A CIRCUIT DESIGN TO TRACE A RESONANCE CURVE ON A CATHODE RAY OSCILLOGRAPH USING A SWEEP FREQUENCY OSCILLATOR AND TO DETERMINE DIELECTRIC CONSTANTS OF SOME STANDARD LIQUIDS

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ABSTRACT

A sweep frequency oscillator of variable reactance type is designed. Its output is fed to a series tunned circuit and a trace of the resonance curve is taken on a C.R.O. The trace is studied before and after the introduction of a given liquid in the air capacity of the series tunned circuit and hence dielectric constant is calculated.

Introduction

It is a well known fact that by using a series resonance curve it is possible to calculate the dielectric constant of a liquid (Calthrop)[1]. Hartshort and Ward[2] elaborated the method for solids and liquids over a wide range of frequencies. In these methods a given liquid is introduced in an air capacity of a resonance circuit and resonance conditions are studied, before and after the introduction of the liquid. The aim of this work is to trace a resonance curve on a C.R.O. with the help of a sweep frequency oscillator controlled by a thyratron oscillator giving a saw tooth voltage. The amplitude of the resonance curve is analysed before and after the introduction of a given liquid in the air capacity of the resonance circuit. From the amplitudes the dielectric constant of the liquid is calculated.

Experimental

The experimental work consists of two parts. In part I the construction of the sweep frequency oscillator is considered. In part II a circuit to trace the resonance curve on a C.R.O. and the nature of measurement is discussed.

Part I—Fig. 1 is a block diagram of the sweep frequency oscillator. In this unit there is a linearised saw-tooth voltage generator (Karnik and DeSa)[3] using a thyratron and a high conductance tube. Its output is fed to the frequency control unit in which there is a triode hexode tube. The hexode section is used as a reactance generator while the reactance is made variable by the triode section; where the linear sweep voltage is superposed on the grid. The variable reactance, varying linearly is shunted across the tank circuit of a tunned grid oscillator. Hence the frequency of the T.G. oscillator is varied over a range with the frequency of the linearised sweep voltage. The output of the T. G. oscillator is taken through a cathode follower circuit and fed to a

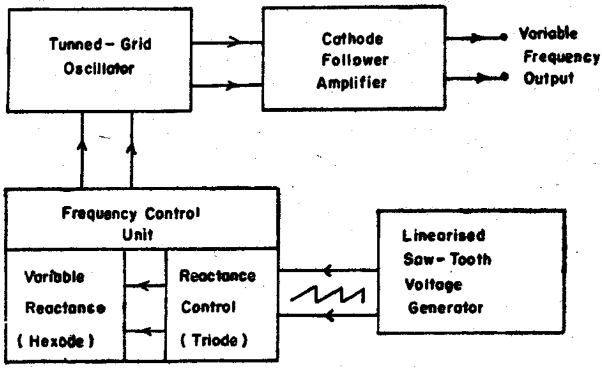

Fig.1.

FIG. 1—The block diagram of the sweep frequency oscillator unit.

series resonance circuit. The fig. 2 shows the circuit design of the sweep frequency oscillator, along with the frequency control unit. There is a 6SL7 double triode, a section of which is used as the T.G. oscillator of range 1·5 M.C. to 2·0 M.C. while the other section is used as a cathode follower circuit for taking out the ouput. The frequency of the T.G. oscillator is varied by the reactance of the hexode section of a 6K8. The reactance varies with the frequency of the linearised sweep voltage fed to the control grid of the triode section of the 6K8. The sweep frequency is adjusted between 80C/sec and 40C/sec. The reactance is varied by the components C_1, R and C_2. The components R and C_2 are connected across the grid circuit of the oscillator. As R is large compared to the reactance of C_2; the r.f. current through the net work is practically in phase with the voltage across the tank circuit, while the r.f. voltage across C_2 lags the current by 90°. The lagging voltage is applied to the

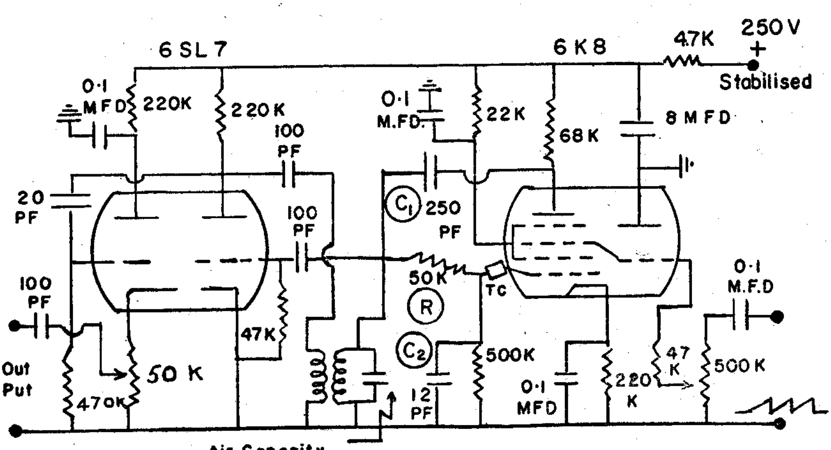

FIG 2

FIG. 2—The circuit for the sweep frequency oscillator.

control grid of the hexode whose r.f. anode current being in phase with grid voltage, also lags by 90° behind the tunned circuit r.f. voltage. This lagging r.f. current is shunted across the tunned circuit through C_1 and gives same effect as an extra inductance connected across the tunned circuit. The magnitude and frequency of the lagging voltage is controlled by the linearised saw-tooth voltage. In this way the sweep frequency oscillator works.

Part II—The output of the sweep oscillator is fed to the resonance circuit containing an air capacity (of our design). (fig. 3). The voltages of the resonance circuit are detected by a germanium diode (OA81) and fed to the Y plates of a C.R.O. while to the X plates the linearised saw-tooth voltage giving variable bias in the sweep oscillator, is applied. Hence on the C.R.O. a resonance curve, for the given circuit and the frequency range, is obtained with automatic synchronisation. The resonance curve is obtained before and after the introduction of a liquid in the air capacity. In terms of the amplitudes of the resonance curves dielectric constant of the liquid is calculated.

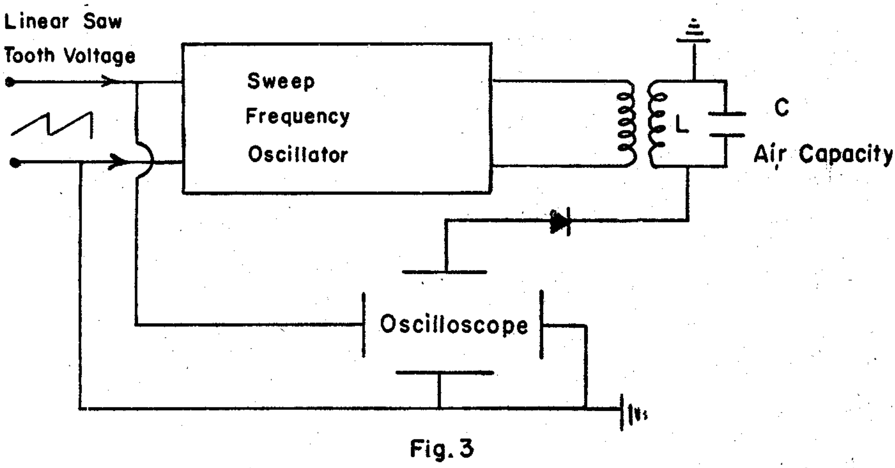

FIG. 3—The circuit diagram for the feed to the resonance circuit and the use of the cathode ray oscillograph.

