GENERAL INFORMATION

Application Note
27703.1A*

HALL-EFFECT DEVICES: SOLDERING, GLUING, POTTING, ENCAPSULATING, and LEAD FORMING

Introduction

The Hall effect, discovered by E. F. Hall in 1879, is the basis for all Hall-effect devices. When this physical effect is combined with modern integrated circuit (IC) technology, many useful magnetic sensing products are possible. The Hall element, when properly biased, produces an output voltage that is proportional to a magnetic field. To make a linear magnetic sensor, this small voltage is processed through a high-quality amplifier, which produces an analog output that is proportional to the applied flux density. In Allegro's switch configurations, the Hall-effect voltage is amplified, then processed through a Schmitt trigger and an output transistor, which supplies an open-collector output that turns on and off at specific magnetic flux densities.

Hall-effect elements respond to stress by modifying the output voltage vs. the magnetic flux-density curve. For this reason, it is important that designers, from chip to final customer, understand that environmental stress from hot, cold, or mechanical sources can affect the output of a Hall-effect element. The chip designer anticipates the end use, builds compensation circuits, and connects multiple Hall elements, such as Allegro's quadratic Hall voltage generator, in such a manner as to minimize the effects of the anticipated environment. When the proper IC design is matched with the proper package design, environmental effects are minimized.

Packaging

The Hall-effect IC designer strives to minimize the effects of environmental stress, and the component package designer must be cautious not to undo this work. At the same time, the packages they design must be in a familiar and usable form so that the assembly packaging engineer can use the device. In 1977, the Sensor Division of Sprague Electric Company (now part of Allegro MicroSystems) chose to modify the popular TO-92 transistor package to create the "U" type package.

Although clever design techniques greatly reduce the effects that package stresses may place on the operation of the Hall-effect IC, it is important that assembly manufacturers take precautions to avoid unnecessary external stresses such as those caused by overmolding, gluing, or clamping.

The end use of epoxy-encapsulated Hall-effect sensors frequently requires the devices to be repackaged, and this repackaging usually necessitates the use of glue, potting compound(s), or molding encapsulation. Although Hall-effect sensors (as supplied) exhibit the same resistance to harsh environments as other epoxy-packaged semi-conductor products (such as transistors, diodes, and ICs), there are some special considerations when they are installed in the finished package.

DESIGN RULES:

Soldering

Allegro leaded Hall-effect devices are designed to be through-hole soldered into printed wiring boards. They will withstand the temperature excursions experienced during hand soldering, reflow soldering, or wave soldering as long as normal, good soldering practices are used. Fluxes should be limited to the halide-free types.

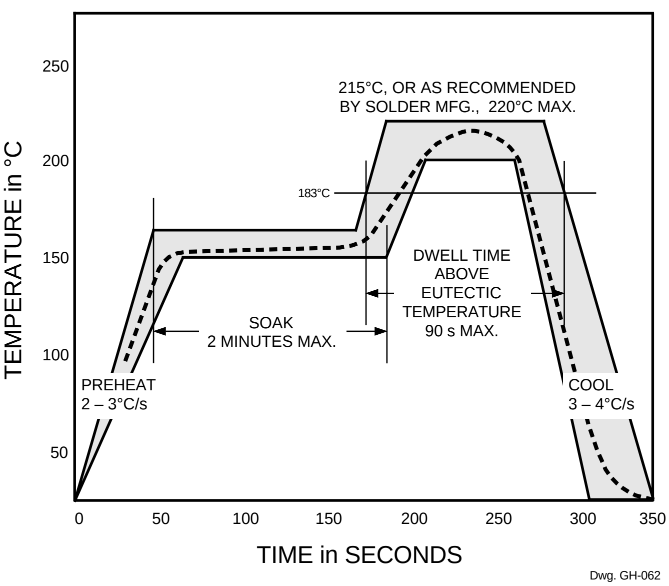
Sensors that have been lead formed for surface mounting (suffix "-TL") can be soldered using *low-temperature* reflow techniques. Low temperature is defined here as any method that does not expose the plastic body of the part to temperatures in excess of

220°C. See reflow chart below. Hand soldering may be used but because of the short leads and the lack of a through hole for a heat sink, care must be taken not to overheat the part.

