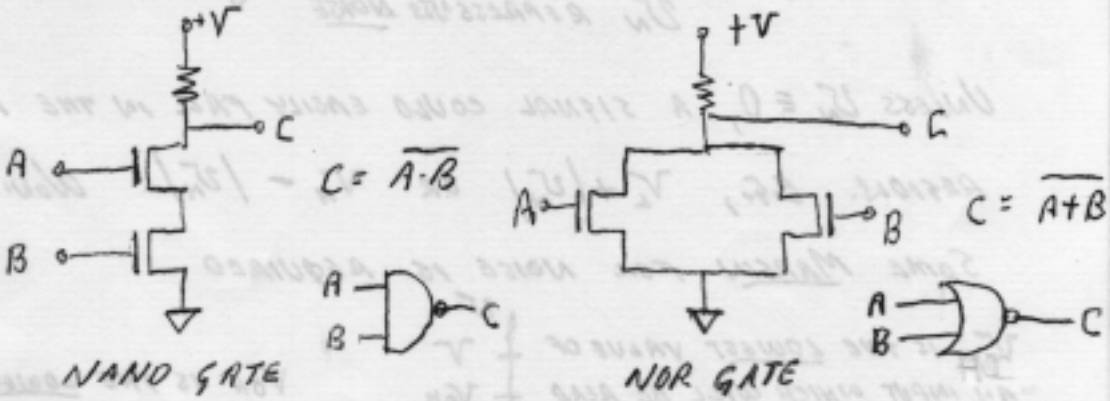
NOTES FOR 6.002 LECTURE #2 FEBRUARY 6, 2003

ERROR IN NOTES FOR LECTURE 1: MIDDLE LEFT p2, i_G THE GATE CURRENT IS MISLABELLED AS i_D BOTH IN THE SKETCH AND THE EQUATION BELOW WHICH SHOULD READ $i_G \cong 0$.

THE MOSFET IS THE ACTIVE ELEMENT (THE "VALVE") IN DIGITAL COMPUTER GATES:

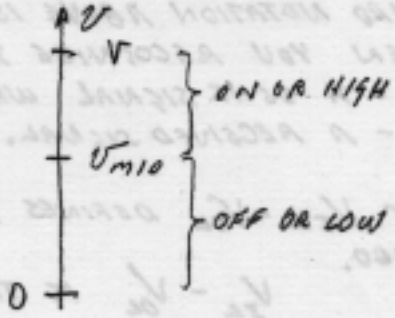


WHAT ARE THE PRACTICAL CONSIDERATIONS IN CIRCUIT DESIGN AND OPERATION?

THE VOLTAGE REPRESENTING A BOOLEAN VARIABLE CANNOT BE PRECISELY 0 FOR THE ZERO OR "OFF" STATE NOR PRECISELY V (THE SUPPLY VOLTAGE) FOR THE "ONE" OR ON STATE. SOME VARIATION MUST BE PERMITTED.

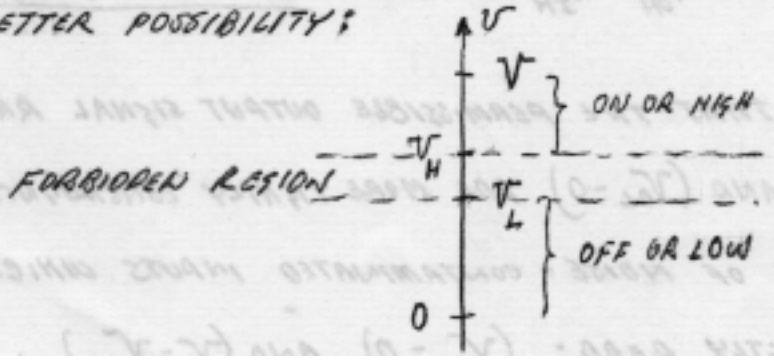
CONSIDER THIS POSSIBILITY:

(v REPRESENT THE INPUT VOLTAGE OF A GATE)



WHAT IF $v \equiv v_{MID}$ WHAT SHOULD BE THE RESPONSE OF THE GATE?

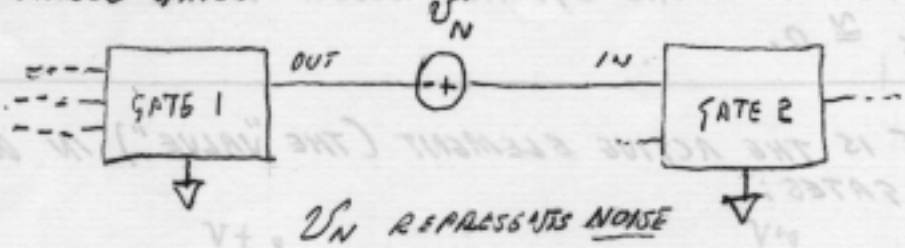
A BETTER POSSIBILITY:



CLEARLY THE THRESHOLD VOLTAGE OF THE FETS MUST FALL IN THE FORBIDDEN REGION

THE CIRCUITS OR SYSTEMS ARE DESIGNED SO THAT THE VOLTAGE REPRESENTING A VARIABLE CAN NEVER BE IN THE FORBIDDEN REGION. IF FOR SOME REASON IT IS: SO WHAT? A FAILED DESIGN. PINK SLIP TIME!

