HOOK IN THICK FILM

HYBRID CIRCUITS

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August 15, 1983

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INTRODUCTION

DEFINITION OF HOOK

Hook is a term which was coined to describe a particular type of distortion associated with the response of RC attenuators to a square wave input. Attenuators are used to reduce the amplitude of a signal. For a square wave input the output should also be a square wave but of a smaller amplitude. Figure-1 demonstrates this.

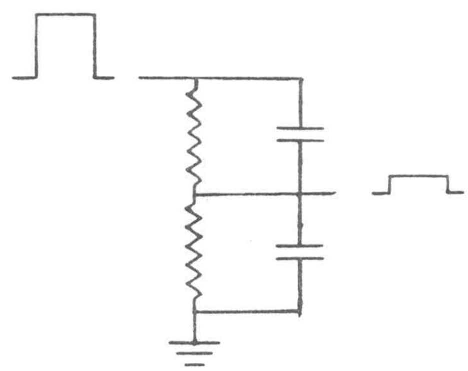


Figure 1 - Voltage Division By An Attenuator

If the output in not a perfect square wave, the signal has been distorted. Several types of distortion can occur. "Hook" refers to the types of distortion shown in Figure-2.

This "hook" cannot be removed or compensated for by adjusting the resistor and capacitor values in the circuit. Oscilloscopes, voltmeters, and other instruments which use attenuators exibiting hook will give inaccurate and inconsistant measurements.

Hook is also used to describe distortions in the response of single capacitors to a square wave. The shape of the distortion is usually similar to Figure 2d.

WHAT THIS REPORT COVERS

The report covers the reasons certain materials have hook, the role of humidity and contamination in hook, and methods to reduce hook in circuits.

The need for this project stemmed from hook in thick film circuits. Although hook occurs in discrete capacitors as well this report deals only with thick film circuits. Many of the ideas, however, are transferable.

Geometric hook will not be dealt with here either. This type of hook results from certain layout phenomena and coupling effects across laser trim gaps.

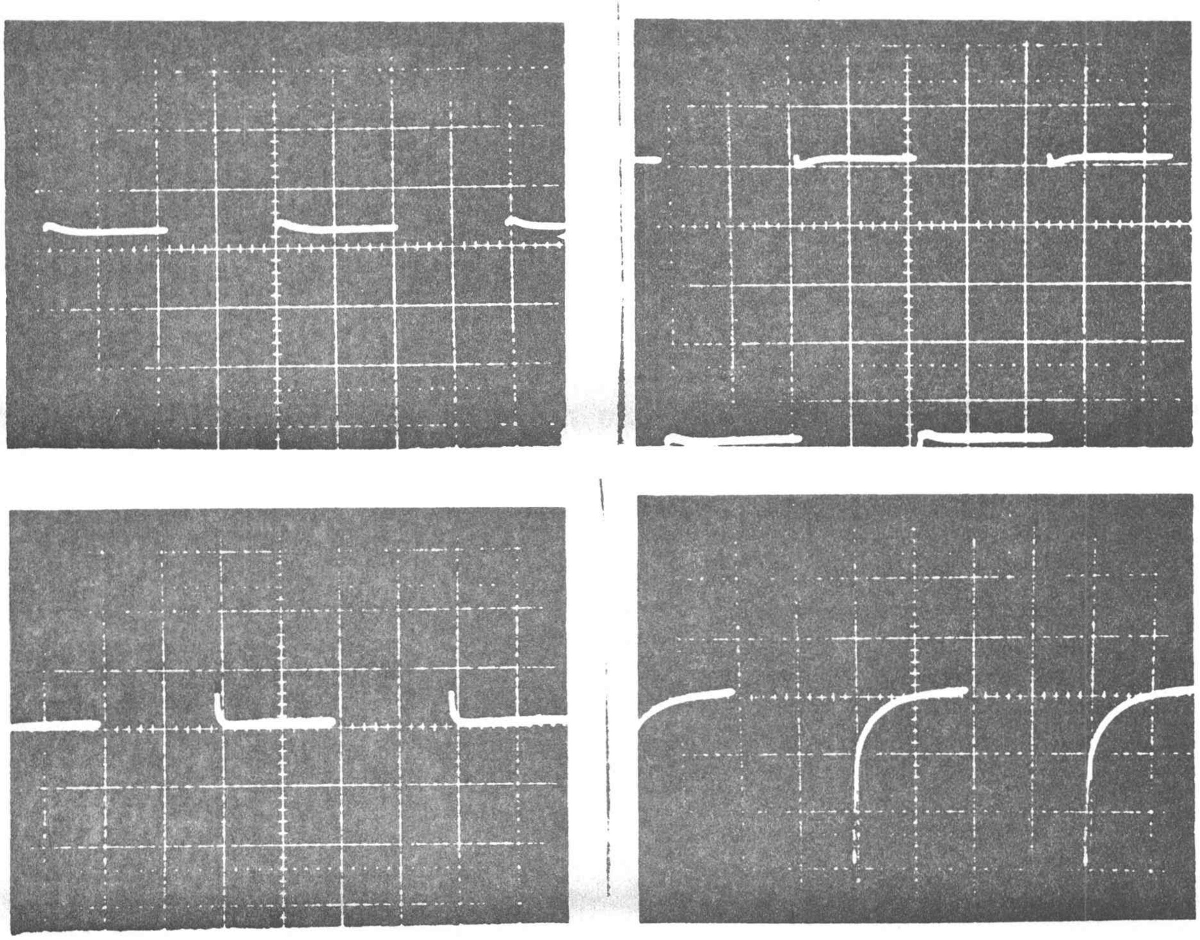


Figure 2 - Forms of Hook

MEASURING HOOK

TAKING READINGS

When someone states that an attenuator has 10% hook, they are saying that the height of the distortion is 10% of the total height of the trace. In Figure-3 the total height is the distance from point A to point C (instantaneous step height) and the distortion is the height of point C minus the height of point B.

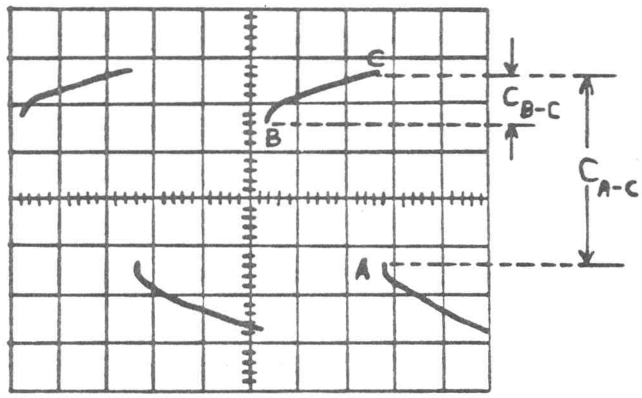


Figure 3 - Hook Measurement

WHAT FREQUENCY TO USE

In hook measurement, some frequency of square wave must be chosen to perform the testing. The selected frequency is like a window into the total response. Low frequencies show more of the total response. Higher frequencies show more detail of the leading edge, but they cut off the trailing edge. Figure-4 shows traces of a hooky capacitor at three frequencies without changing the horizontal time scale. The photos show that the response at higher frequencies is a section of the response at low frequencies (this is expected from Fourier analysis of a step function input). The amount of hook seen at 10KHz is about equal to the amplitude of the 100Hz trace at 1/10 of its horizontal length.

Frequencies of less than 1kHz are useful for comparing hook in capacitor materials since they show more of the complete response. However, at 10Hz and lower, considerable measurement problems can occur. Unless otherwise stated, testing done for this report was at 100Hz for individual capacitors. Attenuators were tested at a variety of frequencies depending on the test.

