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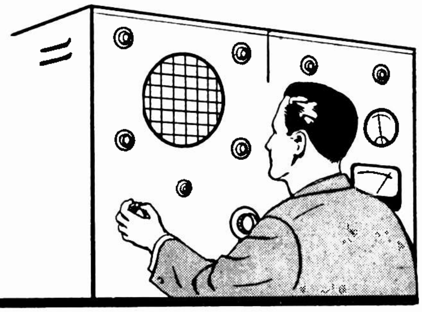

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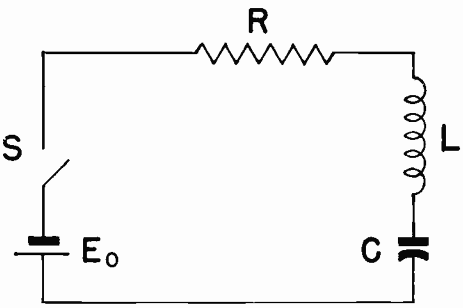
Maximum Charge and Discharge Currents for Capacitor, Inductor, and Resistance Circuits

By the Engineering Department, Aerovox Corporation

ALTHOUGH the analysis of RLC circuits under transient conditions is well known as part of the electronic engineers education, many of us who have rare occasions to use this information soon forget it. This is written as a reminder, with some specific discussion on one or two applications.



$$A = \frac{R}{2L}$$

$$B = \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

FIGURE 1

At any time T after switch S is closed, the current flow in Fig. (1) is equal to:

i = current at time t, Battery voltage = E_0, Capacitor voltage = E_C

$$A = \frac{R}{2L}$$

$$B = \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

(1) $$i = CEe^{-at}\left[\left(\frac{A^2}{B} - B\right)\sinh Bt\right]$$

(2) $$= \frac{C}{BL}e^{-at} \quad \sinh Bt$$

There are three possible conditions which can exist and these are when —

1. B is real
2. B is imaginary
3. B equals zero

Condition (3) is a critically damped condition in which the current *i* reaches the maximum value at the earliest time and the current returns to zero in the minimum time without becoming negative.

Condition (1) is the condition in which there is no reversal of current and the length of time which the current flows and its magnitude at the maximum value is determined by the value of *B*. It should be noted that it is possible for the current *i* to be greater under condition (1) than it is for *B* equal to zero. However, this increase is generally relatively small.

The maximum current for conditions (1) or (3) can be determined when equation (2) is differentiated and made equal to zero. The time for maximum current

$$(3) \qquad t_m = \frac{1}{B} \tanh^{-1} \frac{B}{A} \text{ sec.}$$

Since this equation is indeterminate for *B* equals zero differentiation of equation (3) with respect to *B* gives

$$(4) \qquad t_m = \frac{1}{A} \text{ sec.}$$

$$(5) \qquad i_m = \frac{E}{AL} e^{-1} = 0.369 \frac{E}{AL} \text{ amperes}$$

For condition (2) that is when *B* is imaginary, the instantaneous current is equal to

$$(6) \qquad i = \frac{E_0}{BL} e^{-at} \sin Bt$$

This is an oscillating condition in which the circuit oscillates at a frequency equal to $\frac{1}{2\pi\sqrt{LC}}$

