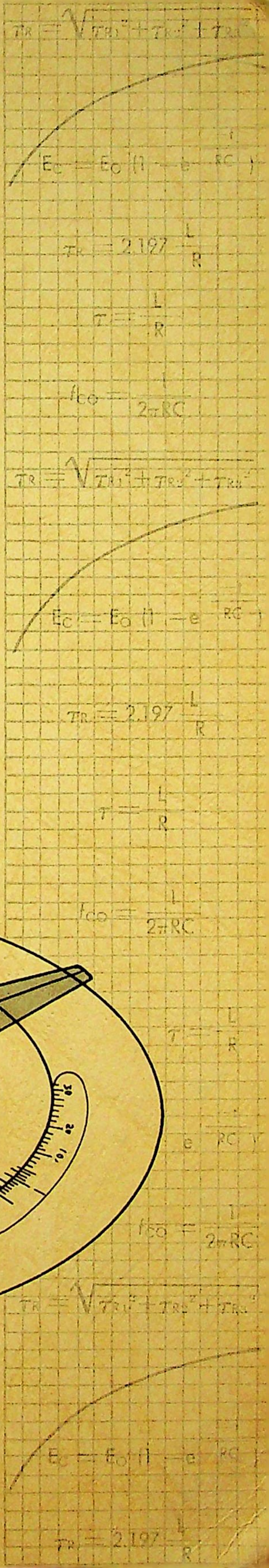

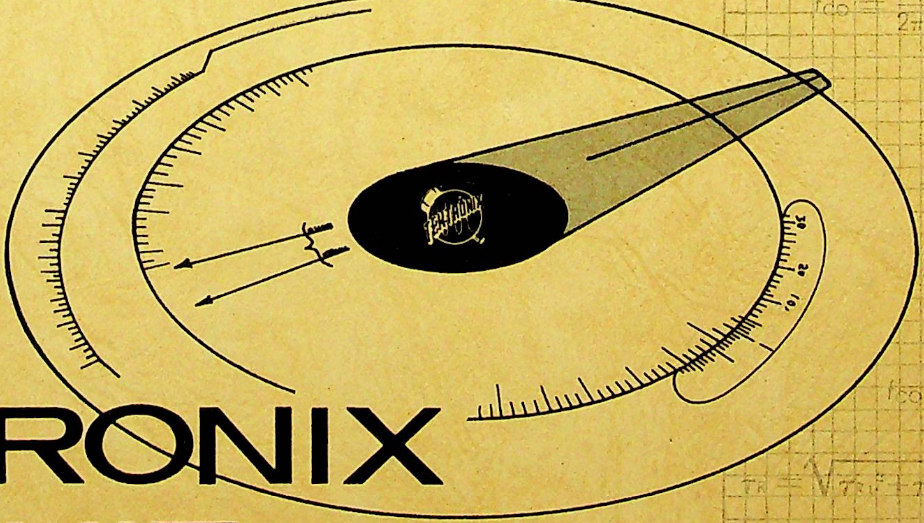

TEKTRONIX CIRCUIT COMPUTER

The Tektronix Circuit Computer has been designed to compute directly problems involving resistance, inductance, capacitance, frequency and **time.** The computer consists of three circular decks, containing seven scales, and a hairline indicator.

The primary design objective is to provide a means of quick computation of time values from other circuit dimensions.

Contents

1. Capacitive Reactance
2. Inductive Reactance
3. Resonance
4. RC Time Constant and Risetime
5. L/R Time Constant and Risetime
6. Filter Cut-off Frequency
7. Risetime
8. Discussion of Risetime and Time Constant

