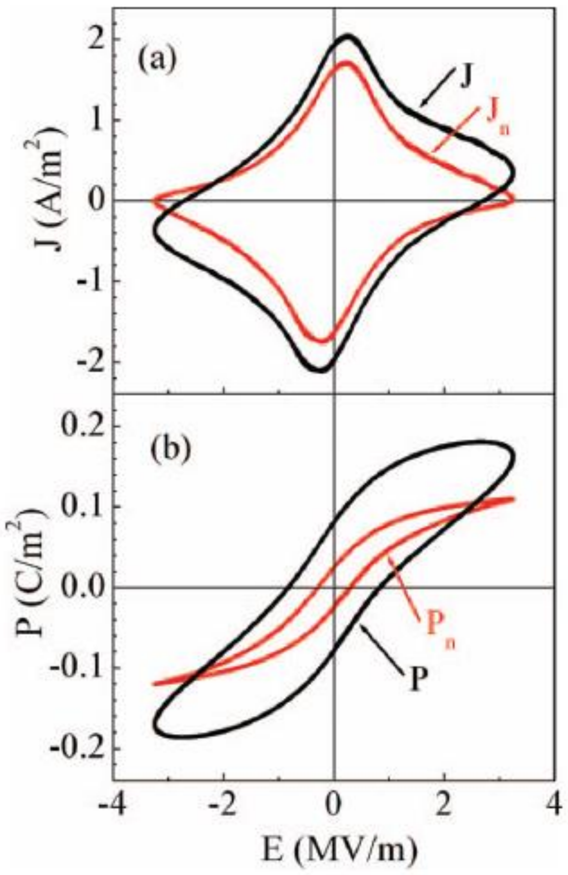


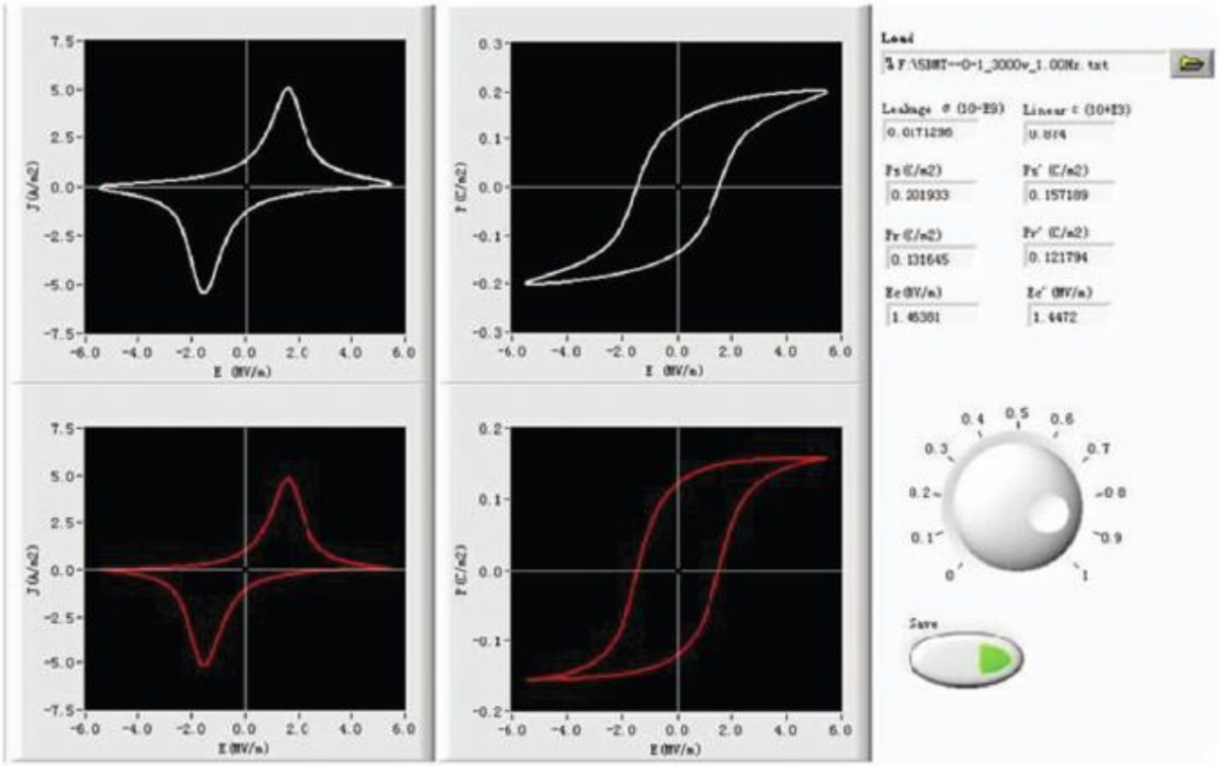
The losses can be compensated for by subtracting from the loop an ellipse of proper shape and ***size*** with its major **axis** along the E axis.



