The purposes of this lab are

- to learn what a shift register is and how to construct one from flip-flops
- to learn what a counter is and how to use it to construct a divide-by-N circuit
- to become familiar with the 555-timer (one-shot) and to build an oscillator with it (only one of its many uses).

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<table>
<thead>
<tr>
<th>Equipment at each station:</th>
<th>Centrally available:</th>
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<tbody>
<tr>
<td>digital oscilloscope</td>
<td>wire and wire cutters/stripper</td>
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<tr>
<td>2 multimeters, 2 power supplies</td>
<td>red and black banana plug cables</td>
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<tr>
<td>signal generator, standard breadboard</td>
<td>assorted resistors and capacitors</td>
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<tr>
<td>CMOS digital ICs: (4040 counter, 4081 quad AND, 4013 dual flip-flop, 555 monostable multivibrator)</td>
<td>HP 3325 signal generator (up to 20 MHz)</td>
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<td>bags of LEDs</td>
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1. Shift Register from Flip-Flops

- Using two dual 4013 D flip-flops, build a 4-bit shift register as shown above. Include the LEDs and current limiting resistors on each output for visual confirmation of the state of your register. It may be necessary to increase the power supply voltage $V_{DD}$ above 5V to drive the LEDs.

- Tie the input of your shift register to high through a “pull-up” resistor and attach a wire to the input so you can easily change the value of the input.

- Clock the shift register at some suitably low speed (∼1 Hz) so that you can watch it in action. Apply a sequence of changing bits at the input and watch them move through the register.

- Optional: Connect all your shift registers together to make a giant register that can handle a larger word.

- Optional: Tie the output of the register to the input, making a circular register. How could you load this type of register?
2. Divide-by-N Counter

- Examine your 4040 12-bit ripple counter and its data sheet. Thankfully you can buy such a device and not have to build it from individual flip-flops! Connect \( V_{DD} \) to +5V and \( V_{SS} \) to ground. Connect a 5VpD square wave through an AC coupling capacitor. Unused inputs (e.g., reset) should be grounded.

- Verify that the outputs divide by \( 2^N \). Monitor a few of them on your scope, or better yet, rig up some LEDs.

- Disconnect the reset and wave your hand around the IC. Note what happens and why unused CMOS inputs should be grounded.

- Using your scope, measure the delay for several different outputs, noting that the delay increases for progressively higher outputs. Increase the power supply voltage \( V_{DD} \) to 15V and note how the delay changes.

- Construct a \("\div 5\) counter by feeding the appropriate outputs to an AND gate and into the reset.

- Optional: Connect our counter to your neighbors to make a 24-bit ripple counter.

3. Monostable Multivibrator

- Construct an oscillator for your counter using the 555 timer (a.k.a. “one-shot”). The figure above shows one way to make this circuit, including the pin numbers. An explanation of how this circuit works is given in the accompanying 555 data sheet.

- Examine the output before you put it into your counter.

- Optional: filter the output to remove the higher harmonics and produce something more like a sine wave.

- Optional: Use a trimpot to make the output frequency variable.