

520.492: Mixed-Signal VLSI Systems

Spring Semester 2005

Midterm

NAME: _____

Guidelines:

1. Open book, open notes, open mind. No communication with others.
2. Time limit: 1 hour 15 minutes (in-class).
3. Mark directly on the handout.

The midterm counts for 25% towards the final grade.

Problem 1 (20 Points):

Sketch the cross-section of possible fabricated structures for the following devices in a standard CMOS process. Denote n and p doped regions (including substrate, well and base regions, if any). You may assume p -base is available in an n -well process, and n -base in a p -well process. Denote all terminals, including bulk/substrate terminals to GND or Vdd where needed.

1a. An n MOS folded cascode mirror in a p -well process (terminals IN, OUT, V_{bn} and V_{cn});

1b. An n MOS transistor in an n -well process (terminals S, G, D, B; all terminals disconnected from the substrate);

1c. An *npn* lateral bipolar transistor in a *p*-well process (terminals E, B, C, and G);

1d. A high-sensitivity photodiode in a *p*-well process (terminals OUT and Vdd, denote photosensitive region).

Problem 2 (40 Points):

Design a 3-bit, binary-code to Gray-code converter. Inputs are the three binary bits B2 (MSB), B1 and B0 (LSB); outputs are the three Gray bits G2, G1 and G0. Minimize the number of transistors used. Show the entire transistor-level circuit diagram. You may save ink by defining and instantiating subcircuit "cells" where this is helpful.

Problem 3 (40 Points):

Consider the current-mode circuit shown below.

1. (25 points) Find the output current I_{out} as a function of input current I_{in} and reference currents I_a and I_b , assuming the transistors are identically sized and operate in the subthreshold region. You may ignore the Early effect ($\lambda = 0$), and assume the output voltage V_{out} is sufficiently large.
2. (15 points) What happens to this relationship between input and output current if the n MOS transistors are replaced with n pn BJTs? Quantify your answer. The BJTs are ideal with infinite current gain (β_F).
3. *BONUS: (15 extra points)* What happens to the relationship between input and output current in the BJT version if the current source I_a is replaced with a capacitor C ? Be specific and express the *large-signal* dynamics of I_{out} in response to I_{in} .

