Engineering Circuit Analysis

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currents. However, circuit analysis is not concerned with this internal displacement current, and since it is fortunately equal to the conduction current, we may consider Maxwell's hypothesis as relating the conduction current to the changing voltage across the capacitor. The relationship is linear, and the constant of proportionality is obviously the capacitance C,

$$i_{\text{disp}} = i = C\frac{dv}{dt}$$

A capacitor constructed of two parallel conducting plates of area A, separated a distance d, has a capacitance $C = \epsilon A/d$, where ϵ is the permittivity, a constant of the insulating material between the plates, and where the linear dimensions of the conducting plates are all very much greater than d. For air or vacuum, $\epsilon = \epsilon_0 = 8.854$ pF/m $\doteq (1/36\pi)$ nF/m.

The concepts of the electric field, displacement current, and the generalized form of Kirchhoff's current law are more appropriate subjects for courses in physics and electromagnetic field theory, as is the determination of a suitable mathematical model to represent a specific physical capacitor.

Several important characteristics of our new mathematical model can be discovered from the defining equation (8). A constant voltage across a capacitor requires zero current passing through it; a capacitor is thus an "open circuit to dc." This fact is certainly represented by the capacitor symbol. It is also apparent that a sudden jump in the voltage requires an infinite current. Just as we outlawed abrupt changes in inductor currents and the associated infinite voltages on physical grounds, we shall not permit abrupt changes in capacitor voltage; the infinite current (and infinite power) which results is nonphysical. We shall remove this restriction at the time we assume the existence of the current impulse.

The capacitor voltage may be expressed in terms of the current by integrating (8). We first obtain

$$dv = \frac{1}{C} i\, dt$$

and then integrate between the times t_0 and t and between the corresponding voltages $v(t_0)$ and $v(t)$,

$$v(t) = \frac{1}{C}\int_{t_0}^{t} i\, dt + v(t_0) \tag{9}$$

Equation (9) may also be written as an indefinite integral plus a constant of integration,

$$v(t) = \frac{1}{C}\int i\, dt + k \tag{10}$$