A Micromechanical Power Amplifier

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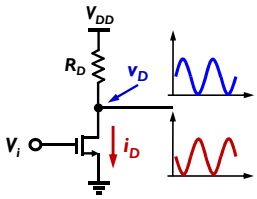
BSAC

Objective

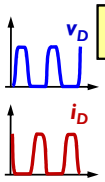
☞ Demonstrate GHz micromechanical switches that enable switched-mode power amplifiers with efficiency approaching *100%*

Class A Operation



Max. η_{drain} = 50%

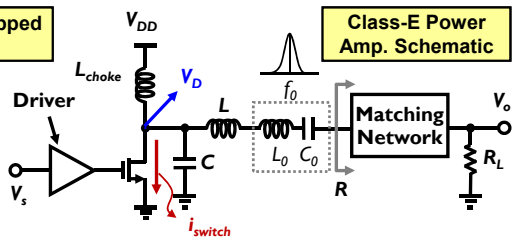
Ideal Case



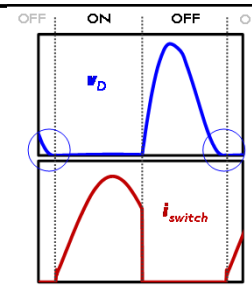
Non-overlapped v_D & i_D

Max. η_{drain} = 100%

In Practice



Class-E Power Amp. Schematic



$v = 0$ (ZVS)

$\frac{dv}{dt} = \frac{1}{C}\frac{dQ}{dt} = \frac{i}{C} = 0$ (ZDS)

$R = \frac{8V_{DD}^2}{(\pi^2+4)P_{out}}$ $L = 1.15\frac{R}{\omega}$ $C = \frac{0.1836}{\omega R}$

Issues with Current Solutions

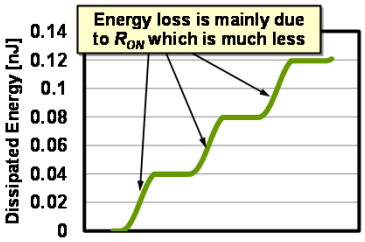
❖ Low $V_{breakdown}$ and large C_{off}

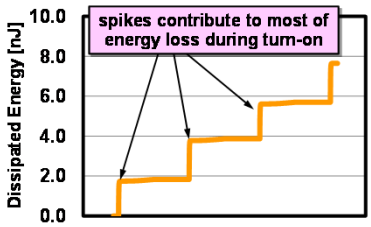
◆ Power-added efficiency (PAE)

$$PAE = \frac{P_{DC} - P_{Ron} - P_{in}}{P_{DC}} = 1 - 2.367\frac{R_{ON}I_{DD}}{V_{DD}} - \frac{\pi}{Q_{in}}\frac{C_{in}v_{in}^2 f}{V_{DD}I_{DD}}$$

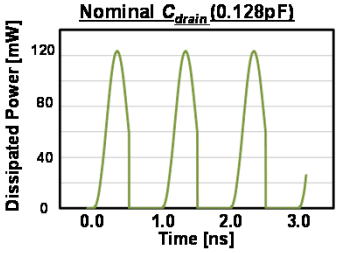
◆ f_{max} for 100% η

$$f_{max} = \frac{I_{DD}}{19.74 C_{off} V_{DD}}$$

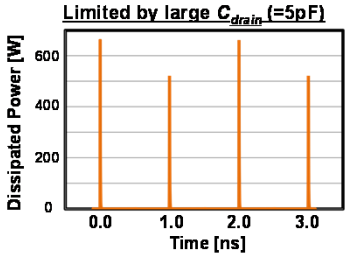




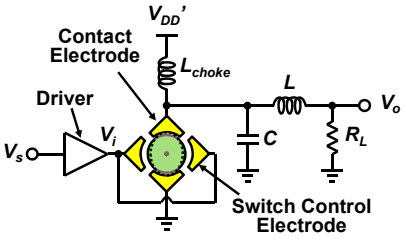
Nominal C_{drain} (0.128pF)



Limited by large C_{drain} (=5pF)



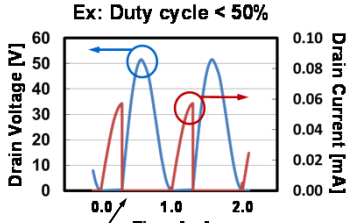
Solution: μmechnical Resoswitch



Goals

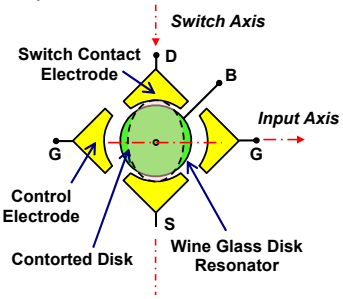
- High $V_{breakdown}$
- Low C_{off}
- Good reliability
- High switching speed

Ex: Duty cycle < 50%



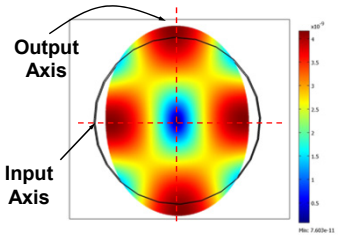
For D<50% component values can be re-designed to still achieve ZVS and ZDS

Top View



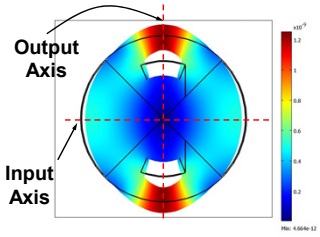
Displacement Amplifying Resoswitch

Conventional Disk Resonator



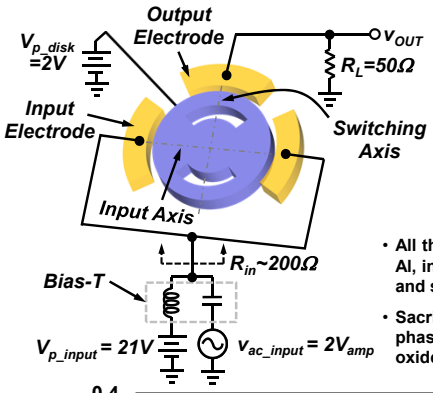
Displacement gain = 1

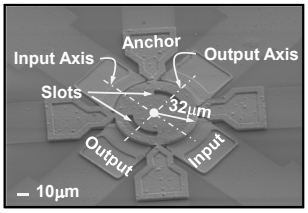
Displacement Amplifier



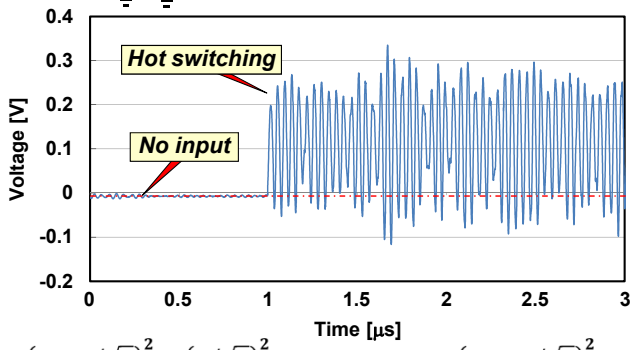
Displacement gain = 2.39

Aluminum Metal Power Amplifier





- All the resoswitch is entirely composed of Al, including interconnects, electrodes, and structure for lower resistances
- Sacrificial oxide is removed via vapor phase HF release etching with a very high oxide:Al selectivity



$$P_{in} = \frac{(v_{ac_in}/\sqrt{2})^2}{R_{in}} = \frac{(2/\sqrt{2})^2}{200k} = 10\mu W \quad P_{out} = \frac{(v_{ac_out}/\sqrt{2})^2}{R_L} = \frac{(0.15/\sqrt{2})^2}{50} = 238.6\mu W$$

$$Power\ Gain = \frac{484}{10} = 13.78dB$$

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