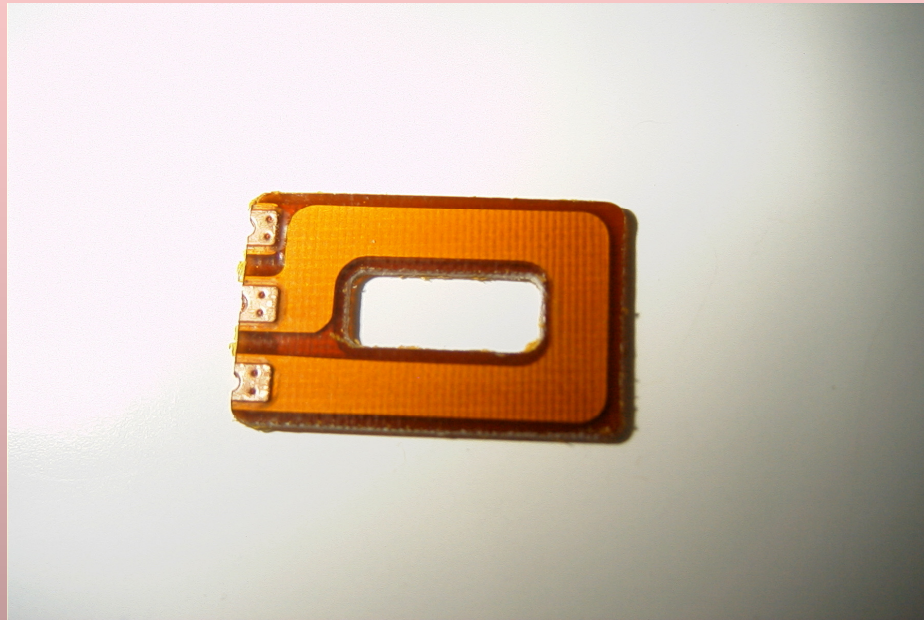


VER 1

# Xtreme Resistance and Impedance Circuits



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ROBERT TARZWELL

February 2009

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The information in this book is current to February 2009. As material specifications and manufacturing practices change and evolve, please ensure you are using up to date information.

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All drawings and Photos by Robert Tarzwell

Front cover is a high resistance sensing coil for a Formula One car

## INTRODUCTION

One of the most amazing things I have seen Robert Tarzwell do, and there are many, is the day he told the owner of a twenty million dollar board shop that he could take a walk through his shop and come up with savings of at least half a million dollars. The owner took him up on his challenge, Bob walked through the shop and came up with a list of things the owner could do to save money; all in about an hour's time frame. A few months later when I was again talking to that owner I asked him if he had ever followed any Bob's suggestions from the walk that day. "Oh yes," he answered with enthusiasm, "*we took all of them and the only thing he was wrong about was that we actually are realizing savings larger than he predicted.*"

Bob Tarzwell is truly one of the Printed Circuit Board industry's technology guru's. With his grasp of today's technology and his insight into the technologies of tomorrow he is the real "go-to" person for anyone who is looking for the right direction to take their company. Bob has that unique ability to take very complicated problems and come up with elegant and seemingly simple solutions. Whether you are talking about learning how to produce the absolutely best four layer board in the most cost efficient way possible, or talking about fabricating a circuit board with one mil lines and spacing Bob is literally the only person in the industry that I know of who can get it done.

Not being technical myself, Bob is the person I go to when I am working with a client who has a new technology and I need it explained to me. Bob will talk to the client for me and then come back and then explain the technology in way that makes it so clear to me that I not only understand it but then can proceed to do my job of helping the client sell it. There are not many people who can do that.

As An Wang once said *The true sign of a genius is someone who can take something very complicated and make it simple enough for everyone to understand.* And this surely applies to Bob Tarzwell.

Dan Beaulieu  
President  
D.B.Management Group L.L.C.

# Chapter 1

## Overview of Xtreme Resistance Printed Circuits

The technology that I developed is a complete system which could offer a totally high resistance, very high dielectric, multilayer circuit. Part of the R&D that I developed was a special High Voltage Polyimide Film (HVPF); a very special printed circuit material that has a surface resistance of  $10^{16}$ . It can be used as a stand alone thin material or be inserted into Fr4 material boards to enhance the high resistance of low loss Pico volt characteristics.

A Pico voltage sensing circuit board is used to capture and amplify very small electrical signals in the .000000000001 voltage range ( $10^{-12}$  ohms). Any resistance in the electronic sensing circuit would attenuate what little voltage is there and cause the signal to disappear. This means for a Pico circuit board the signal loss has to be very minute. A Pico voltage sensing circuit may also have very high impedance requirements, which opens more sales possibilities.

If the circuit needs to have a loss of only .1 Pico volt, the resistance of the operational amplifier would be in the  $10^{15}$  range. The circuit resistance must be one thousand times or more greater,  $10^{16}$ .

It seems that I always have at least one super bright, doctor type, engineer at some remote laboratory who needs to record one tiny little electron emitted from some futuristic plasma cyclotron. Worst of all, they know what they want to do, but have zero knowledge of a printed circuit board. The call usually starts with:

Mad Scientist; *“I understand you know both electronics and printed circuits.”*

Doc PCB; *“To a point, YES.”*

Mad Scientist; *“I need to measure a Pico volt signal of a few electrons and need a very high resistance of greater than 100 gig ohm.”*

Doc PCB; *“Ok, no problem. We have many different solutions depending on your application.”*

Mad Scientist; *“Great! I called three different board shops and no one knew what I was talking about. Wonderful! Tell me what you have.”*

Doc PCB; *“We have five different laminate choices that feature the most important factor for your circuit, high surface resistance. Many are at least 10 times greater than your circuit input requirements. Does your input resistor connect to an op amp?”*

Mad Scientist; *“Yes, we have a 100 gig ohm resistor.”*

Doc PCB; “Okay. The HVPF material has the highest surface resistivity of  $4 \times 10^{16}$  with low moisture absorption. Typically, we start with a double sided or multilayer of Fr4 and lay a dielectric layer of the high resistance film on top.”

