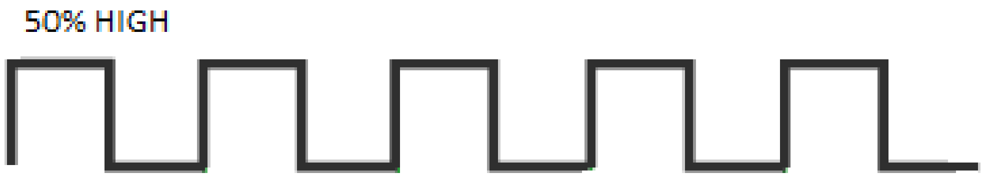
Pulse Width Modulation

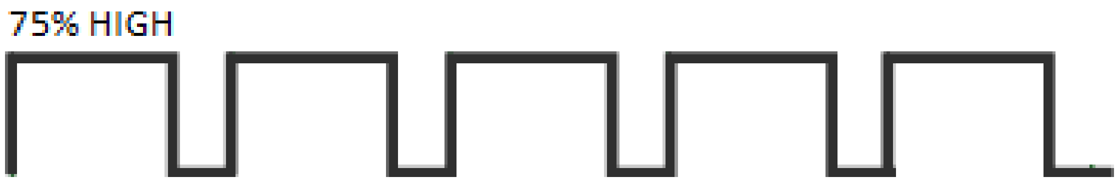
Pulse Width Modulation

* Pulse Width Modulation (PWM) is controlling the pulse width of a digital signal for a given period

* Typically the width of the pulse is HIGH half of the period and LOW the other half, but can be changed

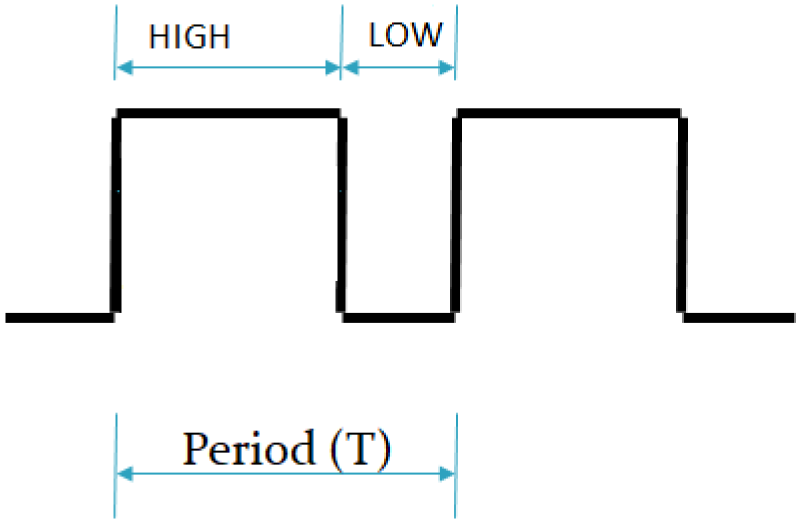
- HIGH 40% of the period, and LOW 60%
- HIGH 75% of period, and LOW 25%





Duty Cycle

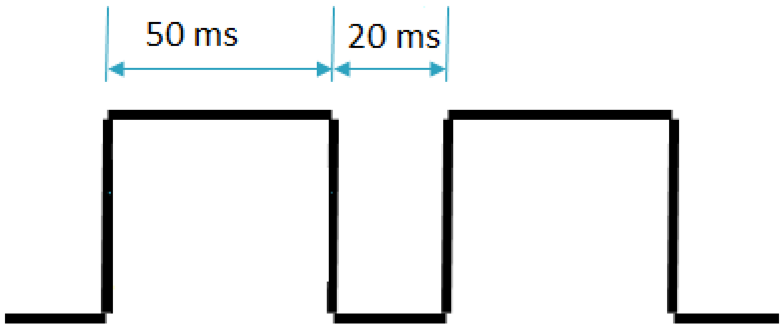
* Duty Cycle is the percent of the pulse HIGH compared to the period
* PWM is expressed as a duty cycle



$$Duty\,Cycle\,(\%) = \frac{HIGH\,Time}{Period} * 100\,\%$$

Example

* Given the following waveform, what is the duty cycle?

