

**Lab 4: Digital Electronics**  
**BMEEn 2151 “Introductory Medical Device Prototyping”**  
**Prof. Steven S. Saliterman**

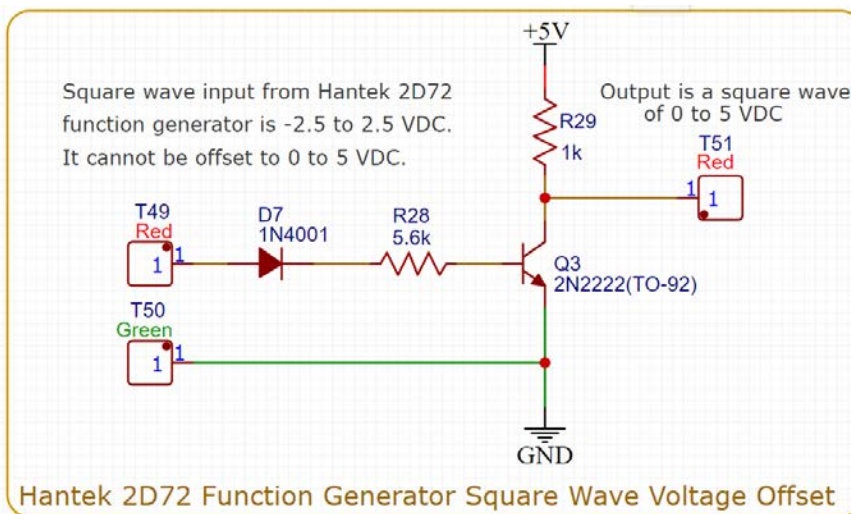
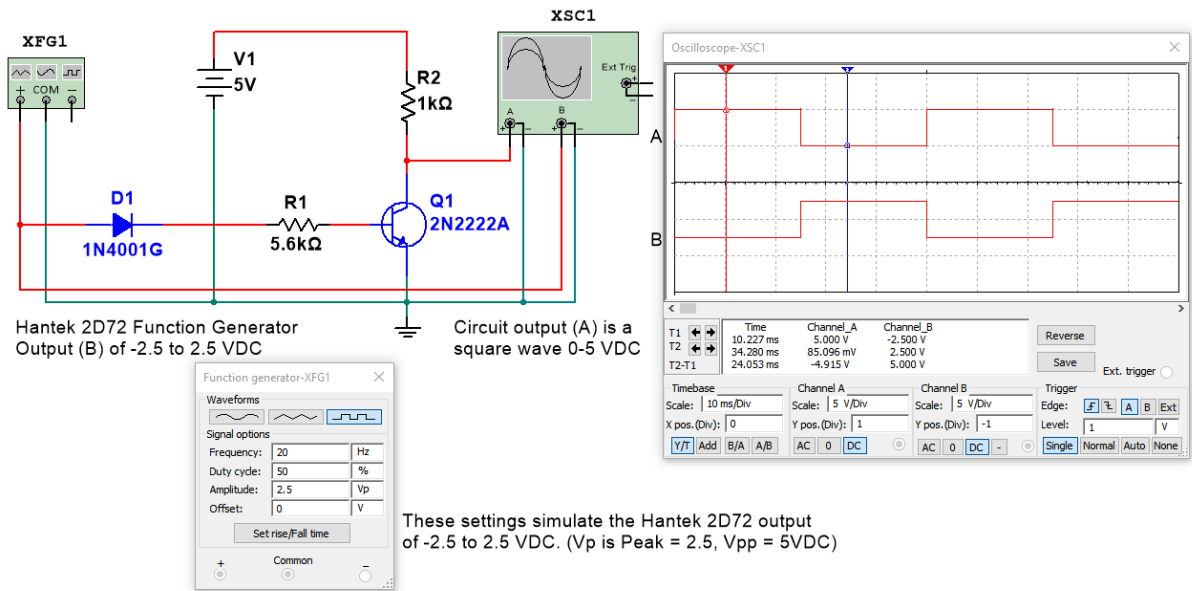
**Contents**

<b>Exercise 4.1: Hantek 2D72 Function Generator Square Wave Voltage Offset .....</b>	<b>2</b>
<i>Multisim Simulation, Schematic, and PCB .....</i>	<i>2</i>
<i>Discussion.....</i>	<i>3</i>
<i>Construction .....</i>	<i>3</i>
<i>Task .....</i>	<i>4</i>
<i>Lab Workbook .....</i>	<i>4</i>
<i>Circuit Not Working?.....</i>	<i>4</i>
<b>Exercise 4.2: The 74HC00 NAND Gate &amp; Transistor Driven LED .....</b>	<b>5</b>
<i>Multisim Simulation, Schematic, and PCB .....</i>	<i>5</i>
<i>Construction .....</i>	<i>6</i>
<i>Task &amp; Lab Workbook .....</i>	<i>6</i>
<i>Circuit Not Working?.....</i>	<i>7</i>
<b>Exercise 4.3 Switch Contact Debouncer .....</b>	<b>8</b>
<i>Multisim Simulation, Schematic, and PCB .....</i>	<i>8</i>
<i>Construction .....</i>	<i>9</i>
<i>Task .....</i>	<i>9</i>
<i>Lab Workbook .....</i>	<i>10</i>
<i>Discussion.....</i>	<i>10</i>
<b>Exercise 4.4: One-and-only One Clock Synchronized Pulse .....</b>	<b>11</b>
<i>Multisim Simulation, Schematic, and Trainer Board .....</i>	<i>11</i>
<i>Construction .....</i>	<i>12</i>
<i>Task .....</i>	<i>12</i>
<i>Lab Workbook .....</i>	<i>13</i>
<i>Discussion.....</i>	<i>13</i>
<b>Exercise 4.5: Four Bit Binary Counter with Buffer Drivers.....</b>	<b>14</b>
<i>Construction .....</i>	<i>15</i>
<i>Task &amp; Lab Workbook .....</i>	<i>15</i>
<b>Exercise 4.6: Trainer Board Breadboard Area Familiarization .....</b>	<b>17</b>
<i>Task &amp; Lab Workbook .....</i>	<i>17</i>

## Exercise 4.1: Hantek 2D72 Function Generator Square Wave Voltage Offset

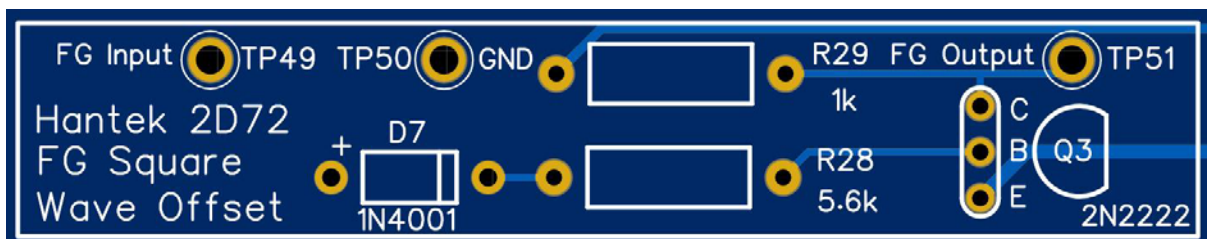
Objective: Convert the Hantek function generator square wave output to something useful for CMOS digital circuitry. Always review the circuit schematic before doing an exercise.