Surface-mount components are designed to withstand the rigors of all accepted reflow techniques and require special care due to their sensitivity to mechanical stress.

Manual soldering of surface-mount products is not recommended!

See Surface-Mounting, below.



Gluing

Gluing a device into a cavity in a manufactured subassembly is a common method of re-packaging a Hall-effect switch. The basic rules are:

1. Match the expansion characteristics of the glue or molding epoxy as closely as possible to the component epoxy, which has an expansion rate of 25 to 65 x 10^{-6} in./in./°C. Most highly filled (non conductive) epoxies fit into this category and usually are good choices.

2. Surface-mount component mounting epoxies can also be used to glue in molded components. These materials do not match the Hall-device characteristics as well as filled epoxies but have the advantage of being effective in very tiny dot sizes and they have a fast cure time.

3. Cyanoacrylate (“Super Glue”) is not a good choice for gluing Hall-effect switches because it has a high rate of shrinkage when it cures. If the glue is applied to only one side of the device, this shrinkage can bend the device and cause severe stress. These glues also tend to be biodegradable and can disappear in many common environments.

Potting

1. The first rule when designing assemblies for a Hall-effect switch is don’t pot if you don’t have to.

Quadratic-element Hall devices are much less susceptible to parametric shift and, in many cases will maintain their original parameters after gluing, potting, or encapsulation. The use of a quadratic-element device, however, does not mean that the design rules can be ignored. The designer should always choose a packaging system that is least likely to produce stress.

2. When potting, it is essential that the material used is as closely matched to the component as possible, and that the shrinkage rate be as low as possible. Almost all potting compounds shrink during cure and this stresses the component being potted.

3. Potting with resilient materials, such as RTV silicones or urethanes, can reduce stress. However, when the resilient materials are enclosed in a housing, it is still possible for stresses to result due to differences in the coefficient of thermal expansion. Resilient materials typically have high expansion rates.

4. Potting with resilient foams is an excellent way to control stress from thermal expansion and still enclose the component. If the foam used is open cell, a sealer will be required to prevent the foam from filling with moisture.

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Plastic encapsulation (direct overmolding)

1. Fully encapsulating Hall-effect devices by overmolding with either thermoset or thermoplastic materials can cause parametric shifts. Hall-effect devices encapsulated in this way should be retested over the full range of temperatures dictated by the application. The temperatures required in the molding of thermoplastics are above the reflow temperature of the tin/lead coating on the leads and the mold design must be such that the tin/lead is not pushed up against the body of the Hall device, shorting the leads. Cavity pressures in thermoplastic molds are very high and the mold design must be such that there are no bending forces applied to the Hall device during the molding process. Bending stresses can alter the device parameters or, if high enough, crack the die inside the epoxy package.

In situations where the Hall devices forms a plug in an injection mold cavity with the device being held by the leads, it is important that the end of the device is supported. If there is clearance between the device and the end of the mold cavity, then the device can become a piston that is pushed forward in the mold cavity, pulling and stretching the leads.

2. The safest way to fully enclose a molded Hall-effect device is to design a housing into which the device can slip fit. The device can then be overmolded, potted, or glued into place.

Surface mounting

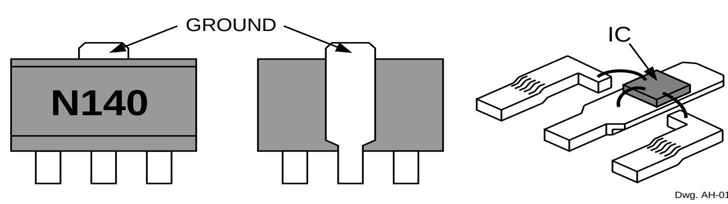
Hall devices are offered in surface-mount packages and these present the designer with additional considerations.

The first surface-mount Hall devices were offered in the industry-standard SOT89/TO-243AA package that Allegro designates “LT” (and a long-leaded variation, “LL”). Because the active area depth* is larger in this package, magnets with a higher field strength may be required than for similar devices in the “U” or other Allegro packages.

