Physics 335
Notes for Lab 3 – MSI Counters, Binary Number Systems, and Displays

April 17, 2009

This week's lab is not in the Student Manual. Work from these notes.

We will build

- A decade counter
- A hexadecimal counter
- A programmable -divide by any integer- counter

Again, as before:

- Use the +5V Fixed Supplies with the negative terminal to ground and bypassed with a 0.1μF Capacitor on the breadboard.
- Before beginning, build a "debounced switch", which you will find in the drawers. The chip and all resistors are wired... Just connect power to pin 14, ground to pin 7, and switches.

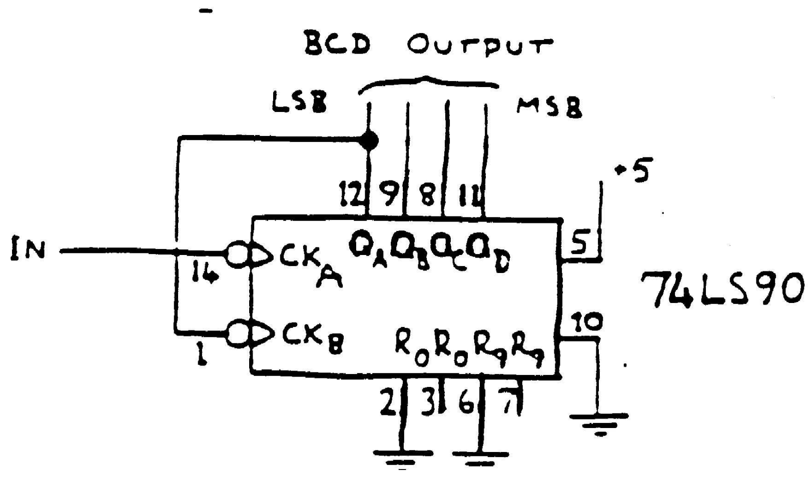
1-1 MSI Counters – The 74LS90 is a decade counter. It has unusual power connections: $V_{cc} = Pin5$; $GND = Pin10$.

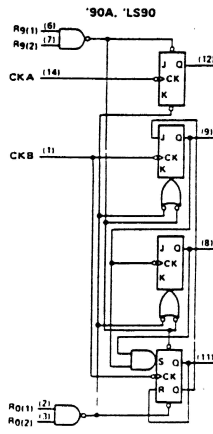
Wire up the chip as shown. Avoid running wires over the top of the chip. You will be replacing with the pin compatible HEX counter 74LS93. The '90 is actually 2 counters, a divide-by-two section "A" and a divide-by-five section "B", each with separate, independent clock inputs CKA and CKB.

Use the 4-LED array to look at the BCD output while clocking the input with the debounced switch. Take the reset of R_0 off ground and figure out what it does, then do the same with R_9. What happens if you assert both?

Is this a synchronous or a ripple counter and how do you determine this?

LS 90 Counter Chip Logic





1-2 Use an HP Display Chip (in the "Display" drawer) to look at the counter outputs. A description of the HP is on p. 348 of the lab manual. You can see the IC in the face of the chip that tells you which side is down. Please be careful in the handling and wiring of this chip as they are stupidly expensive for what they are. ***In particular, note the power wiring of the chip carefully.***

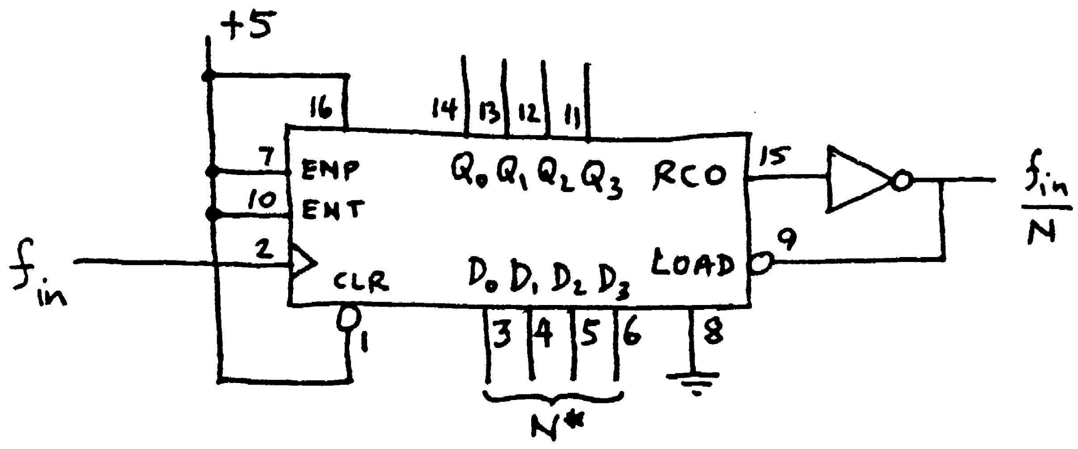
Count through the sates manually toggling the debounced switch. Note that it will count only on one edge of the clock, thus you must cycle the switch fully (back and forth) for each step. Now turn off the power and pull out the the 74LS90 and replace it with a '93 (HEX counter) It is pin compatible but there is no R9 connection (pins 6 and 7). Step through the count and record your observations.