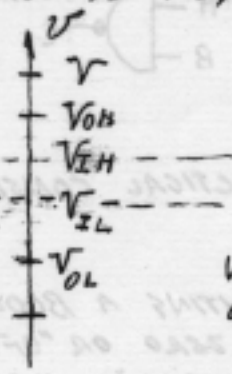
CASCADED GATES



v_N REPRESENTS NOISE

UNLESS $v_N \equiv 0$, A SIGNAL COULD EASILY FALL IN THE FORBIDDEN REGION. E.G., $V_L + |v_N|$ OR $V_H - |v_N|$ WOULD DO.

SOME MARGIN FOR NOISE IS REQUIRED



V_{IH} IS THE LOWEST VALUE OF AN INPUT WHICH WILL BE READ AS A ONE.

V_{OH} IS THE LOWEST VALUE OF AN OUTPUT WHICH REPRESENTS A ONE.

V_{IL} IS THE HIGHEST VALUE OF AN INPUT WHICH WILL BE READ AS A ZERO.

V_{OL} IS THE HIGHEST VALUE OF AN OUTPUT WHICH REPRESENTS A ZERO.

THE STANDARD NOTATION ABOVE IS PUZZLING AT FIRST, BUT COMES EASIEST WHEN YOU RECOGNIZE THAT A SUBSCRIPT O REFERS TO AN OUTPUT - A SENT SIGNAL WHILE THE SUBSCRIPT I REFERS TO AN INPUT - A RECEIVED SIGNAL.

NOTE THAT $V_{IL} - V_{OL}$ DEFINES THE MAXIMUM TOLERABLE NOISE FOR A ZERO.

$V_{IL} - V_{OL}$ IS THE ZERO NOISE MARGIN

SIMILARLY,

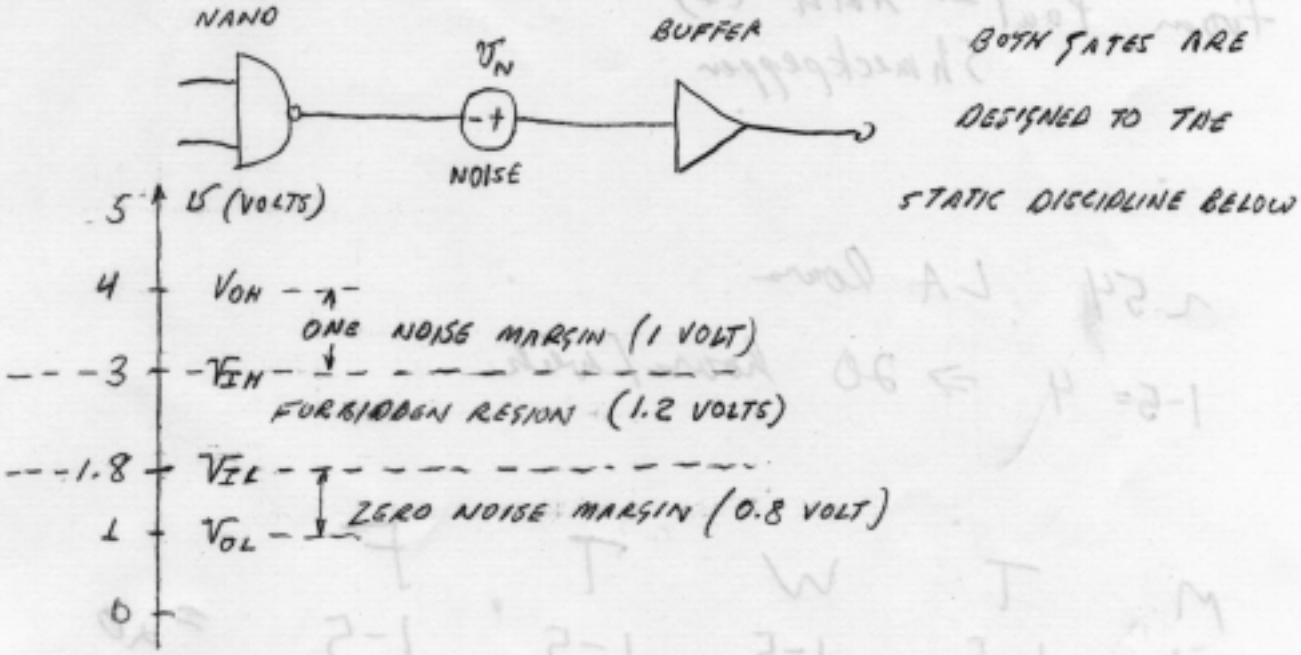
$V_{OH} - V_{IH}$ IS THE ONE NOISE MARGIN

NOTE ALSO THAT THE PERMISSIBLE OUTPUT SIGNAL RANGES $(V - V_{OH})$ AND $(V_{OL} - 0)$ ARE MORE TIGHTLY CONSTRAINED THAN THE RANGE OF NOISE-CONTAMINATED INPUTS WHICH MUST BE CORRECTLY READ: $(V_{IL} - 0)$ AND $(V - V_{IH})$.

THE FOUR CRITICAL LEVELS V_{OL}, V_{IL}, V_{IH}, V_{OH} COMPRISE THE STATIC DISCIPLINE

THUS A PROPERLY DESIGNED GATE RESTORES SIGNAL INTEGRITY.

CONSIDER A NUMERICAL EXAMPLE:



IF THE PEAK AMPLITUDE OF THE NOISE IS LESS THAN 0.8 VOLTS THE BUFFER WILL OPERATE PROPERLY IN BOTH STATES. IF IN THE RANGE 0.8 - 1.0 VOLTS THE ONE STATE WILL OPERATE PROPERLY, BUT THE ZERO STATE MIGHT NOT.

DEMO: