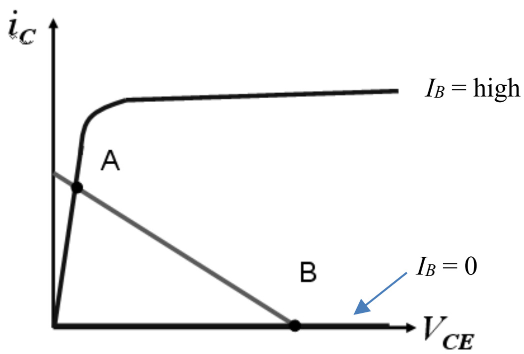
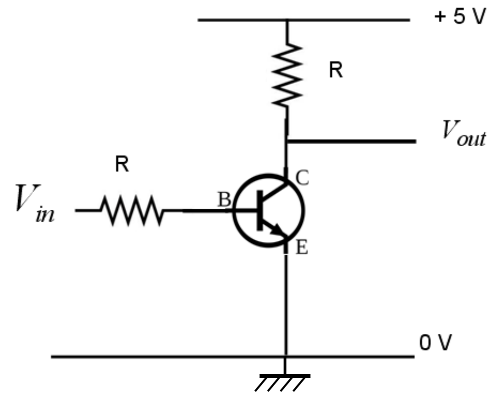
<u>**Experiment 9: Intro to TTL Circuits**</u>

Goals: To construct and test simple TTL gates made from discrete components and to construct and verify a 4-bit decoder using an integrated circuit AND gate chip. No report needs to be handed in for this lab. Simply have each of the 3 circuits verified after you have built it.

<u>**Prelab exercises:**</u>

The figure shows part of the characteristic curves for an NPN. The transistor is biased using two 10 kΩ resistors. The BE junction turns on at about 0.6 V. The load line is shown with A indicating the point with the transistor on (input high), and B indicating the point with the transistor off (input low).



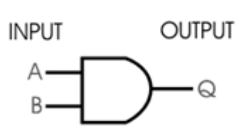


a) What is the value of V_{out} at point B and why? What range of values of V_{in} does this correspond to?

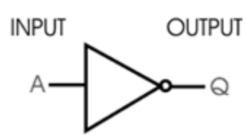
b) If the value of V_{CE} is 0.1 V at point A, what is the value of V_{out} when V_{in} = + 5 V?

c) Fill out the logic table for the AND and NAND functions of two input variables, ie:

AND symbol:



Inverter symbol:

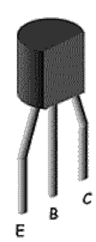


A	B	$A \bullet B$	$\overline{A \bullet B}$
0	0		
0	1		
1	0		
1	1		

d) Draw diagrams for 2 logic circuits to identify the binary numbers 1110 and 1010 using only AND and NOT gates. To identify the bits, use input labels (A, B, C, D). Your output should be F = 1 when the input corresponds to the binary number to be identified, and F =0 for any other inputs.

Equipment List:

- 2N4400 NPN bipolar junction transistors (or similar)
- 7408 quad input AND gate or equivalent
- 1 kΩ, 10 kΩ, and 330 Ω resistors, LED
- DC power supplies, AC function generator
- DMM, digital scope
- 12-bit dip (dual inline package) switch

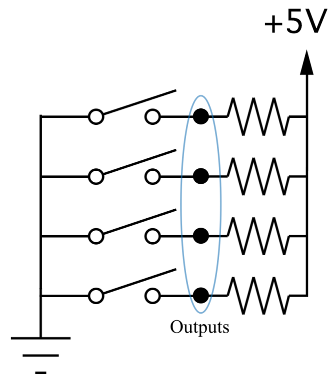


Experiment:

1. 4-bit integer

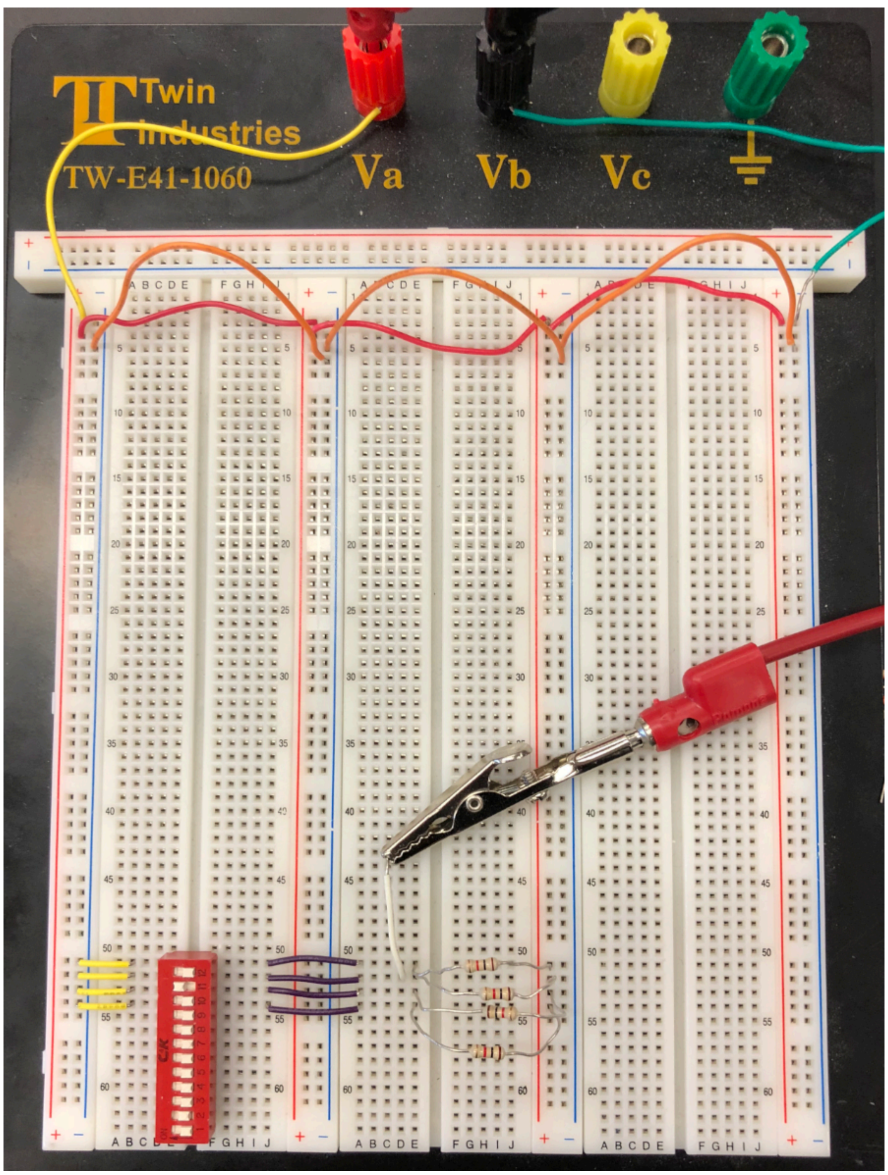
Start by connecting each of the vertical red lines on your breadboard to a +5 V power supply and each of the vertical blue lines to ground (0V). This will make it easier to build the following circuits.

Use 4 switches on a dip switch to provide 4 lines that can be switched between 0 V and +5 V (logic 0 and 1), according to the schematic diagram shown, using 1 kΩ resistors. Set up the dip switch so it is closed in left position. Then the input is low when the switch is on the left, and high on the right.



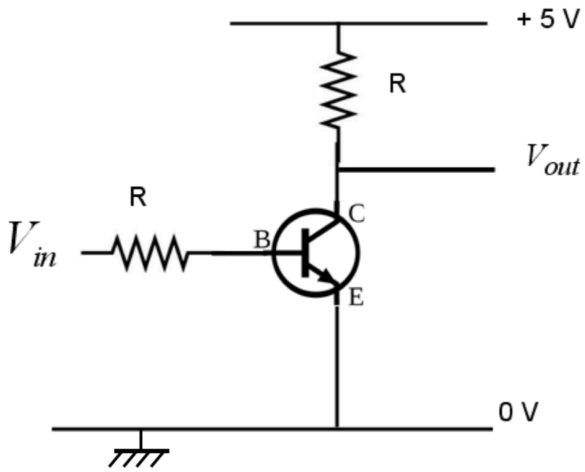
An example breadboard connection is also shown. The purple wires simply allow the separation between the dip switch and the resistors to be increased to make it easier to insert the wires for the output.

