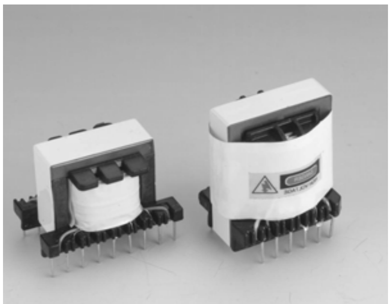
Part V

扁平矩陣變壓器
(Flat Matrix Transformer)

Major Concerns for Transformer Design

- Size, Height
- Leakage Inductance
- Thermal, Hot-spot
- Cost

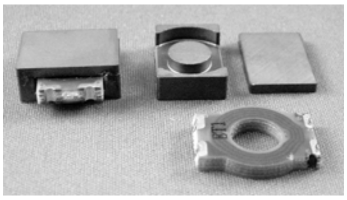
Conventional Power Transformer



Pro
- Cheap bobbin winding

Con
- Bad magnetic coupling
- Big leakage inductance
- Low winding factor
- High profile
- Internal hot spot

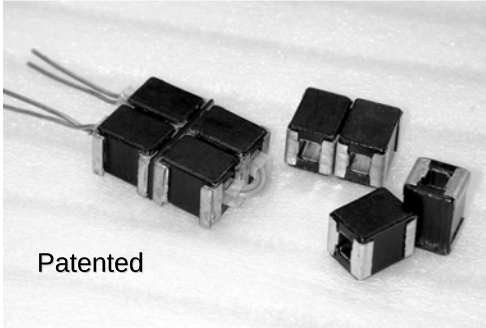
Planner Transformer



Pro
- Very low profile
- Consistent pcb winding

Con
- Very expensive
- Relative high footprint

Flat Matrix Transformer



Pro
- Very low profile
- Relative low leakage inductance
- Easy heat dissipation
- Automatic current sharing
- Half-turn realization

Con
- Low output voltage
- Single output

Application Features

- Suitable for high output current - the higher, the better. (can deliver over 500 Amps)
- Low Output Voltages：< 50Vdc
- High Switching Frequency：> 200Khz
- Markets：Data Comm., Internet Hardware, OEM, Test Equipment, etc.

Magnetics Basis

$$B_{(\text{FluxDensity})} = \frac{E \cdot 10^{-8}}{4 \cdot A_e \cdot N \cdot f}$$

Flux density (gauss)

$$H_{(\text{Magnetiztion})} = \frac{0.4\pi \cdot N \cdot I}{l_e}$$

Magnetic field strength (Oe)

$$L_{(\text{Inductance})} = \frac{0.4\pi \cdot \mu \cdot N^2 \cdot A_e \cdot 10^{-8}}{l_e}$$

Inductance (H)

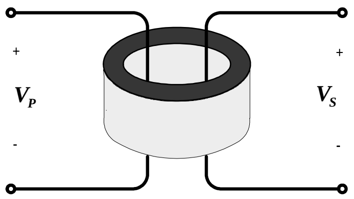
$$P_{C(\text{Core loss})} = K \cdot f^x \cdot B^y$$

Core loss
(hysteresis & eddy current loss)

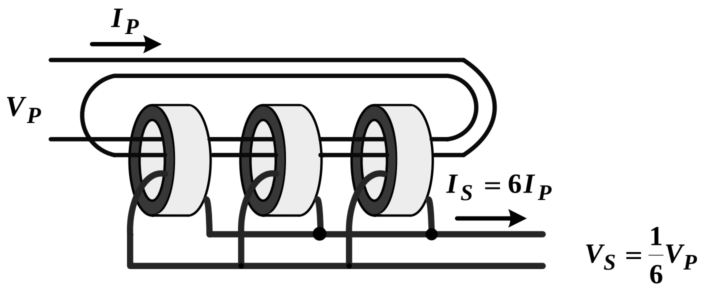
$$P_{W(\text{Copper loss})} = I^2 \cdot R$$

