The eGaN® FET
Journey Continues

National Taiwan University

Emerging Applications for GaN Transistors

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Efficient Power Conversion Corporation

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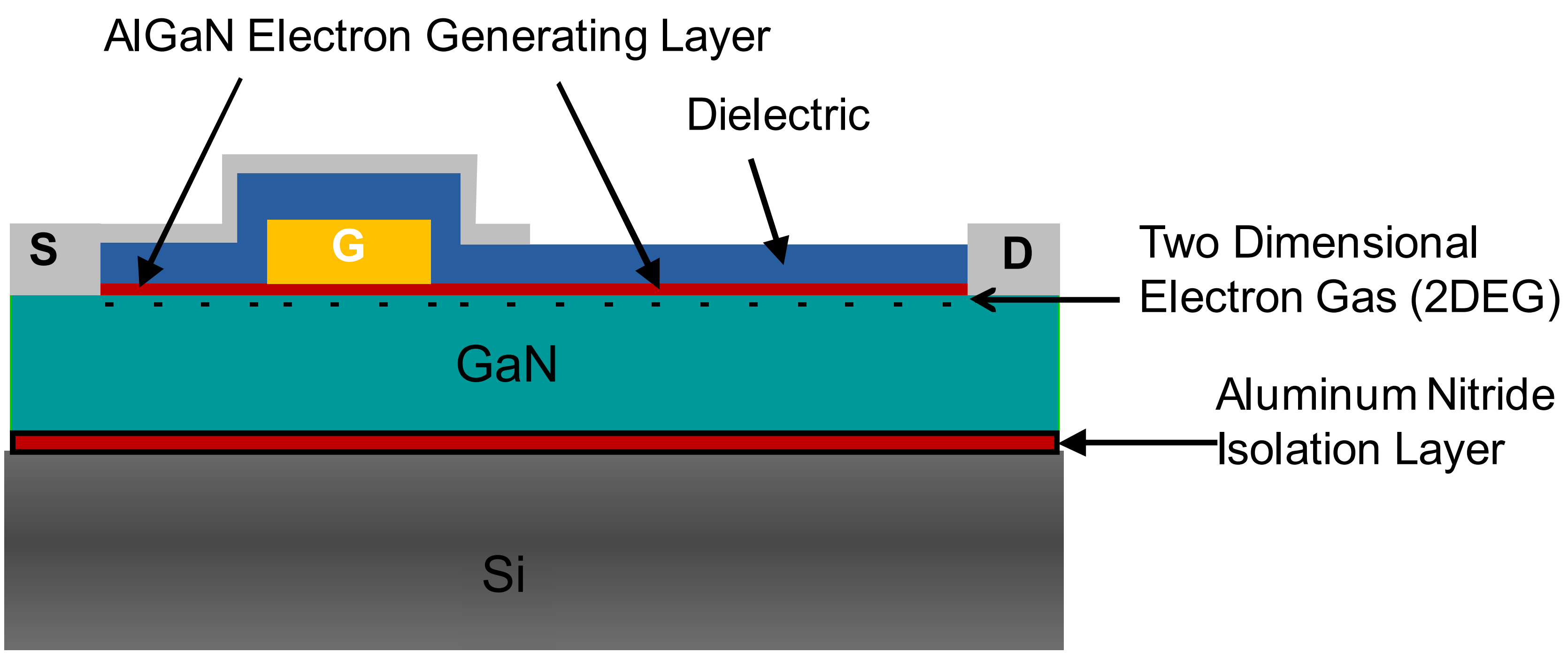
Agenda

- Why Gallium Nitride?
- Hard Switched Converters
  - Envelope Tracking
- High Frequency Resonant Converters
  - Wireless Power
- Summary

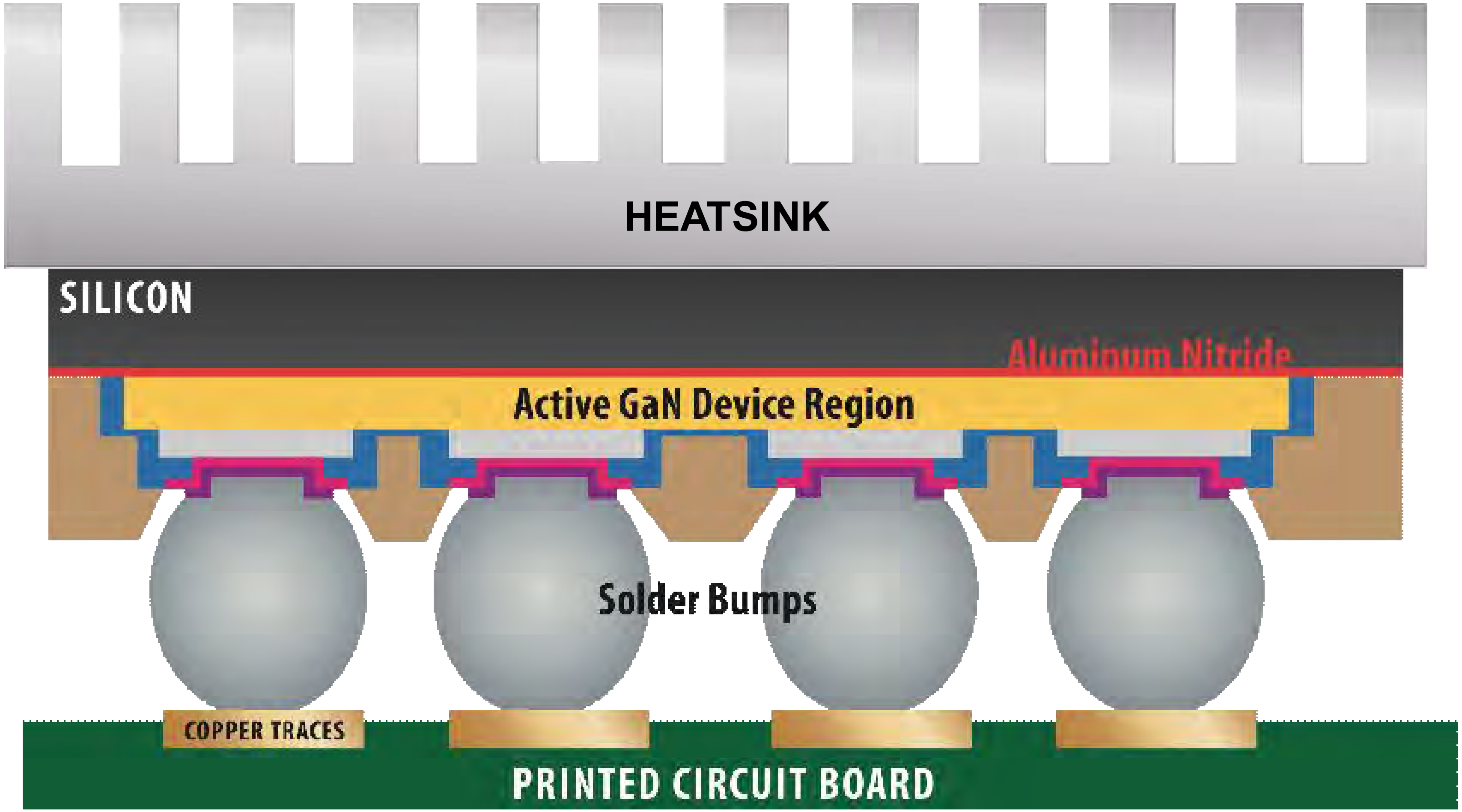
Why Gallium Nitride?

- Enhancement-Mode devices available (eGaN® FETs)
- $R_{DS(ON)}$ per unit area much smaller than silicon power MOSFET
- Much faster switching
- Very low capacitance (C_G, C_{ISS}, C_{OSS})
- No parasitic PN junction body (Q_{RR}=0)

eGaN® FET Structure



Flip Chip Assembly



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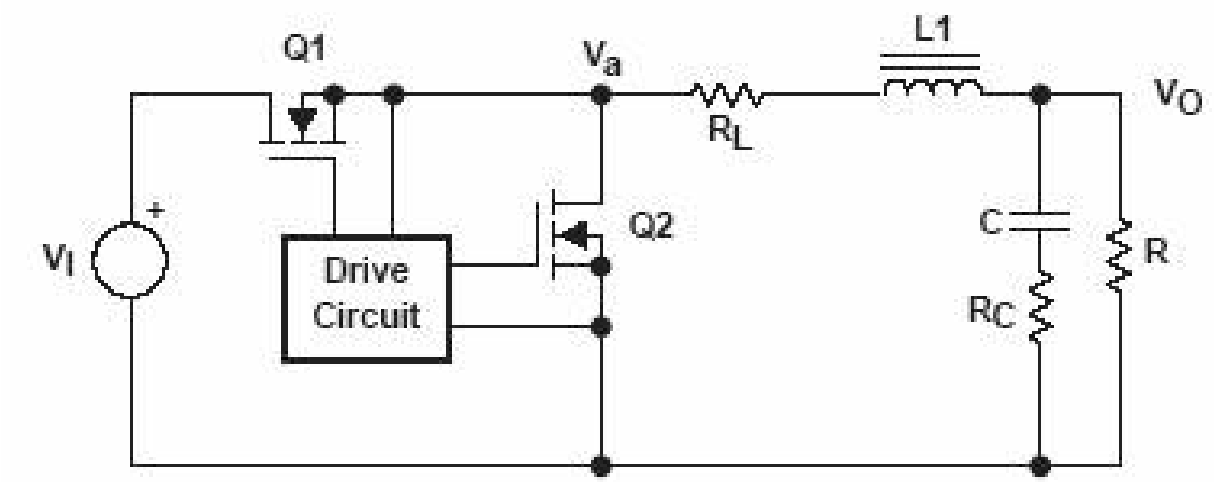
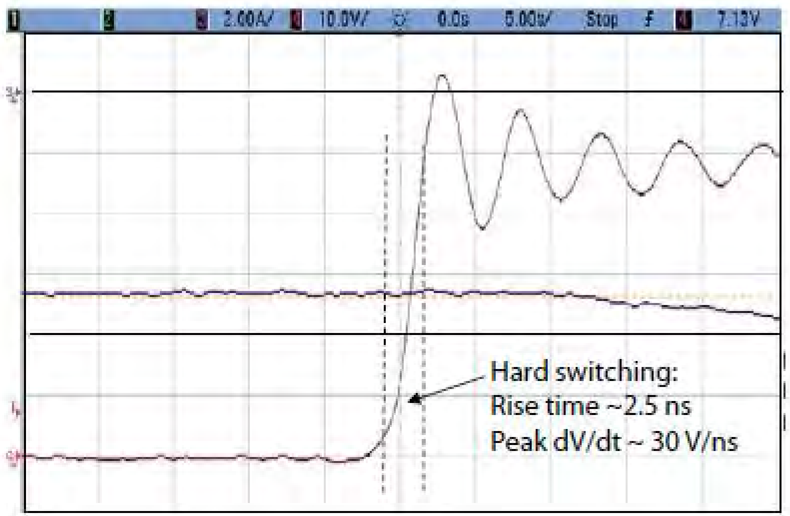
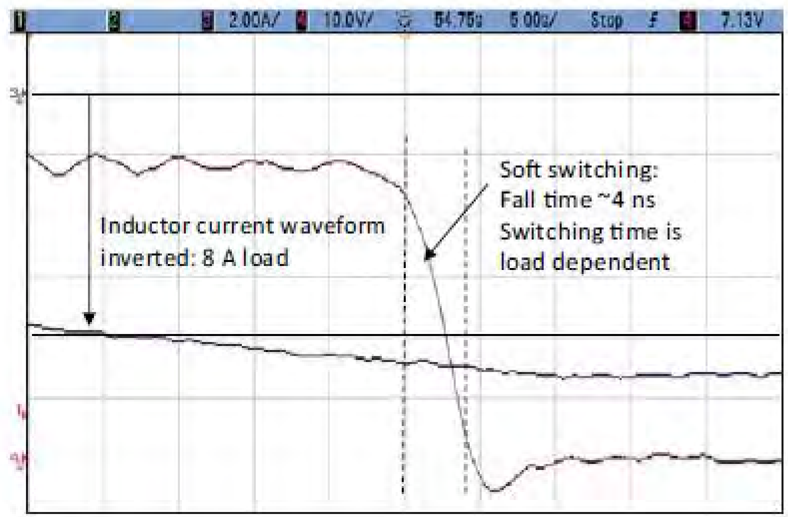
Hard Switched Converters