In the general, both losses and linear capacitance are compensated by producing an ellipse whose major **axis** ***can*** have any desired inclination with respect to the E axis and with any desired ratio ***a*** : ***b*** of the major to minor axis **.**

Computational compensate





$J = Jp + Jcap + Jco_{nd}$

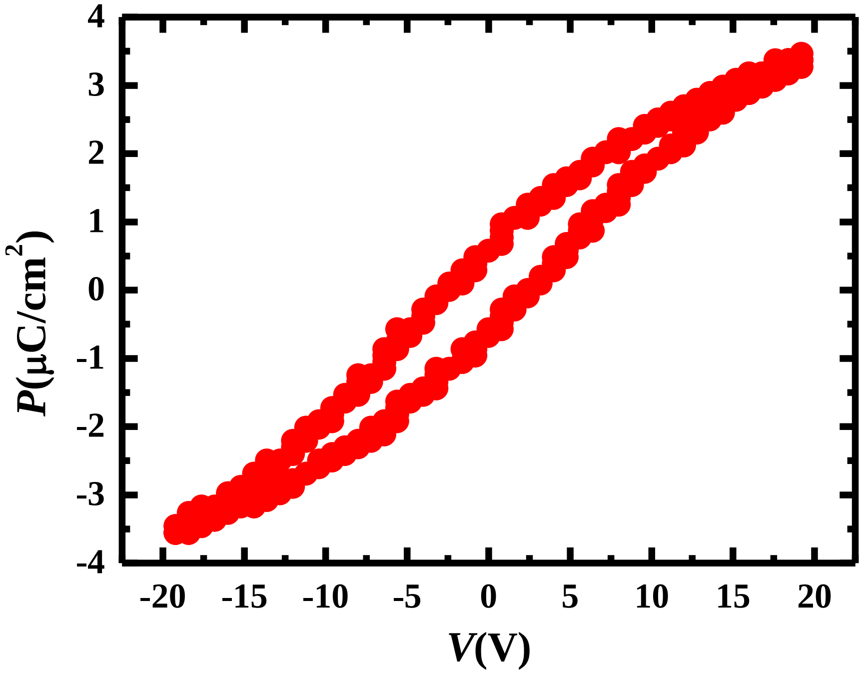
$E = Emsin(wt)$

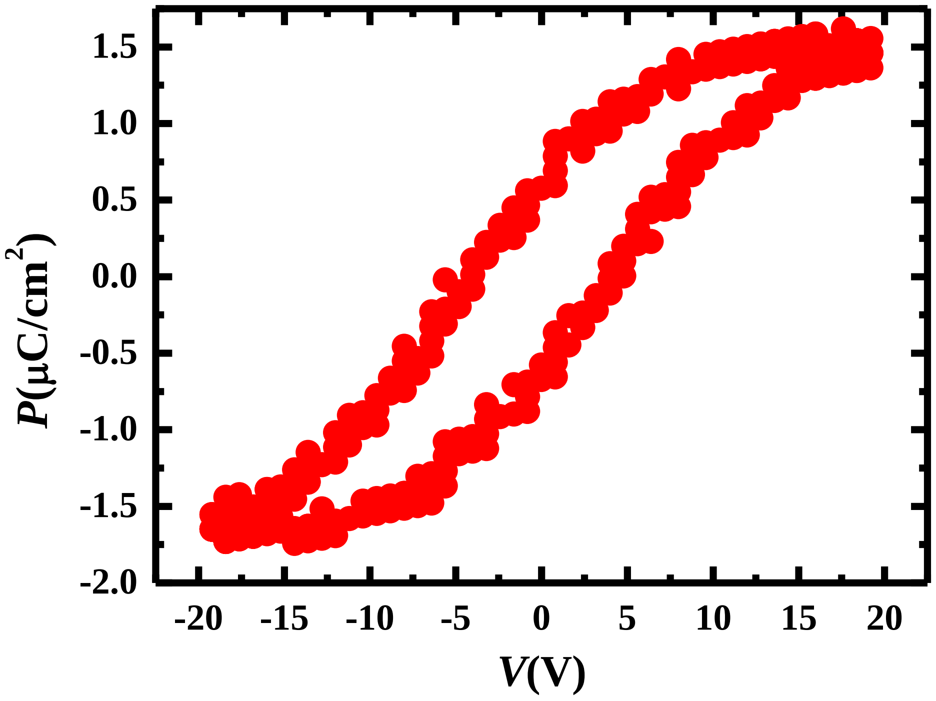
$J_{cap} = \varepsilon_0 \varepsilon \omega E_m cos(\omega t)$

