Enabling Envelope Tracking through GaN Transistors

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Agenda

- Overview of Envelope Tracking (ET)
- Example *eGaN*® FET Power Stage
- Opportunities in ET
- Conclusions

Overview of Envelope Tracking

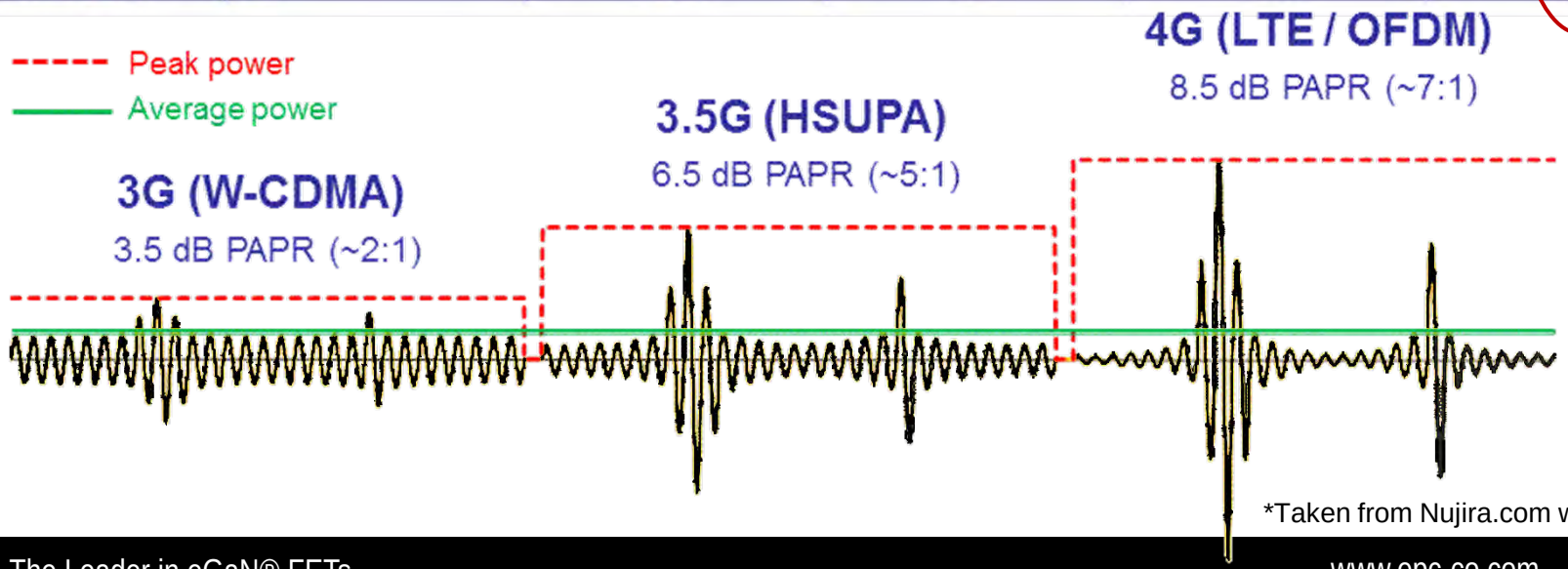
- World of Radio Frequency Power Amplifiers (RFPA)s is changing.

- Increased efficiency driven by:
  - Improved battery life
  - Reduced cooling
  - Reduced size
  - Lower cost of operation

