RADIANT E.M.I. SHIELDING of PLASTICS FOR TEKTRONIX

Jerry D. Holly
12-14-82

ABSTRACT

This paper describes the many methods of shielding on plastics, their advantages and disadvantages. Also what E.M.I. is and why shielding is necessary. A table of several different types and thicknesses of plated coatings and their shielding effectiveness is included. The paper concludes that two types of shielding may best meet Tektronix' needs; component shielding (e.g., a metal or plated plastic part) and cabinet shielding perhaps with a Ni loaded paint.

FORWARD

Any operating electrical or electronic equipment will generate electrical and magnetic impulses (hence termed electromagnetic waves). Magnetic impulses penetrate all plastics and all metals except ferrous metals. Magnetic impulses dissipate fairly rapidly, but the electrical impulses travel much farther and will penetrate plastics but generally not metals, especially when grounded. The electrical field is thus the more potent and disruptive force.

The F.C.C. (Federal Communications Commission) has recently imposed limitations on the amount of electromagnetic energy that computing types of equipment may add to the environment. The European markets have also imposed restrictions via their regulatory agency, the V.D.E. Even the military has entered into the act by generating their own standards. At this time the restrictions are aimed at computing devices that utilize switching signals at 10KHz and above. However, some feel that it is only a matter of time before other devices are included in the regulations.

Each of the specifications are a little different. Tektronix is now in the process of changing their standards to incorporate all of the above agencies standards. Table I compares Tektronix to the agencies as to who regulates what.

METHODS OF SHIELDING

Following are the primary methods of shielding, their reported advantages and disadvantages.

1) Silver Reduction -- a wet, multiple-step silver plating process. A silver nitrate solution is sprayed onto the plastic substrate. The silver is reduced to

pure elemental silver which precipitates out onto the part while the nitrate is formed into a salt. The silver that does not make contact with the part can be reused.

A) Advantages
- o Highest conductivity and attenuation if properly applied.
- o Low capital investment.

B) Disadvantages
- o Tendency to oxidize.
- o Several labor-intensive steps in the process.
- o Raw material (silver) costs are high.
- o Quality control needs to be tight.
- o Masking is difficult to achieve.

2) Conductive Paints -- including silver, copper, nickel, graphite and copper graphite. Conventional spray equipment or paddle guns (continuous stirring) are used to apply the paints to the molded parts.

A) Advantages
- o Little or no surface preparation required.
- o Ease of application, no special equipment required.
- o Elasticity of material, minimizing stress cracking or crazing.
- o Low total costs.
- o Diversity of products on the market, providing various levels of adhesion, shielding capability and conductivity.
- o Excellent record of long-term conductivity and attenuation.

B) Disadvantages
- o Control of film thickness and consistency for economic and performance criteria is critical.
- o Constant agitation during application is required to avoid settling of metallic element in the binder.
- o Multiple coats are usually required which increases material and labor costs.
- o Materials are subject to environmental degradation, pitting.
- o May be suitable for ESD, but not severe EMI.

3) Vacuum Metallizing -- pure metal, usually aluminum, coats the plastic part, which is usually first primed with a base coat. The metal is vaporized in a vacuum

chamber, and the condensing metal is deposited onto the surface of the parts in the chamber.

A) Advantages
- o Uniformity of shielding thickness.
- o Excellent attenuation and conductivity, regardless of distance.
- o Low cost in high volume usage.

B) Disadvantages
- o Requires expensive capital equipment and machinery.
- o Susceptible to loss of adhesion through humidity, inducing flaking.
- o Not ideal system for complex contours in cabinet.
- o Metallic coating must be covered by a second organic coating for protection against damage.
- o Thickness limitations affect the shielding potential.
- o Generally requires batch processing which may restrict throughput efficiency.

4) Cathode Sputtering -- a gas plasma discharge is set up between a cathode, made of the material to be sputtered, and an anode, which serves as both an electrode and the support for the plastic substrates. Positively charged gas ions are accelerated into the cathode, causing atoms of metal to be knocked out and condensed on the substrates, forming a metal film.

A) Advantages
- o Electrical properties are very consistent and uniform at 1.5 ohms/sq.
- o Already decorated parts can be shielded cleanly.
- o Good adhesion.