$J_{cond} = \sigma E_m sin(\omega t)$

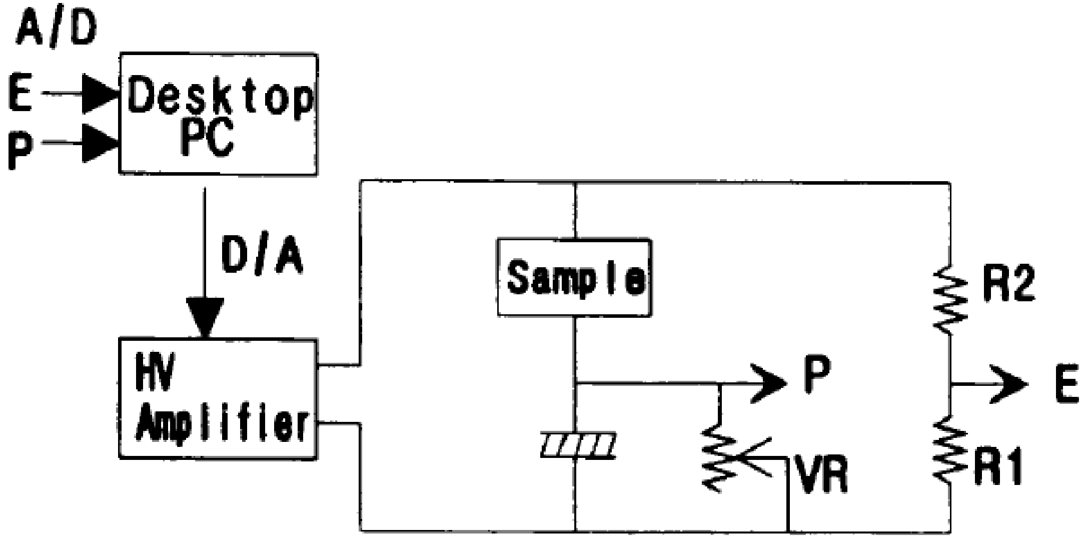
Ferroelectrics, 411:86–92, 2011

Ferroelectric loop for BTO-3





Compensate loss resistor-1965



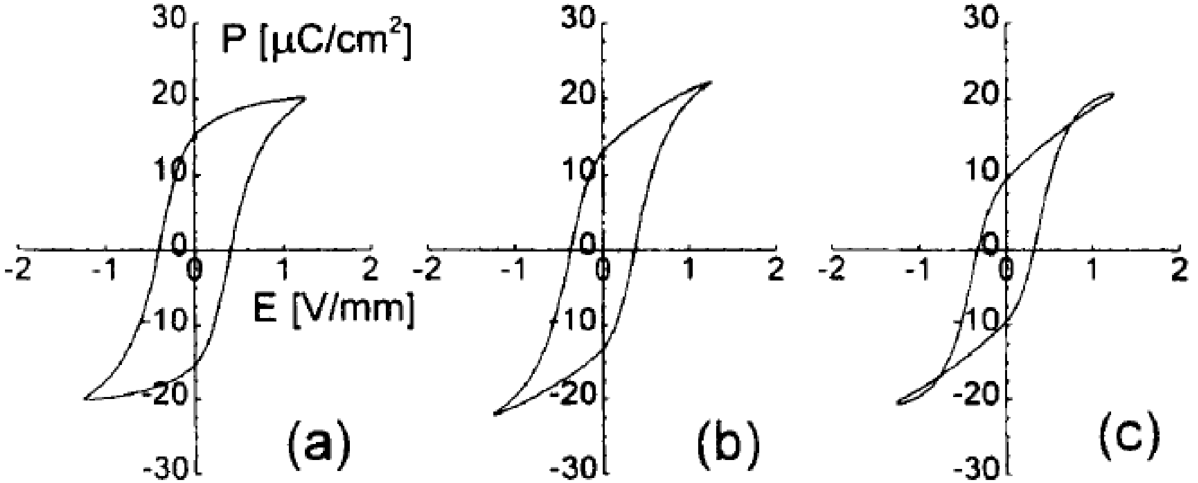


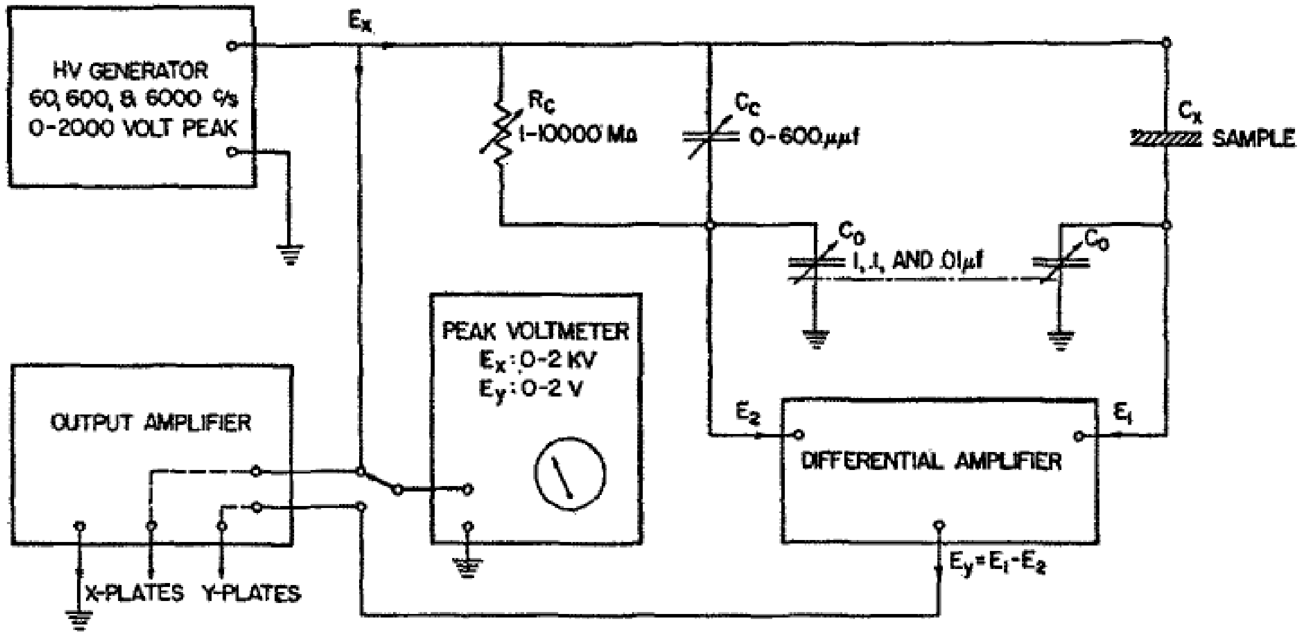
Figure 4 P-E plots of the PZT at the electric-field of 1.5KV/mm with variation of the magnitude of VR. (a) VR, high. (b) VR, properly adjusted. (c) VR, low.

