MP4-06 CMOS CURRENT REFERENCE CIRCUIT DESIGN

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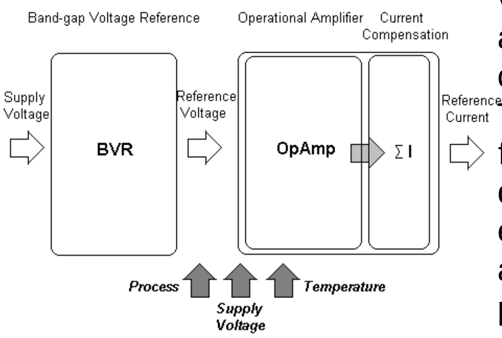
INTRODUCTION

In this project, a couple of current reference circuits were studied and implemented. Current reference is a generated current source with stable current supply relatively insensitive to external variations like temperature, process and voltage. It is essential for applications like operational amplifier and data converter bias circuits, which are commonly used in analog Integrated Circuit design.

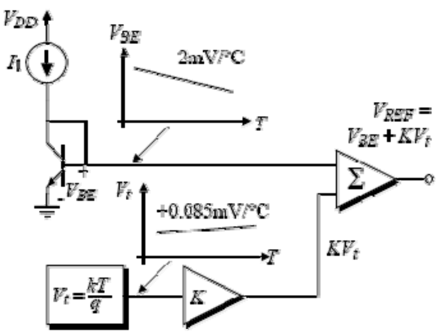
One of the designs uses the bangap characteristic of semiconductor material, the other one utilizes the difference on drain-source voltages of NMOS and PMOS as the general methods of curvature cancellation. The generated voltages were converted to stable currents via a voltage-to-current converter. The designs were also tested for process variations under Four-corner models.

System Block Diagram



The system consists of a bandgap voltage reference and a voltage-to-current converter. The later part can further break down into an operational amplifier and current compensation sub-circuit.

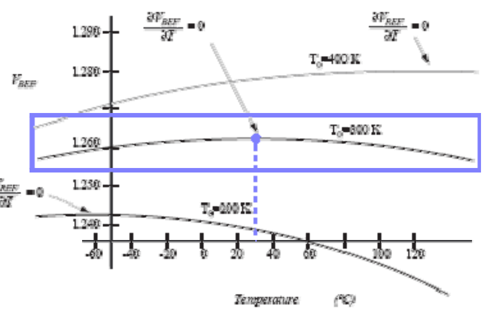
Principle of BVR



It takes two generated currents, one proportional to absolute temperature (PTAT), the other complementary to absolute temperature (CTAT), add them together to minimize the effect of temperature coefficient.

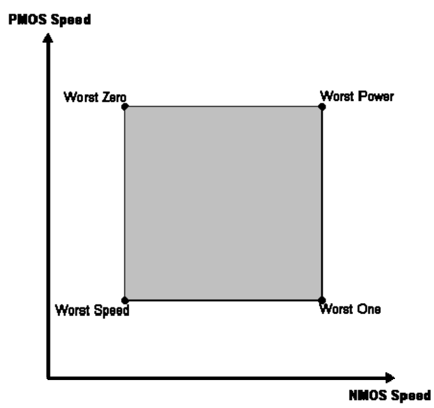
Temperature Coefficient Curves

The sensitivity of parameters with regard to temperature is measured in ppm/°C, part per million per degree. The boxed curve is set at reference temperature of 27°C. The position of the dot has near zero change



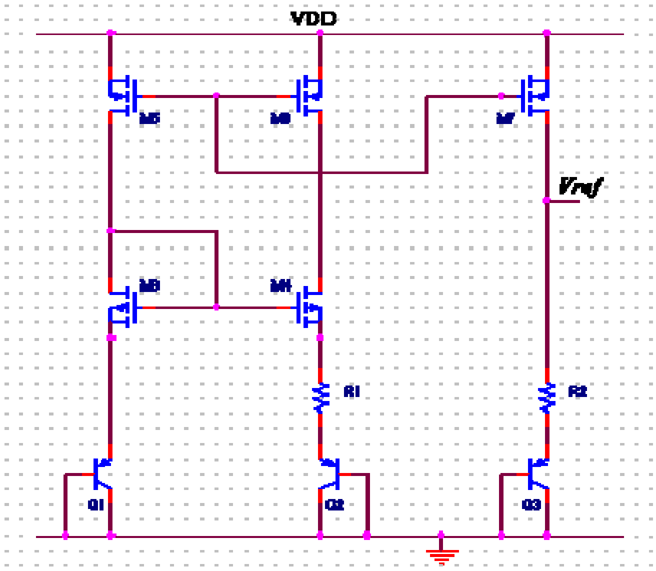
The Four-corner Models

The two dimensional models represent four possible extreme conditions corresponding to speed of MOSFETs:
Worst Zero (WZ),
Worst Power (WP),
Worst One (WO)
and
Worst Speed (WS).