B) Disadvantages
- o Basecoats are often required which increases time and costs involved.
- o The generation of heat precludes many of the plastic materials.
- o High capital costs.
- o Thickness limitations affect the shielding potential.
- o Microscopic cracking has been observed.
- o High power requirements.

5) Flame and/or Arc Spray -- in both techniques molten metal, usually zinc, is deposited onto the prepared substrate. With the arc spray pistol, two metal wires

are fed through an electric arc, which melts the ends, causing a layer of metal to be sprayed onto the part through a hand-held pistol. Flame spray involves a metal powder that is melted by contact with super-heated inert gas in a special spray gun and atomized onto the part.

A) Advantages
- o Traditional method.
- o Low capital and labor costs.
- o Excellent conductivity and attenuation, regardless of distance.
- o Minimal adverse impact from thermal cycling.

B) Disadvantages
- o Grit-blast preparation is a health hazard and a costly step to improve adhesion.
- o Highly toxic material (zinc) in the case of arc spray.
- o Some loss of adhesion due to humidity.

6) Pressure Sensitive Foils -- have an adhesive backing and can be die-cut to be applied to the interior of an injection molded part.

A) Advantages
- o No capital requirement required.
- o High conductivity.

B) Disadvantages
- o Raw material is not inexpensive.
- o Labor-intensive process, not appropriate for large-scale production.
- o Quality control must be tight due to potential for extensive EMI leakage.
- o Complex geometries are particularly difficult to cover.
- o Even the thinnest foils can provide excessively thick shield relative to attenuation requirements.

7) Electroplating of Plastics -- involves numerous etching steps, including the application of a conductive surface before the actual plating process begins.

A) Advantages
- o Good attenuation.

B) Disadvantages
- o Limited experience in EMI shielding.
- o High material and capital costs.
- o Toxic materials.

- o Difficult to mask exterior surface, increasing costs.

8) Ion Plating -- is done in a vacuum chamber like vacuum metallizing. High speed collisions and an ion attraction to the substrate results in an efficient coating.
   A) Advantages
      - o Excellent attenuation and conductivity with copper on aluminum.
      - o Uniform deposition.
   B) Disadvantages
      - o Sophisticated technology.
      - o High per-part cost unless very high volume.

9) Electroless Plating -- is a wet chemical process whereby a thin metallic coating is deposited by catalytic and redox reactions.
   A) Advantages
      - o Coating thickness of an average .03 mils reduces material costs.
      - o Uniform application.
      - o No overspray problem.
      - o Resistant to chipping.
      - o Good attenuation.
      - o Easy to coat both sides for added attenuation.
   B) Disadvantages
      - o Special process required for good adhesion.
      - o Equipment costs are high.
      - o Difficult to mask external surface if required.

10) Filled Conductive Plastics -- several types of material are available to add to the plastic during molding. These include aluminum flakes, powders, etc., carbon, copper, iron powders and even steel wool and stainless steel fibers.
   A) Advantages
      - o Elimination of secondary operations.
      - o Elimination of health hazards (e.g., toxicity) in end-use.
      - o Permanence of conductivity.
   B) Disadvantages
      - o Resin-rich surface makes grounding problematical, necessitating a secondary step.
      - o Materials and processing expensive.
      - o Complex configurations lead to inconsistent

shielding, limit molding options.
- o Degradation of physical properties of the resin, depending on the filler loading.
- o Conductivity depends on the random cross-linking of filler material.
- o With graphite (or carbon), a black color is imparted to the plastic.
- o Can be hard on the molds.
- o 3 ohms/cm best resistivity attainable.

Table II shows the shielding comparisons of the various shielding methods. Note the large variation of attenuation for the nickel loaded paint, probably caused by a lack of homogeniety in the paint and thickness variation. Note also the excellent shielding provided by electroless and electroplating. Table III explains the relative levels of effective attenuation.

DISCUSSION

The advantages and disadvantages for the various shielding methods are directed toward those manufacturers which have no present means of shielding. For example, Tektronix would not be concerned with the initial material and capital costs under electroless or electroplating, since these facilities are already in house.

Most of the shielding methods were not considered as serious contenders for Tektronix for various reasons. For example, a zinc coating (such as is deposited by a flame or arc gun) has been rejected for use by Tektronix environmental lab. The zinc by itself is not very corrosion resistant. Also if it covers another metal such as a metal insert, a bi-metal couple is set up and galvanic action takes place. Zinc being the sacraficed metal, soon corrodes away.

