Pc board forms custom variable capacitor

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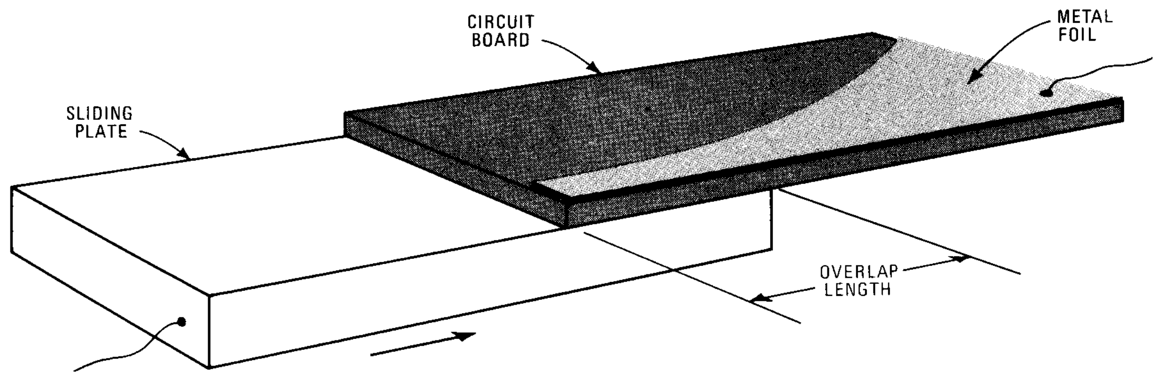
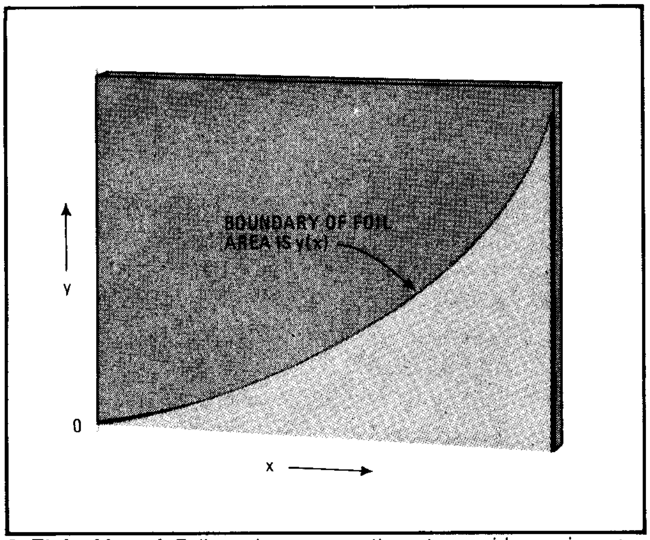
A variable-frequency circuit can exhibit linear mechanical tuning if a specially shaped capacitor is used. Such a capacitor can be used for rf transmitters and rf receivers that have linear slide dials, for position transducers that have direct read-out on a frequency counter, and for many other applications.

One of the simplest capacitor configurations is a metal plate sliding under a printed-circuit board that has been etched to give the desired variation of capacitance (C) with overlap distance (x), as shown in Fig. 1. The capacitance depends upon the dielectric constant and thickness of the board and upon the area of unetched foil that overlaps the plate:

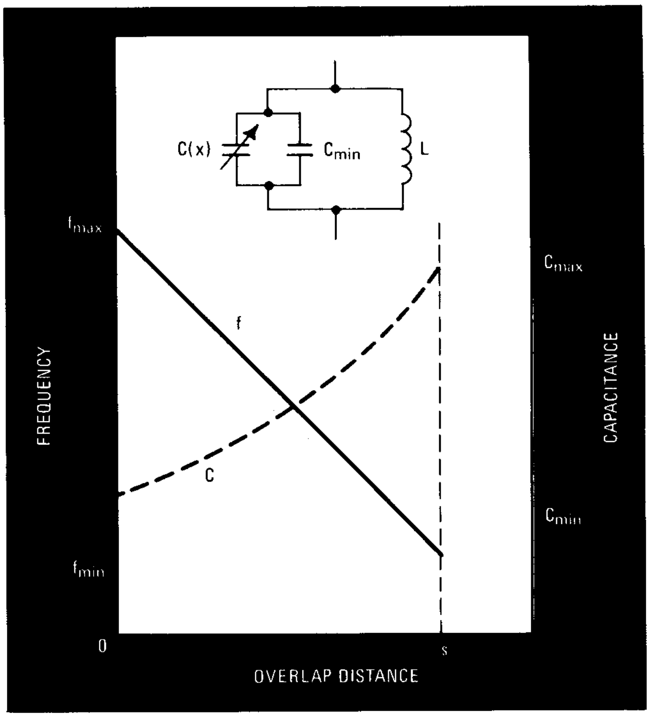
$$C = k\varepsilon_0 A/d$$



1. Variable capacitor. Circuit-board foil and metal plate constitute capacitor that can be varied by changing overlap length. Shape of foil determines relationship of capacitance to overlap. For 1/16-inch paper-base phenolic board, C is about 20 pF/in.² of overlap.



2. Etched board. Foil can have any pattern, to provide any increasing function of capacitance with overlap distance (x). For convenience in analysis, foil shown here covers area from y = 0 to y = y(x). Therefore overlap area is integral of y(x).



3. Linear tuning. To make resonant frequency of LC tank circuit change linearly with overlap, foil needs shape defined in text.

where k is the dielectric constant, ε_0 is 8.85×10^{-12}, A is the overlap area, and d is the board thickness (all quantities expressed in MKS units). For a typical 1/16-inch paper-base phenolic board, C is about 20 picofarads per square inch.

The overlap area, A, is a function of the shape of the foil pattern on the board (Fig. 2)

$$A = \int y(x)\, dx$$

and therefore the capacitance is related to the pattern by

$$C(x) = (k\epsilon_o/d) \int_0^x y(\xi)\, d\xi$$

If the foil area is to be shaped so that the resonant frequency of an LC tank circuit changes linearly with the overlap length, as represented graphically in Fig. 3, then

$$f = \tfrac{1}{2}\pi(LC)^{1/2} = -mx + b$$
$$= -(f_{max} - f_{min})x/s + f_{max}$$

or

$$C = M/(H - x/s)^2$$

where

s = the maximum overlap length, corresponding to resonant frequency f_{min} in Fig. 3
L = the inductance in the tank circuit,
$H = 1/(1 - f_{min}/f_{max})$
$M = 1/[4\pi^2 L(f_{max} - f_{min})^2]$

To obtain the oscillation frequency f_{max} when the overlap is zero, a fixed capacitor must be placed in parallel with the variable one. The value of this capacitance is M/H^2, and therefore the variable capacitance must be reduced by this amount. That is,

$$C(x) = M/(H - x/s)^2 - M/H^2$$

The foil shape that produces this capacitance relation is found from

$$C(x) = (k\epsilon_o/d) \int_0^x y(\xi)\, d\xi$$

or

$$y(x) = (d/k\varepsilon_o)\, C'(x)$$

where $C'(x)$ is the derivative of C with respect to x. Thus the desired foil pattern is

$$y(x) = 2Md/k\varepsilon_o s(H - x/s)^3$$

As an example, suppose the resonant frequency of a 1-microhenry tank circuit is to vary linearly from 40 to 20 MHz when the overlap changes from zero to 5 inches. In this case

f_{max} = 40 MHz
f_{min} = 20 MHz
L = 10^{-6} H
s = 5 in.

These values yield

M = 63 pF
H = 2
$C(x) = 63/(2 - x/5)^2 - 15.8$ pF
$y(x) = 1.3/(2 - x/5)^3$ in.

where x is expressed in inches, and 1/16-in. paper-base phenolic circuit board is used.

Other foil shapes can be devised to provide other capacitance-variation relationships. The function y(x) is found from the derivative of C(x). Properly constructed, these capacitors have excellent mechanical stability and fair temperature stability. □