

**Basic Math section** – questions 1 through 10

- ☐ (Q1) Ohm's/Joule's Law calculations in simple DC circuits
- ☐ (Q2) Resistor color code and tolerance calculations
- ☐ (Q3) Oscilloscope interpretation
- ☐ (Q4) Ohm's Law calculations in simple AC circuits
- ☐ (Q5) Right-triangle distance calculations
- ☐ (Q6) Analog meter interpretation
- ☐ (Q7) Proportions
- ☐ (Q8) Unit conversions
- ☐ (Q9) Manipulating algebraic equations
- ☐ (Q10) Interpreting graphs

**Basic DC circuits section** – questions 11 through 20

- ☐ (Q11) Series or parallel resistor network calculations
- ☐ (Q12) Series-parallel resistor network calculations
- ☐ (Q13) Bridge network calculations
- ☐ (Q14) Qualitative analysis of simple DC circuits
- ☐ (Q15) RC time delay calculations
- ☐ (Q16) LR time delay calculations
- ☐ (Q17) Multi-source network calculations
- ☐ (Q18) Thévenin/Norton equivalent networks
- ☐ (Q19) Voltage divider design
- ☐ (Q20) Time-delay circuit design

**Basic AC circuits section** – questions 21 through 30

- ☐ (Q21) Rectifier circuit calculations
- ☐ (Q22) Series or parallel RLC network calculations
- ☐ (Q23) Series or parallel LC resonant circuit calculations
- ☐ (Q24) Transformer circuit calculations
- ☐ (Q25) Qualitative analysis of simple AC circuits
- ☐ (Q26) Three-phase wye-delta calculations
- ☐ (Q27) Three-phase delta-wye calculations
- ☐ (Q28) AC motor calculations
- ☐ (Q29) Filter circuit design
- ☐ (Q30) Sketch phasor diagrams

**Basic Test and Measurements section** – questions 31 through 40

- ☐ (Q31) Sketch proper multimeter connections in a simple circuit
- ☐ (Q32) Adjusting oscilloscope controls to achieve better display
- ☐ (Q33) Identifying oscilloscope front-panel controls
- ☐ (Q34) Identifying standard electronic test equipment
- ☐ (Q35) Multimeter insertion resistance calculations
- ☐ (Q36) Sketch proper oscilloscope connections in circuits
- ☐ (Q37) Pulse-width-modulation load parameters via oscillograph
- ☐ (Q38) Interpreting curve-tracer graphs
- ☐ (Q39) Using logic tracer to test digital circuits
- ☐ (Q40) Using multimeter to test transistor switching circuits

**Basic Troubleshooting section** – questions 41 through 50

- ☐ (Q41) Identifying possible faults in battery-switch-lamp circuit
- ☐ (Q42) Identifying possible faults in RC or LR time-delay circuit
- ☐ (Q43) Identifying possible faults in an unloaded voltage divider circuit
- ☐ (Q44) Identifying passive filter type and predict effect of component fault
- ☐ (Q45) Identifying possible faults in logic gate circuit
- ☐ (Q46) Identifying possible faults in relay ladder circuit
- ☐ (Q47) Identifying possible faults in semiconductor switching circuit
- ☐ (Q48) Identifying discrete component faults using ohmmeter
- ☐ (Q49) Identify effect of fault in power converter circuit
- ☐ (Q50) Interpreting purpose of a component(s) in a power electronics circuit

**Transistor Circuits section** – questions 51 through 60

- ☐ (Q51) Transistor switching circuit calculations
- ☐ (Q52) Selecting components for transistor switching circuits
- ☐ (Q53) Multi-stage BJT amplifier gain calculations
- ☐ (Q54) Selecting components for transistor oscillator circuits
- ☐ (Q55) Design and sketch interface between microcontroller and power converter
- ☐ (Q56) Identifying possible faults in transistor amplifier circuit
- ☐ (Q57) Design and sketch BJT switching circuit
- ☐ (Q58) Design and sketch FET switching circuit
- ☐ (Q59) Selecting components interposing logic gate output to heavy load
- ☐ (Q60) Identifying possible faults in microcontroller I/O circuits

**Operational Amplifier section** – questions 61 through 70

- ☐ (Q61) Identifying comparator input conditions necessary for specified result
- ☐ (Q62) Design and sketch opamp circuit with specified gain
- ☐ (Q63) Summer/subtractor calculations
- ☐ (Q64) General opamp circuit calculations
- ☐ (Q65) Sensor-conditioning opamp circuit calculations
- ☐ (Q66) Identify expected signals within opamp oscillator circuit
- ☐ (Q67) Precision rectifier circuit calculations
- ☐ (Q68) Integrator circuit calculations
- ☐ (Q69) Differentiator circuit calculations
- ☐ (Q70) Identifying possible faults in opamp circuit