RFPA Standards*

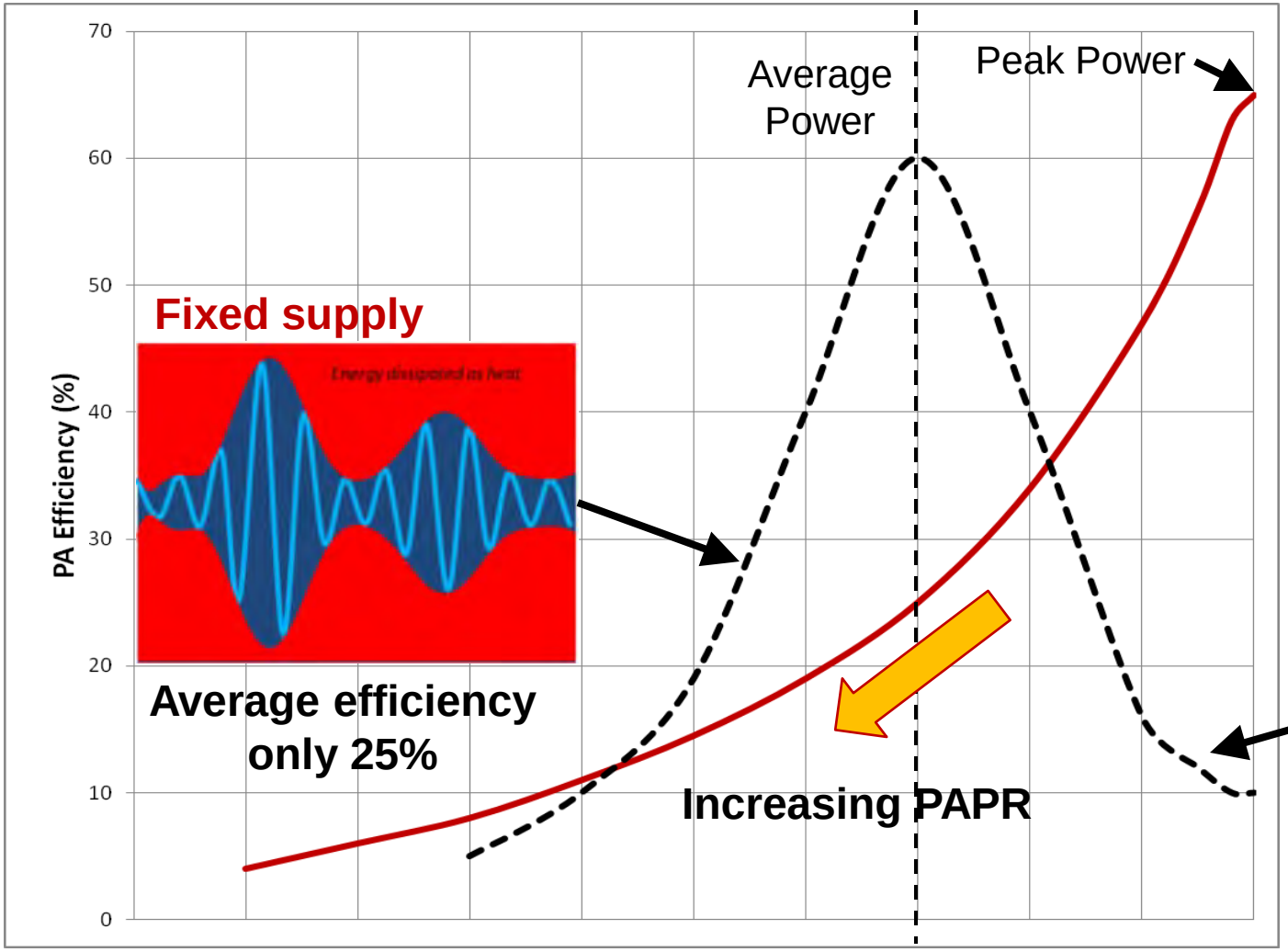
*Taken from www.open-et.org website

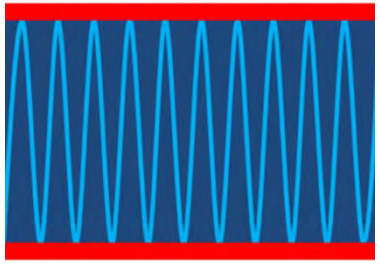
Standard	Launched	Typ. Carrier BW (MHz)	Typ. Spectral Efficiency (bps/Hz)	Approx. PAPR(dB)
2G cellular	GSM	1991	0.2	0.17	0.0
Digital TV	DVB-H	2007	8	0.28	8.0
2.75G cellular	GSM + EDGE	2003	0.2	0.33	3.5
3G cellular	WCDMA FDD	2001	5	0.51	7.0
Digital TV	DVB-T	1997	8	0.55	8.0
Wi-Fi	IEEE 802.11a/g	2003	20	0.90	9.0
WiMAX	IEEE 802.16d	2004	20	1.20	8.5
Wi-Fi	IEEE 802.11n	2007	20	2.40	9.0
3.5G cellular	HSDPA	2007	5	2.88	8.0
3.9G cellular	LTE	2009	20	8.00	10.0



*Taken from Nujira.com website

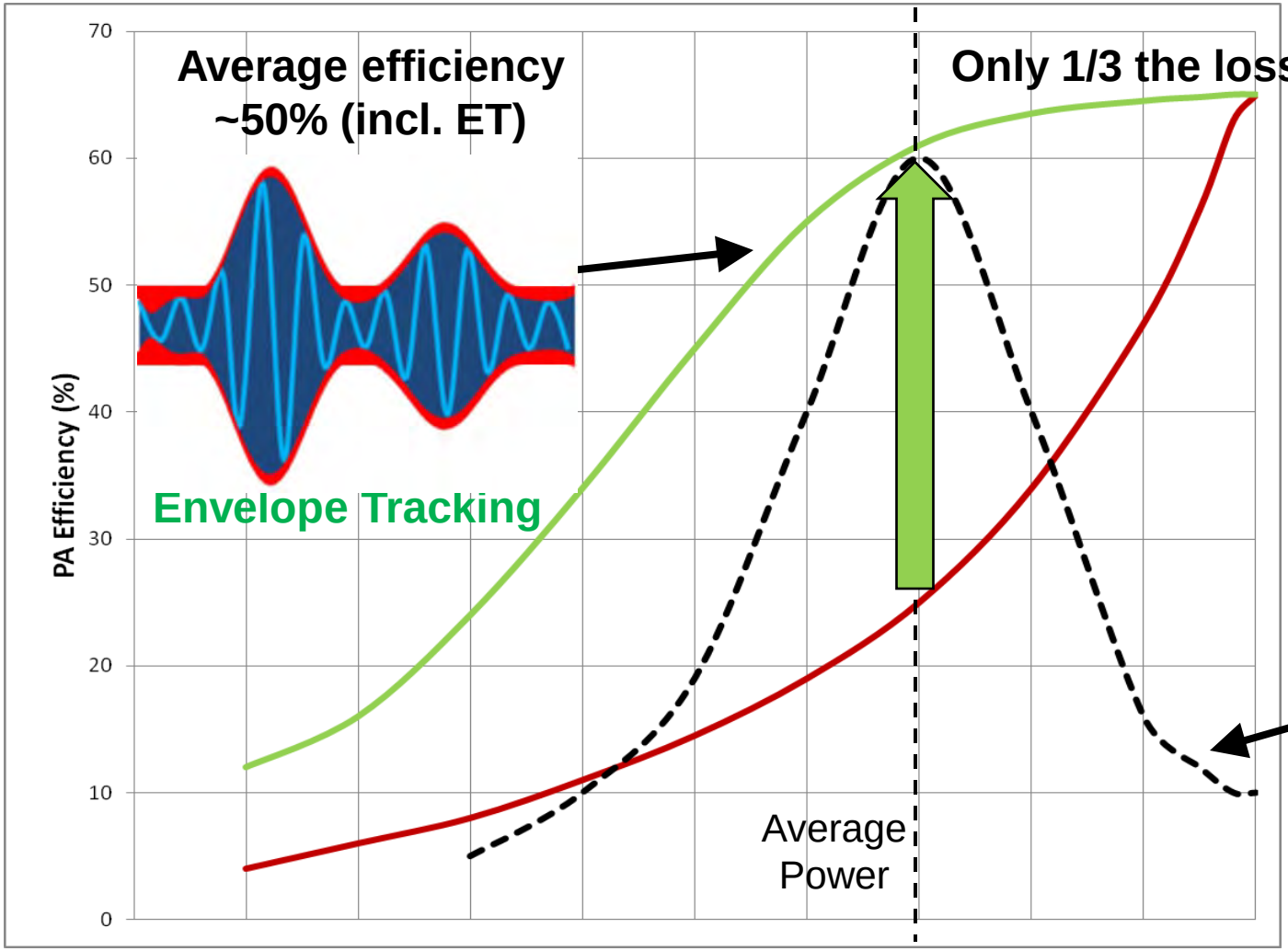
Effect of PAPR





PAPR = 0dB
Peak efficiency up to 65%

Effect of ET


Average efficiency
~50% (incl. ET)
Only 1/3 the losses
Envelope Tracking
PA Efficiency (%)
70
60
50
40
30
20
10
0
Output Probability
Average
Power
Output Power (dBm)