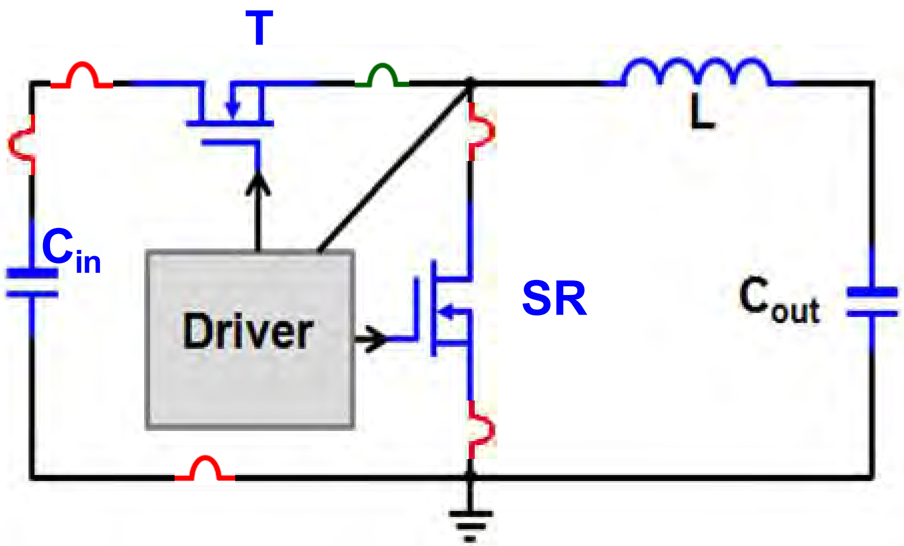
Example: Buck Converter





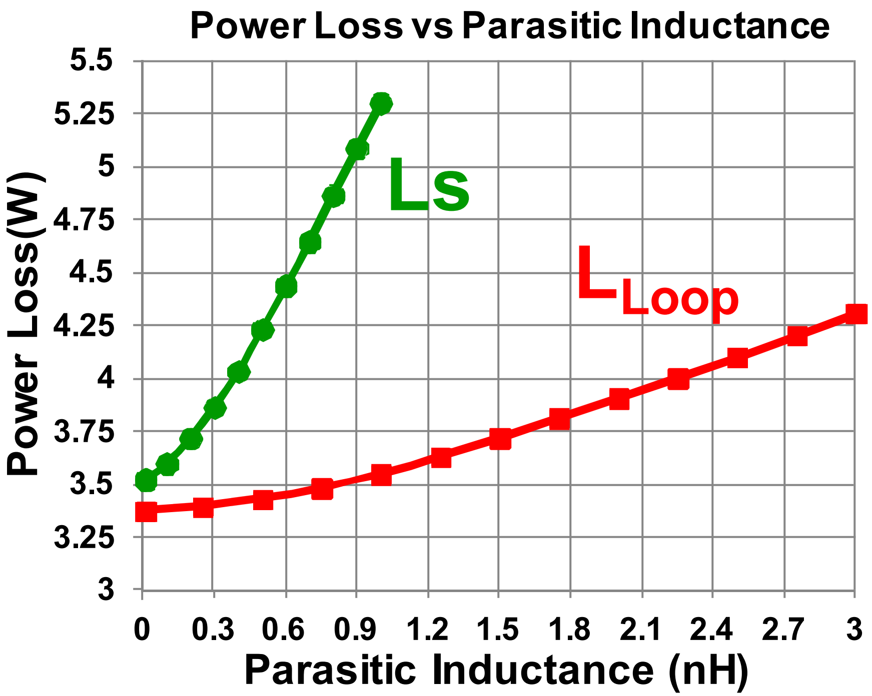


Buck Converter Parasitics



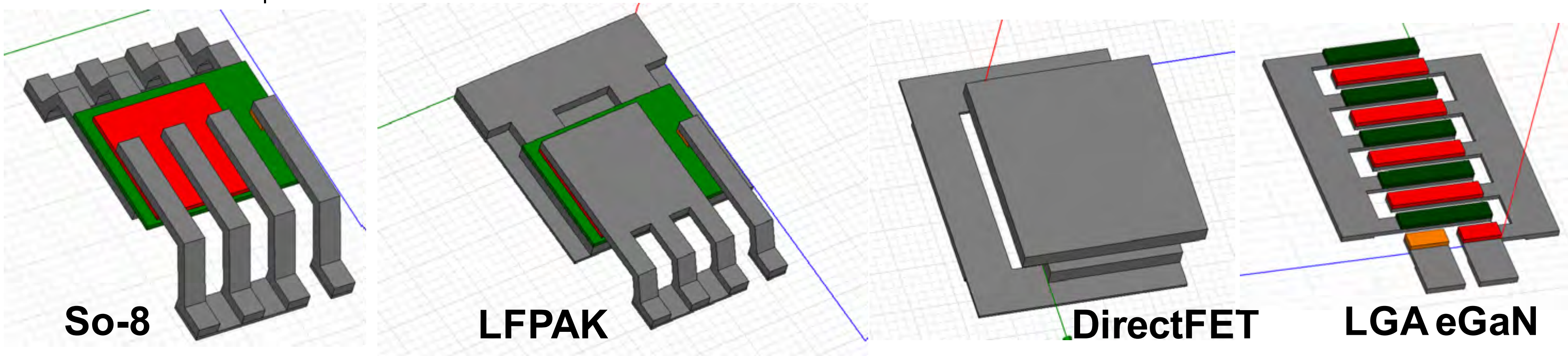
L_S: Common Source Inductance

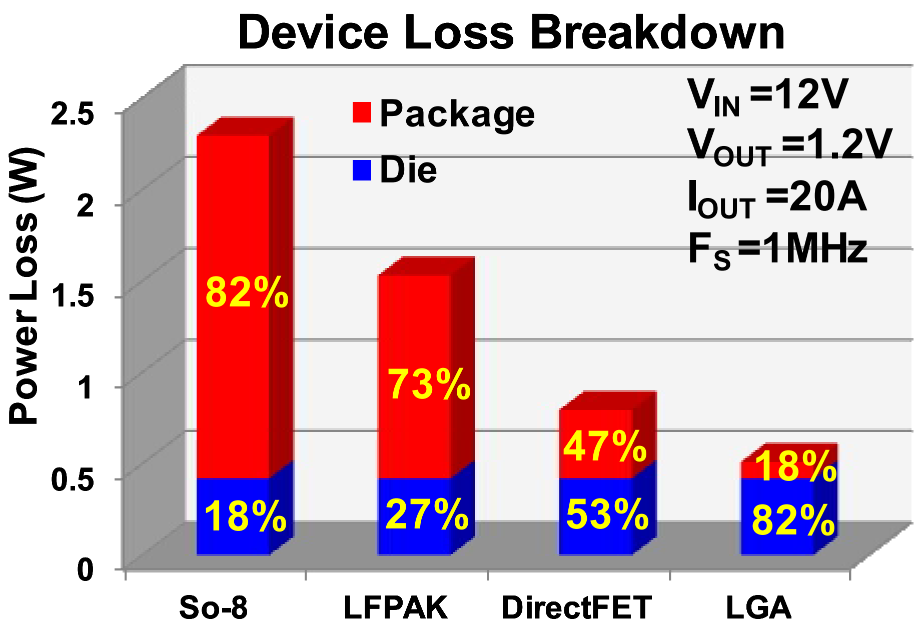
L_{Loop}: High Frequency Power Loop Inductance