Generally-accepted symbols are used in the discussion, but note that we use:

$$\tau = \text{Time Constant} = RC \quad \text{or} \quad \frac{L}{R}$$

τ_R = Risetime; defined on page 8

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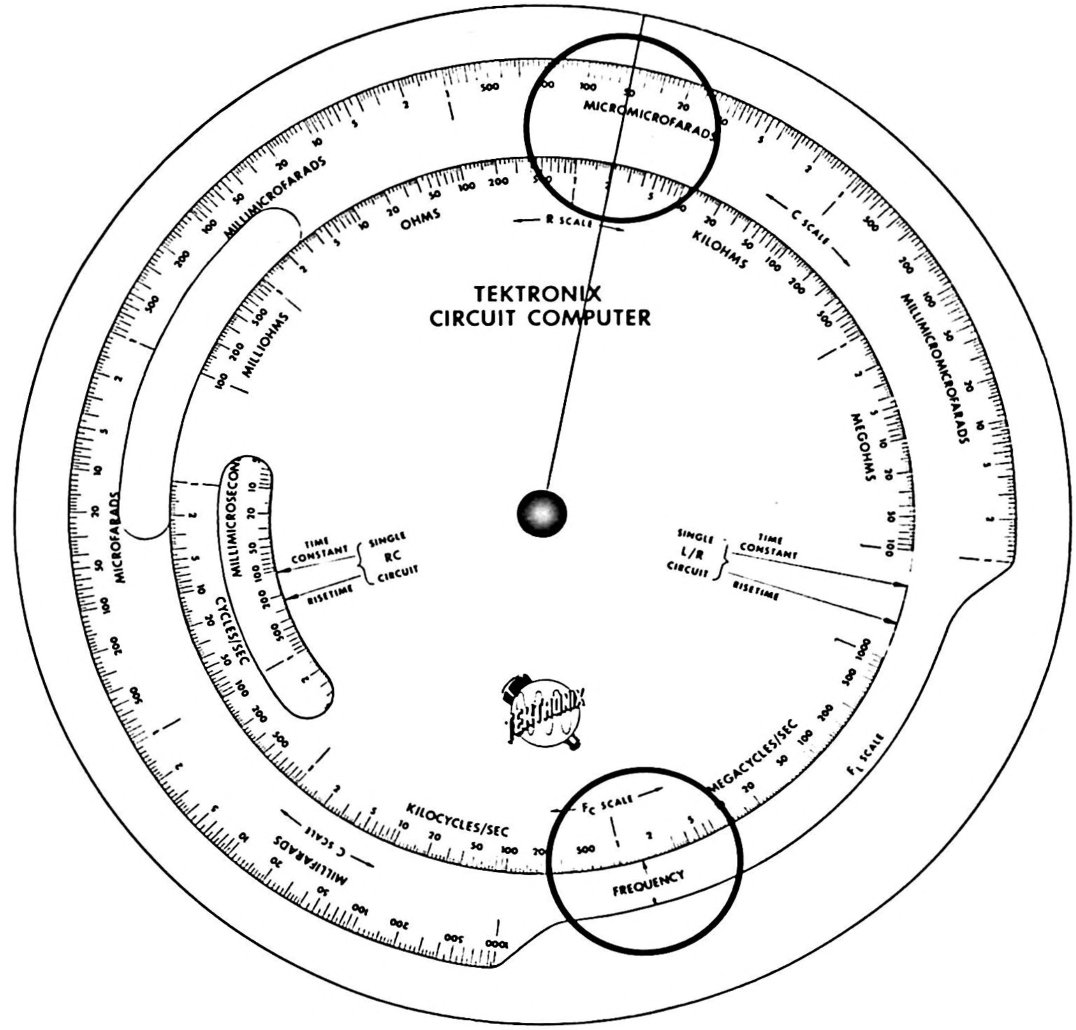

Fig. 1

1. Capacitive Reactance

$$X_C = \frac{1}{2\pi f C}$$

To find reactance X_C, of a capacitor C, at frequency f:

a. Set the arrow marked FREQUENCY (middle deck) to the frequency on the F_C scale (top deck).

b. Set the hairline indicator over the capacitance on the C scale (middle deck).

c. Read the reactance X_C, under the hairline on the R scale (top deck).

Note that f must be the frequency of a **sinusoidal** wave. Any of the three variables in the equation may be solved using these three scales.