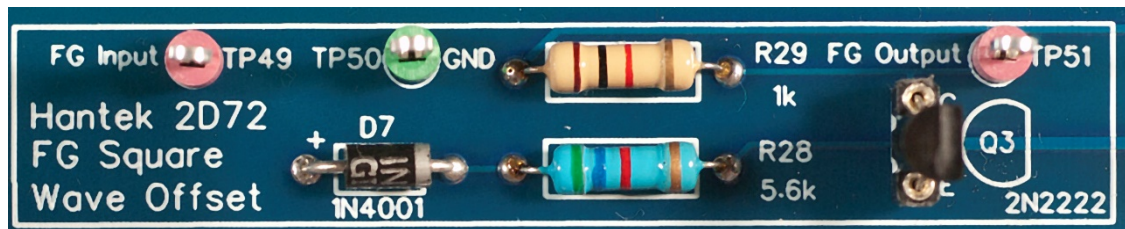
### Multisim Simulation, Schematic, and PCB



**Note:**  
Test point colors are important. The photographs are correct. The schematics may have notes referencing an updated color.

Note: Test points T49 & TP51 are now purple.



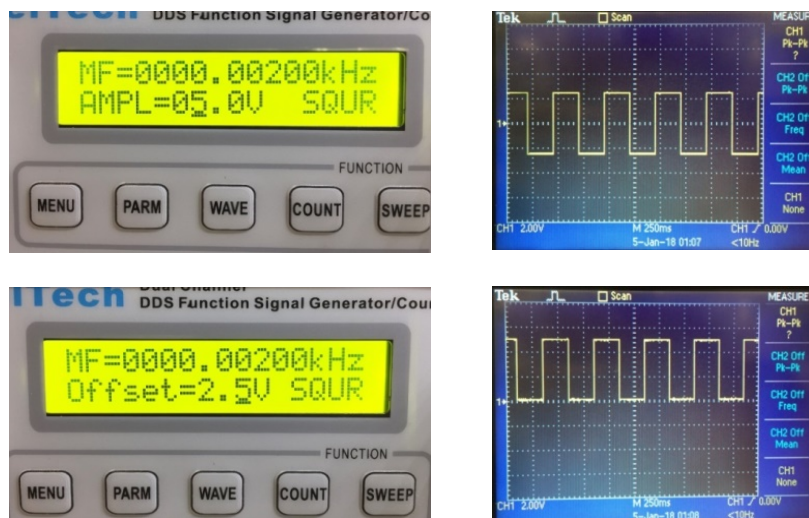


## Discussion

Integrated circuit families have different supply voltages. For the CMOS circuits here we are using 5VDC. Input voltages ranging from 3.5 to 5VDC are recognized as HIGH (or logical state 1) while input voltages of 0 to 1.5VDC are considered LOW (or logical state 0). We will also be using clock pulses that are square waves of 0 to 5VDC.

The Hantek 2D72 has a voltage ceiling of + and/or - 2.5 volts. In contrast, a typical bench function generator (below) will have a greater voltage swing. To compensate for the negative swing, an “offset” voltage is applied for digital logic. The figure below shows typical settings for a square wave from a bench function generator. Note the signal is -2.5VDC to 2.5VDC (5VDC peak to peak). Adding an offset of 2.5VDC will bring the range to 0 to 5VDC.

**Note:** Since the Hantek 2D72 cannot generate 0-5VDC, this circuit will take its square wave and offset the voltage for you. Use this circuit’s output at TP51 later for the needed input at TP41 and TP47, or anytime you need it the prototyping area.

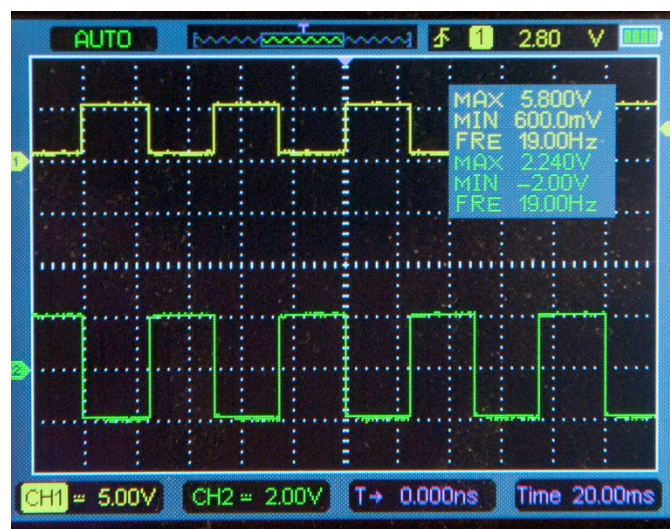


## Construction

With the power supply off, solder the necessary components to the PCB to complete the circuit. Remember that the transistor has a socket.

## Task

1. Select Channel and use the function keys to set both probes to DC coupling (input).
2. Start by applying a 20 Hz, 2.0 volt square wave with no offset from the Hantek 2D72 function generator – red lead to TP49, and the black ground to TP50.
3. Attach scope probe 1 to the output TP51 (you may select any green GND lead for the black alligator clip), and attach scope probe 2 to the input TP49 (you will need to grab onto the function generator red min-grabber). Select Auto. You should see the following tracings:



Notice Auto has selected channel 1 to be 5.0 volts per division and channel 2 to be 2 volts per division (lower left). The input signal (channel 2) is about +/- 2.0VDC, while the output (channel 1) is about a half a volt to 5VDC, and suitable for CMOS circuits. Be sure you understand how this circuit works.

## Lab Workbook

1. Take a photograph of your scope display.

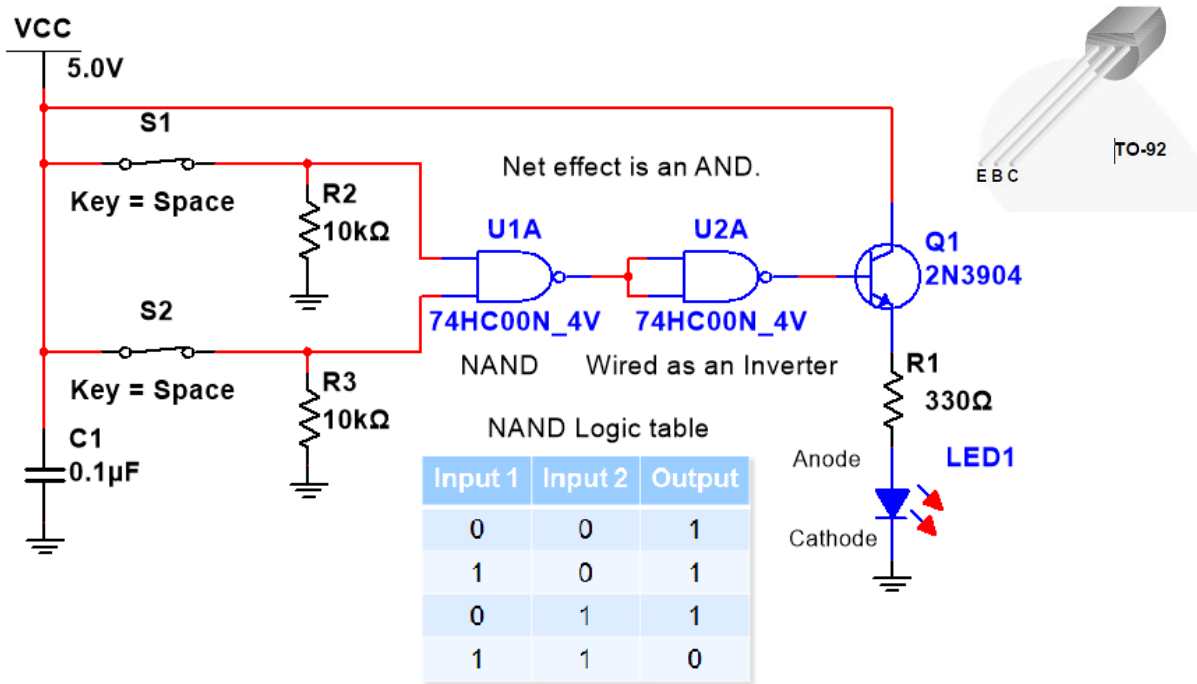
## Circuit Not Working?