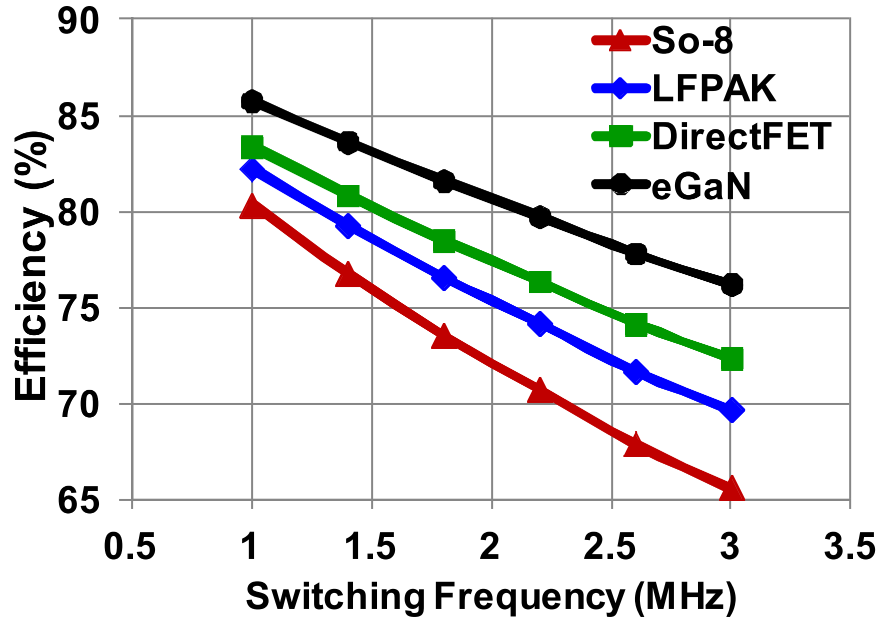


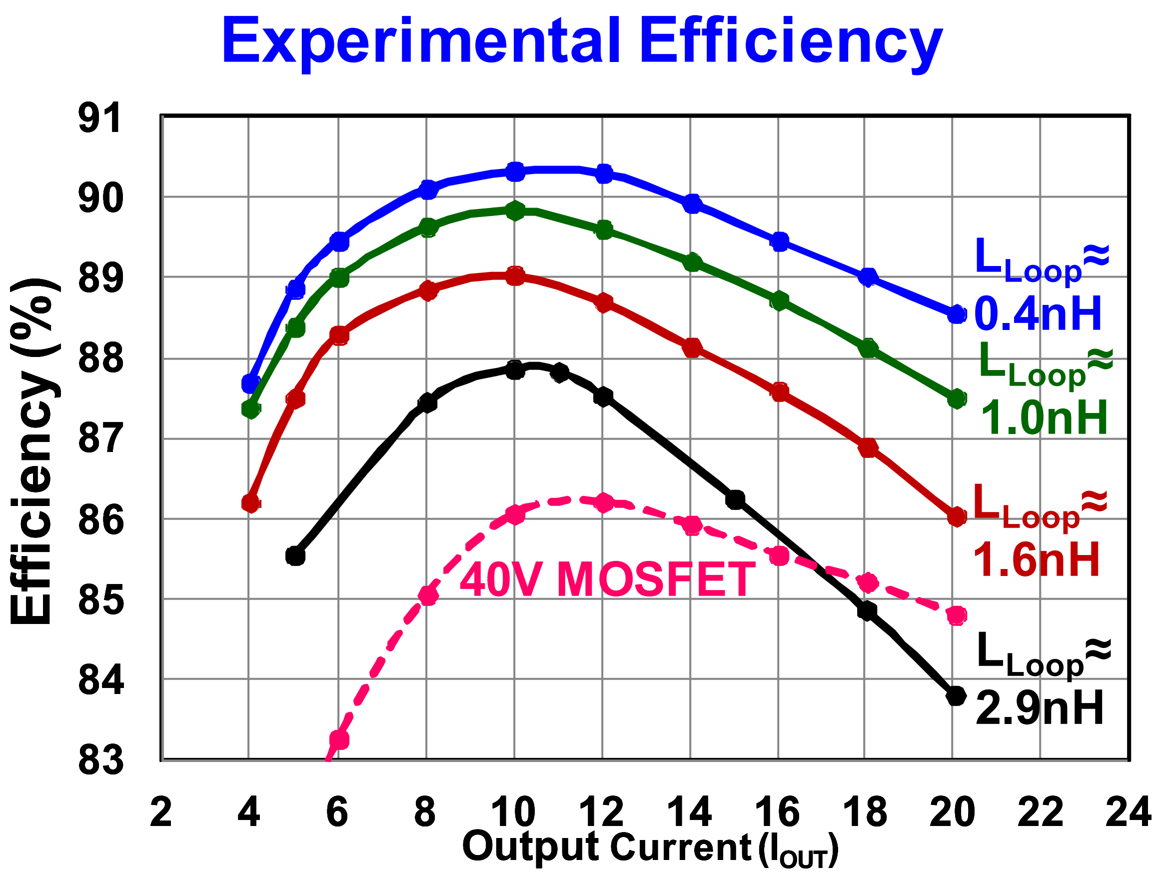
V_{IN}=12 V, V_{OUT}=1.2 V, F_S=1 MHz, I_{OUT}= 20 A

