"Integrated Package Modules for Power and Sensor Applications"

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Abstract:

A range of modules have been developed that incorporate device interconnections, test capability and direct chip mount for sensor units along with fixed type connector designs. Additionally the need for more power has seen the adaption of connectorised modules to incorporate thermal enhancement. These packaging technologies can now be adapted to suit individual high power chips and sensor devices.

Introduction

Developing technologies continue to demand performance extremes from electronic module designs. Applications for multiple chip packages, power conversion and generation, MEMs devices, Solar, LED and Automotive Interfaces are seeing needs for improved thermal dissipation, resistance to shock and extended environment protection. As requirements become more demanding and raw material costs are increasing the needs to enhance device performance continue to challenge packaging designers and manufacturers.

Both power and sensor modules are now taking advantage of the up and coming Press-Fit interconnection technology that has been widely used in the telecom and industrial markets for over 50 years. Press-Fit allows electronic modules to operate under aggressive environmental conditions, designed to withstand the added rigors of vibration, thermal shock and much higher ampacity requirements. Add to this, more efficient thermal mangement, by integrating conductive metal leadframes of various thicknesses or varied materials ar a combination of these, and the whole package provides a an ideal made to measure solution.

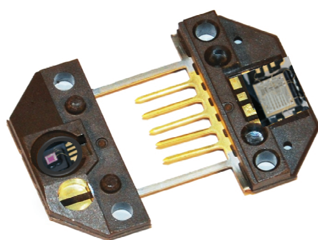

Fig 1 – Mems sensor and ASIC integrated into a cavity package, to allow specialised sealing for Automotive applications

Interconnection

The needs for different methodologies of interconnection have been ever present in the Electronics Industry for many years. A number of methods of male/female pin and socket connections are used by the “connector” industry and are these are well documented. However the development of Sensor parts for Automotve in particular, are seeing the connectors, the boards and the housings all becoming integrated into ‘plug and play’ type modules.

The interconnects, normally soldering between wires, boards and connector pins, are proving to be problematic. Coupled with the need to reduce costs, as well as increase complexity, has laterly also brought into module developments, a hybrid type of system approach, that is particularly needed for sensors and power devices. This is to wirebond devices onto board units and then mount these boards into the housing or to reduce cost and weight, directly wirebond into the module housings, along with the connectors and other components.

The whole process has moved forward at a pace with the need for Lead (Pb) Free connections. However the concerns of outgassing, contamination of sensors elements and the thermal mismatches with new soldering processes has created the demand for solderless connectivity. General methods for such solderless connection are well known. Initially utilised by the connector industry and latterly developed for many applications where a reliable, low cost, quick and easy interconnection is required, the press-fit connection is a key technology for making reliable electronic joints, especially were wiring is involved. The long standing technology of the Insulation displacement connector (IDC) is widely utilised in consumer applications such as telephone sockets, networking and signal connections between parts of an electronic or computer system. When properly made, the connector blade cold-welds to the wire, making a highly reliable gas-tight connection. But for more reliability in non-wired and harsher environments, such as automotive modules, the “Press-Fit” connection, and interference fit style of ‘blade’ connector is the new solution.

Press fit:

Press-Fit Technology has been widely used in the telecom and industrial markets for over 50 years. The Press-Fit Technology available for those markets works well in most non-mobile, controlled environment applications. However, the move to develop electronic modules that operate under aggressive environmental conditions, such as automotive, has created additional challenges that most existing press-fit parts were not designed to withstand. In addition to the added rigors of vibration, thermal shock, etc., press-fits for such applications have much higher ampacity requirements than their telecom counterparts.

The new developed Press-Fit technology allows for the insertion of a specially stamped terminal into a plated-through hole (PTH) in a printed circuit board (PCB) in such a way that an electro-mechanical connection is established without using solder. The press-fit joint is a more permanent connection and needs to generate both the electrical and mechanical connections without the aid of a housing.