**Advanced Digital section** – questions 71 through 80

- ☐ (Q71) Determining logic states within a combinational logic circuit
- ☐ (Q72) Design and sketch latch or flip-flop circuit to fulfill a function
- ☐ (Q73) Evaluate timing diagram for signal integrity
- ☐ (Q74) Select component values for digital (PWM) power control circuit
- ☐ (Q75) Configuring a counter circuit for frequency division
- ☐ (Q76) Identifying possible faults in latch/flip-flop circuit
- ☐ (Q77) Programmable Logic Controller (PLC) output states given pushbutton conditions
- ☐ (Q78) Programmable Logic Controller (PLC) output states given process switch stimuli
- ☐ (Q79) Determine status of shift register circuit
- ☐ (Q80) Identifying mitigations for signal interference in cables

Note: this Comprehensive exam borrows many multi-part questions from regular exams offered throughout the EET program. In order to reduce the amount of time necessary to complete this 80-question exam, you will not be required to answer every part of every question. Instead:

- On troubleshooting questions where there is a “possible/impossible” fault table, you need only answer *three* rows in that table and not the entire table. You may choose which three faults to declare as either possible or impossible, but *all* of those answers must be correct in order to count as a correct answer for that question.
- On all other multi-part questions, you need only answer *one* part of that question. Again, if you answer more than one part of any multi-part question, *all* of those answers must be correct in order to count as a correct answer for that question.

**TOTAL SCORE** = \_\_\_\_\_

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**Question 1**

A simple circuit consisting of a voltage source and a resistor connected together with copper wire has the following properties:

- Circuit current = 8 milliAmperes
- Total wire length = 1.5 meters
- Source voltage = 11.5 Volts
- Ambient (room) temperature = 23 degrees Celsius

Calculate the resistor's value in this circuit as well as the amount of power it dissipates:

$R =$

$P =$

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**Question 2**

Determine the nominal, low, and high resistance values for the following four-band resistor color codes:

**Violet - Green - Red - Silver**

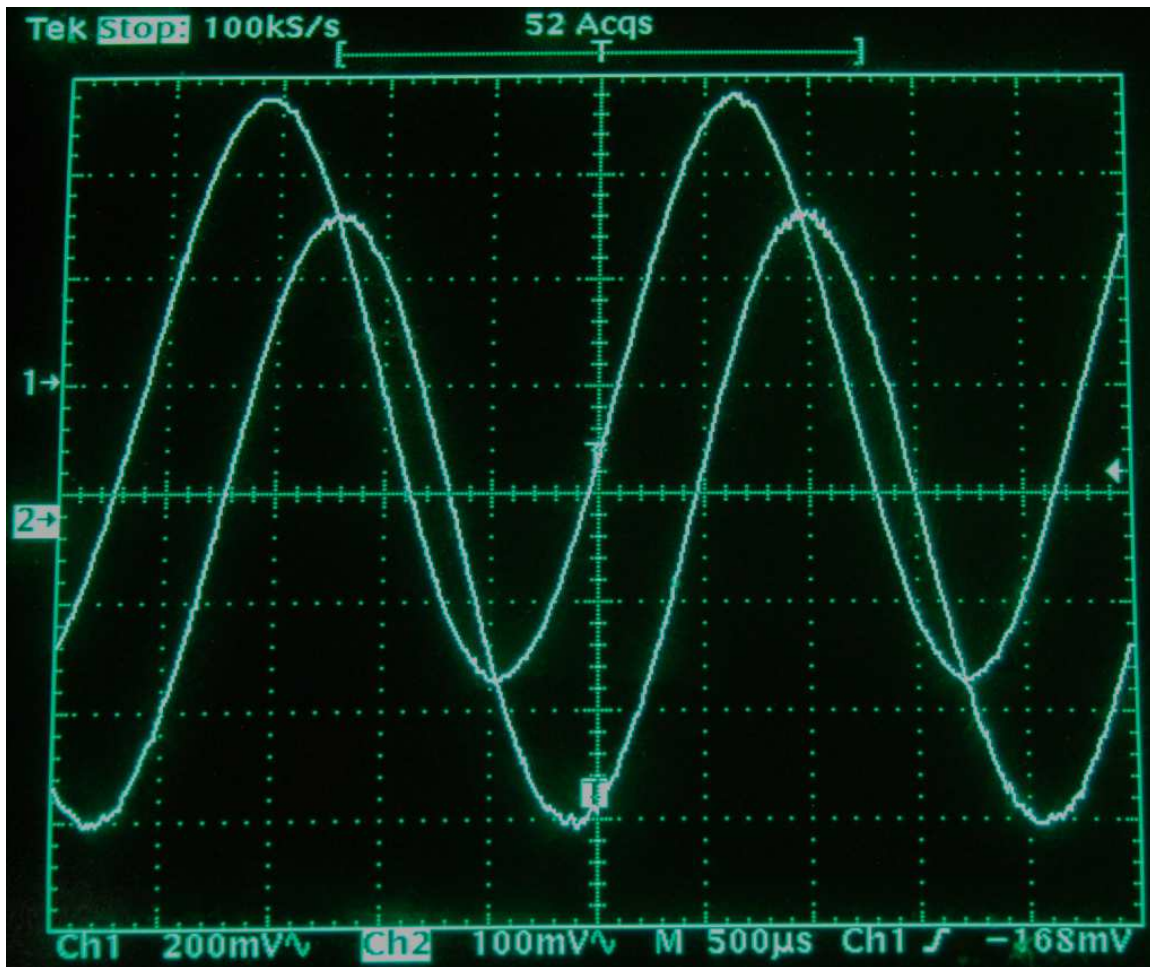
- Nominal (ideal) value = \_\_\_\_\_ Ohms
- Lowest tolerable value = \_\_\_\_\_ Ohms
- Highest tolerable value = \_\_\_\_\_ Ohms

