Application Note – AN1204

Potting Compound Selection for Power Supplies

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Abstract:
There are several different types of potting compounds on the market which are designed to perform different functions. Selection of a particular potting compound depends on several factors such as:

- Thermal performance, i.e. thermal conductivity
- RF Performance, i.e. dielectric constant (indicates how much the EMC will be affected)
- Chemical composition of the compound, i.e. if it is suitable for surface mounted components.
- Time taken for partial and full cure

Introduction to Potting Compounds:

The main types of potting compounds available are:

- Epoxy resin
- Polyurethane resin
- Silicone resin
- Polyester system

Epoxy Resin

Epoxy resins have been widely used for many years and have the following dominant properties:

- Usually hard and tough
- Exhibit low shrinkage on cure[1]
- Good adhesion to wide variety of substrates
- Fast cure hardeners can generate a lot heat during cure, giving rise to high exothermic temperature rise which can damage electronic components, resulting in mechanical stresses on component and circuit.

Polyurethane Resin

Over recent years, epoxy resin technology has tended to mature and currently most of the exciting developments in resin technology are now taking place in polyurethane chemistry. Thus, polyurethane resins are becoming more and more dominant. Some of the main characteristics of polyurethane resins are as follows:

- Generally elastomeric or rubbery when cured
- Preferred when circuits to be potted contain ferrites or glass reed switches or other similar component
- Cure speed, usable life and gel time can be adjusted as required more easily
- Exhibit lower exothermic temperature rise during cure than epoxies – heat generated is usually not a problem even for fast cure systems
- Conventional polyurethanes can be prone to attack by water, particularly at high temperatures
- Polybutadiene based urethanes are very resistant to water attack, both during and post curing.

Silicone Resin

- Generally more expensive than epoxies or urethanes
- Excellent for use at very high continuous operating temperatures, above 180°C
- Exothermic temperature rise with silicone systems is very low.

Polyester System

Polyester systems have been used for potting and encapsulation also.

- Exhibit a very high exothermic temperature rise & high level shrinkage on cure -> can cause component and circuit damage.
- High level of odour from styrene containing systems makes them unpleasant and difficult to use

Potting Compounds Cured by UV

Formulating one part resins to be cured by UV is possible but this technology is not well suited to formulation of potting resins because of shadow and penetration problems of the UV when curing thick sections with inserts.

Effects Caused by Potting Compounds

EMI Effects

It has been found through research that a compound cured by UV (along with silicone) is essentially transparent to RF (i.e. it does not block or absorb RF like other components), i.e. they have a very low dielectric constant/permittivity.

NOTE: Permittivity is a measure of how an electric field affects, and is affected by, a dielectric medium, i.e. the lower the permittivity, the smaller the effect.

This makes them ideal for EMC as they do not change the frequency distribution or amplitude of the EMC output. The potting compound acts as a capacitor and changes the behaviour of the electronic circuit, especially at high frequencies. It has been found in practice that the use of certain potting compounds affects EMC by shifting the frequency distribution and amplifying certain frequencies. It is possible to combat this through careful selection of inductors which can be placed on input and output cables but ideally it should be eliminated before this point.

While UV and silicone compounds are perfect for EMC, they are disastrous for temperatures as their thermal conductivity is close to zero.

NOTE: Thermal conductivity is the property of a material describing its ability to conduct heat.

Solid Filler Effects

Solid fillers are a very important part of many resin systems.[2] Sometimes they are added to reduce cost. Powdered Limestone may be used for this function. Sometimes this does not benefit the cost by a noticeable amount as filled systems have a higher density than unfilled ones. Thus cost comparisons of competing resins should always be done on a per litre basis rather than a per kg basis.

Solid fillers may also cause increased hardness and stiffness in the product. Fillers are also added for other reasons, to make the compound flame retardant (aluminium hydroxide commonly used for this), or to give improved thermal conductivity (zinc oxide and aluminium oxide can be used for this). Aluminium oxide is extremely abrasive and it can cause severe wear problems in mixing and dispensing apparatus.

Compound Density Effects

Density can be reduced and dielectric loss can be lowered through the use of **hollow glass and plastic bubbles**.[3] The potting resin can introduce capacitance effects between conductors on the printed circuit board and adversely alter the characteristics of the circuit, when potting RF circuitry. It may be possible to overcome these problems through the use of hollow glass spheres containing resins of low dielectric constant.

However, inserting hollow glass spheres into the potting compound can reduce the overall thermal conductivity of the compound which will make the thermal performance worse. Mixing the hollow spheres into the compound is a difficult process for several different reasons; mixing the correct amount in every time, ensuring even distribution of the hollow spheres and preventing the spheres from settling.

High Temperature Distribution Effects

Heat sinks should be the first choice to remove heat from a PSU. Thermally conductive materials do not conduct much heat but they can lower the hot spot temperatures – i.e. the temperature next to the component. Thus, the hot spot temperature is spread throughout the potting material to the surrounding components, which may cause an undesired increase in the temperature of the surrounding components. The ideal situation is to remove the excess temperature from the PSU as fast as possible, to minimize the thermal impedance from internal components to the case i.e. to the outside ambient.