Analysis and Calculations

Let us consider a circuit without a dielectric (Fig. 4A) and with a dielectric (Fig. 4B) where

R=ohmic resistance of the coil

L=inductance

C=Capacity, K=dielectric constant of the liquid

R'=Reciprocal of conductivity of the liquid and

E=Signal voltage.

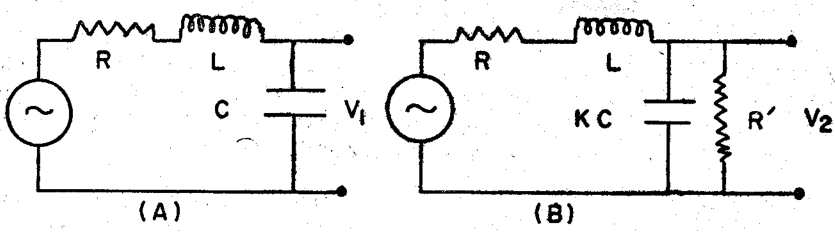

Fig.4

Fig. 4—Resonance circuit (A) without dielectric.
(B) with dielectric.

Therefore in fig. 4A the current vector through L is

$$I_1 = \frac{E}{R + j\omega_1 L + \dfrac{1}{j\omega_1 C}}$$ and voltage vector across C is

$$\vec{V_1} = \frac{I_1}{j\,\omega_1 C} = \frac{1}{j\,\omega_1 C}\left[\frac{E}{R + \omega_1\, L + \dfrac{1}{j\,\omega_1 C}}\right]$$

so that $$|V_1|^2 = \frac{E^2}{\omega_1{}^2\, C^2\left[R^2 + \left(\omega_1\, L - \dfrac{1}{\omega_1 C}\right)^2\right]} = \frac{E^2}{f\;(\omega_1)}$$

The condition for maximum $|V_1|^2$ is $\dfrac{d\,f(\omega_1)}{d\omega_1} = o$

so that $\omega_1^2 = \left[\dfrac{1}{LC} - \dfrac{R^2}{2L^2}\right]$ or approximately $\omega_1^2 = \dfrac{1}{LC}$

Hence

$$V_1\ \text{(maximum)} = \frac{E}{\omega_1 CR}$$

Similarly from the fig. 4B we get the current vector through L as $$I_2 = \frac{E}{R + j\,\omega_2\, L + \dfrac{R'}{1 + j\;\omega_2\; C\cdot K\cdot R'}}$$

and the voltage vector across CK as

$$\vec{V_2} = I_2\left[\frac{R'}{1 + j\omega_2 R'CK}\right]$$ so that

$$|V_2|^2 = \frac{R'^2E^2}{(\omega_2 CKRR' + \omega_2\, L)^2 + (R + R' - \omega^2{}_2 LCKR')^2} = \frac{R'^2E^2}{f(\omega_2)}$$

The condition for maximum $|\,V_2\,|^2$ is $\dfrac{d\,f(\omega_2)}{d\omega_2} = o$

so that $\omega_2^2 = \dfrac{R + R'}{LCKR'} - \tfrac{1}{2}\left[\dfrac{R}{L} + \dfrac{1}{CKR'}\right]$ or

$$\text{approximately } \omega_2^2 = \frac{R + R'}{LCKR'}$$

$$\text{Hence } V_2 \text{ (maximum)} = \frac{R' E}{\omega_2 CKRR' + \omega_2 L}$$

$$\therefore \frac{V_1 \text{ (maximum)}}{V_2 \text{ (maximum)}} = \frac{\omega_2 CKRR' + \omega_2 L}{R'} \cdot \frac{1}{\omega_1 CR}$$

$$= \frac{\omega_2}{\omega_1} \left[K + \frac{L}{CRR'} \right]$$

In the present work the band width of the resonance curve is about 10 KC over a sweep of 1·5 M.C. to 2·0 M.C. for a given air condenser of about 8 p.f., and hence a very small displacement of the resonance curves is possible due to changes in the capacity. The photographs of the resonance curves are taken before and after the introduction of a liquid in the air condenser (Plates 1, 2 and 3). There is no observable shift between the curves, so that