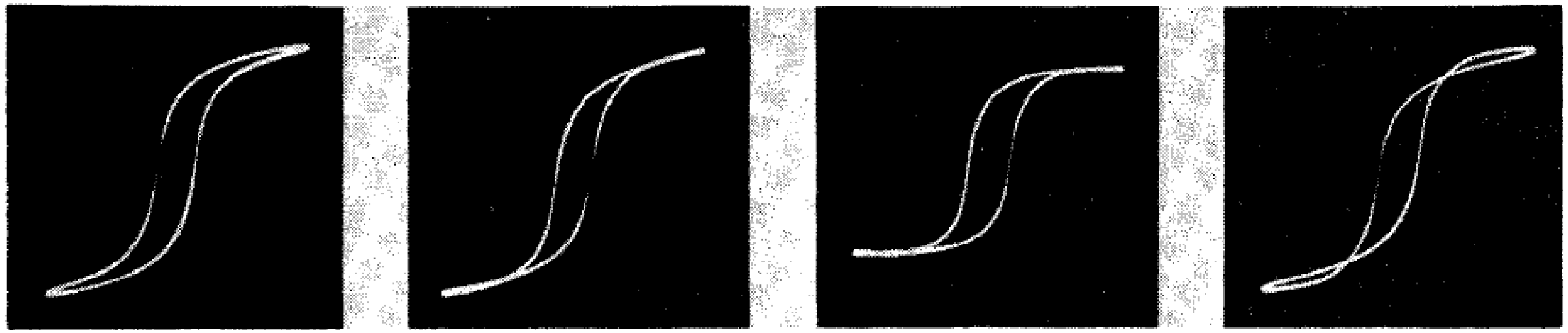
$C_s R_s = C_{sense} R_{sense}$

Ferroelectrics, 230:1, 151-156

Bridge circuit-1957

Adjusting *Rc* to equal the sample resistivity *Rs* removes the rounded ends of the displayed hysteresis loop. The residual capacitance *Cr* can be compensated and measured by adjusting *Cc* to produce a hysteresis loop ending in horizontal lines.