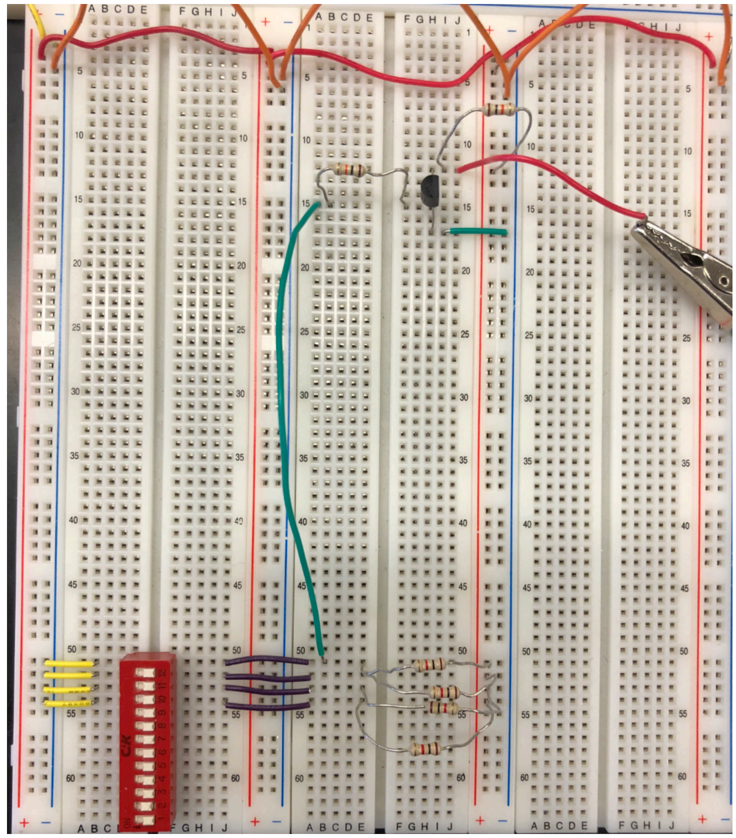
Measure each of the 4 outputs with the respective switch in both positions to be sure it is working as expected.



2. *Transistor inverter gate*

Construct the transistor circuit as shown, with $R = 10\ k\Omega$. Measure the output for dc inputs of + 5 V and zero by connecting the input to one of the outputs from the dip switch and summarize your results in a table.





Before proceeding to more complex circuits, it is worthwhile to examine this gate in more detail:

a) Use a second power supply to determine the maximum value of the input that still gives 5 V on the output. Disconnect the input resistor from the dip switch and connect it to a second power supply.

b) Finally, connect a function generator to apply a square wave TTL pulse train (use the connector on the back of the generator) to V_{in} at ~ 1 kHz, and observe the input and output signals on the digital scope. Try increasing the frequency – how fast does your inverter gate respond?

Is the time response symmetric for turning off and on? Can you account for its behavior?

Have an instructor check that your inverter is working.