Because of its low melting point, zinc is the only metal that is extensively used in flame or arc guns.

Since nickel loaded paints are already being used by some of Tektronix' business units, it is obviously beyond the considering stage.

It was decided that rather than to evaluate the effectiveness of all the methods, we should first evaluate our own in house capabilities. Since we already plate on plastics, it seemed reasonable to evaluate these processes for EMI shielding first.

EVALUATION OF TEKTRONIX PLATED PLASTICS FOR EMI SHIELDING

Several combinations of 8" x 8" ABS plastic sheets were plated in electrochem and submitted to Tektronix' environmental labs for EMI shielding evaluations. Also with these were included samples from two outside suppliers, FCM and Crown City Plating. One of the samples from FCM was a nickel loaded paint (sample 14), all other samples were plated either by electroless or electrolytic process.

Table IV gives the metals plated and the approximate thicknesses. Thin coatings on plastic substrates are impossible to measure with reasonable accuracy. Note that all of the plated samples whether electroless or electralytically plated, showed excellent E.M.I. shielding capability (90dB). The attenuation (90dB) of the electroplated samples agrees pretty well with the like sample (85dB) in Table II, as does the nickel loaded paint sample. However, the electroless nickel samples do not (90dB vs. 45dB). However, note that the electroless nickel thickness from Table II is only 30μ" while those on Table I are 147 and 162μ" per side.

Previous tests performed by Tektronix' environmental labs for ESD shielding, showed that even metal coatings so thin that you could see through them would protect adequately even up to 40KV.

SHIELDING COSTS

It's difficult to get a true or accurate cost for the various coating methods. There are as many different inputs as there are people to ask. Table V is one comparison, and should be used as a guide only (like EPA gas mileage ratings!). The true cost depends on the number of parts, part configuration, vendor, etc. Electrochem has confirmed that the electroless nickel cost is reasonable.

PLATEABLE PLASTICS

Not all plastics lend themselves to plating, either electroless or electrolytic. Table VI is a list of some of the plastics which are available in plateable grades, and also Tektronix' present in house capability.

Since polycarbonate is one of the most popular plastics used, a special comment on its properties is warranted. The reason for its popularity is that it has very good electrical, mechanical

and thermal characteristics. It is also one of the easiest plastics to machine, and has reasonable chemical resistance.

However, when it comes to its coatability, confusion and disagreement reigns. Some companies claim to be able to successfully plate polycarbonate. However, one school of thought that is wide spread in the industry is that because of its poor resistance to solvents and high moisture absorption, there is no coating on the market that does not in some way compromise the impact strength of polycarbonate. And also that polycarbonate is one of the most difficult plastics to coat, from an adhesion standpoint, whether it be a metallic coating or a paint. More work needs to be done in this field before all of the parameters are fully understood, and a final conclusion made.

CONCLUSIONS AND RECOMMENDATIONS

There are several E.M.I. shielding methods available which provide excellent attenuation. The data shows that for the money, electroless nickel is the best system. Previous testing has shown electroless nickel to be environmentally acceptable. The question of U.L. approval must be addressed regardless of which method is used.

It does not appear to be economically feasible to plate large parts, e.g., cabinets. Therefore, it is recommended that the major shielding be done directly over any noisy components. If plastic is used, an electroless nickel plate with or without some electroplate would be the best choice. Any remaining E.M.I., whether due to leakage of shielded parts, or unshielded parts, if small enough, could be shielded by coating the cabinet with a conductive paint such as a nickel loaded paint. In certain cases it may be necessary to coat both sides of the cabinet with a conductive paint, and then add a decorative coat to the outside.

It was beyond the scope of this paper to evaluate other coating characteristics such as durability, adhesion, etc. These will be investigated in the next phase of the project after the actual shielding methods have been chosen.

