DC-DC变换器的集成与封装技术

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1896

目录

- 什么是集成和封装
- 集成技术研究的意义
- DC-DC变换器的集成和封装
- POL变换器的集成和封装
- 总结

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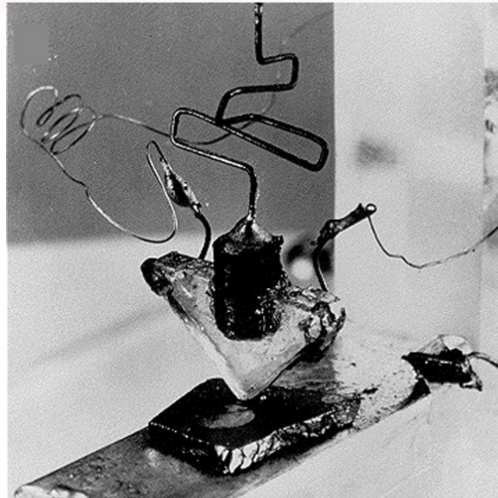
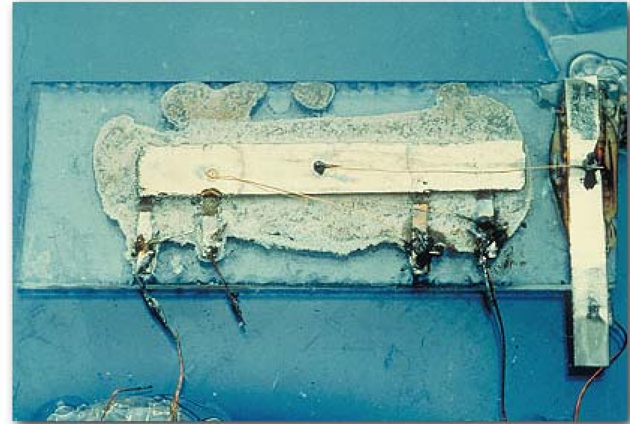
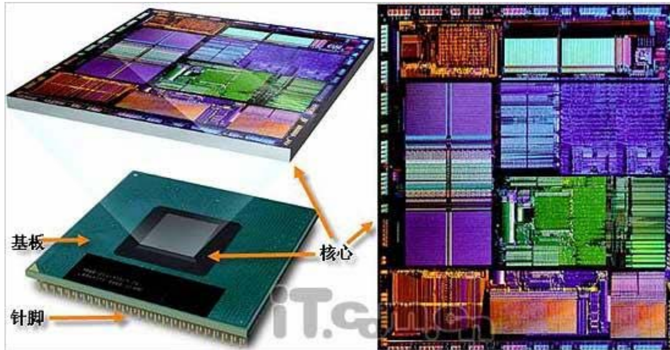
什么是集成



First Transistor
invented in 1947

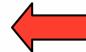


Jack Kilby's first working integrated circuit, tested on September 12, 1958,



现代的微处理器

晶体管数～10亿



小规模集成电路

晶体管数<100

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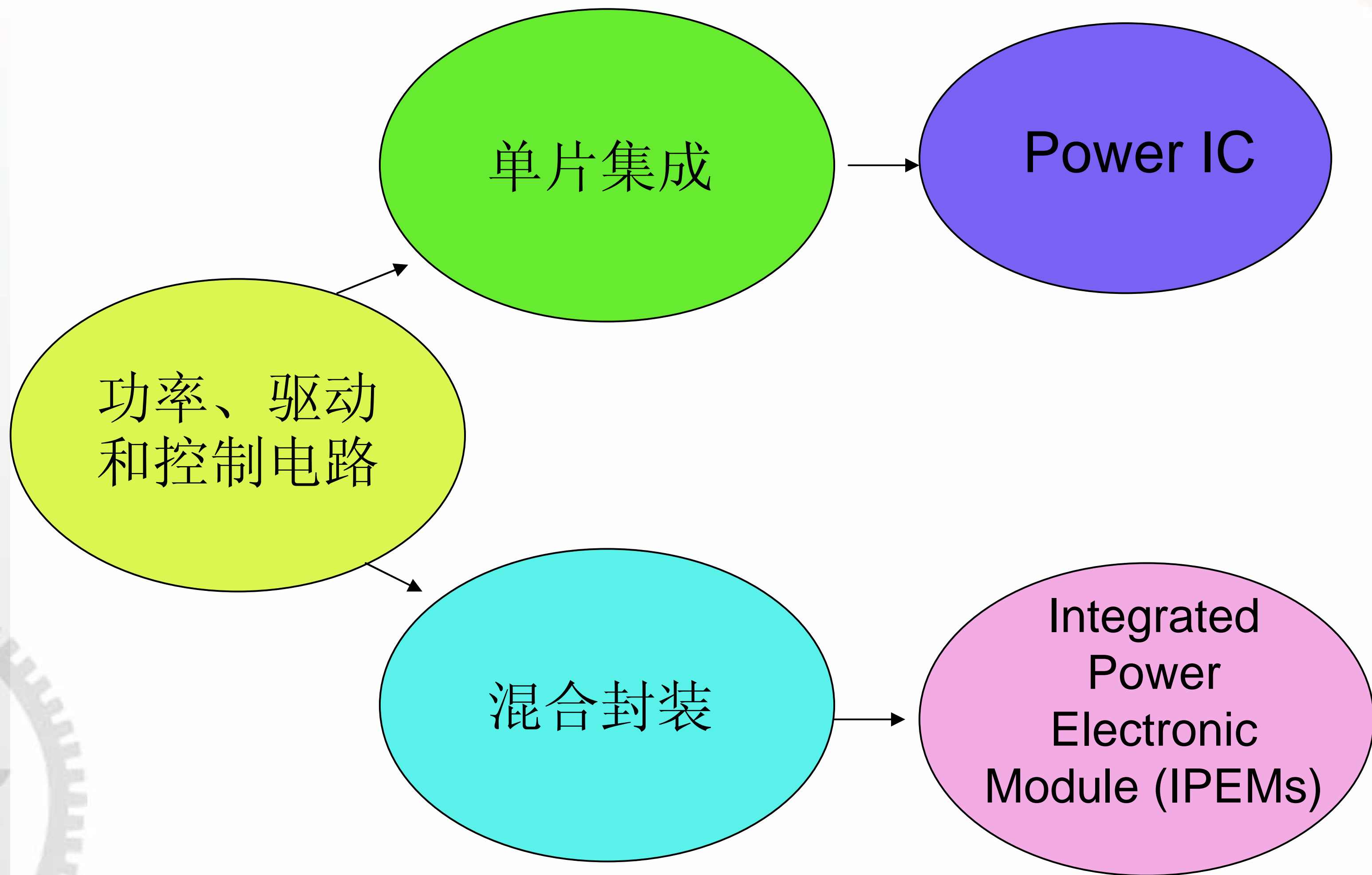
集成化的2种不同方法



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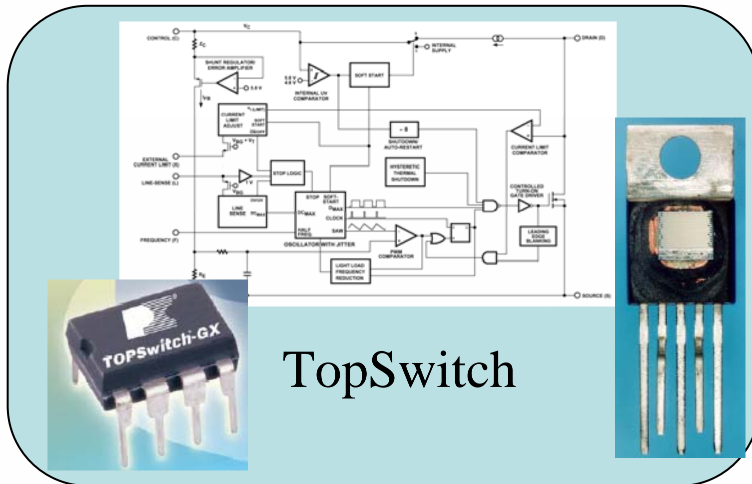
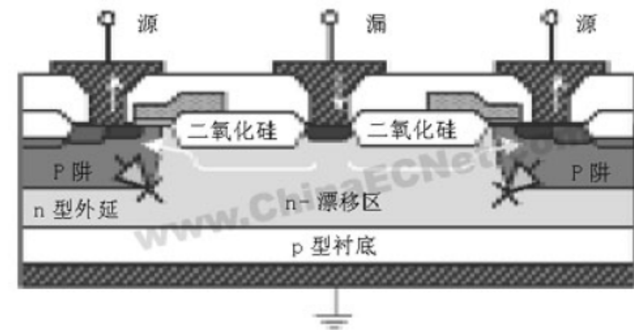
单片集成

- 举例
  - (Monolithic Integration)
  - 主要利用半导体加工工艺





Lateral Diffusion MOSFET

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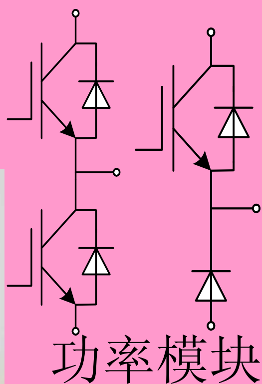
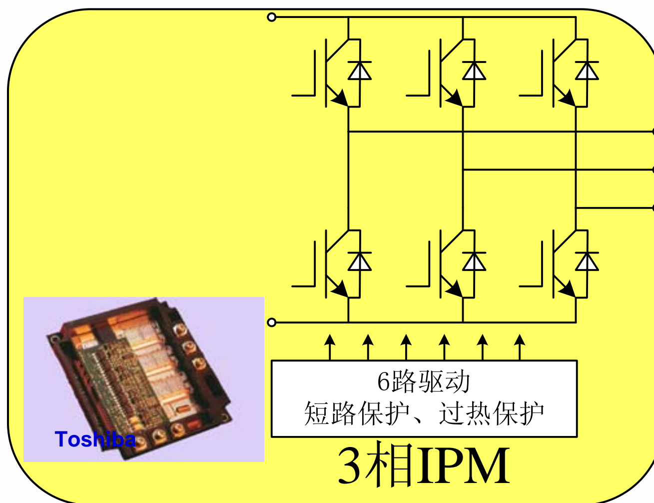
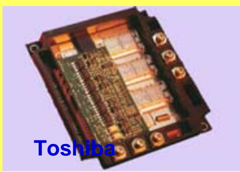
混合集成

