

Lab 5. Binary Counter

Overview of this Session

In this laboratory, you will learn:

- Continue to use the scope to characterize frequencies
- How to count in binary
- How to use an MC14161 counter

Introduction

- The TA will show you the MC14161 counter and the MC14012 quad input NAND gate.

Oscilloscope Measurements

- 5.1 Connect the signal from the function generator to the oscilloscope and determine the type of signal present, the frequency, amplitude, and the DC offset.

Background

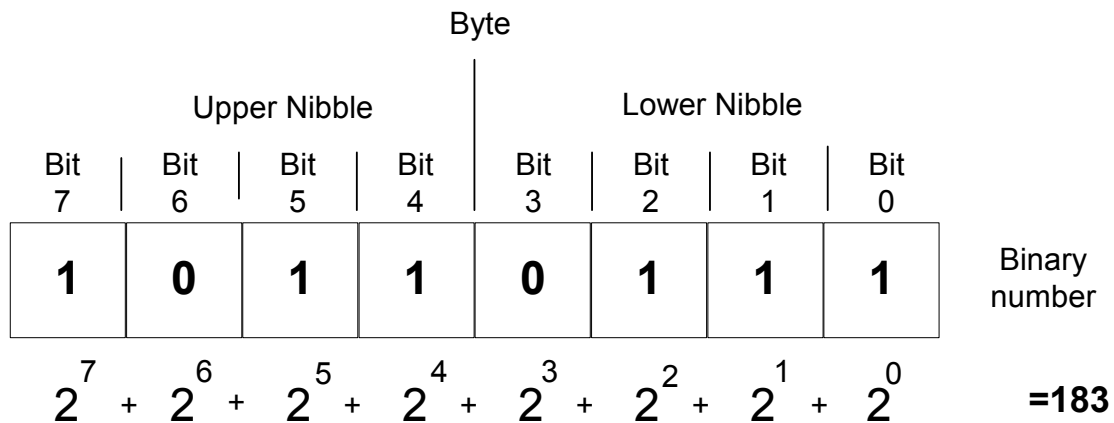
Counting:

Before starting with counters there is some vital information that needs to be understood. The most important is the fact that since the outputs of a digital chip can only be in one of two states, it must use a different counting system than you are accustomed to. Normally we use a decimal counting system; meaning each digit in a number is represented by one of 10 characters (0-9). In a binary system, there can only be two characters, 0 and 1.

When counting up in a decimal system, we start with the first digit. When that digit 'overflows', i.e. gets above 9, we set it to 0 and add one to the next digit over. The same goes for a binary system. When the count goes above 1 we add one to the next digit over and set the first digit to 0. Here is an example.

Decimal	Binary
0	0
1	1
2	10
3	11
4	100

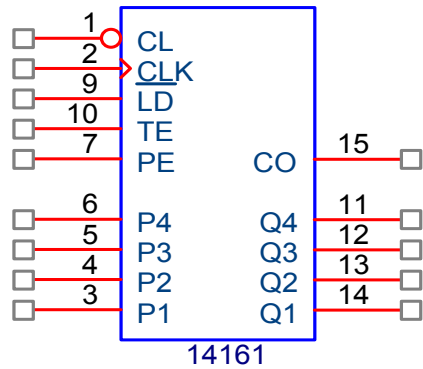
To convert a binary number to a decimal, we use a simple system. Each digit, or 'bit' of the binary number represents a power of two. All you need to do to convert from binary to decimal is add up the applicable powers of 2. In the example below, we find that the binary number 10110111 is equal to 183. The diagram also shows that eight bits make up what is called a byte. Nibbles are the upper or lower four bits of that byte. Referring to nibbles and bytes are useful when dealing with other number systems such as hexadecimal which a base 16 instead of base 10 or base two.



5.2 What are the binary number representations for the numbers 5 through 10?

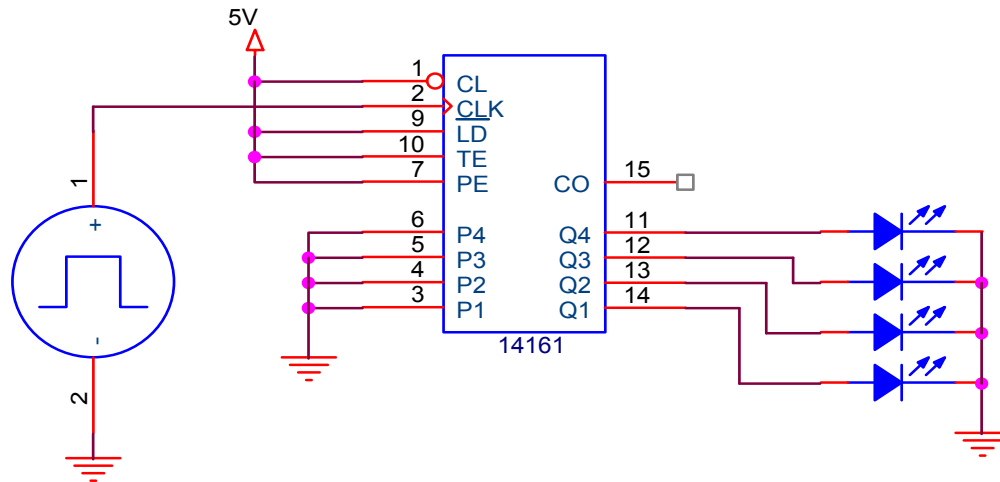
THE COUNTER:

Many digital circuits need to be able to count. The most basic element to every single microprocessor, from the one inside your watch to a Pentium 4, is a counter. So lets see how to use one. Below is a schematic of the MC14161 counter.



QA-QD	= Outputs
P1-P4	= Program Input
CLK	= Clock
CO	= Carry out
TE, PE	= Counter and program enable
CL	= Clear (Master Reset)
LD	= Load P1-P4 value onto QA-QD

Hook up the following circuit. Then set the function generator to output a square wave, of 1Hz with a peak-to-peak voltage of 5 volts. However, the DC offset must be set so that the output goes from 0 volts to 5 volts, that is the negative portion of the square wave does not go below zero volts. Have the TA verify that you have created this signal correctly before connecting it to the counter circuit. Use the scope to show the waveform.



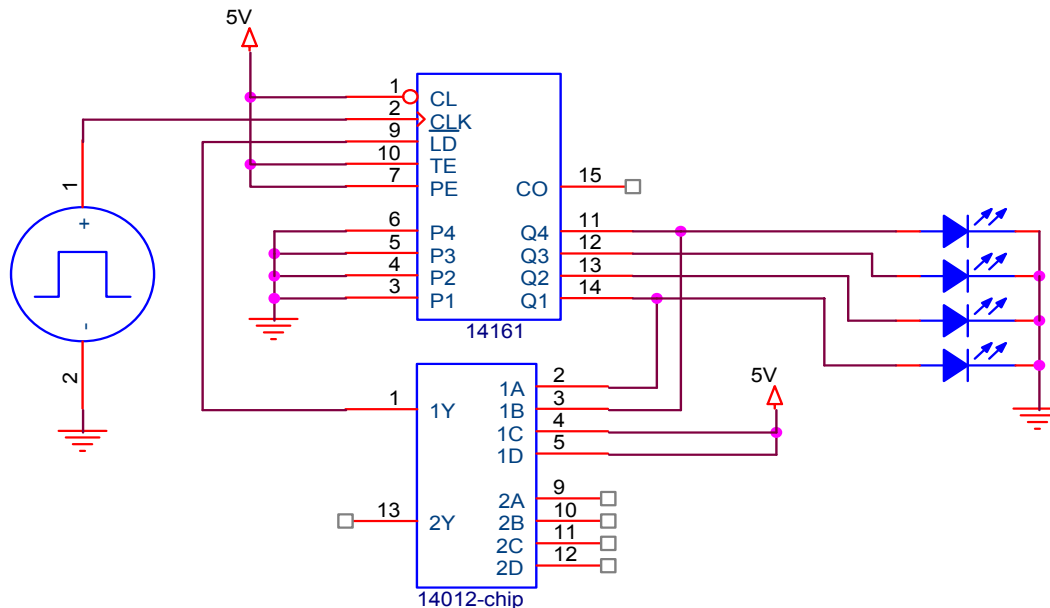
Some very important things should be noticed about this diagram. First, **the pins on the chip diagram are not presented in their actual order!** This is a common practice to keep the schematic as neat as possible. **Be sure to hook up the pins correctly on the actual circuit!** Remember, to locate Pin 1, orient the chip so that the divot is up, Pin1 will be to the left of the divot. Subsequent pins go in a counter clockwise fashion. Second, the CL pin has a little bubble on it and the LD pin has a line over the label. Both of these mean that this function is activated when this pin goes low (to ground). Third, **Power (+Vcc) and Ground (GND) are not shown on the chip in this schematic.** It is common practice to leave them out since all chips need to be powered. **Most logic chips (these included) have power (+Vcc) at the highest pin number (upper right side, pin 16 in this case) and ground attached to the halfway pin (lower left, pin 8 in this case).** **Be sure you power your chips or they will not work!**

Before you power the circuit, verify that your clock signal has an amplitude of 5 volts and a DC offset of 2.5 volts. It should oscillate between 0 and 5 volts.

- 5.3 Does the circuit count input pulses from the Function Generator?
- 5.4 What number does it count to?
- 5.5 What is the frequency of the waveforms that come out of each of the Q pins relative to the frequency of the function generator (you may find it easier to increase the frequency of the function generator so that the lower frequency outputs are easier to see on the scope)? Is this what you expect? Why?
- 5.6 Find another group that has completed this much. Attach the Carry out of one circuit to the CLK of another. What number can you count to now?

