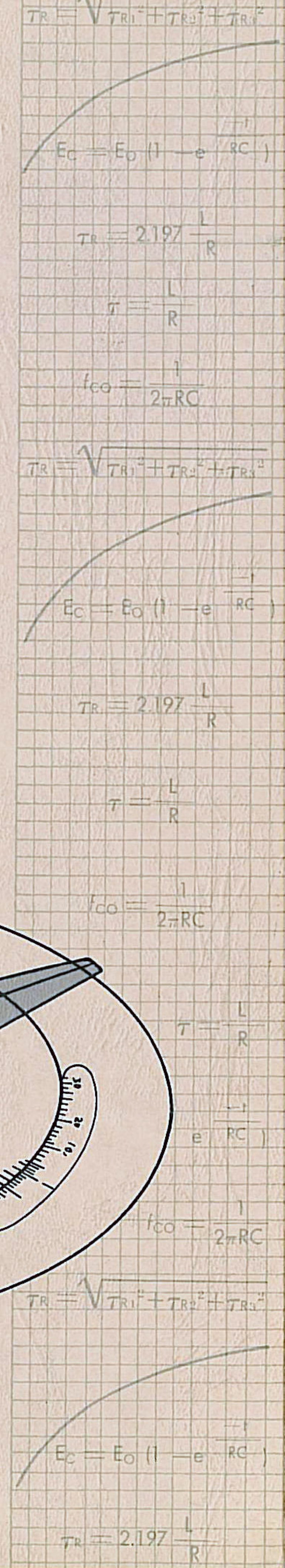

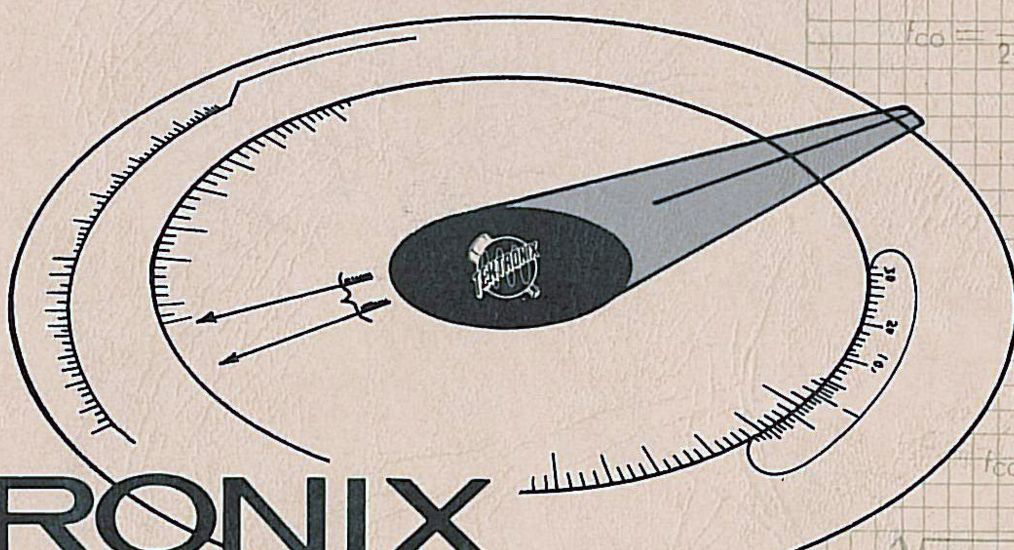

TEKTRONIX CIRCUIT COMPUTER

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

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

Additional copies of this publication may be obtained from your Tektronix Field Engineer or Tektronix Representative, or from Tektronix, Inc., P.O. Box 500, Beaverton, Oregon. The price per copy is twenty-five cents.

