A 0.0064mm² 12.8μW Three-Stage Amplifier with 1.38MHz GBW at 1nF Capacitive Load

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● Motivation

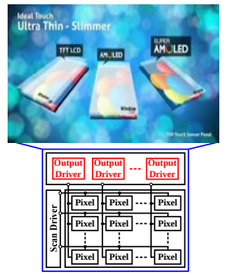
Develop High-Performance Buffer/Error Amplifiers

● Challenges

(1) Power and Area Minimization (2) Fast Settling

● Advanced Three-Stage Amplifiers

- **High Precision**
- **Large C_L Drivability**
- **Low Power and Area**



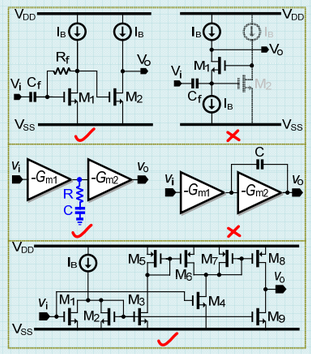
Proposed Solution for Three-Stage Amplifiers

Key Features

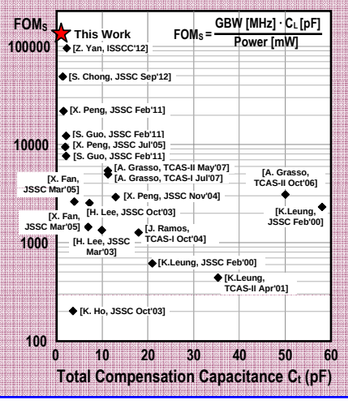
- **CM-Based Current Buffer**
- **Parallel Compensation**
- **Multi-Path *Gm* Boosting**
- **Measured Record FOMs**

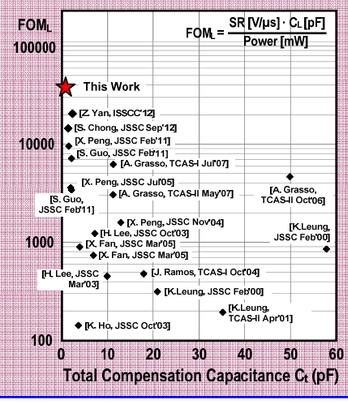
Advantages

- **CM-Based over CG and Its Derivatives**
  - **Small power and area**
  - **High parasitic poles**
- **Parallel over Miller**
  - **Low power**
  - **Wide bandwidth**

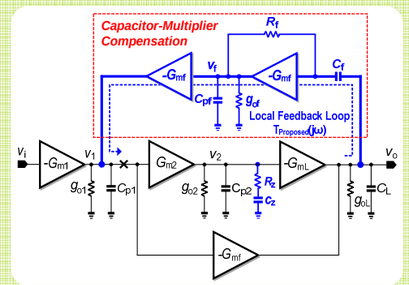


Benchmark with the State-of-The-Art

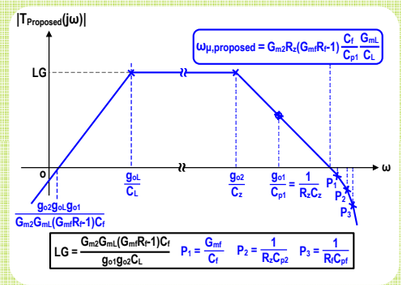




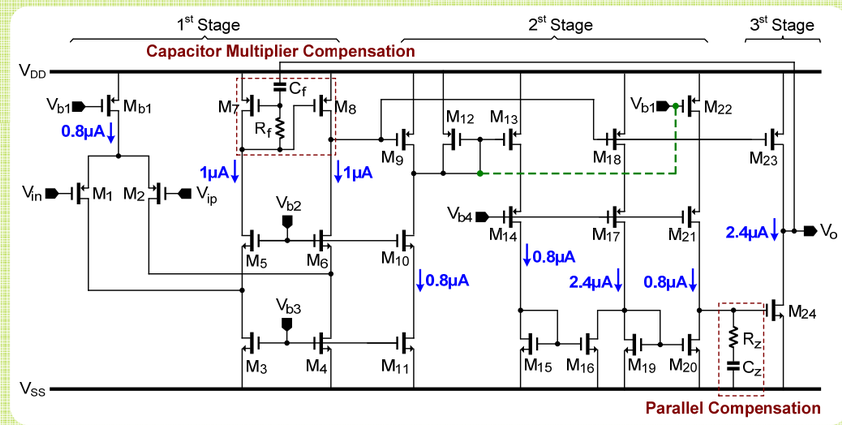
Block Diagram of Proposed Three-Stage Amplifier