TABLE I

SHIELDING SPECIFICATIONS

TYPE OF ENERGY	CRITERIA SOURCE				
	TEK[1]	FCC	VDE[2]	MIL[3]	UL[4]
EMI	yes	yes	yes	yes	coating
ESD	yes	no	no	no	coating
MAG	yes[5]	no	no	yes	coating

[1] - being revised - will cover FCC, VDE, & Mil

[2] - most severe in its range

[3] - covers greater frequency range

[4] - there is a UL spec for coatings on plastics, both for paints and platings

[5] - Tek uses MIL spec U61A-462, however, most business units are not building to meet spec (by intention)

TABLE II

SHIELDING CAPABILITY FOR THE PRIMARY COATING METHODS

METHOD	THICKNESS (mil)	RESISTIVITY (ohm/sq.)	ATTENUATION (dB)
Zinc arc spray	0.5-1	0.0002	50-60
Zinc flame spray	1	4.0	60-90
Nickel-acrylic paint	2	0.5-2.0	30-75
Silver-acrylic paint	1	0.04-0.1	65
Copper-acrylic paint	1	0.5	65
Graphite-based paint	1	7.5-20	30-50
Cathode sputtering	0.03	1.5	70-90
Electroplating	0.03	0.1	85
Electroless plating (nickel)	0.03	0.5	45
Silver reduction	0.05	0.5	70-90
Vacuum metallizing	0.05	5-10	50-70
Ion plating	0.04	0.01	50
Conductive plastics (40% carbon filled nylon)	-	75-100	40-60

TABLE III

RELATIVE LEVELS OF ATTENUATION

0-10 decibels	Very little shielding
10-30 decibels	Minimum range of meaningful shielding
30-60 decibels	Average shielding, should solve moderate problems
60-90 decibels	Above average shielding
90-120 decibels	Best shielding

30-60 dB attenuation should solve normal shielding problems. Being logarithmic 30 dB attenuation shields 99.9% while 60 dB attenuation shields 99.9999% of EMI/RFI.

TABLE IV

SHIELDING EFFECT OF PLATED PLASTIC

SAMPLE	SOURCE	COPPER	NICKEL	Cu,Zn,Sn (alloy)	Sn,Ni (alloy)	TOTAL PER SIDE	ATTENUATION (dB)
1	Crown City	425μ"	[1]55μ"			480μ"	90
2	Crown City	340μ"	[1]37μ"			377μ"	90
3	Tek	92μ"	[2]77μ"	10μ"		179μ"	90
4	Tek	315μ"		10μ"		325μ"	90
5	Tek	95μ"	[2]87 "		235μ"	417μ"	90
6	Tek	280μ"			320μ"	600μ"	90
7	Tek	85μ"	[2]270μ"			355μ"	90
8	Tek	50μ"	[2]42μ"			92μ"	90
9	Tek		[2]147μ"			147μ"	90
10	Tek	507μ"	[2]290μ"			797μ"	90
11	Tek		[2]162μ"			162μ"	90
12	FCM	30μ"	[2]15μ"			45μ"	90
13	FCM	37μ"	[2]12μ"			49μ"	90
14	FCM		[3]675μ"			675μ"	38

[1]electrolytic nickel
[2]electroless nickel
[3]nickel loaded paint, one side only

TABLE V

COST COMPARISON OF E.M.I. SHIELDING METHODS

METHOD	MATERIAL	COST[1] $/SQ.FT.
Thermal spray (arc or flame)	Zn	2.05
Ni loaded paint	Ni	1.25
Conductive plastic	Al	1.40
Conductive plastic	C	3.65
Cathode sputtering	Cu or Al	1.42
Electroless plating	Ni	1.30
Electroplating	Cu	1.50
Foil/tape	Cu or Al	2.35
Ion plating	Cu or Al	2.40
Silver reduction	Ag	3.50
Vacuum metallizing	Al or Cu	1.25-2.00

[1]includes labor and material (but not the substrate)

TABLE VI

PLATEABLE PLASTICS

PLASTIC	TEK PLATED?
ABS	yes
Noryl Ⓣ PN-235	
Stryrene	
Polysulfone	yes
Modified polycarbonate	
Teflon	
Polypropylene	
Phenolic	
Acetate	
Urea	
Polyester	
Polyurethane	yes
Polyphenylene oxide	

Ⓣ a trademark of G.E.

BIBLIOGRAPHY

Goldie, William; "Metallic Coating of Plastics"; Electrochemical Publications, Limited, 1969

Mooney, Peter J. PhD; "Plastics EMI Shielding: Materials, Equipment, Markets"; Business Opportunity Report GB:066, Sept. 1982

Storms, Charles D.; "EMI/RFI Shielding for Structural Foam Business Machine Components"; Tenth Annual Structural Foam Conference, April 5-7, 1982

RFI Shielding, General Electric Bulletin CDC 634