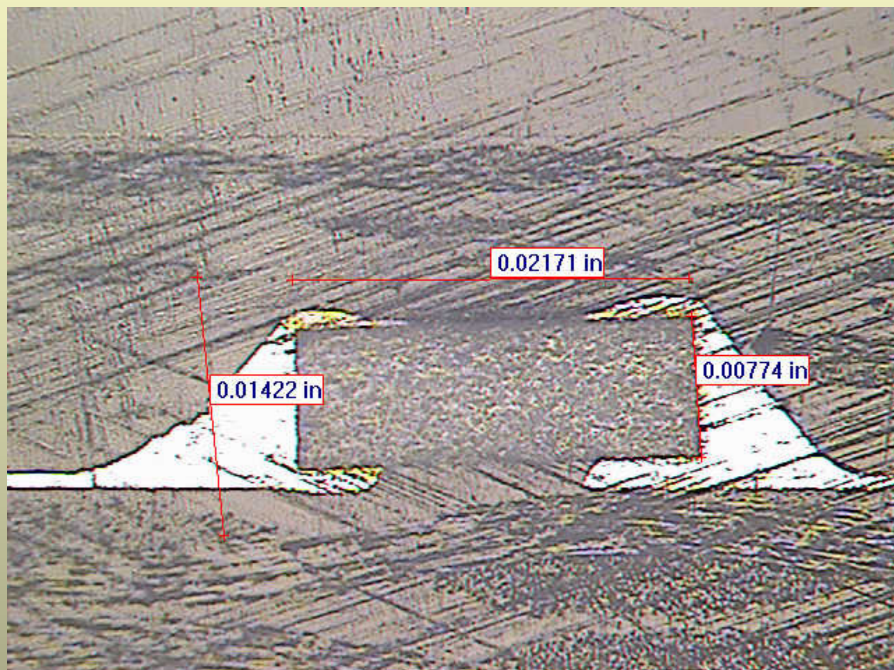
VER 2

# The X Series

# EMBEDDED DISCRETE COMPONENTS




Robert Tarzwell

January 2009

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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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# Introduction for Robert Tarzwell

One of the most amazing things that I have seen Robert Tarzwell do, and there are many, is the day he told the owner of a $20 million  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 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 gurus. 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 explain the technology in a 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 A 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 Embedded Components

I write this book because after many different attempts to produce acceptable screened resistors, I realized it was problematic. I searched for a different, better way. Why accept poor quality resistors when small 0201 chip resistors are readily available, inexpensive and easy to use? During my research into buried passive components, it was obvious that the present manufacturing methods to make buried components are not small enough or electrically good enough, in their technical specifications for advanced micro electronic applications. The silk screened printed carbon resistors are large, consuming too much board real estate which limits their actual improvement. Screened resistors have been around for 40 years. There has to be reasons why they have never become acceptable and grown in use over time. The carbon printed resistors are of poor quality compared to thin film small high precision resistors. The printed low temperature, carbon resistors add noise to the signal. The accuracy is poor and needs to be laser trimmed to even get to 10% tolerance. The resistive thermal drift with temperature is also sub-standard. The screened resistors that we produce today embedded in a PCB are not really usable by today's sophisticated electronics except for pull up resistors.

The nickel sheet resistor technology is better for lower noise but also consumes too much board space for a micro circuit and can be time consuming to manufacture and comes in limited low resistance square values. The situation with capacitors is even worse. The material used as the dielectric sheet material is very poor for ESR. They just do not act like a capacitor but more like a snubber. Real large capacitor values are not available but they are working on many high DK materials.

