High-Power High-Efficiency GaN 13.56 MHz Class-E Power Amplifier

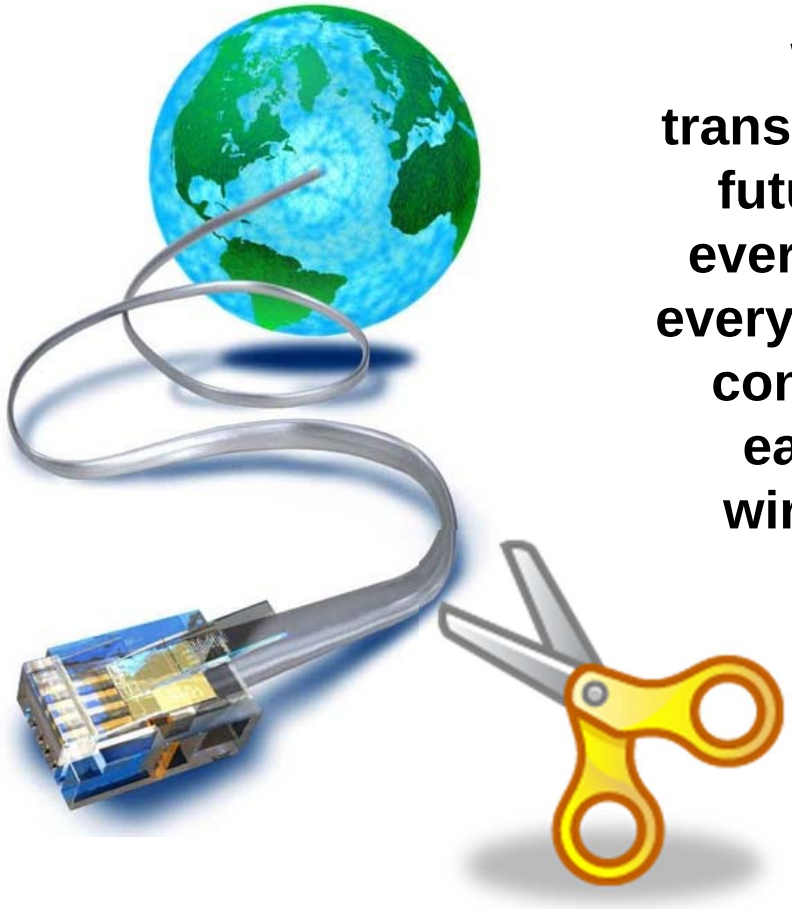
Raul A. Chinga, Wei-Ting Chen, Shuhei Yoshida, and Jenshan Lin

University of Florida

Team

- Dr. Jenshan Lin, Professor in Electrical and Computer Engineering
- Raul A. Chinga, Graduate Student
- Wei-Ting Chen, visiting researcher from the Industrial Technology Research Institute, Taiwan.
- Shuhei Yoshida, visiting researcher from NEC, Japan.

Motivation



We are transitioning to a future where everything and everybody will be connected to each other wirelessly…

Motivation


Television,
meet internet.
World's first HDTV powered by Google TV™.
SHOP NOW
twitter
SONY