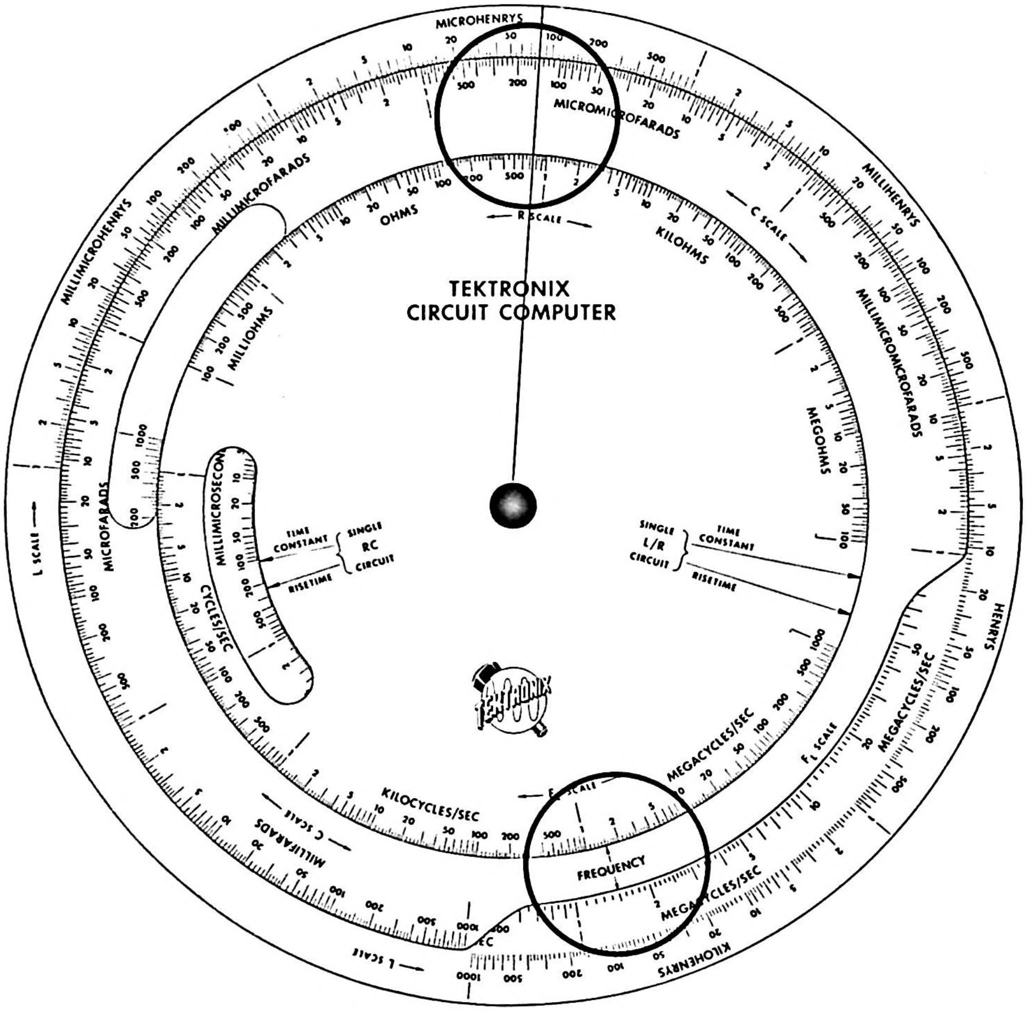

Fig. 2

2 Inductive Reactance

$$X_L = 2\pi f L$$

To find reactance X_L, of an inductance L, at frequency *f*:

a. Set the arrow marked FREQUENCY to the frequency on **both** the F_L (bottom deck) and F_C (top deck) scales.

b. Set the hairline indicator over the inductance on the L scale (bottom deck).

c. Read the reactance X_L, under the hairline on the R scale.