– 混合集成 (Hybrid Integration)
– 主要的技术手段是封装

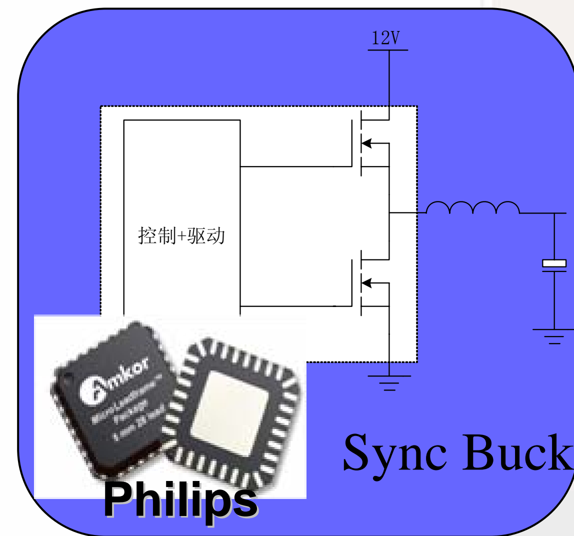


功率模块





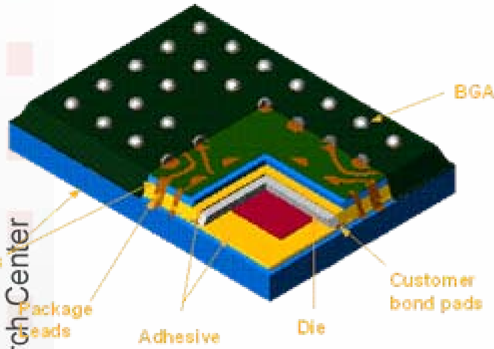
3相IPM

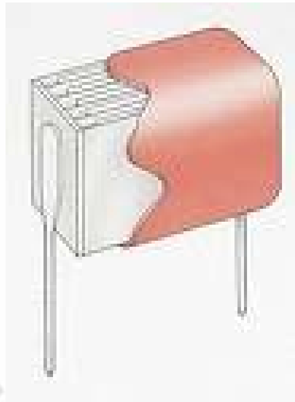


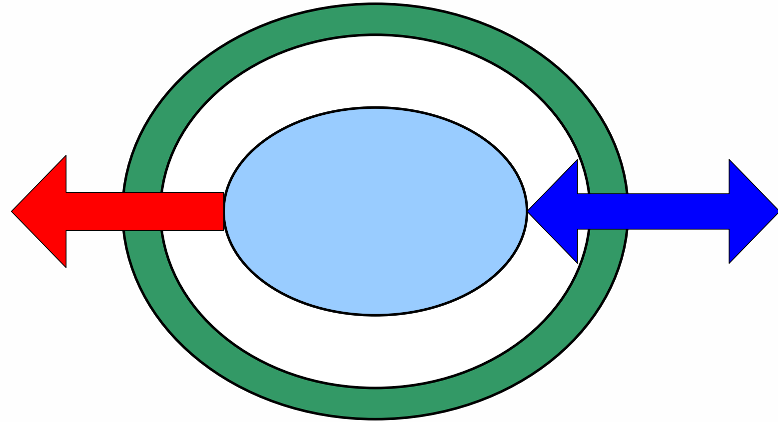
Philips

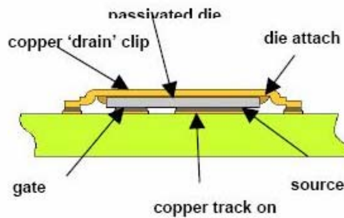
Sync Buck

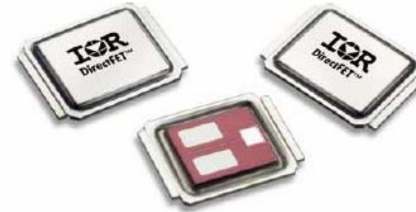
什么是封装



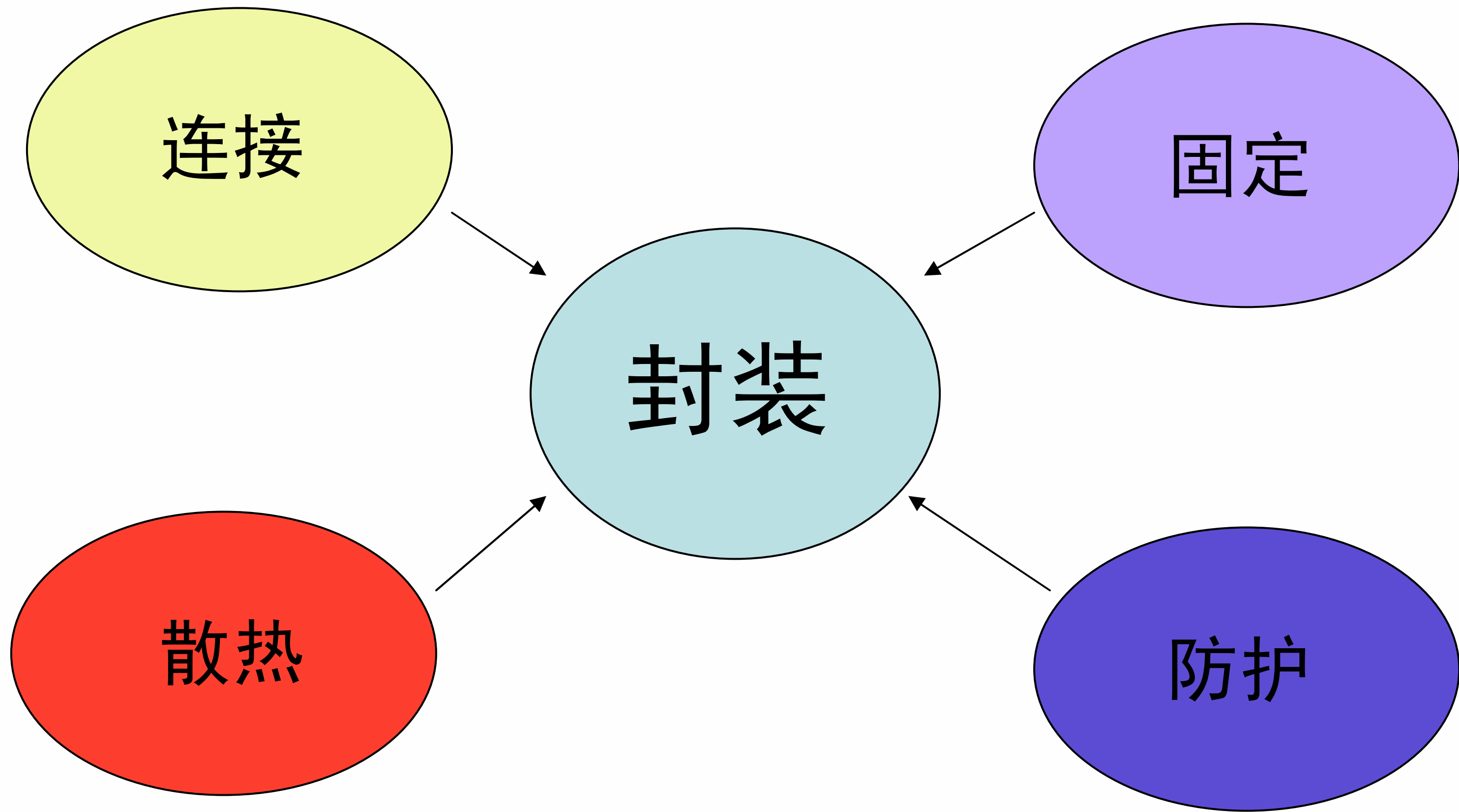








封装的功能



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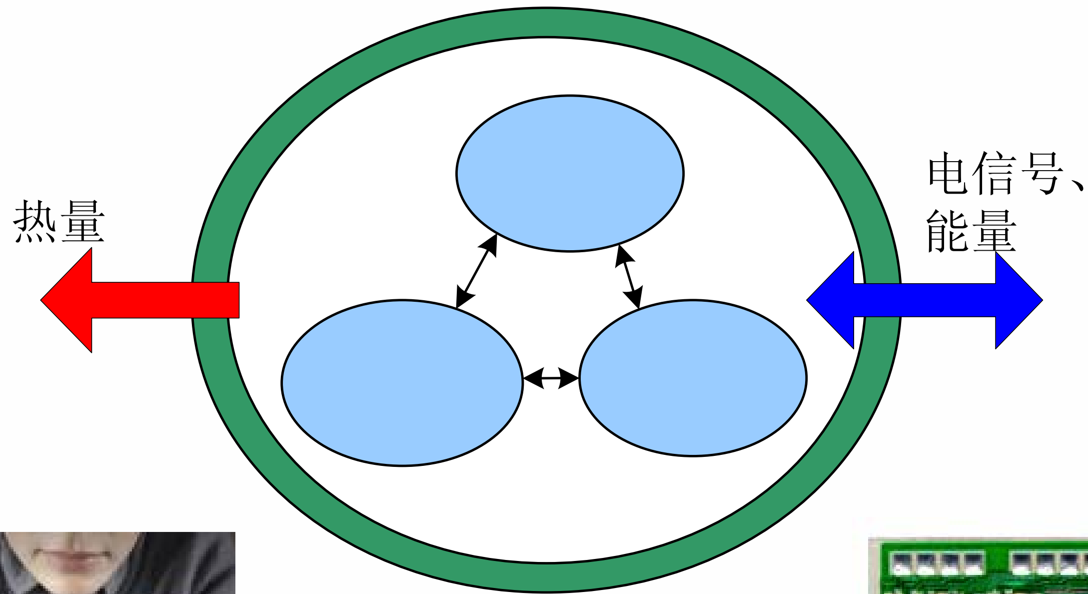
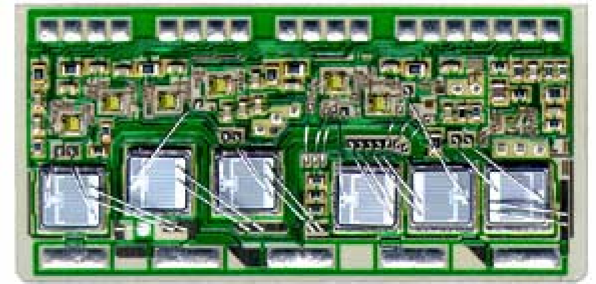
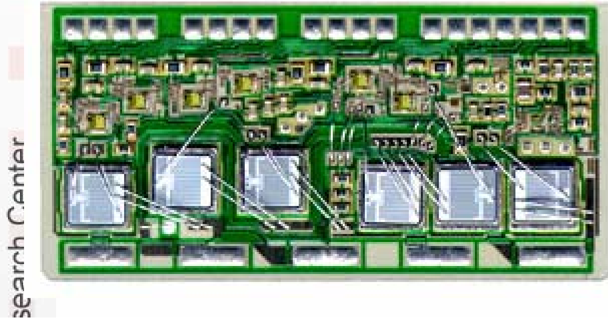
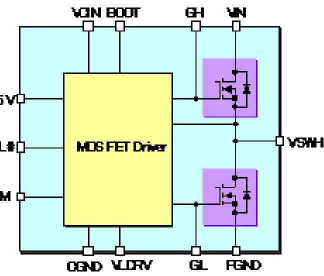
用封装实现集成—多元件的混合封装