Be sure you have turned your power supply back on. Confirm that you have the correct frequency (20 Hz not 1 kHz) and voltage (shown above) on the Hantek frequency generator. If necessary connect the frequency generator directly to a scope probe and measure.

## Exercise 4.2: The 74HC00 NAND Gate & Transistor Driven LED

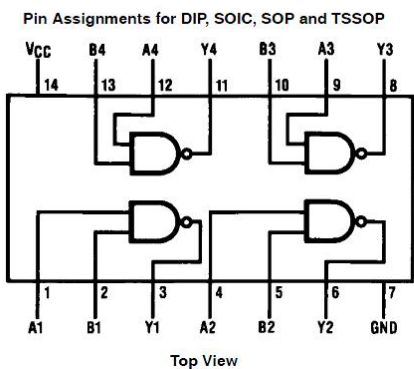
Objective: Deduce the logic table of an AND logic gate created from two NAND gates, and drive an LED using a transistor.

### Multisim Simulation, Schematic, and PCB



The CMOS output can drive other CMOS chip inputs directly, but generally requires the use a transistor to handle higher currents, such as a relay or motor.

#### Connection Diagram



#### Logic Diagram

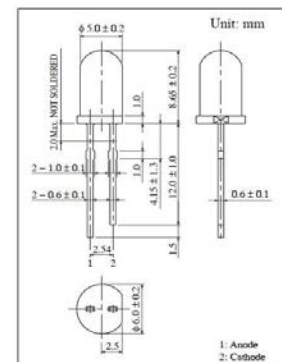
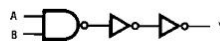
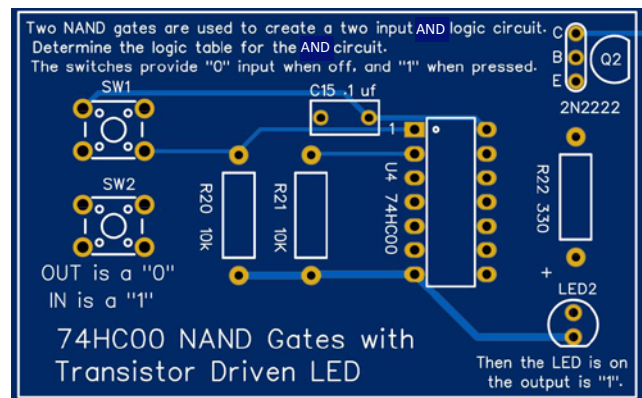
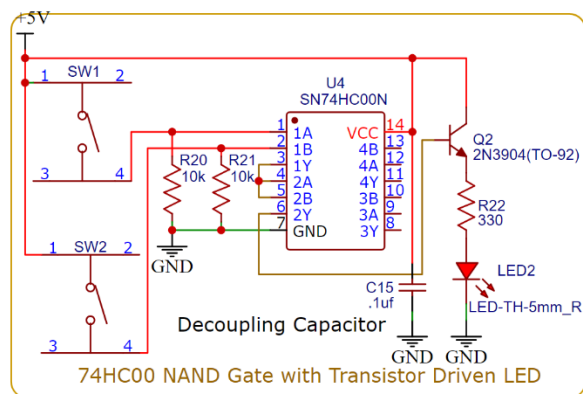
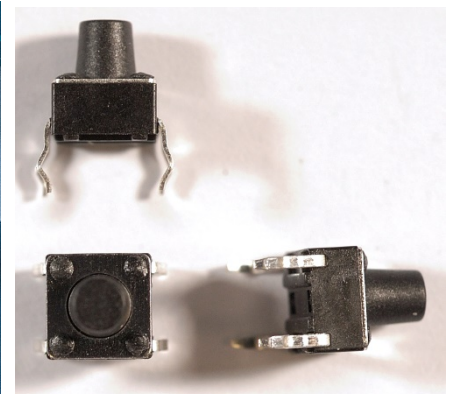
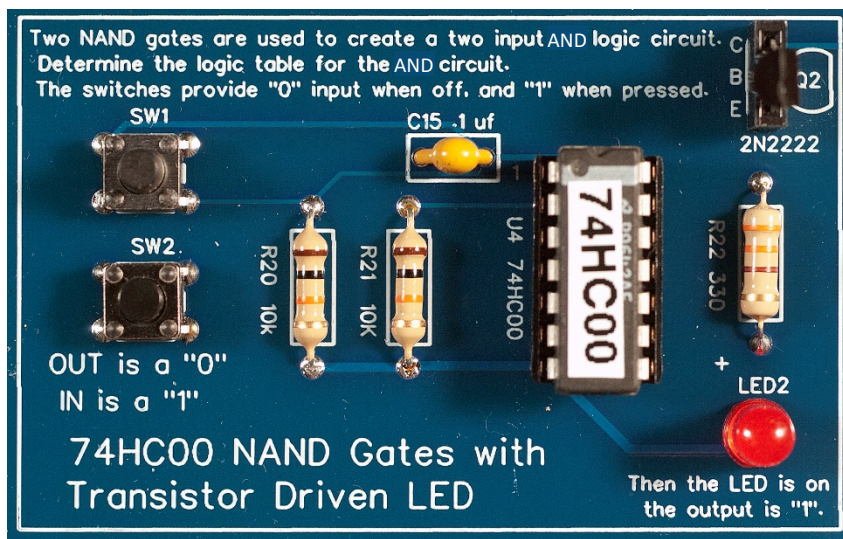


Image courtesy of Fairchild Semiconductor





Note: There is a misprint on your printed circuit board (V2.1) – it should say “AND”, not OR.



## Construction

Solder the necessary components to complete the circuit above. The switch bases are not square, and the pins should easily fit into the holes. Note the polarity of the LED. Carefully insert the IC into its socket observing the location of pin 1. Peak under the IC and see if any leads are crimped. If so, use the green IC remover, straighten the pin and reinsert the IC.

## Task & Lab Workbook

1. Draw the logic table for an AND gate (like what was done for the NAND logic table above), the result of wiring two NAND gates as shown. For help, look up AND gates on the web.