The peak value of the current is

$$(7) \qquad i_m = E_0 \sqrt{C/L}\; e^{-A/B \tanh^{-1} \frac{B}{A}}$$

The damping rate of the current or voltage is δ by definition equal to

$$(8) \qquad \ln \frac{I_n}{I_{n+1}}$$

Also, the figure of merit of such a circuit or

$$(9) \qquad Q = \frac{2\pi FL}{R}$$

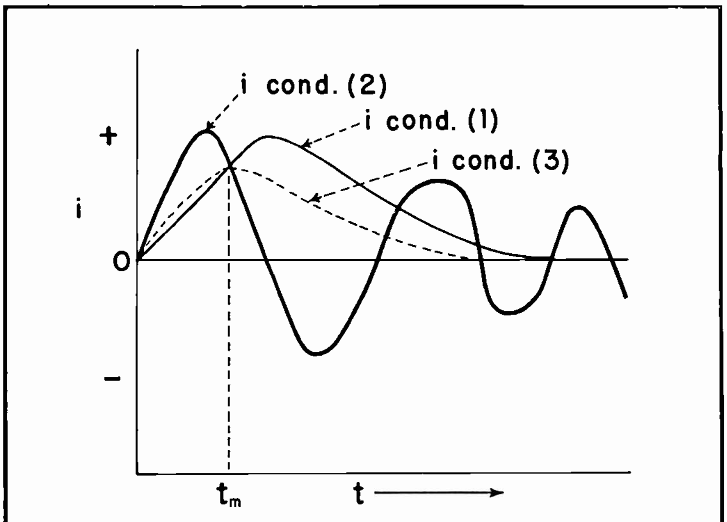


FIGURE 2

The first maximum current will occur at

(10) $$ {}_1t_m = \frac{1}{B}\tan^{-1} B/A $$

(11) $$ = E\sqrt{\frac{C}{L}}\, e^{-at} $$

The second positive peak of the current will occur 360° later

(12) $$ {}_2t_m = {}_1t_m + \frac{2\pi}{\beta} $$

(13) $$ \delta = \ln \frac{e^{-at}}{e^{-at}} = \frac{R}{2LF} = \frac{\pi}{Q} $$

For an analysis of the voltages on the capacitor during the charging cycle, the capacitor voltage starts at zero and approaches

E_0 the battery voltage, at $t = \infty$

For the discharge condition (Fig. 3) $t = O$ capacitor voltage is equal to Eo or the charged voltage of the capacitor, and for $t = \infty$ capacitor voltage is zero.

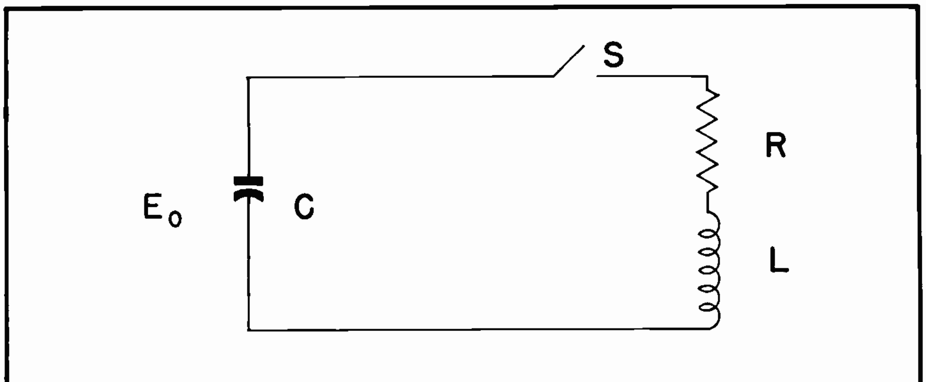


FIGURE 3

In many applications, such as pulse forming networks or energy storage applications, the maximum reverse voltage on the capacitor is of importance. This maximum reverse potential will occur 180° after the maximum forward potential or at a

(14) $$ t = \frac{\pi}{B} $$

At this instant the voltage is equal to

(15) $$ E_{(-m)} = E_0 e^{-\frac{A}{B}\pi} $$

(16) $$ = E_0 e^{-\frac{\pi}{2Q}} $$

Assuming a circuit in which the Q of the circuit is 100, the maximum reverse potential on the capacitor

(17) $$ E_{(-m)} = E_0\, e^{-\frac{\pi}{200}} $$

or 98.5% of the initial voltage.