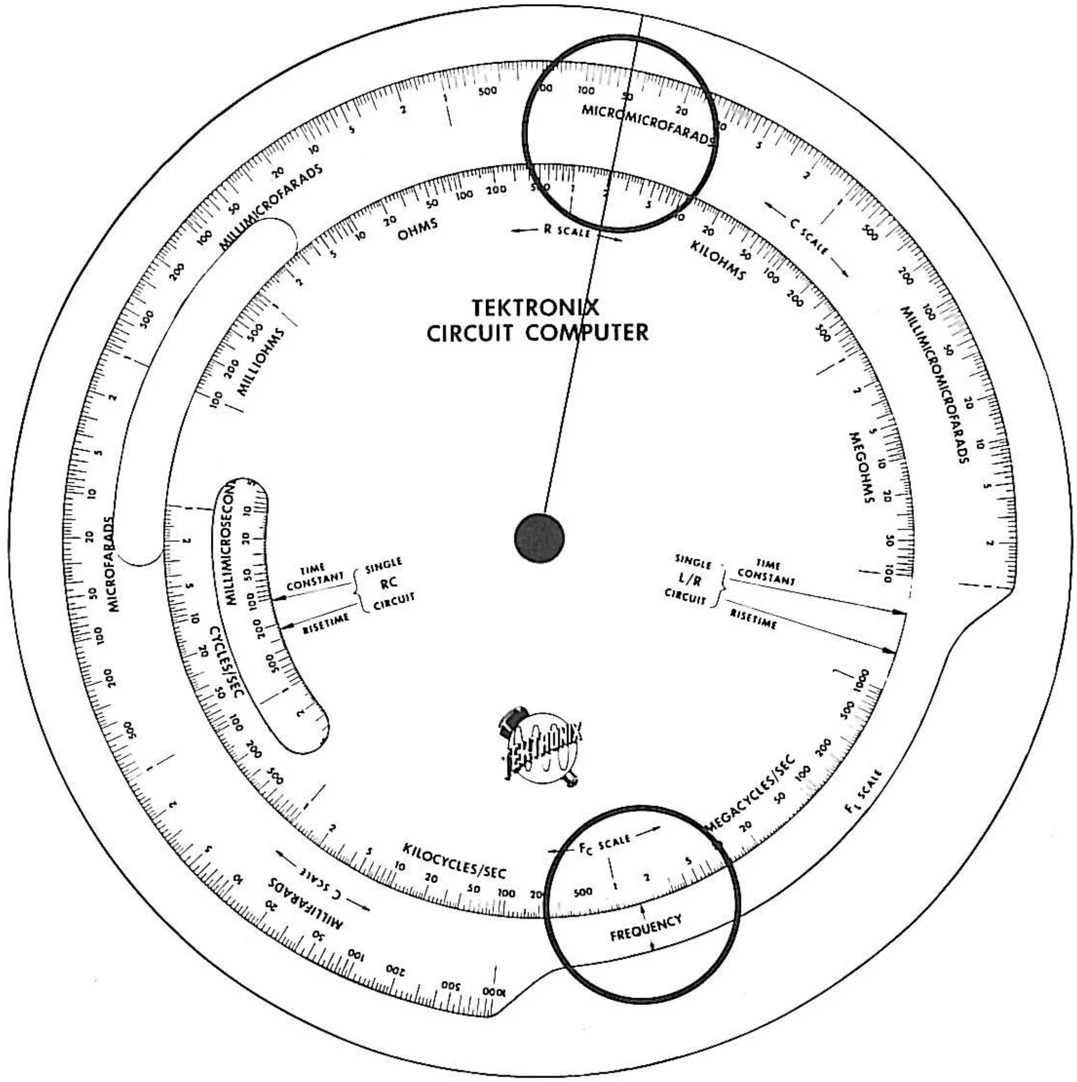

Fig. 1

1. Capacitive Reactance

$$X_C = \frac{1}{2\pi fC}$$

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.