Attenuators use a resistor divider to establish the height of the trace after some amount of time. This implies that looking at an attenuator trace for hook at a frequency below the point where the resistors are doing most of the voltage division is of no use. For most of the current attenuators this is in the range of 100Hz to 1kHz. After the low frequency

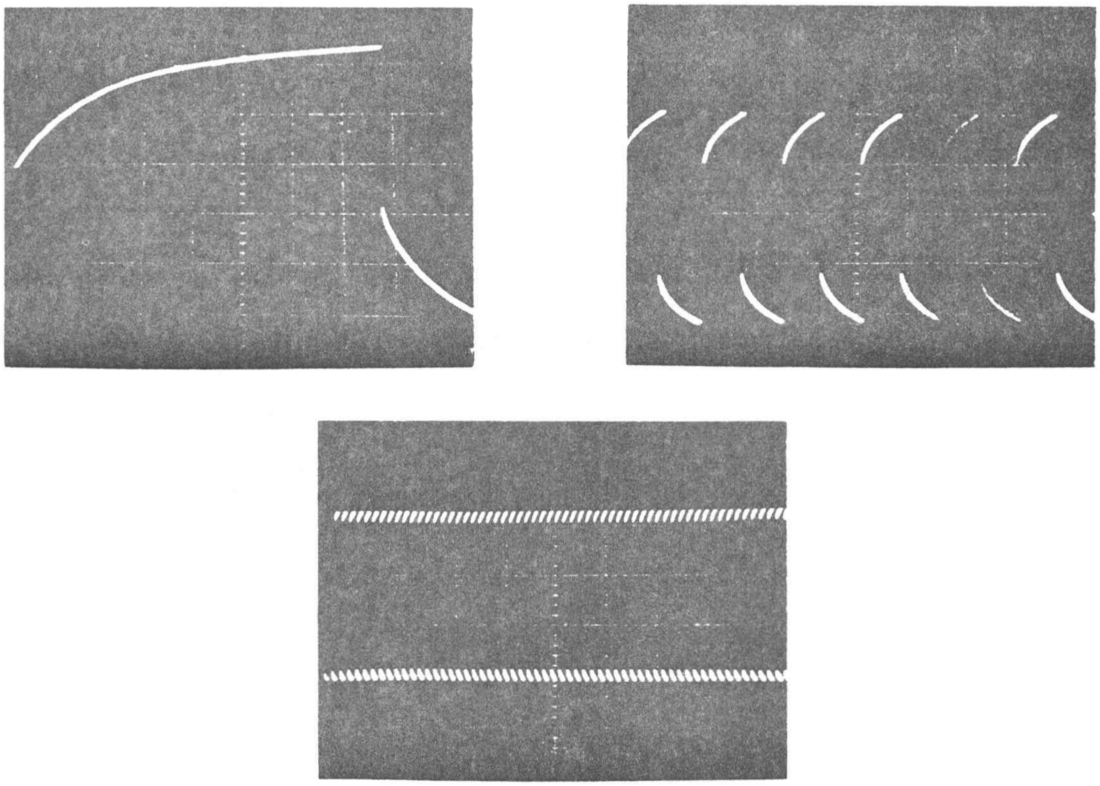


Figure 4 - Hooky trace at (a) 10Hz, (b) 100hz, (c) 1000Hz

response is viewed the leading edge should also be magnified to get full detail of the response (this is easily done with a delayed trigger time base). Figure-5 shows how deceiving a trace can be. Figure 5(a) shows a spike at 100hz and 5(b) shows a horizontally magnified view of the same trace indicating that the trace is not actually a spike.

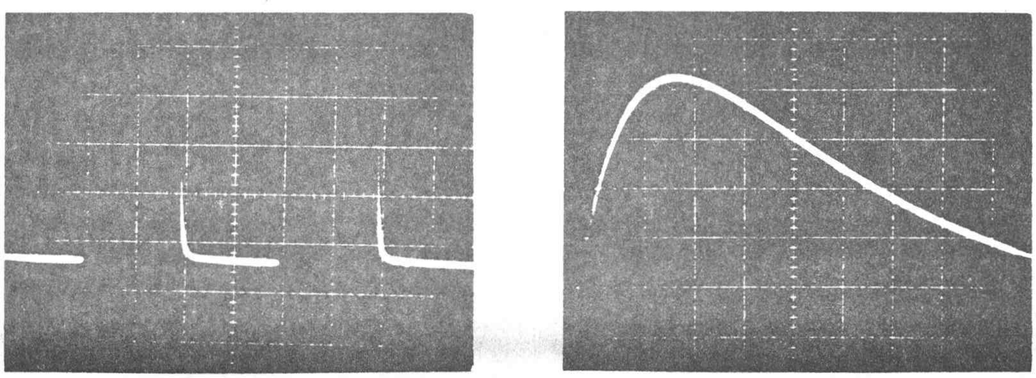


Figure 5 - (a) spike at 100hz, (b) magnified view

ATTENUATORS

For this study the H917 attenuator was chosen as a test part. It had more hook problems during its initial testing than any of the "novar" attenuators currently in production. It should be noted, however, that it was one of the first novar attenuators. Cleaning methods used to reduce hook for the H917 were used on all novars that followed.

To test the H917 in production, a special test fixture had been designed. The fixture contained a circuit board needed because the FET amplifier stage had to be close to the attenuator to work correctly. To test hook as a function of relative humidity, I built an enclosure for the test fixture which could be purged with gas. To obtain gas of a given relative humidity, I used a mixture of dry and wet nitrogen. Wet gas had been bubbled through a column of water to saturate it to 100% relative humidity. These gases could then be mixed linearly to obtain the relative humidity was needed. The test equipment was set up as shown in Figure-6.

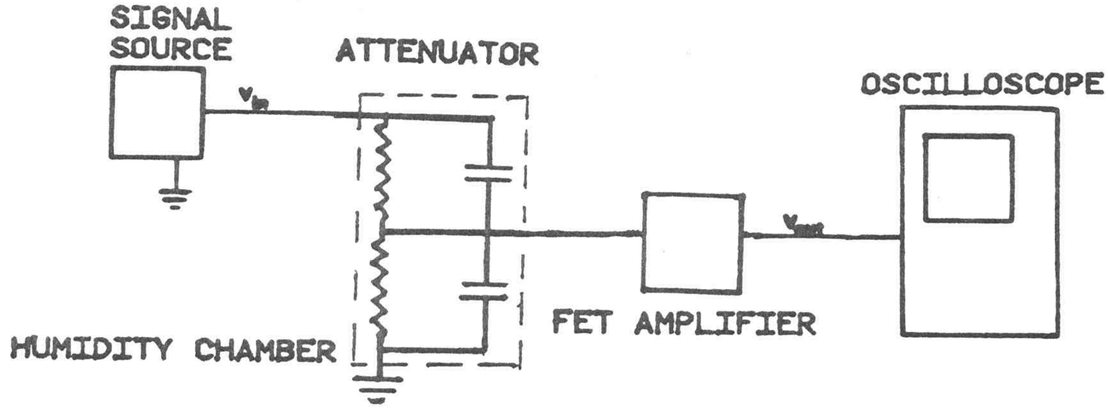


Figure 6 - Test setup for attenuators

CAPACITORS

The setup for measuring capacitors is shown in Figure-7. It uses a charge amplifier. The charge amp circuit uses reference capacitors as feedback elements to an operational amplifier. This, in effect, creates an attenuator with no resistors. The test capacitor acts like a series capacitor in an attenuator and the reference cap acts like a shunt capacitor. The result is that unlike the attenuator, only the series cap (test cap) should show hook. For this type of test, only the rollup form of hook will be seen (an exception to this will be noted later). In addition, since resistors are not present, they do not "pull down" the amplitude at long times. This results in a trace which, in many cases, does not approach a constant amplitude even at 10Hz.