There are some special considerations when soldering the SOT89 type packages.

Wave soldering of SOT89 surface-mount products is not recommended!

The SOT89 package has three surface-mountable leads, the outside pair angle sharply up into the plastic package and the center (ground) lead is exposed for its full length (figure B). The package integrity (e.g., moisture resistance) of the SOT89 is not as good as other IC packages due to the increased metal-to-plastic interface produced by the exposed ground lead. The design of the SOT89 attempts to lock the ground tab into the plastic and to lengthen the potential moisture infiltration path by coining the pad edge (figure C), but precautions still need to be taken to ensure that contaminants are not forced into the package during the soldering operation. Fluxes containing halides should not be used when soldering any plastic-encapsulated semiconductor device, but this is especially true when working with the SOT89 package. It is also important to get the SOT89 package thoroughly clean and dry after any board-cleaning operation.



A B C

Because the solder tab on the back of the package is the same leadframe element that the IC chip is mounted on, soldering the device into the circuit board is likely to produce some stress-induced magnetic shift. Glues used to hold the device in place during the soldering process can be stress-inducing elements and location and quantity can be a factor. The solder pad layout on the circuit board can also be optimized for minimum stress. Stresses caused from thermal effects are a major consideration

* Active Area Depth - The distance from the surface of the package to the Hall-sensor element.

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when using this package and soldering operations with high thermal shock and processes with temperatures that exceed 240°C are known to produce magnetic parameter shifts. In most processes the stress-related magnetic shifts will be small and will not affect the performance of the assembly. It is important, however, to have a stable repetitive process so that these shifts remain constant. For this reason automatic rather than hand soldering techniques are recommended. Testing after surface mount is recommended so that parameter shifts can be monitored (i.e., process control).

Hall devices are also produced in the SOT23/ JEDEC TO-236AB/EIAJ SC-59 type packages but have been limited mostly to Hall elements without signal-conditioning components. Allegro's new "LH" package has a slightly taller body than the SOT23 or SC-59 but is designed to fit on the same solder footprint. This package is only 1 mm thick and requires special consideration to prevent delamination and popcorning due to thermal shock during reflow soldering. Processes for soldering surface-mount Hall-sensor devices are described in Allegro Application Note 27703.2.

Ultrasonic welding

Any ultrasonic welding of plastics in close proximity to the Hall-effect device must be done with caution to avoid work-hardening of the copper lead materials and possible breakage of the internal leads.

Lead forming

Lead-forming operations are often a necessary part of packaging Hall-effect sensors. A few simple precautions will ensure that lead forming does not induce damaging stress to the leads, the epoxy package, or the internal device.

1. Leads should not be formed or clipped closer to the package than 0.030" (0.76 mm), and they must be supported so that no movement or stress can occur in this area during the lead-forming operation (see figure A).

2. When lead forming close to the package, it is wise to prevent the tie bar from falling into the area of the bend radius. Due to the stiffness of the material in this area, a smooth radius will be difficult to achieve.

3. The design of the lead former should clamp the leads sufficiently so that there is no force trying to pull the leads from the epoxy package during the forming process.

4. All bends must be made over a smooth anvil with a radius of at least one-half the lead thickness.

5. Leads should not be deformed in the bend area by squeezing the leads between the former and the anvil. Spring-back must be eliminated by over bending, not by deformation.

6. Lead forming may result in tooling marks on the lead's surface. These are acceptable as long as the marks are not severe enough to penetrate the plating.