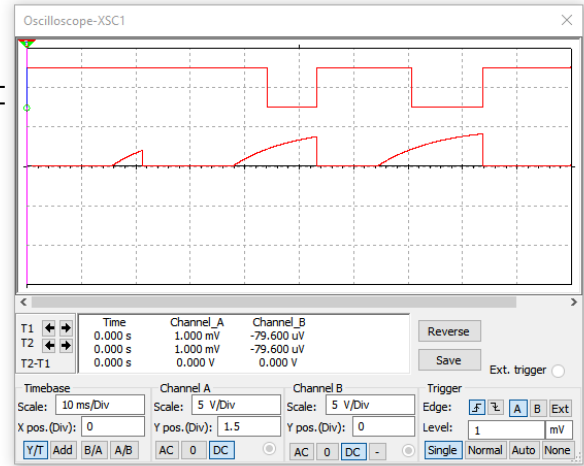
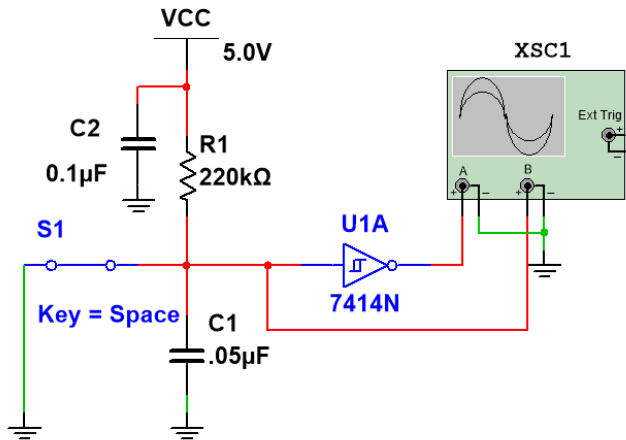
## **Circuit Not Working?**

Double check the orientation of the LED and 74HC00. Check under the 74HC00 (between the chip and socket, and the socket and board) for a bent lead. Finally, try a new IC.

## Exercise 4.3 Switch Contact Debouncer

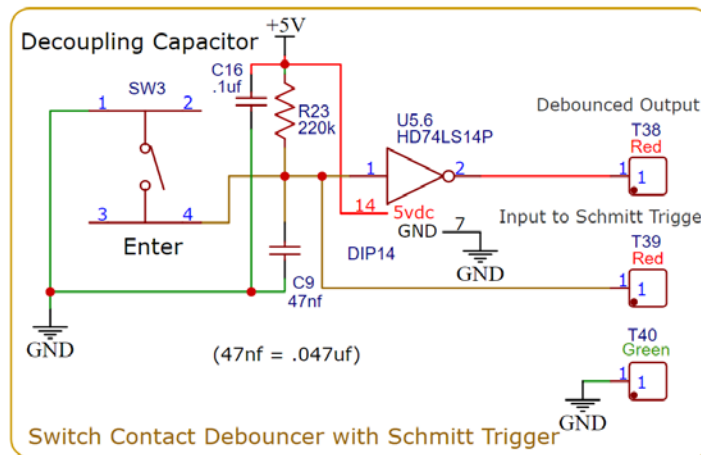
Objective: Create a clean digital pulse from a noisy mechanical contact switch.

### Multisim Simulation, Schematic, and PCB

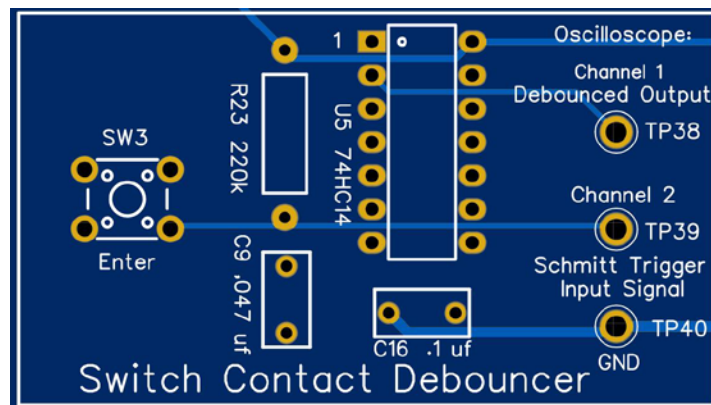


Output (Inverted)  
Input Pulse

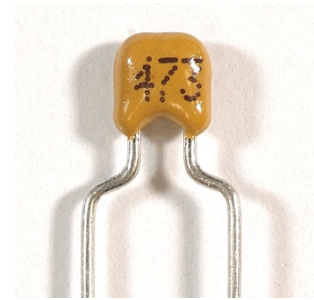
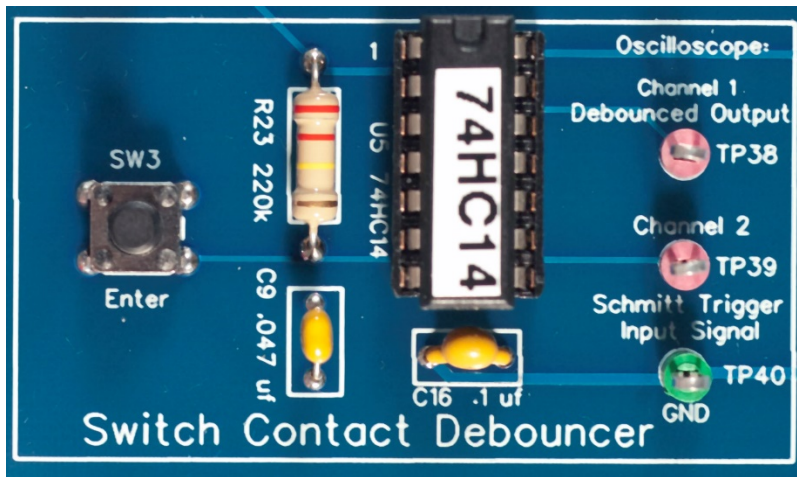
Note: Circuit shows a normally *closed* button. Simulate this by holding the button down, then momentarily lifting your finger to create the input pulse.



Note: Test points T38 & TP39 are now purple.







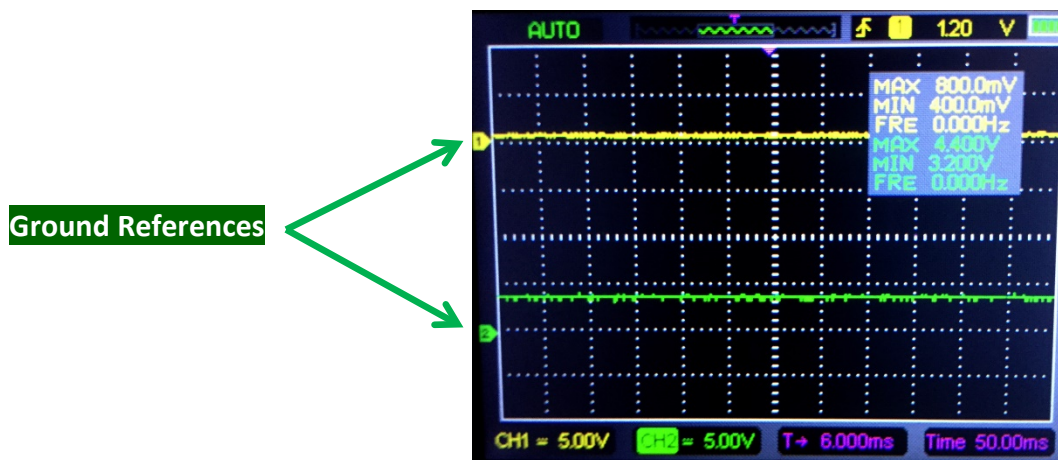
Capacitor: .047  $\mu$ f  
(Code = 473)

## Construction

Solder the necessary components to complete the circuit above. Be sure all IC socket pins are present and soldered. Carefully insert the 74HC14 Schmitt trigger chip.