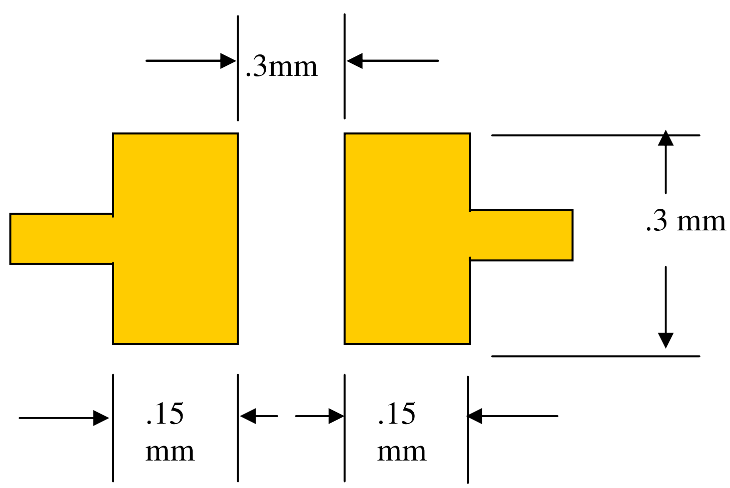
For RF work High Q RF capacitors are not yet possible with the thin sheet capacitor systems. If your application is digital pull up or terminating resistors, only then the screened or sheet resistors may work the best. Similarly, if your capacitor requirements are power supply noise cancellation then buried capacitive Fr4 sheets would work ok. Most of my design R&D work has been on systems where the circuit board is comprised of some digital area, some audio circuits and the rest RF electronics which means normal screened or Ni resistors and capacitors do not work well. In most applications, I have had 15 mils of core Fr4 to work with as it was used for strength only so why not use it to store components. Like any invention, it may not be the best fit for all applications but if it works for your application that's why I invent.

During research on suitable components to be buried, I found the new 0201, 01005 and some 0402 resistors and capacitors are thin enough to be inserted into the core of a multilayer. With a HDI circuit core thicknesses of .012 to .015, a high number of very small high quality passive components can be placed inside the PCB. The chip resistors, capacitors and even bare chip die can easily survive the temperature of the new processing technology of the embedded multilayer manufacturing. Tests have shown no damage or change to the original chip resistor or capacitor voltage rating, resistance or capacitance. Special lower temperature and lower pressure materials assist in the inboard chip's survival ability. The embedded resistors, capacitors and inductors have been qualified, proving the original manufacturers reliability and quality of the chip components did not change during an advanced R&D program.

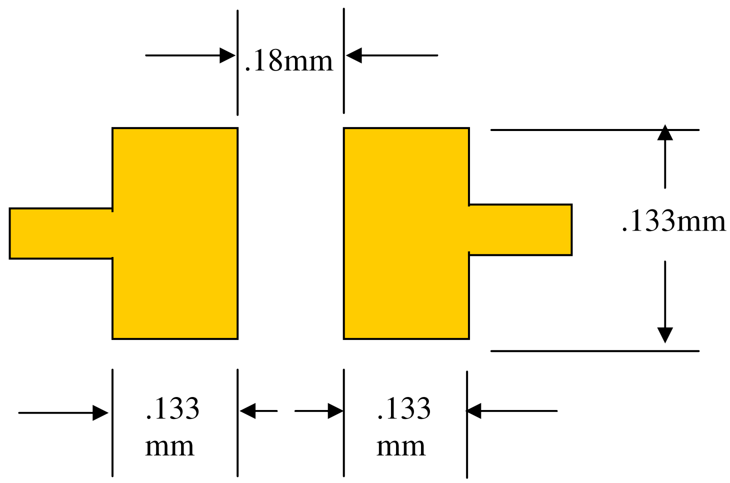
With HDI PCBs, it is typical to use a 12 to 20 mil thick core, to provide the backbone of strength and stiffness needed to laminate the 2-14 HDI layers. I use a lead free high temperature solder and lead free resistors, capacitors and inductors meeting all RohS and Weee standards.