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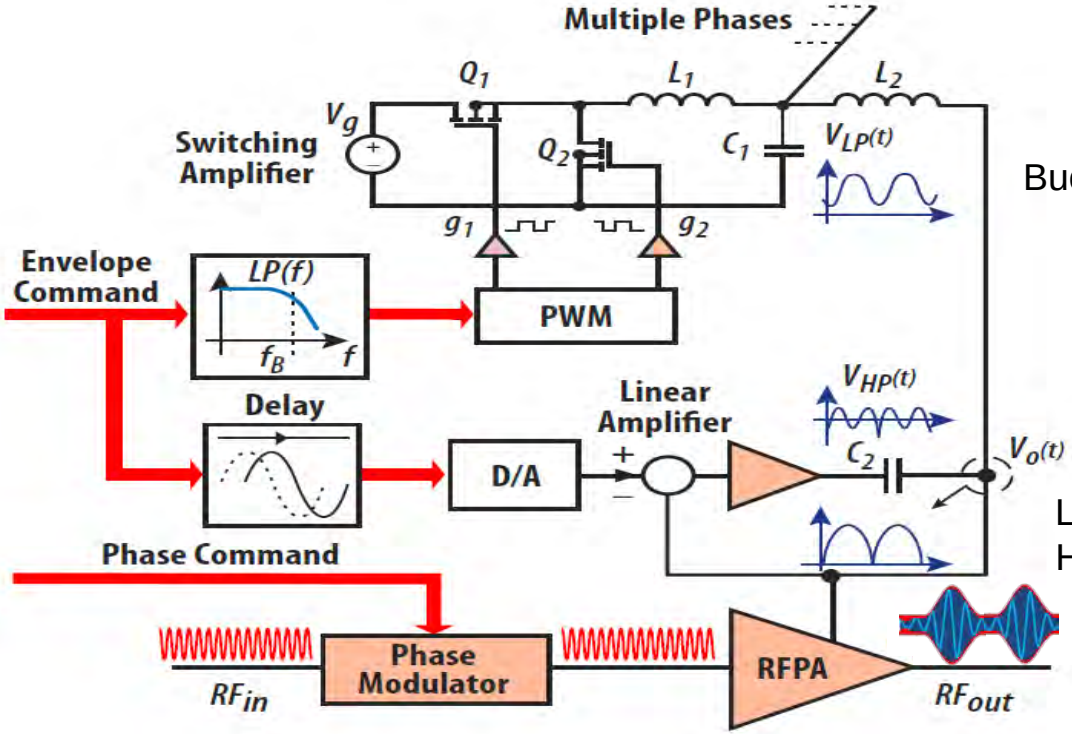
3.9G cellular	LTE	2009	20	8.00	10.0

- Up to 20 MHz Carrier bandwidth required
- Required ET supply BW up to 5x higher if linear control

*Taken from www.open-et.org website

Envelope Tracking Supply

- ET power supply topologies vary
  - Open loop boost – full BW required
  - Closed loop linear-assisted Buck



Buck ~ 10% Bandwidth
~ 90% Power

Linear AMP ~ 10% Power
Highest 90% of Bandwidth

eGaN FET based Buck(s) for ET

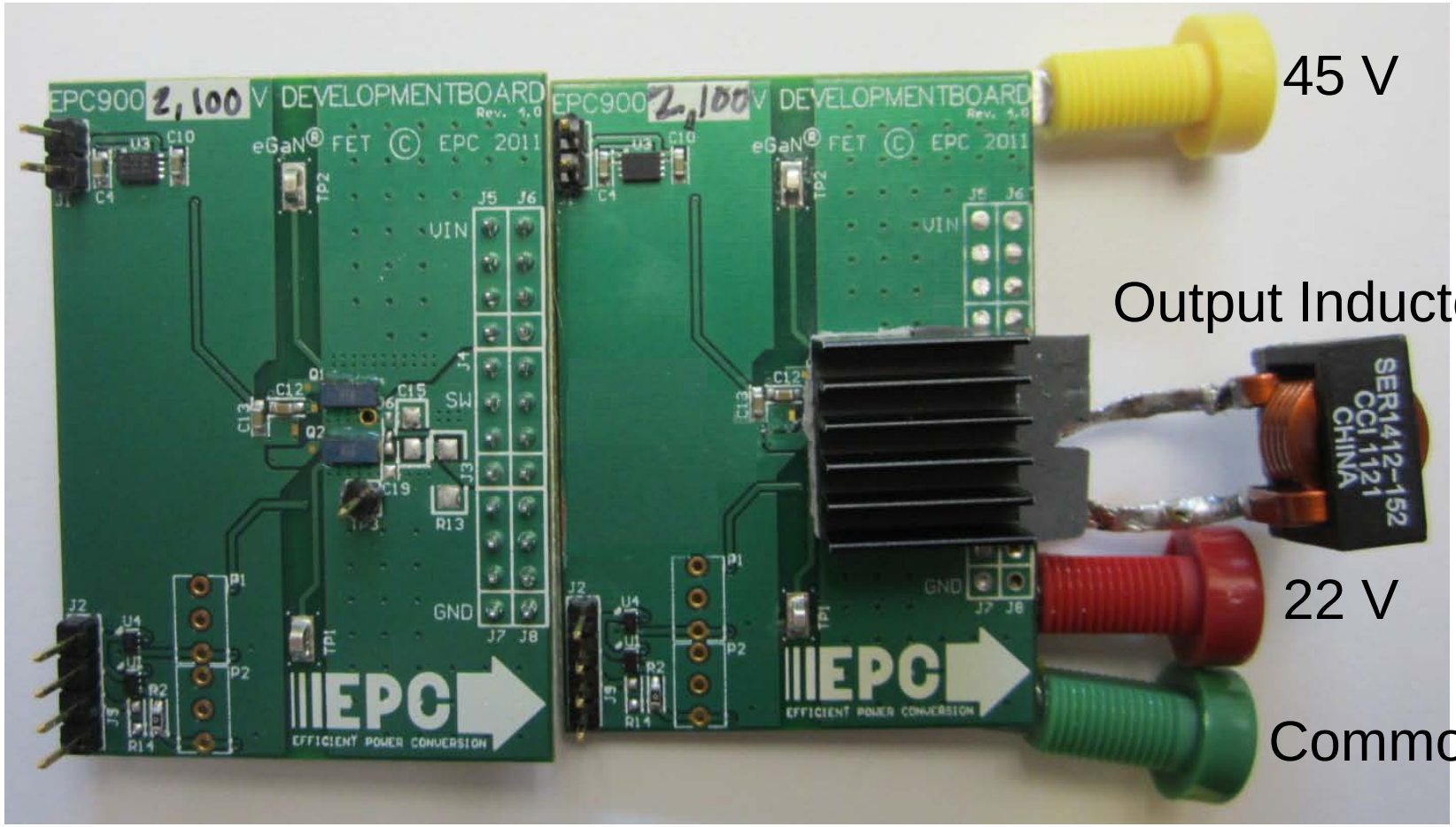
- 1300 W DVB* – 8 MHz BW and 8 dB PAPR
- Linear-assisted Buck for ET
  - 4ϕ x 1 MHz Buck with up to 800 kHz BW
- 45 Vin, 22 Vout/ 15 Aout (Avg)

