

EFFECTIVE MOUNTING OF TOROIDAL CORES

Packaging and Production Considerations

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INTRODUCTION

Mounting and packaging for magnetic devices has become more important as companies gain the ability to view the total cost of a component as a combination of its price, availability, quality, durability and how efficiently it can be put on the circuit board. Today, magnetic components in small and medium quantities are being mounted and packaged to improve durability in transit, to speed inspection time by allowing plug in testing, and to reduce production and rework costs.

More and more the magnetic design engineer using a toroid must consider packaging and production options in addition to core material and size. Often the best magnetic package is a compromise between the optimum magnetic design, "manufacturability", durability and the availability of hardware. This application note will help a magnetic design engineer with the packaging aspects of designing on a toroidal core.

Current technology relies heavily on soldering a component to the printed circuit board (PCB). For a toroidal core and winding, a header or toroid mount is used to facilitate connecting the windings to the PCB by providing a terminal as an intermediate connection, or by positioning the winding for direct connection to the PCB. This can be done using through hole soldering or surface mount soldering.

THROUGH HOLE TOROID MOUNTS

Through hole headers and mounts connect components to a printed circuit board by inserting a terminal or lead through a hole in the board and soldering it to the opposite side. Through hole headers and mounts have two basic configurations: horizontal or vertical.



Horizontal Toroid Mounts

Horizontal through hole headers or toroid mounts are widely used as a platform or holder for mounting wound toroids on their side. They are usually molded from plastic (see "Selecting the Best Plastic for Your Application" on page 5) with the size, shape and number of termination points specific to the wound toroid. They are most often either a platform, as in Figure 1, or cup shape like Figure 2. The molding of either configuration will typically include standoffs which allow the printed circuit board cleaning solutions to easily flow between the component and the PCB. The minimum standoff is usually .015 inches.

The leads from the toroidal winding are attached to the mount's terminals, usually by soldering. If the winding's wire is large and stiff enough, the wire can be "self leaded" and positioned through the header or mount into the printed circuit board, as in Figure 3. Once the toroid is attached to the mount, this component is ready for insertion into a printed circuit board. Magnetic components are heavy and the mechanical characteristics of the solder connection are as important as electrical integrity. Printed circuit boards with un-plated through holes using heavy components may require a clinched terminal as described in MIL-STD-2000 and shown in Figure 4. Printed circuit boards with plated through holes offer good mechanical integrity without clinching, providing a successful intermetallic bond is created during the board solder process as shown in Figure 5.

The toroids can be attached to the mount with either adhesives or mechanical means. Cup shaped toroid mounts can be filled with a potting or encapsulation compound to both adhere and protect the wound toroid. Horizontal mounting offers both a low profile and a low center of gravity in applications that will experience shock and vibration. As the toroid's diameter gets larger, horizontal mounting begins to use up valuable circuit board real estate. If there is room in the enclosure, vertical mounting is used to save board space.

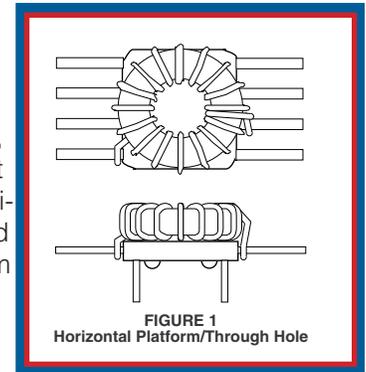


FIGURE 1
Horizontal Platform/Through Hole

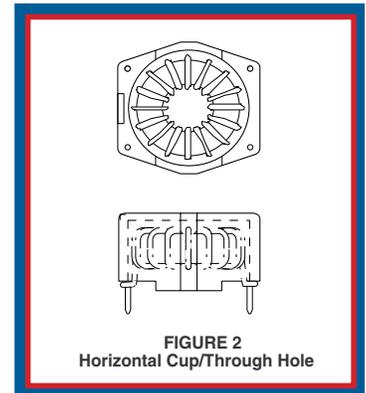


FIGURE 2
Horizontal Cup/Through Hole

Vertical Toroid Mounts

Vertical through hole headers and toroid mounts are designed to stand up wound toroids on the PCB, which saves circuit board real estate. As with horizontal mounts, vertical mounts are usually molded from plastic with the size, shape and number of termination points specific to the application. The molding of either configuration will typically include standoffs which allow the printed circuit board cleaning solutions to easily flow under the component. The minimum standoff is usually .015 inches. Vertical toroid mounts come in many configurations, several of which are shown in Figures 6 through 11. Much of their structure is devoted to supporting the vertical toroid and creating a stable base for connection to the printed circuit board.