Packaging Evolution



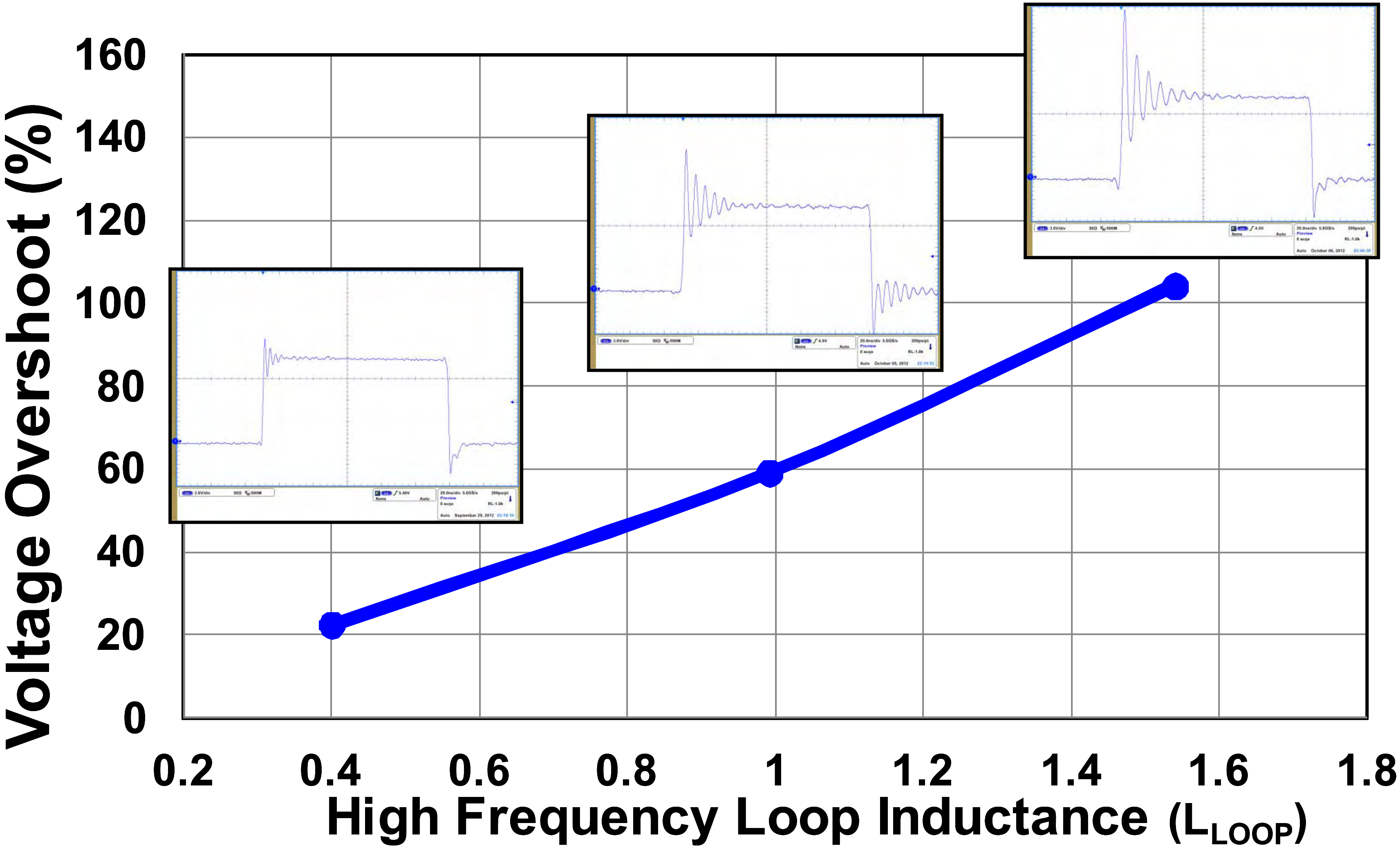






V_{IN}=12 V, V_{OUT}=1.2 V,
F_S=1 MHz, L=150 nH

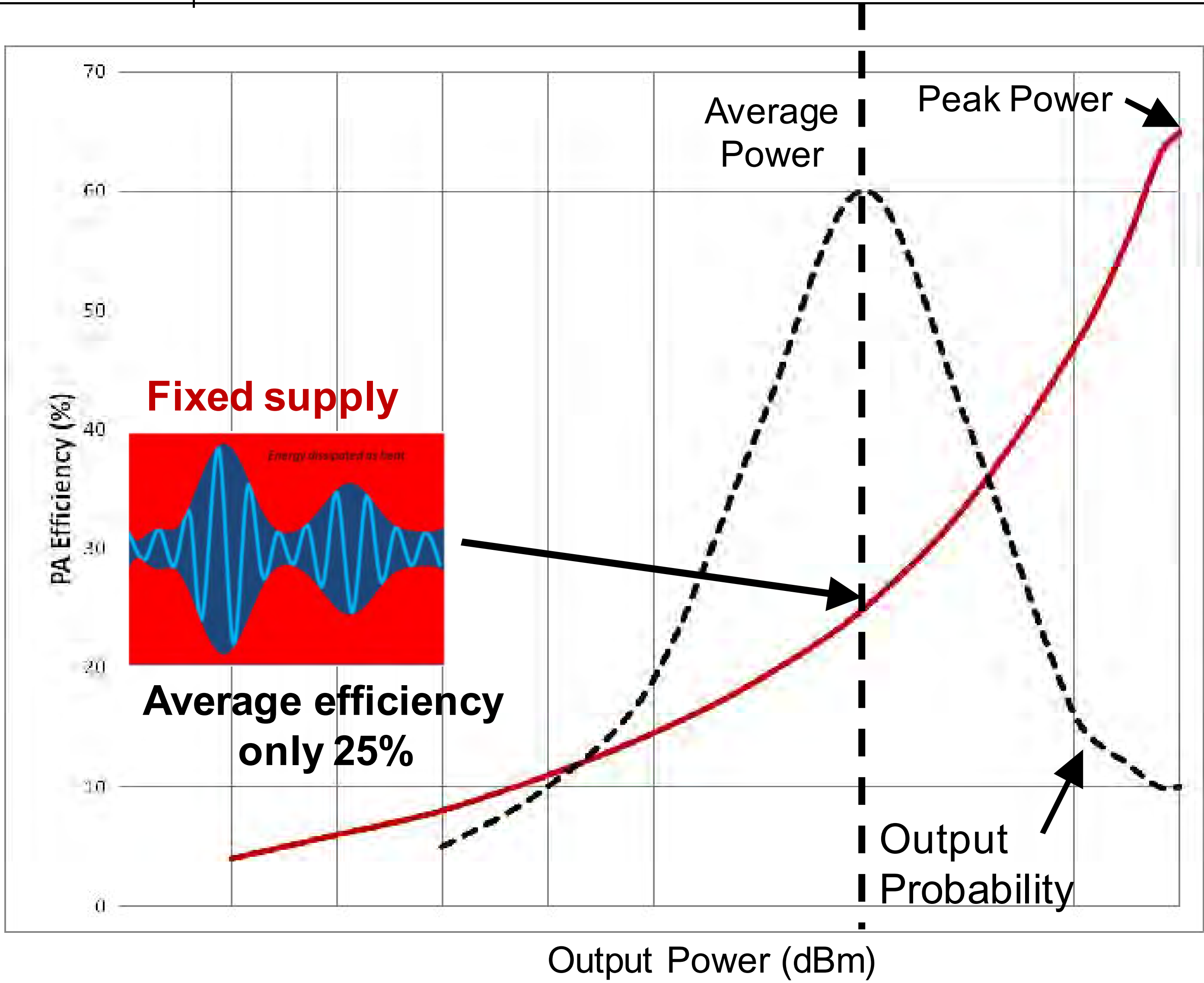
Peak Voltage Comparison

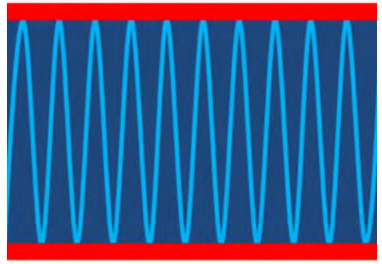


V_{IN}=12 V, V_{OUT}=1.2 V, F_S=1 MHz, L=150 nH

Envelope Tracking

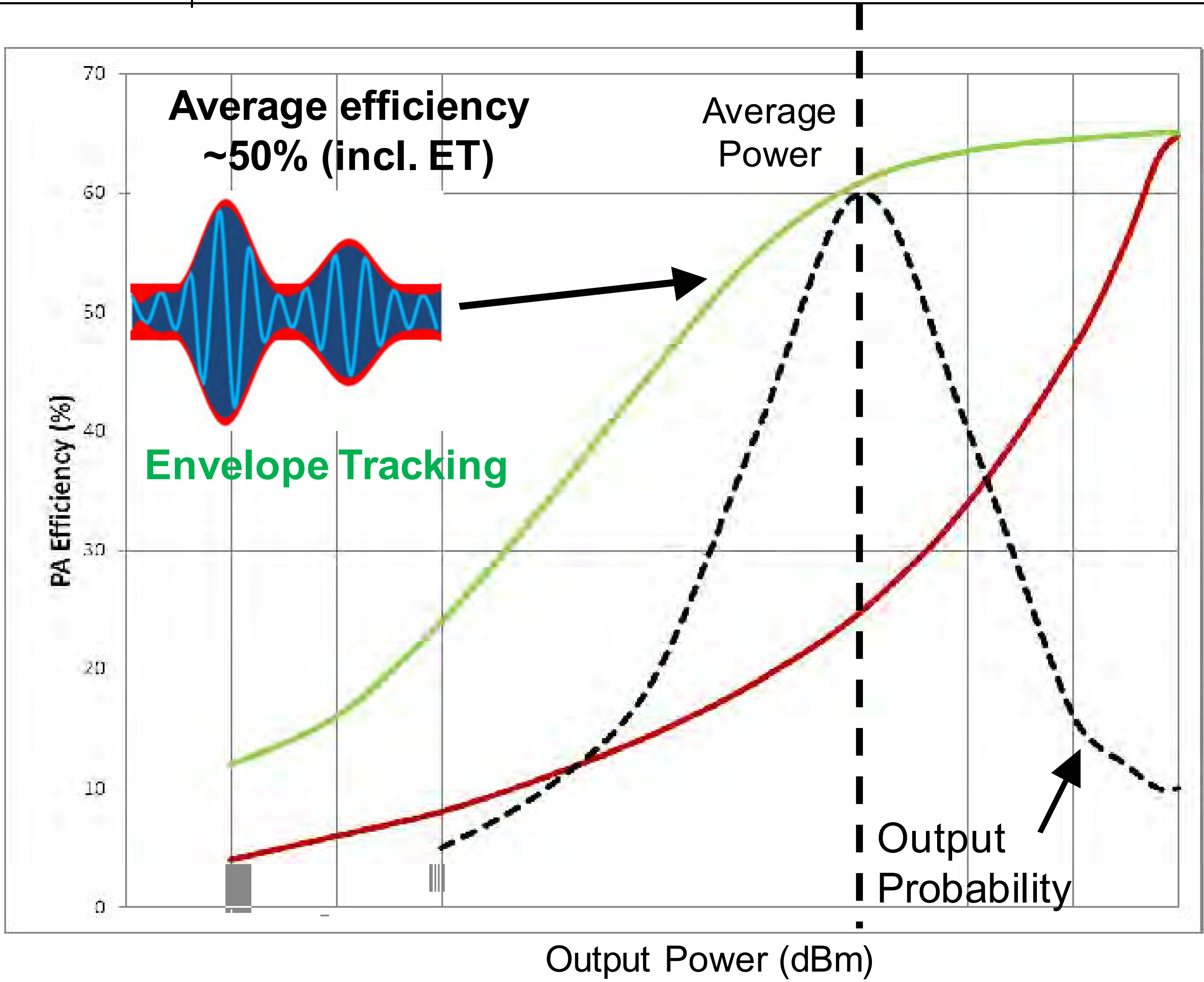
RF Transmission



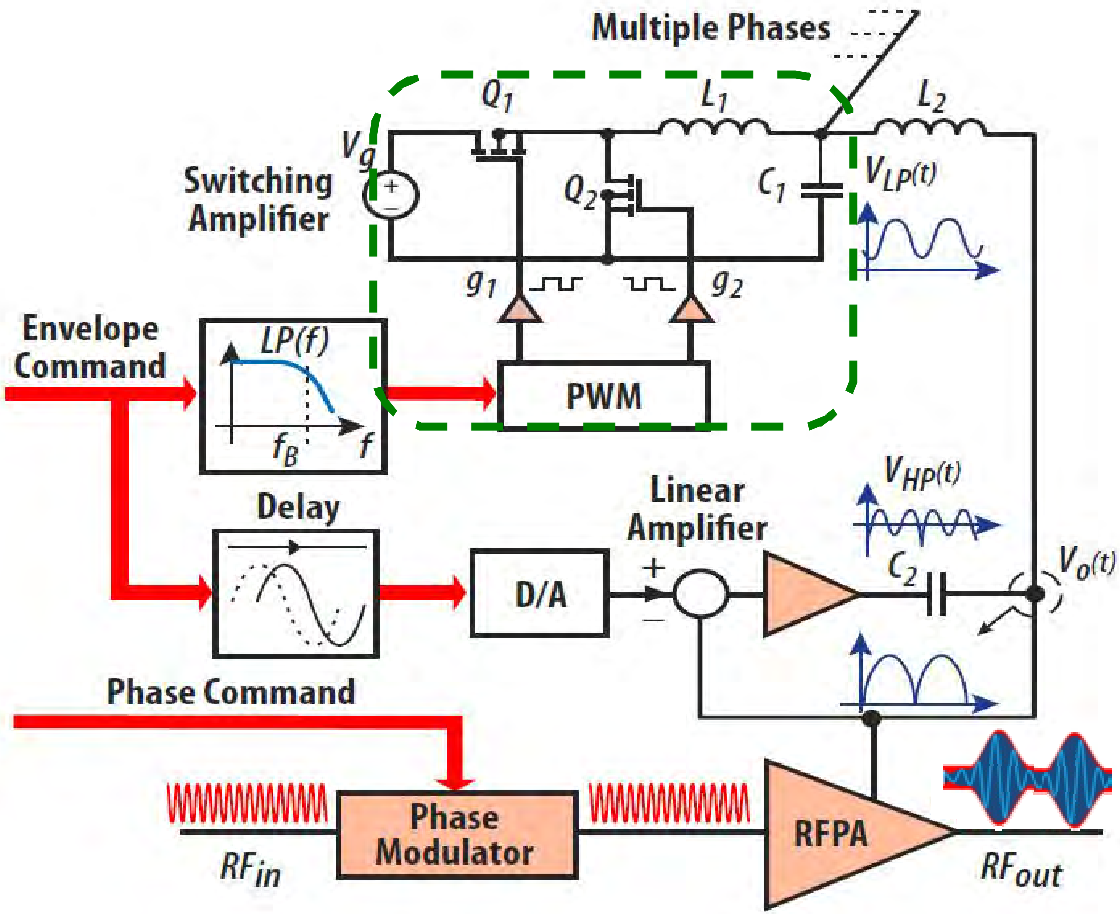


Peak efficiency up to 65%

Effect of ET

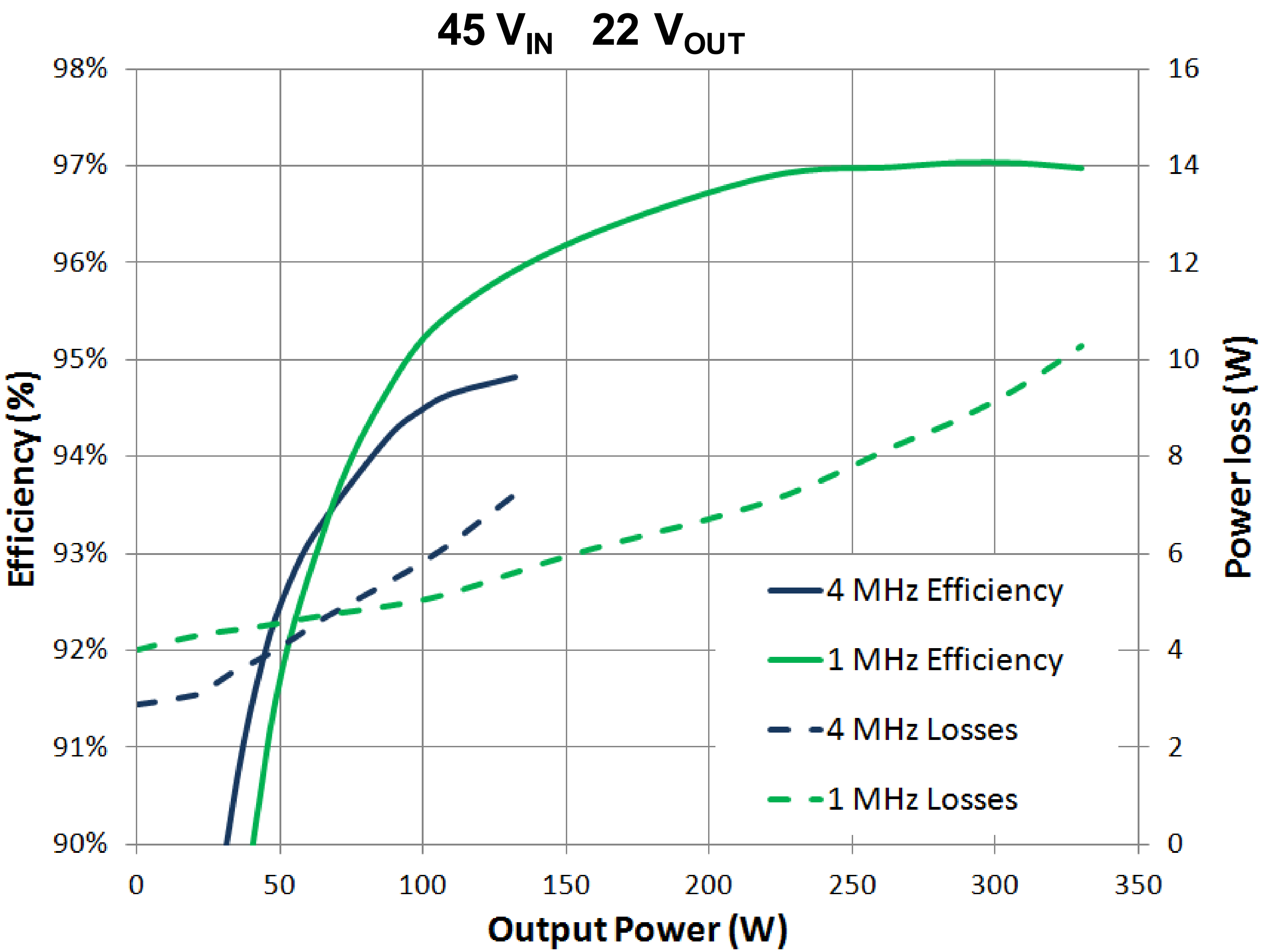


Average efficiency
~50% (incl. ET)
Average
Power
Envelope Tracking
PA Efficiency (%)
70
60
50
40
30
20
10
0
Output
Probability
Output Power (dBm)



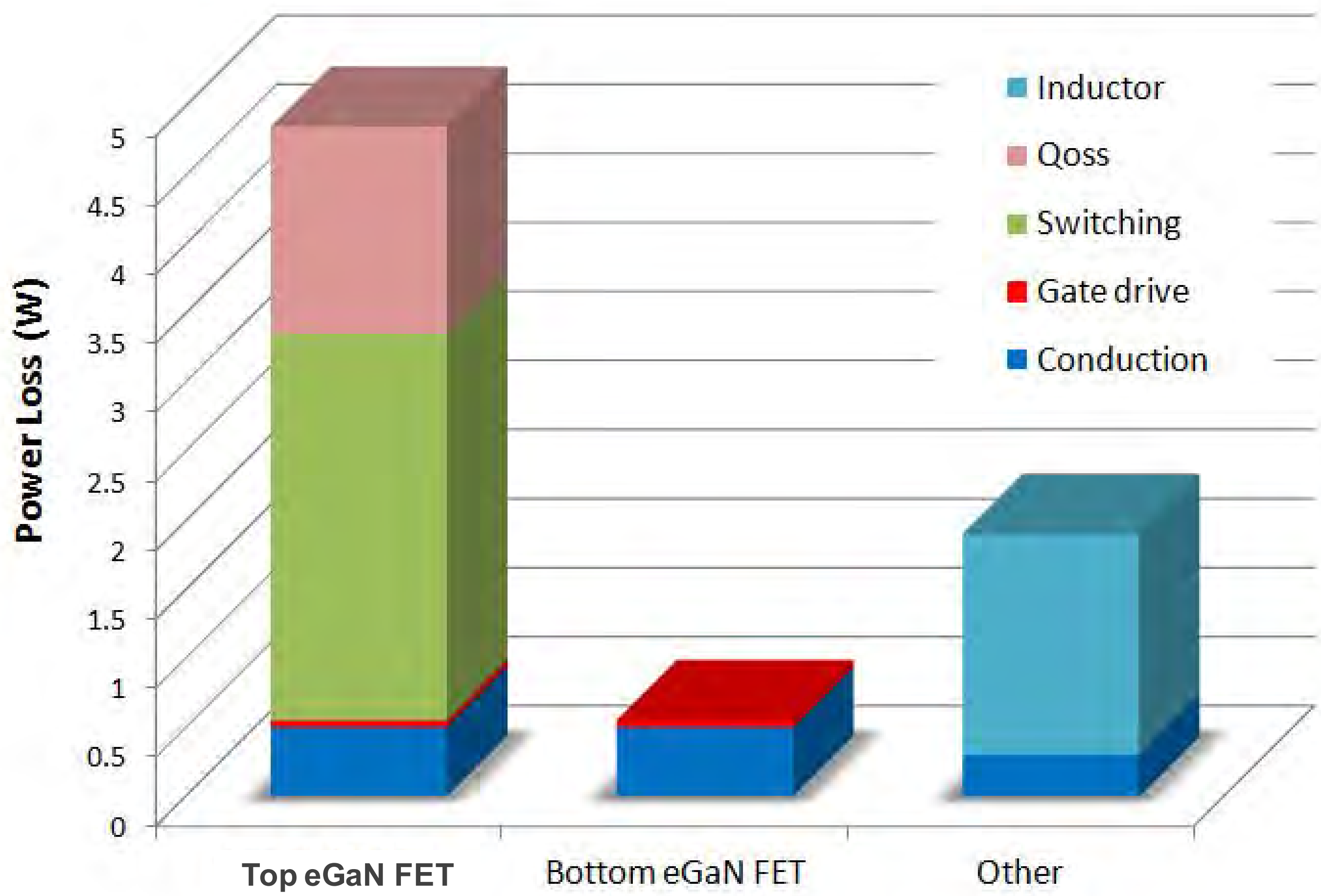
Multiple Phases
Q_1
L_1
L_2
V_g
Switching Amplifier
Q_2
C_1
$V_{LP}(t)$
g_1
g_2
Envelope Command
$LP(f)$
f_B
f
PWM
Delay
Linear Amplifier
$V_{HP}(t)$
D/A
C_2
$V_o(t)$
Phase Command
Phase Modulator
RFPA
RF_{in}
RF_{out}

Efficiency



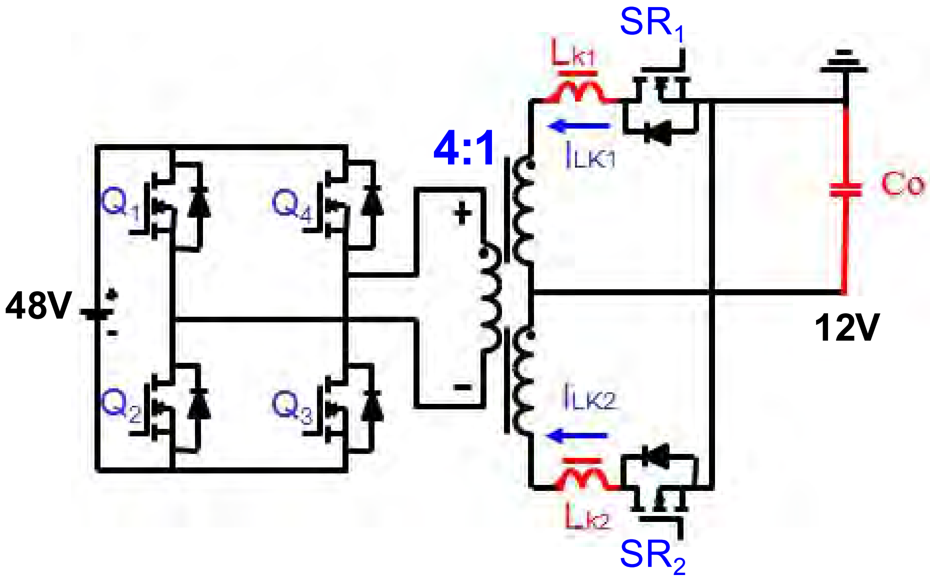
45 VIN 22 VOUT
Efficiency (%)
98%
97%
96%
95%
94%
93%
92%
91%
90%
Power loss (W)
16
14
12
10
8
6
4
2
0
0
50
100
150
200
250
300
350
Output Power (W)
4 MHz Efficiency
1 MHz Efficiency
4 MHz Losses
1 MHz Losses