1-3 Use the TTL output of the funtion generator to clock faster. Look at the outputs QA to QD of the 93 in turn with the scope while you apply a 1 kHz and verify that each is half of the previous one. Then pull out the '93, put back the 90 and do the same and justify what you see. Can you think of a way to use a 90 to give you a symmetrical square wave at one-tenth the frequency? Try out your idea (if you get one!)

2 Programmable Divide by N Counter

The LS161 and 163 are 4 bit synchronous binary (divide-by-16) and the LS160 and 162 are decade (divide by 10) counters. They either have synchronous (162, 163) or jam (=master=asynchronous) resets (160, 161). They can be direct parallel-loaded synchronously (on the rising edge of the clock) from the data inputs d0 through d3 enabled by the "LOAD". The chips also put out "RCO" (Ripple Carry Out) which goes high when the '161 & 163 reach 15 or 160,162 reach 9. With this feature, we can construct a divide by N programmable counter. We put N* (the 2's completement of N) into the data lines D0 - D3 and enable load with the RCO (inverted)

Divide by an Integer Counter



Use a debounced switch or the SYNC OUT of the function generator for f_{in} Use the HP display or the 4-LED array (your choice). For the inverter, usea an 74LS00 or another chip of your choice.

Remember 2's complement is 1's complement plus 1.

What is N* (2's complement of N) for a divide by 4 counter? What logic levels should be applied to D0-D3 for divide by 6 counter? What frequency should each of these output if we apply f=10kHz to pin 2. Look at the output on pin 15. Why isn't the waveform symmetric?

Try it out with various values of N. What states will the Q outputs go through for N=4? For N=6? What frequencies to you expect to measure for each of these values of N? Try it – Can your circuit do the math?

3 Stopwatch

The last project today is a stopwatch running from a 10Hz clock signal from the function generator. Gate the clock into the counter with a 74LS00 as shown. Use a second switch to reset the counter. Remember to figure out what do do with the various inputs (RESET, CLOCK, ENABLE). This takes about an hour to do, so don't start unless you have time.

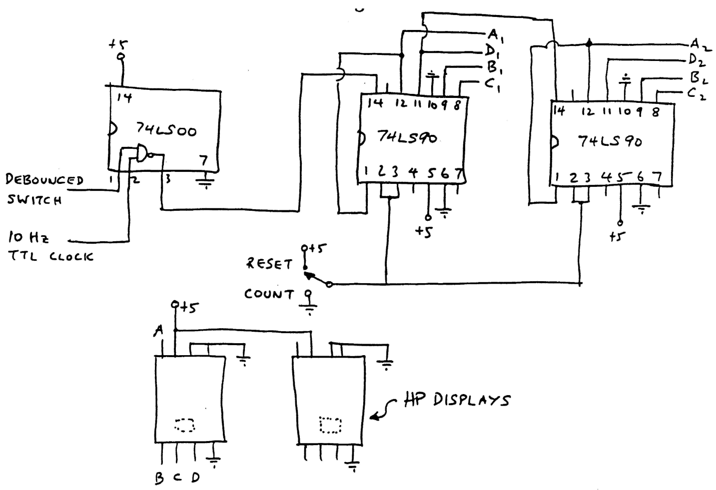
Wire neatly to avoid troubleshooting headaches.

Why is it necessary to debounce the gates switch but not the reset switch?

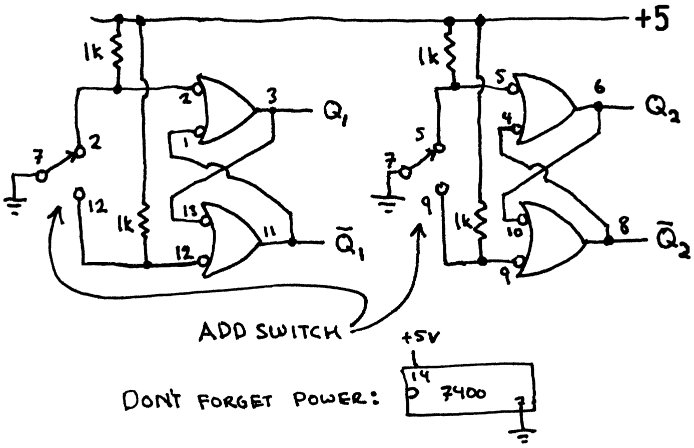
Which counter is the MSB? LSB?

Notice Q3 goes high at binary 1000 (8) of the LSB, but we don't want to increment the MSB until after 1001 (9). Why doen't this pose a problem for us?

Stopwatch Circuit



PARTIALLY PRE-WIRED DEBOUNCED SWITCHES



PRE-WIRED FOUR LED ARRAY