**Grey - Red - Yellow - Gold**

- Nominal (ideal) value = \_\_\_\_\_ Ohms
- Lowest tolerable value = \_\_\_\_\_ Ohms
- Highest tolerable value = \_\_\_\_\_ Ohms

### Question 3

Identify the following parameters relating to these two voltage waveforms, where Channel 1 is the upper waveform and Channel 2 is the lower waveform. Channel sensitivity, timebase, and trigger settings for the oscilloscope appear immediately below the grid:



- Channel 2  $V_{pk} =$  \_\_\_\_\_
- Channel 1  $V_{pk-pk} =$  \_\_\_\_\_
- Period = \_\_\_\_\_
- Phase shift = \_\_\_\_\_
- Channel 1 leads or lags? Channel 2

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**Question 4**

An 8 milliAmpere RMS AC source with a frequency of 40 Hz connects to a  $3.3\ \mu\text{F}$  capacitor. Calculate voltage in this circuit, expressing your answer in either rectangular or polar form, assuming the source is the phase reference (e.g.  $\angle 0^\circ$ ):

$$V = \underline{\hspace{2cm}}$$

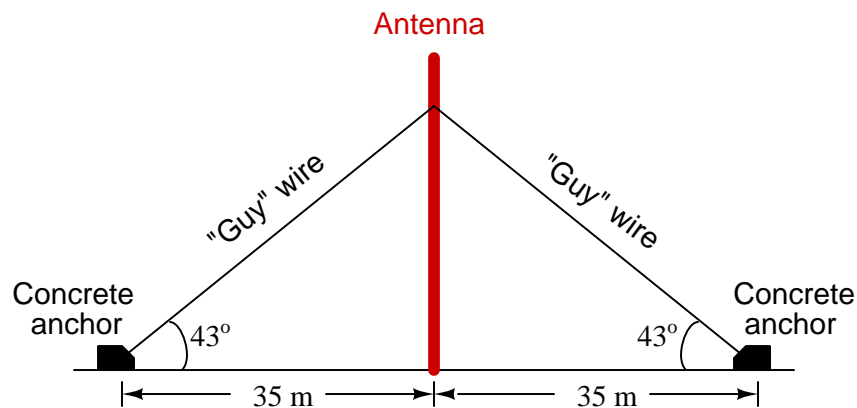
A 16 Volt RMS AC source with a frequency of 1 kHz connects to a 75 mH inductor. Calculate current in this circuit, expressing your answer in either rectangular or polar form, assuming the source is the phase reference (e.g.  $\angle 0^\circ$ ):

$$I = \underline{\hspace{2cm}}$$

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**Question 5**

A radio antenna is braced by *guy wires* connecting to a points 35 meters distant from the based of the antenna tower and anchored to large concrete structures at ground level:



Calculate the length of one of these guy wires, as well as the attachment height of each guy wire to the antenna tower.

