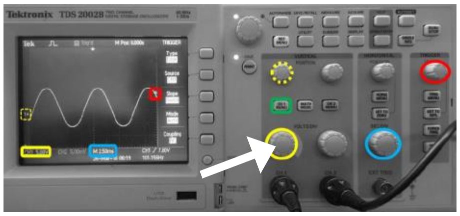
1. What is the function of the knob the white arrow points to?



a) Trigger level
b) Adjusting Secs/div
c) Measuring resistance
d) Chanel 1 menu
e) Adjusting Volts/div

Assume that you measure a wave using the oscilloscope and characterize the wave as:

$$V(t) = 1.5sin(120\pi t) + 1.5$$

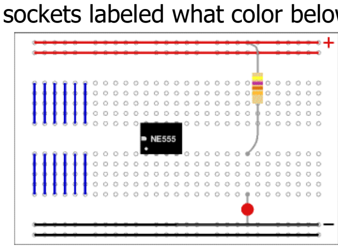
2. What is the frequency of V(t)?
a) 1Hz
b) 10 rpm
c) $1\frac{radian}{sec}$
d) 60Hz
e) None of the above

3. What is the DC offset of V(t)?
a) 1.5V
b) 4.5V
c) 0V
d) 3V
e) None of the above

4. What is the frequency of a sine wave in rad/sec if it has a period of A sec?
a) 2π/A
b) 1/(2πA)
c) $1/(2A^2)$
d) 1/A
e) None of the above

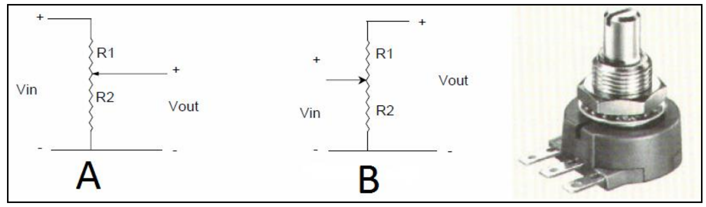
5. For a breadboard, you usually connect power to a chip by connecting it to sockets labeled what color below?

Red
Blue
Blue
Black



a) Red/Red
b) Red/Black
c) Blue/Blue
d) Blue/Black
e) None of the other answers

6. Shown are two ways to wire a pot. One is incorrect. What is the amount of current through *R1* for the correct and incorrect ways, respectively?

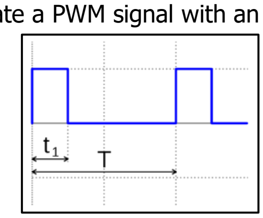


a) Vin/R1 and Vout/R2
b) Vin/(R1+R2) and Vin/R2
c) Vout/R2 and Vin/R2
d) Vin/(R1+R2) and Vout/R2
e) None of the above

7. A notch filter attenuates:
a) High frequencies
b) A band of frequencies
c) Low frequencies
d) Low and high frequencies
e) None of the above

8. The time constant of a first-order system tells when the output has gotten how far along the way to its steady-state value?
a) $100*(1-e^{-1})\%$
b) 37%
c) 60%
d) $100*e^{-1}$ %
e) None of the above

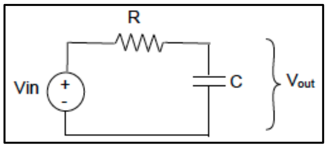
Assume you generate a PWM signal with an Arduino:



9. What does t_1 refer to in the figure?
a) Pulse frequency
b) Period duration
c) Pulse duration
d) Period frequency
e) None of the above

10. Let t_1 = 0.4msec and T=2.0msec in the figure. Roughly, what is the average voltage output if the 5V PWM signal is low pass filtered?
a) 1 V
b) 2 V
c) 3 V
d) 4 V
e) None of the above

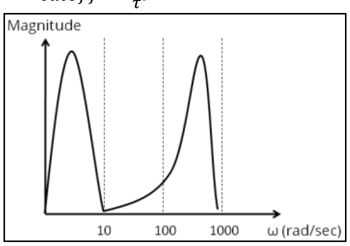
11. What is the equation that relates V_{out} to V_{in} for a step input to this circuit (with $V_{out}(t=0)$ = 0V)?



a) $V_{out} = V_{in}(1 - e^{-tRC})$
b) $\boldsymbol{V_{out} = V_{in}(1 - e^{-t/RC})}$
c) $V_{out} = V_{in}(1 - e^{-t})$
d) None of the above

12. If you now change the circuit so that the resistor switches place with the capacitor, what type of filter would you have?
a) Notch filter
b) Band-pass filter
c) High pass filter
d) None of the above

You are using an accelerometer to measure the vertical motion of your car, with the intent of using an active suspension to cancel the low frequency motion of the car, but not the higher frequency vibrations. Below is your data. You need to design a RC filter that will pass only the low frequency motion. You set R = 1000kΩ. (hint: $\omega_{cutoff} = \frac{1}{\tau}$)



13. What should C be?
a) 1pF
b) 0.01μF
c) 1μF
d) 0.1μF
e) None of the above

14. Which is the lowest sampling rate of the following options that can sample the filtered signal to acquire it without aliasing?
a) 1.6 Hz
b) 5 Hz
c) 10 Hz
d) 25 Hz
e) 100 Hz

Assume that the ODE for a high-pass filter is given by:

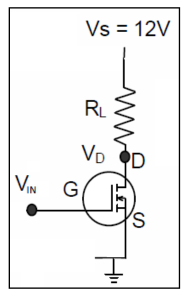
$$A\frac{dV_{out}}{dt} + V_{out} = \frac{dV_{in}}{dt}$$

15. What is the transfer function of this system?

a) $G(s) = \frac{\frac{s}{A}}{s+A}$
b) $G(s) = \frac{1}{s+A}$
c) $G(s) = \frac{\frac{1}{A}}{s+\frac{1}{A}}$
d) $G(s) = \frac{\frac{1}{A}}{s+A}$
e) None of the above

16. What are the time constant and cutoff frequency (in rad/sec) of the above system?
a) 1/A and A
b) A and 1/A
c) τ and ω
d) A and A
e) None of the above

Assume that you create a circuit for controlling a light bulb with a MOSFET as shown below. You can model the light bulb as a resistor R_L. You can turn the light ON and OFF by controlling the input voltage to the MOSFET. You first decide to characterize the behavior of the MOSFET by measuring R_{DS} as a function of the input voltage and get the following values:



V_{IN}(volts)	R_{DS}(ohms)
0	1×10^6
2	90
3	80
3.9	4
5	0.01

17. Assume R_L = 3996 ohms and you supply 0 volts to the input gate. What will V_{DS} be approximately?
a) 12V
b) 0.12V
c) 1.2V
d) 0.012V
e) None of the above

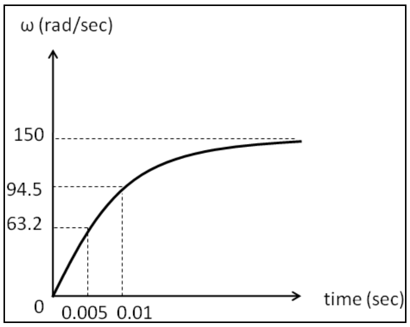
18. Which of the following is true about the MOSFET?
a) The voltage at the gate controls the current flow between the gate and drain.
b) The MOSFET is a type of transistor
c) The voltage at the gate controls the current flow between the drain and source
d) a) and b)
e) b) and c)

Assume you are working with a DC brushed motor. Assume the motor's torque constant and back EMF constant is B, the internal resistance is R, and the inductance L.

19. You hold the shaft fixed and apply a voltage of 5V, and feel the torque. Then you apply 10V and feel the torque. How much bigger is this torque than the first torque?
a) same
b) 4 times
c) half as big
d) 2 times as big
e) None of the above

20. You now run the motor and measure its current to be 1.2Amps and torque to be 12N.m. What is the value of B?
   a) 0.15 A/N.m
   b) 6.67 N.m/A
   c) 0.3 A/N.m
   d) 3.33 N.m/A
   e) None of the above

21. Assume that the time-response of the motor's no-load velocity is as shown below:



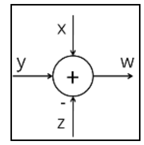
At what speed do you expect the motor to generate maximum power (assuming it's only applying power to the shaft?)?
   a) 150 rad/sec
   b) 94.5 rad/sec
   c) 63.2 rad/sec
   d) 0 rad/sec
   e) None of the above

22. Using the plot above, what would the value of the steady-state velocity be if you doubled the shaft inertia
   a) 300 rad/sec
   b) 150 rad/sec
   c) 100 rad/sec
   d) 75 rad/sec
   e) None of the above

23. In lab 3, you controlled the DC motor using an open-loop PWM signal and the MOSFET. Which statement is true?
   a) The motor was a high-pass filter, filtering the pulses.
   b) MOSFETs use more power with PWM signals than continuously varying input signals.
   c) A disturbance (like pressing the motor shaft with your finger) slowed the motor speed.
   d) A disturbance (like pressing the motor shaft with your finger) changed the pulse modulation frequency.
   e) All of the above.