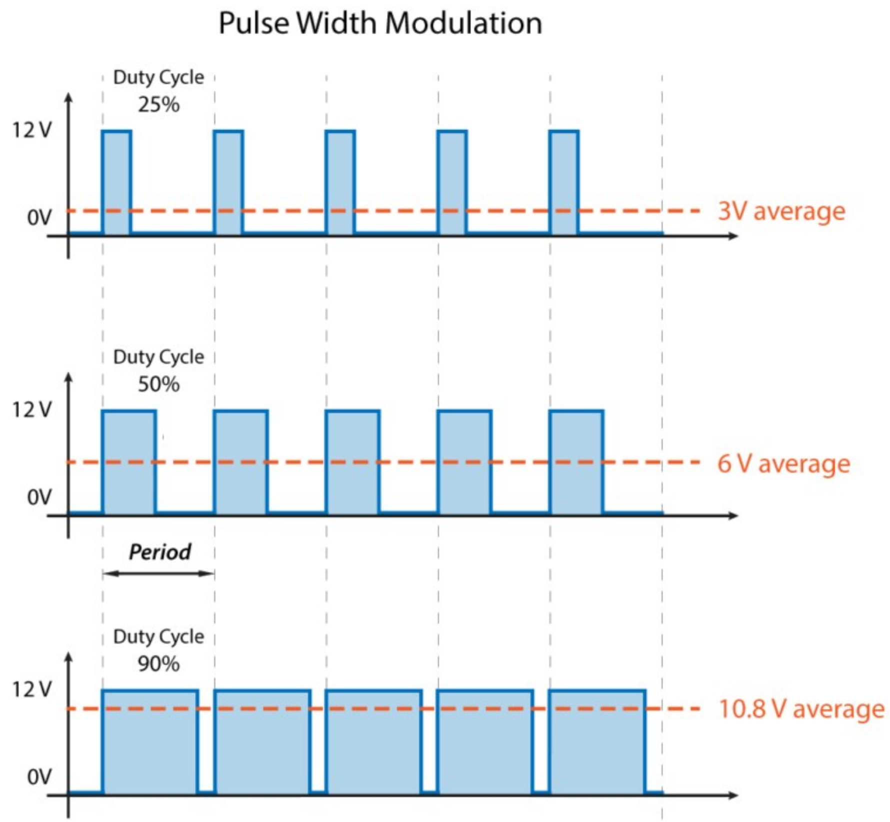


* For a 2 kHz signal, how long would the signal need to be HIGH to give a duty cycle of 35%?

Average Voltage Value

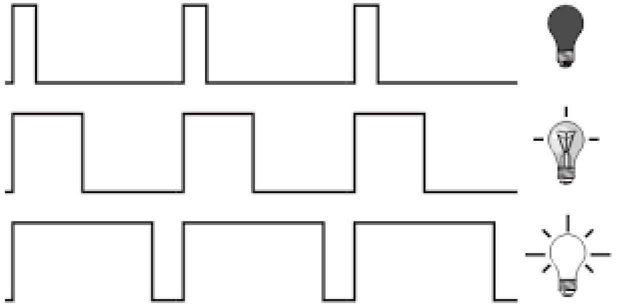
* A smaller duty cycle delivers an effective lower voltage value
  * Motor turn slower or light appear dimmer

$$V_{average} = Duty\,Cycle * V_{HIGH}$$



What Uses PWM?