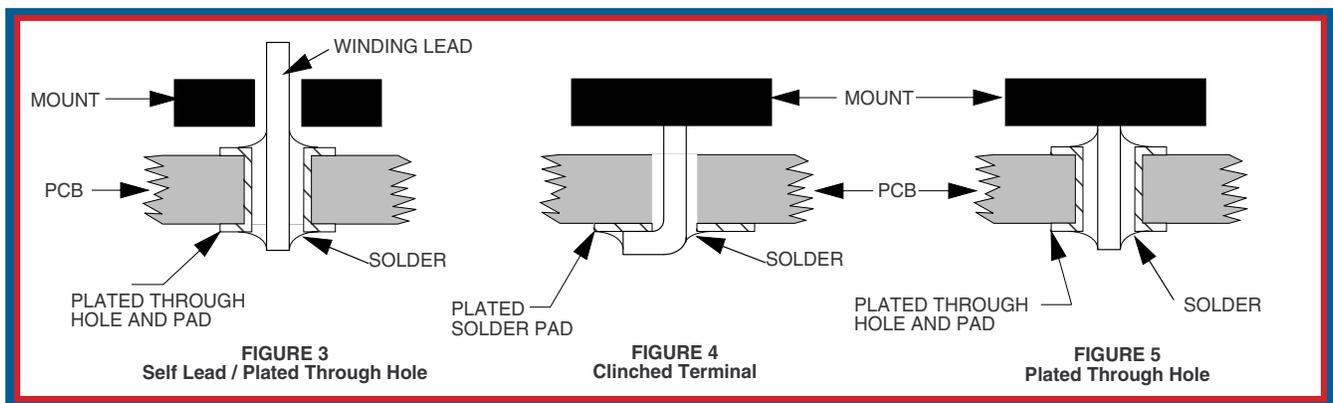
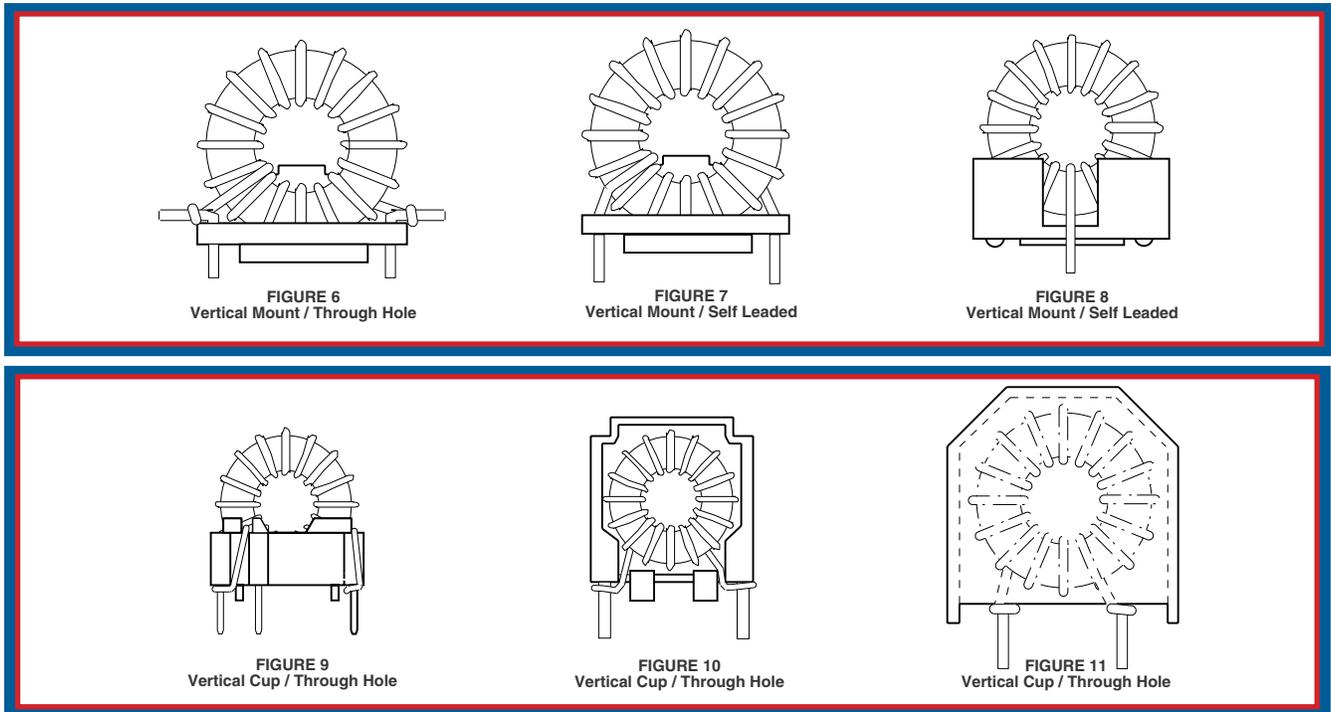