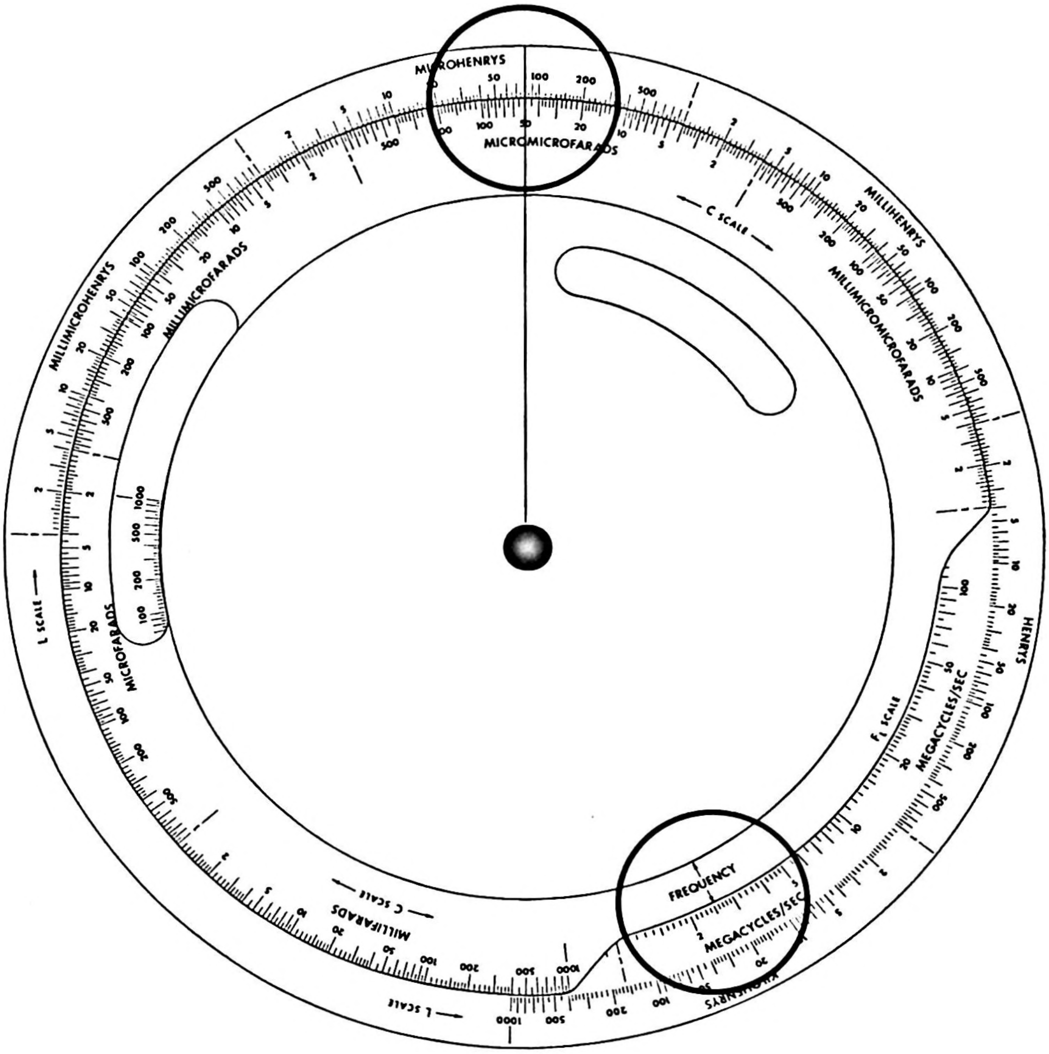

Fig. 3

3. Resonance

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$

To find resonant frequency f_R, of a series-resonant circuit consisting of an inductance L, and a capacitance C:

a. Set the inductance on the L scale opposite the capacitance on the C scale.

b. Read the resonant frequency f_R, on the F_L scale opposite the Frequency arrow.