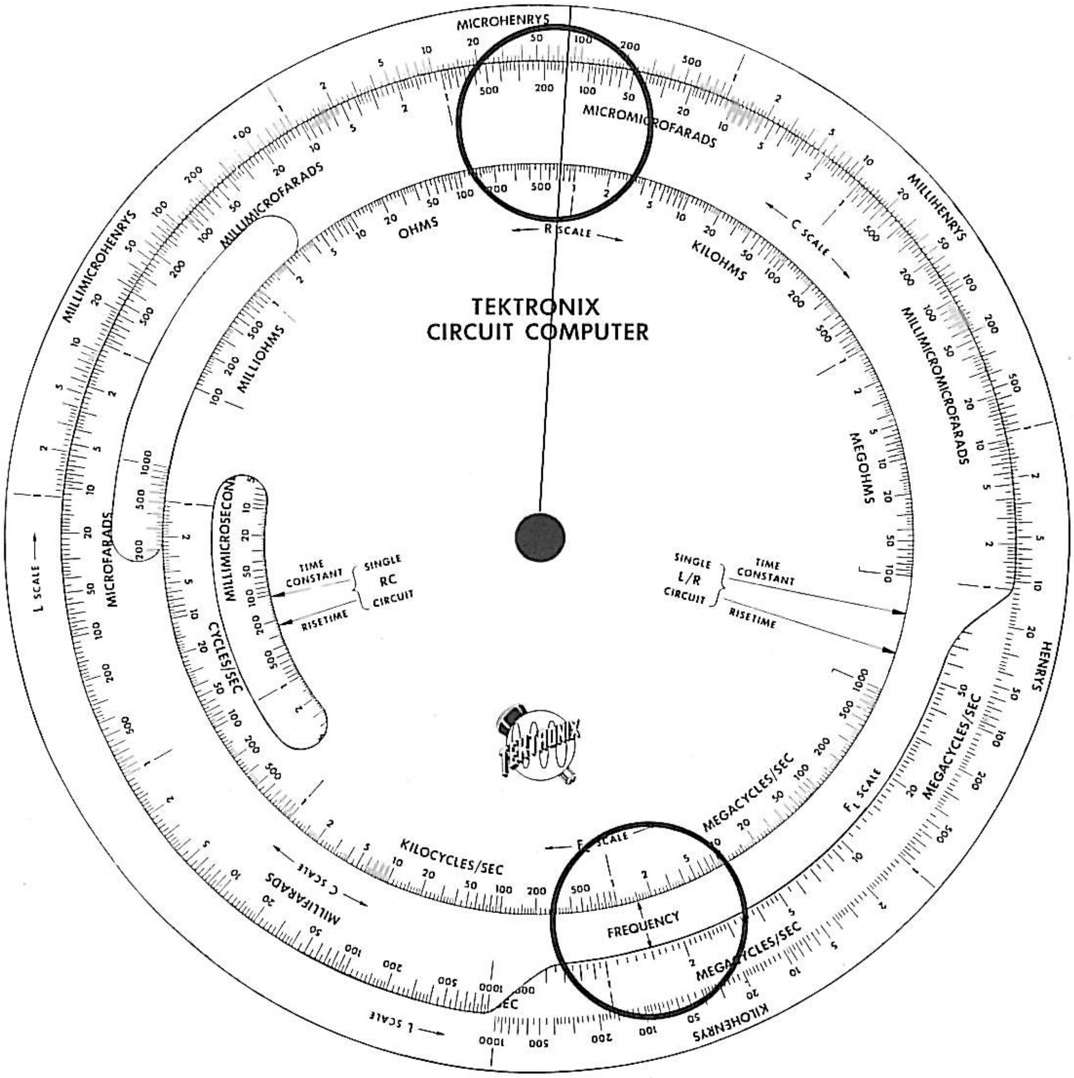

Fig. 2

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.