Conduction Loss

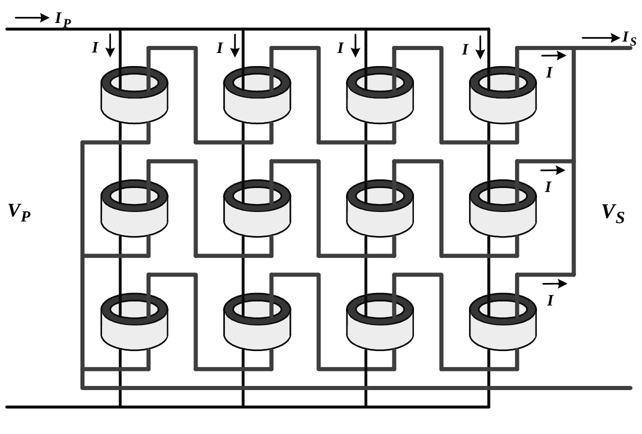
Ideal 1:1 Transformer



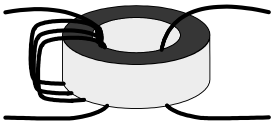
6:1 Transformer



3:4 Transformer

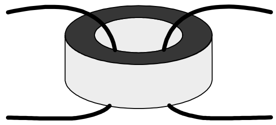


Conventional Transformer

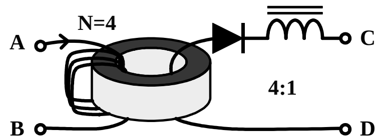


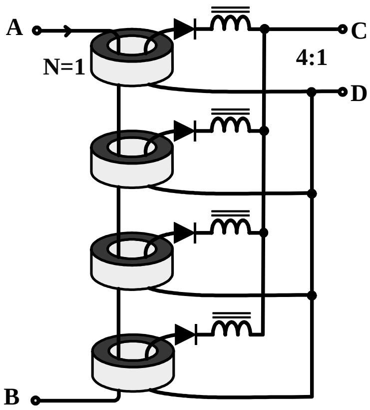
- Invented 60-100 years ago
- Based on single magnetic core
- Use multiple turns
- Outdated
- Not suitable for low voltage, high current

Ideal Transformer



- Zero leakage inductance
- Energy in primary winding = Energy in secondary winding
- Minimum core loss
- Minimum winding or copper loss
- Flat matrix transformer uses this ideal transformer structure as its basic transformer cell.



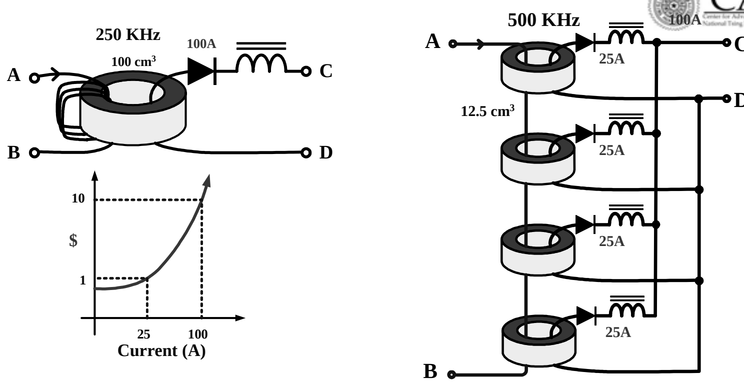


Conventional Transformer

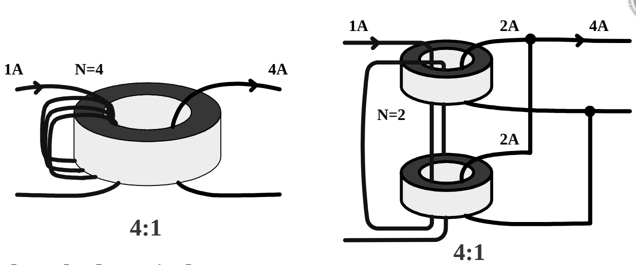
To get a 4:1 turn ratios, minimum N is 4. Hence, leakage inductance is proportional to 4^2