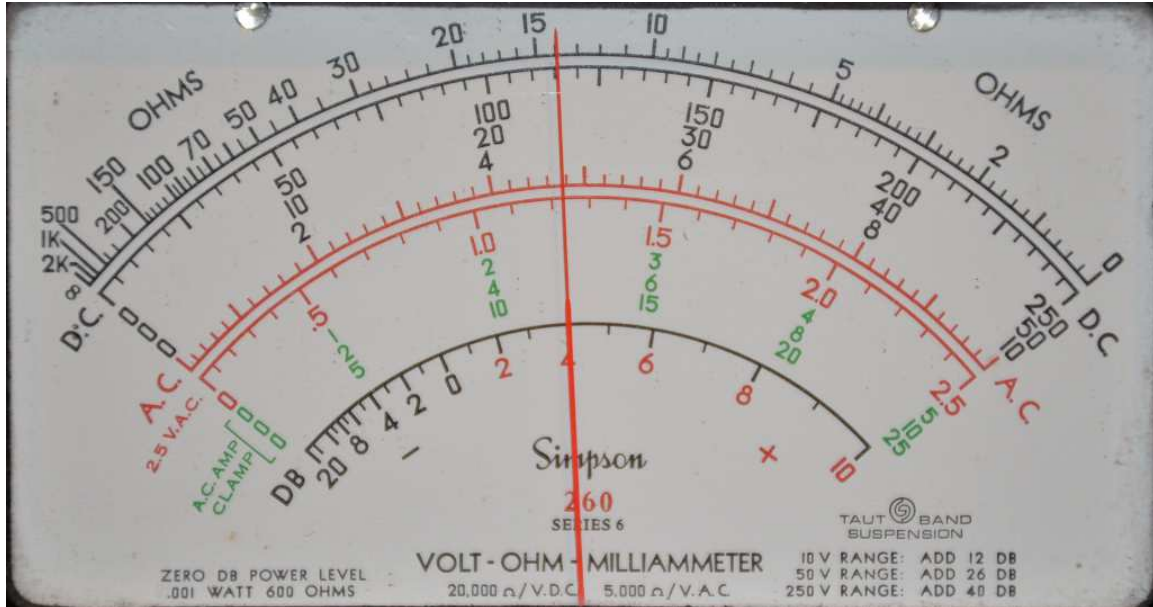
$$\text{Guy wire length} = \underline{\hspace{2cm}}$$

$$\text{Height of attachment point} = \underline{\hspace{2cm}}$$

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**Question 6**

Determine the amount of resistance being registered by this analog VOM (Volt-Ohm-Milliammeter) with its selector switch set on the  $R \times 1$  Ohms range:



Meter indication = \_\_\_\_\_

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**Question 7**

If a transformer outputs 3.1 Amperes AC given a primary current of 92 Amperes AC, how much primary current will it require to output 4.5 Amperes AC?

$I_{primary} =$  \_\_\_\_\_

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**Question 8**

Convert the mass rate **81 pounds per minute** into **ounces per second**. The following equivalents are given as a helpful reference, though you may not need to use all of them:

- 1 minute = 60 seconds
- 1 pound = 16 ounces
- 1 kilogram = 2.2046 pounds
- 1 hour = 60 minutes

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**Question 9**

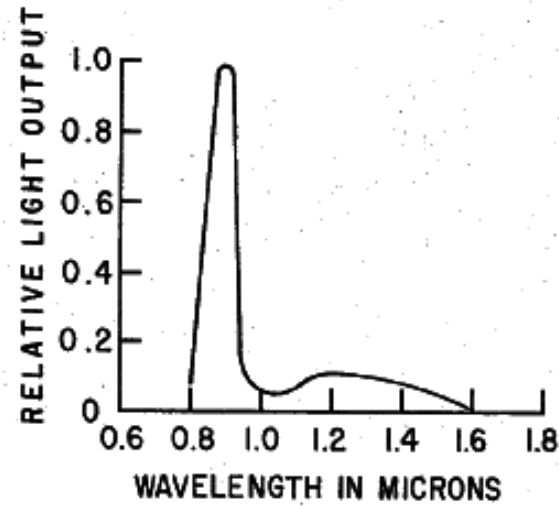
Solve for  $x$  in this equation:

$$c = \log(x - 4b)$$

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**Question 10**

Identify the wavelength of maximum light output by an LED according to this graph:

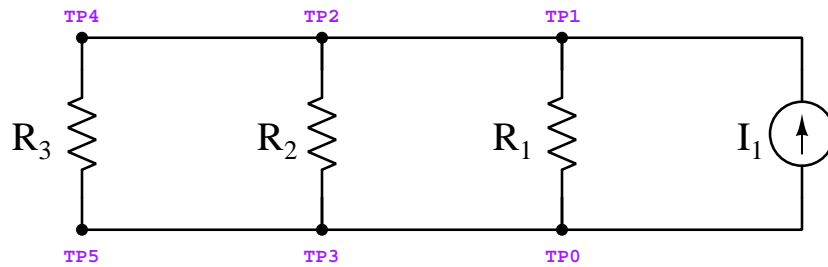


$\lambda =$  \_\_\_\_\_ microns

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**Question 11**

Calculate the following parameters for this circuit, assuming  $I_1 = 35$  mA,  $R_1 = 1.8$  k $\Omega$ ,  $R_2 = 7.1$  k $\Omega$ , and  $R_3 = 1$  k $\Omega$ :



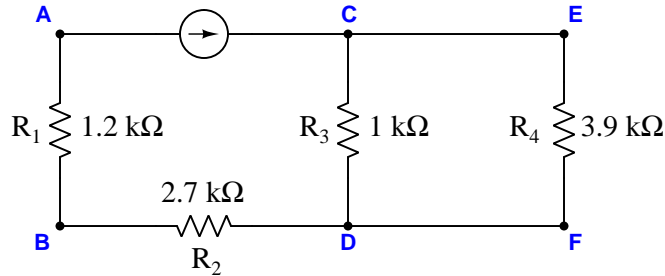
- $I_{R1} =$
- $P_{total} =$
- $I_{R3} =$
- $V_{TP2-TP5} =$