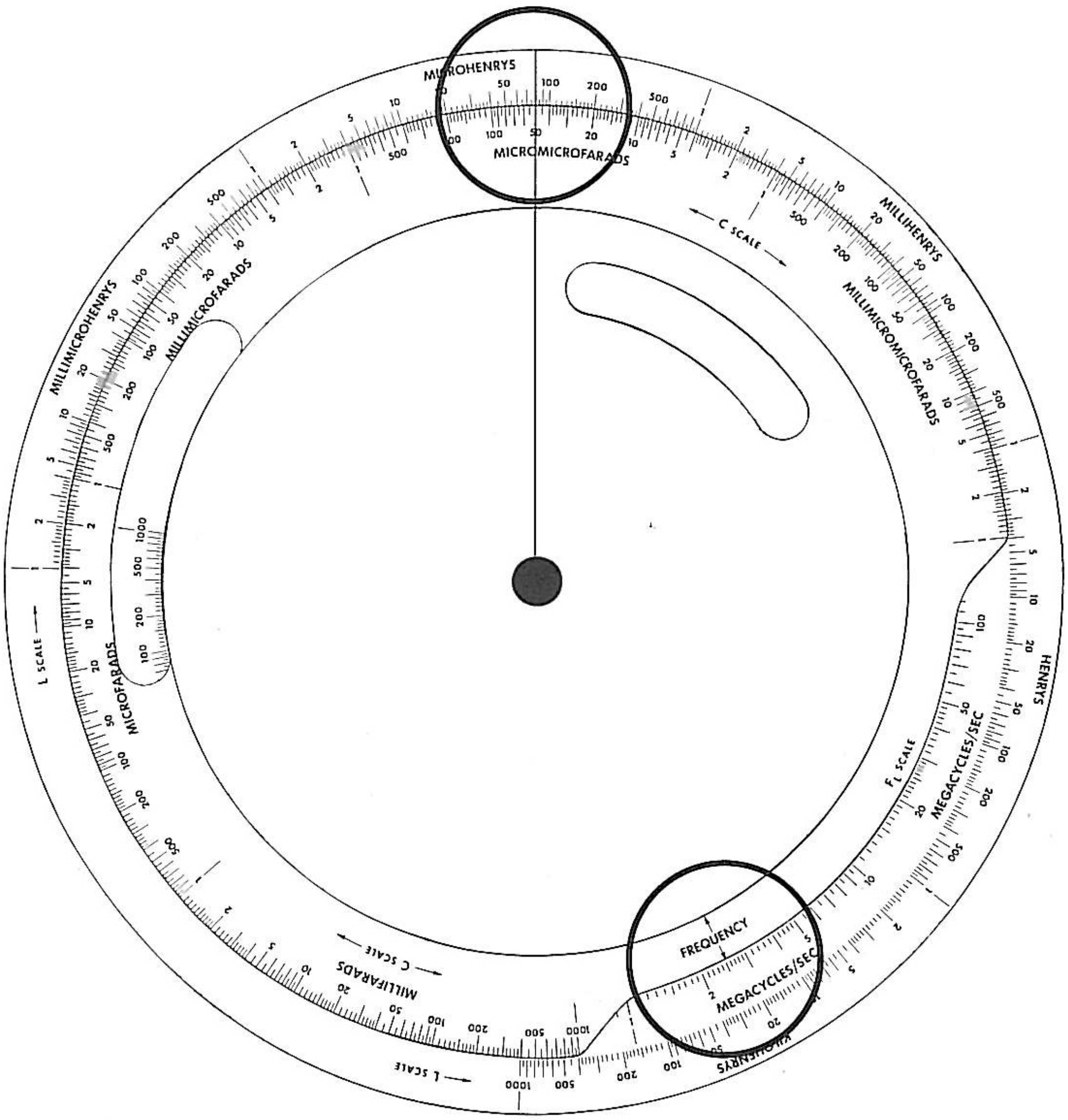

Fig. 3

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.