To test hook of capacitors as a function of relative humidity, the gas mixer from the attenuator tests was used. A small sheetmetal box contained the gas over the test parts.

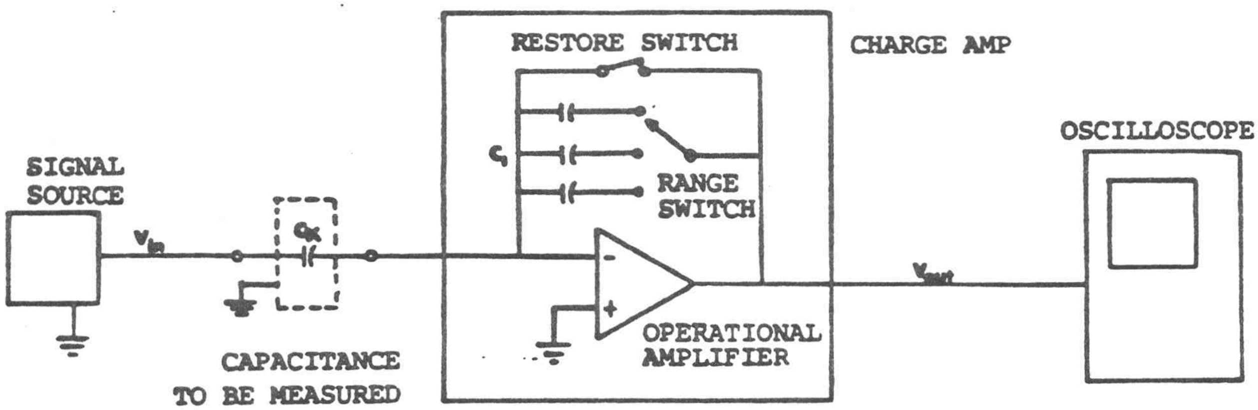


Figure 7 - Setup for hook measurement of capacitors

COMPARING HOOK IN ATTENUATORS TO HOOK IN CAPACITORS

Hook is a term used in talking about both attenuators and individual capacitors. In both cases the term refers to a distortion in the response to a square wave. However, it is difficult to compare the measured values for the two cases. Measurement of individual caps is useful to compare dielectric materials, but can only give a general idea of how much hook will show up in an attenuator. Five percent hook in a capacitor will not result in five percent hook in an attenuator. Testing of individual capacitor is in a sense simulating hook of the series cap of an attenuator. Comparison of a dielectric's hook in an attenuator to its hook in the charge amp test becomes very hard because hook is usually a result of contamination. This means that a method of applying a controlled contaminant to the series cap of the attenuator would be needed to compare absolute values of hook. Other factors that cause problems in comparing the two tests are the geometry dependence of hook, effects from the rest of the circuitry, and cancellation effects when both shunt and series caps have hook. Values for hook given for dielectrics in this report are large compared to most hook measurements. The reason is that the test pattern used contains a guard ring of conductor around the capacitor which tends to couple in hook more than a typical capacitor design. This was used to give more resolution in the measurements. It also had advantages in testing capacitors with high leakage currents.

MODELING HOOK

Lossy dielectrics were thought to act like a distributed RC network in parallel with components of the circuit. It was desirable to model this in order to account for the various forms of hook. For hook, the distribution of R's and C's is dependent on layout geometry of circuits. They do not have to be a uniform distribution. This results in a wide variety of curvatures in the response trace depending on how components are coupled. Figure-8 shows hooky traces which were produced by moving around a drop of water above a capacitor test part (separated by a thin glass slide).

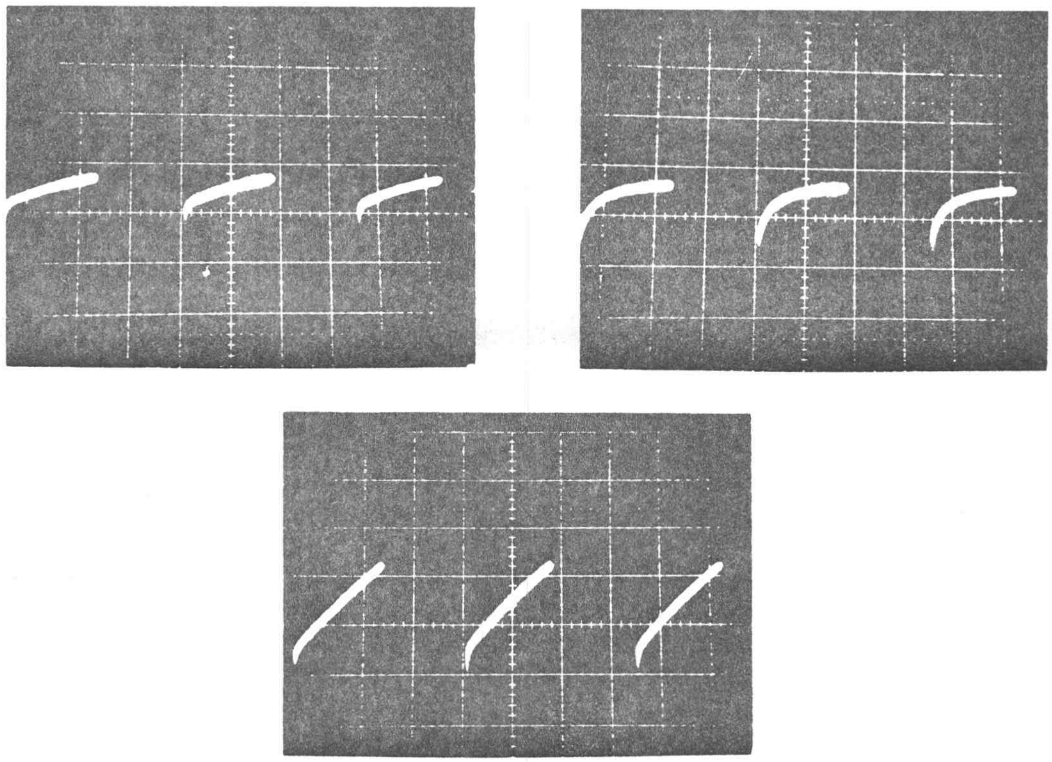


Figure 8 - Hook traces from water drop

SPICE, a modeling program on the CYBER, was used to model a proposed equivalent circuit for hook in attenuators. An equal distribution of R's and C's was used for simplicity. Two models were used, one with distributed RCs on the series leg, and one with RCs on the shunt leg (Figure-9).

Effects of the RC on the series half were modeled first (the distributed RC on the shunt half was removed). The result is shown in Figure-10a. This matched hook traces seen in the past.

Next, the shunt leg of the attenuator was modeled (Figure-10b). The results matched one of the other forms of hook seen in testing of attenuators.

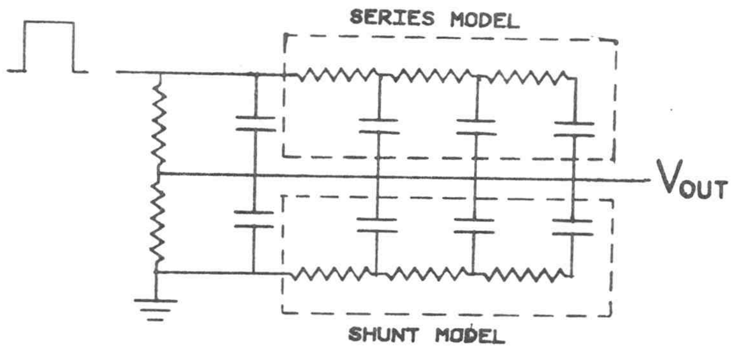


Figure 9 - Equivalent circuit for hook

Variations of the time scale and the values of the R's and C's in the model produced traces 10c to 10f. If the time scale is long, the bump or droop in the leading edge loses detail and begins to look like a spike or rollup, respectively. This will also result if the RC time constant of the stray RC is very short. If the time scale is short (or the test frequency high) part of the leading edge is magnified, yielding the rollup and rolldown of 10(e) and 10(f).