Flat Matrix Transformer

To get the same 4:1 turn ratios, the minimum N is 1. Hence, leakage inductance is proportional to 1^2



- Reduction in cost of rectifications devices (rectifiers or synchronous Mosfets) - lower current rating devices can be used with flat matrix transformer designs.
- Reduction in DC bias requirement of inductors – lower dc bias current = smaller chokes, lower cost.
- Reduction in the I^2R losses – $100^2 \times R$ versus $(25^2 \times R) \times 4$

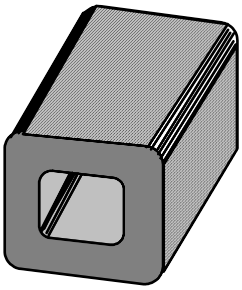


Reduce leakage inductance

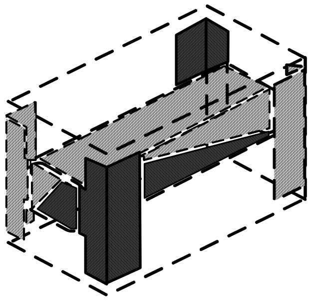
$$L_{leakage} \propto \frac{N^2 \cdot A_e}{l_e}$$

Multi-core, multi-winding is the optimal combination in most applications. Achieving the goal of reducing leakage inductance and spreading of heat.

Basic Elements

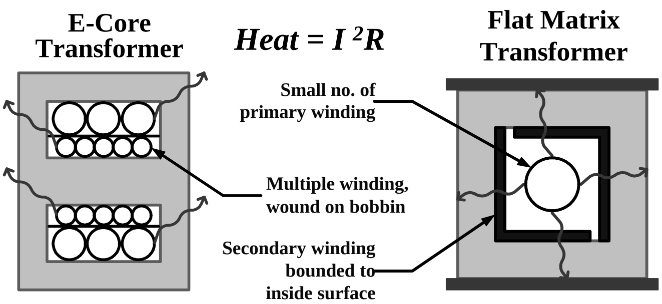


Core



Core + 2^{nd} winding

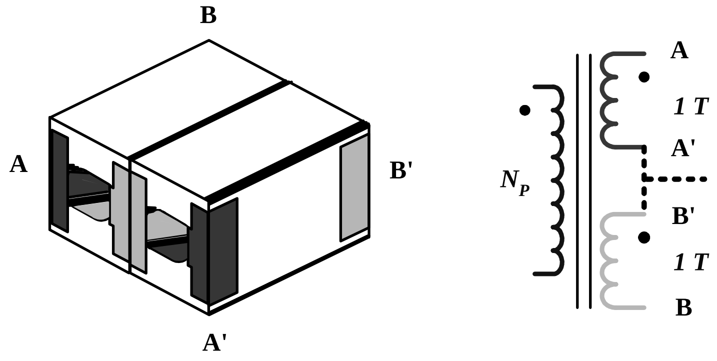
Embedded Secondary Winding Reduces Heat Form Copper Losses



Conventional transformer
Transfers heat out by convection
Poor efficiency

Flat transformer transfers heat out by conduction
More efficient

Basic Unit of Matrix Transformer

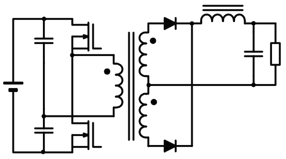


Topologies Used with Matrix Transformers

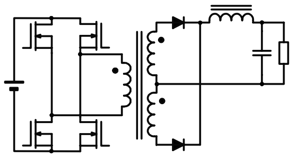
- Forward
- Half Bridge
- Full Bridge
- Push Pull
- Proprietary symmetrical push-pull
- Resonant

1 Watt to 10KW

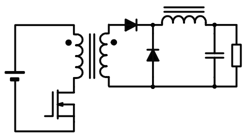
Topologies Used with Matrix Transformers