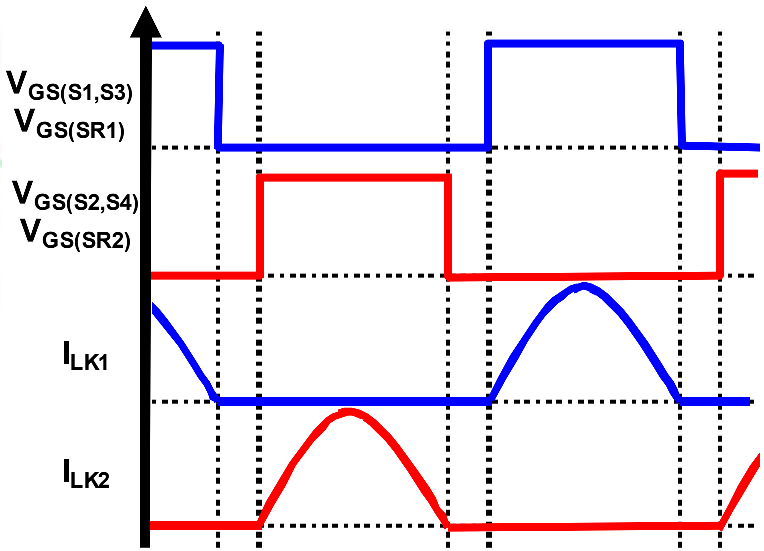
4MHz Loss Breakdown



Resonant Converters

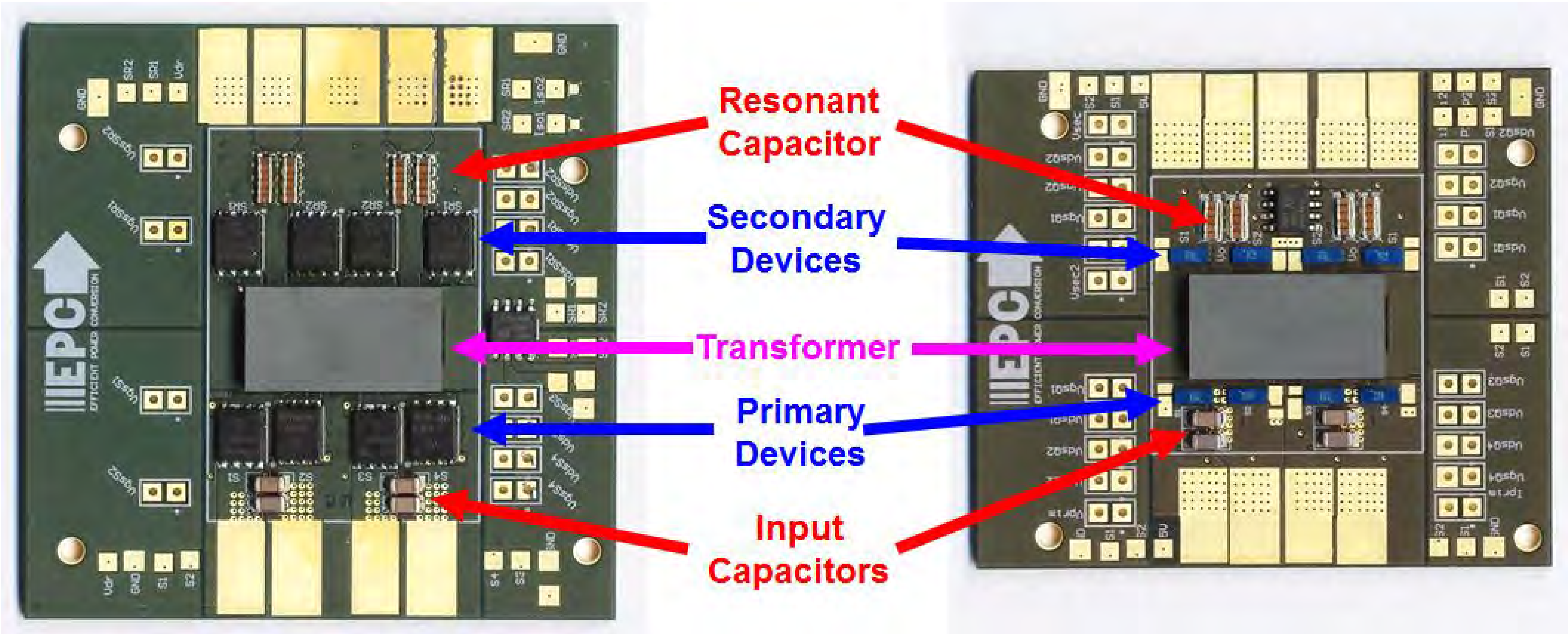
Resonant Converter



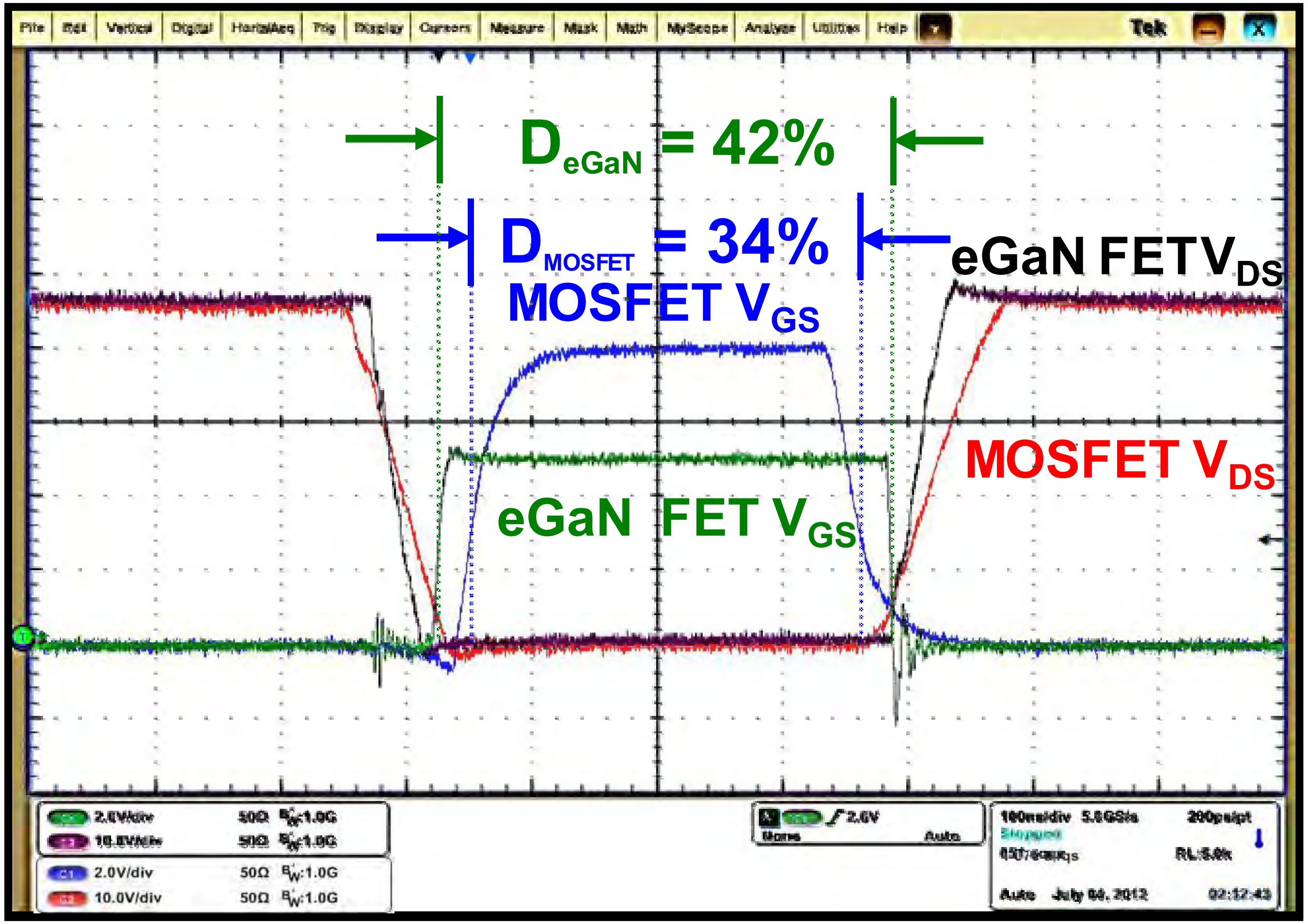


Ref: Y. Ren, M. Xu, J. Sun, and F. C. Lee, "A family of high power density unregulated bus converters," IEEE Trans. Power Electron., vol. 20, no. 5, pp. 1045–1054, Sep. 2005.