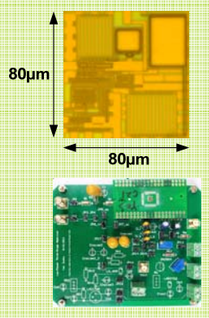


Local Feedback Loop Analysis



Transistor-Level Implementation

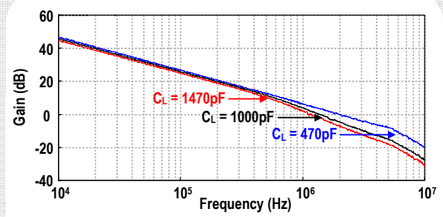


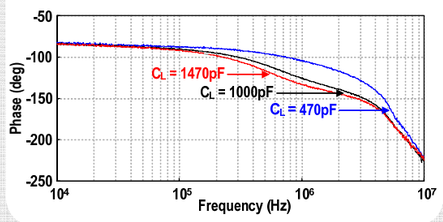


Performance under Different C_L

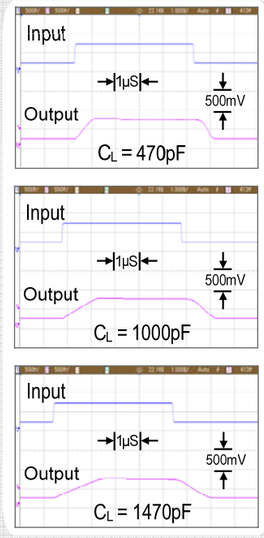
Technology	0.18μm CMOS		
I_{DD}(μA) @ V_{DD} (V)	10.5 @ 1.2		
C_L (pF)	470	1000	1470
GBW (MHz)	1.97	1.38	1.18
Phase Margin (°)	63.0	53.3	49.1
Gain Margin (dB)	11.6	16.5	19.2
SR +/- (V/μs)	0.74/1.12	0.37/0.59	0.27/0.43
T_s +/- (μs)	1.21/0.92	1.63/1.12	2.11/1.49

Measured AC Responses





Measured Transient Responses



Performance Summary and Comparison

	This Work	[1] [Z. Yan ISSCC'12]	[2] [S. Chong JSSC Sep'12]
Load C_L (pF)	1,000	15,000	500
GBW (MHz)	1.38	0.95	2
Phase Margin (°)	53.3	52.3	52
Gain Margin (dB)	16.5	18.1	7.70*
Average SR (V/μs)	0.48	0.22	0.65
Average 1% T_S (μs)	1.38	4.49	1.23
DC Gain (dB)	>100	>100	>100
I_{DD}(μA)	**10.5**	72	17
Power (μW) @ V_{DD}	**12.6** @1.2	144 @ 2	20.4@1.2
Output Noise Density (nV/sqrt(Hz) @ 100kHz)	212	174	N/A
Total Capacitance C_t(pF)	**0.95**	2.6	1.15
Chip Area (mm²)	**0.0064**	0.016	0.0088
Technology	0.18μm CMOS	0.35μm CMOS	65nm CMOS
FOM_S[(MHz· pF)/mW]	**109,524**	98,958	49,020
FOM_L[(V/μs· pF)/mW]	**38,095**	22,917	15,931
LC-FOM_S(MHz/mW)	**115,288**	38,061	42,626
LC-FOM_L[(V/μs)/mW]	**40,100**	8,814	13,853

* denotes the simulated result