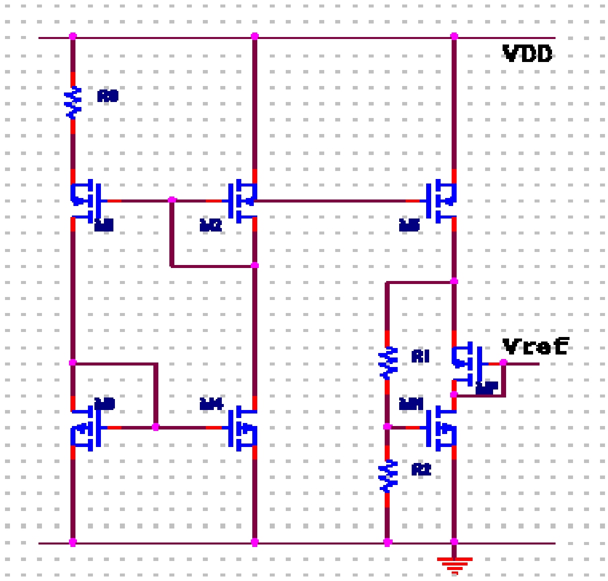


DESIGN

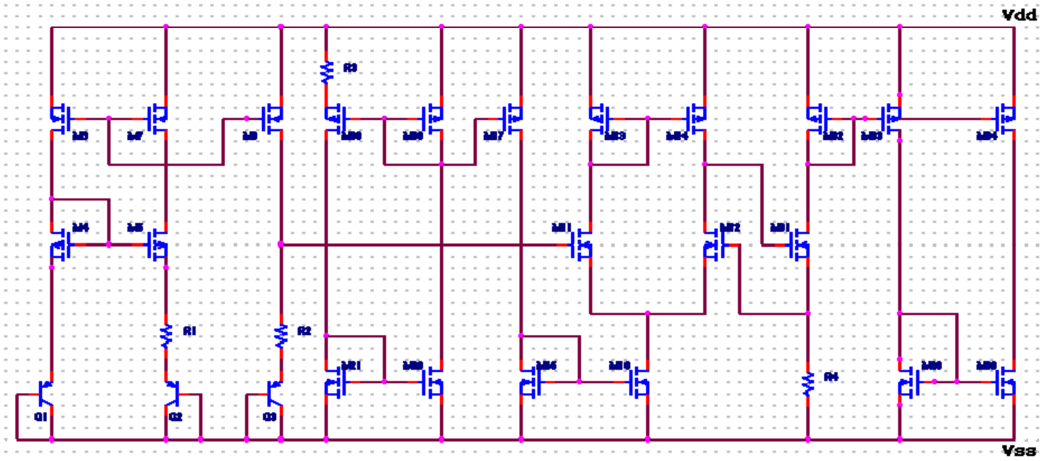
Bandgap Voltage Reference



Voltage Reference Utilizing Gate-Source Voltage

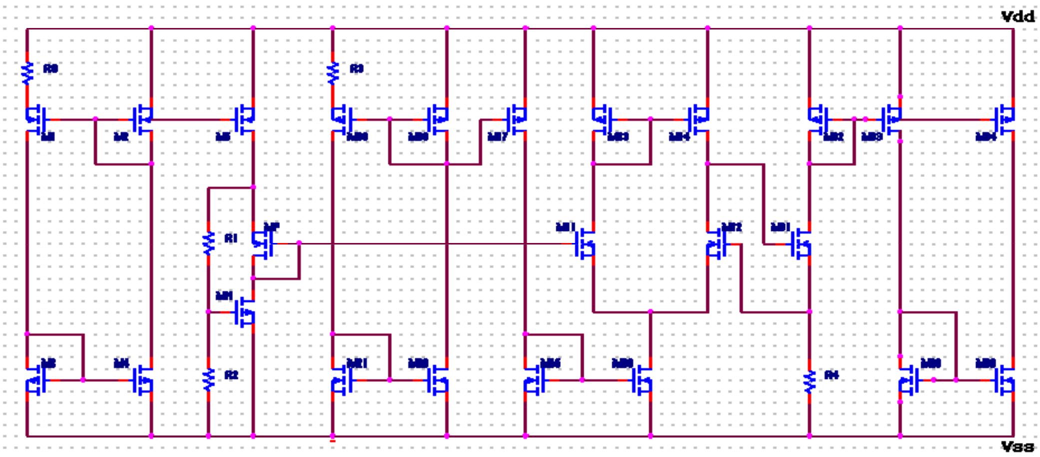


Current Reference Circuit with the Bandgap Reference



The first block consists of M4-M8 is a simple bandgap voltage reference; the second block (M9-M28) is the V-I converter, in which M11-M14, M16 make an op amp; the current from M33 is retrieved and adjusted by the last block.

