Class:	CECS 201, Section 7
Lab:	10
Title:	Digital Clock
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Due Date:	11:59:59 P.M., 06, May 2015
Instructor:	Dan Cregg

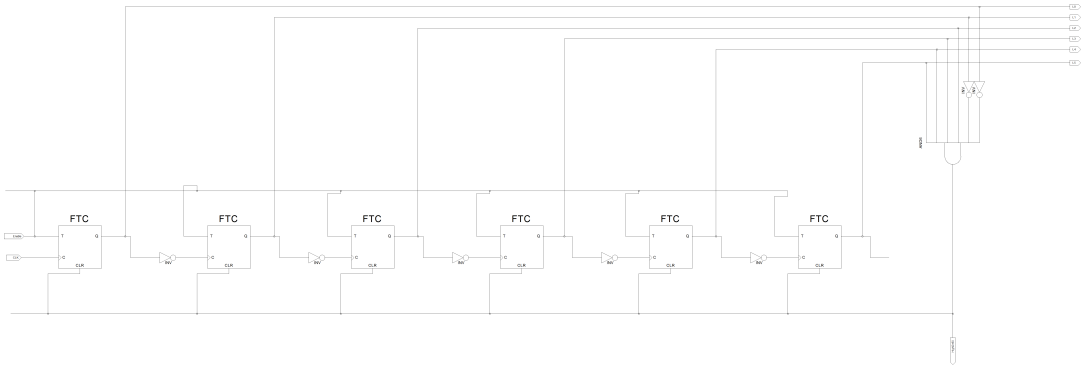
Introduction. In this lab, the student is tasked with creating a digital clock using all the tools that he has learned during the course of the semester.

Description. Our digital clock will use the leftmost 7-segment LEDs to display the hour (ranging from 00-23), the two rightmost LEDs to display the minute(ranging from 00-59), and the 6 rightmost green LEDs (N11,M11,V15,U15,V16,U16) to display the seconds. The 7-segment LEDs will display their data in decimal while the green LEDs will display their data in binary (U16 is the least significant bit).

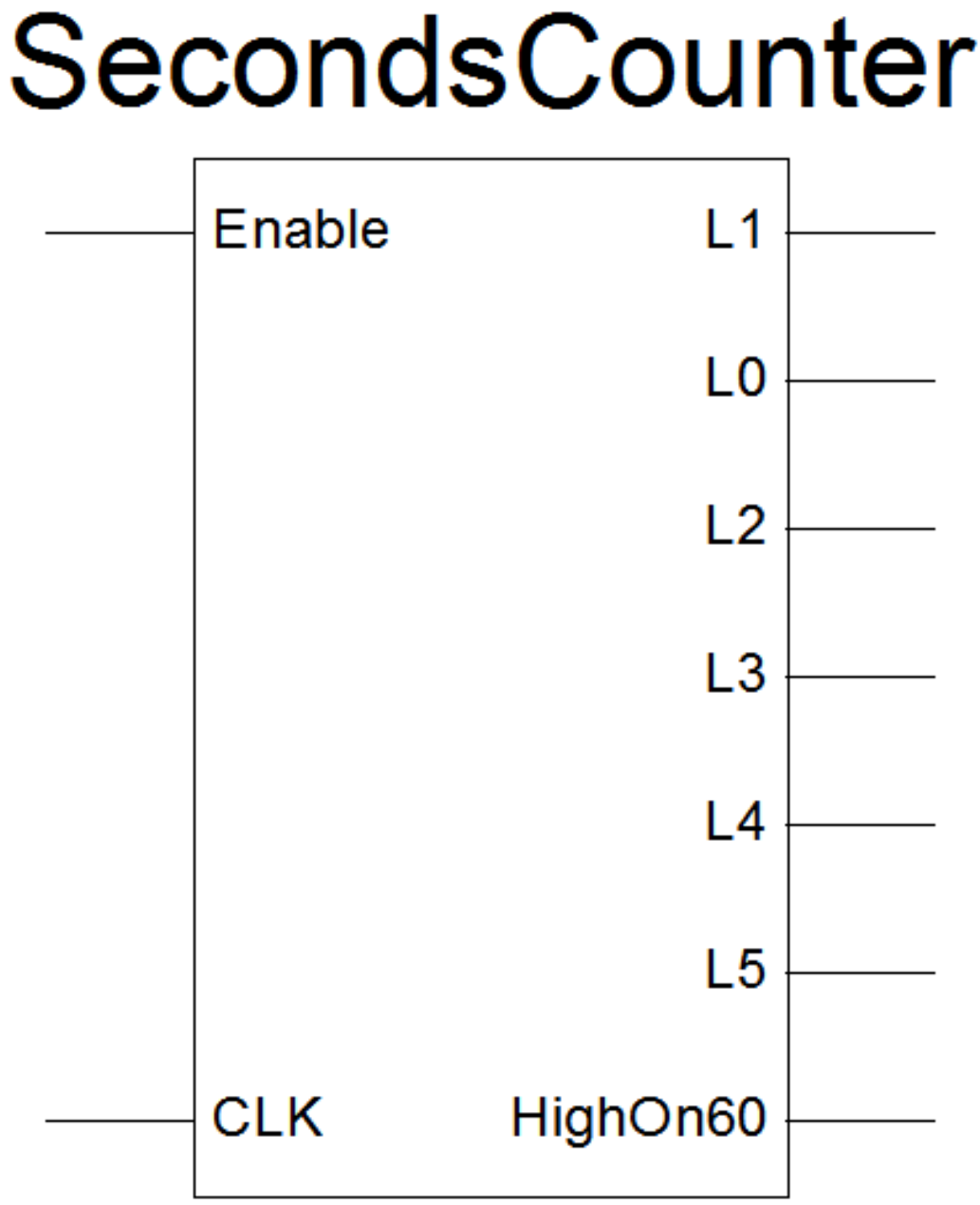
T5 will be used to enable or disable clock and C9 will be used to set the clock.

