Desk Top Power Supplies

External Power

Embedded Power

110V AC

12V

12 Phase VR for CPU and iGPU

6 Phase VR

4 Phase VR for Memory
Embedded VR
Device & Packaging

Discrete
- Lead frame (Source, Gate)
- Au wire
- Die
- Ag paste
- Die pad (Drain)

Die related loss
25-30%

Packaging related loss
60-70%

30-40%

Dr. MOS

25-30%

70-75%
VR for Desktop

Dr. Moss
Inductors
Capacitors
Voltage Regulator

1 MHz
2 MHz
>5 MHz
3-D Point-of-Load

Inductor

Dr. MOS

C_{in}

Inductor embedded into PCB

20A, 5MHz
1100W/in3

More Integration

1 Phase

5 Phase

Microprocessor

$C_{in}$

Dr.MOS

iVR

Non-uniform Flux Distribution

$\mathbf{DC \ Flux}$

$I_{DC} = 4A$

10A

15A

20A

$\mathbf{AC \ Flux \ (i_{AC} = 50\% \ I_{DC})}$
Magnetic Property of NEC’s Materials

Heat Treatment

Flux

Core Loss Density ($\text{kw/m}^3$)

$B_m = 20 \text{mT}$

Frequency (kHz)

$\mu_r \Delta$

Flux
DC Flux Cancellation

**Inverse Coupled**

- $d = 1.8 \text{ mm}$
- $|\alpha| = 0.5$

- $d = 0.4 \text{ mm}$
- $|\alpha| = 0.8$

- Cancelling DC flux.
- Increasing permeability.
- Reducing core volume.

- $\Delta \mu_r = 34$
- $\Delta \mu_r = 22$
- $\Delta \mu_r = 11$

**Graphical Representation**

- $H_{DC} (\text{A/m})$
- $\mu_r$ variations with $H_{DC}$.
LLC Converter

1KW, 400V/12V DC/DC

Major Losses

SR loss percentage (%) vs. $P_o$ (W)

- 2SR
- 4SR
- 6SR
- 8 SR

$P_o = 1200$ W

$I_o = 83$ A

Core

Winding

Termination

Diagram showing LLC Converter with components labeled $C_r$, $L_r$, $L_m$.
Reducing Losses

Transformer losses breakdown

- Core: 60%
- Winding: 40%
- Termination: 100%

16:1:1  12V/83A

Diagram showing a schematic of a transformer with components labeled as follows:

- VIN
- Q₁
- Q₂
- Cᵣ
- Lᵣ
- SR
- Vₒ

Graph showing the breakdown of transformer losses with "Old" and "New" categories.
The Alternative

8 Transformers

Primary in series

1MHz

2:1:1

Primary in series

V_IN
Q_1
Q_2
SR_2
V_O
SR_1
R_L
L_m

C_r
L_r
N:1:1
Magnetic Integration

Primary in series
Secondary in parallel

2:1:1

Core1
Core2

Core1’
Core2’

2 cores become 1 core
Winding length is reduced
Two Transformers in one Core

- SR are mounted on the Sec winding
- No termination losses
- 4 layers PCB
Shielding for CM Noise Reduction

EMI Shielding

6 layers PCB

W/O Shielding

With Shielding

US patent

Further Improvement Shielding for CM Noise Reduction

Sec1

Shield

Pri1

Pri2

Sec2

SR1

SR2

SR3

SR4

SR5

SR6

SR7

SR8

L

Lm1

Lr2

Lm2

A

A'

B

B'

US patent

CPES

APEC
Matrix Transformer

- 4 cores/8 outputs
- 4 layer PCB
- 1MHz
- 700W/in³
- 6-layer board

Efficiency (%)

Output Power (W)

- Gen. 1
  - 6-layer board
  - 2 cores/4 outputs
  - 4 cores/8 outputs

- Gen. 2
  - 4 layer PCB
  - 2 cores/4 outputs

![Graph showing efficiency vs. output power for Gen. 1 and Gen. 2 with blue and green lines, respectively.](image-url)
DC Data Center

4160V

60Hz Transformer 4160V/480V

480V/277V

Server Hall 1

Transformer

4160V/480V

Server Hall 3

60Hz

Transformer

4160V

18% energy saving → 54 nuclear power plants (each @ 1GW)
Automated Manufacturing
Thanks !