Equipment

Solderless breadboard, 5-v power supply, LED’s, resistors, a signal (germanium) diode, 0.1 μf capacitors, signal generator, Hall effect switch, DVM, oscilloscope, and the following IC’s: 74LS73 J-K FF, 74LS74 D-type FF, 74LS04 Hex Inverter, and a 74LS14 Schmidt trigger.

1 Introductory comments

- If you use any of our four prototyping stations, you can just use the push-button switch they have. It is supposed to be bounceless.

- To use the Hall effect switch, you must power it with 5 v at one terminal and ground at another, as illustrated. The output is normally high, but goes low when you depress the switch. The advantage of this switch is that it is bounceless. We’ll get into other debouncing techniques later. NOTE: you should have a 390Ω pull-up resistor between the 5 v and output terminals of the switch. When not depressed, the Hall effect switch is practically an open circuit and cannot supply enough current to keep certain types of inputs at a high voltage.

To get a normally low clock signal, we’ll invert the Hall effect switch output with an inverter (74LS04).

- To define a “high” for TTL and LS TTL, we ordinarily put a 1 K resistor between +5 v and the gate input. This protects the gate from drawing too much current. Very often you can get away without using this resistor and hook the gate directly to +5 v, but it is not a good idea.

To keep your circuit board neat and not have 1 K resistors all over, you can use a SIP, or Single In-Line, resistor package. This consists of several resistors hooked usually as follows:
We have a few of these with 1 K resistors, and many with other values. If you cannot find 1 K SIPs, you can use a 2.2K SIP or a 0.47K SIP.

- De-spiking capacitors are often necessary to get counter circuits to work properly. We discuss these in lecture. Briefly, you should put a 0.1 \( \mu \text{f} \) capacitor between \(+V_{CC}\) and ground on every counter chip, and sometimes gates as well. Certain circuits you will build this term will not work at all without de-spiking capacitors.

## 2 Flip-flops and counters

### Circuit A

Wire up a 74LS73 J-K flip-flop as shown.

With “ordinary” TTL, you can usually get away with leaving the CLR, J, and K inputs open; they will each act as if they were high. However, I have found that with LS TTL you must wire the CLR input to +5 v, and sometimes the J and K inputs as well. (Use pull-up resistors, of course.)

Copy the function table for a 74LS73 (or 7473) from a databook, and verify that the IC works as stated. In particular, with J, K, and CLEAR high, you should obtain toggling as you open and close the Hall effect switch. (With LS TTL, often a floating CLR input will act like a “low”: you have to hook the input to +5 v to get the circuit to toggle.) Do you see why the function, with J and K high, could be described as “divide-by-two”?

### Circuit B

Use both halves of a 7473 to form the following circuit.
Observe and record the sequence of states of outputs A and B as you use the switch to clock the flip-flops. This circuit functions as a divide-by-[what]?

Circuit C

Modify the previous circuit as follows.

What is the function of the circuit now? Describe how this circuit works, making reference to the function table of the 74LS73.

2.1 Circuit D

Use both halves of a 74LS74 D-type FF to form the following circuit:
NOTE: you should make all preset and clear inputs high through a 1K or 2.2K resistor. Letting them float should work, but in practice it does not, and glitches occur. Also, use 0.01 μF or 0.1 μF despiking capacitors between \( V_{cc} \) and ground on each chip.

Describe the action of this circuit, giving the states of the two outputs after each of several sequential clock pulses:

<table>
<thead>
<tr>
<th>pulse</th>
<th>( Q_1 )</th>
<th>( Q_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>:</td>
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</tbody>
</table>

You will note that although it repeats every 4 clock pulses, the circuit does not count in binary. (This is a very short “walking ring” counter, which we will discuss later in the course when we cover shift registers.)

A bouncing switch

Keep the previous circuit but replace the Hall effect switch by an ordinary push-button switch, as shown below.

Try to get your counter to advance one state at a time by pressing the push-button switch. Are you able to? TTL can count at about 35 MHz, so just about any bounce can cause spurious “clocking”.

Problems

1. Draw a diagram for a 3-bit binary counter using 7473 J-K flip-flops. This will count from 000 to 111 and start over. (Note: the logic for TTL and LS TTL is the same, so I will often not bother to differentiate between them.)

2. Consider the circuit below. Predict the behavior of the outputs \( Q_1, Q_2, \) and \( Q_3 \) for a series of clock pulses. Assume the initial conditions are \( Q_1 = Q_2 = Q_3 = 0 \). Use enough pulses to obtain at least one complete ”cycle”, or repetition of conditions. How many pulses are required for one complete cycle?
3 The Schmidt trigger

We learned in lecture how to use feedback to make a Schmidt trigger from a comparator. Here we will examine the properties of the 74LS14 Schmidt trigger.

Place the 74LS14 on the solderless breadboard and hook up $V_{CC}$ and ground. Connect the signal generator as shown, obtaining a rectified sine wave with a peak voltage of about +3 to +4 volts.

Make sure the scope inputs are DC-coupled. Spread the waveform out on the scope face (the time base has a variable control) so that only about 2 cycles are visible. Draw the waveform you see. The Schmidt trigger should be switching output states during each as its input voltage goes up and down. Describe the amount of hysteresis you see, giving the minimum trigger voltage (input going up) and the turn-off voltage (input going down.) You can superimpose the waveforms to obtain accurate readings. What is the voltage “gap” between turn-on and turn-off voltages?

In order to observe the hysteresis a different way, hook the Schmidt trigger input to the horizontal scope input and the Schmidt trigger output to the vertical scope input. Draw the waveform you see, and label the direction of each ”sweep” for turning on and off. (Remember that this is a Schmidt trigger inverter.) Be sure the scales on your drawing are clear so the amount of hysteresis can be estimated.

END