123RF

Motivation

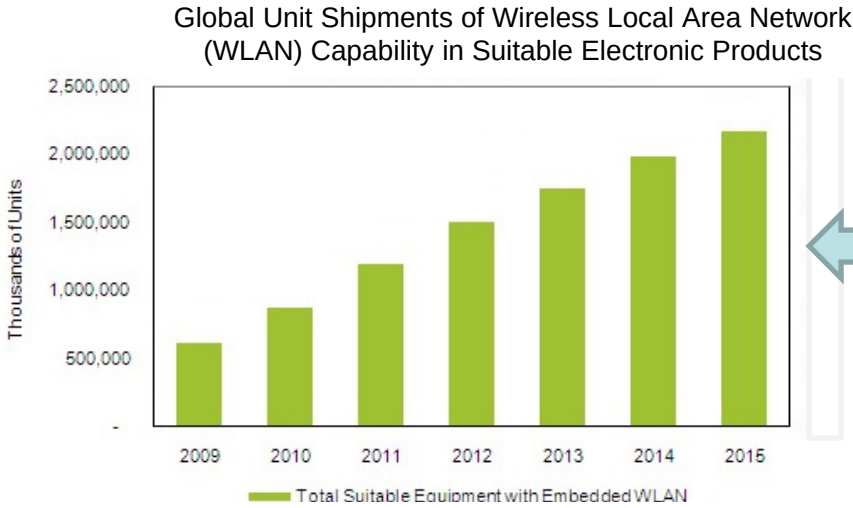
WiPower

Plugless Power
park and go

Cutting the last cord…

Wireless power…

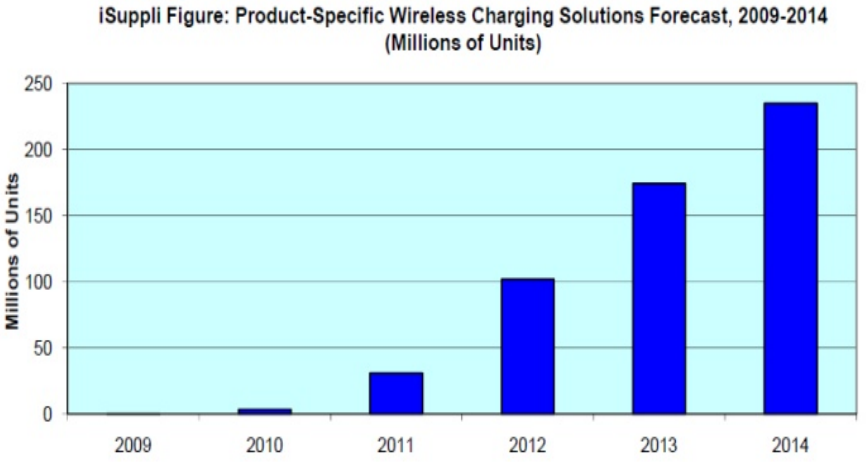
Motivation



The wireless device market is rapidly growing

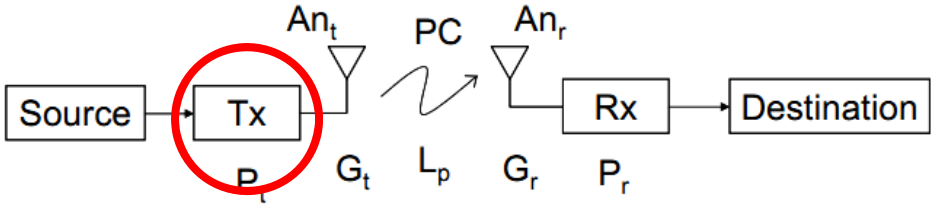
WLAN devices will reach over **2 billion** by 2015

Wireless Charging Devices will reach almost **250 million** by 2014

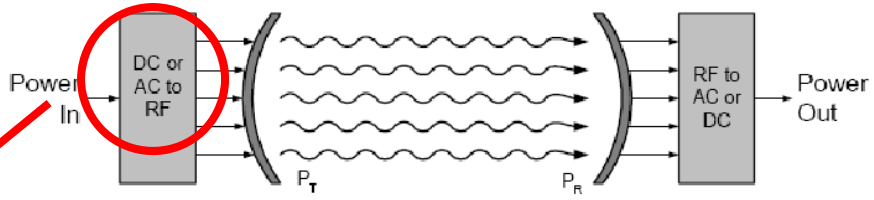


- Near Field Communication (NFC) devices will reach over **1/2 billion** by 2015
- Mobile phone connections will reach **6 billion** by 2012