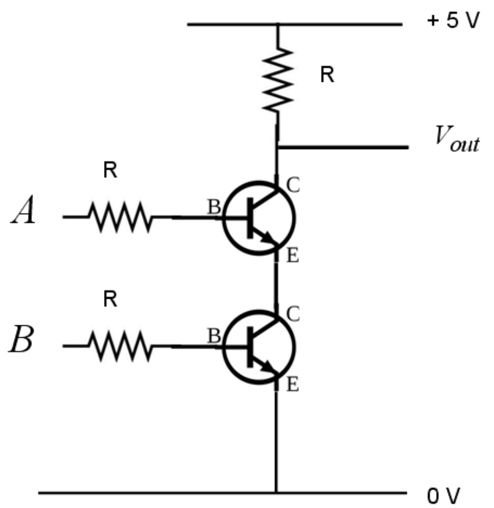
3. Two input transistor gate

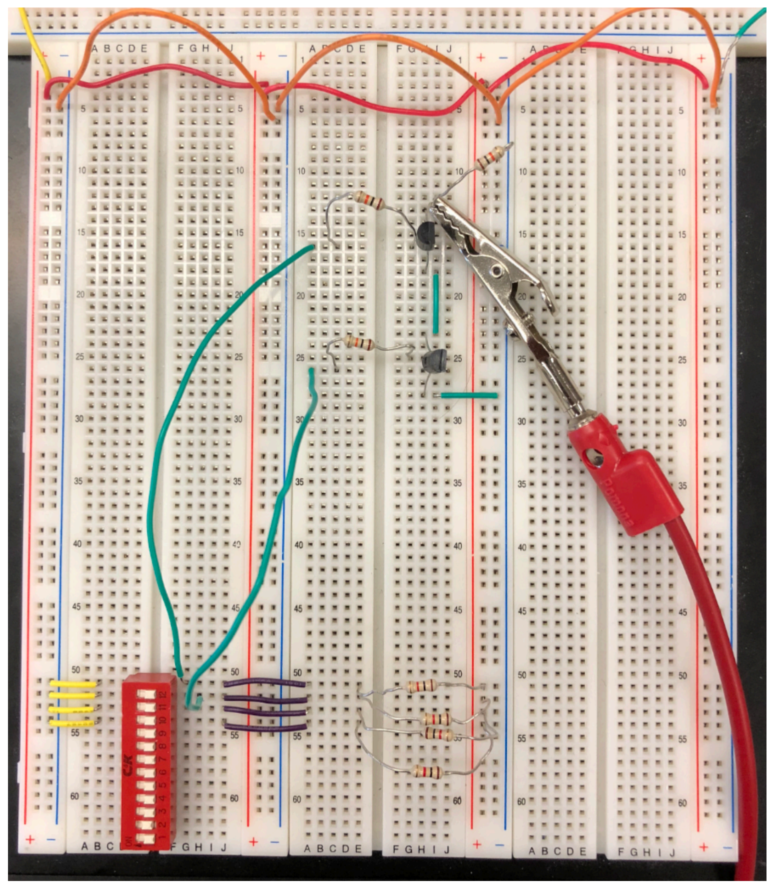
Add another input channel to your transistor gate as shown, again using $R = 10\ \text{k}\Omega$.

Measure the output voltage for the four possible TTL inputs *(A, B),* using two outputs from the dip switch, and record these in a table.

What logical operation does this circuit perform?
(Refer to prelab question c).

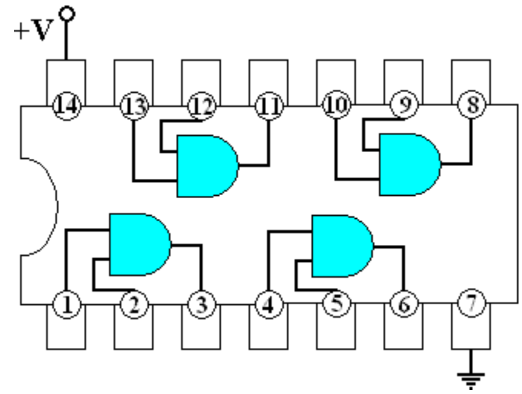
Have an instructor check that your gate is working.





4. Digital decoder

Build a circuit to identify a 4-bit binary number assigned to your group. The number will have no more than 2 zeros. Start by drawing a logic diagram as you did in exercise (d) for your number using inverter gates and AND gates.



Using one or two inverter gates as constructed in part 2, and a 4-unit AND chip (74HC08 N) construct the circuit. To identify when the output goes high, connect it to an LED through a 330 Ω resistor.

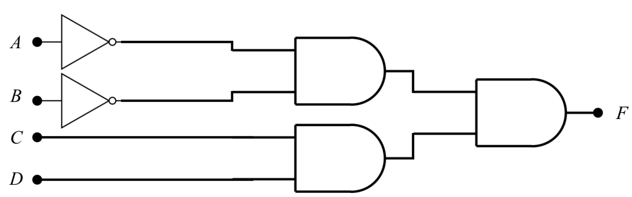
The pinout for the integrated circuit is indicated in the figure, with V = 5 V for pin 14 and V = 0 (ground) for pin 7.

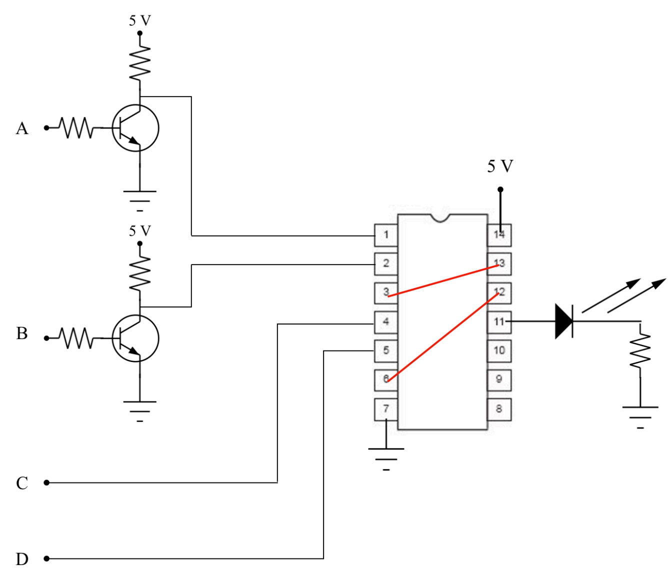
Treat the IC gently, as its legs are easily bent and damaged. Tweezers are available for manipulating the connecting wires.

