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Circuit Design Considerations for Low Dielectric Absorption Applications

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Sample hold, dual slope integrators, filter and coupling networks are only a few of the circuit categories influenced by dielectric absorption errors. In this application note some of the capacitor characteristics important to low dielectric absorption (D.A.) applications will be reviewed. A D.A. test method and typical measured values are also discussed.

There are various methods used to characterize this parameter. However, to the circuit designer, D.A. is probably best described by using an equivalent circuit model. Such a model[1] is shown in **Figure 1.**

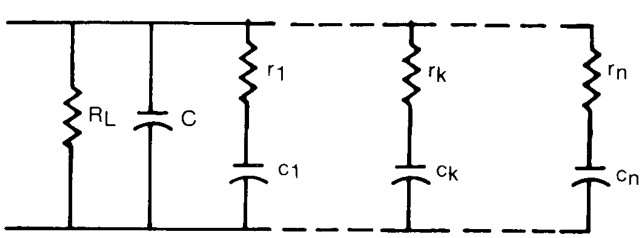


FIGURE 1

Where:

R_L ≡ Leakage Resistance

C ≡ An Ideal Capacitance

r_1, c_1 ≡ First Order Parasitic Branch

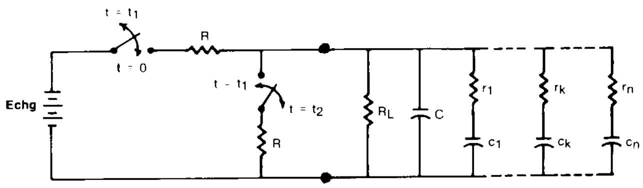
r_k, c_k ≡ k^{th} Order Parasitic Branch

r_n, c_n ≡ n^{th} Order Parasitic Branch

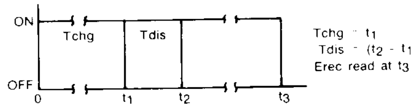
The number of parasitic branches required to represent an accurate D.A. model is a function of many variables, some are:

1. The type of dielectric film used (i.e. polyester, polycarbonate, polstyrene, polypropylene, teflon, . . .).
2. Capacitance value (i.e. part size, . . .).
3. Part construction (i.e. metallized, film foil, dielectric thickness, . . .).
4. Manufacturing processing (i.e. process control and uniformity, type of processing used, . . .).
5. . . .

If the network model shown in **Figure 1** is first charged to a DC voltage, Echg, for a time period Tchg, then discharged into a low impedance for a time period Tdis and then the terminal voltage is observed by using a high impedance measuring instrument, a recovery voltage Erec appears across the terminals.



Test Circuit



Switch timing diagram

FIGURE 2

Some typical Measurement Values Are:

Tchg = 5 Sec.
Tdis = 5 milli-Sec.
R = 100 Ω

Echg = 50 VDC
Erec Read at
$(t_3 - t_2)$ = 10 Sec.

This recovery voltage is an indication of the capacitor's unwillingness to give up some of the initial energy stored in the dielectric media when the device is discharged.

A number of observations can also be made about the recovery voltage characteristic by recognizing that the model network form is such that the terminal property behavior can be influenced by external circuit elements, (i.e. charging source impedance levels, working into a low vs. a high impedance, . . .).

If a first order equivalent model is assumed the recovery voltage characteristic transfer function for the network shown in **Figure 3** is as follows:

$$\left.\frac{E_0}{E_1}\right]_{t>t_2} = \frac{\epsilon^{-bt} - \epsilon^{-at}}{r_1\, C\, (a - b)} = \mathbf{G}$$

Where

$$\mathbf{a} = \frac{R_L C + R_L c_1 + r_1 c_1}{2R_L r_1 C c_1} + \tfrac{1}{2}\sqrt{\left(\frac{R_L C + R_L c_1 + r_1 c_1}{R_L r_1 C c_1}\right)^2 - \frac{4}{R_L r_1 C c_1}}$$

$$\mathbf{b} = \frac{R_L C + R_L c_1 + r_1 c_1}{2R_L r_1 C c_1} - \tfrac{1}{2}\sqrt{\left(\frac{R_L C + R_L c_1 + r_1 c_1}{R_L r_1 C c_1}\right)^2 - \frac{4}{R_L r_1 C c_1}}$$

$$\mathbf{(a - b)} = \sqrt{\left(\frac{R_L C + R_L c_1 + r_1 c_1}{R_L r_1 C c_1}\right) - \frac{4}{R_L r_1 C c_1}}$$

In the case where R_L is large:

$$\left.\frac{E_0}{E_1}\right]_{\substack{t>t_2 \\ R_L\to\infty}} = \frac{c_1}{C+c_1}\left(1 - \epsilon^{\frac{-(C+c_1)t}{C\, c_1 r_1}}\right) = \mathbf{G}$$

Evaluation of the transfer function for the two extremes of working into a high and low impedance produce the following results:

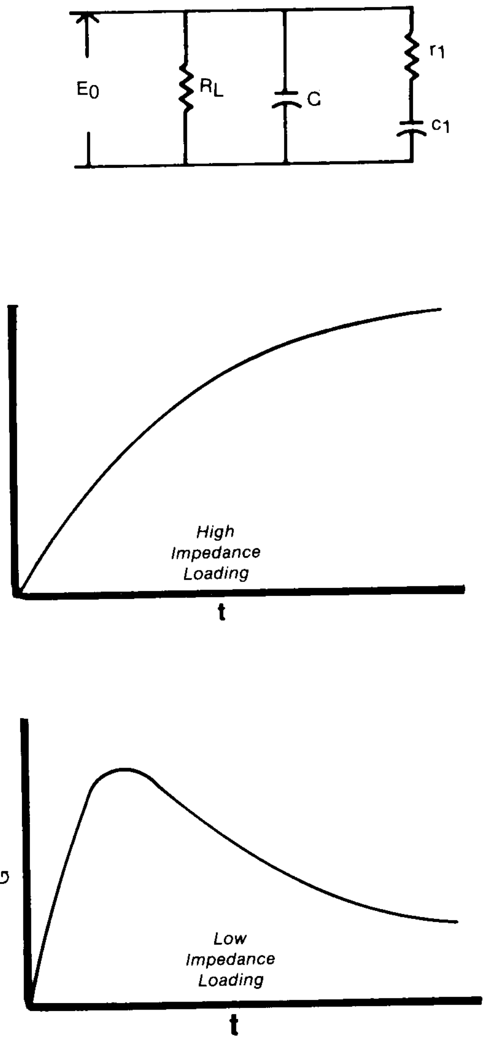


FIGURE 3

Although the exact numbers are seldom calculated, the ratio of C to c_1, c_k . . . c_n, the r_c time constants and the number of parasitic branches in the network are of interest.

The percent D.A. is generally defined as follows:

$$\%\ \text{D.A.} = \frac{\text{Erec}}{\text{Echg}} \times 100$$

Echg - The magnitude of the DC voltage, the charging impedance levels and the charge time Tchg should be specified.

Erec - The discharge time Tdis, the time at which the recovery voltage is measured, the discharge impedance levels, and the method of measurement should be specified.

A set of measured characteristics is shown in **Figure 4.** For this data only the discharge time and the dielectric type were changed. This data was measured at 25°C using a test circuit similar to **jure 2.** An x preceeding the dielectric type indicates a metallized construction.

DA vs DISCHARGE TIME

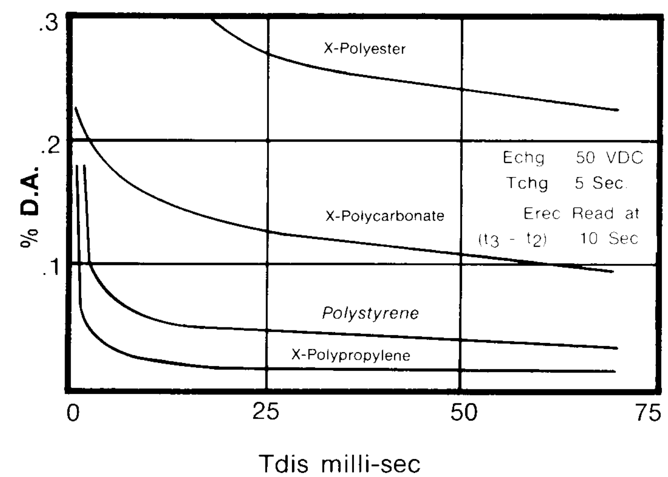


FIGURE 4

Probably the two most important characteristics of any single curve shown in **Figure 4** are the rate of change and the magnitude of the recovery voltage level as a function of time. The rate of change is an indication of the speed of dipole alignment or in equivalent circuit terms, the size of $r_1\ c_1$, $r_k\ c_k$, $r_n\ c_n$, and the voltage magnitude is an indication of the ratio of c_1, $c_k \ldots c_n$ to C.

The comparison of the four film curves shown in **Figure 4** also displays the contrast between dielectrics. Polyester for example, is much slower to respond and has a much higher D.A. percentage than the other three films shown.

Polypropylene is a much better choice since dipole alignment occurs very fast, and the recovery voltage magnitude is the lowest in short time .mes. Fast recovery times are important in many applications, (i.e. coupling of waveforms made up of fast changing transient conditions, . . .). A high percentage of applications fall in this time category.

Some other important capacitor parameters are insulation resistance (which contributes to leakage current), dissipation factor (an indication of lead termination properties and power losses), and capacitance variation (temperature coefficient).