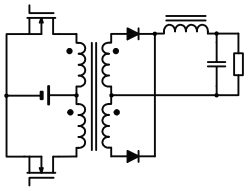
Half-Bridge



Full-Bridge

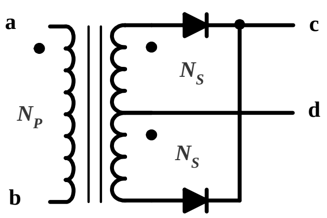


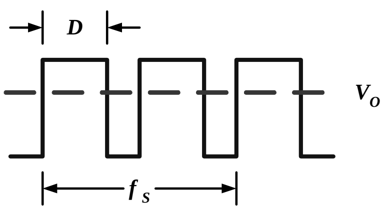
Forward



Push-Pull

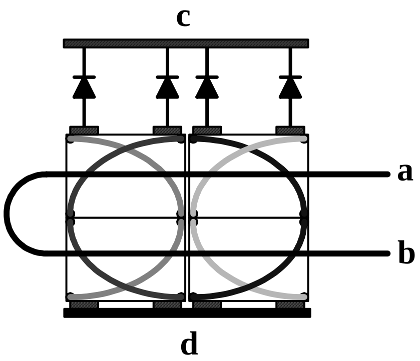
Secondary Tapping

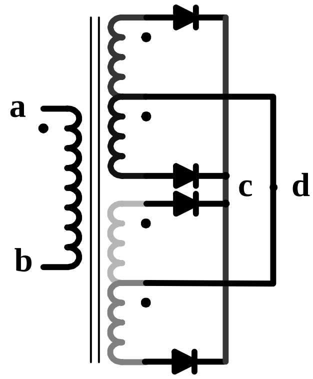




c, d waveform (D<0.5)

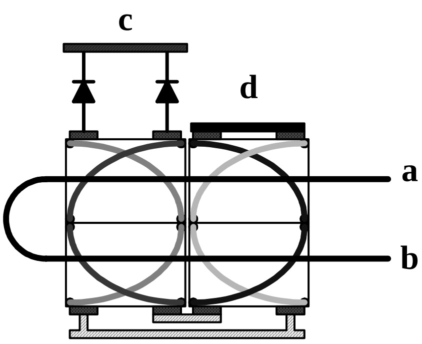
2x2 Construction I : Pri-Series, Sec-Parallel

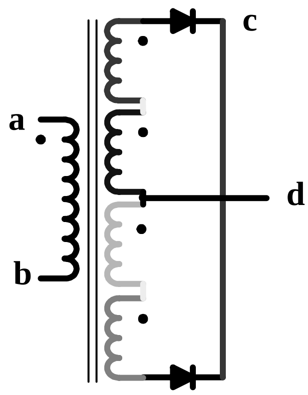




equivalent circuit

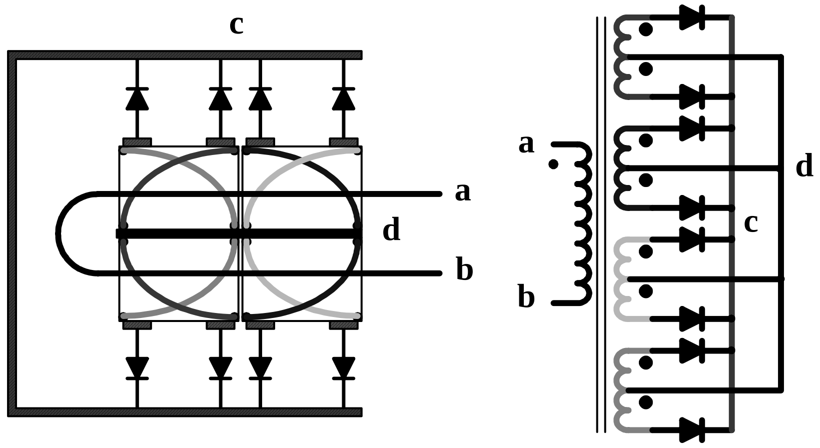
2x2 Construction II : Pri-Series, Sec-Series