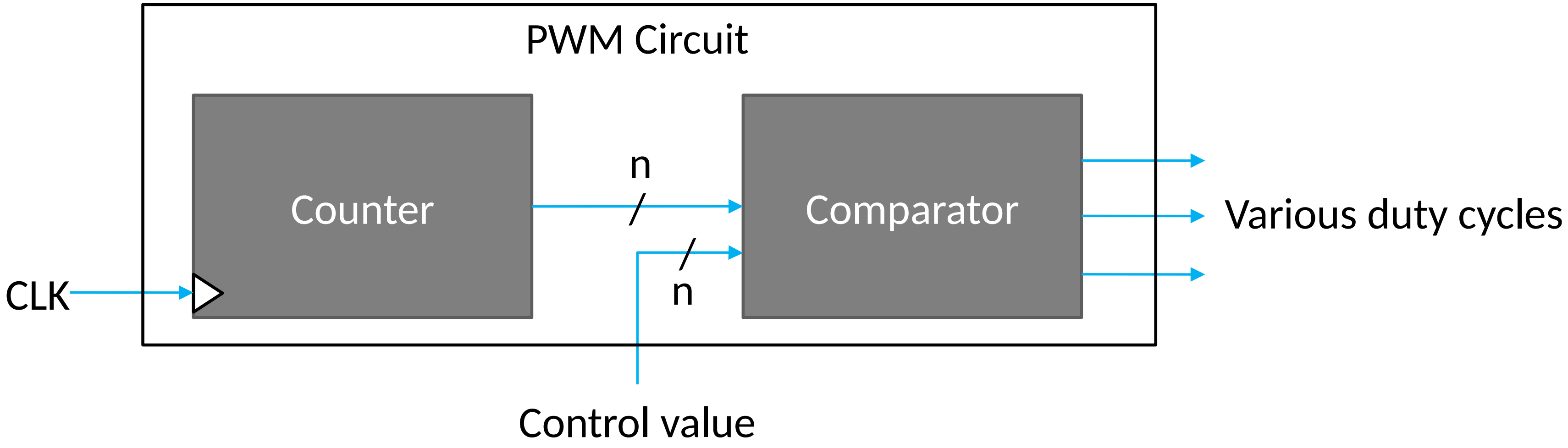
* Motors
  ◦ DC motors use PWM for speed
  ◦ Servos use for positioning
  ◦ Stepper for moving and maintaining an angle
* Lighting for dimmer or brighter light
* Audio signals



Creating PWM

* PWM is created by comparing a control value to a count value
  - The frequency of the PWM is determined by the master clock and size of the counter
  - The resolution of the PWM is determined by the size of the counter and comparator
  - The duty cycle is determined by how the outputs of the comparator are used

* This technique is not exclusive to this course, microcontrollers generate PWM using this method of a counter with a comparator



Frequency and Resolution of PWM

* The resolution of the duty cycle is a function of the size of the counter
  * Every change in one bit of the control value will adjust the duty cycle by the resolution

$$DC\,Resolution(\%) = \frac{1}{2^n} * 100, where\ n\ is\ number\ of\ bits\ in\ counter$$

* Frequency of the PWM is a function of the master clock and size of the counter

$$f_{PWM} = \frac{f_{CLK}}{2^n}, where\ n\ is\ number\ of\ bits\ in\ counter$$

Example

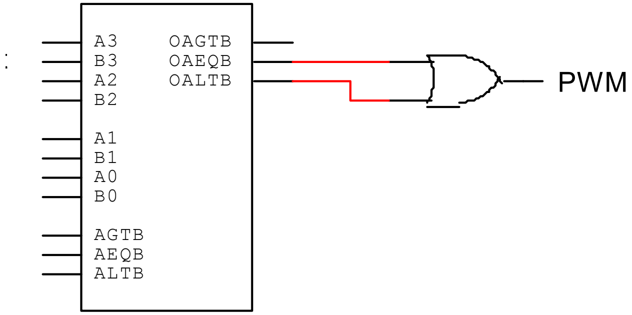
* A 4-bit counter running at 160 kHz is to be used to generate a PWM. What is the PWM resolution and frequency?