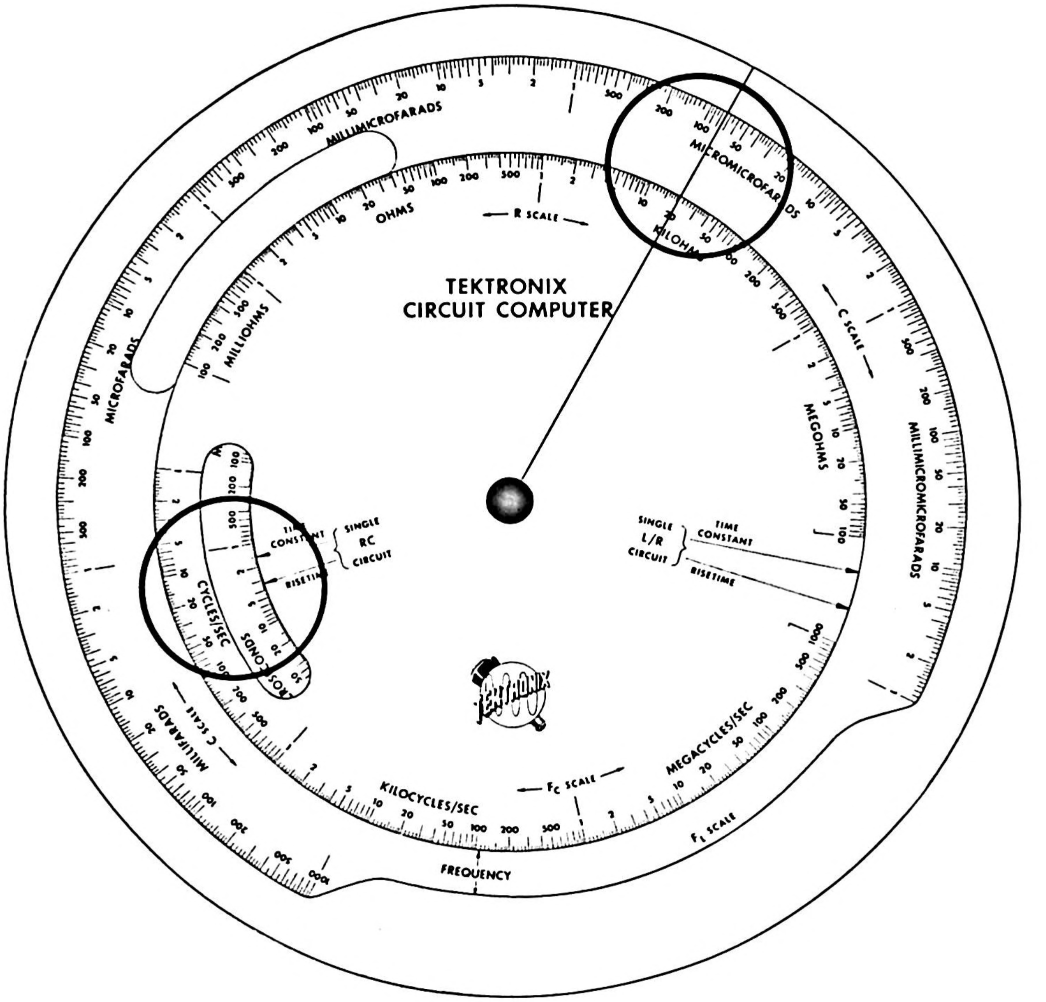

Fig. 4

4. RC Time Constant and Risetime

$\tau = RC$ $\qquad\qquad$ $\tau_R = 2.197\ RC$*

a. Set the capacitance on the C scale opposite the resistance on the R scale using the hairline indicator.

b. Read the RC time constant and the risetime on the τ_C scale (middle deck) through the window in the top deck, opposite the appropriate arrows.

*See page 7 for discussion of risetime and time constant.