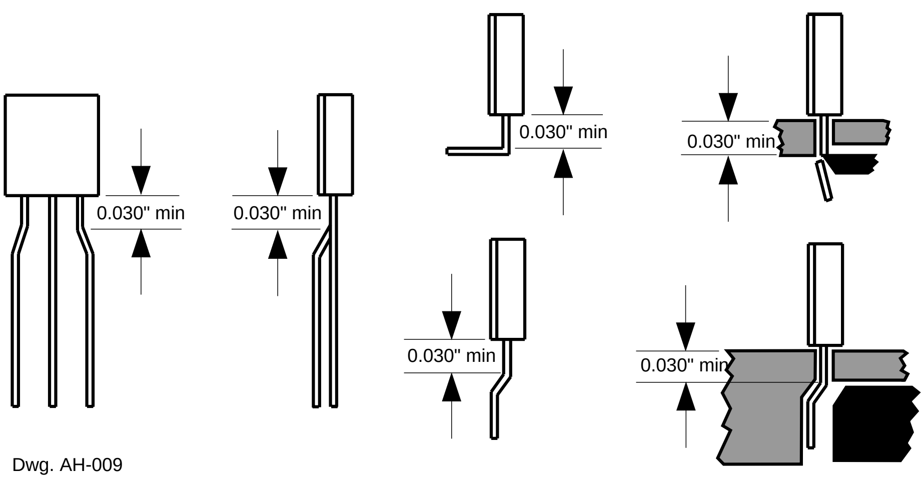

Figure A. Lead-forming operations

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MODULES

Allegro offers a selection of gear-tooth sensors (GTS) as packaged modules. These modules include the Hall sensor, a pole piece, and a magnet as an optimized subassembly (thus avoiding many of the stress-related assembly issues described above) and may include signal-conditioning and protective circuitry.

Allegro recommends that all packages have the leads clamped between the plastic package and the lead form. However, gear-tooth sensors (GTS) assembled in SE, SG, or SH packages can be lead formed against the package (see figure B) without internal damage if the following recommendations are followed:

a) If no clamping of the leads is possible, hold the package (anywhere but over the face of the die) and form the leads using a “paddle form” mechanism (figure B). This type of form will allow bending of the external leads next to the package with minimal disturbance to internal components. Any other subsequent forming of the leads to fit custom applications, should have lead clamping between the package and the formed leads to prevent damage to the plastic package. These packages should not have excessive force exerted against the die surface (front face) when holding the plastic package for lead forming.

b) If possible, leave the molded lead bar attached to ensure lead position. If the application does not lend itself to leaving the lead bar attached, do not remove it until all forming of the leads is complete. This will optimize lead planarity and pitch spacing prior to final use.

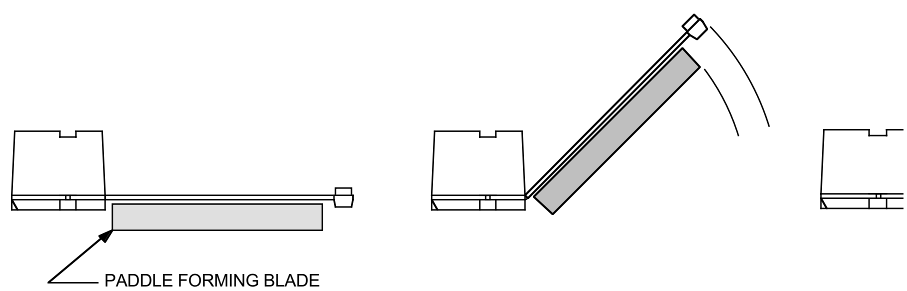

Figure B. GTS lead forming with paddle form

Hall-Effect Devices: Soldering, Gluing, Potting, Encapsulating, and Lead Forming

APPLICATIONS ENGINEERING

Almost any repackaging of a Hall-effect sensor produces some shift in the magnetic parameters. In many cases where this has become a field problem, it has been shown that the selection of device parameters and magnet strength did not allow for minor parametric shifts. In many cases it was not realized that the assemblies were working close to the magnetic limits because testing of the completed assembly over the complete operating temperature range either was not possible, or deemed unnecessary.

New designs need not have problems with magnetic parameter issues. Allegro has available a calibrated linear device (gauss meter) that can be assembled into prototypes of the intended design. The output readings from this device will allow mapping of the magnetic field and the resultant data will indicate which Allegro device type is best suited for the magnetic circuit design.

Allegro MicroSystems maintains an extensive applications laboratory and problems that do occur with finished assemblies can sometimes be solved by a co-operative effort with the customer.

For Applications Assistance

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