FIGURE 3
Self Lead / Plated Through Hole

FIGURE 4
Clinched Terminal

FIGURE 5
Plated Through Hole

The leads from the toroidal winding are attached to the mount's terminals, usually by soldering as shown in Figure 6. If the winding's wire is large and stiff enough, the wire can be "self ledged" and positioned through the header or mount into the printed circuit board, as in Figures 3, 7 and 8. The advantage of self leading mounts is that the expense and vulnerability of an additional intermediate solder connection is avoided. The toroids can be attached to



the mount with either adhesives, mechanical means or by encapsulation. Cup shaped toroid mounts, (Figures 8, 9 and 10) can be filled with a potting or encapsulation compound to both adhere and protect the wound toroid. Vertical mounting saves circuit board real estate when a toroid's diameter gets larger, but creates a component height issue. Vertical mounting also raises the component's center of gravity making it vulnerable to shock and vibration.

SURFACE MOUNT TOROID MOUNTS

Surface mount components are a direct response to cost reduction efforts that center around improved circuit board production. Automatic or robotic pick and place equipment can pick up and place surface mount style components on a printed circuit board faster and more accurately than previous technology would allow. Instead of a pin or terminal passing through a printed circuit board and being soldered on the opposite side, surface mount components utilize a flat solderable terminal that is soldered to a flat solderable pad on the face of the printed circuit board (Figure 14, 15, 16). The pad on the circuit board is usually coated with a paste like formulation of solder and flux. With careful placement, surface mount style components on solder paste will stay in position until elevated temperatures, usually from an infrared oven, melt the solder paste and solder the mount's flat terminals to the circuit board's pad.

Because the mount's leads lay on the printed circuit board, it is important that all the mount's leads are flat and on the same plane. If one or several of the leads are out of position or not on the same plane as the others, the solder connection can be defective. The industry specification for lead "co-planarity" allows a tolerance of .004 inches from the plane of the printed circuit board. This makes the handling and packaging of surface mount devices critical to the overall cost and performance of the technology.

A wound toroid must be incorporated in a header or mount in order to utilize surface mount technology. There are several styles of surface mount headers and mounts for toroids which are usually molded from plastic (see "Selecting the Best Plastic for Your Application", page 5) with the size, shape and number of termination points specific to the wound toroid.

The most familiar styles are either gull wing (Figures 12 and 14) or "J" lead (Figures 13 and 15) horizontal surface mount devices. The gull wing style is widely used because it is relatively inexpensive to mold and form. The gull wings are flexible to withstand thermal expansion and contraction and it is easy to inspect the integrity of the gull wing lead to circuit board solder connection. The "J" lead also has wide acceptance because it uses up less board real estate than the gull wing. However, the "J" lead to board solder connections are hidden from inspection and the leads are more difficult to form. Once the toroids are attached to the mount with either adhesives, mechanical means or by encapsulation, the winding leads are connected, usually by soldering, to the mount's terminations.

Surface mount components need to be shaped so the robot can pick them up from tape and reel, tubes or trays, and place them on the circuit board. Two common methods are either a mechanical grabber or a vacuum pickup. In either case the mount needs to be designed with a shape a robot can grab or a flat horizontal surface that allows vacuum pickup. Figure 12 shows how a cup can be placed on the device which creates a flat horizontal surface for vacuum pickup. Figure 13 shows an inverted cup design with "J" lead terminals which also allows vacuum pickup. Both the gull wing and "J" lead are subject to co-planarity problems if packaging for shipment and production handling is not carefully considered.