## Task

1. Rather than using Auto, you will set up the scope parameters manually. Enable both scope probes and set both for DC coupling.
2. Set channels 1 and 2 to 5.00V/division (x-axis). To do this, press Channel, then F1 until you are on channel 1. Next press the right or left arrow key on the keypad to change the number on the lower left to 5.00V/division. Do the same for channel 2.
3. Next change the time base to 50ms/division (y-axis). To do this press Time, and then the up or down arrows until the 50.00ms appears in the lower right display.
4. If the probe traces are overlapping you will need to reposition them on the screen. The tiny arrows of the left of the display show the ground reference (zero potential). Press Channel and select channel 1 with the function keys. Press and hold the up arrow on the keypad to move the ground reference up two grid units. Do the same for channel 2, but hold the down arrow to lower the ground reference two grid units. Your display should like the one below (button is not pressed):



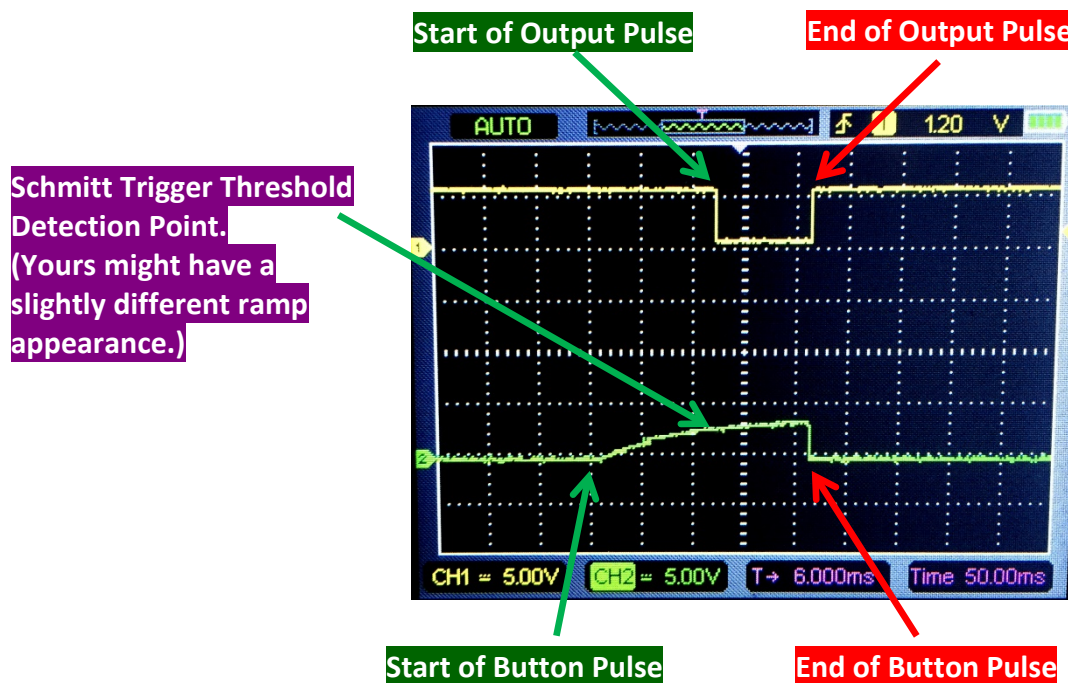
5. Connect your scope probe 1 to TP38, and probe 2 to TP39 (remembering to attach the alligator clips to TP40 or any other green test point - GND).

6. Remove the Max/Min/Freq display from the screen by pressing Menu, and finding the Monitor item. Select, and in the submenu, select disable.

7. Press and hold the button down. Momentarily lift your finger to send several pulses of variable duration. Observe the momentary display of the debounced button pulse (channel 1) and the input to the Schmitt trigger (channel 2). Send pulses in rapid succession to begin with. It takes several random button presses to appreciate what is happening.

## Lab Workbook

1. See if you can capture a photograph of a button pulse (release) event and the output similar to below:



2. Why is the output pulse inverted?

3. Why is the duration of the output pulse less than the button pulse (time released)?

## Discussion

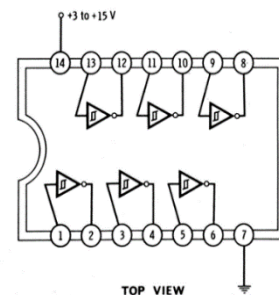
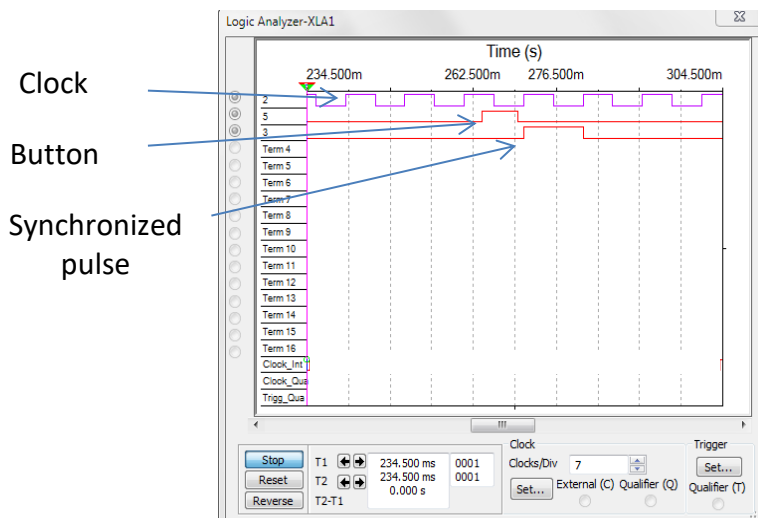
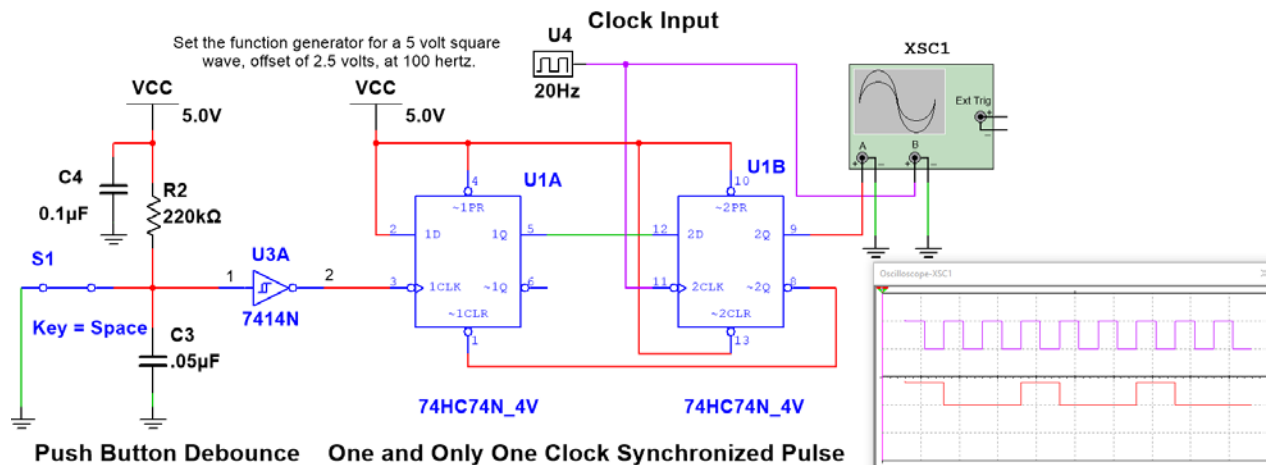
The C9 and R23 time constant (charging the capacitor) smooths out the mechanical noise. The Schmitt trigger uses a threshold to detect the rising ramp voltage, switching quickly and creating a clean square wave. In the next module you will see how to synchronize this pulse this with a system clock. You will jumper the output at TP38 to the input of the One-and-only One Clock Synchronized Pulse at TP42.