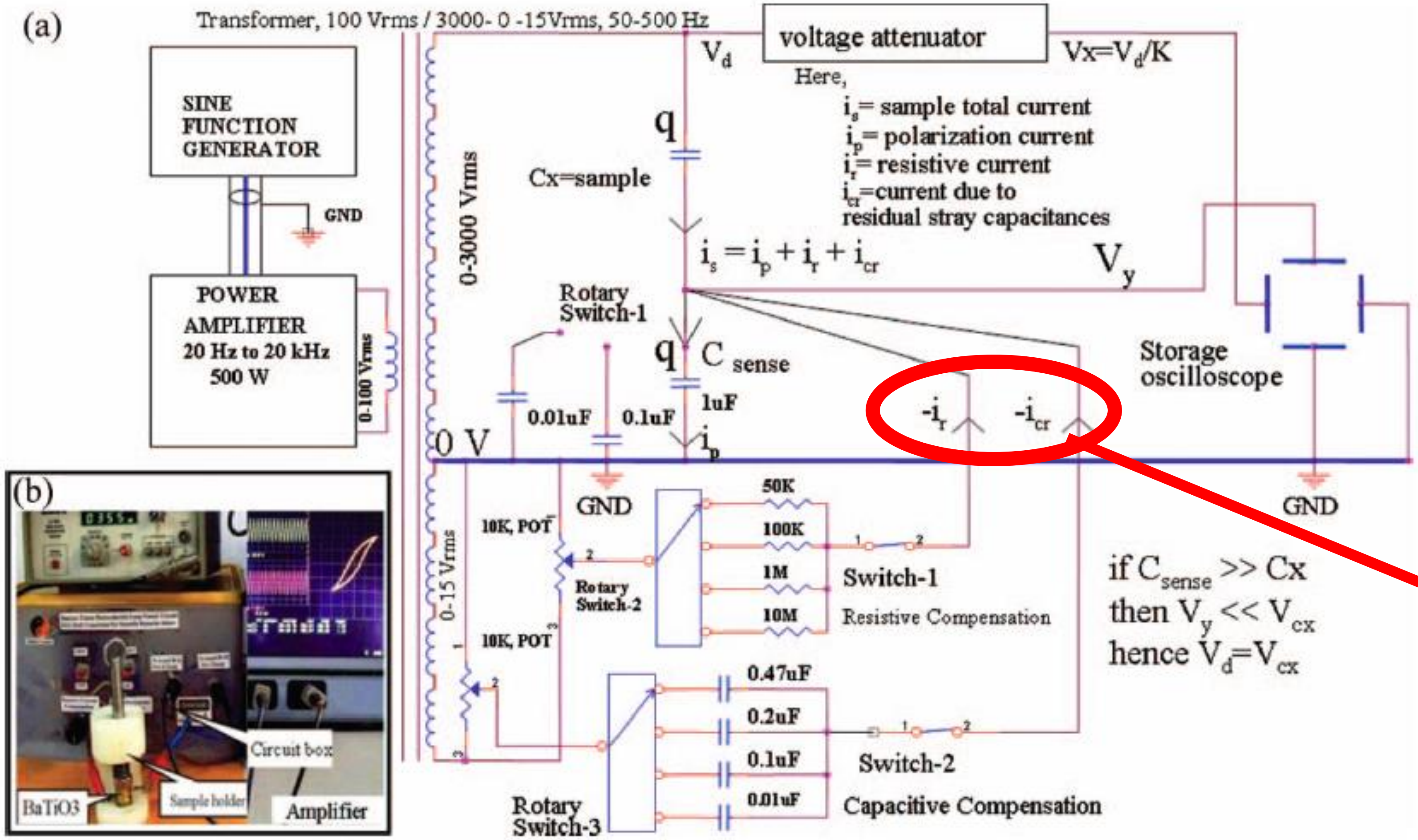


(a) (b) (c) (d)

FIG. 11. Rochelle salt with artificial conductivity ($\rho = 5.8\times 10^8\Omega$ cm); hysteresis loops as measured by hysteresis bridge. $V_0 = 500$ v, 60 cps; $A = 1.05$ cm^2, $b = 0.179$ cm, $Q_s = 0.22\mu$C, $t = 0$°C. (a) $R_c = \infty$, $C_c = 0$; (b) $R_c = 10^8\Omega$, $C_c = 0$; (c) $R_c = 10^8\Omega$, $C_c = 130\mu\mu f$; (d) $R_c = 5\times 10^7\Omega$, $C_c = 0$.