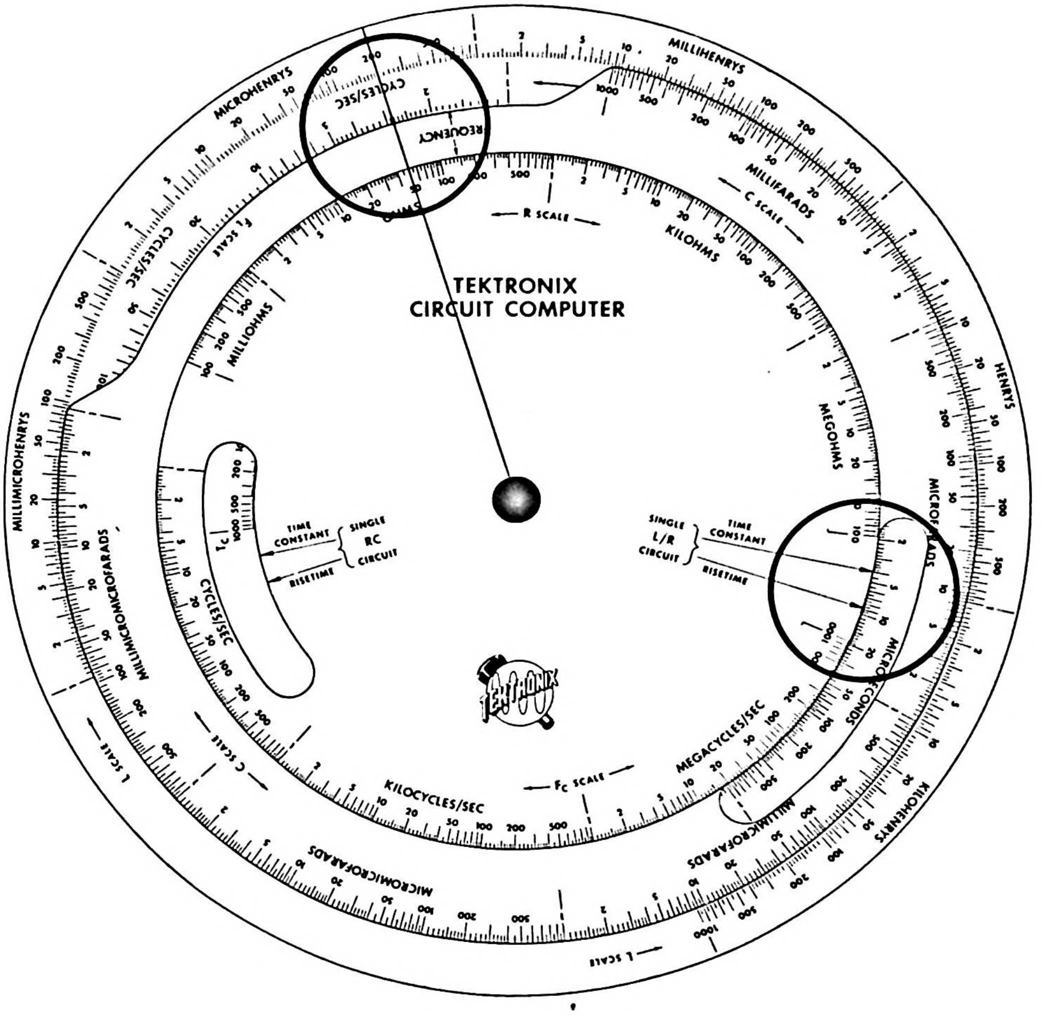

Fig. 5

5. L/R Time Constant and Risetime

$$\tau = \frac{L}{R} \qquad \tau_R = 2.197 \frac{L^*}{R}$$

To find the time constant or the risetime of a circuit consisting of an inductance L in series with a resistance R:

a. Set the arrows for the L/R time constant and risetime to the window in the middle deck.

b. Set the resistance on the R scale opposite the inductance on the L scale using the hairline indicator.

c. Read the L/R time constant and risetime on the τ_L scale (bottom deck) through the window in the middle deck opposite the appropriate arrows on the top deck.

*See page 7 for discussion of risetime and time constant.