- Pure Buck option for ET (Push frequency)
  - 10ϕ x 4 MHz Buck with up to 8 MHz BW
- 45 Vin, 22 Vout/ 6 Aout (Avg)

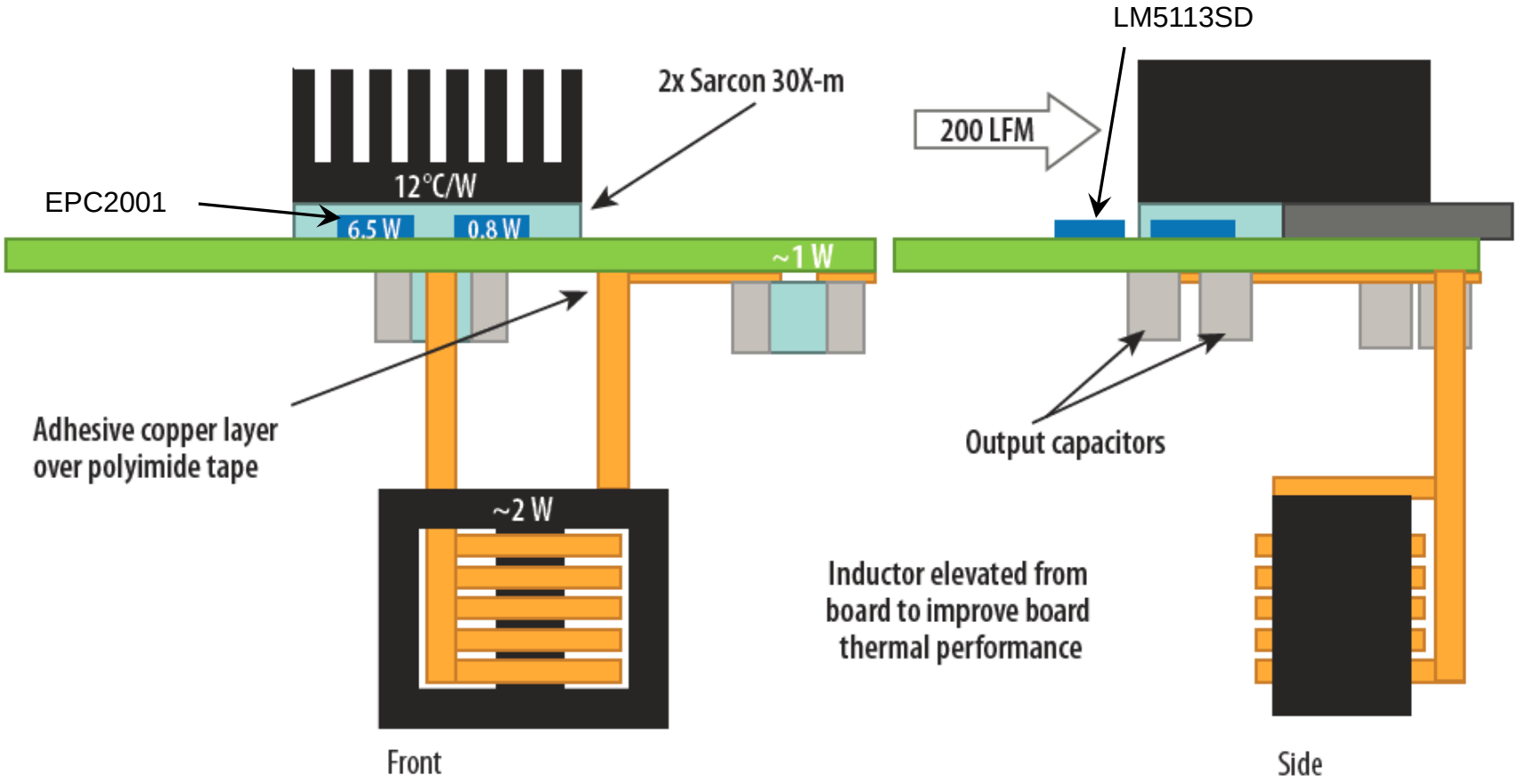
*Representative of a high power ET buck in HV LDMOS, such as that implemented by ET specialist Nujira.