Low Temperature Distribution Effects

Very low temperature is normally the greatest problem with stress since as the temperature goes down the potting compound gets harder, depending on the type of potting compound selected.[4] The glass transition temperature, Tg, is the temperature at which the potting compound changes structure, becoming harder and more brittle. Some polyurethane systems have a Tg below 50°C, and the potting compound does not become hard at those temperatures so it can deform rather than putting pressure on the part, meaning less stress. For SMT boards, polyurethane is recommended so that solder bonds are not broken at low temperatures.

Pressure Effects

It should be noted that some components will change their properties when pressure is applied, such as frequency generating crystals, powdered iron parts and glass encased reed switches. The potting compound should be carefully selected so that their properties are not changed. Potting compounds that are soft and have a low Tg are recommended.

Another way to prevent pressure on a part is to cocoon it, i.e. pot the part twice, first with a very soft, low Tg material and then with a harder potting compound over the soft compound. However, this is not ideal as it may lead to other problems such as temperature distribution with the possible introduction of an air gap.

Shrinkage Effects

All potting compounds shrink as they change from the liquid to the solid state with a chemical reaction.[5] The act of shrinkage may cause stress to the components that are to be potted. The amount of shrinkage can be minimized and the stress it brings through a slow, orderly hardening of the potting compound. Thus, the hardening temperature should be lowered to minimize exothermic temperature rise and slow the reaction to all orderly flow in to shrinking areas. The polymer is the only item that shrinks. The use of filled systems results in less shrinkage. Thus, when potting a power supply unit, speeding up the curing time in the oven may stress the components.

EMC Experimental Data

Radiated EMC analysis was performed on different types of potting compounds, the significant parameters of which are listed in Table 1. The system was uncalibrated so the testing was done for comparative purposes only.

	Stated Permittivity Constant	**Thermal Conductivity (in W/mK)**
Robnor Resins EL171H	~4 @ 50Hz	0.75
Cytec EN-9545	4.1-4.5 @ 100Hz, 3.9-4.3 @ 1kHz, 3.6 @1MHz	0.75
Robnor Resins EL297E	3.6 @ 50Hz	0.85
Electrolube: UR5111	2.6 @ 50Hz	~0.25

Table 1: Analysis of Permittivity & Thermal Conductivity of Potting Compounds

The EMI comparative testing was performed in an anechoic chamber, using the following equipment, resulting in the data shown in figure 1 below:

- LDV100-012SN – 12V, 100W LED Driver
- 90W resistive load
- Very High Frequency (VHF) aerial set to vertical position, 1.5m above ground, 1m away from apparatus.