In building this clock we shall be using a myriad of building blocks, and they are described below:

SecondsCounter. Schematic.



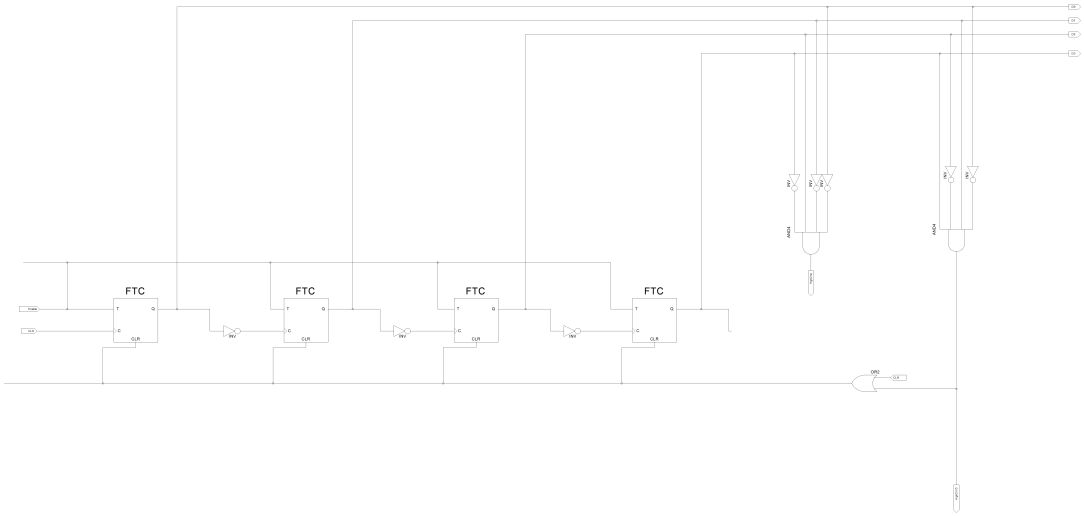
Symbol.



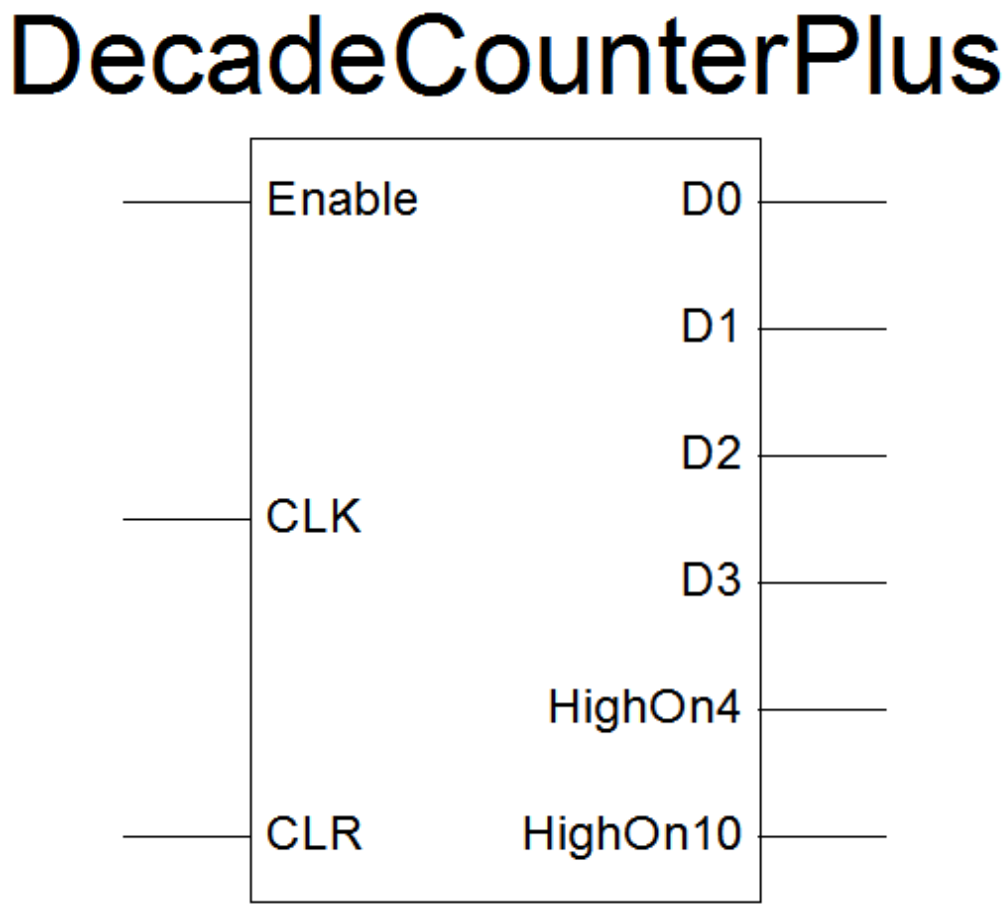
Description. The seconds counter is a 2-input to 7-output counter. It counts from 0 -