COUNTING TO A SPECIFIC NUMBER

What if you only want to count to a specified number? How can we make the circuit above count from 0 to 9 and then restart at 0? For this we will need a logic gate. We need a chip to monitor the output of the counter. When it sees that a 9 is there, it needs to set the counter to 0. Build the following circuit (don't forget the power and ground pins for both chips!):



Examine this circuit closely. Here, the counter will increment as before. However, when the number 9 (1001) is on the outputs, all the inputs to the 4-input NAND gate will be high (1). Therefore the output of the NAND gate will go low, thereby, loading the outputs of the counter with the number present at the inputs (P1-P4), which, in this case is the number 0. At the next clock cycle, the counter will set the outputs to 0.

Assemble the circuit and answer the following questions. Start with the clock at a low frequency, around 2 Hz to verify that the circuit is actually counting from 0 to 9.

- 5.7 Why are the 1C and 1D pins of the NAND gate tied to 5 volts?
- 5.8 How can we get the counter to count from 0-5? (Hint: you only need to adjust the wires from the output of the counter to the NAND gate)
- 5.9 How can we get the counter to count from 1 to 6? (Hint: The wires between the counter output and the NAND gate need to be changed again, and so does the number on the counter load inputs (A-D).

LAB 5 DATA SHEETS

The 74xx161 has the same pin out as the MC14161, which is no longer made.

Synchronous Presettable Binary Counter

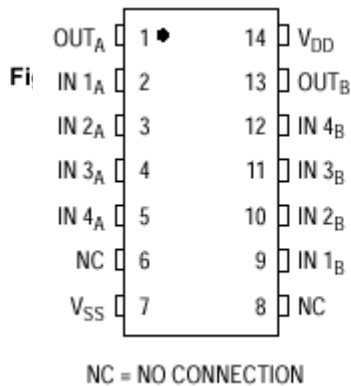
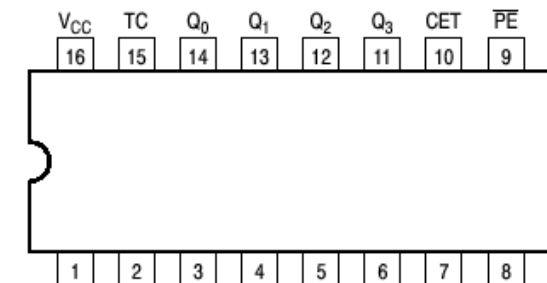
The MC74AC161/74ACT161 and MC74AC163/74ACT163 are high-speed synchronous modulo-16 binary counters. They are synchronously presettable for application in programmable dividers and have two types of Count Enable inputs plus a Terminal Count output for versatility in forming synchronous multistage counters.

The MC74AC161/74ACT161 has an asynchronous Master Reset input that overrides all other inputs and forces the outputs LOW. The MC74AC163/74ACT163 has a Synchronous Reset input that overrides counting and parallel loading and allows the outputs to be simultaneously reset on the rising edge of the clock.

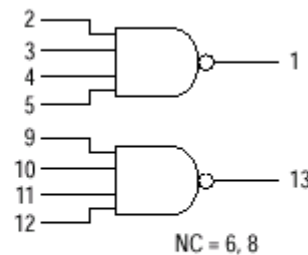
- Synchronous Counting and Loading
- High-Speed Synchronous Expansion
- Typical Count Rate of 125 MHz
- Outputs Source/Sink 24 mA
- 'ACT161 and 'ACT163 Have TTL Compatible Inputs

PIN NAMES

CEP	Count Enable Parallel Input
CET	Count Enable Trickle Input
CP	Clock Pulse Input
\overline{MR}	('161) Asynchronous Master Reset Input
SR	('163) Synchronous Reset Input
P ₀ -P ₃	Parallel Data Inputs
\overline{PE}	Parallel Enable Input
Q ₀ -Q ₃	Flip-Flop Outputs
TC	Terminal Count Output



MC14012B
Dual 4-Input NAND Gate



V_{DD} = PIN 14
V_{SS} = PIN 7

Lab 5. Binary Counter Answer Sheet

Name: _____ Section Number: _____
TA init: _____ Date _____

- 5.1 Draw the waveform shown on the oscilloscope. What is the name of this waveform? What is the amplitude, frequency, and DC offset? Show all your calculations.

- 5.2 What are the binary number representations of 5 through 10?

- 5.3 Does the circuit count input pulses from the Function Generator?

- 5.4 What number does the circuit count to?

- 5.5 What frequency comes out of each of the output pins? Why are these the expected values?

- 5.6 What is the maximum number that two circuits can count to?

- 5.7 Why are the 1C and 1D pins of the NAND gate tied to 5 volts?

- 5.8 How can we get the counter to count from 0-5?

- 5.9 How can we get the counter to count from 1 to 6?