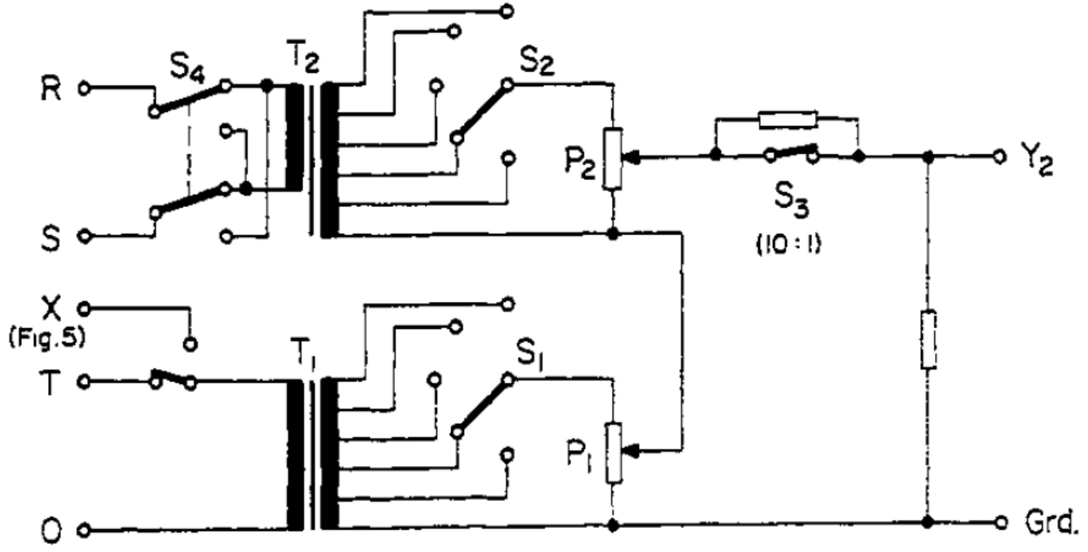
THE REVIEW OF SCIENTIFIC INSTRUMENTS, 28, 30, 1957

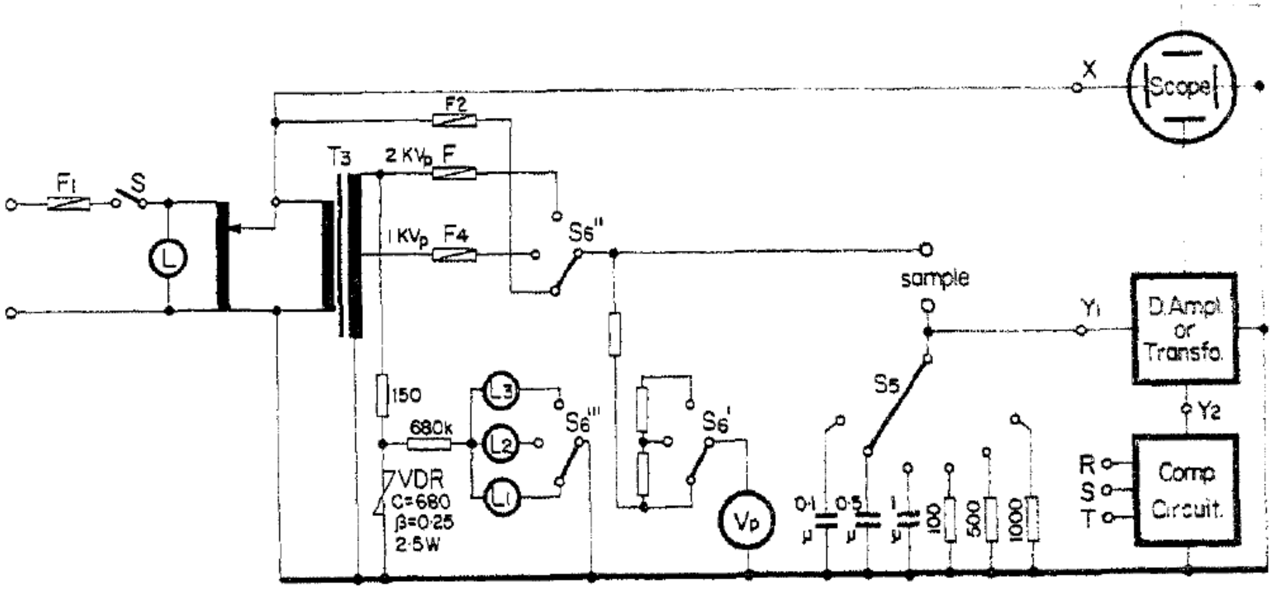
Negative current compensate



Compensate

3-phase supply-1962





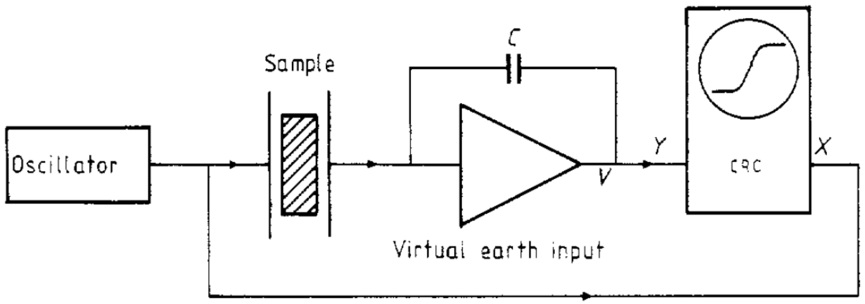
The points 0, T, S, Rrepresent the neutral point and the **three** phases of a three phase ***50*** c/s line.

Across the two secondaries of the transformers **Tl** and **Tz** we have two sinusoidal voltages 90" out of phase with each other. The two potentiometers **P1** and **Pz** and the two switches **S,** and **Sz** permit one to obtain any desired voltage. The connection between the two secondaries of the transformers is such that the two voltages add up so that the **sum** appears at point **Y2.** With switch **S3** a 10 : 1 voltage divider ***can*** be inserted.

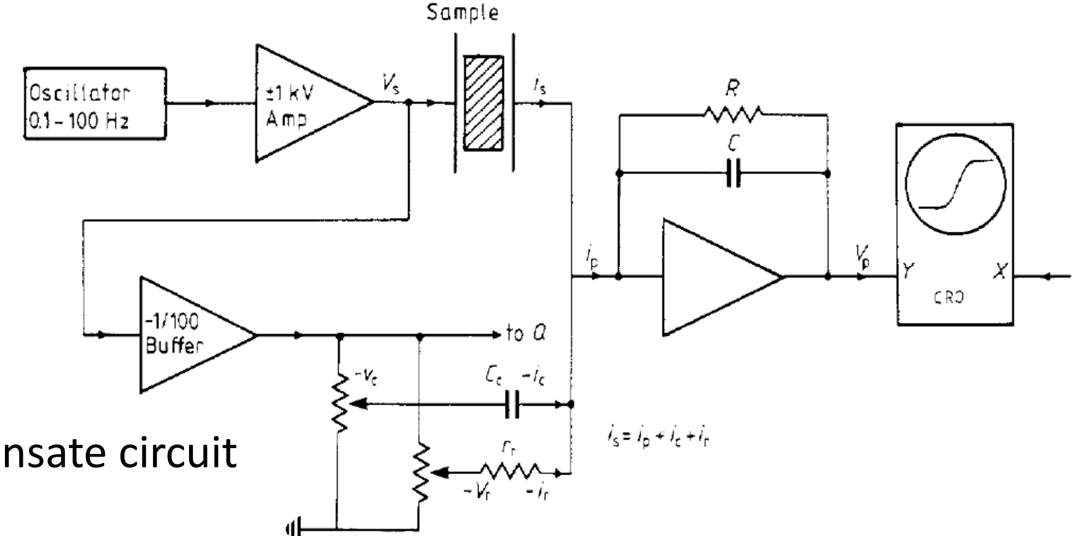
If the voltage applied to the ferroelectric sample has the same phase **as** T, then the switch **Sz** and the potentiometer **Pz** vary the ratio ***a*** : ***b*** of the two axes of the ellipses (**loss** compensation); the switch **S1** and the potentiometer **P1** **vary** the inclination of the major axis with respect to the E axk (linear capacitance compensation).