## Exercise 4.4: One-and-only One Clock Synchronized Pulse

Objective: This exercise introduces the concept of synchronized and clock driven circuitry. Using a clock allows multiple chips to carry out their operation in tandem, independent of the time it might take for information to propagate along a chain of integrated circuits. This eliminates “settling time” and improves the chances of relevant data being present at the input of a chip when called for. This exercise uses the output of the previous Switch Contact Debouncer circuit (Exercise 4.3) and clock output from the Astable Multivibrator (Exercise 3.11)

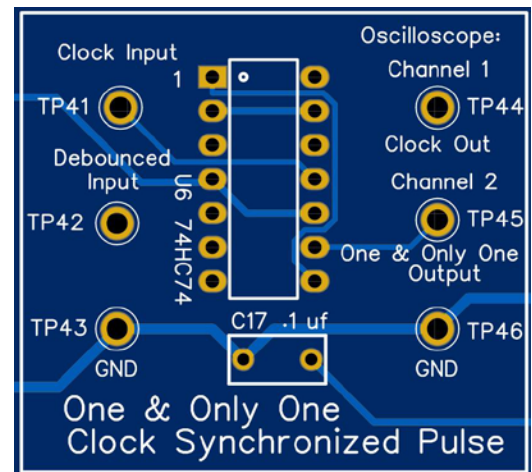
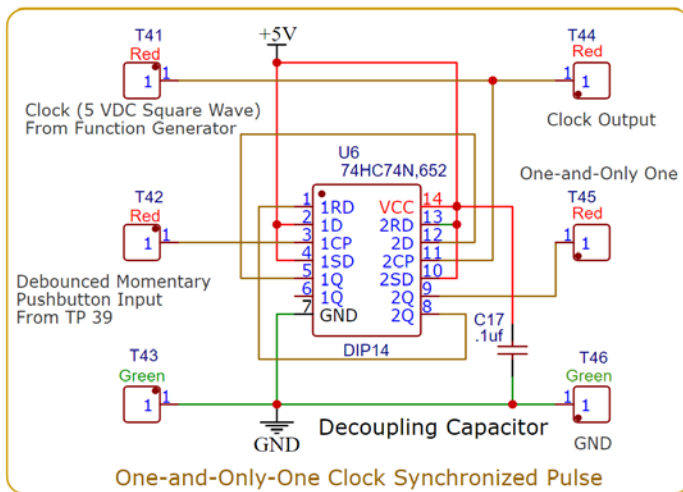
### Multisim Simulation, Schematic, and Trainer Board

Study the Multisim circuit below closely. A virtual *logic analyzer* has been incorporated so that the timing of the clock, debounced pushbutton and synchronized pulse (the “one and only one”) can be visualized. You can accomplish this with your oscilloscopes, but only two channels at a time. This timing relationship is shown in the display that follows the circuit. This circuit uses a 74HC14 Schmitt trigger for debouncing a push button (previous exercise) and 74HC74 flip flops. When the button is momentarily released, you not only get a single pulse, but the pulse is synchronized to the clock, and lasts only one clock cycle.

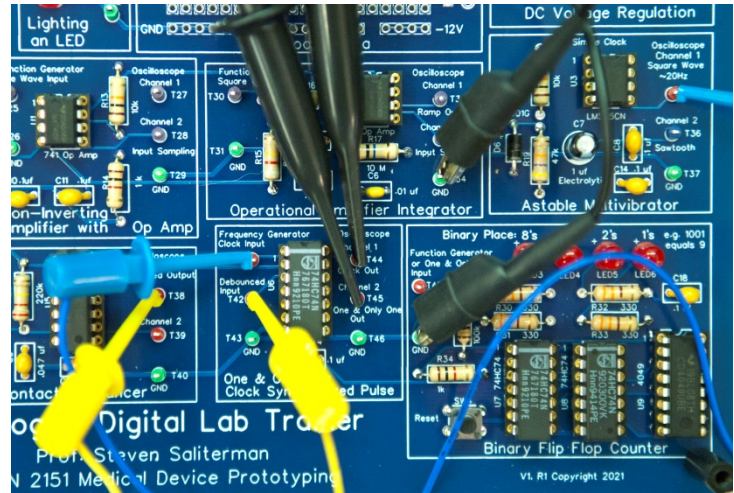
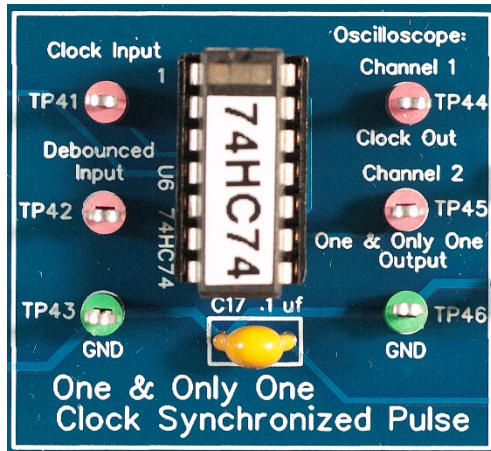


T74HC14 Hex Schmitt Trigger  
Connect pin 14 to plus 5 volts,  
and pin 7 to ground.





Note: Test points T41, 42, 44, 45 are now purple.



Interconnecting modules

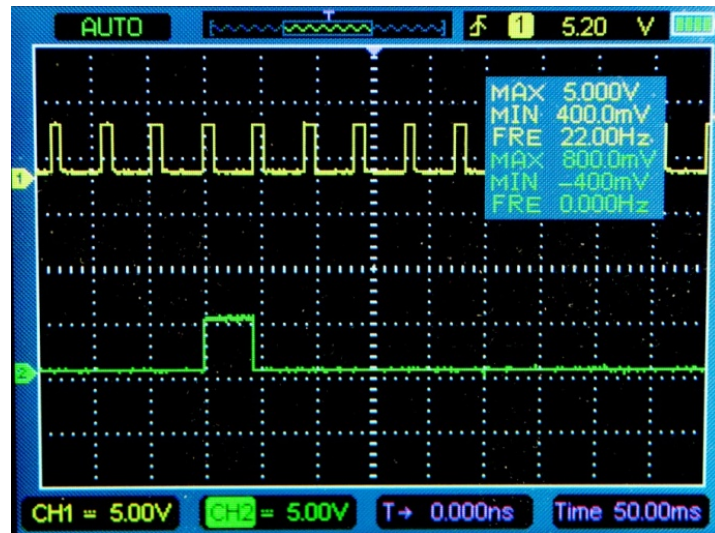
## Construction

You constructed a button debouncer in the previous exercise. Now assemble the components to complete the one-and-only one synchronized pulse circuit above. Be sure all IC socket pins are present and soldered. Insert the IC carefully so as not to bend leads underneath.

## Task

1. Connect a clock to pin TP41 – use a two-sided mini-grabber lead and jumper from TP35, the Astable Multivibrator. Use another two-side mini-grabber, and jumper the output of the contact debouncer TP38 to the input on the one and only one TP42. (You need not worry about the GND leads here – they are connected internally.)
2. Manually set both scope probes to DC coupling and 5V/division. Put scope probe 1 on TP44 and scope probe 2 to TP45 (connecting the ground alligator clips to TP46 – GND, or

any other nearby green test pin). Momentarily press the button and you should see a pulse similar to the display below. Adjust the Time base manually if necessary. Try several button presses of variable duration.