59 and resets on 60. On each clock input, it increments by 1, and its current states are stored in the outputs L5, L4, L3, L2, L1, and L0, listed from most significant bit to least significant bit. When the state is momentarily 111100_2 (60_{10}), the output HighOn60 goes high. We shall be using this circuit to count the seconds by tying the outputs to the appropriate locations ((N11,M11,V15,U15,V16,U16) on the board.

DecadeCounterPlus. Schematic.

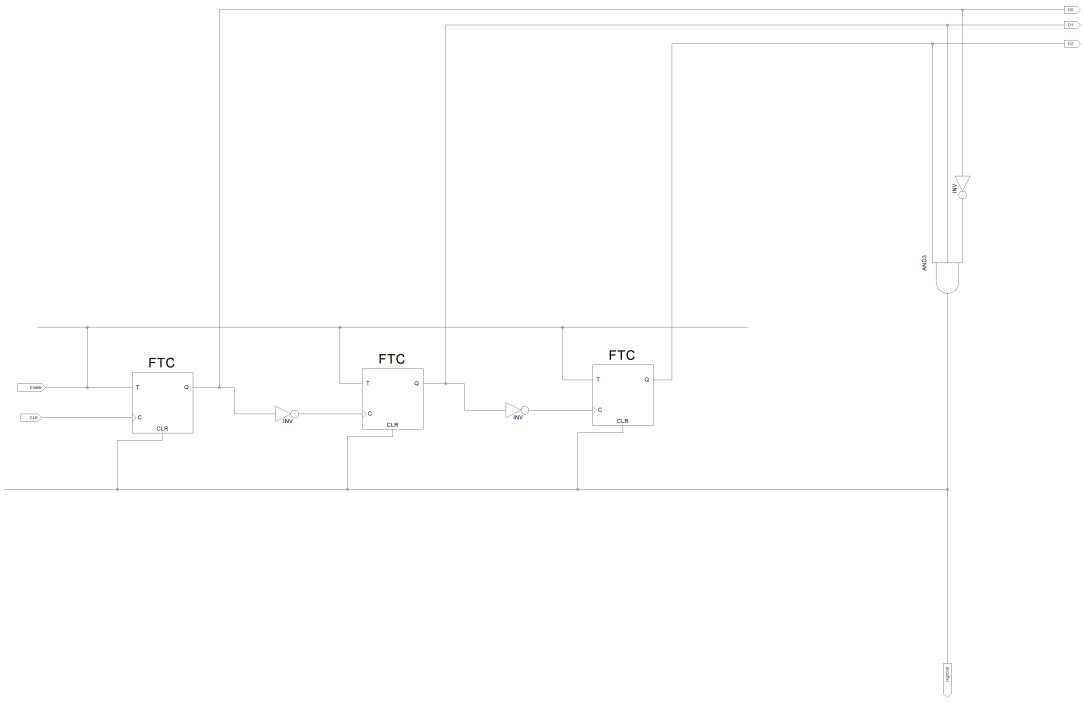


Symbol.