J. sa. INSTRUM., 1962, **VOL.** 39, 152

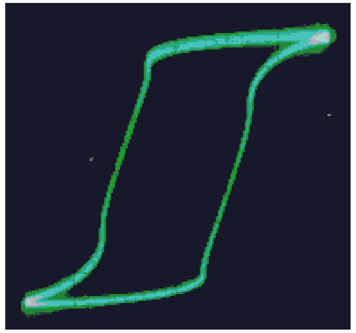
Current to charge converter-1983

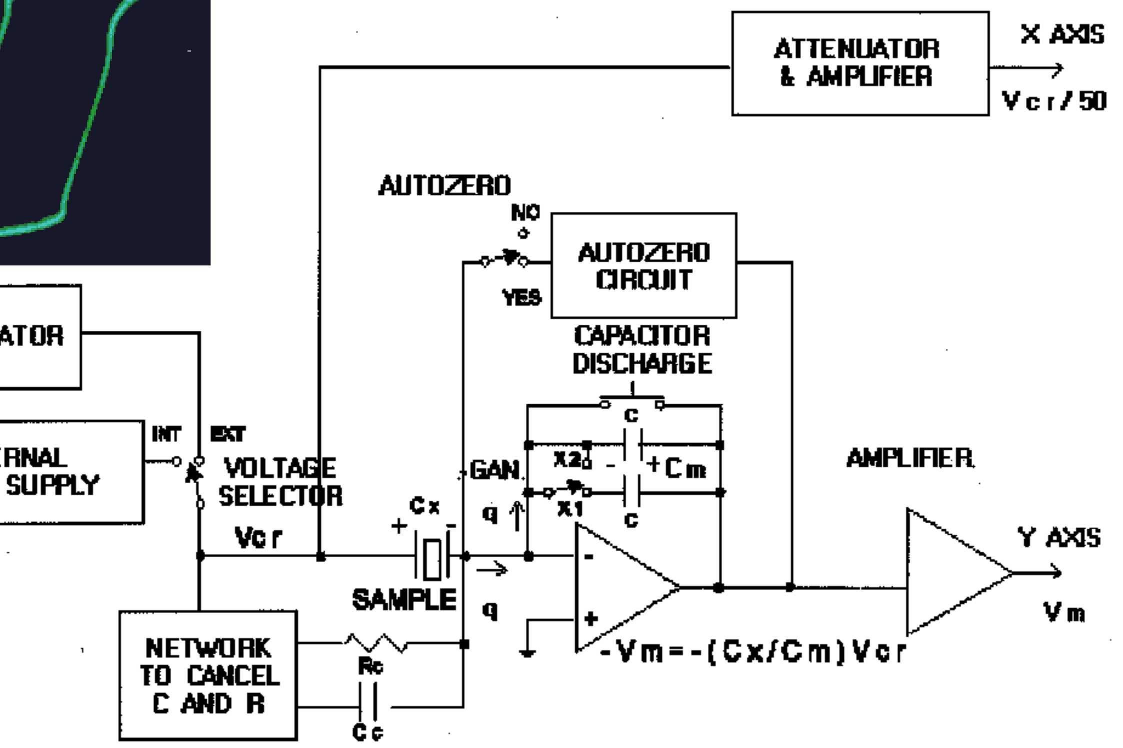


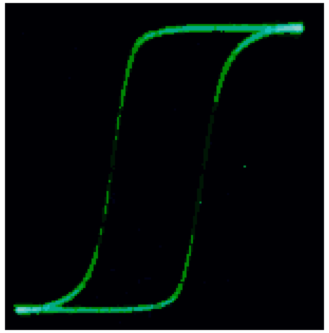
Basic circuit



Compensate circuit







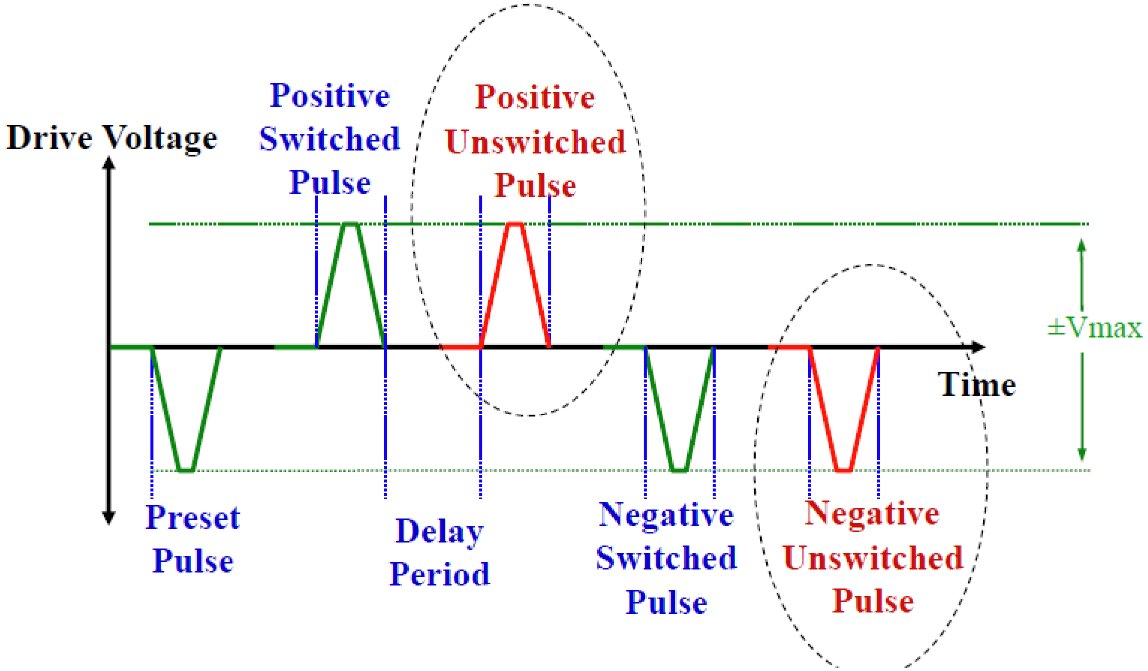
Feedback capacitors Care switched from 10 to 1000 nF, and feedback resistors *R* are switched from 10 MR up to open circuit.

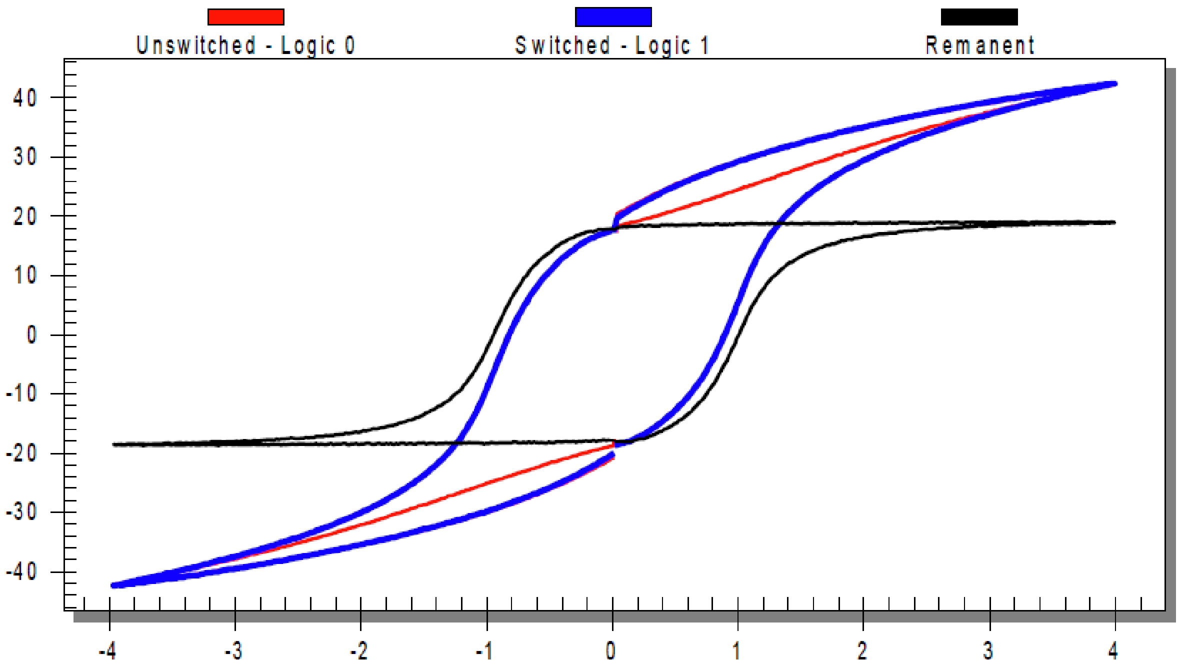
In our circuit R_c and C_c have values of 24.9 kohm and 4700 pF respectively. These values allow the compensation of the ferroelectric sample resistance and linear capacitance in the following ranges: 1245 kohm $\leq R_x \leq \infty$, and $0 \leq C_x \leq 94$ pF.

J. Phys. E: Sci. Instrum., Vol. 17, 95, 1984

Journal of the Korean Physical Society, Vol. 32, 1998, pp. S380S381

PUND setup


Drive Voltage
Positive Switched Pulse
Positive Unswitched Pulse
±Vmax
Time
Preset Pulse
Delay Period
Negative Switched Pulse
Negative Unswitched Pulse


Unswitched - Logic 0
Switched - Logic 1
Remanent
40
30
20
10
0
-10
-20
-30
-40
-4
-3
-2
-1
0
1
2
3
4