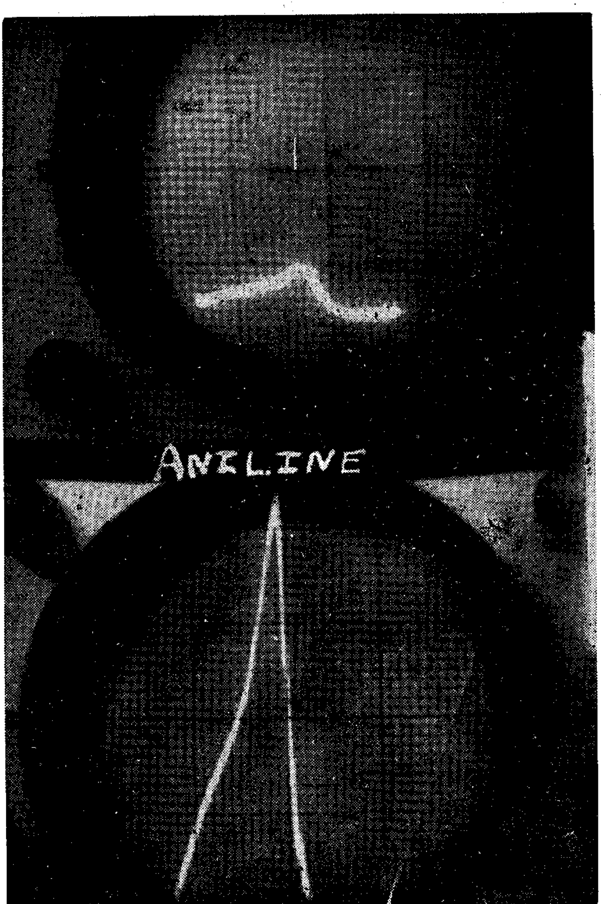

PHOTO PLATE 1—Aniline.

approximately $\frac{\omega_2}{\omega_1} = 1$ under our experimental conditions. So $\frac{V_1}{V_2}$ (maximum) $= K + \frac{L}{CRR'}$. The values of L, C and R are measured by an impedance bridge while the value of R′ for a given liquid is taken from the International Critical tables (1929)[4]. As the factor $\frac{L}{CRR'}$ is very small, the dielectric constant K is merely the ratio of voltages, which in turn is the ratio of the amplitudes of the resonance curves generated before and after the introduction of the liquid in the air capacity. A cathitometer is used to measure the amplitudes and hence K is calculated (The value of K is also calculated from the photographs). The following standard liquids are

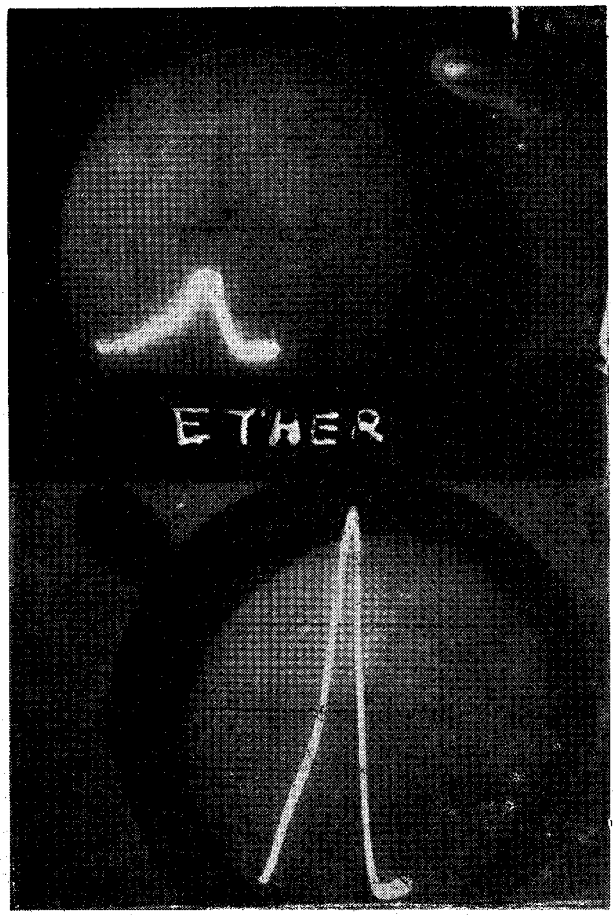

PHOTO PLATE 2—Ether.