Press-Fit technology allows for the insertion of a specially stamped terminal into a PTH in a PCB in such a way that an electro-mechanical connection is established without using solder. This solderless connection functions like the blade and socket pair in a connector, except the genders are reversed. In a traditional blade-and-socket pair, the socket has flexible beams that provide the necessary normal force for an electrical connection and the blade is rigid. In a press-fit joint, the “blade”- called either a compliant pin or a Press-Fit pin – has the flexible beams, and the socket, which is the plated through hole or PTH, remains rigid. (See Figure 2).

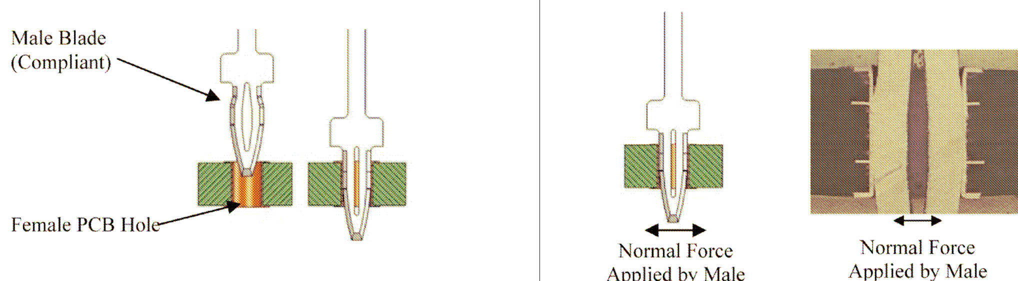

Figure 2: Typical Press-Fit Male/ Female Interconnect

While the press-fit joint and its blade-and-socket cousin both employ a pressure connection, the similarity ends there. The blade-and-socket is intended to be mated and unmated numerous times, so it is designed with lower normal forces. It is also surrounded with an insulative housing that ensures

that the connector stays together during use. The press-fit joint on the other hand, is a more permanent connection and needs to generate both the electrical and mechanical connections without the aid of a housing therefore, its normal forces are much higher.

The development of electronic systems for use in such applications as automotive and transportation equipments requires the units to operate under quite aggressive conditions and severe ambient environments. Technology generally available works well in most controlled environment applications where mobility, vibration and harsh environmental conditions are not encountered. In addition to the added rigors of vibration, thermal shock, etc., the required connections utilising press-fits often have much higher power handling (ampacity) requirements than telecom counterparts. For example, where telecom press-fit pins can be made from material of 0.64mm (.025") thick and less, Press-Fits used in automotive modules are made from 0.64mm (.025") for signal pins and 0.80mm (.032") for power pins. Automotive Press-Fit pins therefore have to be available in a range of materials that offer higher conductive capabilities than telecom pins.

Modules

The growing consumer and regulatory demand for electronically controlled features in Automotive, such as anti-lock brakes, vehicle stability control, navigation, hybrid drive trains, and tyre pressure monitors, coupled with a strong movement to lower costs, has created a significant demand for more and more varied sensor modules and now the new demand is for power modules both in Automotive and in other harsh environments such as Transport systems and renewable Energy system designs. Combining power and sensor parts together is therefore a next step in the developing integration.

To handle power and environmental issues, major developments have been undertaken to ensure that press fit will suit such assemblies and there are several factors that make Press-Fit technology the ideal interconnect component for power modules:

- Press-Fit Technology can reduce or eliminate the need to perform secondary solder operations on PCB assemblies. Not only does this reduce labour and work-in-process, it removes an extra heat cycle that can degrade existing components on the board, and it reduces the amount of solder used in the assembly.

- Press-fit joints are highly reliable. The press-fit joint is not subject to quality problems associated with solder such as cold spots, voids, splatter and cracks.

- Press-Fit parts can be readily customized to enable package designers to meet their envelope and manufacturability targets.

- Material costs can be reduced when compared to pin and socket interconnects.

- The high strength of the press-fit joint eliminates the fretting risk associated with pin and socket interconnects. Precious metals are not required.