15 A / 1 MHz Single ϕ Buck

- Modified an EPC9002 development board



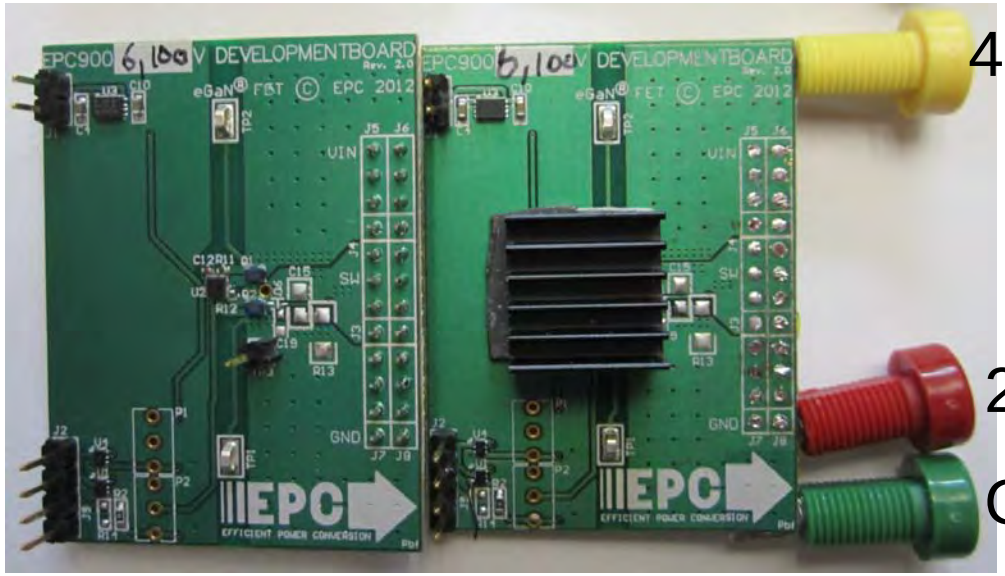
15 A / 1 MHz Single ϕ Buck

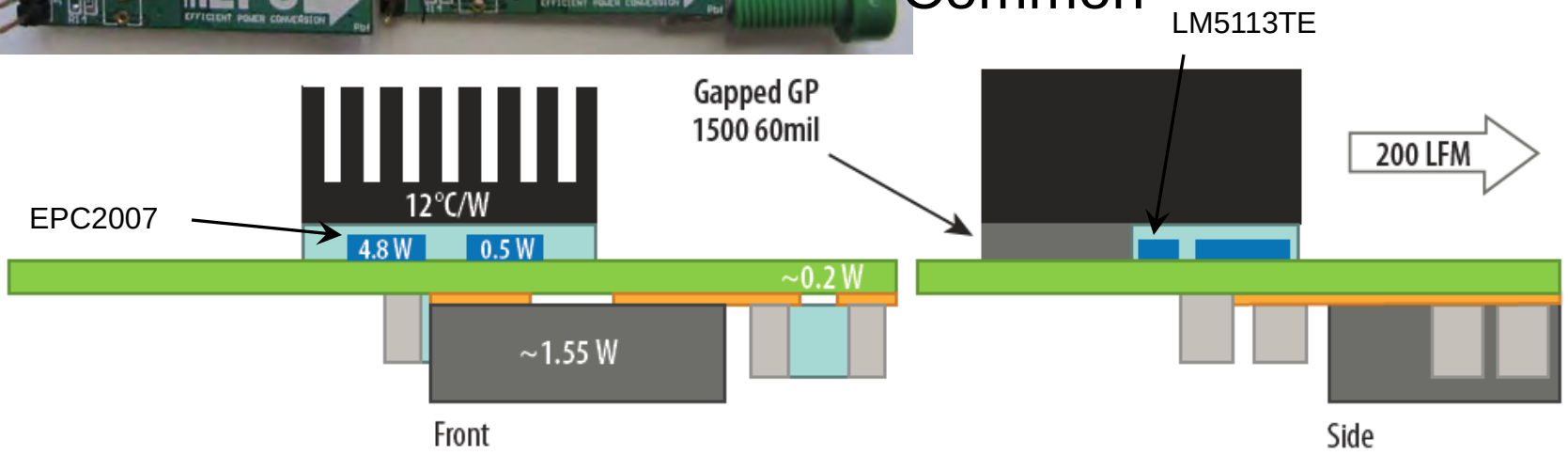


45 V to 22 V, 15 A, 1 MHz buck converter using EPC9002

6 A / 4 MHz Single ϕ Buck

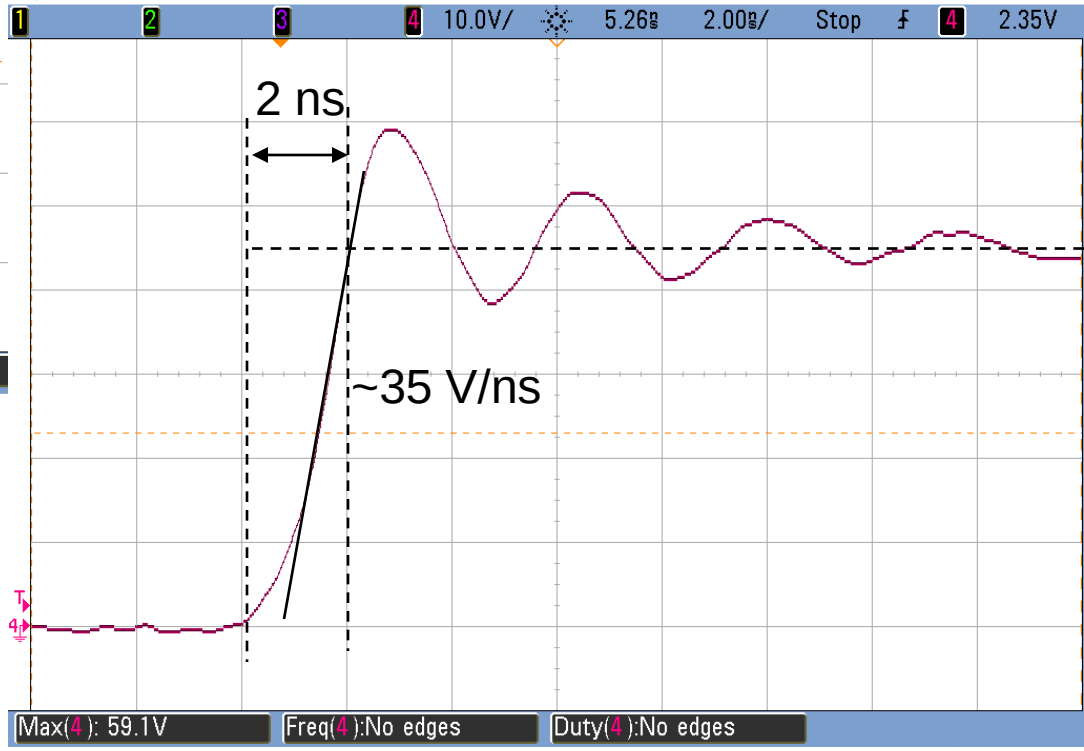
- Modified an EPC9006 development board



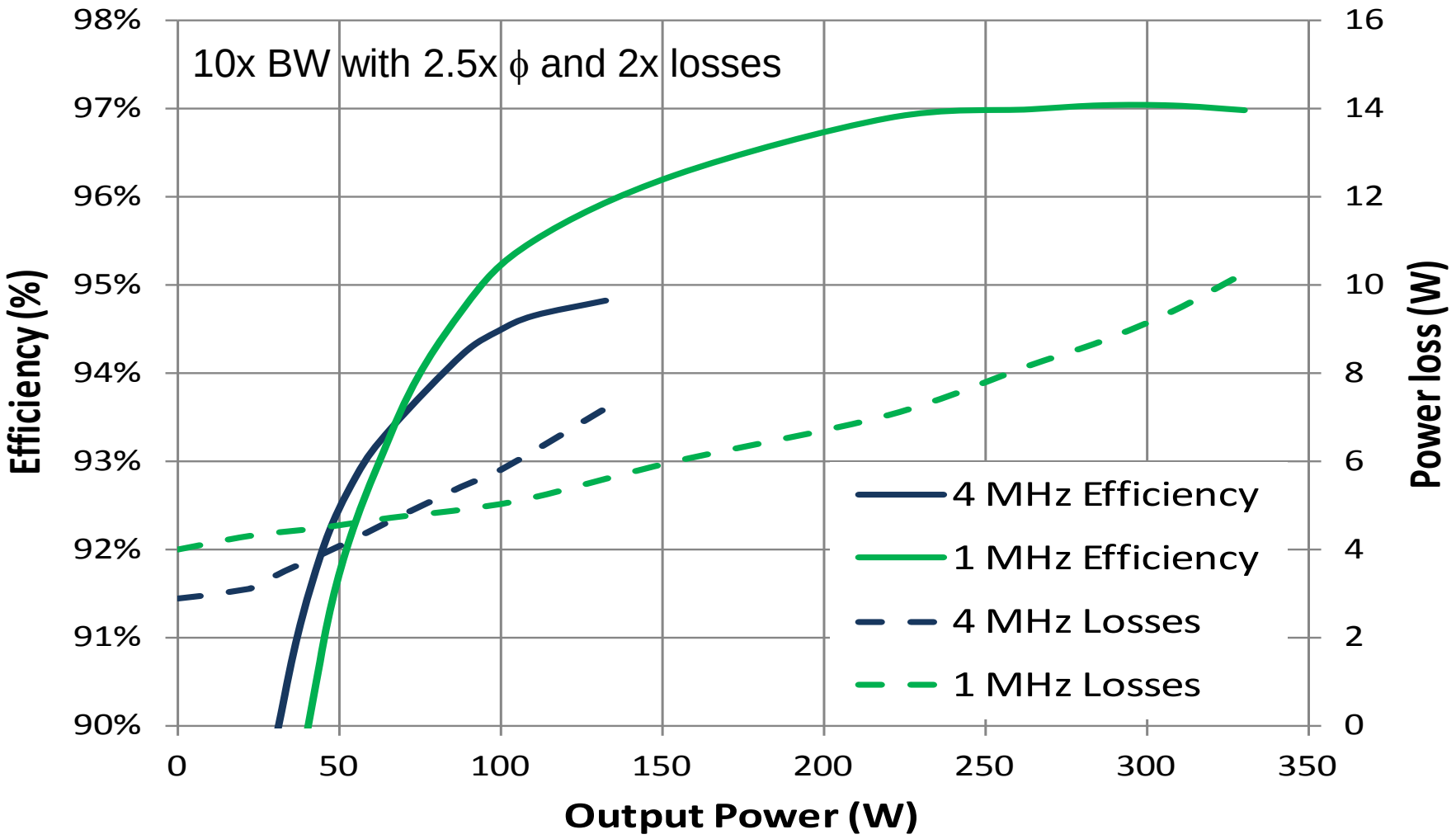


Switching Waveforms