IR vs TEMPERATURE

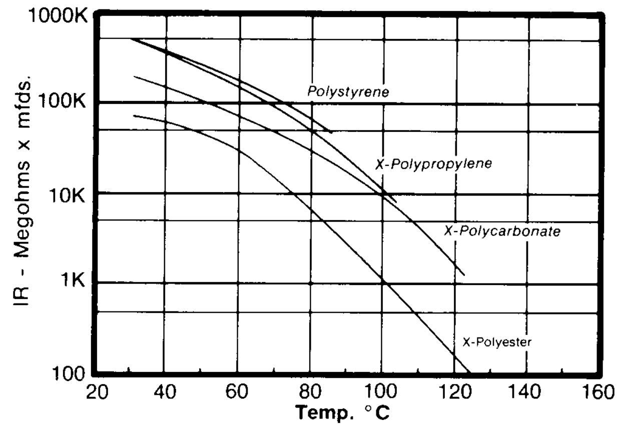


FIGURE 5

Figure 5 shows the relationship of insulation resistance (I.R.) as a function of temperature for the four films under comparison.

DF vs TEMPERATURE

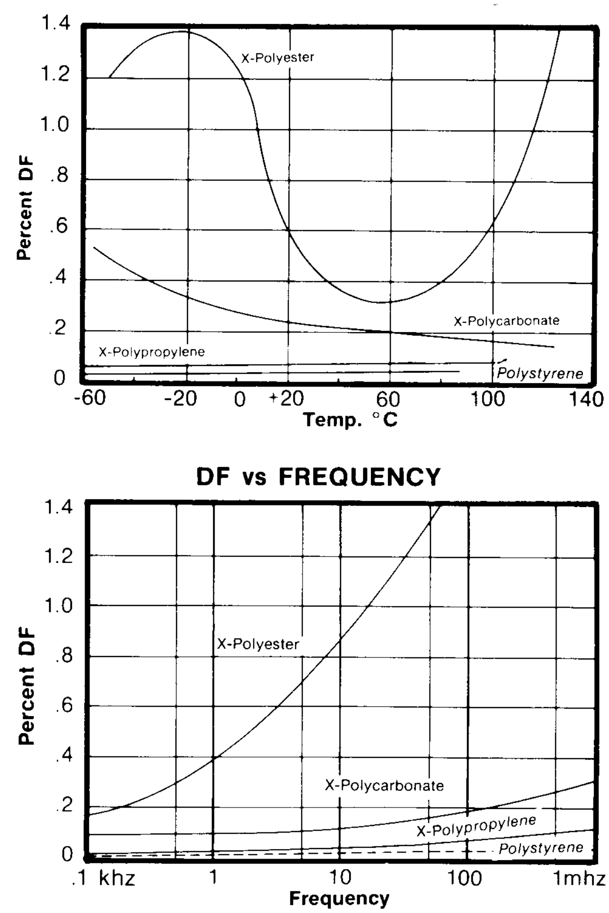


FIGURE 6

Figure 6 shows dissipation factor (D.F.) properties. D.F. varies considerably as a function of temperature and frequency with some films. This parameter is quite important in networks where high currents and/or complex waveforms containing high frequency components are present.

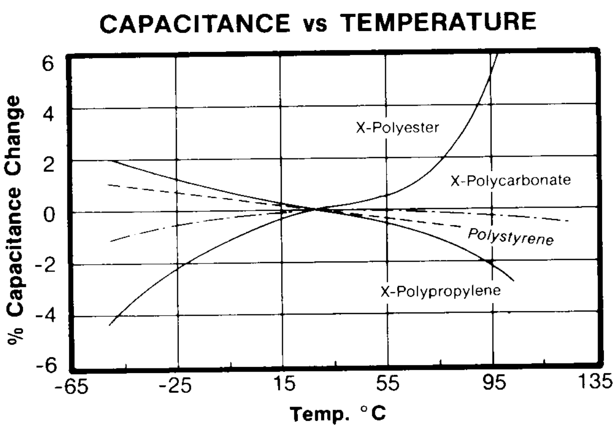


FIGURE 7

Capacitance change is illustrated in **Figure 7** for the films under discussion.

SUMMARY

In an effort to optimize overall circuit performance passive element parameters must be considered in detail.

It should be noted that selection of a part by dielectric alone is not always sufficient (i.e. improper processing can cause a considerable degradation in D.A. and other parameters).

All polar dielectrics (i.e. tantalum, aluminum electrolytics, . . .), and ceramics have a high D.A., while mica and glass show improved D.A. characteristics. Films are a much better choice.

Should your circuit design require special D.A. characteristics (those beyond our standard X363), a special capacitor design with lower D.A. paramaters should be considered. Our applications engineering department will be glad to discuss your requirements.

The X363UW Metallized Polypropylene Capacitor has been researched, designed and tested and found superior in DA and ideally suited for sample and hold circuitry as well as in other applications requiring low dielectric absorption.

REFERENCES

(1) **Paul C. Dow, Jr.**

"An Analysis of Certain Errors in Electronic Differential Analyzers II - Capacitor Dielectric Absorption", IRE Transactions on Electronic Computers, Volume EC-7, Mar, 58.