- Press-Fit Technology is RoHS compliant

There have been several design upgrades and changes to past Telecom press-fit designs that were needed to move the technology to support harsher environments such as automotive applications. These design upgrades now make press-fit technology more compatible to other industrial and mobile applications where before they hadn't been considered.

Some of these upgrades are:

- Stronger beam designs with increased coining to help with retention but maintain reduced insertion forces.
- Introduction of alloys such as CuNiSi for higher operating temperatures and added conductivity.
- Improved plating for example, thin tin in the press fit sections as well as Ag and SnAg options.

Thermal mangement

Where ceramic packages are constrained to use a metal base CTE matched to the Ceramic, injection molded plastic packages can use inexpensive copper as an alternative to more expensive CTE matched metals or composites. The advantages of using a thin metal alloy leadframe enables the ability to form 3 dimensional structures to be overmolded and allow various metal finishes to suit wirebonds, solder or hard connector interfaces. The Copper alloys used in leadframes, meet most applications requiring good thermal management (High thermal conductivity) however the CTE mismatch to Silicon,Compound Semiconductors, Glass and other materials utilised in Sensor devices is perceived the more critical factor. The choice between CTE match and thermal conductivity will govern the material selelction.

The move to high power devices for Automotive electric vehicles is changing many aspects of the packages, no less the heat sink. The choice of AlSiC for the substrate is now becoming popular especially for Power devices. However, integrating such a base into a module is a novel process but the capability to change the substrate to match different materials, without having to change the footprint of the device, the size or the position of the interconnection leads offers a new dimension for the system designer. A new approach has been developed that allows a preformed heatsink to be “dropped in“ to the molding process, providing an isolated thermal pad. This approach can provide an ideal solution for the device yet keep costs down particularly in the development and pre-production cycles (see figure 3).

Module development

The automotive market has settled on two PTH sizes to be used in press-fit joints. These are Ø1.016mm (Ø.040”) for 0.64mm thick signal pins, and Ø1.486mm (Ø.0585”) for 0.81mm thick power pins. There is general agreement as to how these holes should be constructed and toleranced. While the tolerances are fairly tight from the PCB manufacturer’s viewpoint, they are large from the viewpoint of the Press-Fit pin designer. The (half) tolerance of the finished hole diameter is nearly as large as the nominal deflection of the pin’s active feature, or “beam”. The beam’s geometry, its deflection, and its composition determine the pin’s insertion force (I/F) and to a large extent, its retention force (R/F) for a given hole.

Another factor in the design of Press-Fit pins is plating. Although a conventional tin over nickel is sufficient for most applications, the tin must be kept thinner than typical in the press-fit area to keep it from scraping off and creating a possible conductive particle hazard when the pin is inserted into the PCB.

Figure 3: A fully featured Integrated package test module with isolated thermal mangement pad.

The test module has been developed (by Interplex) as shown in figure 3, to provide a module that has all of the necessary features for a typical Automotive system unit. The terminal materials are of a copper base alloy with a base plating of Matte-Tin over Nickel and have been tested and are compatible with PCB finishes with PTH in Immersion Tin & Immersion Silver finishes. For these, the minimum PCB thickness tested was 1.57mm (.062”).

Matching the outer plating on the press-fit terminal to the plating on the PCB hole, for example tin to tin or silver to silver also helps to enhance that retention force of the pin to the PCB hole. This is due to the creation of a cold weld that occurs between similar materials resulting from the high force of the press-fit interconnect.

Applications

A key application for an integrated package module is to combine a sensor housing and a control chip into the same housing as in Figure1. Developing this strategy further as as system module, Power management, switches, junction boxes and other electronic assemblies can be included. These may have several PCB's that need to be connected together within one assembly. In most cases the final interconnect between these two PCB's would include some type of hand or customized automated soldering operation. A press-Fit can be designed in sections so that multiple parts can be incorporated in each of the sections. The PCBs can be placed to allow for a solderless PCB to PCB interconnect. Alternativlely (See figure 3 and 4), the Press-Fit Terminals can either be a direct insert type of terminal or, as detailed, integrated into the connector housing or embodied into the header assembly. Aditionally, power control can be wirebonded, or otherwise coupled directly to heat sinks which can be built in, solderbearing leads can be utilised or whole assemblies can be integrated using flex circuits.