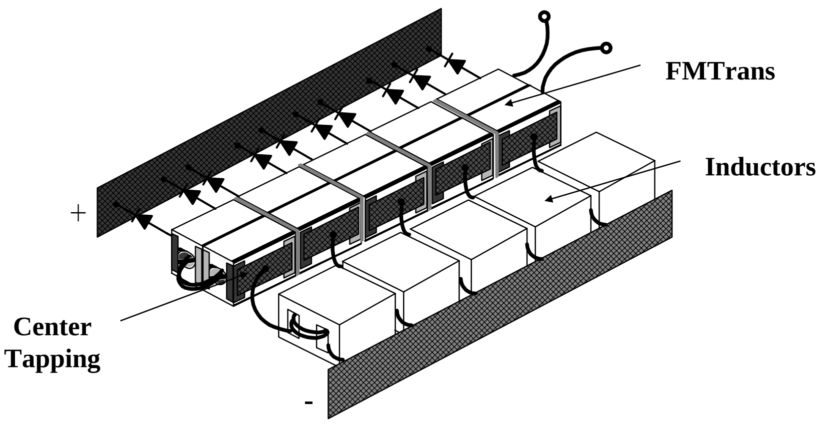
equivalent circuit

2x2 Construction III : Pri-Series, Sec-Parallel (Half-Turn)

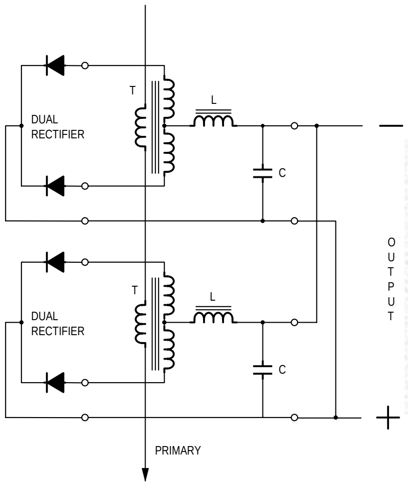


equivalent circuit

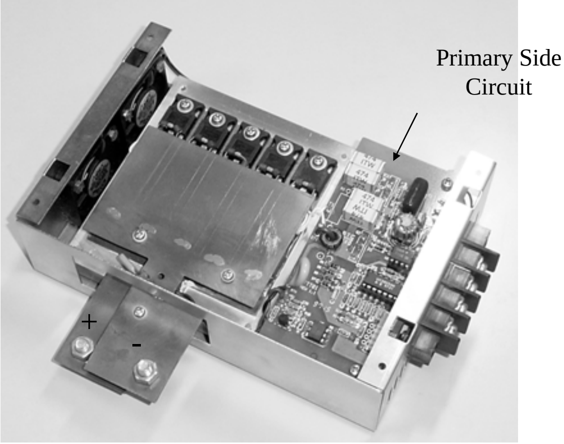
Example : 500W Converter



500W Converter Schematics



500W Converter Prototype

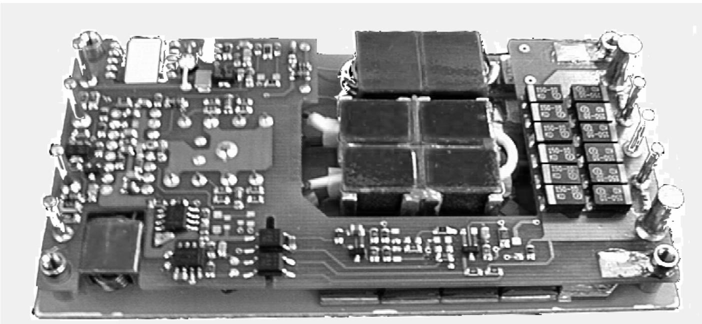


Advantages of Flat Matrix Transformer

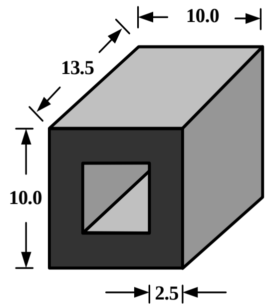
- Very Low Leakage Inductance
- Automatic Current Sharing in Secondary side
- Half-Turn Technology Realization
- Low Profile
- No Hot Spot, Easy Heat Dissipation
- Simple Structure, Inexpensive