PWM Control Value

* The control value is used to specify a duty cycle
  - It is compared to the current count of the counter
* The output of the comparator will create different duty cycle
  - Equal –
  - Less Than -
  - Greater Than -

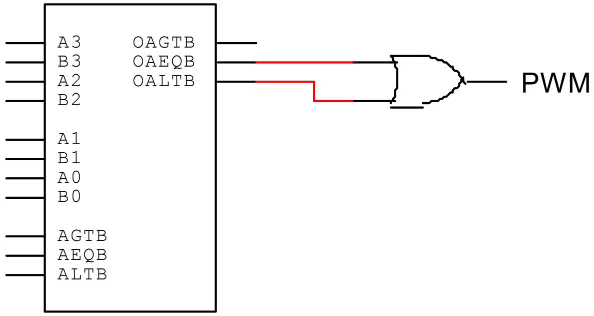
Achieve 100% Duty Cycle

* OR equal and Less Than together
* * 100



Example

* Using a 4-bit PWM, what is the control value to achieve the following duty cycles if the output from the comparator is equal OR less than?
  - 50%
  - 25%
  - 80%



Steps To Create PWM

1. Determine size of PWM. Determines how many counters and comparators are used.

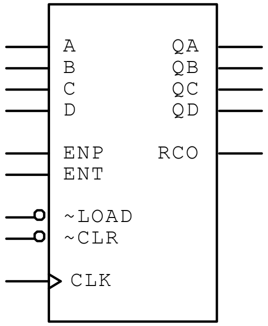
2. Set control value to give desired duty cycle.

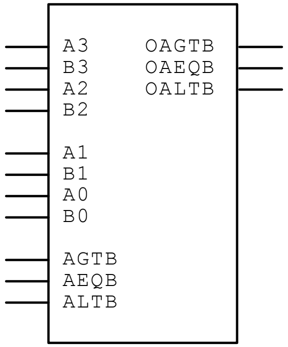
3. Use appropriate output of comparator for duty cycle.

Example

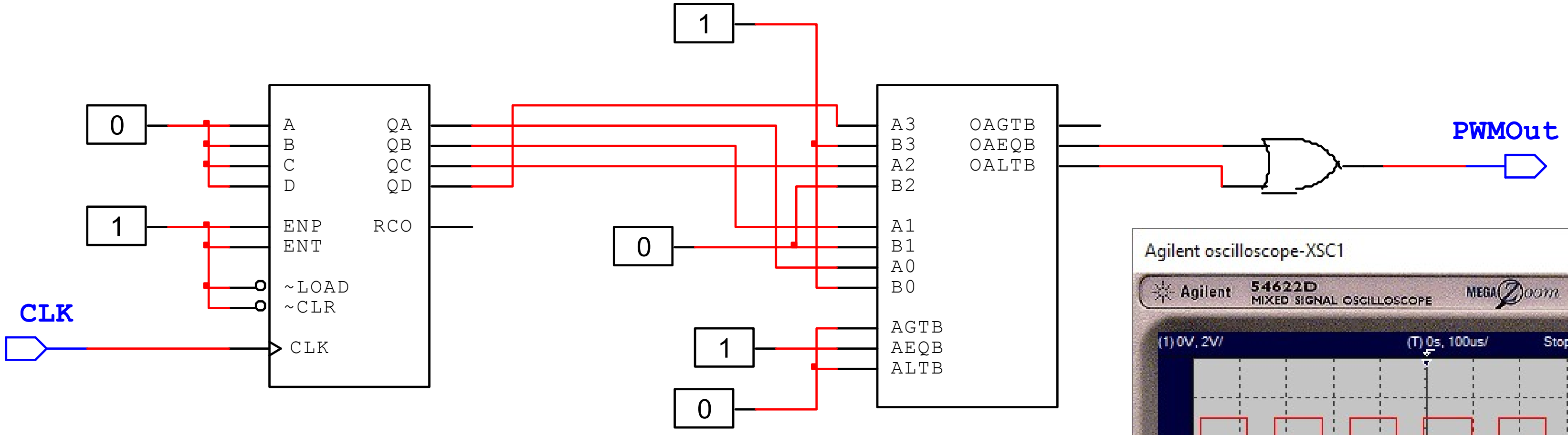
* Design the complete PWM circuit that has the following
  * 4-bit PWM
  * Creates ~60% duty cycle
  * Use 4-bit synchronous counter and 4-bit comparator