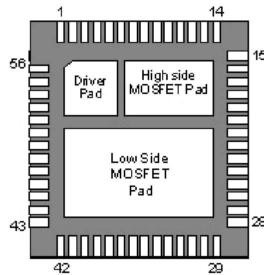


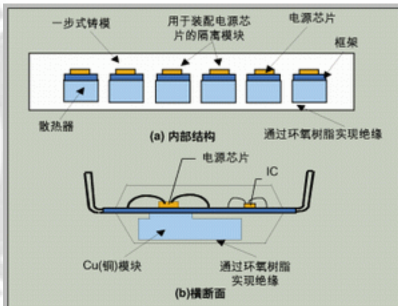


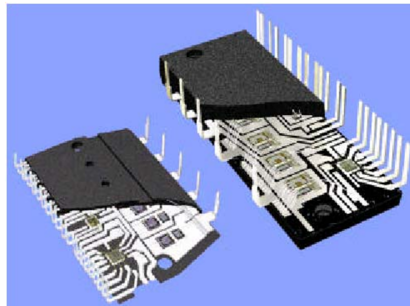
芯片为主的封装







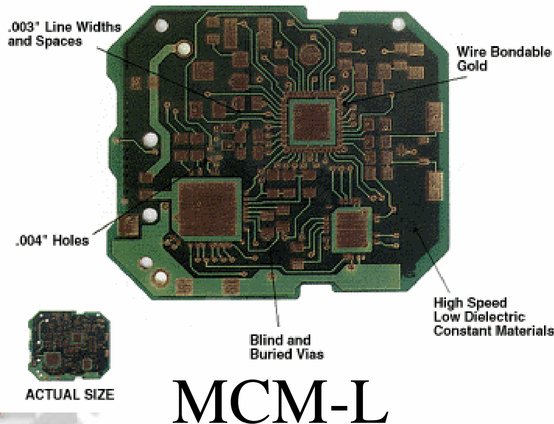




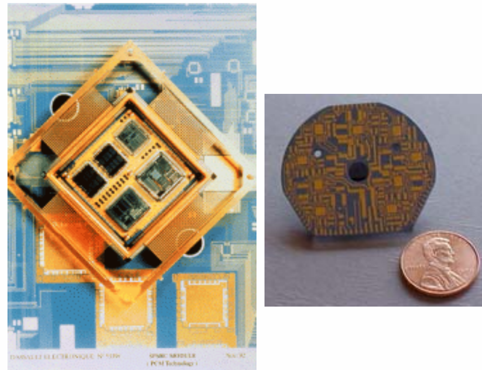
- 主要的问题
  - 芯片间的互连
  - 散热
  - 寄生参数
  - …

主要的工艺手段

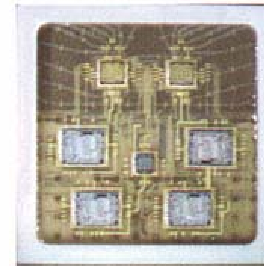
- MCM 技术
  - MCM-L (Layered / laminated)
  - MCM-C (Ceramics)
  - MCM-D (deposited thin film)

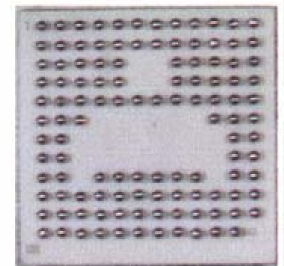


MCM-L



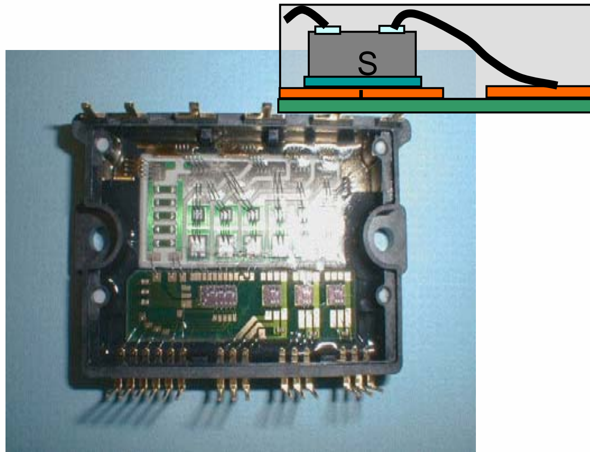
MCM-C



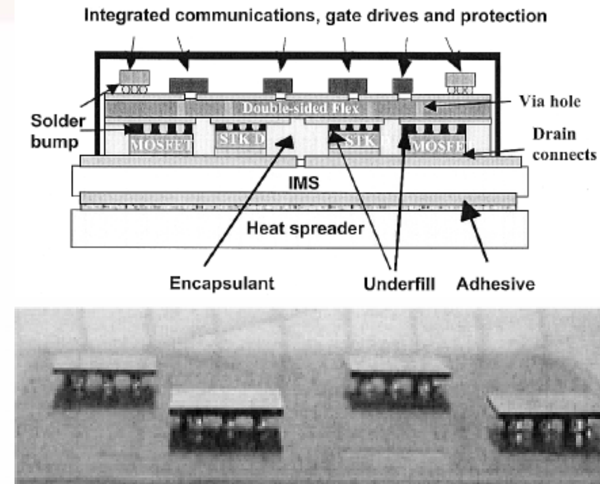


MCM-D

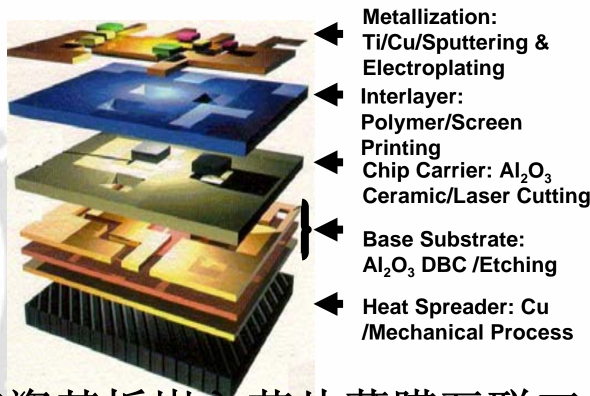
电力电子中采用的MCM技术



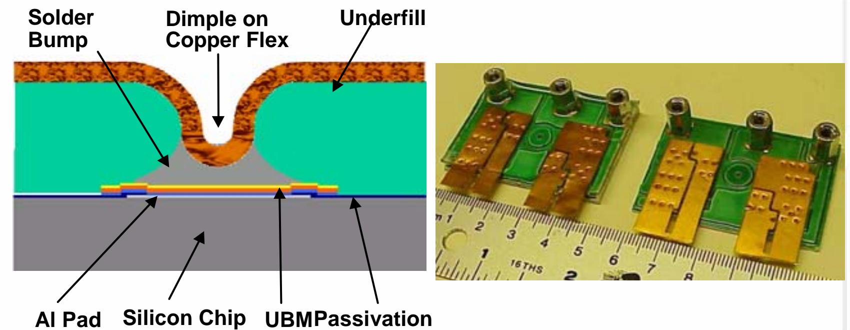
铝基板和DBC基板上的铝丝压焊工艺 (Wire-bond)



焊球工艺
(Solder Bump)



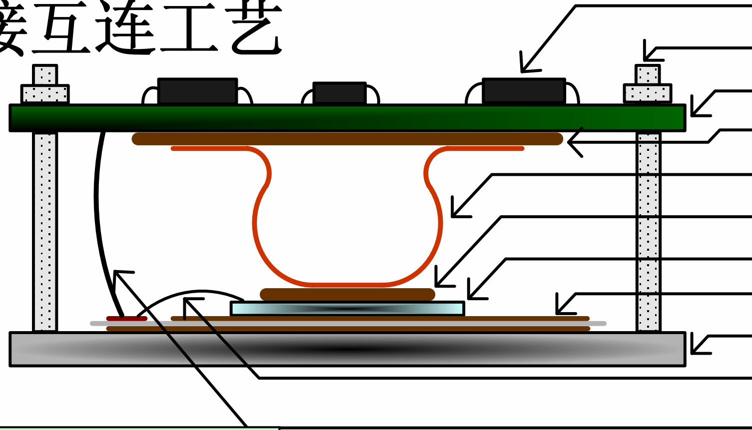
陶瓷基板嵌入芯片薄膜互联工艺
(Embedded Power)

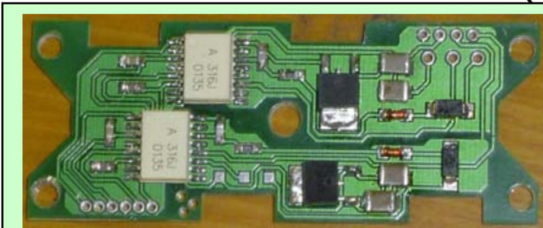


改进的焊球工艺
(Dimple)

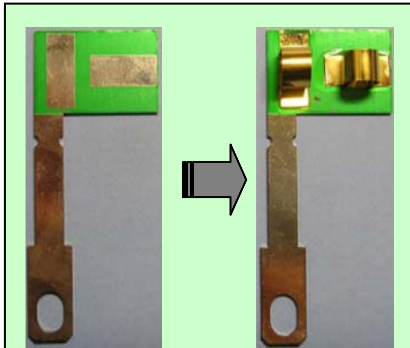
电力电子中采用的MCM技术

- 簧片压接互连工艺

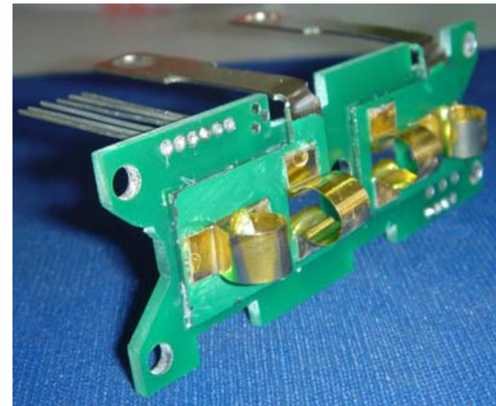




PCB正面制作驱动保护电路

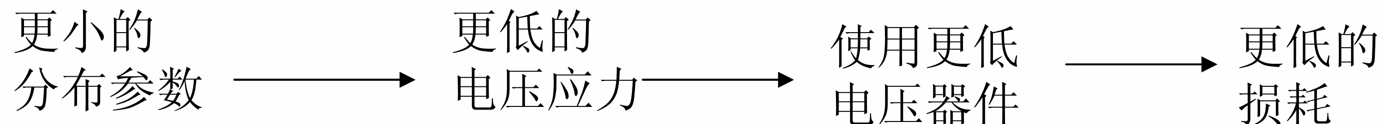


焊压接簧片



芯片为主的封装

- 评价
  - 有源分立器件的封装密度越来越高，功能部分占总体积比例接近1。
    - CSP, DirectFET, LFPack…
  - 有源部分占整个变流器的体积比例越来越小。
  - 单纯的有源部分进行封装对于提高功率密度的贡献越来越小。
  - 但高性能封装对于性能的改善仍然是值得关注的。