New surface mount techniques are being introduced to the industry constantly. One style is the Lunar Lander which is shown in Figures 16 and 17. The Lunar Lander incorporates a lead style that is more rigidly supported by the plastic molding. This style is very robust and will tolerate handling and shipping with little or no effect on the co-planarity. This style is mostly visible for inspection. Figure 17 shows the Lunar Lander lead style incorporated with a cup shaped mount. This can be filled with a potting or encapsulation compound to both adhere and protect the wound toroid. The cup shape also offers a flat surface important to pick and place vacuum pickup as well as convenient location for a part number marking.

A self leaded surface mount header/toroid mount is a relatively recent development. In this style of toroid mount, the toroid's winding becomes the surface mount connection to the circuit board. The winding terminations are first tinned, then channeled and gripped by the design and characteristics of the plastic molded mount, making a suitable surface mount connection point. This concept improves reliability and reduces cost by eliminating an intermediate solder connection.

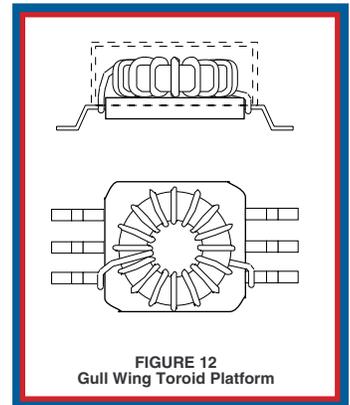


FIGURE 12
Gull Wing Toroid Platform

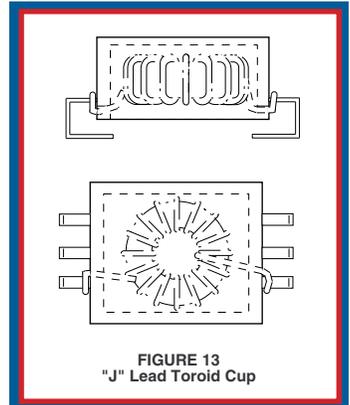


FIGURE 13
"J" Lead Toroid Cup

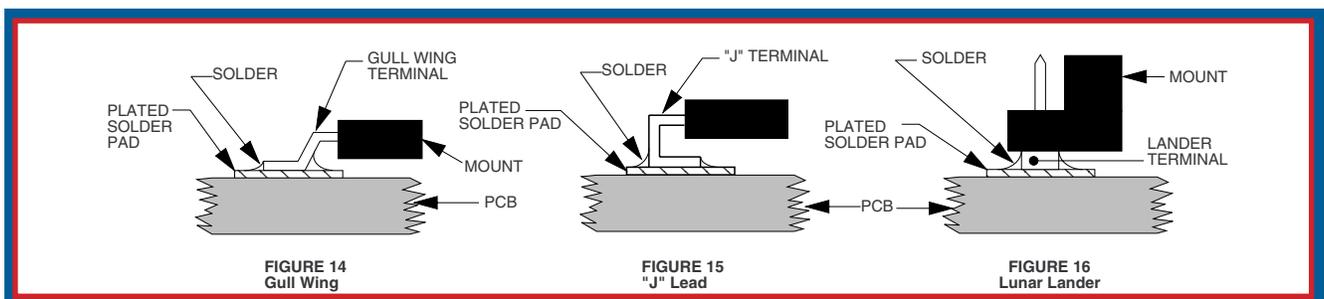


FIGURE 14
Gull Wing

FIGURE 15
"J" Lead

FIGURE 16
Lunar Lander

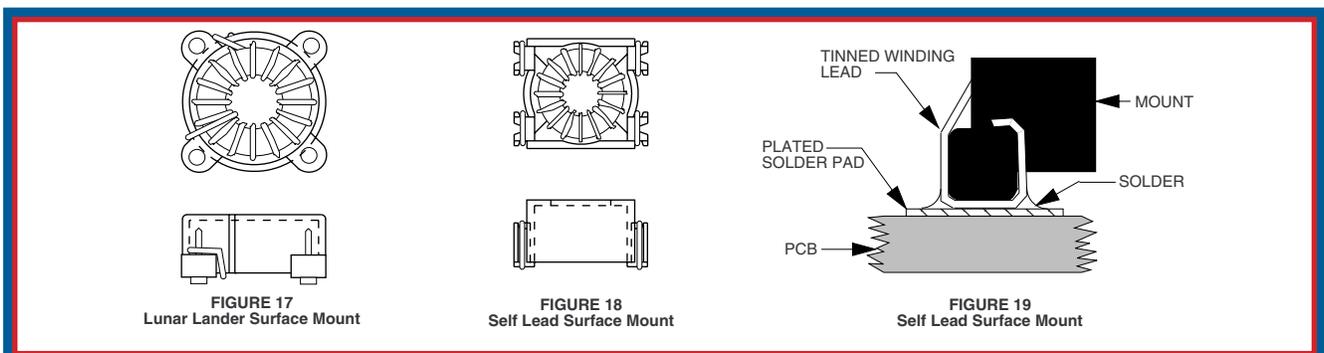


FIGURE 17
Lunar Lander Surface Mount

FIGURE 18
Self Lead Surface Mount

FIGURE 19
Self Lead Surface Mount

Figure 19 shows how the tinned winding lead is held in position by the mount, on a solder paste pad for example, allowing the surface mount connection to be made during infrared re-flow. While this can offer a cost effective connection method, the mount is usually specific to a particular wire size, and will be subject to co-planarity problems if the wire is not positioned correctly. As with the other surface mount styles, a flat surface for vacuum pick up needs to be incorporated into the toroid mount's design.

Selecting the Best Plastic for Your Application

Plastics used in molding toroid mounts and headers come in two broad categories, thermoset and thermoplastic. Thermoset plastics include epoxies, phenolics and Diallyl Phthalate (DAP) which are known for their environmental stability and ability to tolerate over 750° F without melting. Thermoplastics include nylon, polypropylene, polycarbonate, polyester (Valox, Rynite), LCP (Vectra) and PPS (Ryton) which will begin to melt if they experience temperatures much above 500° F for an extended period. The chemistry that gives thermoplastics a lower melting point also makes them less expensive to mold, providing a cost advantage over thermoset plastics.

