

## 2006 Paper 8 Question 2

### VLSI Design

A *majority gate* with three inputs signals logic one on its output if two or more of its inputs are one, and zero otherwise. A *minority gate* is its complement.

- (a) Give the boolean equation for a minority gate as a sum of products. [2 marks]
- (b) Sketch the circuit diagram for a minority gate using NAND gates and inverters. [3 marks]
- (c) Sketch the transistor-level circuit diagram for an alternative implementation as a single stage of CMOS logic. [3 marks]
- (d) Calculate the number of transistors required for each implementation. [2 marks]
- (e) Assuming that a conducting p-channel has a resistance twice that of a similarly sized n-channel, use logical effort to compare the performance of the two implementations. [10 marks]