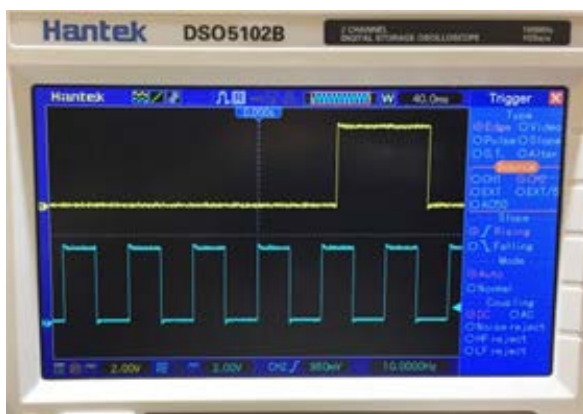


## Lab Workbook

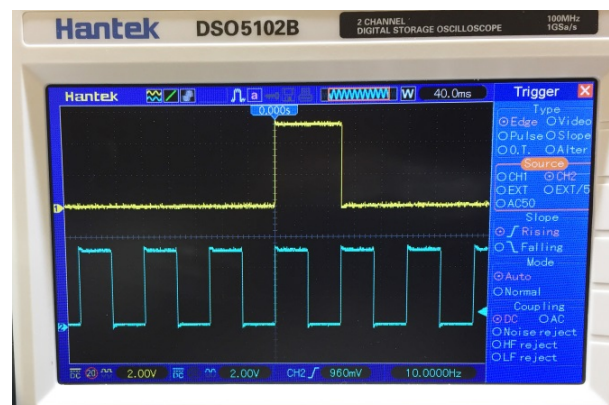
1. See if you can photograph the one-and-only one pulse and clock signal together. You will use this output as an input to the Binary Counter (Exercise 4.5) next.

## Discussion

The displays below contrast the previous switch contact debouncer pulse relative to the clock (TP38 and TP44); and with the one & only one pulse relative to the clock (TP45 and TP44). On the left, the duration is determined by how long the button is pressed. While the pulse is a clean square wave, it is not synchronized with the clock. Notice that oscilloscope triggering is set on the clock. On the right you can see that the pulse is exactly one clock cycle in duration and timed with the clock (as above).



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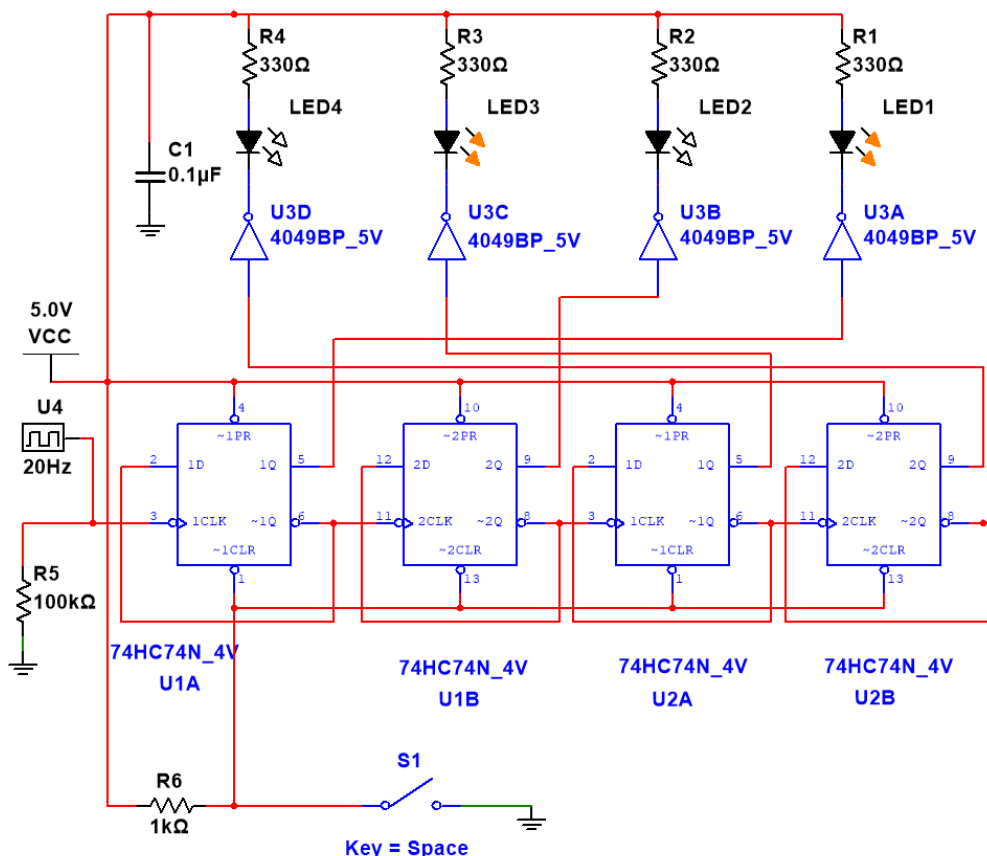
Labs should be done under supervision.



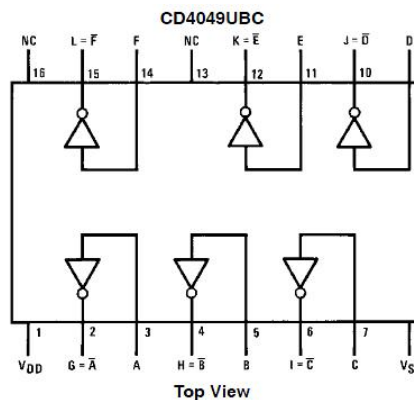
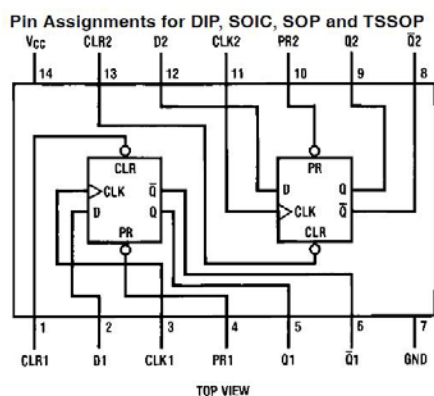
## Exercise 4.5: Four Bit Binary Counter with Buffer Drivers

Objective: To demonstrate asynchronous counting with CMOS flip flops, and driving LEDs with a CMOS hex buffer, the 4049. You will be using the previous two modules for input to the counter.