Proposed work: Efficient Power Amplifier



System block for wireless communication and power transmission

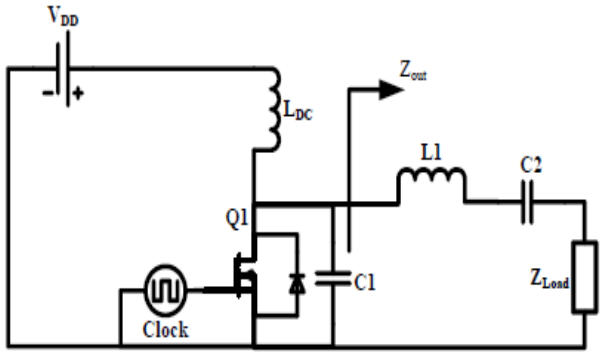


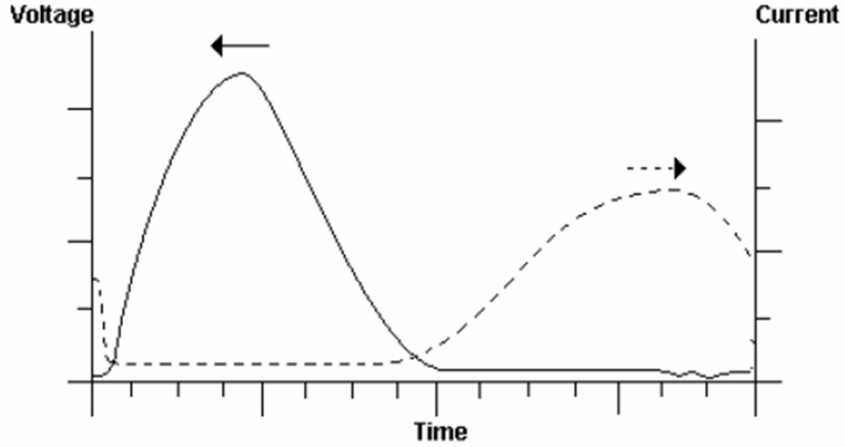
Power Amplifiers are an important aspect of any wireless system

Total system efficiency=$(n_T)x(n_c)x(n_R)$

Class E Amplifier

Goal: To design a high efficient power amplifier capable of delivering high power for wireless communications and/or wireless power transmission applications.





- 100% theoretical efficiency
- Low number of components
- High reliability

➢Voltage and Current across transistor do not overlap, hence no power loss

Challenges

- Operating at 13.56 MHz brought up a few complications:
  1. Internal shunt capacitance across the drain and source of transistor is not negligible
  2. Rising and falling time has to be small enough to achieve proper switching at 13.56MHz
  3. High Q for the load requires a large inductor (L2). The larger the inductor the larger the parasitic resistance, causing greater power loss across the inductor

Transistor selection

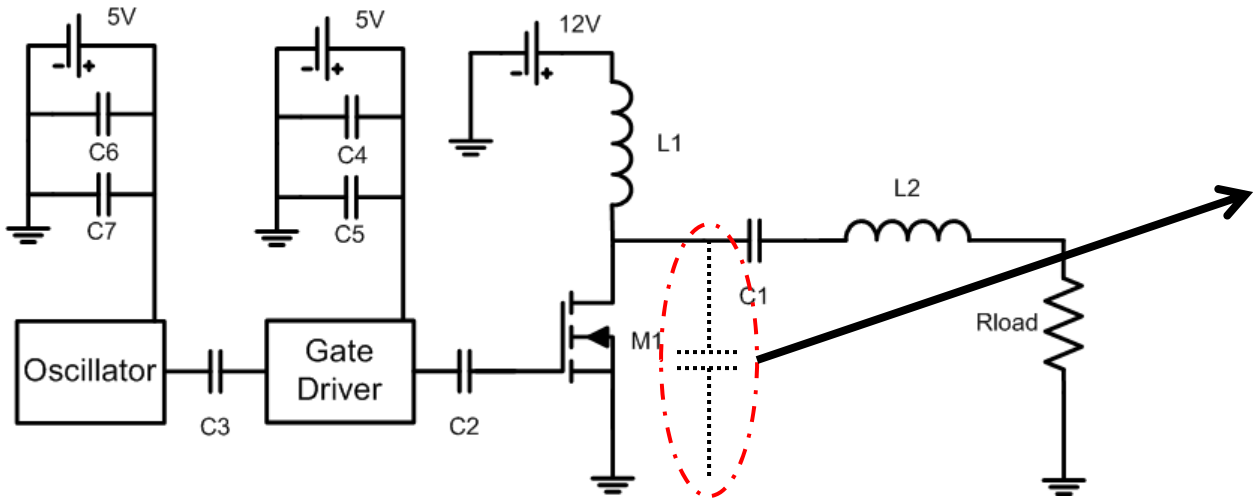
- Power MOSFETs
  - Advantages:
    - Capable of handling large currents and voltages.
    - Robust
    - Cheap
  - Disadvantages
    - Not meant to be used at 13.56MHz.
      - Large Cds
      - Slow switching time
- RF transistors
  - Meant to be used at really high frequency providing very low power
  - Very expensive

Gallium Nitride(GaN) Transistor

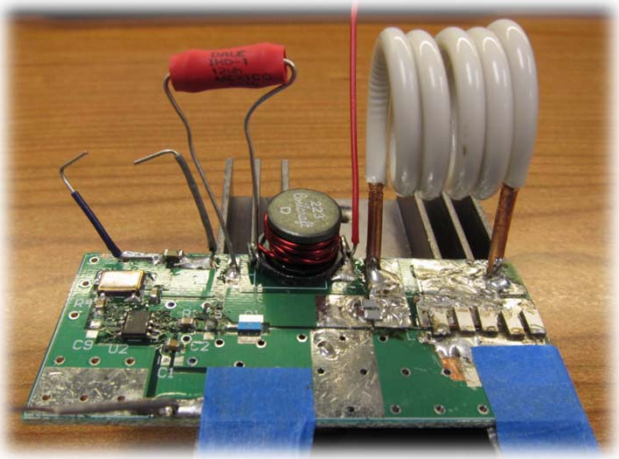
- Small capacitance across drain and source
- Fast rising and falling times, allowing proper switching at 13.56 MHz
- High Vds and ID, thus allowing high power delivery
- Very small package

➢ Disadvantage: Very delicate. It can only dissipate 1W and gate voltage cannot exceed 6V, otherwise transistor could be destroyed

Circuit Implementation

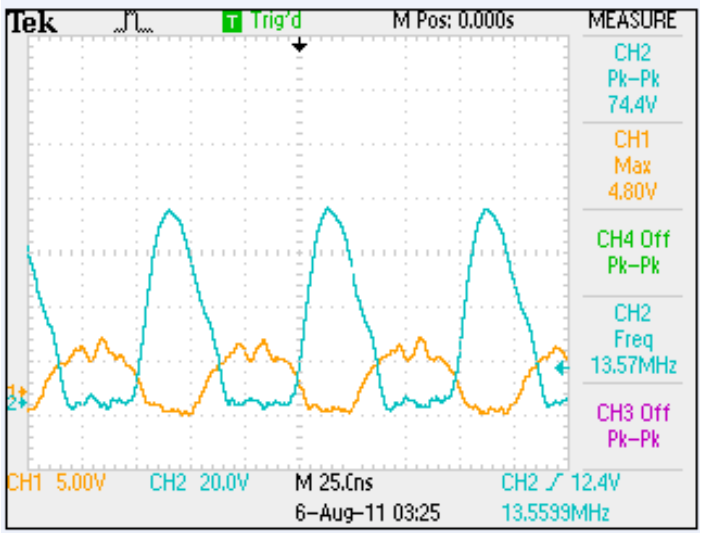


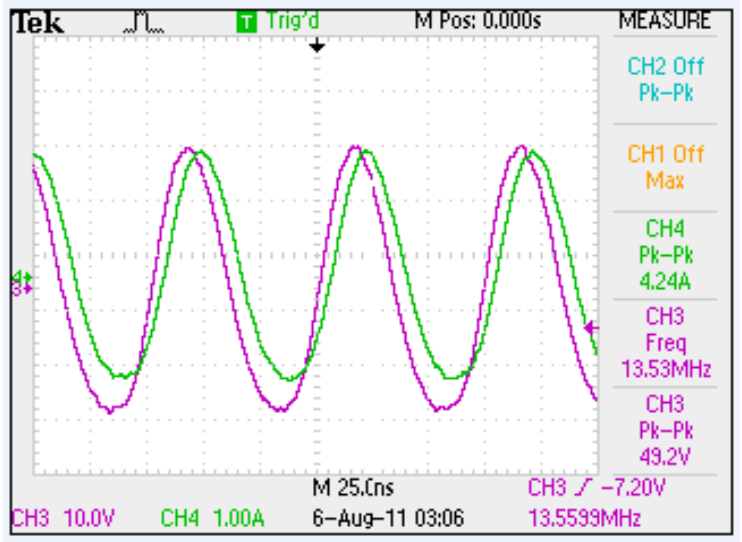
Removed. Internal shunt capacitor is sufficiently large