The only form of hook which the modeling did not demonstrate was true rollup at low frequencies. True rollup is when the trace has rollup even when the leading edge is highly magnified. This form has been seen in testing of attenuators. It is likely due to more complex coupling than the model accounts for.

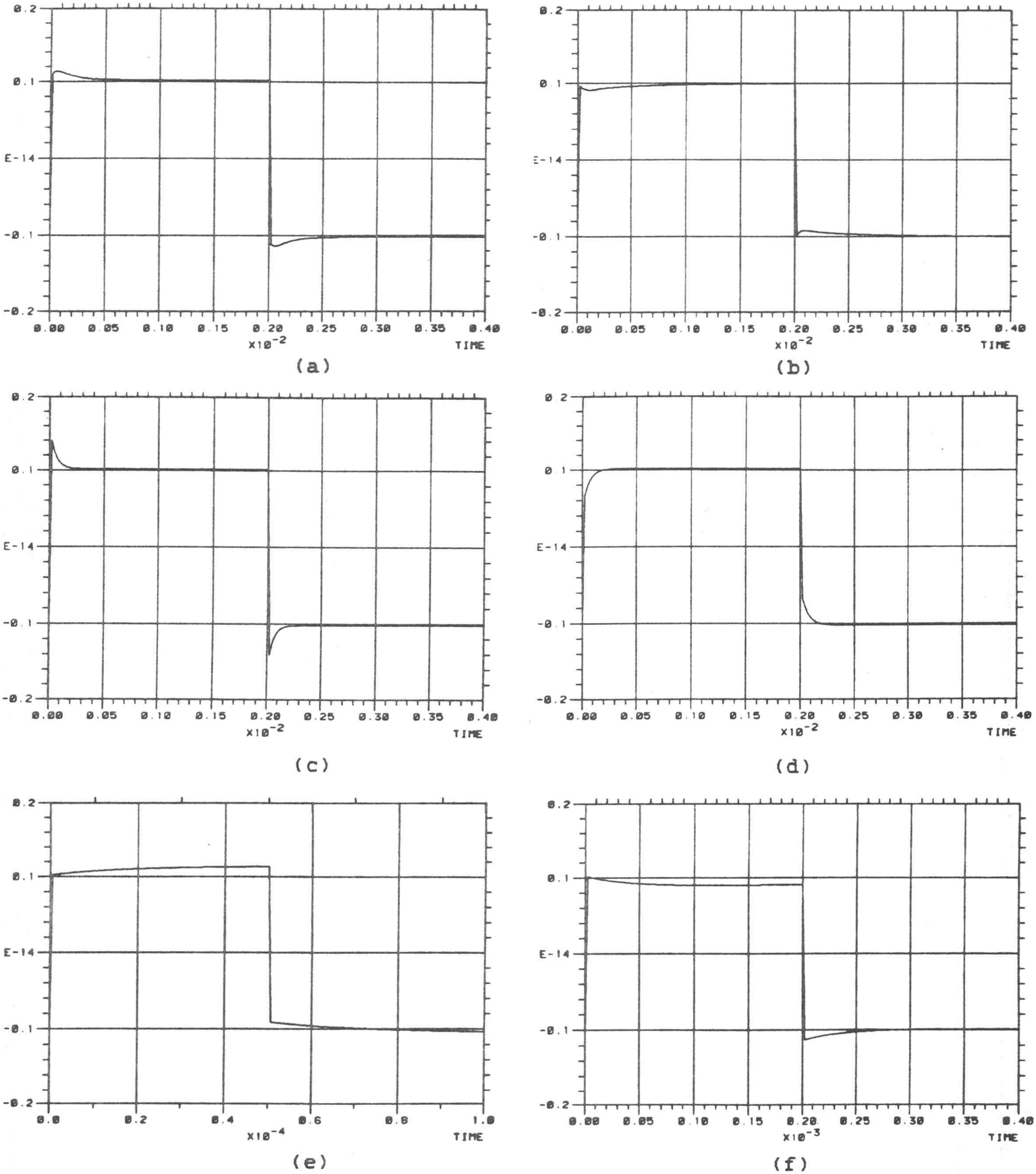


Figure 10 - Hook from an RC tied to attenuator

UNDERSTANDING HOOK

WHERE HOOK COMES FROM

Hook results from two phenomena, lossy dielectrics and water adsorption on surfaces. As Scaife<1> discusses, a lossy dielectric will respond to a step function as shown in Figure-11.

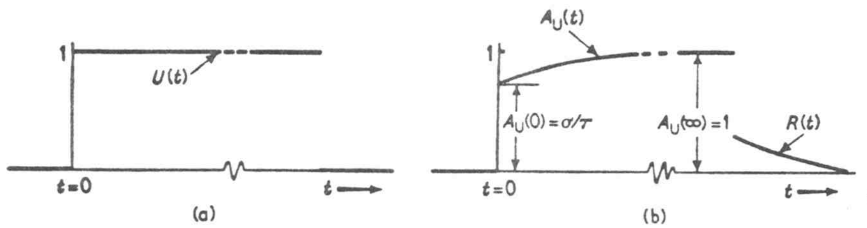


Figure 11 - The Response of a Lossy Dielectric(b) to a Step Function(a)

Water happens to be a very lossy material. Figure-12 shows the response of a capacitor which uses water as the dielectric. At a given relative humidity solid surfaces will allow a certain quantity of water molecules to become attached, or adsorbed, to the surface. As water molecules are adsorbed on a circuit their response will be superimposed, in a sense, onto the response of the circuit. If the circuit happens to be an attenuator, the result is hook. The form of hook which shows up in the circuit is controlled by which parts of the substrate and components are adsorbing water and how much they adsorb.

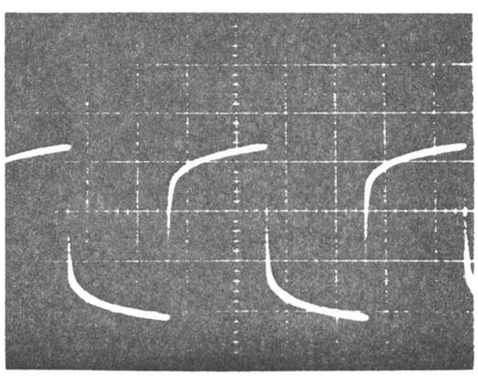


Figure 12 - Response of water to a square wave

Any lossy material (one that dissipates energy) will have some amount of hook. The dielectrics used for thick film materials generally will have small amounts of hook. Materials which have higher dielectric constants will tend to have greater amounts of inherent hook (hook measured with no adsorbed water present).

It also seems that resistivity of conductors plays a part in how much inherent hook materials have. In dry nitrogen, parts made with gold conductors and DuPont 9429 have close to zero hook. If palladium-silver conductors are used rather than gold, parts will show much more hook. This may be a result of the "skin effect" where as frequency increases, current will travel closer to the surface of the conductor. If the conductor has high resistivity, a lot of energy is dissipated in this surface layer. The response is similar to hook (Figure-13). These effects are small compared to surface effects. They drop the inherent hook from a small amount with Pd/Ag conductors to none at all with gold (Figure-14). In certain applications, such as high resolution sample and hold cercuits, it may become significant.