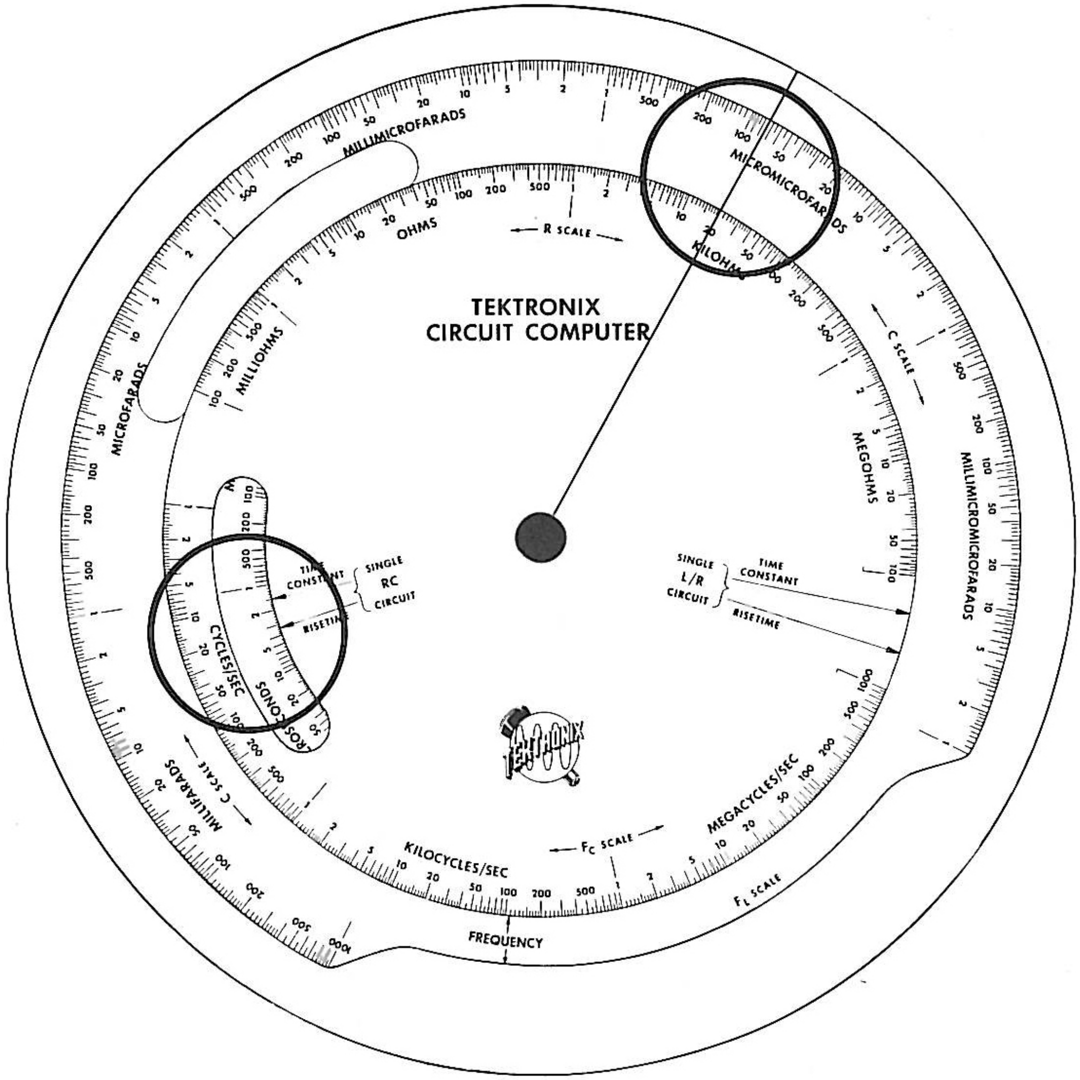

Fig. 4

4. RC Time Constant and Risetime

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

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.