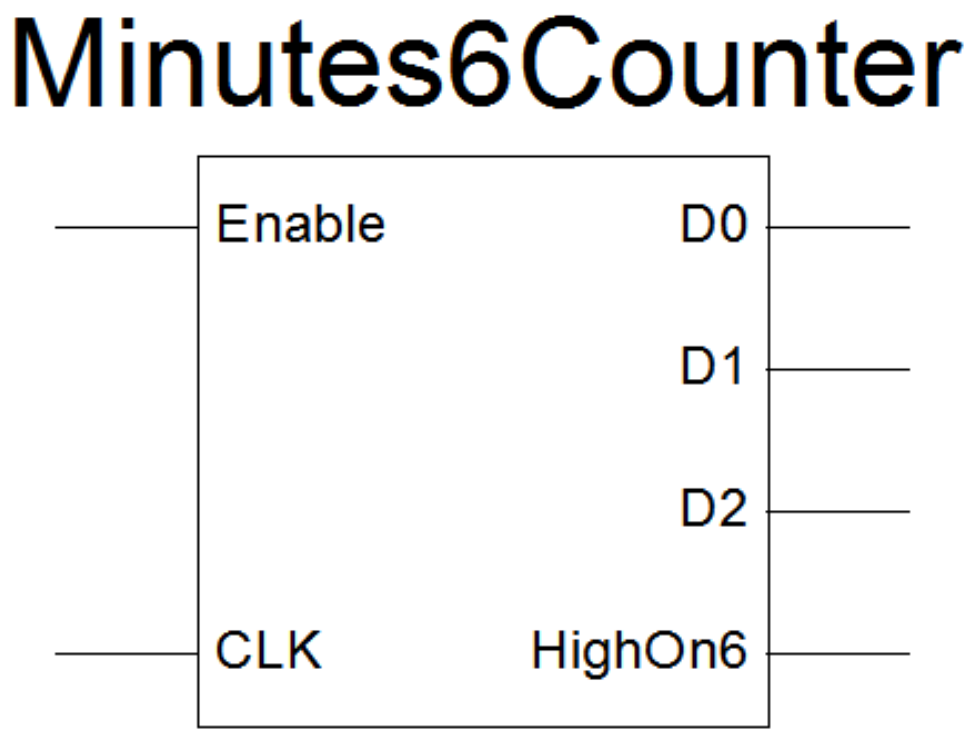


Description. The decade counter plus is a 3-input to 6-output counter. It counts from 0 - 9 and resets on 10. On each clock input, it increments by 1, and its current states are stored in the outputs D3, D2, D1, and D0, listed from most significant bit to least significant bit. When the state is momentarily 1010_2 (10_{10}), the output HighOn10 goes high; similarly when the state is momentarily 0100_2 (4_{10}), the output HighOn4 goes high. Why do we need the HighOn4 output? We need it because we shall be using this circuit for both the minute ones and the hours ones. For the minute ones, we do not need the HighOn4 output; however, we need it for the hours ones because we need to know when the hour segment is at 09 and at 23. For the former we transition from 09 to 10, and for the latter we transition from 23 to 00.

Minute6Counter. Schematic.

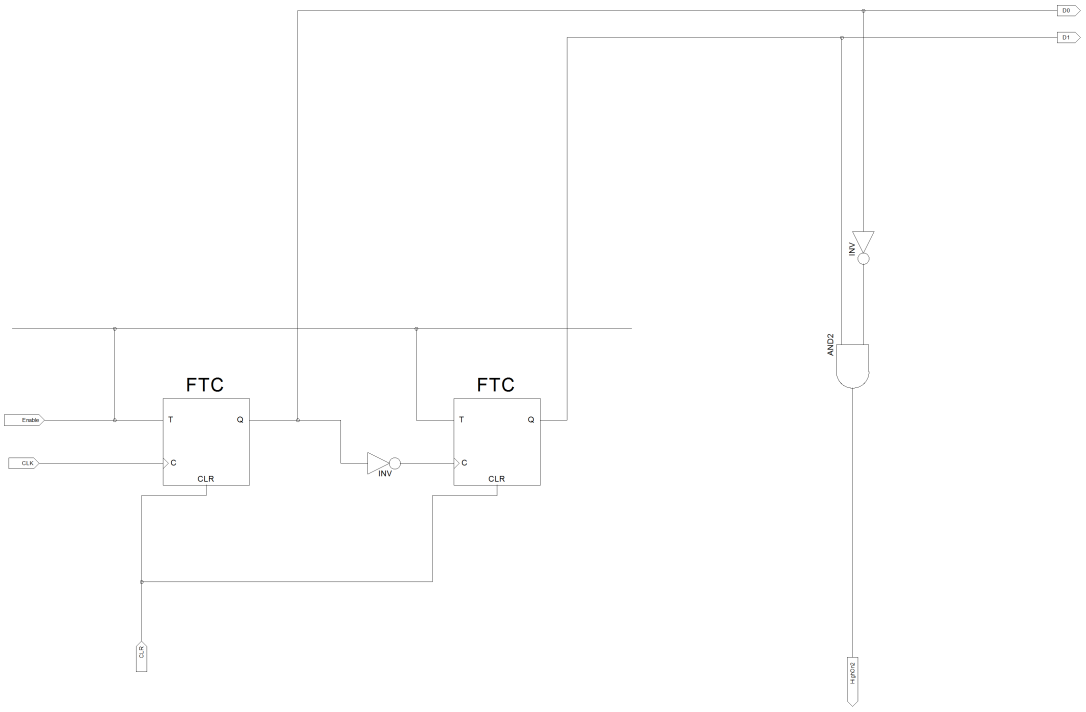

D0
D1
D2
INV
AND3
FTC
T
Q
C
CLR
ENABLE
CLK
INV
FTC
T
Q
C
CLR
INV
FTC
T
Q
C
CLR
ENOUT

Symbol.