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**Question 12**

Calculate the power dissipated by  $R_1$  and the voltage between points B and C in this circuit, if we know there is 4.5 Volts dropped between points E and F. Annotate the polarities of  $V_{BC}$  and  $V_{EF}$  using + and - symbols, both annotations shown in the original diagram:



$$P_{R1} =$$

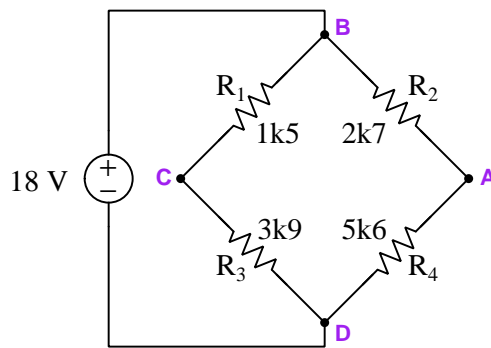
$$V_{BC} = \quad \text{(Also draw + and - polarity marks on diagram)}$$

$$V_{EF} \text{ polarity} = \text{(Only draw + and - polarity marks on diagram)}$$

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**Question 13**

Replace resistor  $R_1$  with one having a value necessary to balance this bridge circuit, then calculate the requested voltages and currents in the balanced circuit:

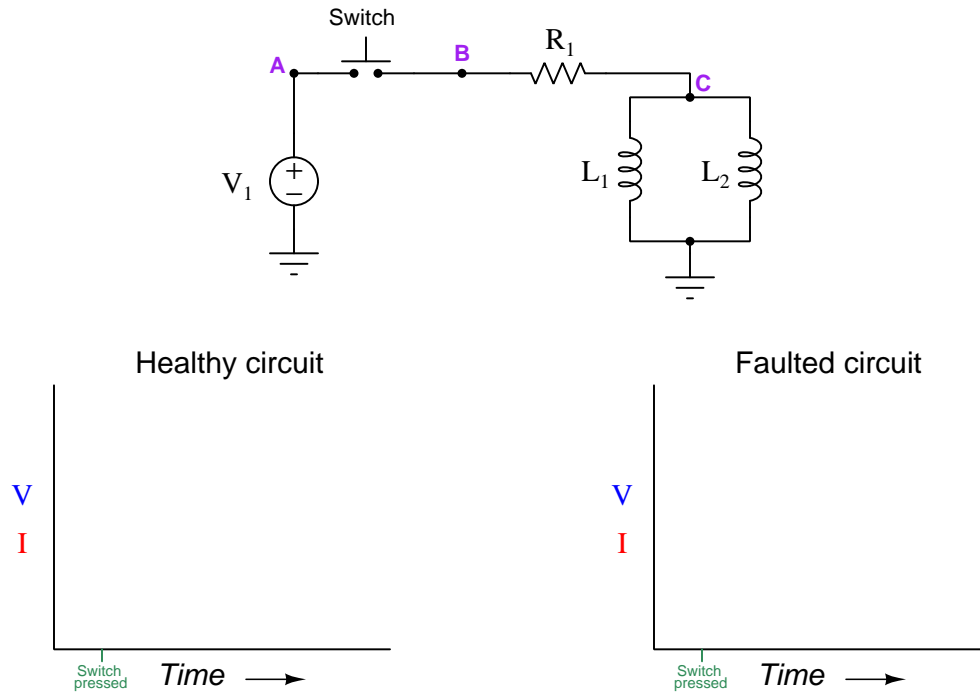


- $R_1 =$
- $V_{CB} =$
- $V_{BA} =$
- $I_{R3} =$
- $I_{source} =$

Be sure to specify whether the voltage values are positive or negative, following the convention that the first subscript represents the voltmeter's red test lead and the second subscript the black test lead (e.g.  $V_{AB}$  = red on A and black on B).

### Question 14

Suppose inductor  $L_1$  fails open in the following circuit:

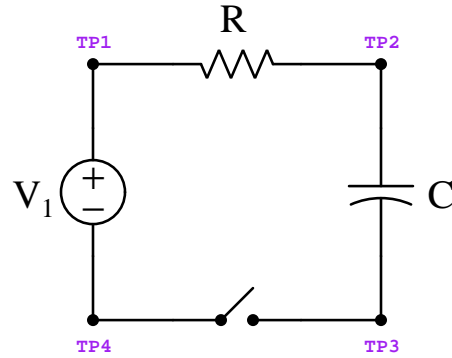


Sketch graphs for  $L_2$  voltage and current in the circuit assuming no faults (left) and again with the failed component (right).