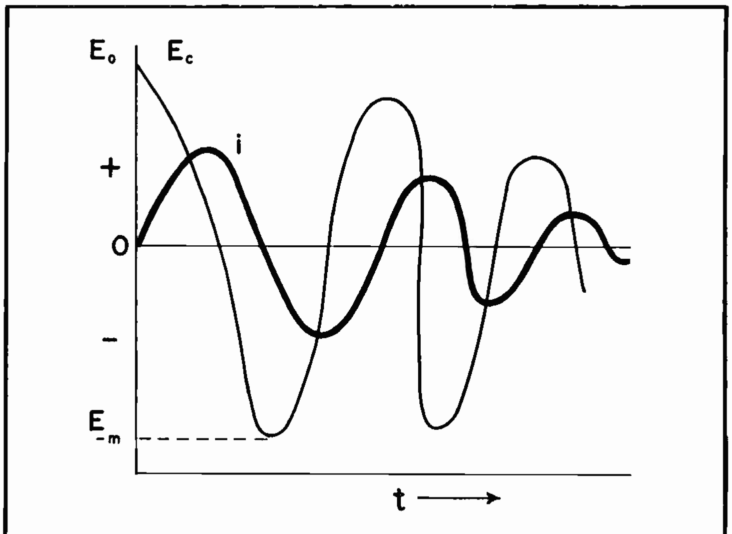
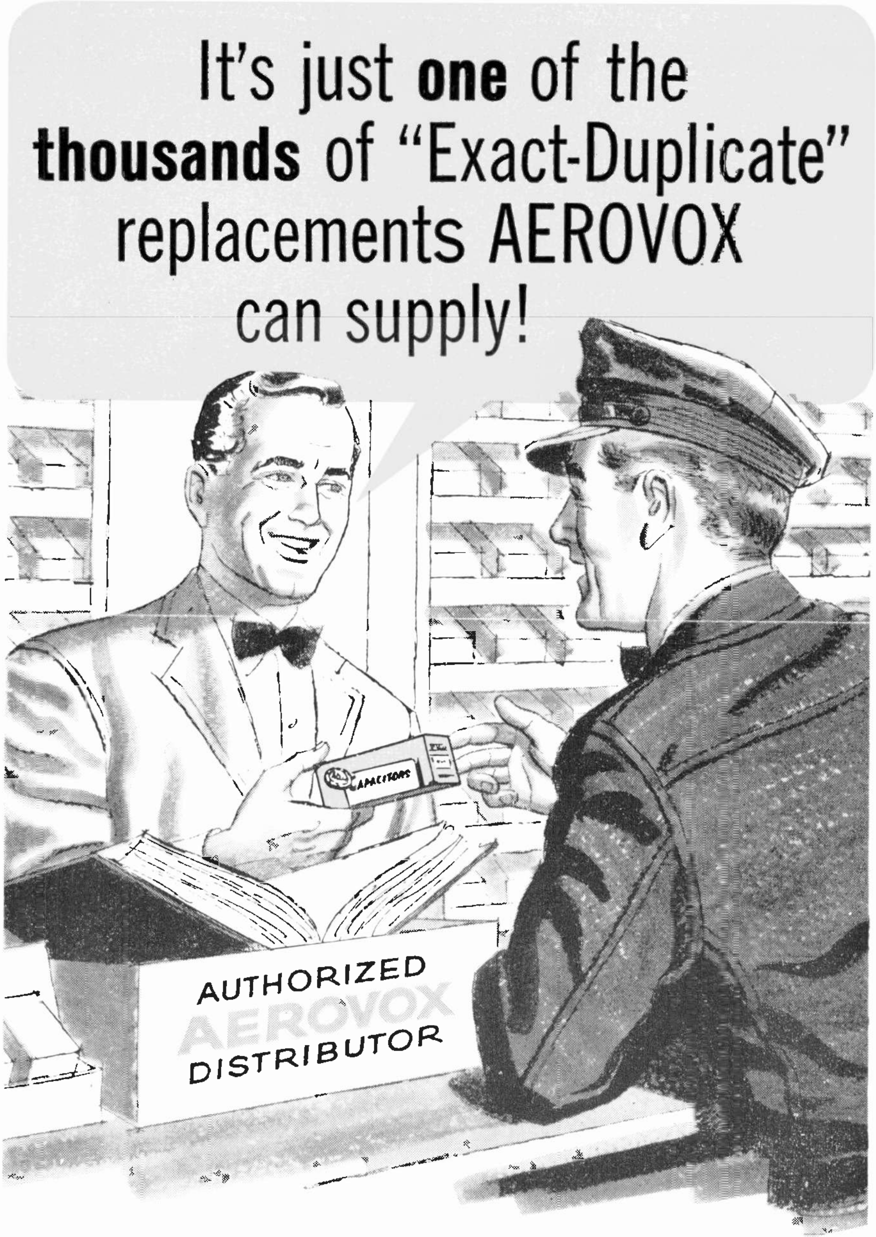


FIGURE 4



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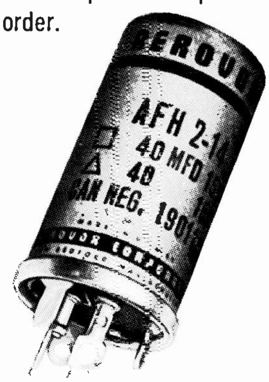

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