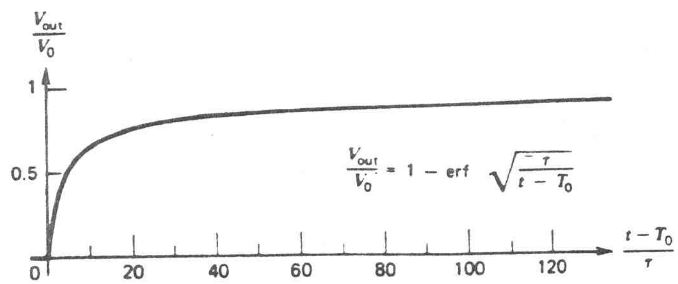
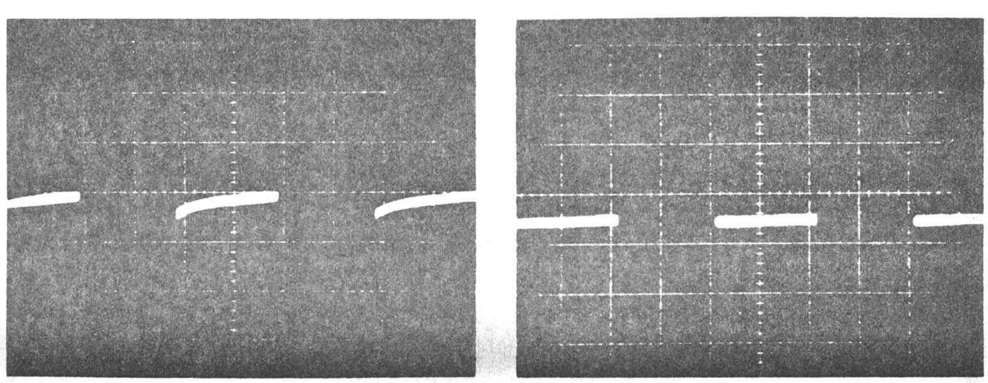


Figure 13 - Response of transmission line with lossy conductors<2>



(a) (b)

Figure 14 - Hook of a (a) part with Palladium-Silver conductors, (b) part with gold conductors.(1%/div)

Since typical materials used for low K dielectrics do not have much inherent hook there are only three possible causes for environmentally induced hook: a bulk change in the thick film dielectric, an absorption of water into the bulk dielectric, or a change in the surface properties. It has been proposed by some that bulk changes in the dielectric might occur over the ten days of humidity testing, or that water diffuses into the dielectric over this long period of time. However, this is probably not the case. Parts made with DuPont 9429 dielectric had large increases in hook after 10 day humidity (measured at 60% R.H.). The instant parts were flooded with dry nitrogen all hook disappeared except the inherent hook for 9429. If there had been a bulk change in the material it would not have reversed so quickly, if at all. In addition, silicone coatings (discussed later) nearly eliminate hook. Since these coatings do not stop the diffusion of water (only modify the surface), it appears that bulk diffusion of water into 9429 is not a major cause of hook (although it may be more important in poorly sintered discrete ceramic capacitor).

Any other material which is a lossy dielectric can also induce hook. These materials cause "permanent" hook which will not go away when the parts are heated as it does with hook from water. These materials are not common and do not include fluxes and oils as originally expected. If the lossy material is a contaminant it will usually adsorb water more than the thick film dielectric. This will cause both a permanent hook and additional hook which is a function of relative humidity.

<u>HOOK VS. RELATIVE HUMIDITY</u>

The number of water molecules adsorbed on a material's surface is a function of the relative humidity of air surrounding the surface (Figure-15). It also is very dependent on surface properties. Bikerman<4> points out that a surface's roughness, cleanliness, and chemical nature play a major role in how well the surface wets. That is why dielectrics and contaminants show variations in how much hook they have as humidity goes up.

The result of energy dissipation in the surface coating of water is hook. Hook increases with relative humidity for the dielectrics tested. How much it goes up is a function of how much water is adsorbed on the surface.

To test inherent hook of dielectrics, newly made parts were tested in dry nitrogen. The parts were processed carefully to avoid contamination and since the test was in dry nitrogen adsorbed water was virtually eliminated as a variable. Next, hook was tested at 10% relative humidity, 20%, 30%, etc. Figure-16 shows the result for 4 DuPont dielectric materials.

Results show that dielectrics vary considerably in their ability to wet. Tek's standard material, Dupont 9429, performs quite well in comparison to other materials. This indicates a definite need to test new dielectrics for hook.

One of the materials tested, DuPont 49b, has the same chemical makeup as DuPont 9429. The only difference between the two is the particle size distribution of the powders used to make the paste. As the SEM in Figure-17 shows the 9429 has

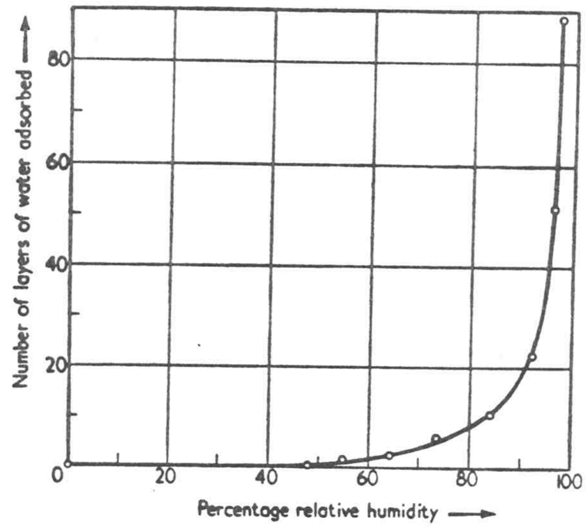


Figure 15 - Water adsorbed vs. Relative Humidity(3)

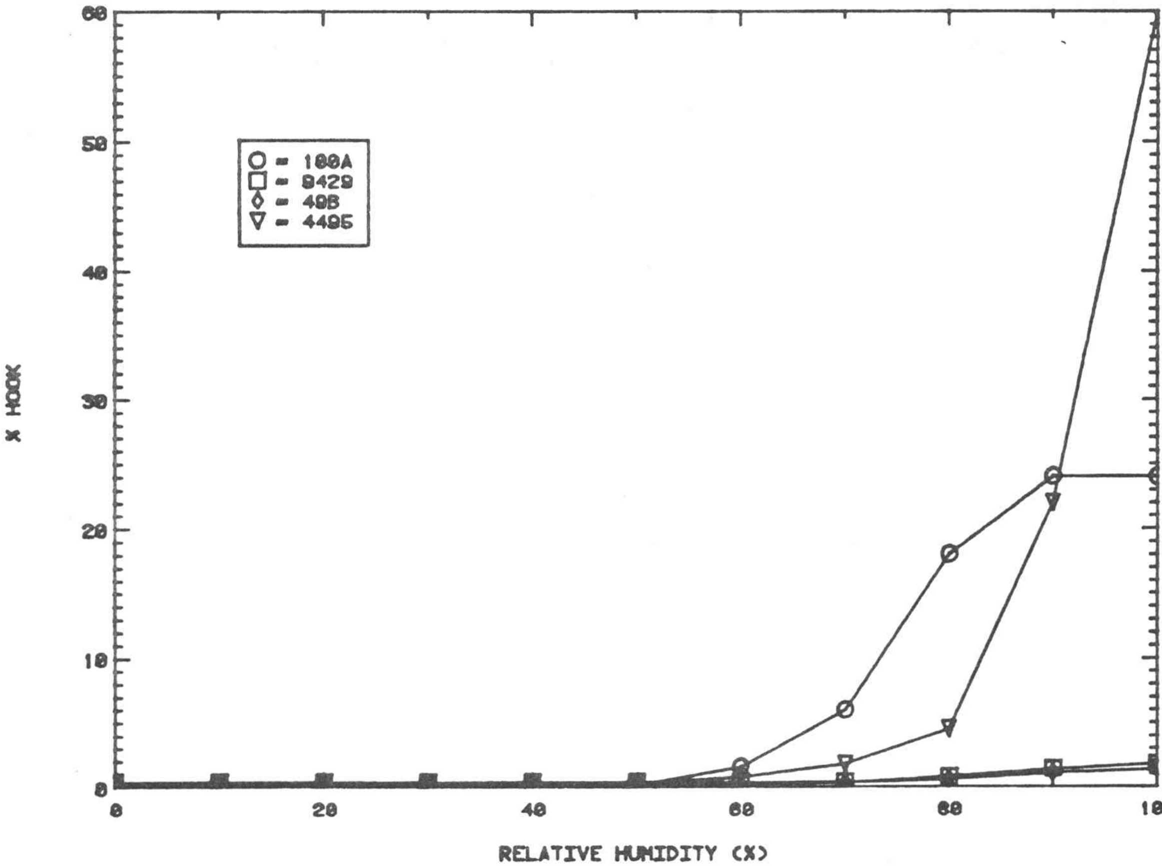
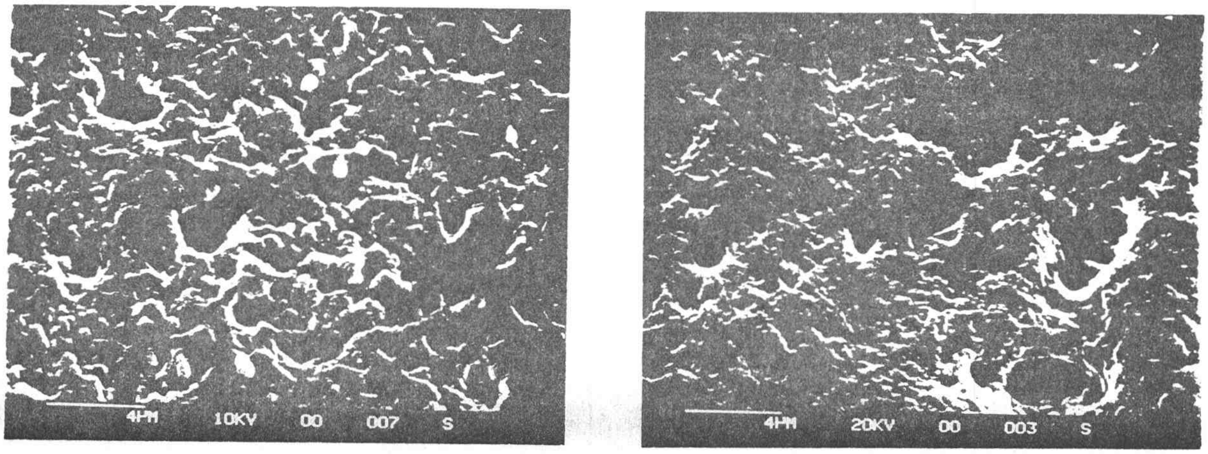


Figure 16 - Variation of hook with relative humidity

a coarser surface, and from Figure-16 it has more hook at higher relative humidities. It is interesting to note that 49B also has less inherent hook than 9429 (inherent hook meaning hook of a clean part measured in dry nitrogen).



(a) (b)

Figure 17 - SEM of (a) 9429 and (B) 49b

Silicones and Teflons are not wetted well by water (liquid or vapor). These and any other "hydrophobic" material should provide a great deal of protection from hook. Figure-18 shows the dramatic differences in how much water materials adsorb. A particular silicone, Dow Corning 1107, was used as a test vehicle for non-wettable coatings. The 1107 silicone greatly reduced the sensitivity of parts to hook (Figure-19).

WETTING ANGLE AND HOOK

The wetting angle between a liquid and a solid is the contact angle θ as shown in Figure-20. High values of wetting angle indicate poor wetting. They also relate to how well a vapor from a liquid can adsorb onto a solid surface. The wetting angle of water on several dielectrics was tested using a Reme Hart contact angle goniometer (model 100-07-00) with a 25 gauge syringe. The instrument places a given size drop of liquid onto samples and allows contact angles to be measured with a calibrated microscope. The values were found to correlate to the amount of hook seen in the dielectric at high relative humidities. Table-1 gives values of wetting angle for the dielectrics above. Low wetting angles indicate easier wetting and more hook sensitivity.

Use of wetting angle can apparently be used as an additional tool to testing hook directly. This may be very helpful in evaluating contaminants as well as new dielectrics.

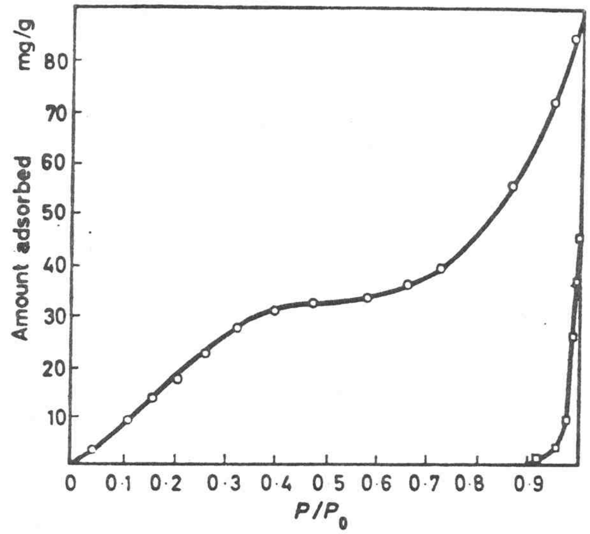


Figure 18 - Water adsorption curves for two materials<5>

Caution should be used, however, in that 4495 was found have more hook than 100A at high R.H. but its wetting angle was higher. Wetting angles may need to be tested as a function of relative humidity (due to prewetting effects of the vapor).

CONTAMINANTS AND HOOK

It was believed for some time that hook was related to contamination, but testing done was seldom conclusive. Humidity was never controlled in these tests. As a result, changes in relative humidity from day to day caused inconsistant results. In addition, breathing on parts induced large amounts of hook and caused traces to drift temporarily.

Another problem in past tests has been the method of inducing hook. Parts were either run through ten day humidity or they were soaked in water overnight. Results from these tests varied greatly from part to part and it was difficult to draw conclusions.

To identify the role of contaminants in hook, a piece of Teflon plumbers tape was placed on top of the test parts. On seperate parts, drops of solder flux, oil, and D.I. water were placed on the tape (see Figure-21).

By moving the tape around until the drop of liquid was over the capacitor or its leads, hook was induced. For both D.I. water and flux the shape and amplitude of the hooky trace varied widely as the drop was moved. However, oil produced almost no hook. The part with D.I. water was used to find out how conducting ions in water would affect hook. A grain of salt was dropped into the D.I. water to provide the ions. Surprisingly, the hook reduced to about half its original value as the salt disolved.

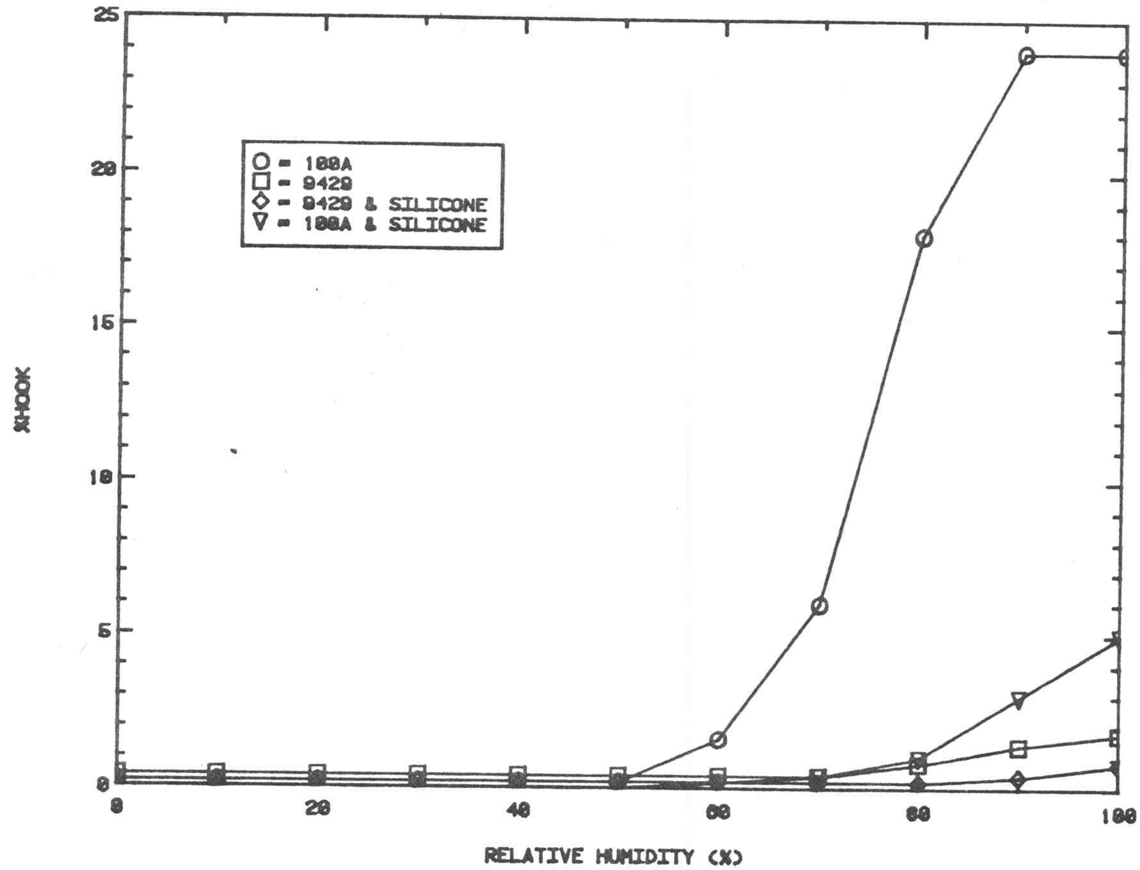


Figure 19 - Silicone coated and uncoated parts

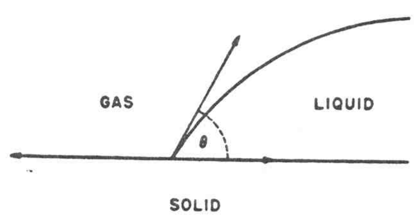


Figure 20 - Wetting angle of a liquid on a solid(4)

Hook was then measured for parts which had been dried after dipping in flux, oil, and saltwater. Flux did not increase the inherent hook of the dielectric. As humidity was increased the flux-coated part had less hook than the control. Oil also did not change the inherent hook and induced less hook at high humidities than both the solder flux and the control part. The salt-coated part did not perform as well. The salt increased the inherent hook from .2% to .4% (not terribly significant for individual cap measurement). At 60% R.H., all

TABLE 1

Dielectric	Wetting Angle (degrees) Without 1107	With 1107
9429	56	98
49b	59	100
100A	46	107
4495	54	100

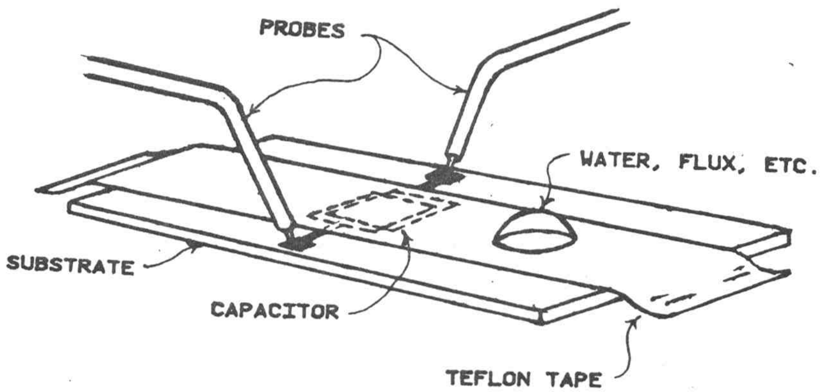


Figure 21 - Test method for liquid dielectric materials

other parts were still at 0.2% while the salt-coated part had jumped to 5.0 %. The hook at 90% R.H. was under 1% for parts coated flux and oil. The control part was at 2.5% and the salt-coated part was so hooky it could not be measured (>100% and leaky).

These results indicate that solder flux and oils are not the major cause of hook. Liquid solder flux induced hook, but dried flux did not. Hook in the liquid flux was probably from dissolved water in the flux or a solvent thinner (IPA is also a lossy material). Salt apparently induces a small amount of hook, but its major effect is to allow water to accumulate at its surface and possibly into its bulk. Other materials which are wetted easily will cause hook just as salt does.

Even washing a part has a large impact on its surface chemistry. Test parts using DuPont 9429 dielectric were tested for initial hook. Then one part was rinsed with D.I. water, one with IPA, and another kept as a control. The parts were checked before and after rinsing in both dry nitrogen and 90% relative humidity. The control part stayed below 1% hook at 90% R.H. but the D.I. rinsed part and the IPA part jumped to above 10%.

Inducing hook in attenuators was accomplished by placing drops of saltwater on individual capacitors of the circuit. The parts were then dried leaving a salt residue. The trace obtained from testing these parts would show a bump or droop depending on which capacitor was coated with salt. This was expected from using the distributed RC model for hook. At 0% relative humidity, no hook was present. As humidity was increased hook began to show up. It was constant for any given relative humidity. The position of the hook as well as the amplitude changed at different relative humidities. The time to respond to changes in humidity was very short. If the part was in dry gas and suddenly the chamber is purged with wet nitrogen, the trace would whip through its contortions within seconds to some final value. If the part was coated with porous materials, such as some encapsulation pastes, it took much longer to respond.

One very interesting trace was obtained by placing salt residue on an attenuator. The trace showed multiple time constants due to uneven distribution of the residue (Figure-22).

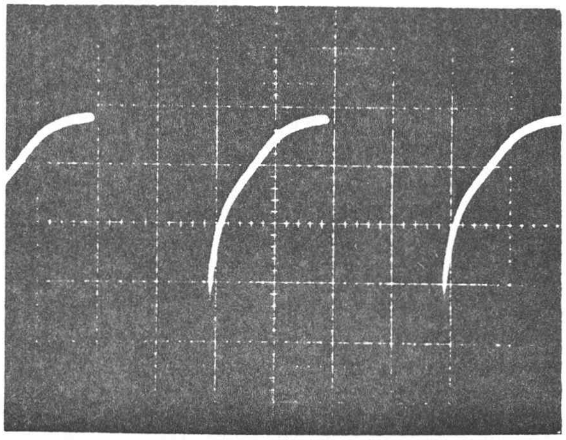


Figure 22 - Multiple time constants from salt residue

HOOK AND LASER TRIMMING OF ATTENUATORS

When a square wave is fed into an attenuator, the output waveform should be a square wave of smaller amplitude. For the response to a low frequency square wave input, the height of the leading edge is controlled by the capacitors. The height of the trailing edge, if the frequency is low enough, is set by the resistors. For intermediate times, the response height is a function of the resistors, capacitors, and any stray RC.

To produce a square wave output of correct height, resistors and capacitors of the attenuator are laser trimmed. Resistors are passively trimmed to give the correct height of the trailing edge, or DC response. Then the capacitors are actively trimmed to give the correct amplitude at a point near the leading edge. If the capacitors cannot be trimmed to make the leading edge the same height as the DC response, and at the same time have the entire trace be flat, the attenuator is said to be "hooky".