24. Assume that a motor has an internal resistance of 10 ohms and that the motor draws 250mA. What is the power, in watts, dissipated by the motor?
   a) 0.022W
   b) 25W
   c) 0.375W
   d) 1.5W
   e) None of the above

25. Based on the summation block shown below. What is the value of input z?



   a) x + y – w
   b) x * y * -w
   c) w – x - y
   d) x + y + w
   e) None of the above

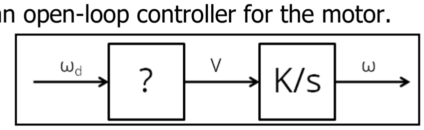
26. Say you use the summation block to implement a feedback controller for a motor and set x = 0 and design the feedback gain so that G > 0. What signal should z be?
   a) e
   b) ω
   c) ω_d
   d) u
   e) none of the above

27. What is true about the closed loop feedback controller?
   a) Needs to have an accurate model of K
   b) Can't handle unpredicted disturbances
   c) An error has to develop before the controller acts
   d) Need a sensor
   e) c) and d)

Assume that you control a motor's speed with a feedforward controller. You use a current amplifier with the motor and thus the speed of the motor is related to the input voltage to the current amplifier by the transfer function:

$$G(s) = \frac{K}{s}$$

You know very well the behavior of the motor and want to implement an open-loop controller for the motor.



28. What should the denominator of the transfer function in the controller box (?) be to make the output (ω) equal ω_d?
   a) ω
   b) ω_d
   c) V
   d) s
   e) K

29. What would happen if the value of K doubled in the transfer function (K/s box) but you did not update the controller box?
   a) Nothing would change
   b) The system would go unstable
   c) The motor would spin faster than ω_d
   d) The motor would spin slower than ω_d
   e) The motor would not spin

30. What function did you use for the Arduino to dim the LED?
   a) createPWM()
   b) digitalWrite()
   c) analogWrite()
   d) printPWM()
   e) None of the above

Challenge problem for extra credit (10 points) – Prove using Laplace Transforms that, for a system described by a linear ordinary differential equation, sine in -> sine out, and find the equation for the scaling

Write down a linear differential equation (1 point – OK if only a first order equation)

$$\frac{d^n x}{dt^n} + a_{n-1}\frac{d^{n-1}x}{dt^{n-1}} + \ldots + a_0 x = b_{n-1}\frac{d^{n-1}u}{dt^{n-1}} + b_{n-2}\frac{d^{n-2}x}{dt^{n-2}} + \ldots + b_0 u$$

Take the Laplace transform (2 points)

If we take the Laplace Transform:

$$X(\underbrace{s^n + a_{n-1}s^{n-1} + \ldots + a_0}_{A(s)}) = U(\underbrace{b_{n-1}s^{n-1} + b_{n-2}s^{n-2} + \ldots + b_0}_{B(s)}) + IC(s) \rightarrow X = \frac{B(s)}{A(s)}U + \frac{IC(s)}{A(s)}$$

Note that if system is stable, the term due to initial conditions goes to zero (1 point)

Insert Laplace transform of sine for U(s) (2 points)

$$X(s) = \frac{B(s)}{A(s)}\frac{a\omega}{s^2+\omega^2}$$

Note that X(s) can be factored (1 point):

$$X(s) = \frac{B(s)}{A(s)}\frac{a\omega}{s^2+\omega^2} = \underbrace{\frac{k_1}{s+j\omega} + \frac{k_2}{s-j\omega}}_{\text{roots of } s^2+\omega^2}$$

Take the Inverse LT (1 point):

$$x(t) = k_1 e^{-j\omega t} + k_2 e^{j\omega t} +$$

Solve for x(t) using partial fraction expansion and Euler's formula (2 points):

But using Euler's formula: $\sin(\theta) = \frac{1}{2j}\left(e^{j\theta} - e^{-j\theta}\right)$,

$$x(t) = a\,|G(j\omega)|\sin(\omega t + \phi)$$