eGaN® FET vs MOSFET

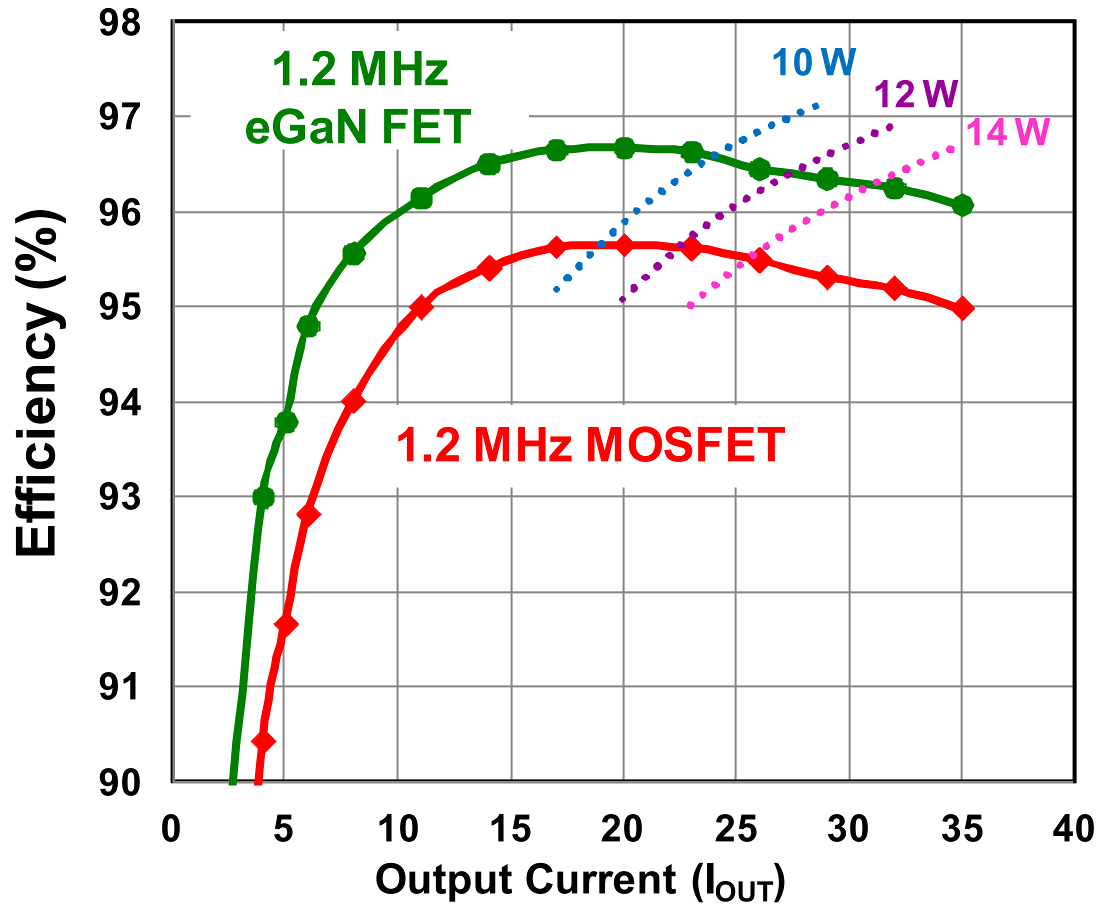


Duty Cycle Comparison



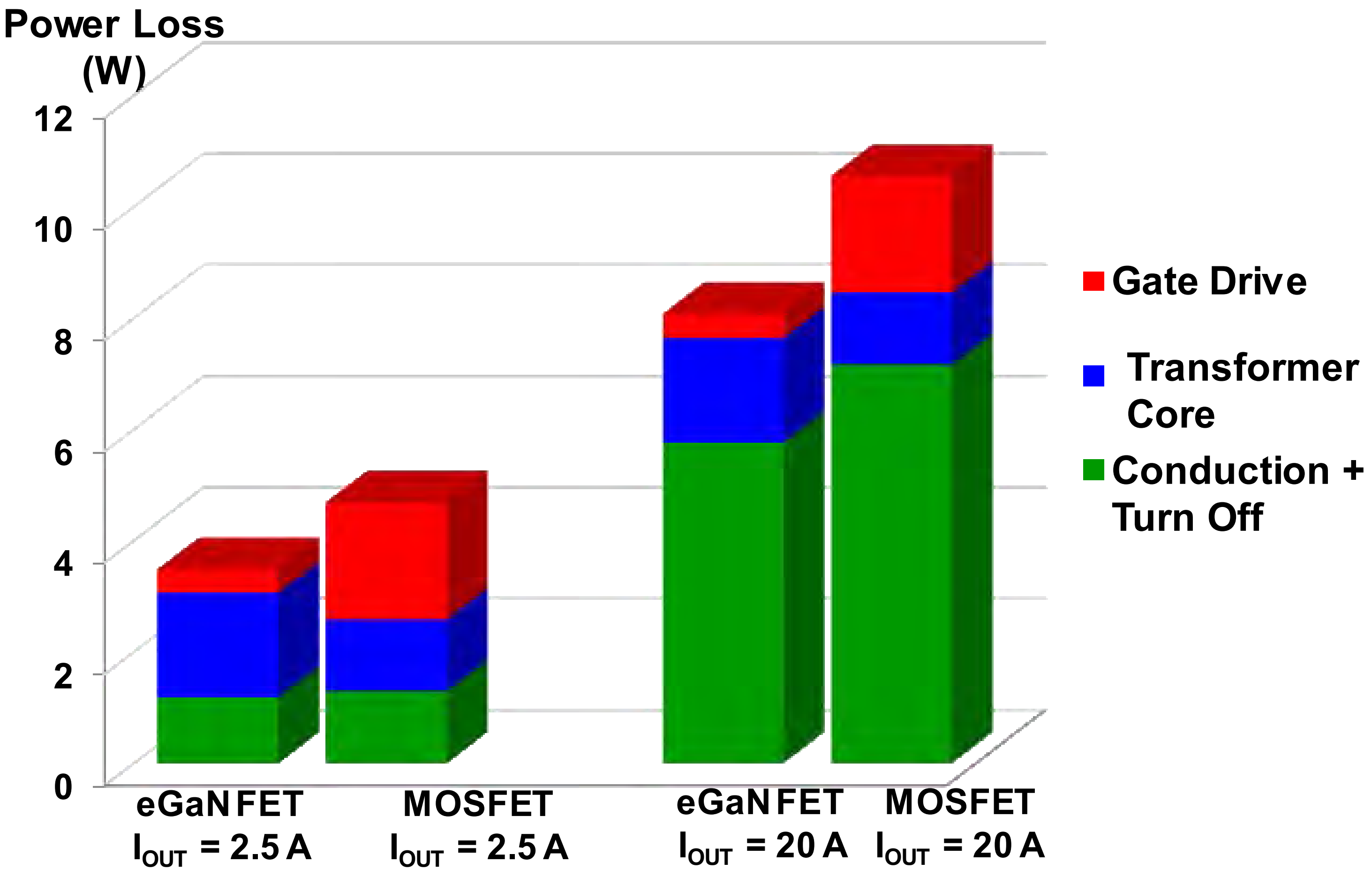
F_S = 1.2 MHz, V_{IN} = 48 V, and V_{OUT} = 12 V

Efficiency Comparison



F_S = 1.2 MHz, V_{IN} = 48 V, and V_{OUT} = 12 V

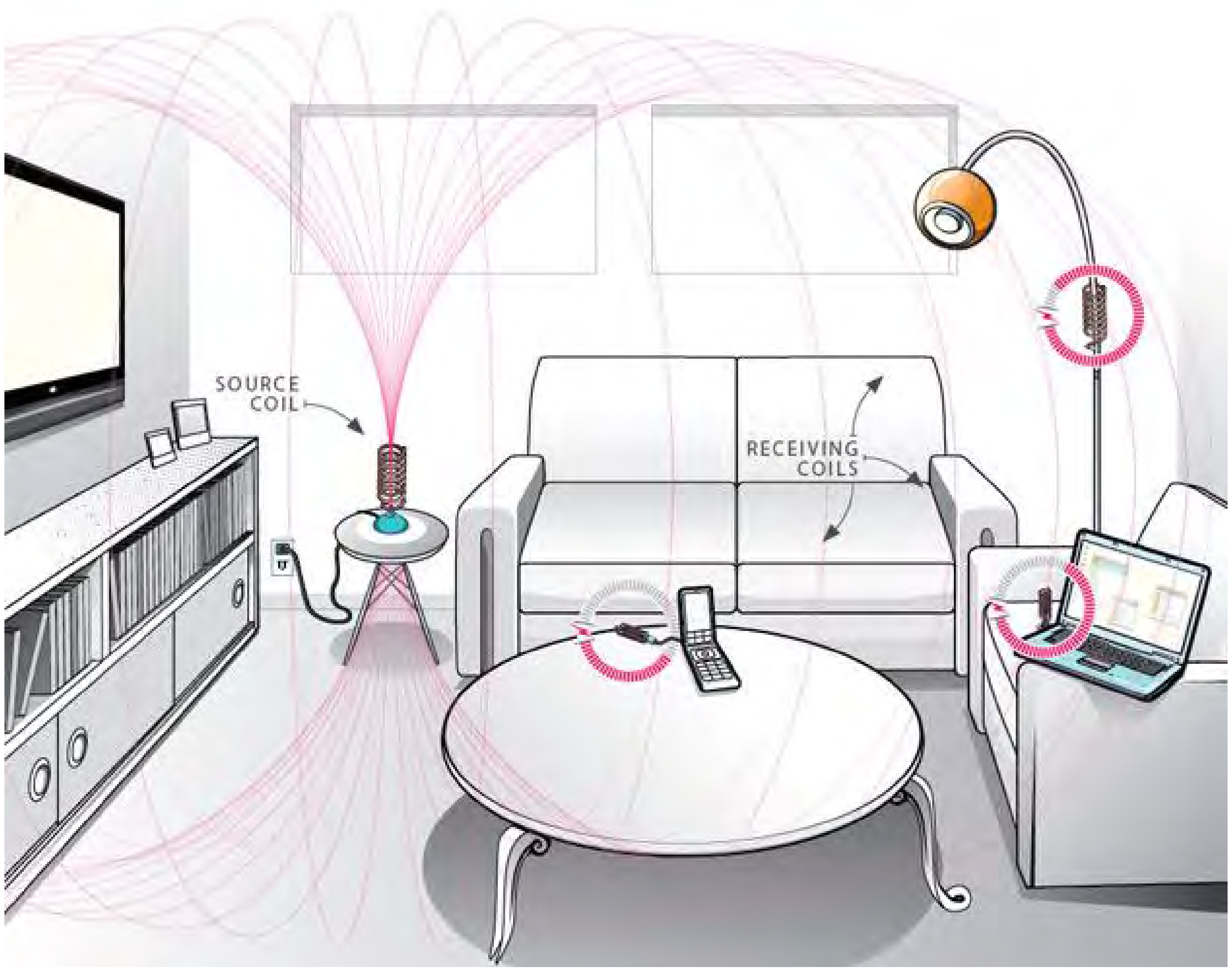
Loss Breakdown



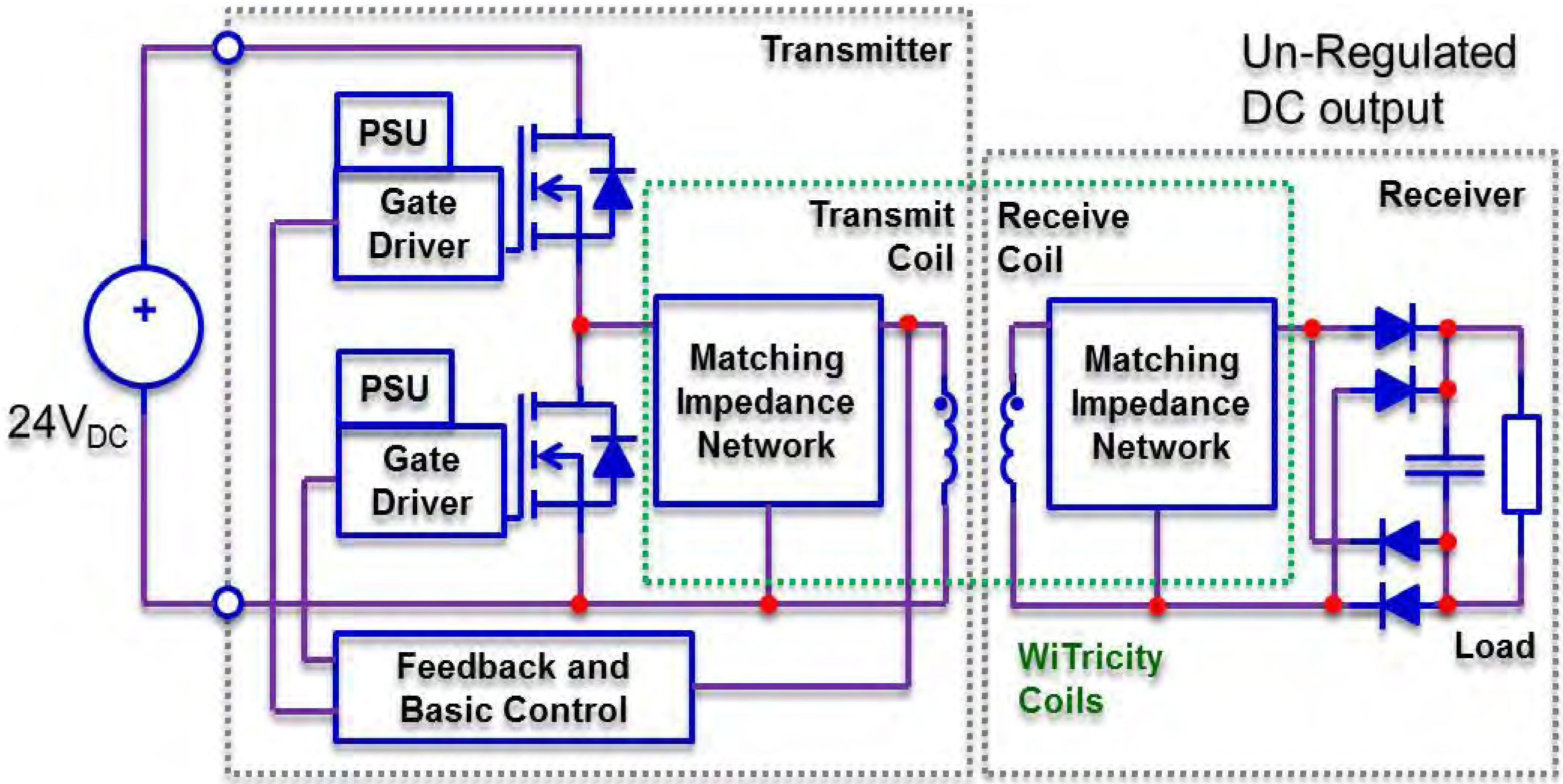
F_S = 1.2 MHz, V_{IN} = 48 V, and V_{OUT} = 12 V