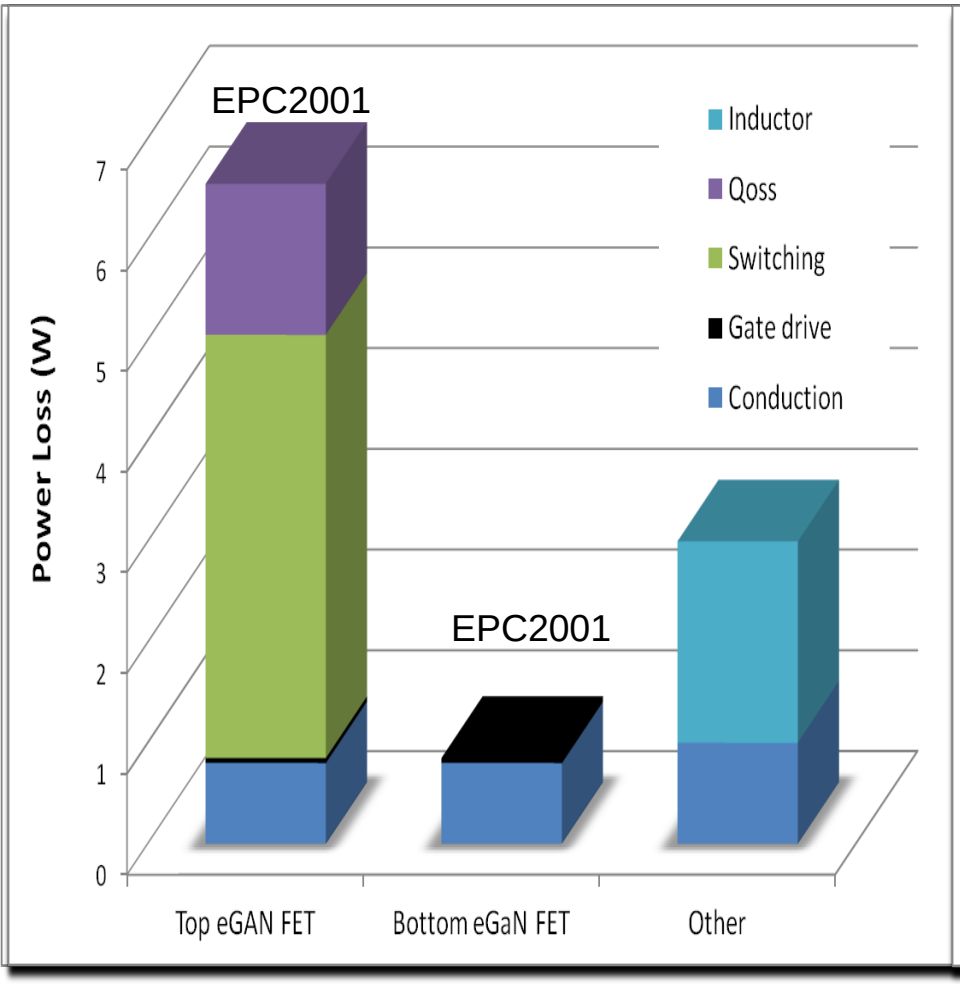
EPC9006 @ 2 A / 4 MHz

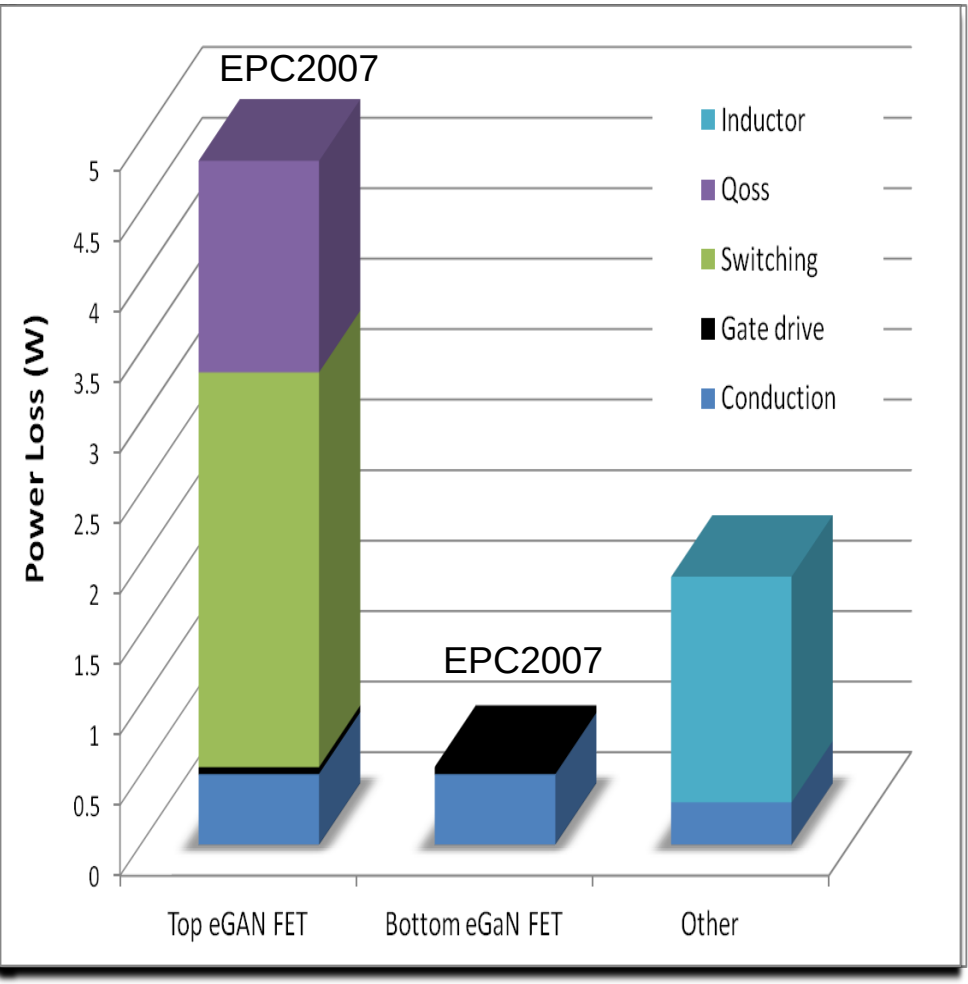


Efficiency Results



Loss Breakdown



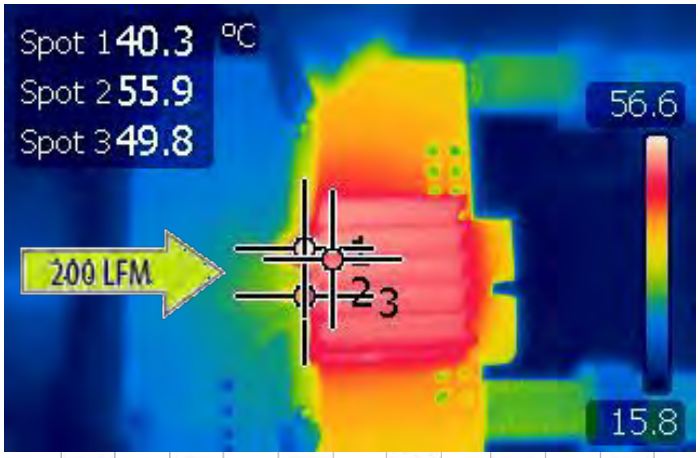


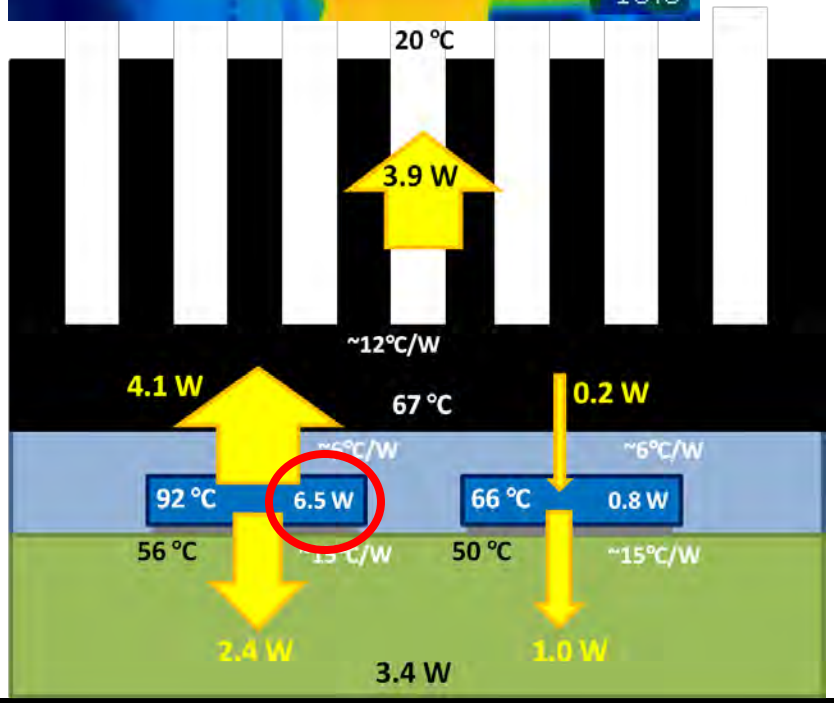
1 MHz EPC9002

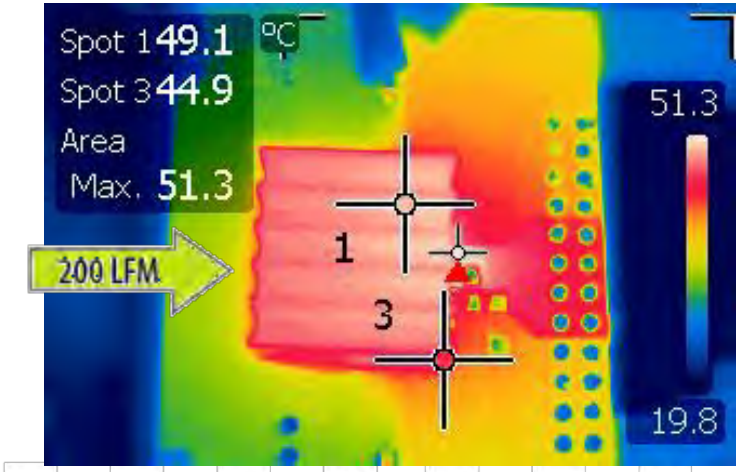
4 MHz EPC9006

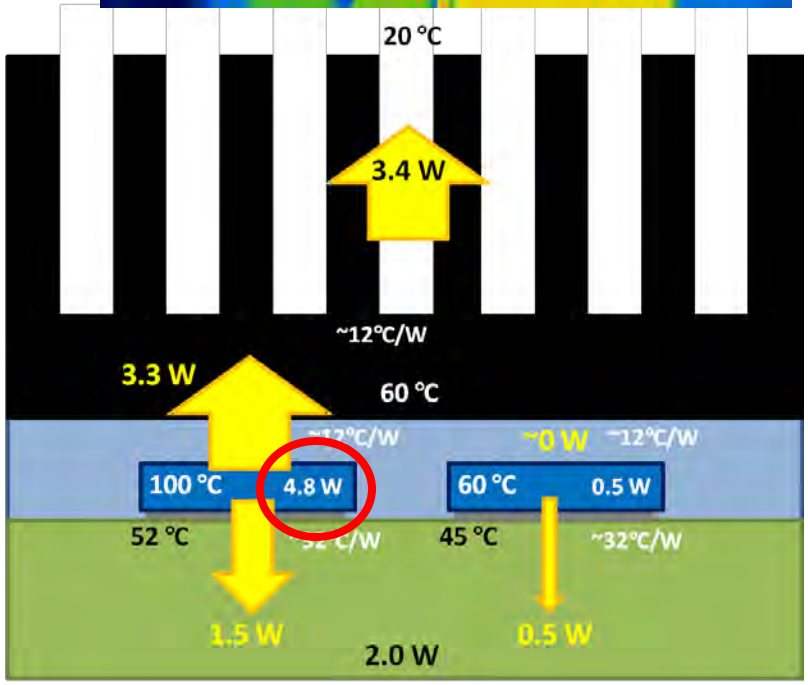
Future die size optimization possible

Thermal Results









Opportunities in ET

- eGaN FET switching times not limiting factor
  - <1 ns delay / 2-3 ns switching time.
- 20 MHz BW require loop delay < 12 ns (90 deg)
  - Possible with pure buck requiring level-shifter?
- Linear assisted buck ‘cleans up’ Buck distortion.
  - Relaxes controller delay requirements

Conclusion

- eGaN FETs are an enabling technology for ET
  - Low charge reduce delay and switching times
  - Thermally possible with dual sized cooling
- Results are representative, but not optimized
  - Improve inductor selection
  - Improve thermal design
  - Reduce HS peak device temp. by reducing LS device size / Q_{OSS} losses
- Power and number of phases application specific

EFFICIENT POWER CONVERSION

The end of the road for silicon…..

is the beginning of the eGaN FET journey!