Thermoplastics are widely used in applications that do not experience temperatures above 500° F, except for a few seconds during the winding lead to terminal and component to PCB soldering process. Thermoset plastics on the other hand, are popular in magnetic applications when it is used in conjunction with self stripping magnetic wire. The un-stripped and un-tinned magnetic wire is wrapped around a terminal molded into a thermoset header or toroid mount, and then dipped into a 750° F solder pot. The high temperature solder will burn off the wire's insulation, tin the wire and solder it to the terminal all at once, without melting the mount.

There are trade offs between the two plastic types that must be considered. The mount may be less expensive if molded from thermoplastic but will require pre-tinning the winding leads and careful heat management while soldering the leads to the mount and soldering the mount to the circuit board. The thermoset mount can be more expensive, but with self stripping magnetic wire, several terminations can be soldered at once and the wire will not need to be stripped or pre-tinned, possibly making the overall cost of producing the component lower.

Plastic Type	Mat'l Code	Mfg	Trade Name	UL Card No.	UL Flameability	System Class **	RoHS Compliant
<u>THERMOSET</u>							
Phenolic	PH	Sumitomo	PM-9630	E41429	UL94-VO	N (200°C)	Yes
Phenolic	PH2	Sumitomo	PM-9820	E41429	UL94-VO	N (200°C)	Yes
Phenolic	PH3	Chang Chun	T357 / T373J / T375J	E59481	UL94-VO	F (155°C)	Yes
Diallyl Phthalate	DAP	Synress-Amico	5562	E48036	UL94-VO	F (155°C)	Yes
Diallyl Phthalate	DAP2	Cosmic	D72	E64213	UL94-VO	F (155°C)	Yes
Diallyl Phthalate	DAP3	Sumitomo	52-70-70	E123472	UL94-VO	F (155°C)	Yes
<u>THERMOPLASTICS</u>							
Glass Filled Nylon	GFN	DuPont	FR50	E41938	UL94-VO	F (155°C)	Yes
Glass Filled Nylon	GFN2	DuPont	70G33L	E41938	UL94-HB	F (155°C)	Yes
Glass Filled Nylon	GFN3	DuPont	132F/101L (Zytel)	E41938	UL94-V2	B (130°C)	Yes
Glass Filled Nylon	GFN4	RTP	RTP205FR	E84658	UL94-VO	F (155°C)	Yes
Glass Filled Nylon	GFN5	DSM Co.	TE250F8 (Stanyl)	E172082	UL94-VO	B (130°C)	Yes
Polyethylene	PET	DuPont	FR530 (Rynite)	E41938	UL94-VO	N (200°C)	Yes
Poly Butylene	PBT	Chang Chun	4130	E59481	UL94-VO	B (130°C)	Yes
Polyphenylene	PPS	Phillips	R-4 (Ryton)	E54700	UL94-VO	F (155°C)	Yes
Liquid Crystal	LCP	Sumitomo	E4008	E54705	UL94-VO	F (155°C)	Yes
Liquid Crystal	LCP2	DuPont	6130L (Zenite)	E41938	UL94-VO	N (200°C)	Yes
Liquid Crystal	LCP3	Nippon	HM402	E91944	UL94-VO	F (155°C)	Yes

**Insulation System Class Temperature is for use as mechanical support. Review specific insulation systems to determine if the material is suitable as a ground insulation or as mechanical support at a higher temperature class.