Flat Matrix Transformer

Applied in High-Power Density DC-DC Converter

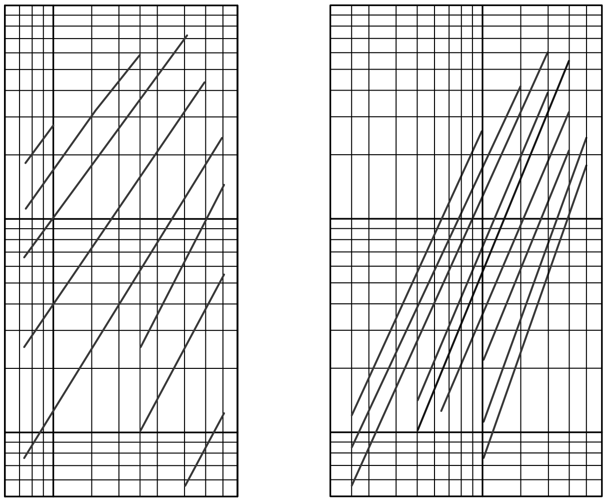


Dimension of Transformer Core Cell



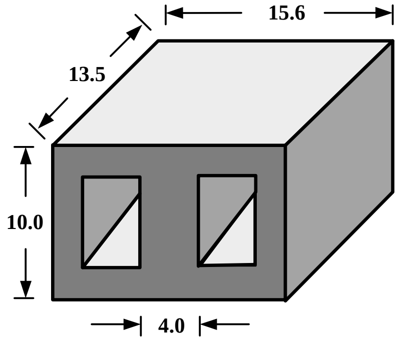
Ferrite (PC40, PC50)

