# PHY 335, Spring 2019 Finals Group A (4 problems, 90 min)

**Please write your name, group and seat number on every page!**

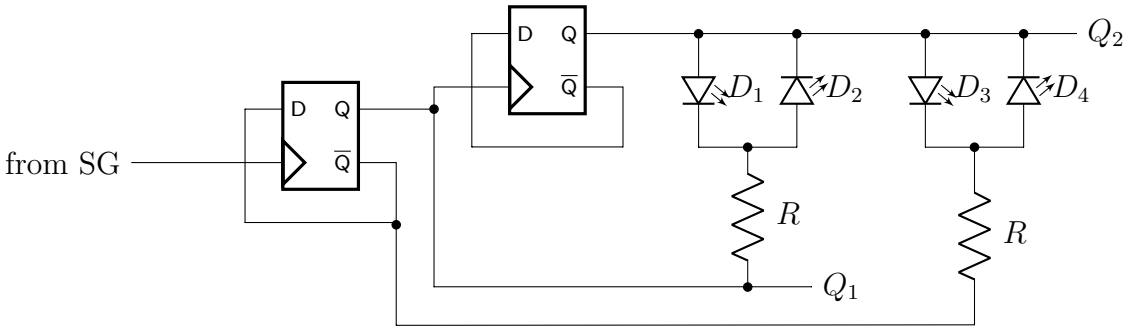
**Problem #1 (12 points)**

1. Describe in a short sentence what a via is (on a PCB).
2. Using De Morgan's theorem, transform $\bar{A} + \bar{B}$.
3. In LTSpice, what analysis mode give you the signals as a function of time?
4. What is 0x34 in decimal and binary?
5. What does active-low mean?
6. Given a suitable $V_{DS}$ and with $V_{GS} = 0$, does the transistor conduct (current from drain to source, answer yes or no):
   - Enhancement mode MOSFET
   - Depletion mode MOSFET
   - JFET

**Problem #2 (24 points)** 2-bit multiplier. Assume you have two 2-bit (unsigned) input binary numbers $A_1A_0$ and $B_1B_0$. After multiplication, you will get a 4-bit (unsigned) output $C_3C_2C_1C_0$. ($A_1$, $B_1$ and $C_3$ are the MSB, respectively)

1. Write down the truth table
2. For $C_3$ and $C_2$, write down the logic expression and simplify as much as possible.
3. Draw the schematic for these two outputs using standard logic functions only (Inverters, 2-input AND/NAND, 2-input OR/NOR, 2-input XOR)

**Problem #3 (40 points)** Four on the floor. Using a single 7474 (see blackboard), build the following circuit using two D-FF. R should be in the range of 300 Ω to 1 $k\Omega$.




a) If you supply a sine wave of 1 MHz to the clock input of the first FF, what waveforms at what frequency do you expect for outputs $Q_1$ and $Q_2$? Sketch them.

b) Which LEDs will light up, in which order?

c) Build the circuit.

d) Set up the signal generator to produce a square wave between 0V and 5V (use the offset knob). Set the frequency to 1 kHz.

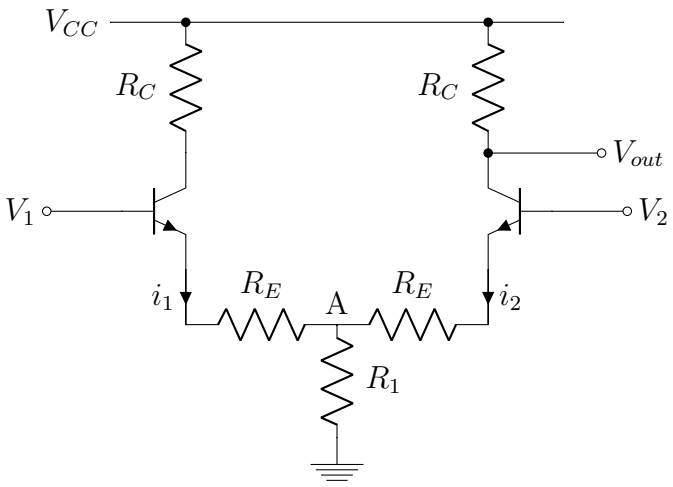
e) Connect it to the first D-FF and switch on the power supply.

f) Measure with the oscilloscope the waveforms of $Q_1$ and $Q_2$. Do they match your expectation? Sketch them.

g) Measure the propagation delay from the clock input of the first flip flop to $Q_2$.

h) Lower the frequency to about 5Hz. What pattern on the LEDs do you observe? Does it match your expectation? Show the instructor!

**Problem #4 (24 points)** The following circuit is often called "long-tailed pair". Assume that the working point, i.e. all voltages and resistor values are chosen so that the transistors are in the active region. Note the node labeled A. The voltage (compared to ground) at that node is $V_A$. Perform a *small signal analysis* by following the steps below:




a) Ignore base current, i.e. emitter and collector currents are the same.

b) Calculate the currents $i_1,\ i_2$ in terms of $R_E$, $v_1$, $v_2$ and $v_A$.

c) Calculate $v_A$ in terms of $i_1$, $i_2$ and $R_1$.

d) Combine the results and solve for $i_2$.

e) Calculate $v_{out}$.

f) Calculate the differential gain $G_{diff} = v_{out}/v_d$ by setting $v_1 = v_d$ and $v_2 = -v_d$.

g) Calculate the common mode gain $G_{CM} = v_{out}/v_{CM}$ by setting $v_1 = v_2 = v_{CM}$.

h) Compare the two gains, assume that $R_E$ is small compared to $R_1$.

i) In which common electronics part would you expect such a circuit to exist?