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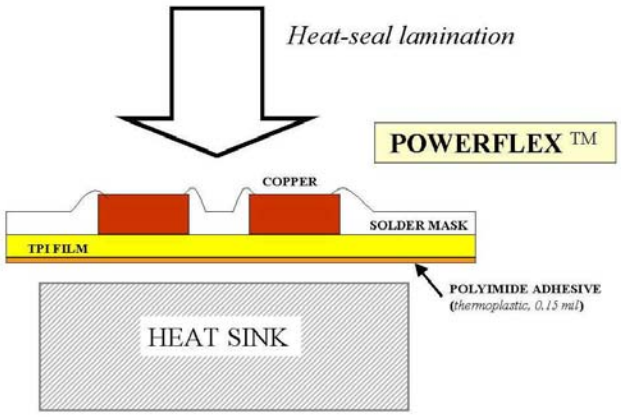
PowerFlex™ : Thermal management with printed circuits

PowerFlex (*patents pending*) -- a flexible printed circuit based on our TPI film, laminated by heat-seal bonding directly to an aluminum heat sink -- offers an electronic packaging technology that utilizes conventional circuit processing and provides excellent thermal management.



The Kapton* MT substrate and thin coating of polyimide adhesive of the proprietary TPI bond film yield a construction where the copper conductors are bonded within about 1.3 mils of the heat sink (thermal impedance of about 0.1°C-in^2/W), while providing over 4000v dielectric strength.

The illustration below shows examples of PowerFlex applications (finned and walled heat sinks with the bonded TPI printed circuits):

PowerFlex Advantages	
Features	**Benefits**
Any printed circuit configuration on any heat sink (*within reason*):	• Optimized manufacturing: *Circuits made by PCB mfgr, heat sinks made by metal mfgr*
⇨ Circuits can be heat-sealed to heat sinks at OEM (or subcontractor)	• Manufacturing flexibility • Tailored product offering: *Different heat sinks for same circuitry* • Cost savings
⇨ Circuit footprint SMALLER than heat sink	• Lower cost: *Don't pay for circuit area that you don't need*
⇨ Circuit footprint LARGER than heat sink	• Electronic components and connections beyond the heat sink plane
⇨ No baseplate-to-heat sink interface possible	• Enhanced thermal transfer to ambient --*higher power output possible*-- with no attachment hardware required
Conventional materials for circuitry and heat sink (*in addition to TPI bond film*)	• Lower cost • Enhanced supply options
Conventional manufacturing processes	• Lower cost
Excellent thermal transfer	• Resistance = 0.1°C-in^2/W across the TPI bond film (*for single-layer design; multilayer designs will have higher thermal resistance*)
Physically-robust Kapton* dielectric insulation	• All-polyimide durability • >4000V dielectric strength • No cracking • No handling issues

Why PowerFlex™ technology?

- ***Higher thermal transfer*** *than conventional mounting methods of flexible and rigid printed circuit boards to heat sinks* ***at comparable cost.*** The thermal resistance of a PowerFlex construction (from the heat-producing electronic components and conductors on the circuit board to the heat sink) is a fraction of the thermal resistance of conventional circuit board mounting methods, which include various tapes and adhesive sheets. Better thermal transfer can provide the following performance advantages:
  - ⇨ lower electronic component temperatures (increasing reliability),
  - ⇨ reduction in component and/or heat sink rating and cost (less-expensive devices and/or heat sinks can be used),
  - ⇨ increase in output from same system (ex., more Watt output from same power supply unit).

- ***Elimination of assembly hardware*** – the PowerFlex printed circuit construction is bonded directly to the heat sink with the 4-micron-thick, thermally-activated polyimide adhesive on the TPI film. In many applications, printed circuit boards are merely pressed against heat sinks with electrically-insulating and thermally-conductive interface material between the PCB and the metal heat sink. Insulated metal substrate (IMS) and direct-bond copper ceramic (DBC) constructions also often need to be mechanically-attached to a heat sink. In addition, a thermally-conductive interface material is required between the IMS or DBC and the heat sink.