The various plastic types within the thermoplastic or thermoset categories will have individual characteristics that relate to moldability, roughness, brittleness, flexibility, thermal expansion, moisture absorption and cost. In addition, each plastic will also be evaluated for its plastic's flammability characteristics, its environmental impact and compatibility with other component ingredients.

UL Temperature Class, Flammability, and Insulation Systems

Underwriters Laboratory (UL) is a non-profit private agency that evaluates public safety for a variety of products that include electronic devices. UL regulations are focused on maintaining the integrity of an insulation system so a short circuit does not occur. This is done by first ensuring the insulation structure within a component is sufficient, and that it will not degrade over time.

UL opens a file for each plastic manufacturer where it records the safety ratings for each manufacturer's plastic. On this UL file or "Yellow Card", each plastic will be rated by temperature class and flammability. The UL temperature class designates the maximum temperature a plastic will tolerate during normal operation. Design engineers need to understand the temperature demands of their application and select a plastic to match.

The UL94 Flammability Rating is a measure of whether a plastic will self extinguish when held over a flame, and then removed. The faster the plastic stops supporting a flame, the higher the flammability rating. If components are going to be used in a consumer or industrial application, the highest rating of VO is generally required.

In a transformer or inductor, the integrity of the wire insulation is a critical safety concern. Transformer components including wire insulation, bobbin, toroid mounts, tape, ferrite, iron powder, varnish, epoxy, and glues each have their own unique chemistry. UL conducts extensive testing under UL Standard 1446 to ensure that the chemistry of one component, or several components in combination, do not have an adverse effect on the component's wire insulation over time at an elevated temperature.

Once this combination of ingredients are tested and approved, all the tested subcomponents become part of a UL recognized insulation system specific to an operating temperature or class. For a design engineer designing a product, using the sub-components listed in a recognized insulation system will insure a reliable insulation and proven sub-component compatibility.

Requirements on Hazardous Substances, or RoHS.

The electronics industry worldwide has developed several programs that limit or eliminate specific elements and compounds that are harmful to the environment from component construction. The most significant directive is the Requirements on Hazardous Substances, or RoHS. This directive seeks to eliminate or reduce 6 harmful elements or compounds. The most significant banned element in the RoHS directive is not the flame-retardants in the plastic molding, but the lead (Pb) that is used in the plating and solder on terminals.

When tin (Sn) and lead (Pb) are combined in an alloy of approximately 60% tin and 40% lead, this alloy has a melting point of approximately 361°F (183°C). When you "get the lead out", the fundamentals of solder connections change significantly. Solder alloys that are more than 95% tin have a 90°F, (50°C) higher melting point. (Approximately 450°F, 230°C). Components, including the plastic moldings, must now tolerate this increased solder temperature during the solder process.

Thermoplastics like nylon, Pet, PPS will become soft above 450°F, (232°C), especially when heat is transferred up a terminal. If the plastic experiences these temperatures for an extended time, the terminals will begin to "float" out of alignment. Using plastics that are not properly engineered for process temperatures, or do not meet the requirements of agency regulations, will have the potential to fail, which will increase manufacturing cost, result in product failure, and costly customer rejections.

UL Class	Max Temperature Rating
A	105°C (221°F)
B	130°C (266°F)
F	155°C (311°F)
H	180°C (356°F)
N	200°C (392°F)
R	220°C (428°F)

UL94 Rating	Flammability Specifications
VO	Will support combustion for up to 10 seconds and self extinguishes when tested under specific conditions.
V1 & V2	Will support combustion for up to 30 seconds and self extinguishes when tested under specific conditions. V2, dripping melted material allowed.
V5	Will support combustion for up to 60 seconds after 5 test burnings of 5 seconds each and self extinguishes when tested under specific conditions.
HB	Will support combustion and may not self extinguish when tested under specific conditions.