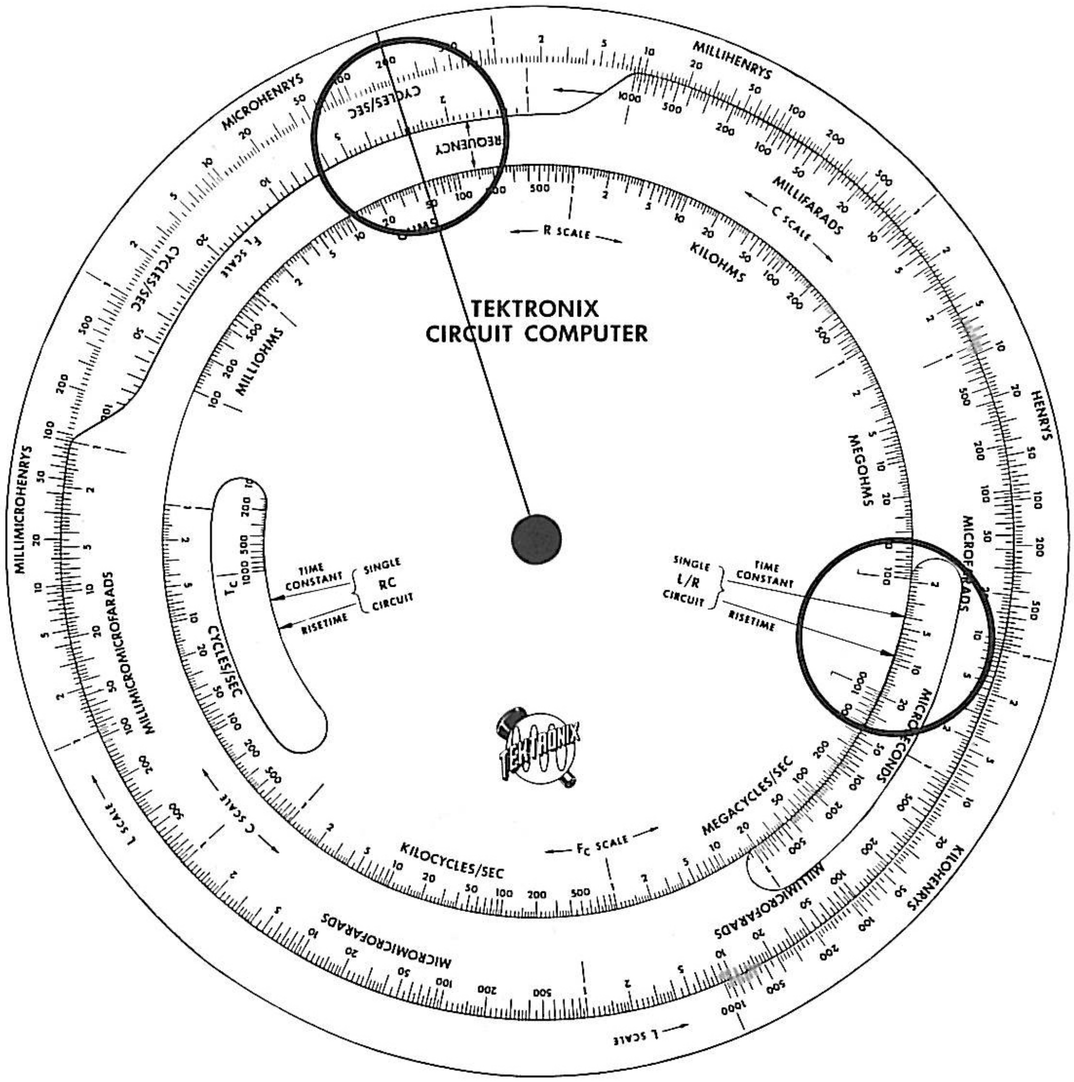

Fig. 5

5. L/R Time Constant and Risetime

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

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.