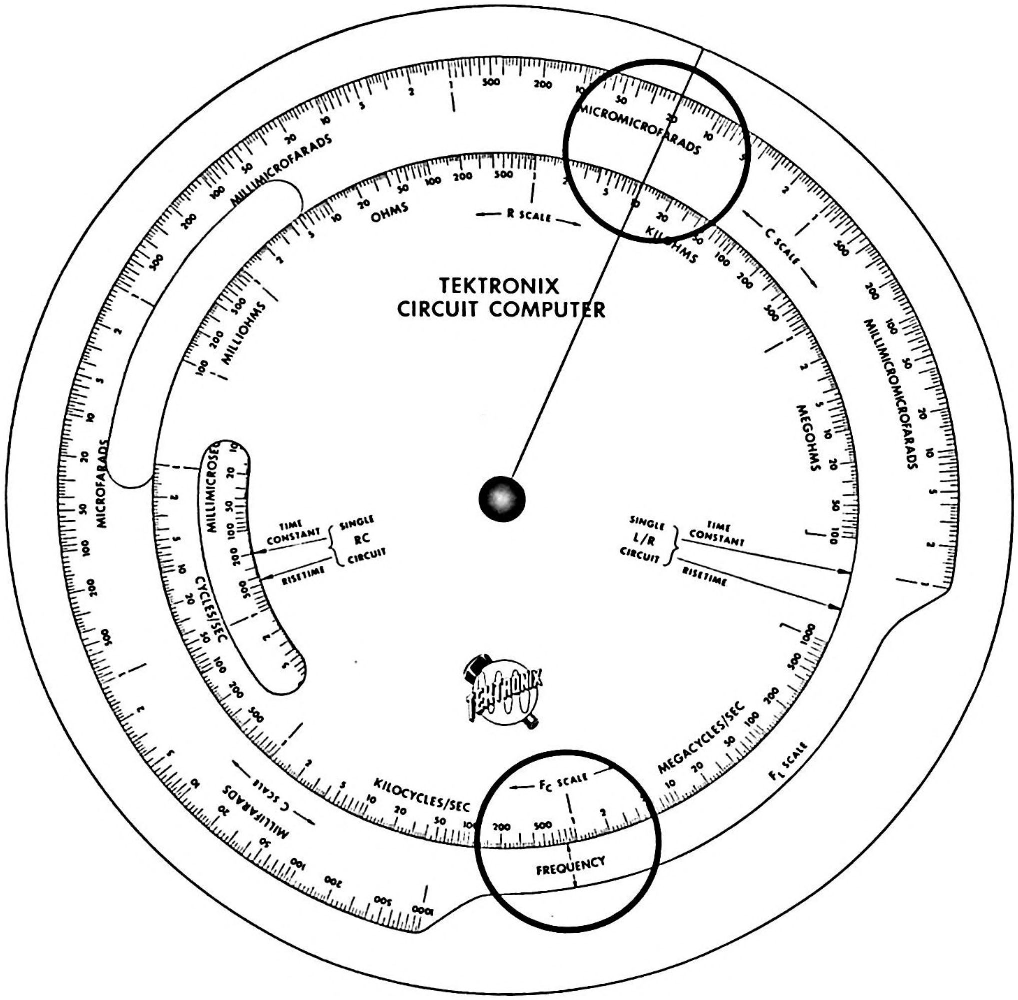

Fig. 6

6. Filter Cut-Off Frequency

$$f_{CO} = \frac{1}{2\pi RC}$$

To find the cut-off frequency f_{CO} (3-db-down point) of a circuit consisting of a resistance R, and a capacitance C, connected as a mid-series section of a low-pass or a high-pass filter:

a. Set the resistance on the R scale opposite the capacitance on the C scale using the hairline indicator.

b. Read the cut-off frequency f_{CO} opposite the Frequency arrow on the F_C scale.

7. Risetime

For most pulse work, risetime τ_R is defined as the time required for the instantaneous amplitude to rise from 10% to 90% of its maximum value.

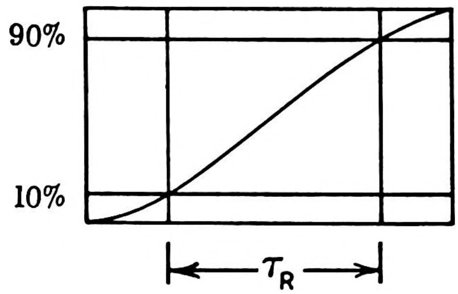

Fig. 7

The overall risetime of a system can be computed to useful approximation from the risetimes of its individual components by the formula:

$$\tau_R = \sqrt{\tau_{R1}^2 + \tau_{R2}^2 + \tau_{R3}^2 \ldots}$$

8. Discussion of Risetime and Time Constant

Consider the simple low-pass filter shown in Fig. 8.