- ***Higher thermal transfer*** *than more-expensive IMS and DBC constructions in many applications*. The PowerFlex printed circuit can be bonded directly to the heat sink -- the thermal interface resistance resulting from the mechanical attachment of the IMS and DBC to the heat sink is eliminated.

- ***Lower cost than IMS and DBC constructions***. IMS and DBC use expensive materials and processes that have limited availability. PowerFlex uses conventional printed circuit processes that are widely-available.

- ***Greater design flexibility than IMS and DBC constructions***. Both IMS and DBC technologies are based on flat plates, requiring all circuitry and components to be on one plane only. Circuitry can only extend to the edge of the planar substrate (metal sheet in IMS, ceramic wafer in DBC). Adding multiple conductor layers is an expensive process in both IMS and DBC. DBC is also very brittle and has a limited process size (maximum of 4" x 4"). PowerFlex has significant design advantages over IMS and DBC in that it can produce thermal management assemblies that:
  - ⇨ are physically flexible (plastic film dielectric),
  - ⇨ can be bonded directly to practically any shape or size or material type heat sink (assuming that the heat sink can withstand the lamination process),
  - ⇨ allow circuitry to extend past the edge of the heat sink (perhaps connecting to other subassemblies),
  - ⇨ use conventional circuit processing equipment and materials,
  - ⇨ are physically robust ('unbrittle' plastic film dielectric and metal heat sink), and
  - ⇨ can be made into literally any dimension (width or length).

APPLICATION NOTES:

- **Heat-seal lamination with TPI's thermoplastic polyimide adhesive** – bonding the PowerFlex circuit to the heat sink is done in a hot platen press and is a two-step process run at 250-300°C. Total cycle time of 1-3 minutes, depending on the construction. The first process step at low pressure brings the assembly up to temperature and drives out moisture; the second step at high pressure bonds the circuit to the heat sink.
- **Single-layer PowerFlex circuits use TPI bond film for the circuit substrate** – copper foil is pre-bonded to the top surface, for printing and etching.
- **Multi-layer PowerFlex circuits can use commercially-available double-sided laminates**, such as Pyralux* AP or thin FR4 (2-5 mil). TPI bond film is laminated to the finished panel after print-and-etching and soldermask addition.
- **In multi-layer constructions, plated-thru hole thermal vias are critical** to ensure thermal transfer to the TPI bond film.
- **The quality of the heat sink surface is critical** to ensure good bonding between the PowerFlex circuit and the sink. Anodization or chromate coating of the heat sink is recommended.
  (NOTE: *A very thin primer coating on the heat sink –less than 0.5 micron-- can ensure surface bondability and lower bond temperature. Contact Fraivillig Technologies for details*.)
- **The heat sink will require special fixturing** for the heat-seal lamination of the PowerFlex circuit.
- **The heat sink must withstand the lamination process** – high temperature and pressure.
- **Capacitance between circuit conductors and the heat sink** (or between non-connected conductors) is an excellent way to monitor PowerFlex-to-heat sink bonding.
- **PowerFlex technology can be used in demanding thermal applications in power supplies, motion control, motor control and automotive.**

TPI bond film properties (130TPI-2**)**

Property	Value	Method
Thickness	1.3 mil (0.033mm)	ASTM D374
Voltage breakdown	>4000 Vac	ASTM D149
Thermal impedance	$0.1^{o}C\text{-}in^{2}/W$	ASTM D5470-95 (Laminate of TPI, copper, solder)
Thermal resistance	TO-220 = 2.7 °C/W TO-247 = 0.7 °C/W	Rj-s (using Anatech)
Tensile strength (TPI bond)	600 psi at 25 °C 200 psi at 150 °C	ASTM D412
Shear strength (TPI bond)	4000 psi at 25 °C 2000 psi at 150 °C	ASTM D412
Operating range	-65 to 150 °C	
Flammability	V-0	Recognized