The real chip resistor's inductors and capacitors give a broader range of values and also better precision and known temperature drift numbers that customers are familiar with. There is an additional cost to install the inboard chip components on the core. The cost is primarily in the solder paste stencil and the cost to pick and place the chips. Remember, we are reducing the assembly cost of the outer layers and transferring it to the inner layers. After assembly of the PCB, the resistance and capacitance is verified through electrical testing.

The market requires ever increasing densities to meet the insatiable demand for the smaller but more powerful consumer electronics gadgets. The high density electronic products of tomorrow will need more components and silicon chips in smaller printed circuit layouts. The most efficient method to reduce the size of the PCB is to bury the components inside the core allowing the entire two outside surfaces for the silicon chips.




Resistor layout pad for a 0210 chip component



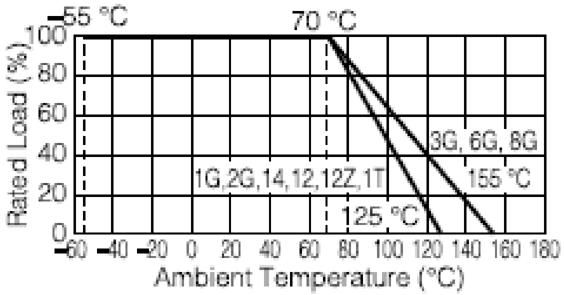

01005 Layout

The dominant passive component sizes from the 1990's have changed. The 1206 (3.2 x 1.6 mm) and 0805 (2.0 x 1.25 mm) chips no longer make up the majority of passives used today. The formats have generally migrated to 0603 (1.6 x 0.8 mm), 0402 (1.0 x 0.5 mm) and 0201 (0.6 x 0.3 mm) to reduce component footprints. There has been a considerable reduction in the components occupied board area and an equal increase in the area occupied by silicon chips. Limitations are sometimes admittedly set by the components themselves. A 100 µF capacitor will still need 1210 format chips. Similarly, a 47 µF capacitor needs the 508 format, which can be embedded. The maximum capacitance of a 01005 chip is 0.01 µF but still very high capacitance per sq. cm.

Utilizing embedded chip components can improve the density over screened or sheet resistors. The minimum inter-spacing of 0402 components are a minimum150 µm, which are limited to around 100 components/$cm^2$. Smaller 0201 types allow a tighter 100 µm inter-spacing to triple the density to 300/$cm^2$. And, with 01005 components on 50 µm inter-spacing, the maximum density could double again to **600** components per square centimeter.

| Size | Length | | Width | | Height | |
|---|---|---|---|---|---|---|
| 01005 | 0.40 mm | .016" | 0.20 mm | .008" | 0.12mm | .0048" |
| 0201 | 0.60 mm | .024 " | 0.30 mm | .012 " | 0.15mm | .006" |
| 0402 | 1.00 mm | .040" | 0.50 mm | .020" | 0.25 mm | .010" |
| 0603 | 1.60 mm | .064" | 0.81 mm | .032" | 0.35 mm | .014" |

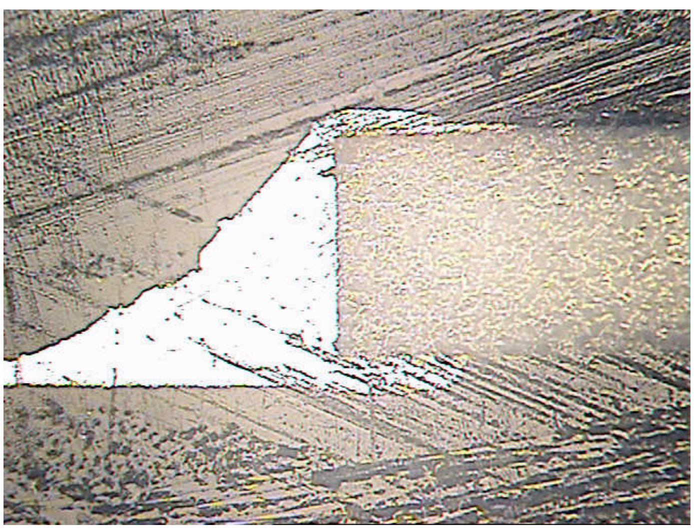
A typical silk screened resistor would be in the size range of .025 by .025 for a single square to .025 by .150 for a higher ohm resistor. Sheet nickel resistors are smaller but still suffer the problem of creating long strings to get higher resistance due to low square resistance.