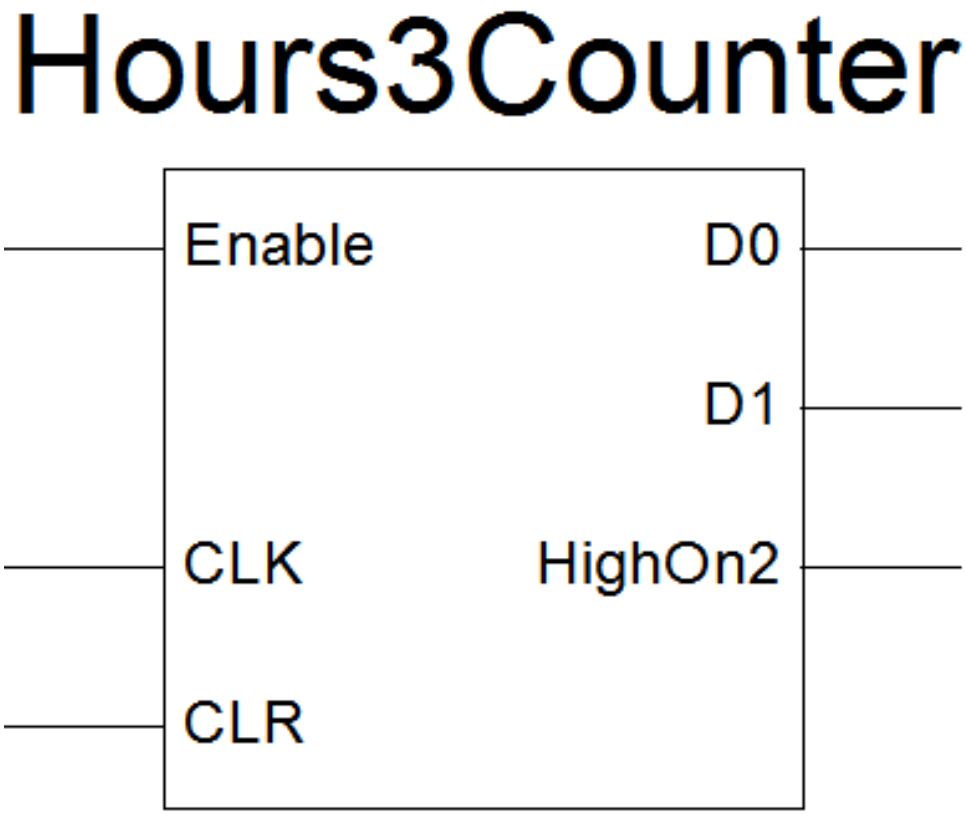


Description. The minute 6 counter is a 2-input to 4-output counter. It counts from 0 - 5 and resets on 5. On each clock input, it increments by 1, and its current states are stored in the outputs D2, D1, and D0, listed from most significant bit to least significant bit. When the state is momentarily 110_2 (6_{10}), the output HighOn6 goes high. This circuit will be used in the counting the minute tens.

Hour3Counter. Schematic.

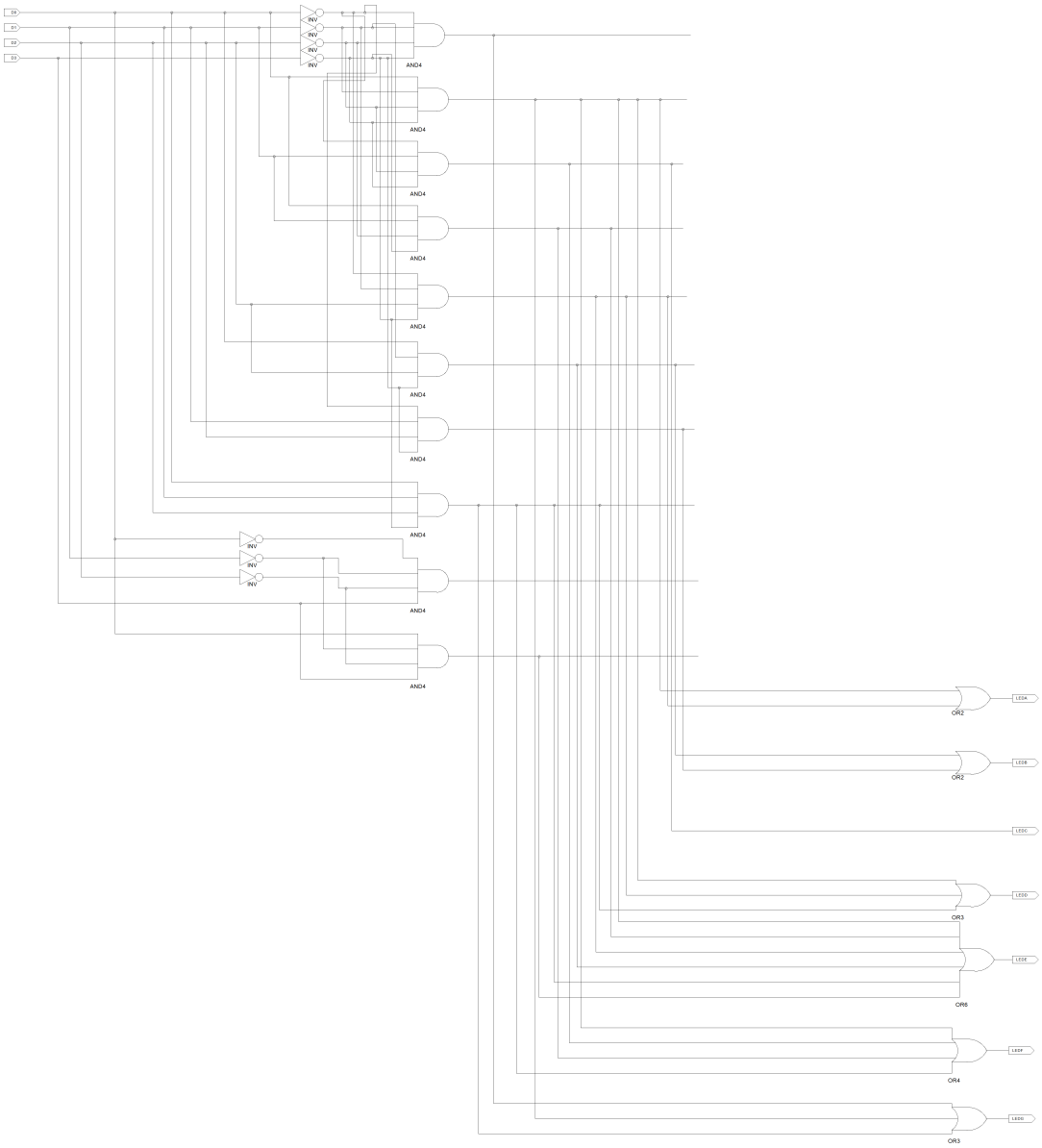

D0
D1
INV
AND2
FTC
FTC
Enable
CLK
T
Q
C
CLR
T
Q
C
CLR
INV
CLR
1-pDn'd

Symbol.

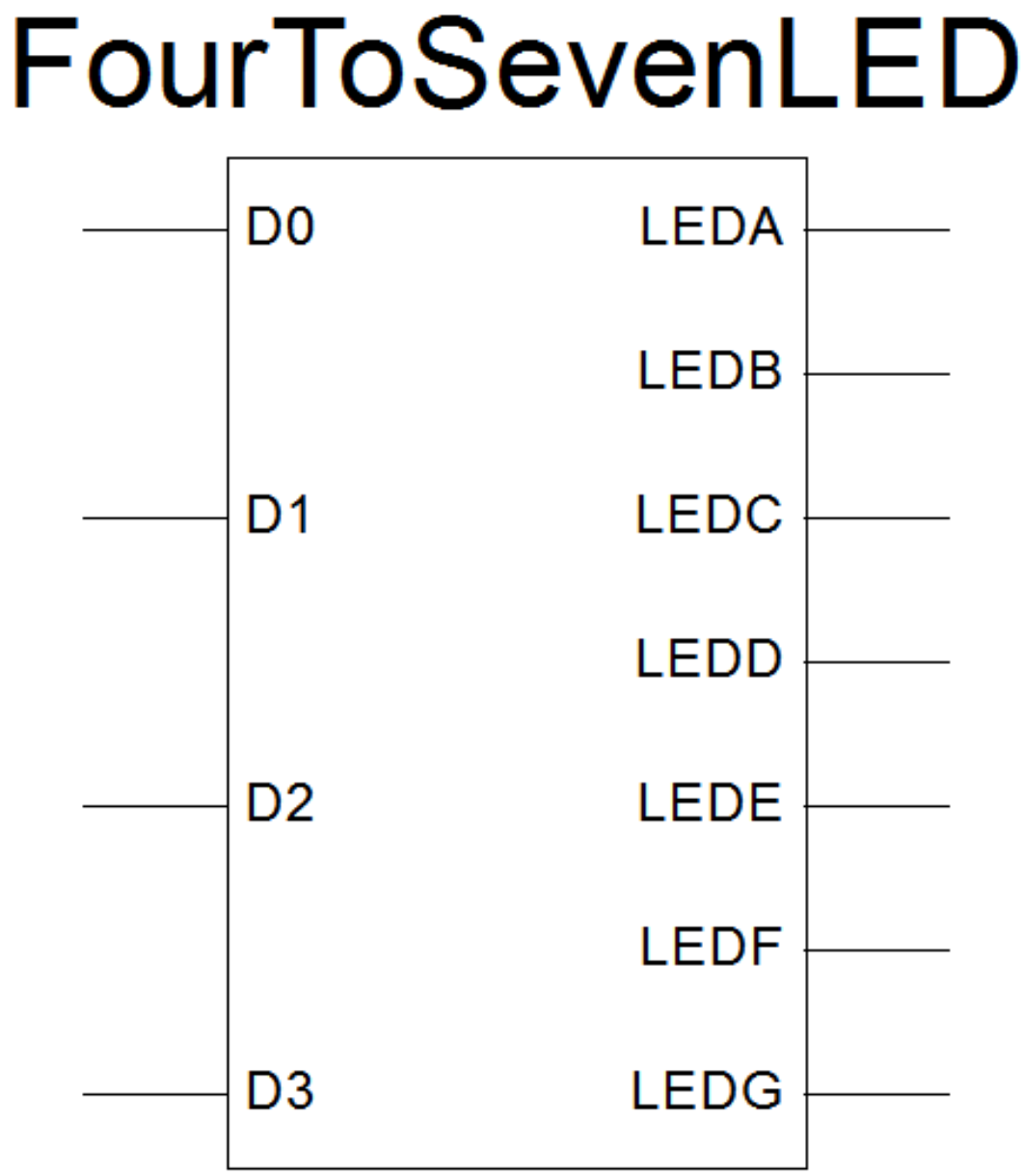


Description. The hour 6 counter is a 3-input to 3-output counter. On each clock input, it increments by 1, and its current states are stored in D1, and D0, listed from most significant bit to least significant bit.It is used for counting the hour tens. Unlike the other counters above it does not automatically reset when it reaches 3. Instead we shall rely upon external circuit to reset this counter when the HighOn2 output(which goes high when D1 = 1 and D0 = 0) is high and when hour ones is HighOn4 (see decade counter plus above).

FourToSevenLEDs. Schematic.

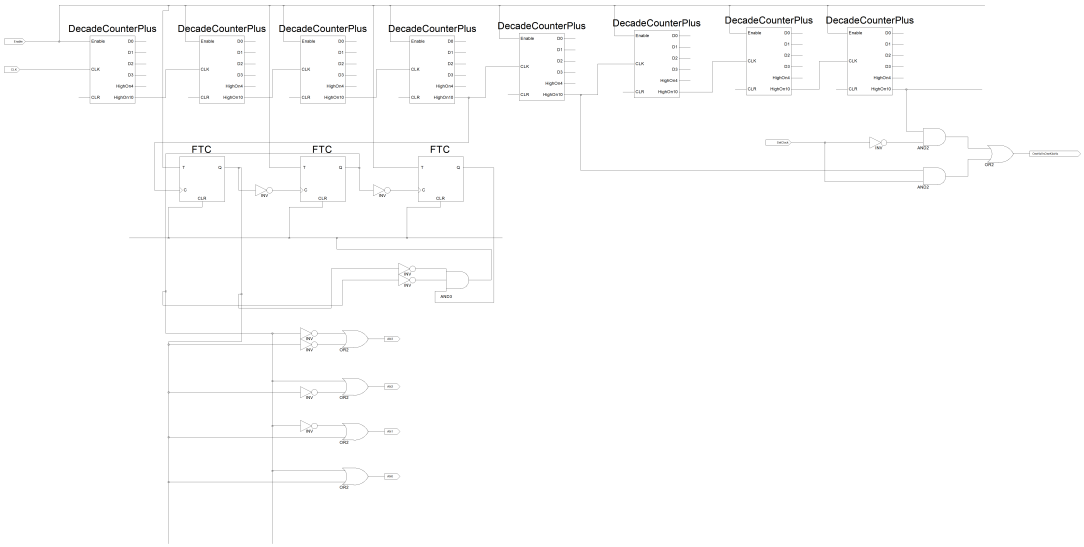

D0
D1
D2
D3
INV
INV
INV
INV
AND4
AND4
AND4
AND4
AND4
AND4
AND4
AND4
AND4
INV
INV
INV
OR2
OR2
OR3
OR6
OR4
OR3
LEDA
LEDB
LEDC
LEDD
LEDE
LEDF
LEDG

Symbol.

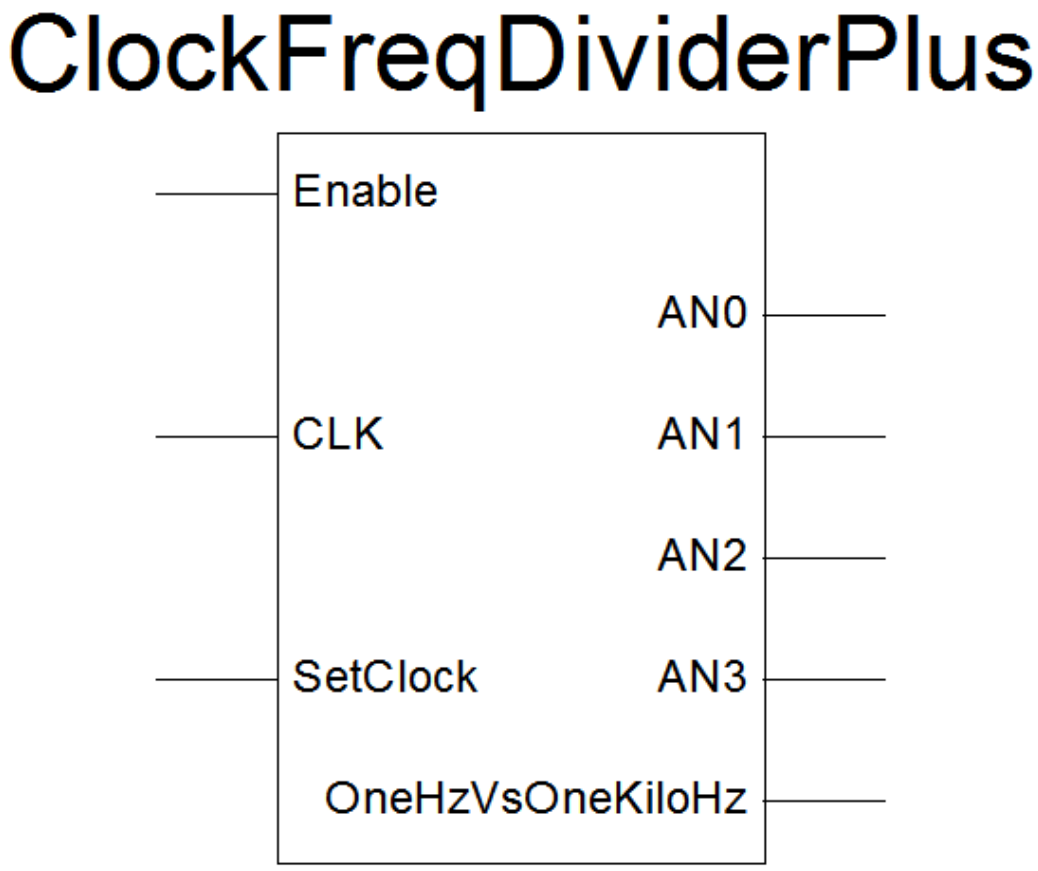


Description. This is a 4-input to 7-output circuit used for displaying decimal numbers (0-9) on a LED segment. The four bit input(D3, D2, D1, D0), where D0 is the least significant bit, is simply displayed on the 7 Segment LEDs.

ClockFreqDividerPlus. Schematic.

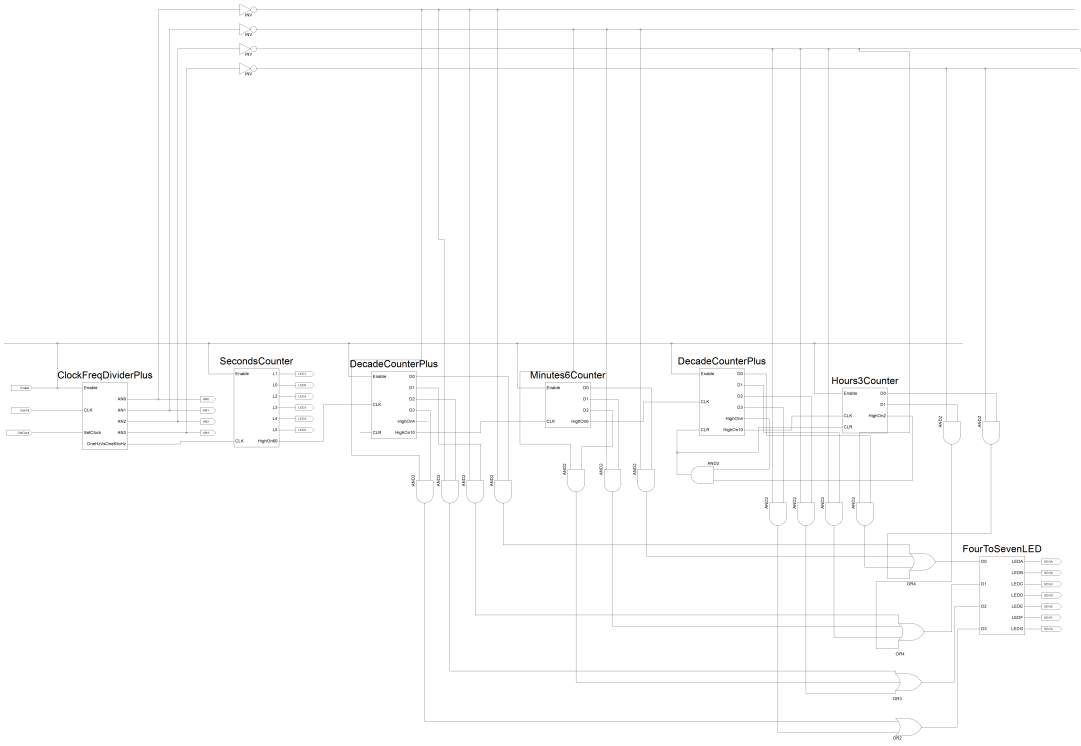


Symbol.



Description. This circuit divides the 100MHz Clock frequency on our board to 1Hz. Thus it is a clock frequency divider. The set clock input blocks the 1Hz output and instead allows a 1000Hz to go through. The AN0, AN1, AN2, and AN3 outputs are used to select a particular 7-segment LED to display. We used a 2-4 decoder to periodically select exactly one of AN0, AN1, AN2, and AN3. The inputs to the decoder are taken from the state of a counter (clocked by selecting the input of the 10000Hz Flip Flop (see schematic)). By periodically selecting a particular 7-segment, we create an illusion that all segments are always on. This method works because the human eye cannot detect such a fast frequency. Note that the output of the decoder are inverted because a 7-segment is active low.

Digital Clock. Schematic.


INV
INV
INV
INV
ClockFreqDividerPlus
Enable
CLK
AN0
AN1
AN2
AN3
SecondsCounter
Enable
CLK
HighOnSD
L1
L0
L2
L3
L4
L5
DecadeCounterPlus
Enable
CLK
CLR
HighOnDS
Minutes6Counter
Enable
CLK
HighOnM6
DecadeCounterPlus
Enable
CLK
CLR
HighOnH10
Hours3Counter
Enable
CLK
CLR
HighOnH2
AND2
AND3
AND4
AND5
AND6
AND7
AND8
AND9
AND10
AND11
AND12
AND13
AND14
AND15
AND16
FourToSevenLED
LEDA
LEDB
LEDC
LEDD
LEDE
LEDF
LEDG
OR4
OR3
OR2

Symbol.

Description. Now we put everything together to create our digital clock. The clock on the board will clock the frequency divider; then the frequency divider will clock the seconds counter; the seconds counter will clock the minute ones; the minute ones will clock the minute tens; the minute tens will clock the hour ones; and the hour ones will clock the hour tens; we also tie all the output of the decimal outputs using OR gates to the corresponding inputs of the 4-7 display.