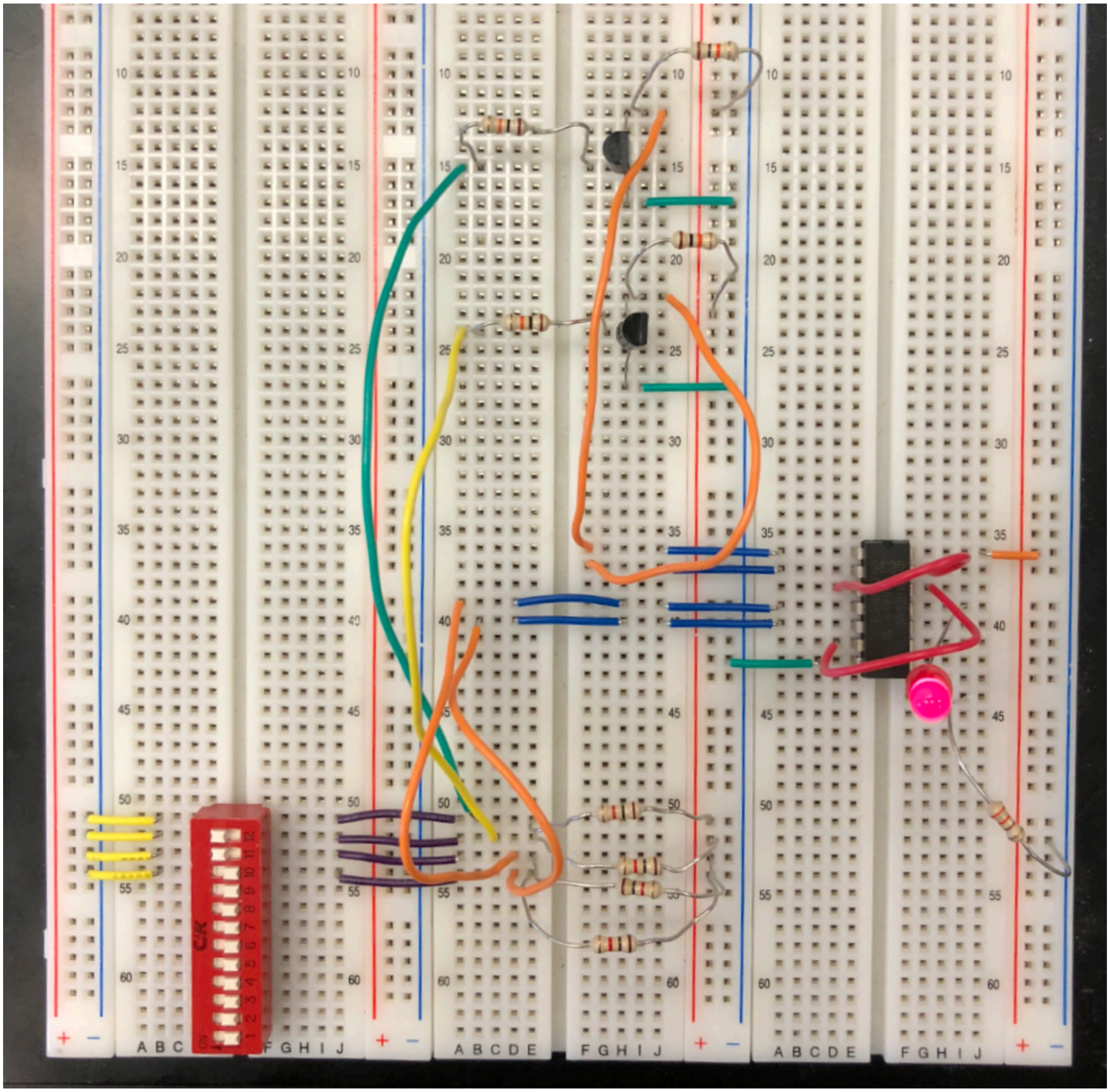
As an example, a logic diagram is shown for the binary number 0011, along with a schematic diagram of the electronics, and a photograph of the completed circuit on a breadboard.

Have an instructor check that your decoder is working.

What would you do to make the LED flash on and off at a rate of ~ 1 Hz? Try it if time permits!







A B C D E
F G H I J
+ −