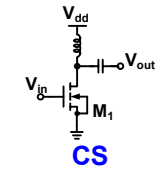
A Comparison between Common-source and Cascode Topologies for 60GHz Amplifier Design in 65nm CMOS

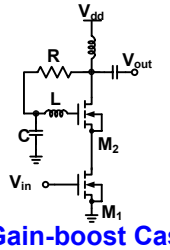
Qinghong Bu, Ning Li, Hiroki Asada, Kenichi Okada and Akira Matsuzawa
Matsuzawa and Okada Laboratory, Tokyo Institute of Technology, Japan

1 Background

- Issues of mmW amplifier design
  - Gain
  - Impedance matching
  - Stability factor
  - Linearity
  - Noise figure
  - Life time
  - Output power
  - Power consumption
- Topologies
  - Common source (CS)
  - Cascode (Cas.)
  - Gain-boost Cas.

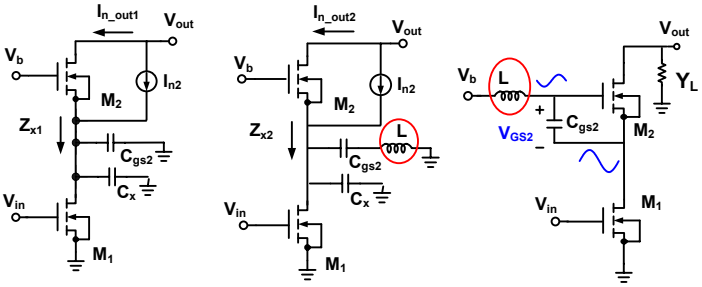


CS



Gain-boost Cas.

2 NF and linearity calculation



Assume: $g_{ds} << \omega(C_x + C_{gs2})$

So:

$$Z_{x1} = -\frac{1}{j\omega(C_x + C_{gs2})} \qquad Z_{x2} = -\frac{1-\omega^2 LC_{gs2}}{j\omega(C_x + C_{gs2} - \omega^2 LC_{gs2}C_x)}$$

$$L = \frac{C_{gs2} + C_x}{\omega^2 C_{gs2} C_x} \Longrightarrow |Z_{x1}| << |Z_{x2}|$$

$$I_{n\_out} = -\frac{I_{n2}}{1 + Z_x g_{m2}} \Longrightarrow I_{n\_out1} > I_{n\_out2}$$

NF calculation

$$\frac{1}{A^2_{IP3,Cas}} = \frac{1}{A^2_{IP3,CS}} + \frac{g^2_{1\_CS}}{A^2_{IP3,CG}} = \frac{3}{4}\left|\frac{g_{3,CS}}{g_{1,CS}}\right| + \frac{3}{4}\left|\frac{g_{3,CG}}{g_{1,CG}}\right| g^2_{1\_CS}$$

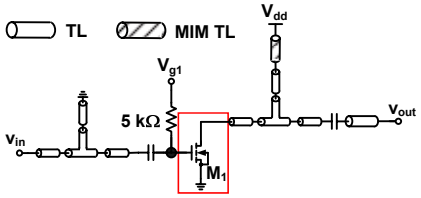
$$\left\{ \begin{array}{l} g_{1,CG} = \dfrac{2I_{D,Cas}}{V_{GS2}} \\ V_{GS2,Cas} < V_{GS2,Cas\_boost} \end{array} \right\} \Longrightarrow g_{1,CG\_Cas} > g_{1,CG\_Cas\_boost}$$

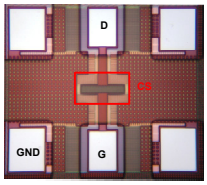
$$A_{IP3,Cas} > A_{IP3,Cas\_boost}$$

Linearity calculation

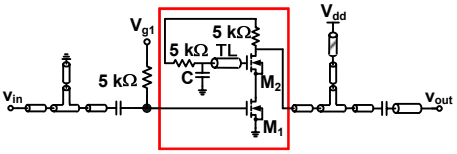
3 Verification method

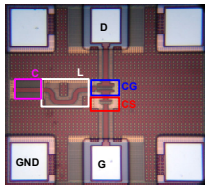
- Measurement results of CS and Cas. transistor TEGs in 65nm CMOS process
- Transistor models based on the measurement data
- 1-stage amplifier with 50Ω matching using TL and MIM TL for simulation.





CS



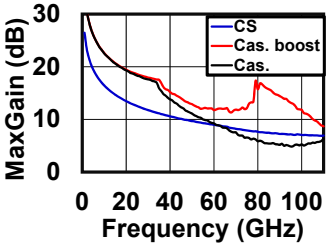


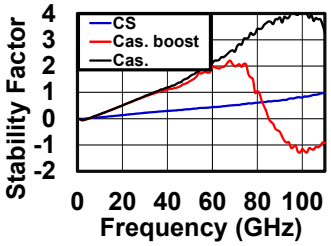
Gain-boost Cas.

4 Comparison of CS and Cas. topologies

Issues	CS	Cas.	Gain-boost Cas.	CS @60GHz	Cas. @60GHz	Gain-boost Cas. @ 60GHz
*Maximum gain (dB)	△	△	O	9	9	11.7
*Power consume (mW)	△	O	O	8.3	6	6
*S_{12} (dB)	×	△	O	-13.4	-28	-32.8
*Stability factor	×	O	O	0.44	2	2
**S_{21}	△	×	O	5.2	4.3	6.4
**OP_{1dB} (dBm)	O	△	×	0.2	-5.7	-7.7
**P_{sat} (dBm)	O	△	△	8.2	2.2	2.2
**Peak PAE (%)	O	△	×	11.7	2.9	3
**IIP3 (dBm)	O	△	×	5.3	-0.9	-4.9
**OIP3 (dBm)	O	△	×	10.5	3.4	1.5
**Noise figure (dB)	O	×	△	5	5.4	5.3
**Life time @ P_{1dB} (Year)	×	△	O	0.077	0.2	0.3
**Stability factor2	×	O	△	1.1	4	3.8

* Measurement results of Cas. TEGs **Simulation results of 1-stage amplifier with 50Ω matching





5 Conclusion

- A comparison between CS and Cas. topologies is carried out considering most of the issues of mmW amplifier design.
- Better NF and worse linearity of the gain- boost Cas. topology is verified by calculation and simulation.
- The comparison is useful for the design of mmW amplifiers, such as LNA and PA.