There is a small difference between this hook and the hook discussed so far. In testing an attenuator which had a flat response during its initial test and "went bad" during environmental testing there is a reference point. The part was properly trimmed to begin with. The trim engineer has a more difficult problem. In trimming he must select some delay time after the leading edge of the square wave to measure the amplitude. Any delay at all begins to include the distortions from hook. Most of the time the hook present is a result of water-adsorbing contaminants on the surface. Trimming the parts in dry nitrogen will eliminate this problem. However, his customers will probably not test them in nitrogen and will find hook if the contaminants are not removed. To avoid this problem a final check in 90% R.H. could be used to determine if the parts should be cleaned or recoated.

HOOK FROM ENVIRONMENTAL TESTING

Although hook has been a problem in the laser trim operation, it is more commonly associated with environmental testing. Parts which had no hook during laser trim are run through environmental tests. When they emerge, the parts show large amounts of hook. This hook is most often a result of contamination from the environmental oven. The contaminants alter the surface and allow water to adsorb onto it more readily.

Another problem occurs when electrical tests must be performed immediately after humidity cycling and, in some cases, in the test chamber. When this is done, the relative humidity can be different during the final test than when the initial test was done. Since both contaminants and dielectrics adsorb more water at a higher relative humidity, they will show more hook.

MINIMIZING HOOK

STARTING OUT WITH A GOOD DIELECTRIC

Materials to be used for a dielectrics should be tested for hook in dry nitrogen. This indicates whether the bulk material is too lossy for use in the application. Conductors play a part in this as well. In at least one case, gold conductors induce less inherent hook than Pd/Ag conductors. However, the small difference in magnitude may not be worth the extra cost of using gold conductors.

Dielectric hook should also be tested as a function of relative humidity. Parts should be newly made so they have no chance to get contaminated. Even cleaned parts will have too much contamination.

It may be a good idea to expose materials which are suspected of being porous to high humidity for long times. If they are then tested in dry nitrogen and still have hook, they should not be used.

KEEP IT CLEAN

Operators must avoid touching parts, especially after non-wettable coatings have been applied. Salt from skin oils will induce a great deal of hook.

In many cases, environmental testing ovens will contaminate the part. This can happen when condensation on the oven ceiling drips onto test parts. As the condensate dries, it leaves residues which make the surface very wettable. This is an invalid test since it tests uncontrolled contaminants that may not be present in the instrument. To perform a reasonable test, the oven must be clean and/or parts must be protected from condensation falling onto them.

This points out the need to test for hook when the circuit is contaminated by residue from materials in the instrument. No standard method for this testing exists yet. A method which might be useful would be to condense water on the contaminant material and let the runoff drip onto the test circuit. Next, dry the test circuit and test it for hook as a function of relative humidity.

USE HYDROPHOBIC COATINGS

Coatings which modify the surface by adsorbing less water have been shown to greatly reduce surface related hook (the most common form of hook in our present dielectrics). The coating material which has been used most and has given the best results is Dow Corning 1107. A fluorine containing material from 3M (Fluorad FC-725) was also tested. It reduced hook, but not as well as 1107. Scotchguard, a fluoroaliphatic resin, worked better than FC-725, but not as well as 1107.

Any of these coatings will help reduce hook. The 1107 is currently the best available for most applications. To apply 1107, it is mixed 1 part 1107 to 99 parts solvent (1,1,1 Tricloroethylene). Parts are dip coated, allowed to dry, and then the silicone is cured at 150 degrees C for 15 minutes.

Electrical contact through 1107 has not been a problem with test probes, attenuator fork contacts, or conductive elastomer pressure interconnects. If selective coating is required, a masked spray coating would probably work best. Colored dye is also available for use in selective coating.

IT'S NOT JUST THE CAPACITORS

Capacitors have a lot of exposed edges, especially digital trim caps. Distortion of the electric fields around these edges by adsorbed water is a major cause of hook, but not the only one. Any conductor runs on the surface of the circuit which can form a coplanar capacitor can cause hook. When the conductor runs and substrate are coated with adsorbed water vapor, hook results. Water has a dielectric constant of about 80. This allows a very thin layer of water to have a big impact on the response.

This type of hook is easily demonstrated by using a coplanar capacitor as a test part. A glass slide put on top of the coplanar cap will induce very little hook. But, if a lossy material is placed on top of the slide, parts can have hundreds of percent hook (traces several times the original height). As the glass slide is moved about over the capacitor, the hook will vary in magnitude. This test will also show the one exception to a statement made earlier about testing capacitors with the charge amplifier. Normally in this test of individual capacitors, the only distortion seen is rollup. However, if the glass slide with lossy material is placed correctly over a cap, a trace showing rolldown rather than rollup results (Figure-23). No conclusive explanation for this phenomena has been found, but it seems to occur most often when a small portion of the test cap is coupled to a large floating plate on an adjacent capacitor.

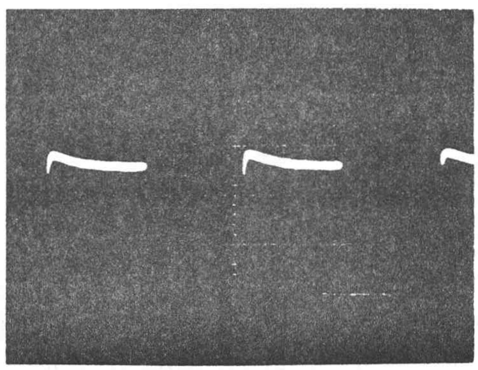


Figure 23 - Variation of single capacitor hook

DESIGNING FOR LOW HOOK

First, large distances between runs and short run lengths will generally help reduce coupling. Each run should be evaluated as to how critical this is. For instance, incoming signal runs to an attenuator will simply draw more current from the signal source. If, however, the center tap runs are coupled with a lossy material, the signal will be distorted. Second, smaller caps will be affected more than larger ones because stray capacitance from the leads is a larger proportion of the total capacitance. Third, the higher the voltage on adjacent lines, the farther away they need to be separated to avoid coupling.

In mechanical design of component housings, several factors should be considered. Housing parts which are close to conductor runs can cause hook if they are a lossy material and/or if they allow water to adsorb on their surface. If condensation is allowed to form on the housing and drip onto the circuit, hook may result. The condensate will carry any contaminants with it. If this happens, silicone coatings will not help because the silicone's surface will be modified by the contaminants and can adsorb moisture. It may be worth coating the entire housing with 1107. To avoid condensate from other instrument parts dripping onto the circuit, a deflection plate could be built into the housing. Simply placing the part upside down may help. Thorough cleaning before application of the 1107 and avoiding contamination after coating will do a great deal to reduce hook.

CONCLUSION

Attenuators are the most common circuit where hook is a problem. Typically these circuits do not display hook until they go through environmental tests. This implies that ceramic materials used for capacitors do not have much inherent hook. From testing done for this project, it appears that surface changes are the most common cause for hook. The major change in the surface is in its wetting characteristics. Contaminants will usually allow water to adsorb more easily onto the dielectric. This is especially true of salt. As the water is adsorbed it induces hook. If parts are coated with a non-wettable material and kept clean, they should not have much hook (with the possible exception of geometric hook).

Designers should design for low hook by reducing coplanar coupling as much as possible. They should also test effects on hook of other materials in the instrument. In addition, precautions should be taken in environmental tests to make certain parts are not contaminated from uncontrolled sources. Non-wettable coatings should be used whenever possible.

Some circuits may require absolutely no hook, inherent or environmentally-induced. These circuits should use gold conductors with DuPont 9429 dielectric. This reduces the inherent hook to virtually zero. Attenuators and the majority of other circuits will usually not require this since the magnitude of inherent hook with Pd/Ag conductors is already very small. Parts must also be coated with a non-wetting material, such as Dow Corning 1107, to prevent hook at high humidities. Most important of all, parts must be kept clean.

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