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**Question 15**

Calculate the following parameters for this circuit, assuming  $V_1 = 15\text{ V}$ ,  $C = 1000\text{ }\mu\text{F}$ ,  $R = 33\text{ k}\Omega$ , and that the circuit begins with the switch open and with the capacitor completely de-energized (i.e. no stored charge):

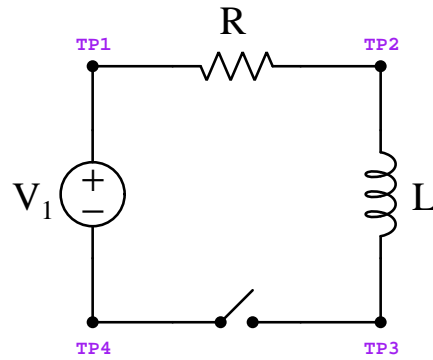


- $V_C$  10 seconds following switch closure =
- $V_{TP4-TP3}$  18 seconds following switch closure =
- $I_R$  20 seconds following switch closure =

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**Question 16**

Calculate the following parameters for this circuit, assuming  $V_1 = 15\text{ V}$ ,  $L = 5\text{ H}$ ,  $R = 120\text{ }\Omega$ , and that the circuit begins with the switch open and with the inductor completely de-energized (i.e. no magnetic field):

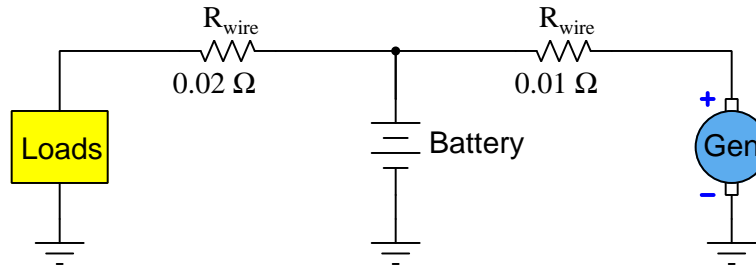


- $I_R$  50 milliseconds following switch closure =
- $V_L$  25 milliseconds following switch closure =
- $V_{TP4-TP3}$  100 milliseconds following switch closure =

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**Question 17**

In this circuit, a generator turned by an automobile engine provides electrical power to various loads in the automobile as well as current to re-charge the automobile's battery. The battery, of course, discharges when needed to provide additional current during "heavy" load conditions. The wires connecting these components together have small amounts of resistance as shown:



Supposing the battery's terminal voltage is 13.3 Volts, and that it is *discharging* (i.e. acting as an electrical energy *source*) with a current of 11.5 Amperes, and the load current is 18.2 Amperes, calculate the following:

$$V_{\text{generator}} =$$

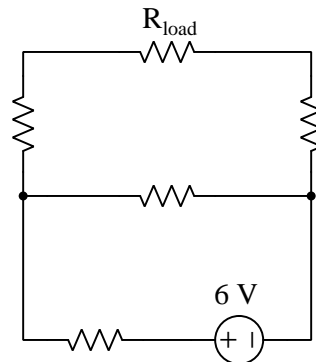
$$V_{\text{loads}} =$$

Also, show the direction of current (conventional flow notation) through both wires and through the battery.

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**Question 18**

Sketch a Thévenin equivalent circuit for this network complete with  $V_{Th}$  and  $R_{Th}$  values, and also calculate load voltage. Assume a load resistance of  $1.5 \text{ k}\Omega$ , and that all other resistors in the original network have equal values of  $1 \text{ k}\Omega$  each:

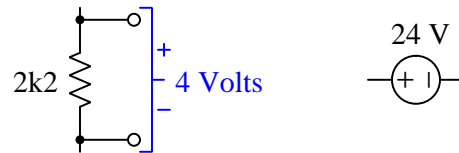


- $V_{Th} =$
- $R_{Th} =$
- $V_{\text{load}} =$

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**Question 19**

Design and sketch an unloaded voltage divider circuit powered by a 24 Volt DC source that outputs 4 Volts (with polarity shown) between a pair of terminals in parallel with a  $2.2\text{ k}\Omega$  resistor, being sure to specify any necessary component value(s).



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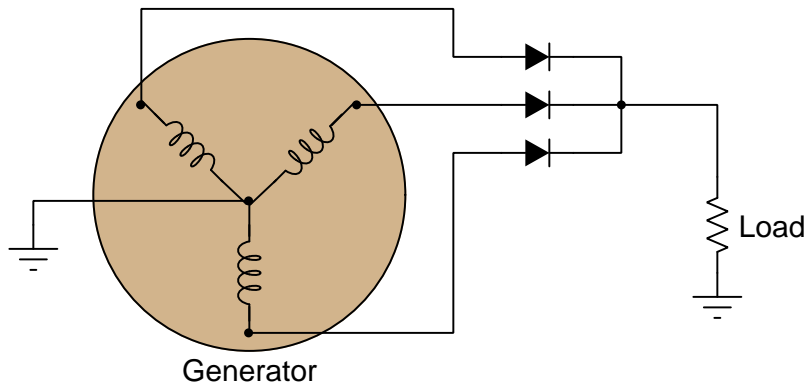
**Question 20**

Design and sketch a circuit where a measured voltage begins at a value of zero, then inverse-exponentially climbs after toggling a switch, and eventually settles at a maximum of 30 Volts. Be sure to specify *where* in your circuit this voltage will be measured.