studied for the time being to test the circuit : 1) Aniline (C_6H_7N), 2) Ether ($(C_4H_{10})O$, 3) Carbon tetrachloride (CCl_4), and 4) liquid paraffin (medicinal). The table–A contains the standard values (Kye and Laby.)[5] as well as observed values of the dielectric constants of the liquids. In the experimental work stabilised D.C. voltages have been applied to all the electrical circuits and shielded leads of the air condenser are made as short as possible.

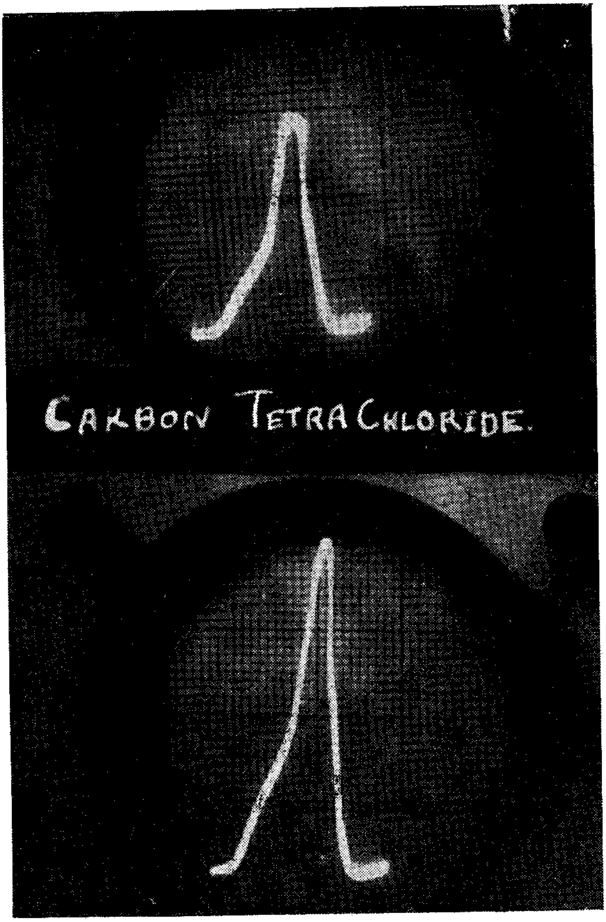

PHOTO PLATE 3—Carbon tetrachloride.

The method is approximate and hence it is useful where accurate value of a dielectric constant is not essential for further calculations. However, it may be useful for quick visual estimation of approximate values as well as coarse comparison of dielectric constants in routine tests.

Acknowledgement

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TABLE (A)

Liquids	L	C	R	1/R′	L/CRR′	V1/V2	Value of K_{oG} at Temp 26·8°C	Standard value of K
Aniline C_6H_7N	$45{\cdot}5\times10^{-6}$ H.	$7{\cdot}94\times10^{-12}$ F.	4·6 Ohms.	85×10^{-9}	0·106	7·17	7·064	7·21
Ether $C_4H_{10}O$				4×10^{-13}	$4{\cdot}99\times10^{-7}$	4·23	4·23	4·34
Carbon Tetrachloride CCl_4				4×10^{-18}	$4{\cdot}99\times10^{-12}$	1·59	1·59	2·25 at 18° C.
Paraffin liquid (medicated)				—	—	2·1	2·1	2·2

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