Mad Scientist; “How do we limit electrical noise in the signal layer?”

Doc PCB; “Most designs have an analog ground as the top layer on the 4 layer Fr4 PCB. Then the VTF layer and either a metal can soldered on or an additional layer of VTF with a ground plane and micro vias around the edge to create a faraday shield.”

Mad Scientist; “Good! That means we can put the digital amplifier on the back side of the multilayer and leave only the Pico signal parts in the top layer. This is good. I will have the designer get in touch with you.”

Doc PCB, “Glad we can help.”

This is exactly what happens. Well, except for the mad scientist part. Selecting the correct laminate is not really difficult. You must remember to account for all physical and electrical requirements, then try and balance cost, electrical and mechanical properties. All factors must agree with each other. High input resistance circuits are needed to measure very diminutive signals, sometimes, only a few electrons. The surface resistance (ohms /sq) of the laminate has a direct effect on the signal, effectively adding parallel resistors to the signal input, lowering its signal strength.

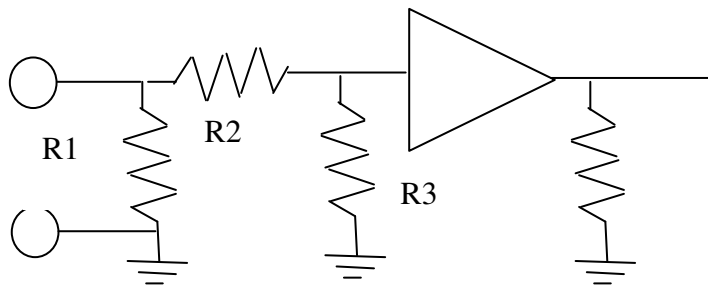


Figure 1: R1 and R3 is the signal stealing resistance of the circuit board.

Drawing of the input resistance chart for a Pico voltage op amp.

As the signal enters the board, the resistance of the material attenuates the signal. When we add the 100 gig ohm resistor, the via and trace are again subject to the resistance of the laminate. The very minute signal will be further attenuated and lost in the background noise. To limit the voltage loss in the laminate, we use very high resistance laminate material.

The other problem is one of electrical noise. All resistors and most components have some electrical noise generated by the junctions of the resistor molecules and leads touching each other. When the molecules rub, due to temperature and mechanical vibrations, they release electrons as electrical noise. To build a very high resistance circuit board, we need to control the high resistance of the laminate and the low resistance of the tracks to reduce electrical noise.

In the mad scientist design, we chose a dielectric film. The film version has a slightly higher surface resistance than the epoxy film version. The surface resistance difference between Fr4 and a polyimide film is typically, 1,000,000 times larger; a significant difference. Typically, Fr4 has a surface resistivity of  $3 \times 10^{10}$  ohms, whereas a dielectric film has surface resistivity of  $4 \times 10^{16}$  ohms.

We need to be concerned with moisture absorbance. Many glass types Fr4 laminates absorb moisture because of the gaps around the glass fibers. If we eliminated the glass fibers, we greatly reduce the source of the moisture problem. The dielectric films feature a very high voltage dielectric rating, well over 4000 volt per mil, compared to 650 volts per mil for Fr4. Typical Fr4 moisture absorbance is .05 to .07 (% 24h) where dielectric films are in the .02-.03 range.

In higher frequency small signal boards, we also need to consider the Dielectric Constant, Dk; the lower, the better. Teflon is also a laminate of choice when higher frequencies are required with its high surface resistance and a low dielectric constant as well as a low loss factor, but it has a very high cost factor and is hard to laminate into an Fr4 package which limits its use to the more expensive but only double sided requirements.

Solder mask, typically, has  $1 \times 10^{12}$  resistivity which can present problems with very high resistance circuits. To eliminate the solder mask, I have used a laser cut dielectric film layer as a replacement high resistance solder mask.

FR4	$3 \times 10^{10} =$	30,000,000,000	ohms
Dielectric films	$4 \times 10^{16} =$	40,000,000,000,000,000	ohms.

Bleeding edge circuits need to use and take advantage of little known, physical and electrical properties of laminates. You also need to look outside the normal Fr4 world.

# Chapter 2

## Manufacturing of High Resistance Printed Circuits

The manufacturing process used in high resistance circuits is essentially the same steps as a normal printed circuit. There are, however, differences in the material used and the properties of those materials. When a normal Fr4 printed circuit is designed and manufactured, it is more about thermal properties than the ability to carry very low voltage signals. As the voltage signal level goes down, the surface resistance and loss values become critical.

### THE SECRET

To hide the real material that I used for high resistance boards, I called it HVPF. Yet, the material is a normal material in the industry; not many people in ten years ever figured it out. I learned many years ago that patents do not work. They are expensive, take years to get and in the end, you told everyone the secret. So, I do not patent my ideas but find ways to hide the real truth. HVPF material is three different potential materials, ???

Please purchase the book on low voltage circuits to learn the secret and manufacture xstream low voltage PCB.