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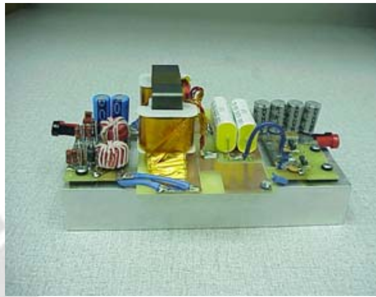
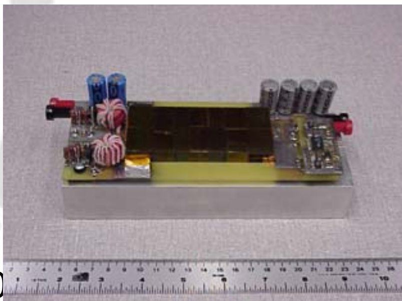
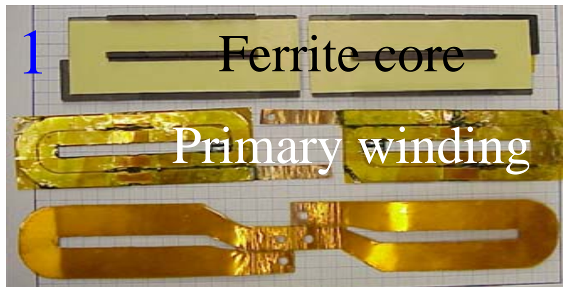
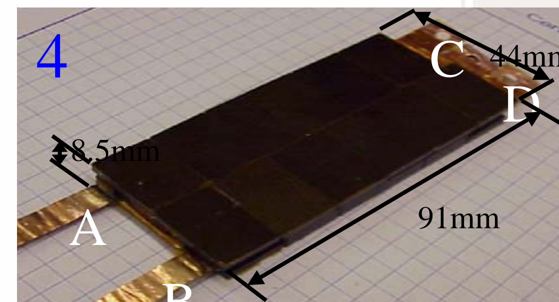
无源元件为主的封装

- 主要问题
  - 功率密度的问题
  - 场的设计
  - 空间利用率
  - …



采用平面磁件的LCT集成

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无源元件为主的封装

- 评价
  - 单纯的无源元件集成和封装对于整个变流器的封装密度改进有限
    - 形状的问题
    - 散热的问题
    - 与其它部分的互联问题。

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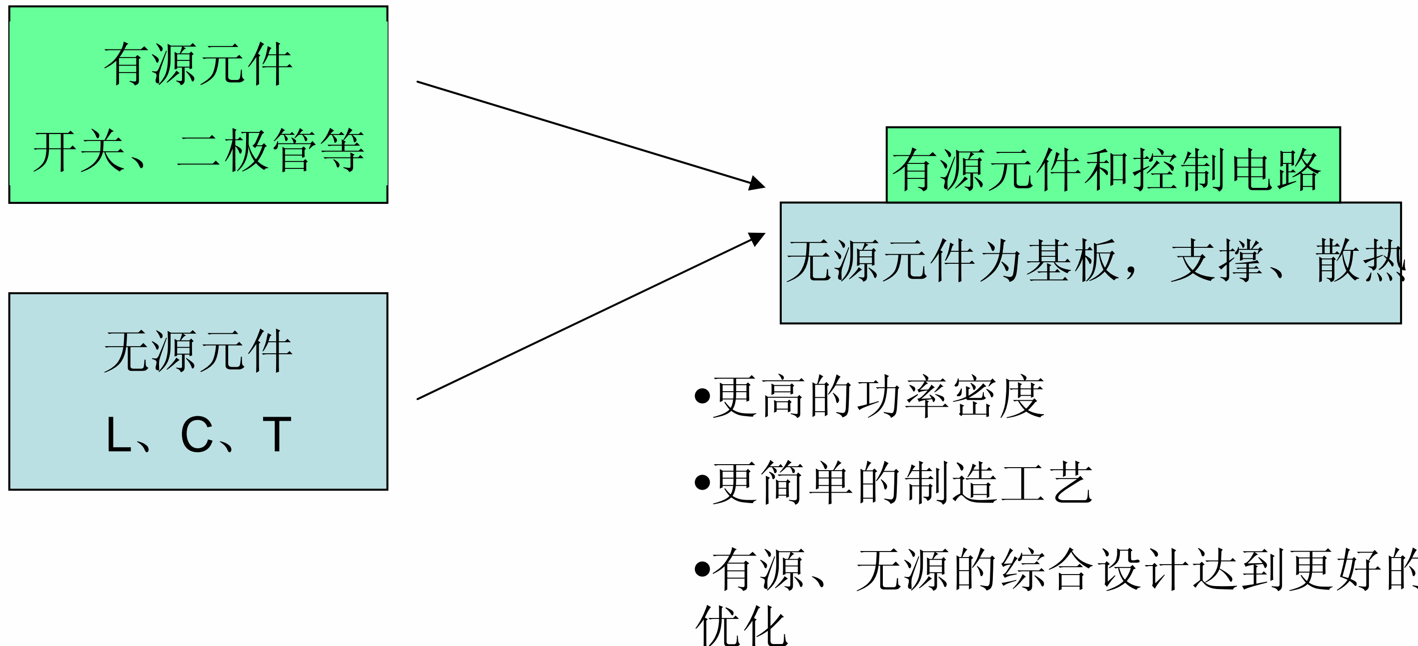
有源无源混合封装

- 将变流器看作一个整体来考虑封装和集成的问题。
  - 无源和有源的关系



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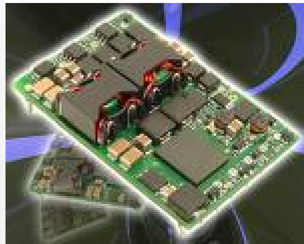
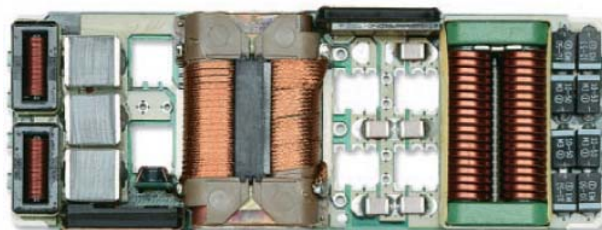
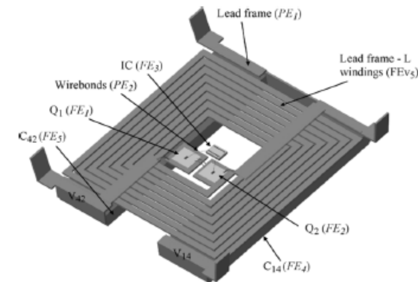
DC-DC模块的封装

- 根据基板材料分类







PCB基板

- 成本低
- 容易实现多层布线
- 安装密度高
- 传热特性差

绝缘金属基板(IMS)