Discrete chip resistor featuring low temperature drift.

0201 Chip Resistor Specification

Metal glaze thick film resistive element and three layers of electrodes utilizing an alumna substrate of high reliability; approved under the QS-9000 system
Power rating .05 w @70°C
Max voltage 30 volts
Resistance tolerance available +- 5 %, 1% and .1%
Minimum resistance .1 Ohms
Maximum resistance 10 Meg Ohms
T.C.R X 10 ↓6 /°C +- 25 to 200.



Good resistor in dielectric material on Fr4 core

Could the resistors and capacitors survive the high temperature processing of the multilayer lamination? The experiments for high pressure press lamination of the soldered components with prepreg as the cover material did not work well. The pressure of the Fr4 prepreg hydraulic cracked the ceramic based components. The cantilever effect of soldering the chip resistors allowed the pressure to push in the unsupported middle section and crack it. Attempts to back fill and support the chip middle section were difficult due to the thin gap. A different approach was needed.

With HDI PCB's, we use a 10 to 21 thick core, to provide the backbone of strength and stiffness needed to laminate the 2-4 HDI layers. So, it would be feasible to use high temperature solder and thin 0201 resistors and then bury them within the next dielectric layer to make a core for HDI PCB's. However, as stated, the pressure of the prepreg in the hydraulic press at 250 lbs per sq. in. cracked the ceramic resistors. The second thought was to solder the components on a 5 mil core, then create a layer with a fill epoxy using a mold. This would encapsulate the components without the damaging pressure of the multilayer press. It was difficult to get a flat surface and to get electroless copper to properly stick on the smooth molded epoxy. The final test was to find a soft thermal cure dialectic material. This worked well with the dielectric material flowing around and under the chip resistors. The soft dielectric material enabled the resistor chips to survive and the dielectric layer is designed to accept electroless, so we can easily add a copper layer to the top of the dielectric layer without using the multilayer press.

Basic theroy behind discrete component embedding is that all the resistors, capacitors inductors, diodes, transistors and even chip die all can be buried in the core.

The real resistors and capacitors give a broader range of values, better precision and known temperature drift percentage. They feature much lower electrical noise numbers with a known thermal temperature gradient across the resistor. Capacitors can offer a big advantage over capacitive Fr4 core material, with many times larger PF/sq. cm. values and better Q values for RF use. If all you need is some power supply noise reduction, then the capacitive core material is ok. If, however, you need real Q capacitors, then embedded real 0201 capacitors are needed. Compared to the cost to screen print carbon or laminate and etch nickel sheets, the resistors are very inexpensive to buy at less than one cent each but have some cost to install in the core. The cost is in the solder paste stencil and the cost to pick and place the chips. If you use outside services, it may be too expensive for proto types. If you had a small internal assembly shop, you could save a considerable amount of money over outside assembly, depending on volume.

The market is unknown at this time. It is, however, a technology many companies are seeking. Many high density electronic products need higher density. The best way to reduce the size of the PCB or to increase density with the same size is to bury the components inside the PCB.

The possibility for this to expand to capacitors, inductors, diodes, transistors, chip die and even security wires is huge. The final future of this invention is unknown but I believe it's a huge potential for a leading edge PCB shop.

# Chapter 2

## THE SECRET

Before I tell you the secret, remember, it may seem simple. You may even think you could have thought of that. Well, you did not! Do not worry about how simple this is but think more how you can make money on the invention.

Please buy the embedded component book to reveal the secret to manufacturing embedded real 0201 components.