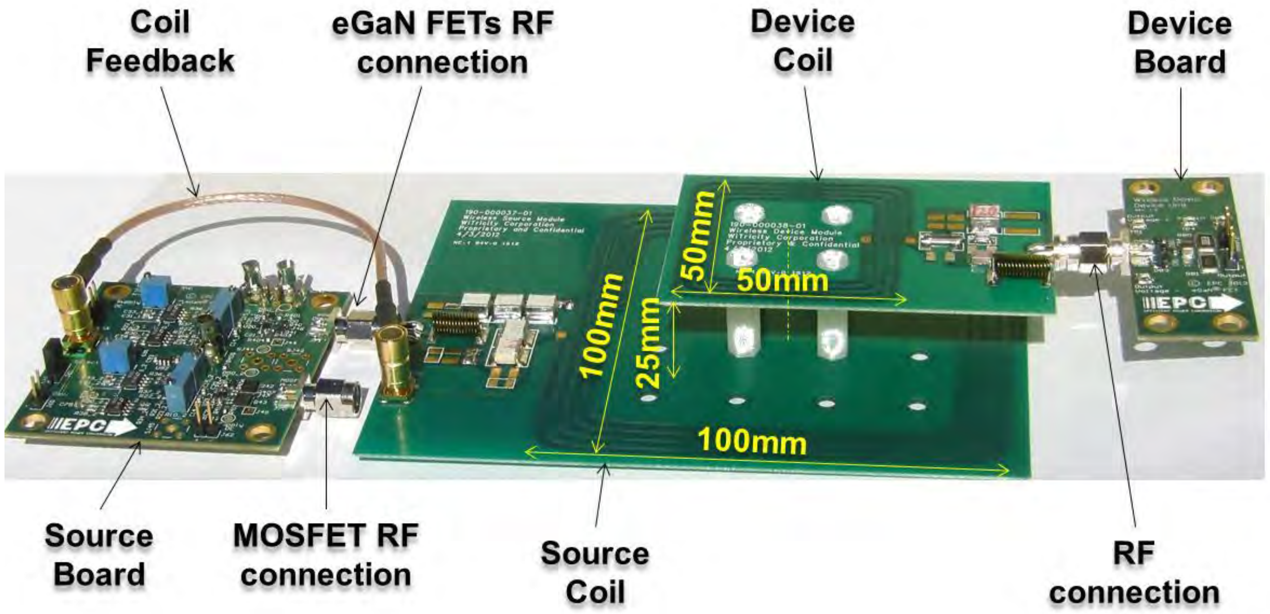
Wireless Power

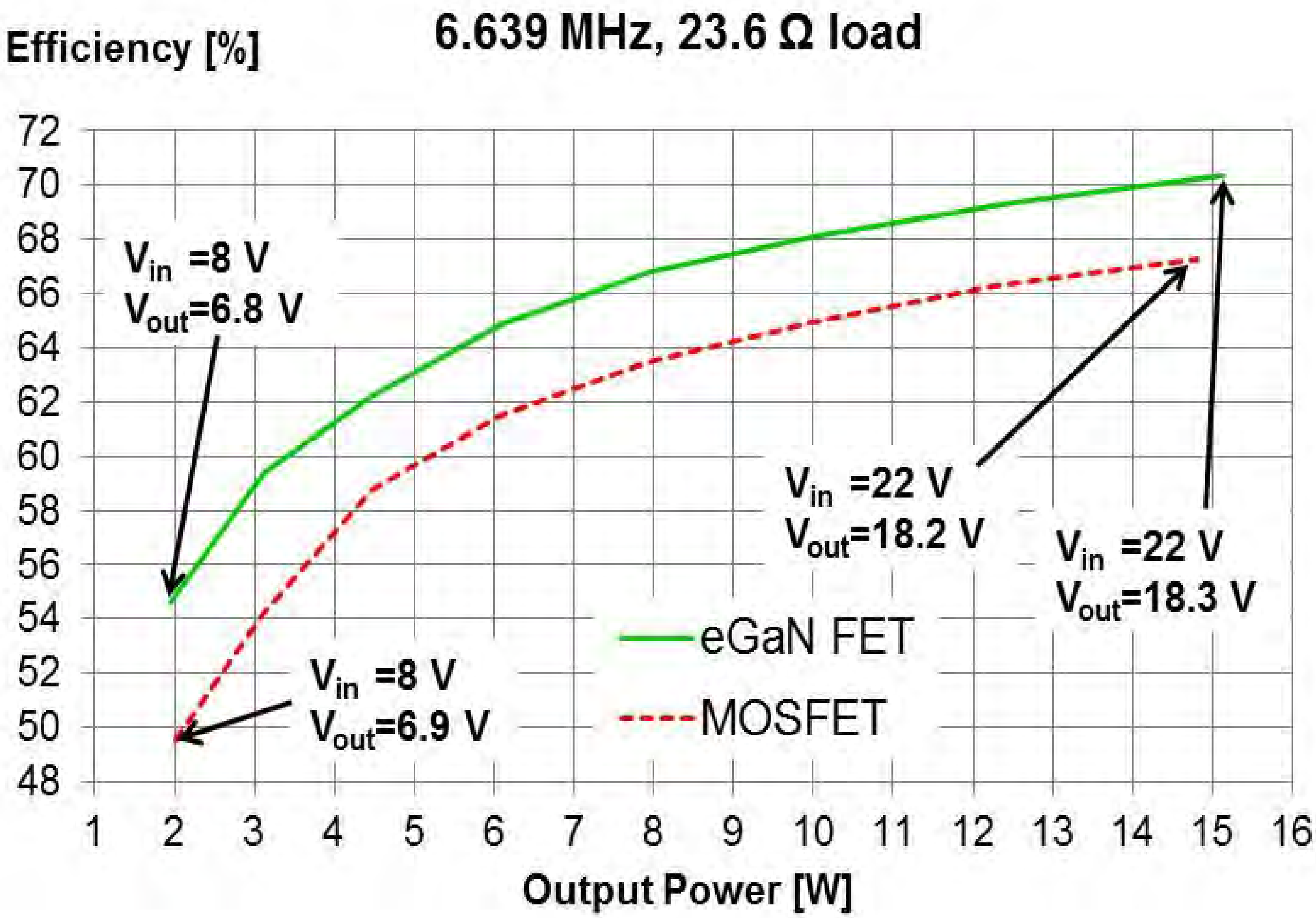
Wireless Power



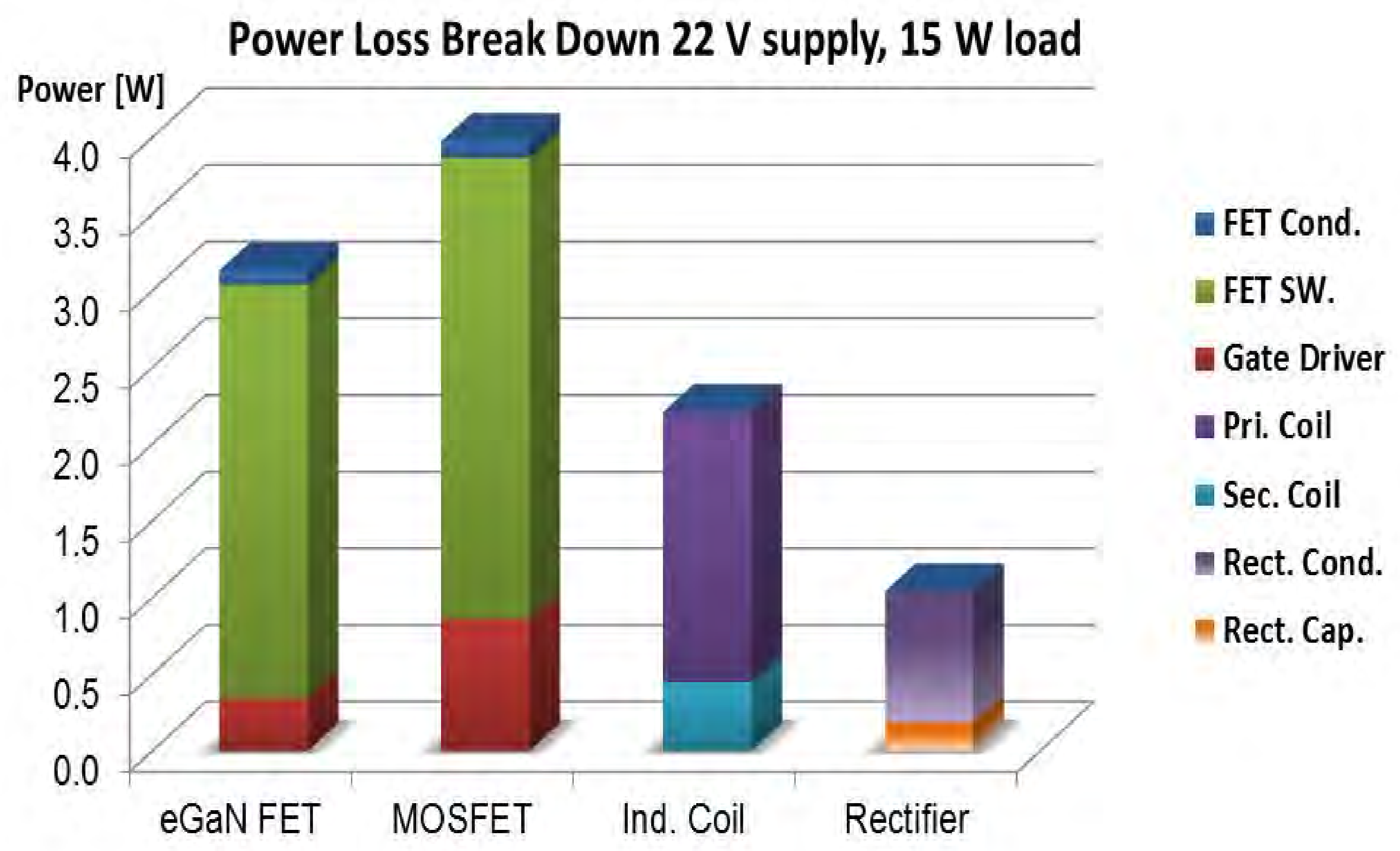
Wireless Power




Coil Feedback
eGaN FETs RF connection
Device Coil
Device Board
50mm
50mm
100mm
25mm
100mm
Source Board
MOSFET RF connection
Source Coil
RF connection


Efficiency [%]
6.639 MHz, 23.6 Ω load
72
70
68
66
64
62
60
58
56
54
52
50
48
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Output Power [W]
V_in =8 V
V_out=6.8 V
V_in =8 V
V_out=6.9 V
V_in =22 V
V_out=18.2 V
V_in =22 V
V_out=18.3 V
eGaN FET
MOSFET

Loss Breakdown



Summary

- eGaN FETs operate efficiently in multi-megahertz envelope tracking systems which can reduce transmit power by 50%.
- eGaN FETs reduce power losses by 25% or more in 1.2 MHz resonant DC-DC converters.
- eGaN FETs reduce power losses by 25% in 6.78 MHz wireless power transmission systems.
- You can always improve efficiency with eGaN FETs!

EPC
EFFICIENT POWER CONVERSION

The end of the road
for silicon…..

is the beginning of
the eGaN FET
journey!