- 传热稍好
- 成本适中
- 不易多层布线
- 寄生电容大

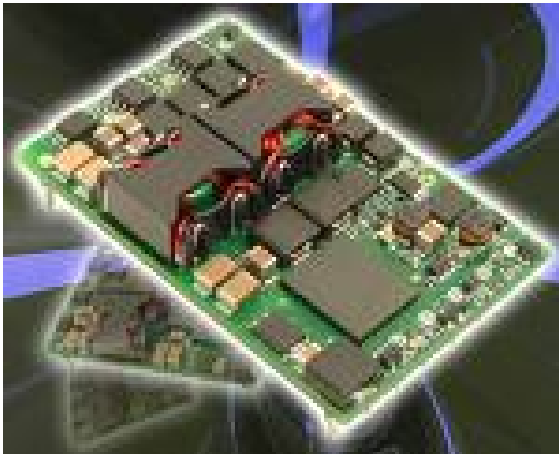
陶瓷基板

- 传热好
- 成本高
- 不易多层布线

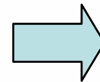
无基板

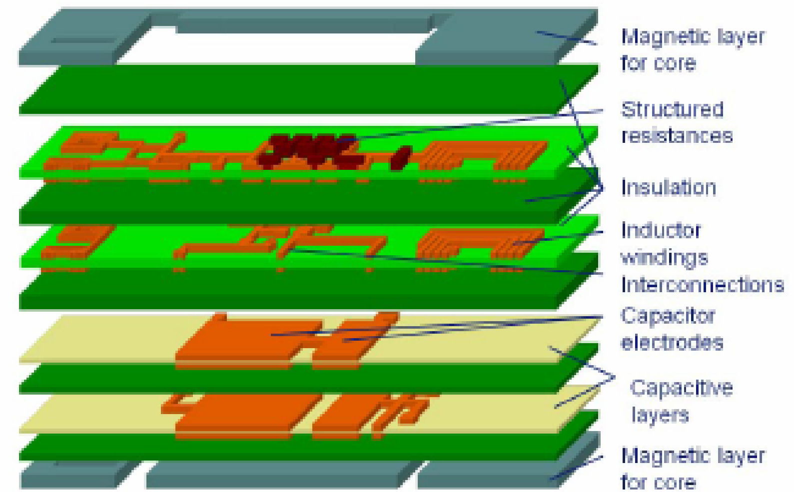
- 成本低
- 仅能简单布线
- 仅适合非隔离电路

采用PCB基板的集成化



分立元件组装



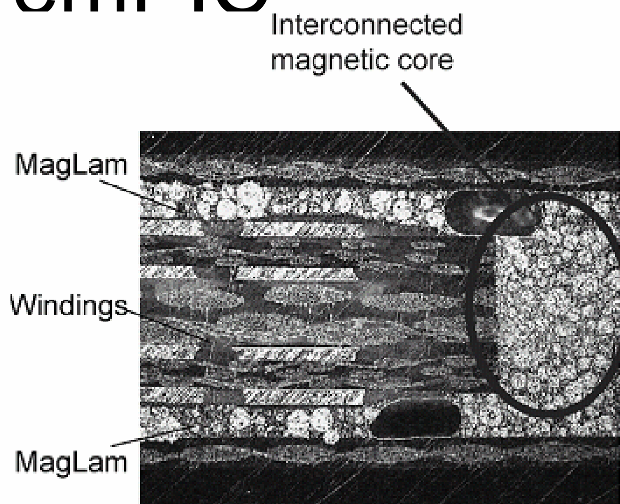


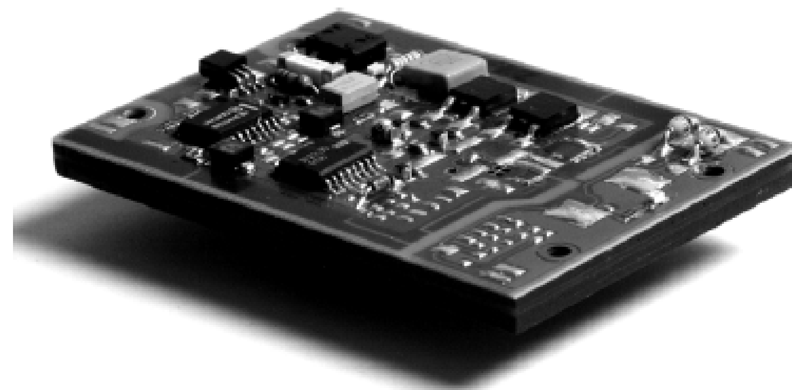
集成化PCB基板

- 基本的思想是无源元件通过PCB工艺进行一体化封装。

采用PCB基板的集成化

- emPIC





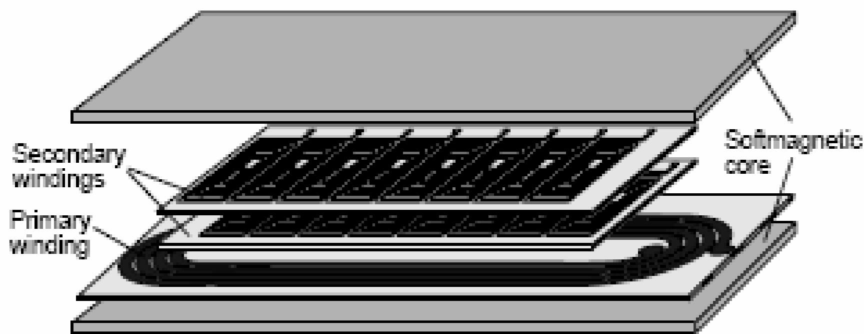


Figure 4: PCB integrated transformer with 16 isolated secondary windings side by side.
a) Top view of the windings. b) Perspective view.

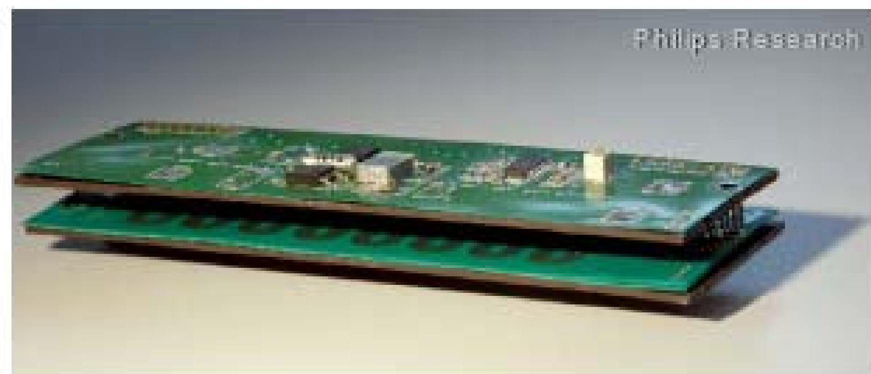


Figure 2: Converter with printed circuit board integrated transformer for 16 galvanically isolated outputs.

Eberhard Waffenschmidt* and Joep Jacobs Philips Research, Aachen, Germany **Planar Resonant Multi-Output Transformer for Printed Circuit Board Integration**

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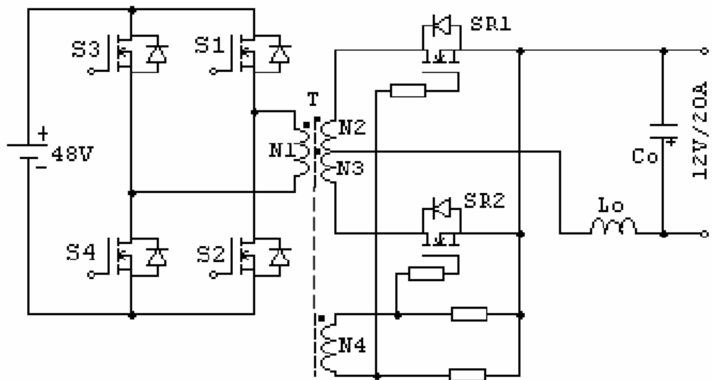
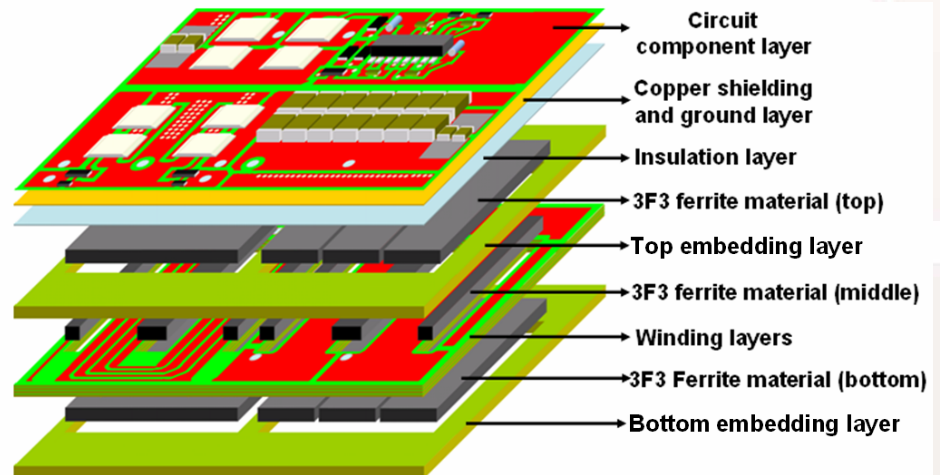
采用PCB基板的集成化