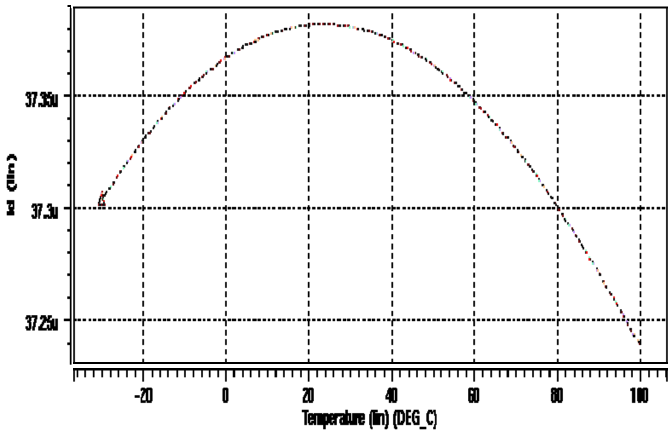
Current Reference Circuit with ΔV_{GS} Voltage Reference



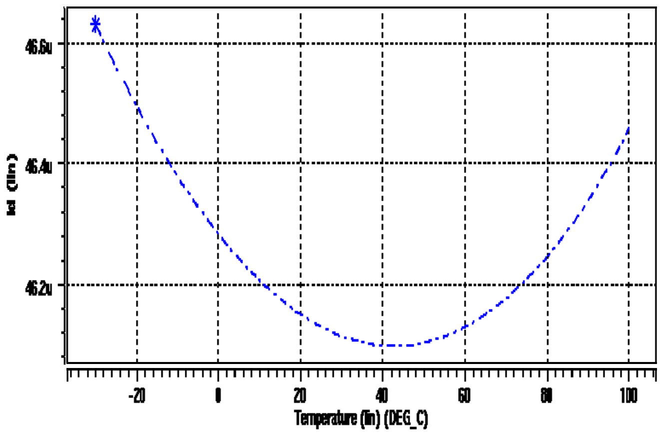
The first block (M1-M5, MN, MP) is the ΔV_{GS} configuration. The gate-source voltages of MN and MP cancel each other primarily to provide a stable reference voltage. The subsequent blocks are nearly identical to those of design I.

RESULTS

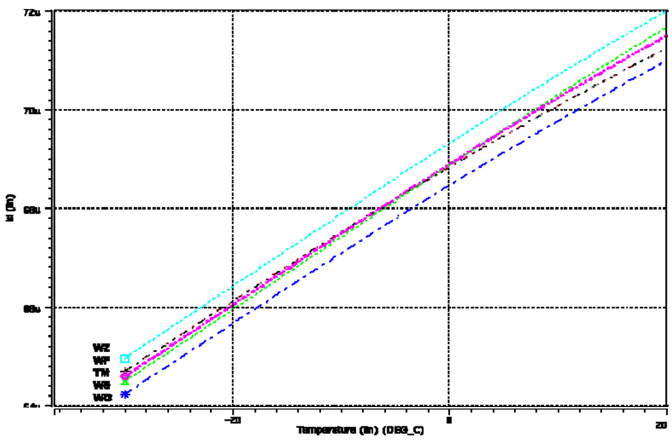
Temperature Coefficient of Design I



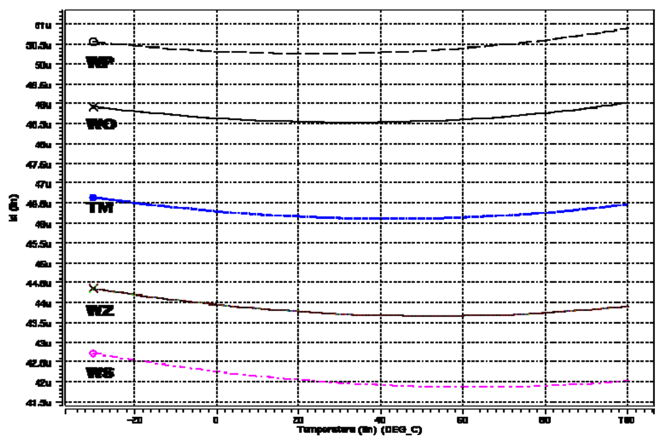
Temperature Coefficient of Design II



Performance with Process Variation (Design I)



Performance w/ Process Variation (Design II)



COMPARISON

Parameters	Sansen et al. [1]	Badillo [2]	Design I	Design II
Technology	(not applicable)	0.25-µm	0.35-µm	0.35-µm
Temperature	0°C -80°C	-40°C -150°C	-30°C -100°C	-30°C -100°C
I_{ref}	0.774µA±4%	4.95µA±7%	37.4µA±0.4%	46.1µA±1.1%
TC	375ppm/°C	368ppm/°C	28.8ppm/°C	88.4ppm/°C

[1] W.M.Sansen, F.O.Eynde, M.Steyaert, "A CMOS Temperature-Compensated Current Reference", *IEEE Journal of Solid-State Circuits,* Vol.23, No.3, pp.821-824, June 1988.
[2] D. A. Badillo,"1.5V CMOS Current Reference with Extended Temperature Operating Range", *Proc. The 2002 IEEE International Symposium on 2002 IEEE International Symposium on Circuits and Systems* (ISCAS'02), Scottsdale, USA, May 2002.