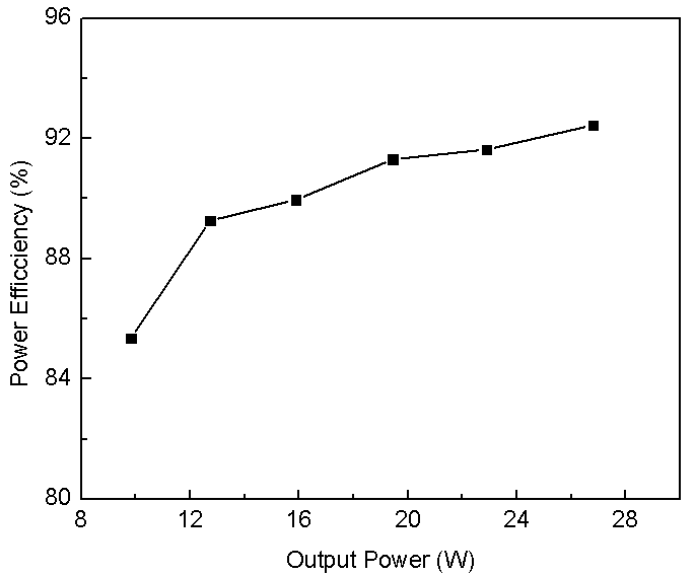


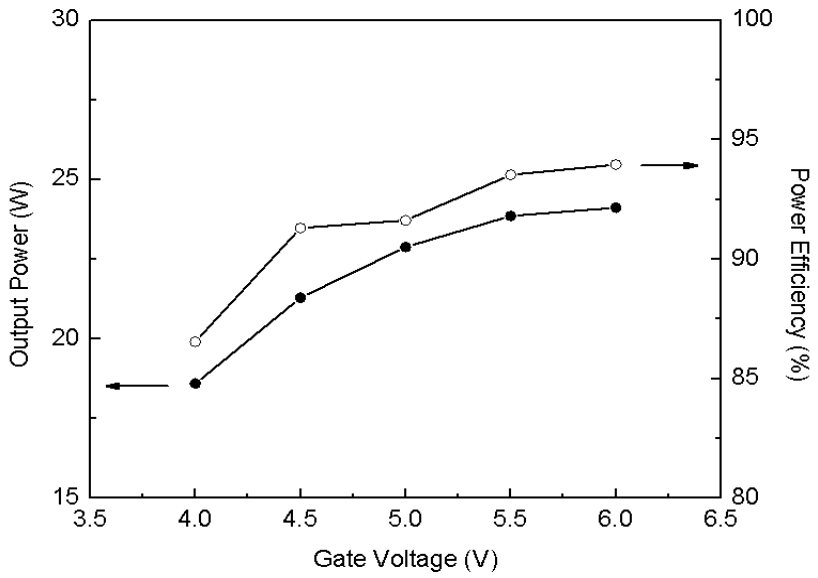
M1	EPC1010	C1	690pF
Gate Driver	IXDI502	C2	0.1uF
Oscillator	K50-HC	C3	0.1uF
L1	50uH	C4	0.1uF
L2	0.3uH	C5	22uF
Rload	13ohm	C6	0.1uF
		C7	22uF

Results


Tek
Trig'd
M Pos: 0.000s
MEASURE
CH2
Pk-Pk
74.4V
CH1
Max
4.80V
CH4 Off
Pk-Pk
CH2
Freq
13.57MHz
CH3 Off
Pk-Pk
CH1 5.00V
CH2 20.0V
M 25.0ns
CH2 ∕ 12.4V
6-Aug-11 03:25
13.5599MHz


Tek
Trig'd
M Pos: 0.000s
MEASURE
CH2 Off
Pk-Pk
CH1 Off
Max
CH4
Pk-Pk
4.24A
CH3
Freq
13.53MHz
CH3
Pk-Pk
49.2V
M 25.0ns
CH3 ∕ -7.20V
CH3 10.0V
CH4 1.00A
6-Aug-11 03:06
13.5599MHz


Power Efficiency (%)
96
92
88
84
80
8
12
16
20
24
28
Output Power (W)


Output Power (W)
30
25
20
15
100
95
90
85
80
3.5
4.0
4.5
5.0
5.5
6.0
6.5
Power Efficiency (%)
Gate Voltage (V)

Conclusions

Other work:

- 1W Class E at 82% efficiency
- 13.4 W Class E at 93% efficiency

This work:

- Achieved output power of **27W** at **92%** efficiency

- Successful Class E power amplifier at 13.56 MHz
- GaN has been proven to work very well at this frequency and deliver high power.