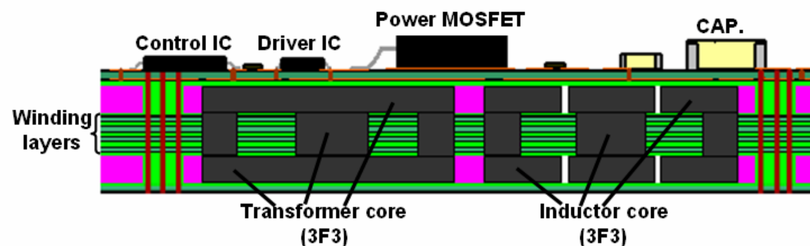
- PCB板内嵌入磁体。



a) 所采用的电路

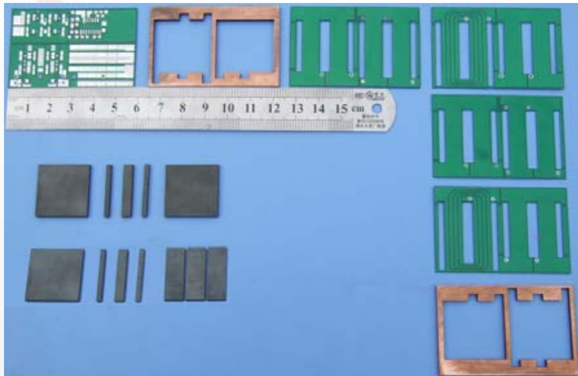


c) 无源集成模块的分解示意图

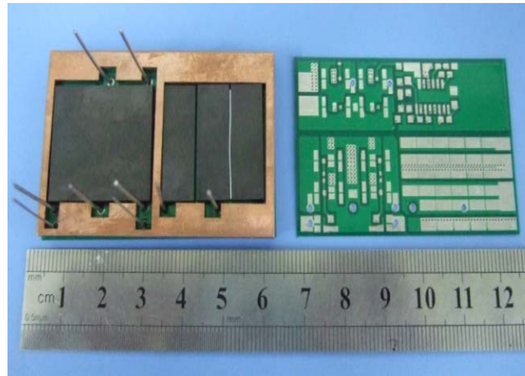


b) 无源集成模块截面结构图

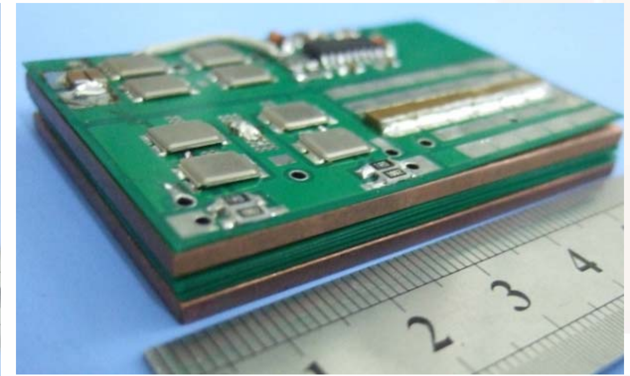
采用PCB基板的集成化



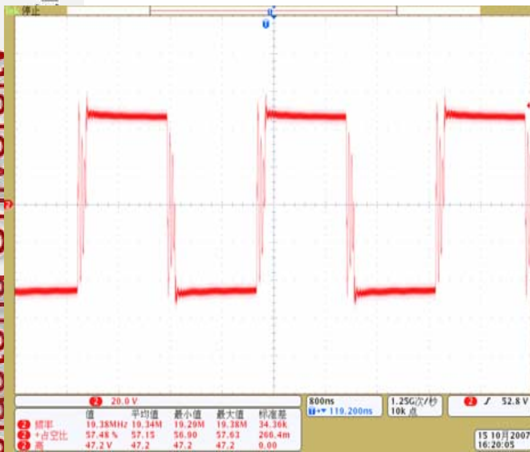
零件分解



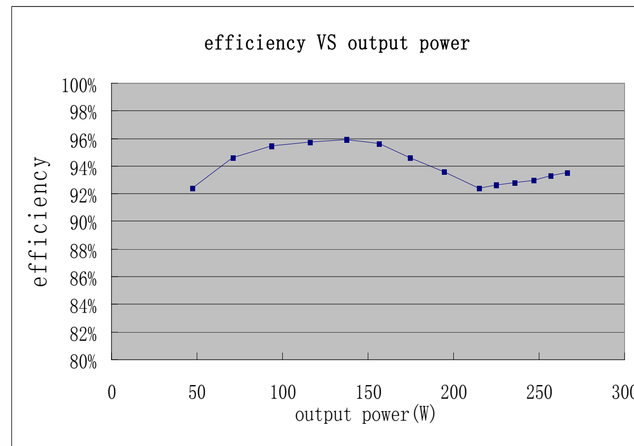
嵌入磁体组装



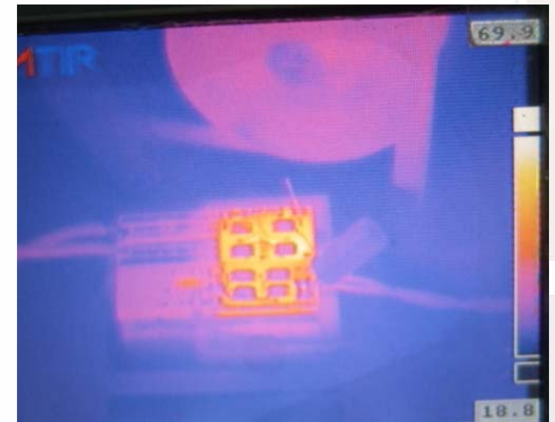
组装好的模块



电路中的波形



效率曲线



工作时的红外热像

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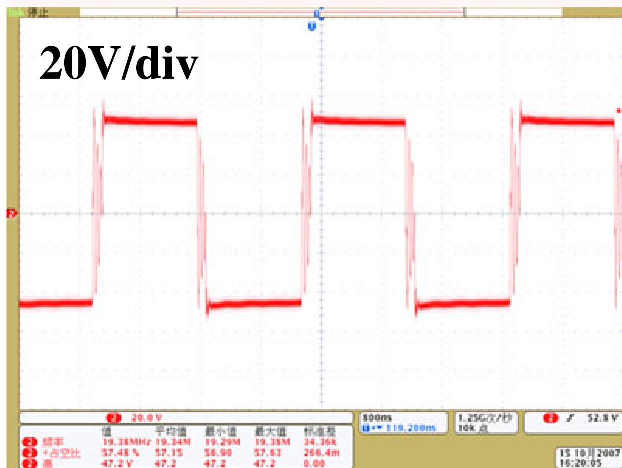
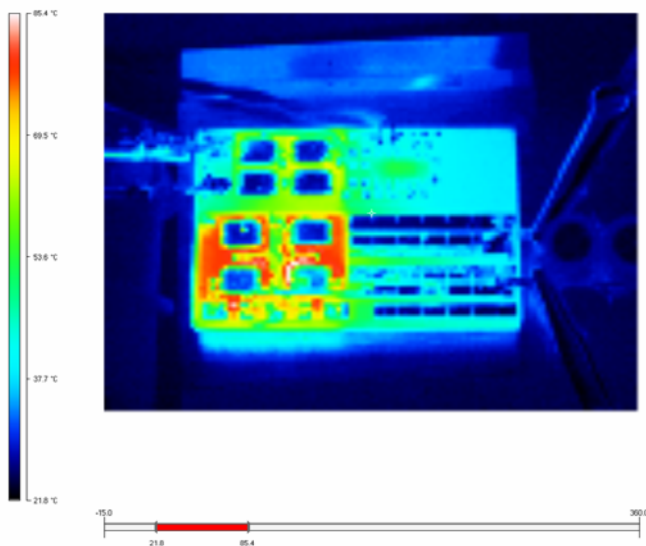
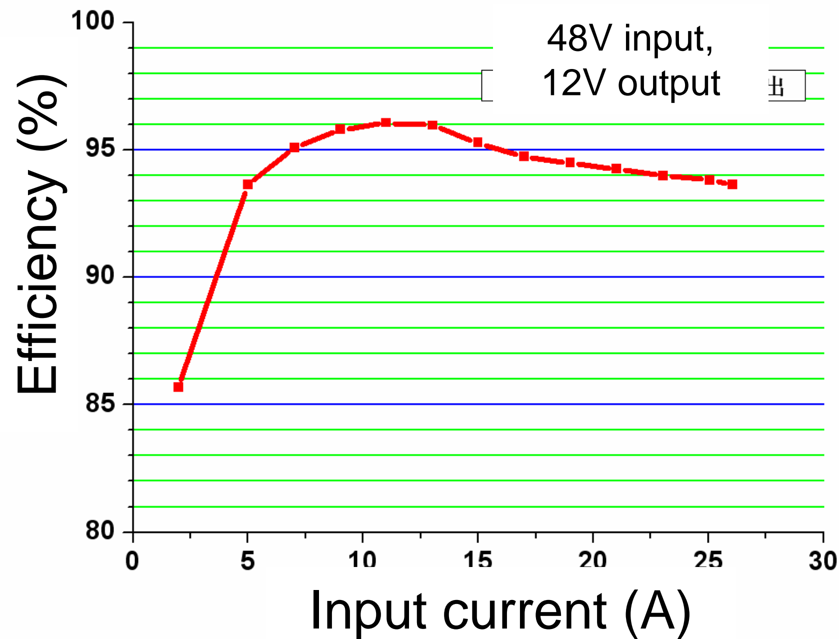
样品1测试结果



原边开关的 Vds


热成像图片



功率密度: **250 W/in³**

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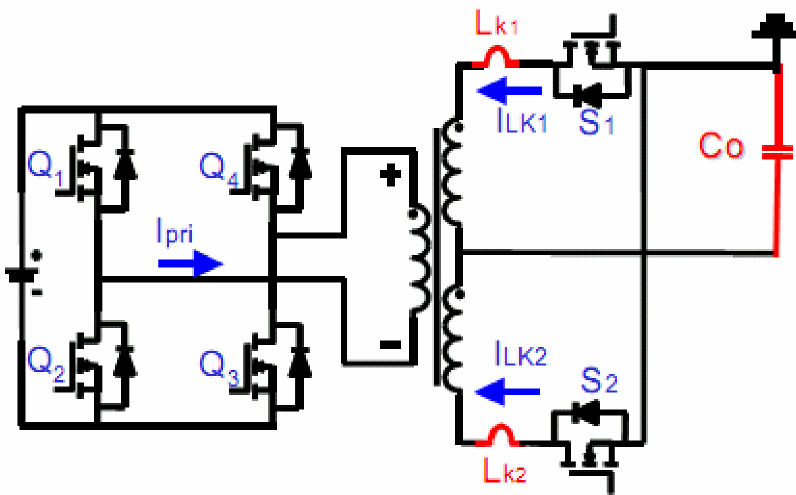
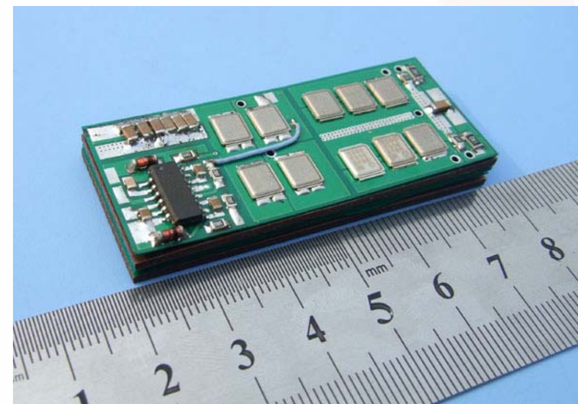
样品2



- 模块尺寸：**23 × 58×6.7 mm**
- 开关频率：**>400kHz**
- 原边开关**MOFET**：**IR6668 （DirectFET）**
- 副边同步整流**MOSFET**：**IR6648（DirectFET）**
- 控制器：**IR2086s**



(6.7mm thick)

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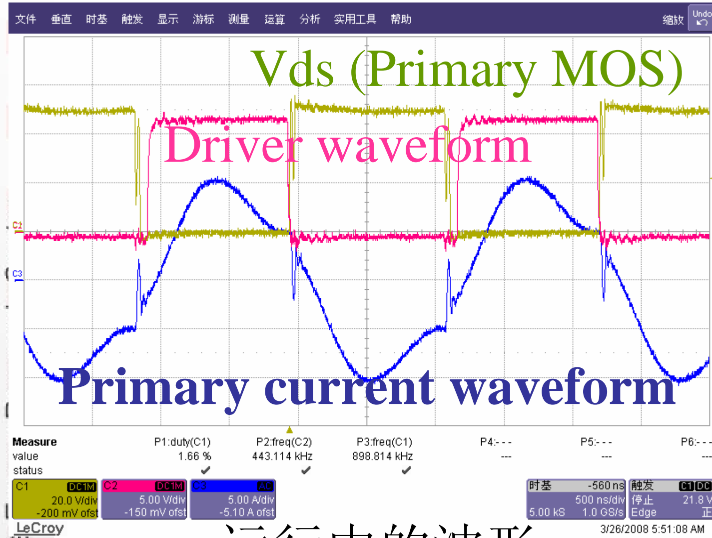
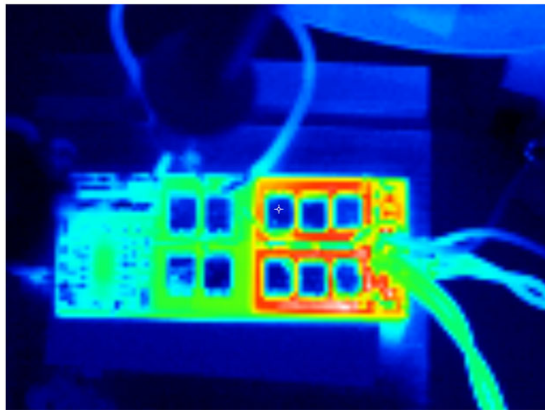
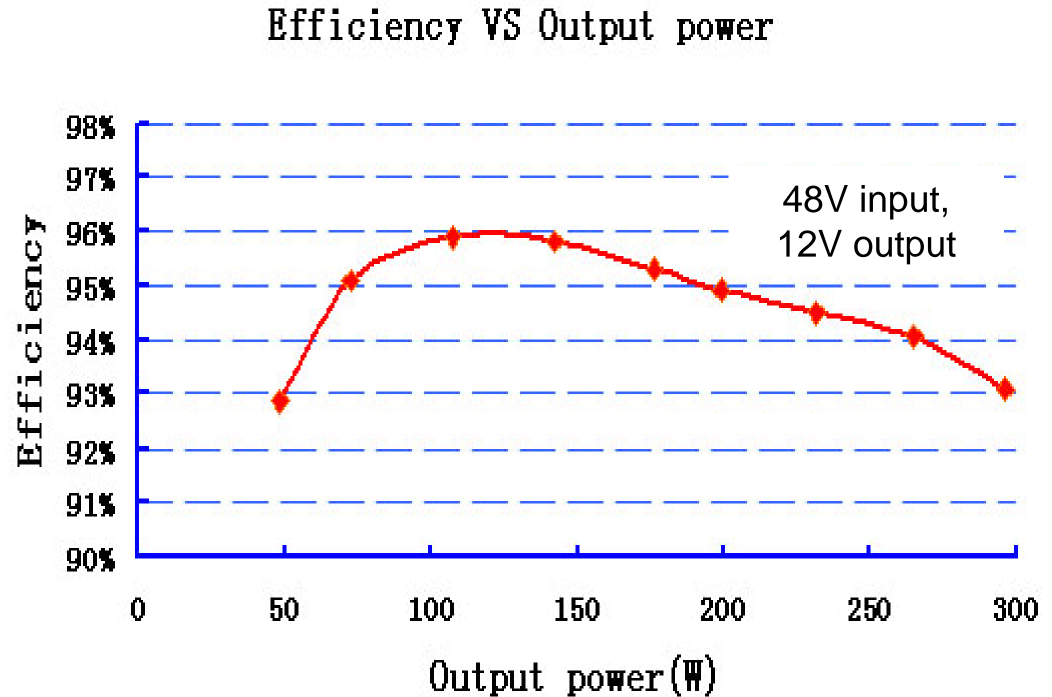
样品2 测试结果