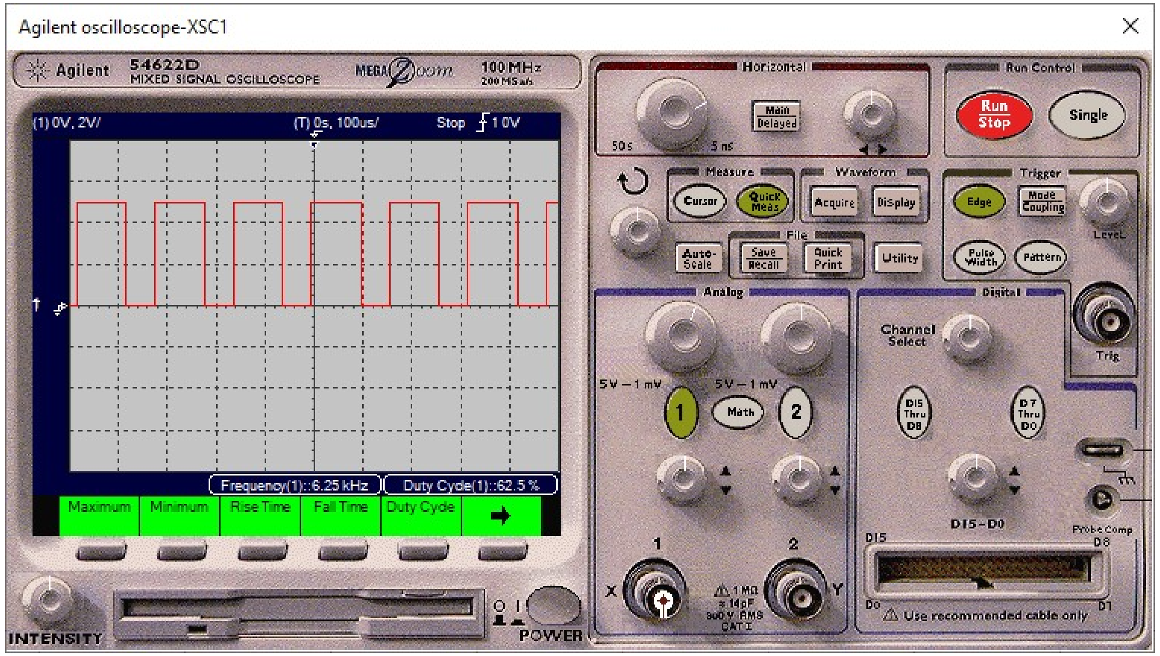
* For the created PWM circuit
  * What is the resolution of the PWM?
  * If a 100 kHz master clock is used, what is the PWM frequency?





4-Bit PWM

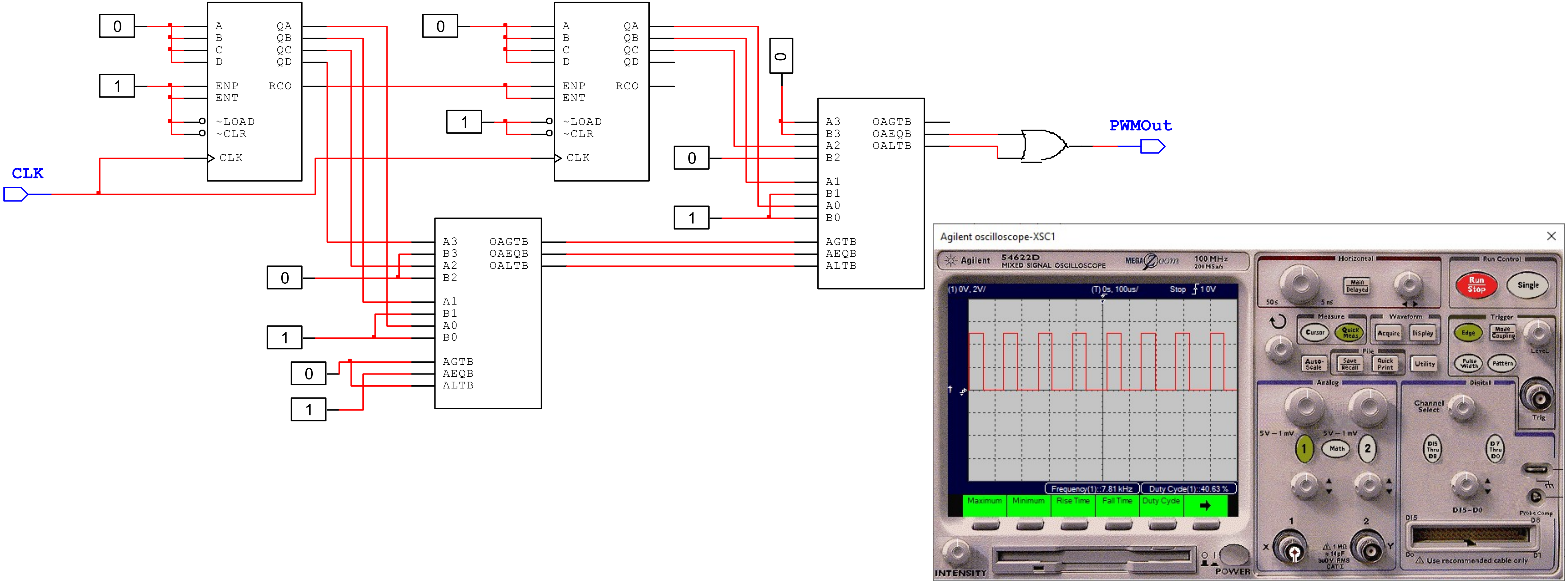

0
1
A
B
C
D
ENP
ENT
~LOAD
~CLR
CLK
QA
QB
QC
QD
RCO
CLK
1
0
1
0
A3
B3
A2
B2
A1
B1
A0
B0
AGTB
AEQB
ALTB
OAGTB
OAEQB
OALTB
PWMOut


Agilent oscilloscope-XSC1
Agilent 54622D
MIXED SIGNAL OSCILLOSCOPE
100 MHz
(1) 0V, 2V/
(T) 0s, 100us/
Stop
1.0V
Frequency(1)::6.25 kHz
Duty Cycle(1)::62.5 %
Maximum
Minimum
Rise Time
Fall Time
Duty Cycle
Horizontal
Run Control
Run Stop
Single
Measure
Waveform
Trigger
Analog
Digital
INTENSITY
POWER

Example

* Create a 7-bit PWM circuit that has ~40% duty cycle

7 – Bit PWM


A
B
C
D
ENP
ENT
~LOAD
~CLR
CLK
QA
QB
QC
QD
RCO
A3
B3
A2
B2
A1
B1
A0
B0
AGTB
AEQB
ALTB
OAGTB
OAEQB
OALTB
0
1
CLK
PWMOut
Agilent oscilloscope-XSC1
Agilent 54622D MIXED SIGNAL OSCILLOSCOPE
(1) 0V, 2V/
(T) 0s, 100us/
Stop
Frequency(1)::7.81 kHz
Duty Cycle(1)::40.63 %
Maximum
Minimum
Rise Time
Fall Time
Duty Cycle
Horizontal
Run Control
Run Stop
Single
Measure
Waveform
Trigger
Cursor
Acquire
Display
Edge
Auto-Scale
Save Recall
Quick Print
Utility
Pattern
Analog
Digital
Math
Channel Select
INTENSITY
POWER