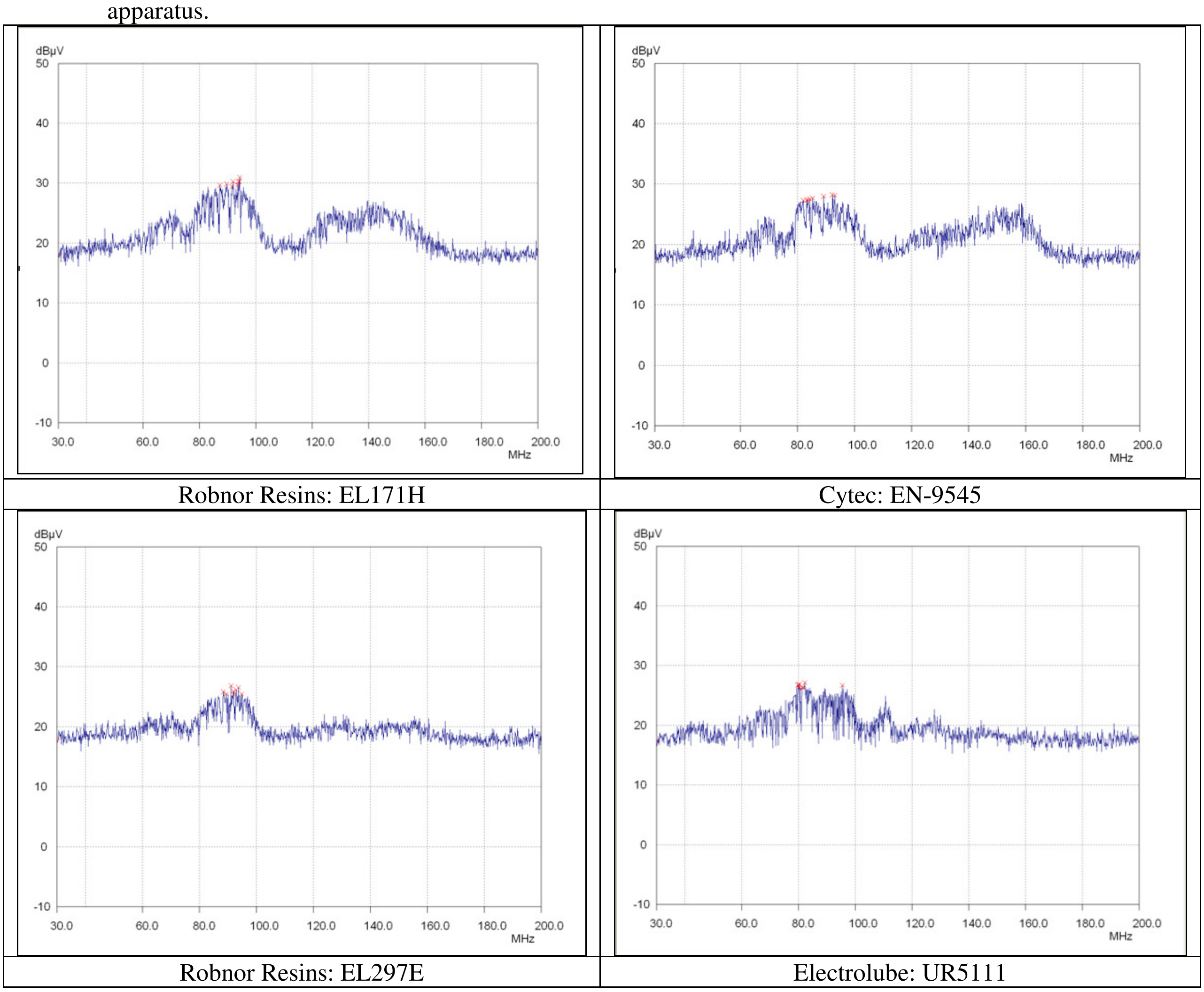

Figure 1: Potting Compound Comparison for Vertical VHF testing

Temperature Analysis

The temperatures were monitored for the different types of potting material to compare the thermal conductivity. The tests were done with the LDV100-012SN unit in a box and the oven turned on to keep the temperature of the hottest point on the chassis at 80°C. The tests were done at an input voltage of 90VAC and an output power of 90W.

Potting Type	**Electrolube UR5111**	**Robnor Resin EL297E**	**Robnor Resin EL171H**
Ambient-coin	36.04	29.21	30.57
CR Case	78.39	80.09	80.08
L3	…..	66.56	68.38
T1	90.20	79.00	79.14
BD2	94.03	62.55	62.68
Q3	110.80	68.56	68.38
Q5	102.34	81.52	80.98
Q6	101.56	83.45	82.89
CY1	87.70	80.03	77.22
C201	91.13	86.41	85.76
C202	93.15	….	83.19
CR201	108.38	95.20	91.49
CR202	107.66	92.65	91.19
CR203	106.15	93.42	93.27
Heatsink	101.70	….	88.21
C203	89.04	….	82.35
L201	91.13	….	….
C210	87.04	….	79.13
Label Tc	78.39	80.09	80.08

Table 2: Temperature Comparison of Three Potted Units.

At the time of testing, for UL safety regulations, the temperature limiting factor of the unit was 85°C for CY1. Thus UR5111 cannot be used as the thermal conductivity is poor and the temperatures are exceeded, as shown in Table 1 above. The temperatures for EL297E seem to be slightly higher than EL171H but they are still within the safety limits. Using LDV100-024SN, comparative thermal testing was performed on key components using the Cytec compound and the temperatures were found to be equivalent to those with EL171H.

Conclusion

As discussed in this paper, potting compounds have many different uses in a wide variety of applications. Selection of the potting compound depends on its primary purpose, which can include any of the following:

- To dissipate the hotspots across the unit, normalising the component temperatures to a certain extent.
- To make the unit waterproof and dust proof
- To protect the components/unit, etc

However, when potting a power supply, some hitherto unexpected side effects can also occur which can affect the operation of the unit, such as:

- Thermal performance:
  - A potted unit at sub zero temperatures (e.g. -30°C) takes longer to react to inrush current, i.e. can have problems starting up unless the inrush thermistor is insulated somewhat from potting. Low temperatures can also affect the ESR of electrolytics.
  - At high temperatures, the heat from one component can pass to another causing the second component to exceed its maximum temperature ratings.
- RF Performance:
  - A potting compound can adversely affect the EMC of the unit.
- Chemical composition of the compound:
  - Extreme care must be taken when selecting a potting compound for a unit that uses surface mount or glass components.
- Time taken for partial and full cure:
  - This becomes very important in the manufacturing environment, where an efficient turnaround is essential.

In this paper, the experimental results compared polyurethane compounds, in terms of EMC behaviour and thermals. The best radiated EMC results occurred with EL297E. It gave a few dBµV margin over the Cytec potting, particularly at the higher frequencies and when the VHF aerial was in the vertical position. UR5111 was not a viable option as it has poor flowability, making it extremely difficult to pot the unit and also the thermal performance was inadequate. The temperatures of the components using EL297E were slightly higher than EL171H but they were still within the safety limits. However, EL297E is a specialist product and thus is more expensive than Cytec. Hence, Cytec potting is currently used as a result of its chemical properties and cost advantages.

References

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