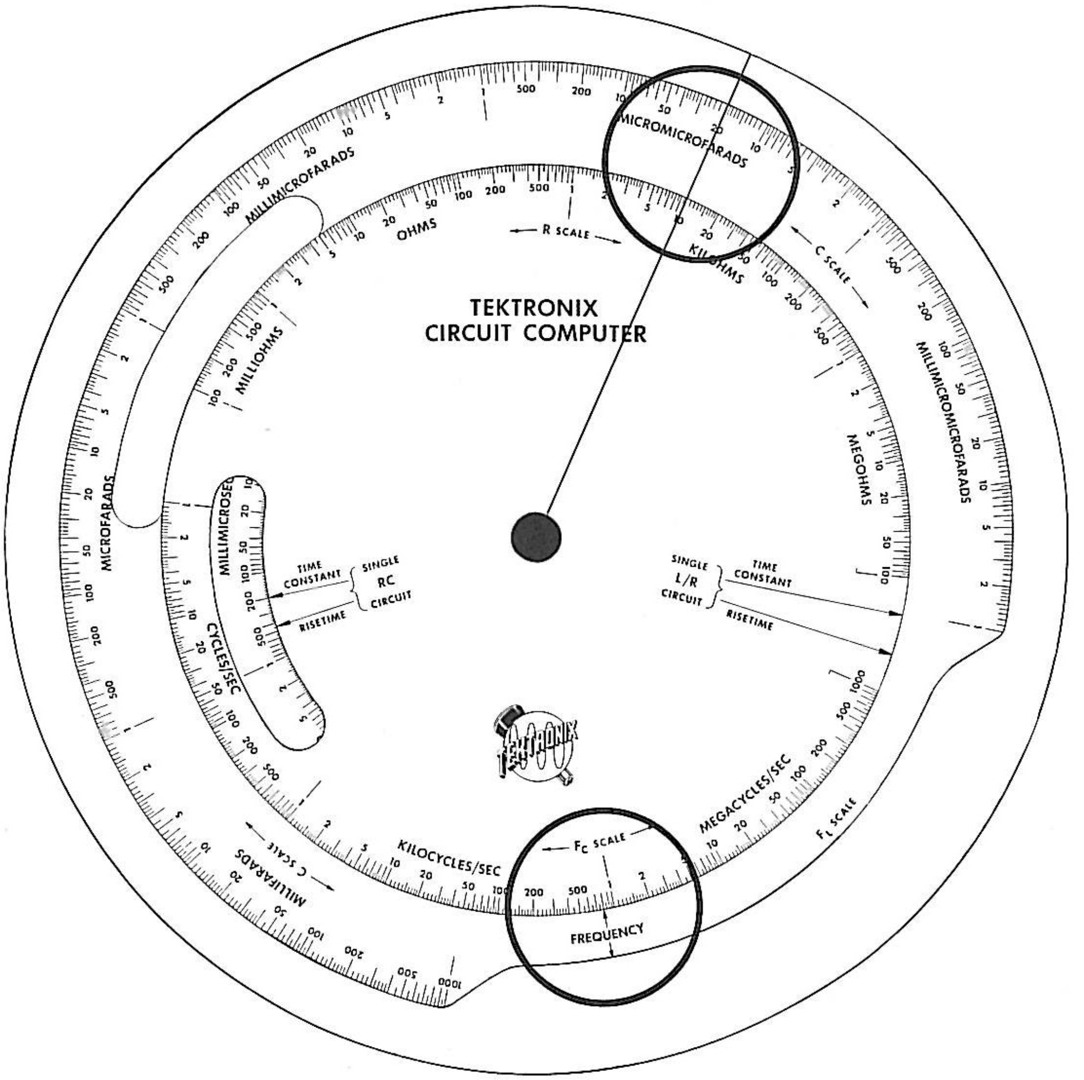

Fig. 6

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.

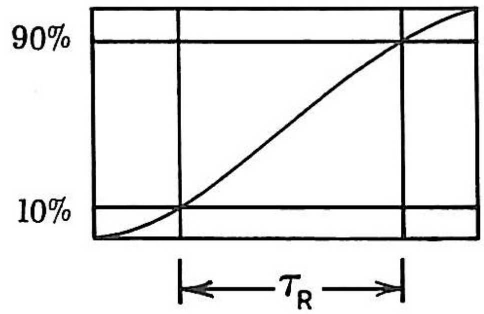

Fig. 7

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.

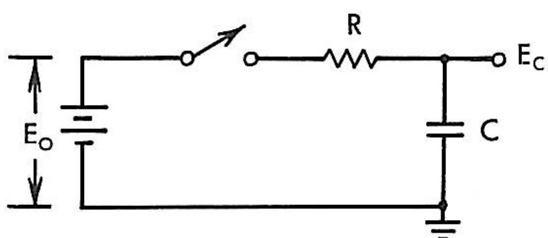

Fig. 8

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.

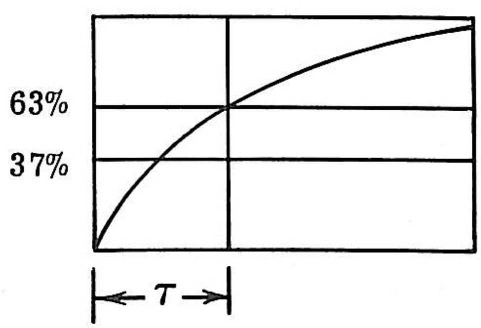

Fig. 9

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:

$$X_C = R \tag{10}$$

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

Solving for RC:

$$RC = \frac{1}{2\pi f} \tag{11}$$

Substituting in (9):

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

$$\tau_R = \frac{.349}{f} \tag{12}$$

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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