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Xtreme Voltage Printed Circuits



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

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Written by Robert Tarzwell © 2009 DMR LTD.

Foreword

With potentials as high as 40,000 volts, an engineer now has the ability to design one printed circuit that can carry large voltages and support the fine traces and features of the computer circuits needed to drive the high voltage. The high voltage circuits of today can contain from 1 to 40 layers. I had to learn using the good old fashion trial and error method. New and different ways of manipulating the same materials were required without the help of large databases of information. Many experiments were successful and some failed. These experiments allowed me to keep a detailed diary of high voltage design ideas.

Introduction for Robert Tarzwell

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 Voltage Printed Circuits

A few years ago, the idea that a printed circuit board could effectively handle a large voltage in excess of 40,000 volts was unheard of. Today that reality not only exists, but also is orbiting the earth, imaging through our bodies and controlling our power grid. Through years of research and experiments, I slowly developed and improved the high voltage copper printed circuit board. In 1998, my company was contacted to develop a high voltage board for a critical space operation. Through countless experiments, I developed a system, which could offer totally encapsulated, very high dielectric multilayer circuits. I developed High Voltage Polyimide Film (HVPF), a very special printed circuit material that has a dielectric breakdown of over 3000 V/mil (volts per mil). It can be used as a stand alone thin material or be inserted into Fr4 material boards to enhance the voltage characteristics.

A new exciting product emerged. And I ran out to tell the world. Success was quick to follow. Quotes came in and new methods were developed in the lab creating such exotic circuits as high voltage planar multilayers, bendable high voltage circuits and high voltage flexible circuits. The result was an engineering system designed to handle just about any high voltage situation imaginable. This book contains all the information you need to manufacture this advanced technology.

The basic underlying principle is the ability to carry very high voltage with a thin layer of HVPF material. Yes, the manufacturing cost is higher but so is the price you charge because it is special. What was previously mechanically attached off the circuit board through special insulated wire, terminal blocks and potted black boxes, can now be located on the high voltage circuit board and designers will pay extra for a high voltage circuit board which reduces their overall cost.

In the early days, high voltage printed circuits which I manufactured for companies were suspected of being faulty when a high voltage board would function for only a short period of time and then self destruct. After a serious study of the effects of corona, it was determined that, this near silent force could quickly destroy any organic material's ability to insulate. The effects of corona through ionization and particle bombardment of the epoxy will cause the epoxy to become carbonized and conduct electricity. Any serious high voltage printed circuits would need to address and solve the corona problem.

A short overview of the technologies problems and solutions designers face

Designers who need high voltage separation between layers of over 5000 volts find that typical Fr4 has too many micro voids within its structure to be effective as a high voltage laminate. The micro voids in most glass fiber based laminates allow low voltage arc over and carbon growth within the laminate and therefore limits, the highest voltage usable; both a bad thing. We use HVPF high voltage polyimide film, trademarked by DMR LTD, which provides a micro void free

film rated at over 3500 volts per mil of thickness. Copper coated HVPF film laminates to Fr4 with good strength. HVPF accepts electroless plating properly as well as typical solder masks.

With a single layer of 5 mils of HVPF, you can obtain a maximum voltage rating of 25,000 volts. At 25,000 volts you have other problems, such as corona to worry about. Corona is a plasma-like field of highly excited molecules. They are very corrosive to items such as epoxy laminate. Some laminates and plastics withstand the effects of corona better than others. The HVPH film has a very solid void free matrix which limits corona's destructive effect. There is now a new high voltage film HVPF2; a higher voltage phenolic dielectric with 4000 volts per mil. HVPF2 has other redeeming features, in that it will level the circuit traces below and create a flat upper surface. HVPF2 also can be stacked. You can now laminate four 1 or 1.5 mil HVPF2 films on top of each other to create a thicker coherent high voltage spacer up to 10 mils or 40,000 volts.

Like most advanced electronics, high voltage design has special areas of concern. Your traces should be free of 90 degree turns. Avoid sharp pointed corners; round all traces; use fillets to join pads as this decreases the voltage ability to form corona. All requirements for traces and spaces arc over voltage according to established rules should be engineered at two times the potential voltage.

Spacing in the vertical plane is always tough. Your minimum arc over rating in free air is 10,000 volts (dc) per .250 inches to arc. This rating is based on sea level atmospheric pressure. Some extreme designs send the high voltage board into space or high up in a fighter plane. As you lower the atmospheric pressure, the voltage arc over point drops dramatically. It must be calculated and then compensated for in increased spacing.

In really extreme applications, a high voltage arc guard area can be utilized, by creating a lower voltage shield with a copper guard ring between the high voltage and ground. The half voltage guard is divided between the high voltage source and ground with a pair of large resistors such as 100 meg ohm or pf capacitors for an AC circuit. The shield is at one half the potential of the high voltage, so your arc voltage potential decreases by half.

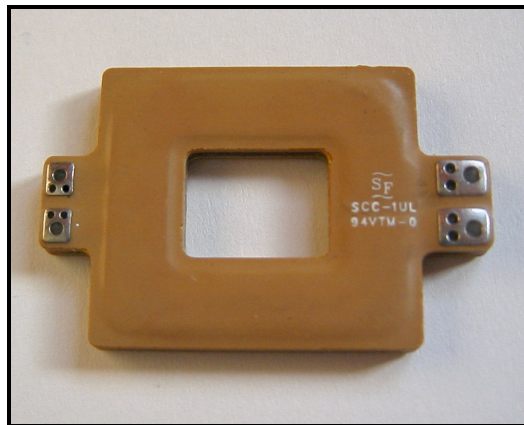


Figure 1: High voltage 3500 volt planar transformer

Chapter 2

Manufacturing of Xtreme Voltage Printed Circuits

The manufacturing process used in high voltage circuits is essentially the same steps as a normal printed circuit. There are however, differences in the material used for high voltage and the properties of those materials. When a low voltage printed circuit (meaning, 5 to 600 volts) is designed and manufactured, it is more about spacing and circuit design than material, as all printed circuit materials can support up to 1000 volts.

Medium voltage boards of typically 600 to 3000 volts require greater care in selecting the base material and the subsequent processing as this voltage can easily support arcs and corona. This is where high voltage boards start to become effective.

High voltage boards of 3000 volts to a maximum limit of about 100kvolts are limited to HVPF, Teflon and in some cases BT epoxy with serious effort and testing in areas of corona, field strengths and temperature control. Your manufacturing group must know what high voltage is all about to successfully suggest a build and laminate for an incoming job.

The Secret

Now before I tell you the secret, remember I spent literally hundreds of thousands of dollars developing this technology. When you read the secret, you will be surprised. Then you will say "Well, that is to simple. I could have thought of that!" Well, you didn't. It took many years of research to find the secret, then years to develop it to be as simple as it is. What you need to study is the engineering behind Xtreme high voltage so that your company can understand the technology involved and how to properly design the manufacturing variables. Your success with this technology will be your company's ability to properly interpret the customer's high voltage requirement and manufacture a suitable board, achieving return orders.

To conceal the real material I used for high voltage boards, I called it HVPF. Yet the material is a normal material in the industry. Not many people in 10 years ever figured it out. I learned years ago not to patent an idea, as 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 materials; ???

Please purchase the book on high voltage to revel the secret which will enable you to manufacture high voltage circuits.