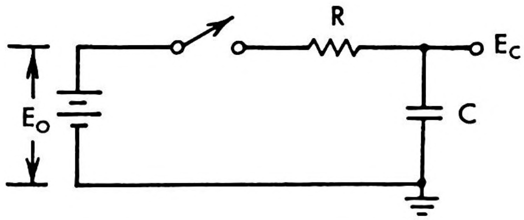

Fig. 8

After the switch is closed, the voltage E_C will approach E_O according to the function:

$$E_C = E_O \left(1 - e^{\frac{-t}{RC}}\right)$$

as shown in Fig. 9.

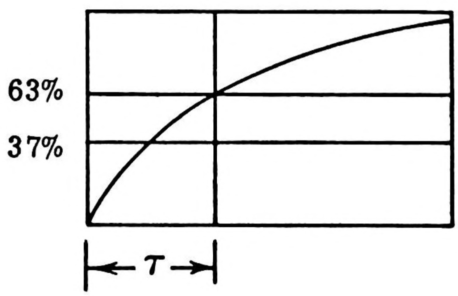

Fig. 9

The time constant of a circuit is defined as the time required for the instantaneous voltage to rise from 0 to 63.2% $(1-\frac{1}{e})$ of its maximum. Risetime is defined here as the time it takes the instantaneous voltage to rise from 10% to 90% of its maximum.

Defining risetime as the time $(t_2 - t_1)$ it takes for E_C to rise from 0.1 to 0.9 volts, we may write:

$$1 - e^{\frac{-t_1}{RC}} = 0.1 \qquad\qquad 1 - e^{\frac{-t_2}{RC}} = 0.9 \qquad (1)$$

$$\frac{1}{e^{\frac{t_1}{RC}}} = 0.9 \qquad\qquad \frac{1}{e^{\frac{t_2}{RC}}} = 0.1 \qquad (2)$$

$$e^{\frac{t_1}{RC}} = \frac{1}{0.9} = 1.111\ldots \qquad\qquad e^{\frac{t_2}{RC}} = \frac{1}{0.1} = 10 \qquad (3)$$

Solving for $\frac{t_2 - t_1}{RC}$ we take the log of equations (3) to the base e:

$$\log_e e^{\frac{t_1}{RC}} = \log_e 1.111 \qquad\qquad \log_e e^{\frac{t_2}{RC}} = \log_e 10 \qquad (4)$$

$$\frac{t_1}{RC} \log_e e = \log_e 1.111 \qquad\qquad \frac{t_2}{RC} \log_e e = \log_e 10 \qquad (5)$$

Since $\log_e e = 1$:

$$\frac{t_1}{RC} = \log_e 1.111 \qquad\qquad \frac{t_2}{RC} = \log_e 10 \qquad (6)$$

Subtracting we get:

$$\frac{t_2 - t_1}{RC} = \log_e 10 - \log_e 1.111 = \log_e \frac{10}{1.111} = \log_e 9 = 2.197225 \qquad (7)$$

$$\frac{\tau_R}{RC} = \log_e 9 = 2.197225 \qquad (8)$$

$$\tau_R = 2.197225\ RC \qquad (9)$$

Or,

$$\tau_R = 2.1972\ RC$$

This relationship can be demonstrated for L/R current risetimes as well.

The frequency response of the low-pass filter shown in Fig. 8 will be down 3 db when:

$$X_C = R \qquad (10)$$

$$R = \frac{1}{2\pi f C}$$

Solving for RC:

$$RC = \frac{1}{2\pi f} \qquad (11)$$

Substituting in (9):

$$\tau_R = 2.1972 \frac{1}{2\pi f}$$

$$\tau_R = \frac{.349}{f} \qquad (12)$$

And

$$f = \frac{.349}{\tau_R} = \frac{K}{\tau_R}$$

Note that K, the translation factor, was determined for sine waves as 0.349; for other waveforms K would fall between 0.34 and 0.39.

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