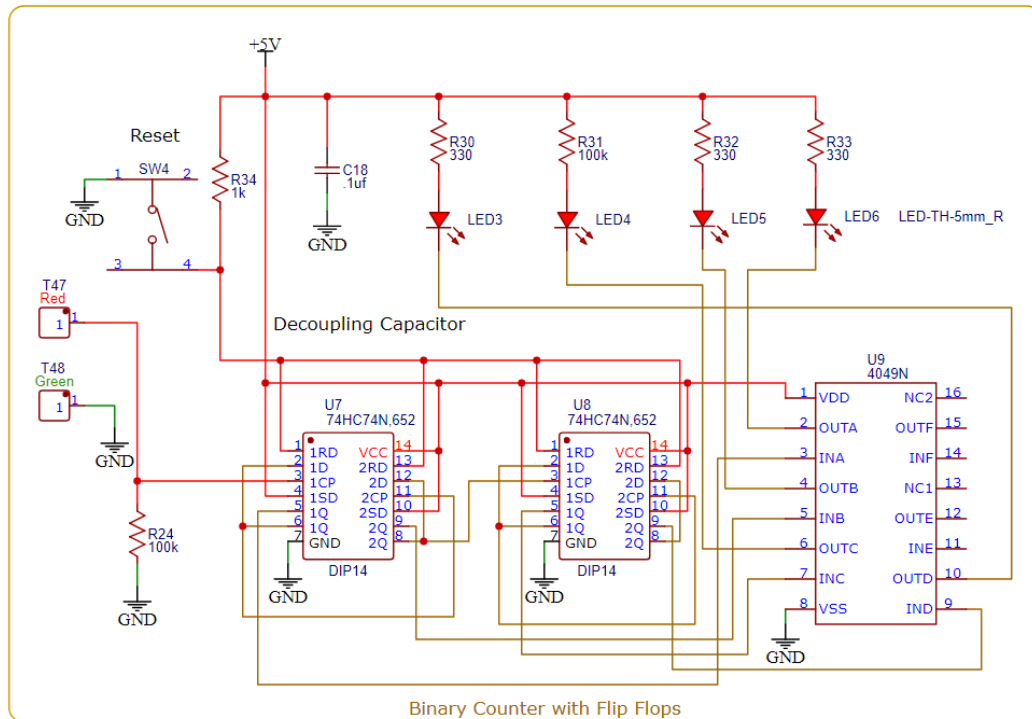
### Multisim Simulation, Schematic, and PCB



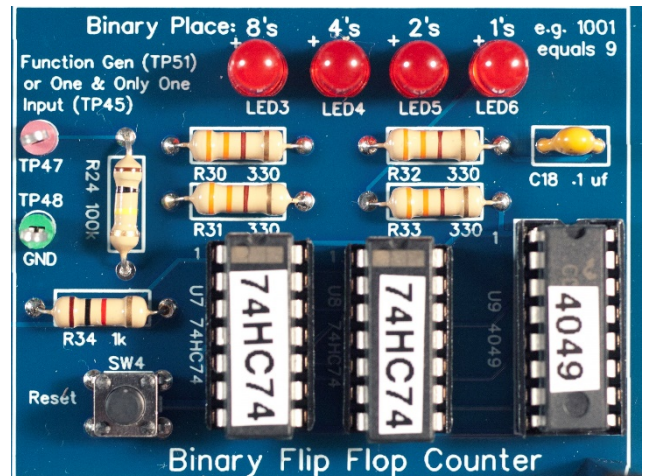
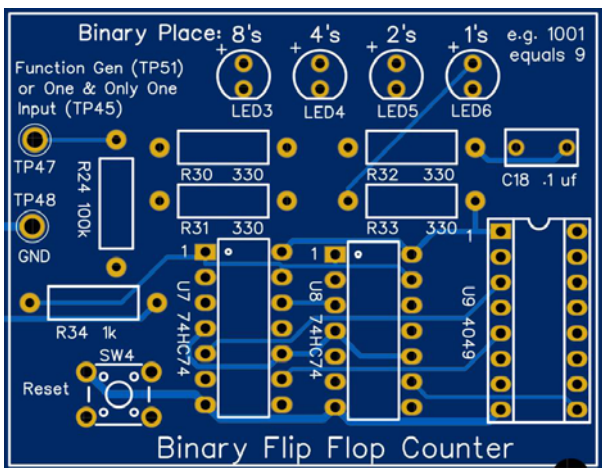
### Connection Diagram



Images courtesy of Fairchild Semiconductor



Note: Test point T47 is now purple.



## Construction

Solder the necessary components to complete the circuit above. Be sure all IC sockets pins are present and soldered. Insert the ICs carefully so as not to bend leads underneath.

## Task & Lab Workbook

Verify (yes or no) seeing each of the following scenarios using three different inputs at TP47 (1-3):

1. Interconnect the Contact Debouncer output TP38 to the One and only One input TP42 with a two-sided mini grabber jumper. With a second jumper, interconnect the Astable

Multivibrator output TP35 to the One and Only One clock input TP41. With a third jumper interconnect the One-and-only-One output TP45 to the Binary Counter input TP47. Reset the counter. The counter should advance in binary each time you press the push button on the Contact Debouncer module. Troubleshoot before proceeding. Now, take a picture of the binary number 1010 (LEDs left to right, ON-OFF-ON-OFF). This is the same as a decimal ten.

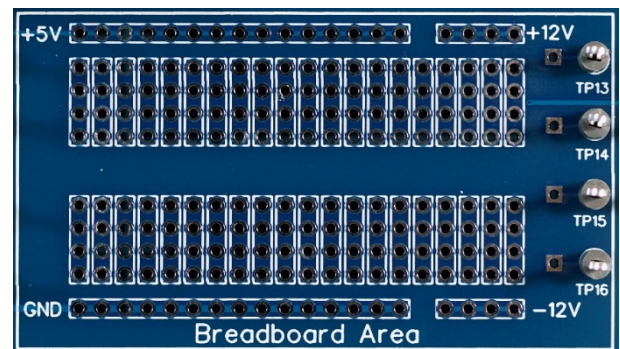
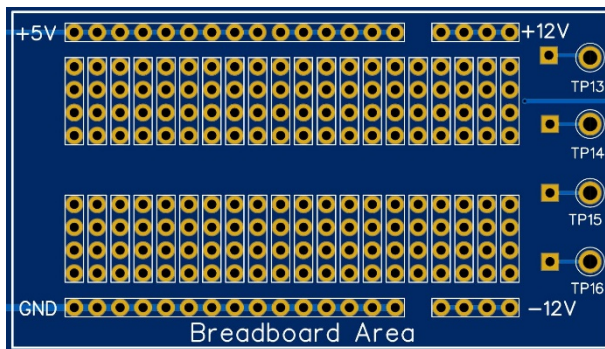
2. Remove the previous jumpers. Jumper the Astable Multivibrator output TP35 directly to the Binary Counter input TP47. The counter should start counting up at 20 hertz. (The counter restarts itself when it overflows.)

3. Now remove the previous jumper. Connect your Hantek 2D72 function generator leads to the Hantek 2D72 Function Generator Square Wave Voltage Offset module inputs TP49 & TP50. Jumper the Offset module output TP51 to the Binary Counter input TP47. You should now be able to vary the count rate by changing the frequency of a square wave on the function generator of the Hantek 2D72. (Start with a 20 Hz square wave.)

(Review Exercise 4.1: Hantek 2D72 Function Generator Square Wave Voltage Offset to understand why you do not directly connect the Hantek 2D72 function generator output to the Binary Counter.)

## Exercise 4.6: Trainer Board Breadboard Area Familiarization

This module on the PCB allows for placing a circuit you design, inclusive of typical breadboard columns and rows, and test points. The rows contain +5, +/-12 VDC and GDN rail (bus) already wired internally. Unlike a typical breadboard, here you solder in the components after you have confirmed your circuit works with a “jumper wire” style breadboard. Test point colors may be chosen based on the type of signal and your preference (gray is shown below).



### Task & Lab Workbook

1. I did this (Yes/No): \_\_\_\_\_
2. Take a photograph of the front and back of your Analog & Digital Lab Trainer Board to finish the job!
3. You may use this breadboard area for sensor or actuator projects.

## End of Digital Electronics Lab



# Appendix

## A-1 Analog & Digital Lab Trainer Board