Core Loss Data



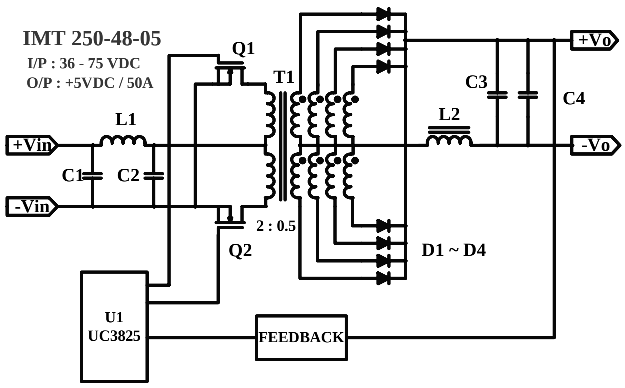
1 unit cell
10mm

Matrix Inductor

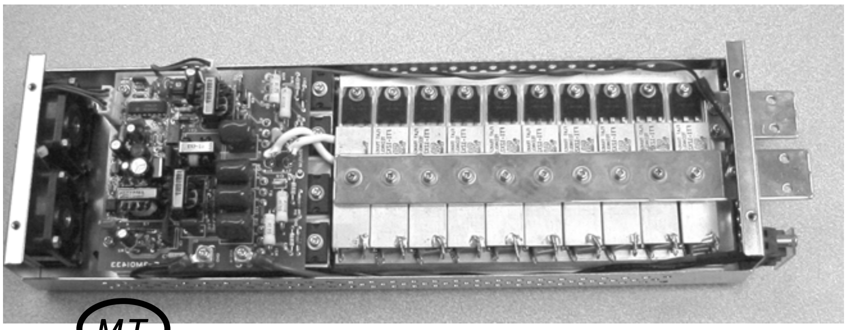


MPP, Sendust, Iron Powder

Push-Pull Schematics



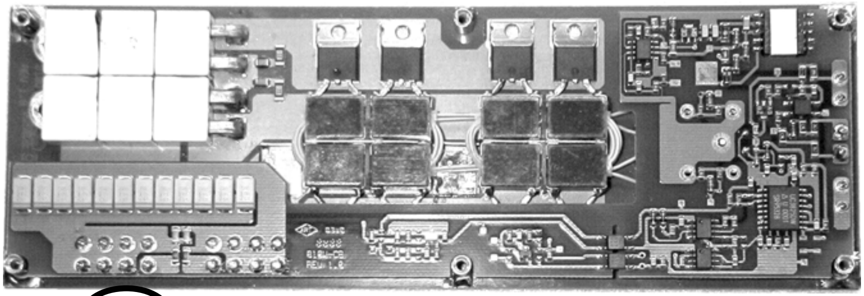
Example 1



MT

5V/250A

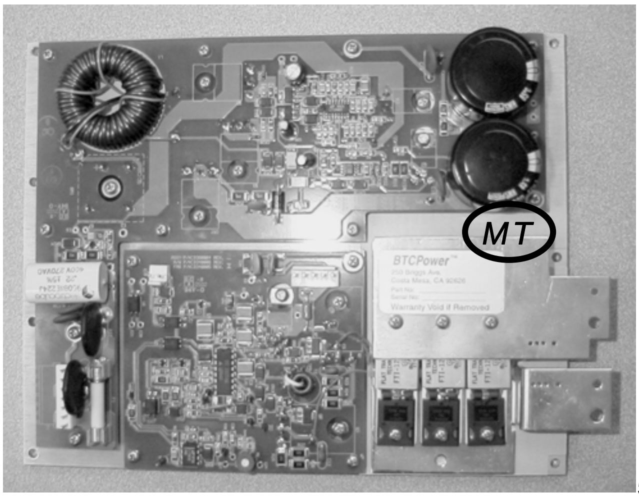
Example 2



MT

5V/160A

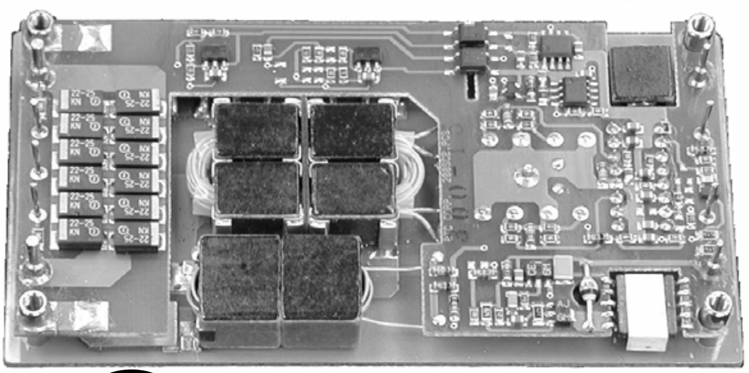
Example 3



5V/75A

Example 4

IMT 200 & 400 Series



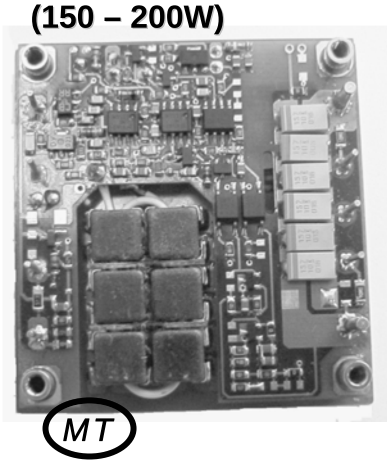
MT

I/P : 24, 48, 72, 150, 300V
O/P : 2, 3.3, 5, 12, 15, 24V

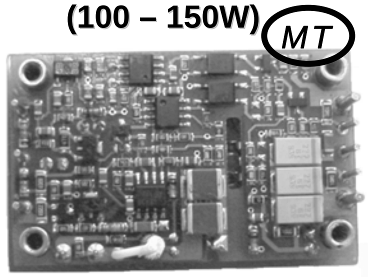
CAPT

Example 5

HMT Series
(150 – 200W)



QMT Series
(100 – 150W)



I/P : 24, 48, 300V
O/P : 1.5, 2, 2.5, 3.3, 5, 12V

CAPT

Thank You