Figure 4 – Multiple interconnection processes for application specific sensor housings

The input / output requirements in these assemblies still have a very high pin count, typically from 44 up to 72 plus interconnect positions. With the assemblies shrinking in size designers are using some very high density multilayer PCB's with very small surface mount (SMT) components on both sides of the PCB. After the electronics is assembled it is very difficult to introduce the additional heat needed for soldering the I/O interconnect without damage to the assembly. Press-Fit technology allows the interconnect to be pressed in to the assembly without an additional heat cycle.

Many Sensor systems

For transport systems, the move is to smaller power modules. However the power handling required determines the need for a range of heatsink pads that can have power IC devices, such as IGBT chips wirebonded into the units and provide the connections between power circuits and control circuits. Here (see figure 5), 2 leadframes of different materials (Copper and Aluminium inlay) are utilised to provide the interconnections and heat sinking. Devices are mounted and multi-wire bonded before silicone sealing and lidding.

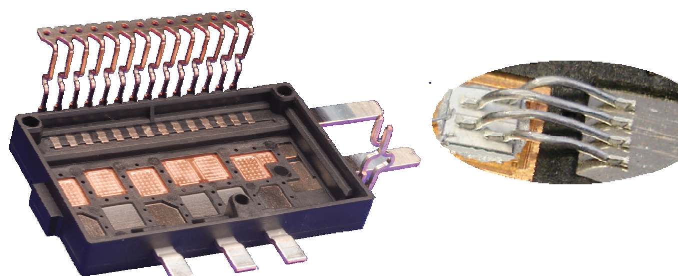

Figure 5 – *A power module integrating a multi-frame approach for wirebond capability*

In automotive, a design of engine and transmission (power) controller module has been designed that benefits from these approaches (see figure 6). It involves the incorporation of press-fits to interconnect the pre-assembled controller circuit board to a power control device and to the input/output connector system. The power device is bonded to the heat sink and interconnection after the assembly of the connectors into the plastic molding. The PCB is then inserted as the last peration before sealing and lidding the module. These types of modules, especially in vehicles, enable rapid interchange at the same time dramatically increasing functionality but also shrinking physical size.

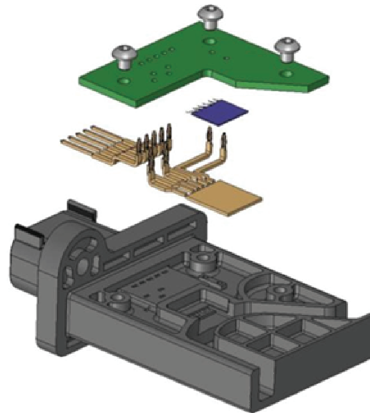

Figure 6 – Housing design process – combining press fit assembly parts together with integrated system controls,MEMS Sensors and Power Mangement.

Conclusion

Although the development of various connector technologies has been driven by Automotive applications [1] it is clear that the future needs of electronic systems utilised can benefit from the development of this more integrated approach to system module housing. There is an urgent need to develop higher efficiency motor and power controllers for transport systems, invertor modules in renewable energy systems and wireless modules for telecomm systems that will meet the needs of higher temperature excursions, higher power handling capacity and long term reliability. The inclusion of sensor components into the housings will provide added levels of performance by offering ‘fit for purpose‘ modules. With added freatures of Press-Fit interconnects the reliability and high level interconnect capability is also extended, enabling the system designers and the module manufacturers to meet the needs of the operating environments that such applications demand. These smaller, more compact, integrated connector package modules now meet or exceed the reliability requirements and also provide cost reductions in the manufacturing processes. The technology also extends the life of products and enables the adoption of “design for dis-assembly” engineering, the next step in ensuring a more eco-friendly, reusable, recyclable interconnect.

References

[1] Interplex Industries Inc. Application note – Automotive Products – Press-Fit InterconnectTechnology. Rev. L