运行中的波形



热成像照片



功率密度: **553 W/in³**

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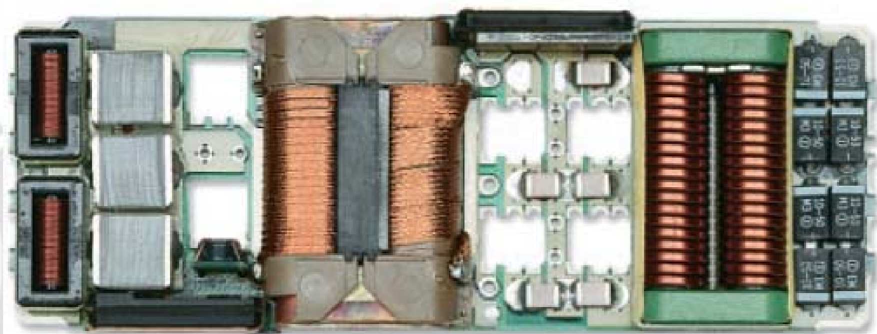
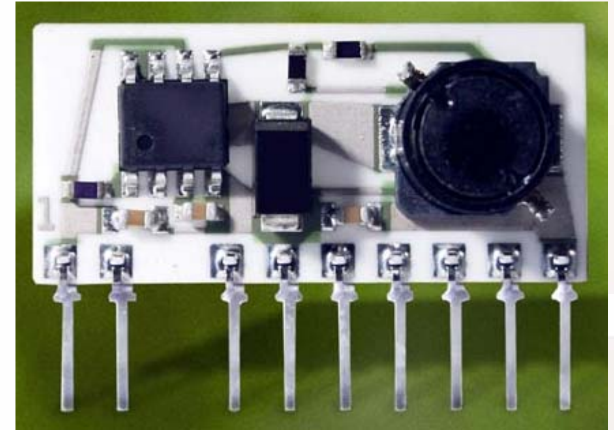
金属基板

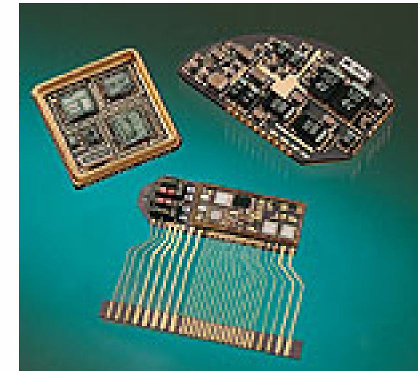
- 传热性能好于PCB
- 成本略高
- 多数情况下采用单层布线
- 用于较大功率的应用



陶瓷基板的封装

- 厚膜工艺等
- 良好的传热性能和高温性能
- 高可靠性
- 较高的成本
- 一般仅适用于航空航天和军事





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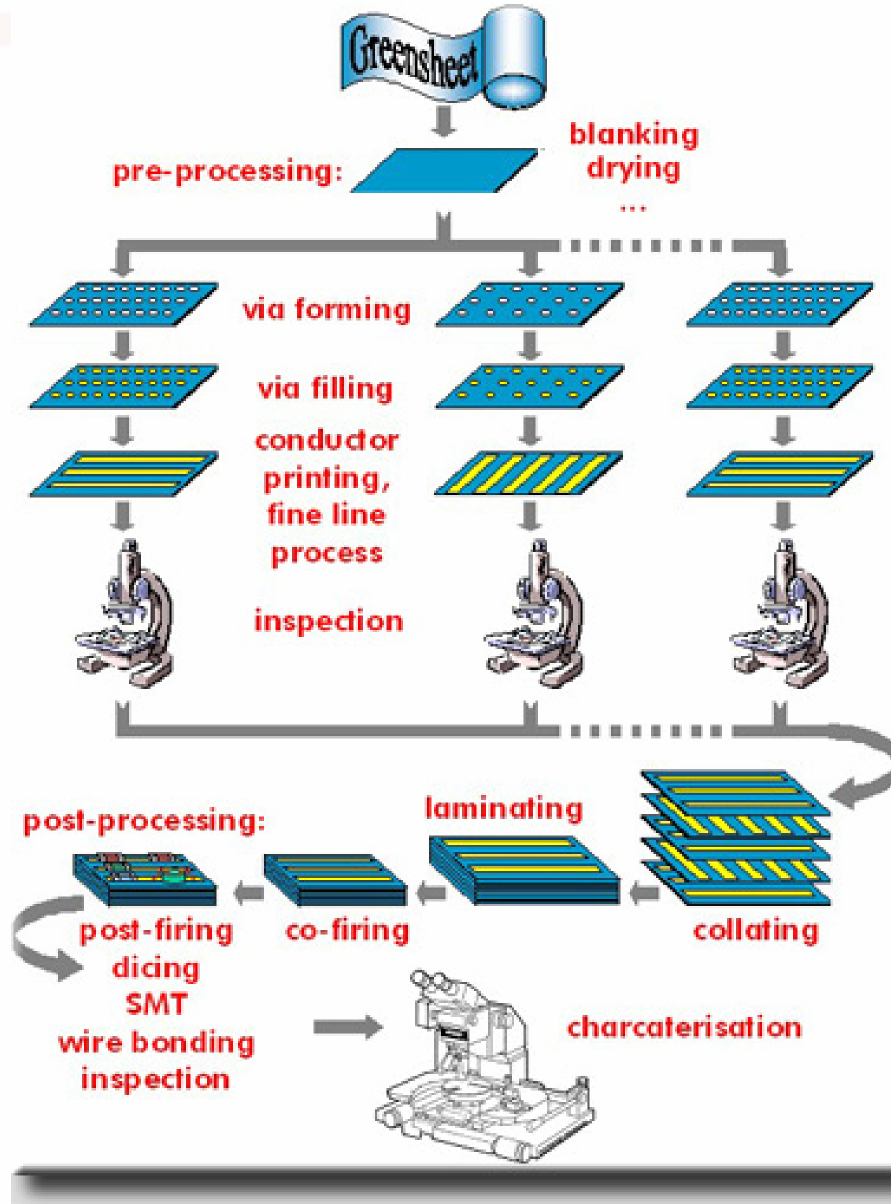
基于LTCC工艺的集成化

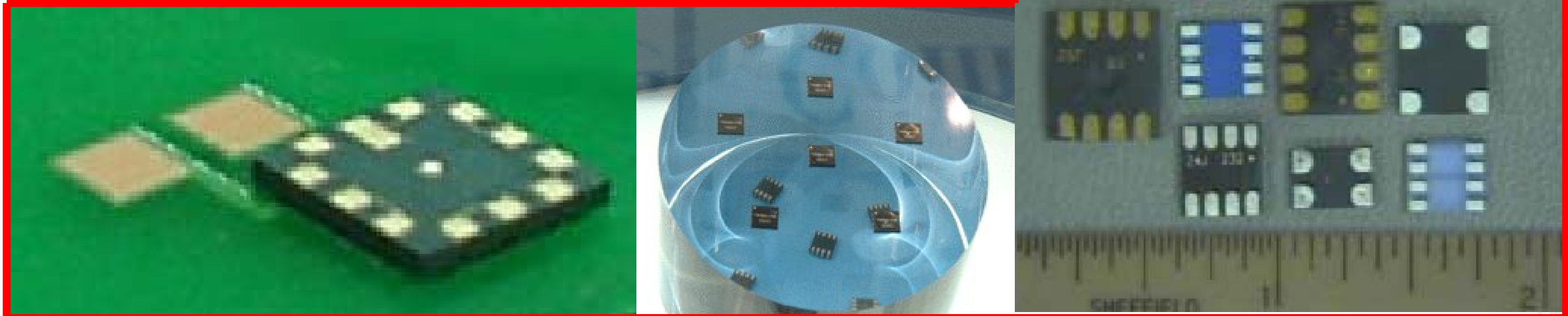
- LTCC



基于LTCC工艺的集成化

- LTCC技术制成的电感和变压器无源元件

主要公司：村田、太阳诱电、京瓷、TDK、MIDCOM、爱立信、 Catel、Bellnix等



2003年，村田公司通过解析电磁场 ,实现磁路结构的最优化。最终提高了耐压特性和耦合系数 ,从而成功开发出外形尺寸只有 7.5mm×5.5mm× 1.5mm的薄型 LTCC型变压器。

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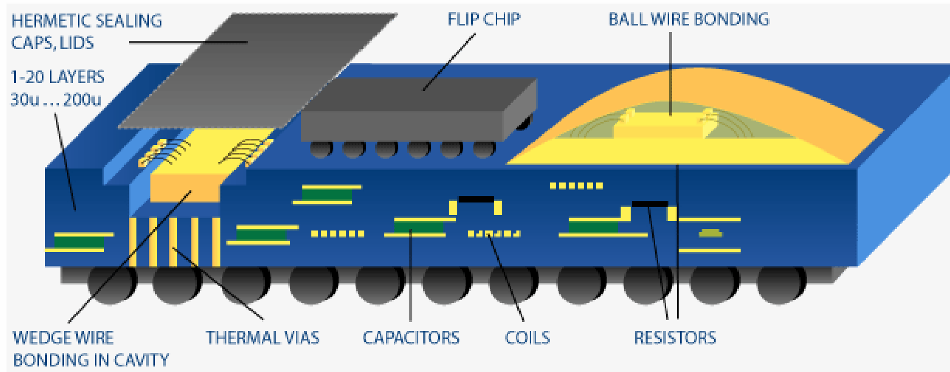
基于LTCC工艺的集成化

- 工业界已经可以开始提供包含无源元件的LTCC基板。



SELMIC

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POL的集成化

- 集成电感的模块
  - 在小封装中实现有源、无源集成
  - 布线简单
  - 很少的外围器件
  - 中高功率
  - 高频化

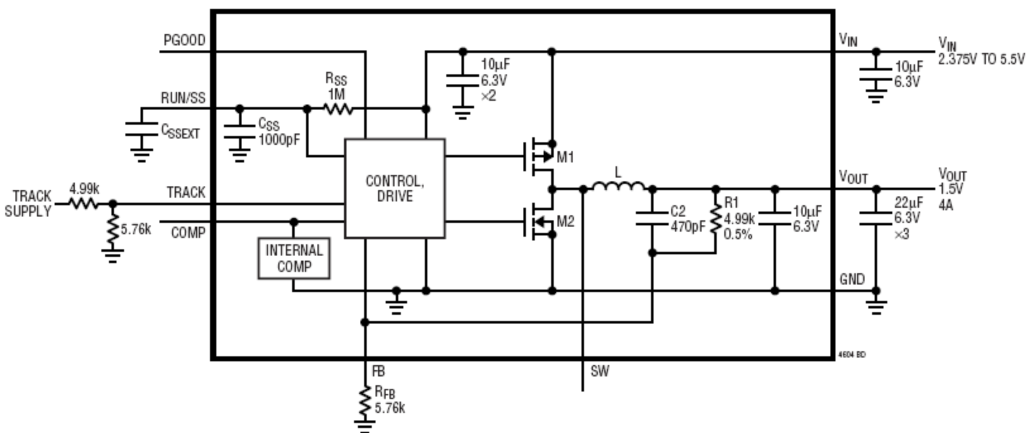
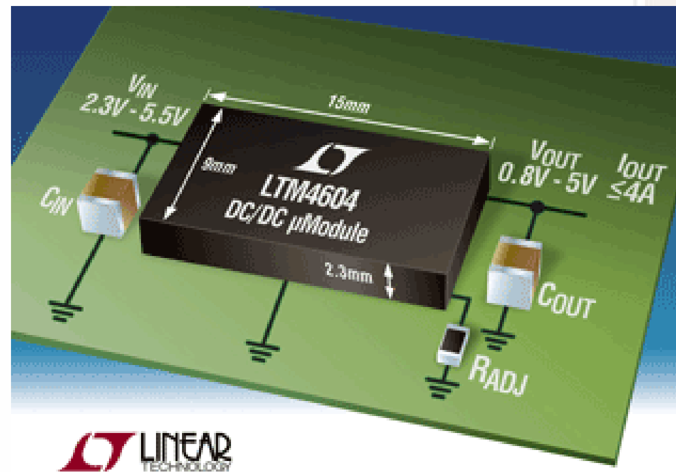
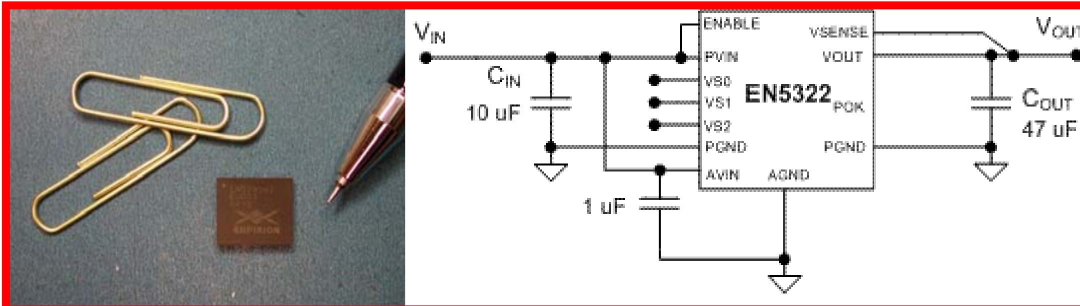


Figure 1. Simplified LTM4604 Block Diagram

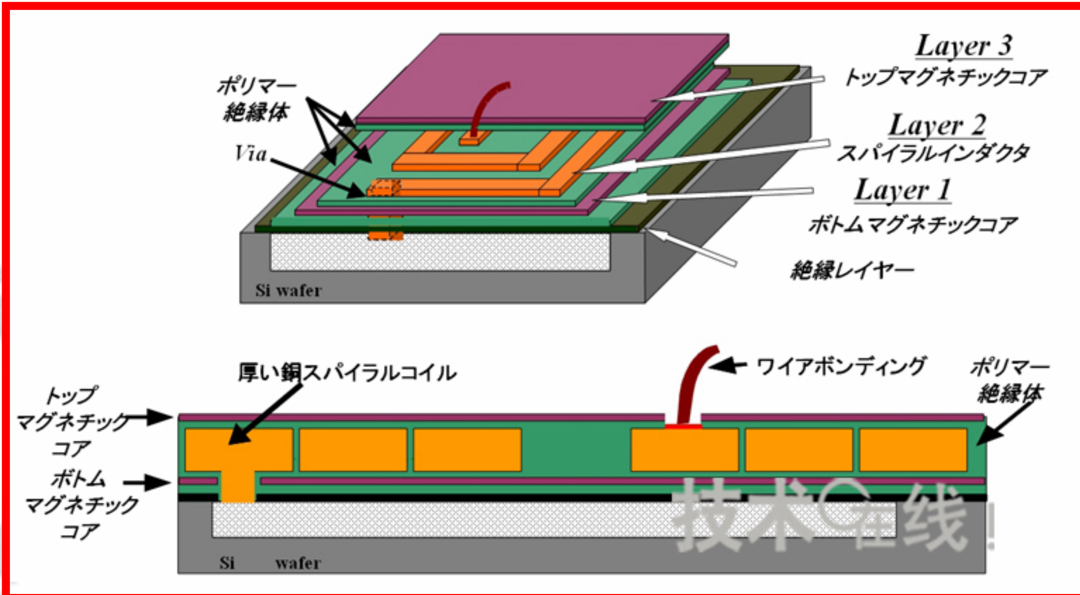


采用薄膜技术的集成化

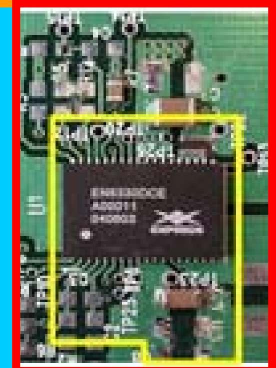
- Enpirion 集成电感技术简介



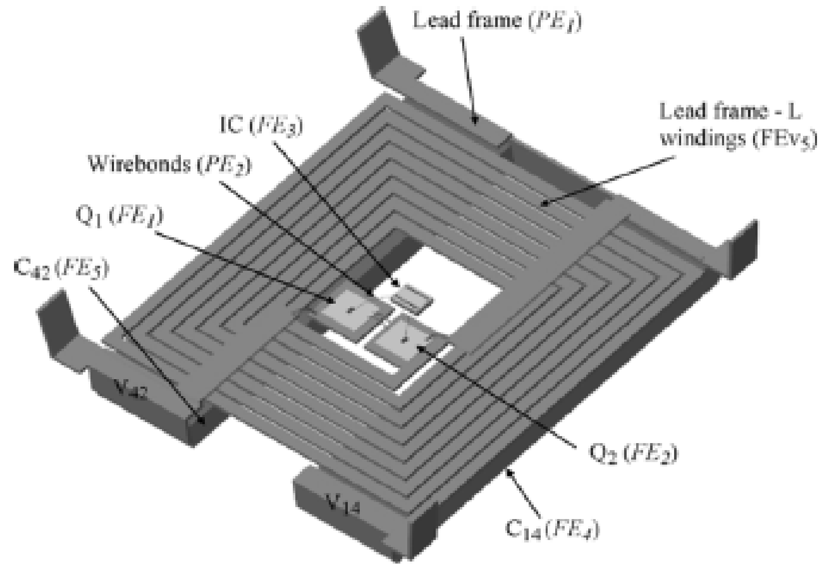
电感、MOSFET、控制器集成在一个10×12×1.85mm的封装内

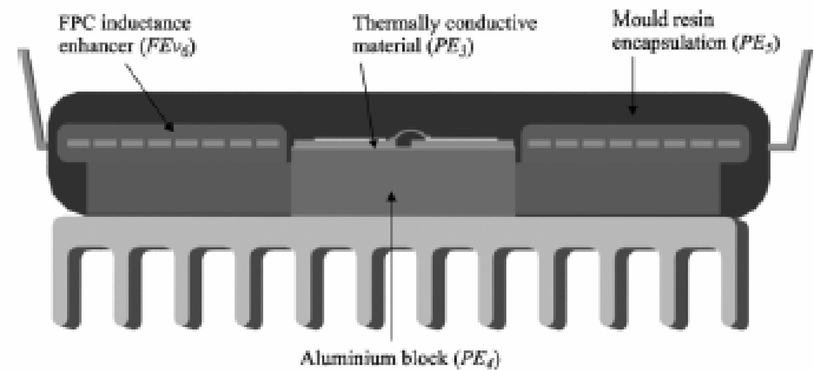


基板的面积缩小70％，电感高度降低有利于降低整个电路板的高度



利用引线框的集成化





Jelena Popovic´ , *Student Member, IEEE,* and J.A. Ferreira*, Fellow, IEEE.*

Converter Concepts to Increase the Integration Level

总结

- 集成化是DC-DC变换器技术发展的重要方向，在航空航天和军事领域已经得到广泛应用，未来的商业应用也会越来越多。
- 对于追求低成本的商业应用，PCB为基础的有源、无源混合封装将发挥重要作用。
- 在电源芯片中集成电感等无源元件将会是重要方向。
- 如果未来能够降低成本，LTCC工艺将会对DC-DC变换器的封装产生深远的影响。

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谢谢！