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**Question 21**

Calculate peak load voltage as well as peak load current in this circuit, assuming the use of standard silicon rectifying diodes and a generator line voltage of 208 Volts RMS and a load resistance of 20 Ohms:



$$V_{load(pk)} = \underline{\hspace{2cm}}$$

$$I_{load(pk)} = \underline{\hspace{2cm}}$$

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**Question 22**

Calculate the following parameters for a parallel resistor-inductor-capacitor circuit given the following component values:

- $V_{source} = 7$  Volts RMS
- $f_{source} = 60$  Hz
- $R = 79 \, \Omega$
- $L = 150$  mH
- $C = 56 \, \mu\text{F}$

$$Z_C = \underline{\hspace{2cm}}$$

$$I_R = \underline{\hspace{2cm}}$$

$$Z_{total} = \underline{\hspace{2cm}}$$

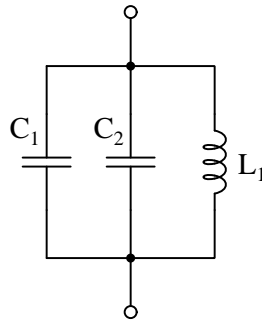
$$I_{source} = \underline{\hspace{2cm}}$$

All answers must be shown as phasor (i.e. complex-number) quantities in polar form.

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**Question 23**

Choose the necessary value for  $C_2$  to make this network resonate at a frequency of 1 kHz assuming  $L_1$  is 7 mH and  $C_1$  is 1  $\mu$ F, and determine whether the total impedance at that resonant frequency will be extremely high or extremely low:



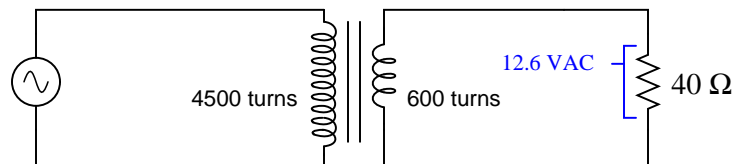
$$C_2 = \underline{\hspace{2cm}}$$

$$Z_{total} \text{ @ resonance} = \textit{high / low}$$

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**Question 24**

Calculate the source voltage and current in this transformer circuit. Assume an ideal transformer with no power losses at all:



$$V_{source} =$$

$$I_{source} =$$

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**Question 25**

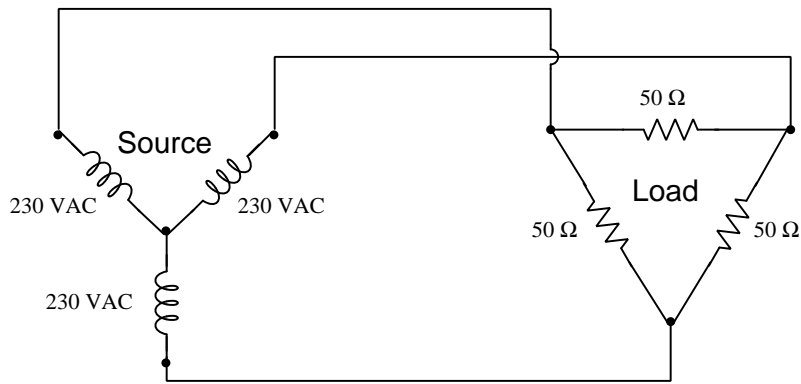
Predict the effects on the following currents if frequency decreases in a parallel RC network with constant source voltage:

- Current through source (*increases, decreases, or remains the same*)
- Current through  $C$  (*increases, decreases, or remains the same*)
- Current through  $R$  (*increases, decreases, or remains the same*)

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**Question 26**

Calculate the following parameters in this balanced 3-phase power system, assuming a source phase voltage of 230 VAC and a load phase resistance of 50 Ohms:



$$V_{line} = \text{_____ Volts}$$

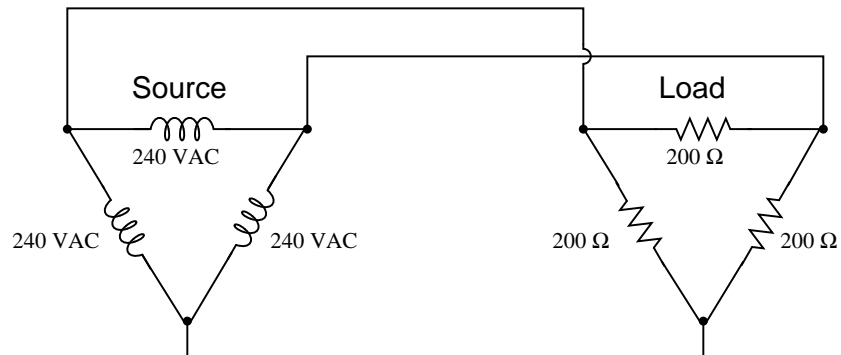
$$I_{line} = \text{_____ Amperes}$$

$$I_{phase} \text{ (source)} = \text{_____ Amperes}$$

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**Question 27**

Calculate the following parameters in this balanced 3-phase power system, assuming a source phase voltage of 240 VAC and a load phase resistance of 200 Ohms:



$$V_{line} = \text{_____ Volts}$$

$$I_{line} = \text{_____ Amperes}$$

$$I_{phase} \text{ (source)} = \text{_____ Amperes}$$



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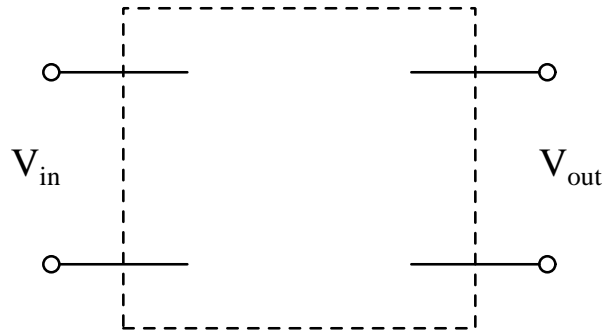
**Question 28**

A single-phase electric motor running on a line voltage of 230 Volts draws 8.3 Amperes of current. Calculate the horsepower output of this motor at this line current, assuming 100% efficiency and a perfect power factor (1.0).

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**Question 29**

Design a low-pass filter with a cutoff frequency of 1 kHz, using either a 1 H, 1.5 H, or 2 H inductor. Sketch the components between the terminals shown below:



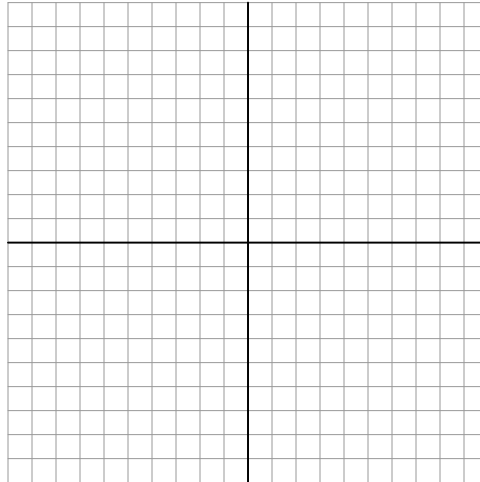
Be sure to show all component values within your diagram.

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**Question 30**

Sketch a phasor diagram for all impedances in a simple series resistor-capacitor circuit given the following component values:

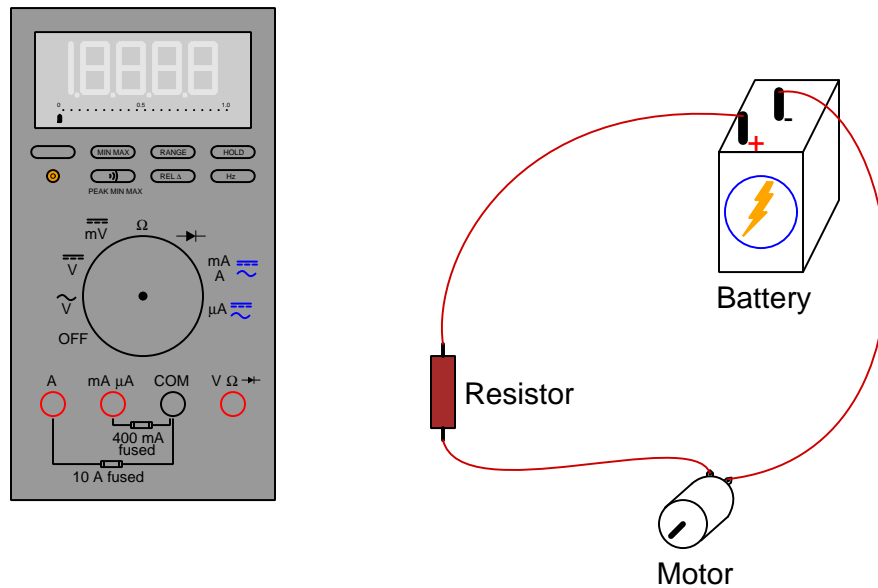
- $V_{source} = 50$  Volts RMS  $\angle 0^\circ$
- $f_{source} = 60$  Hz
- $R = 30\ \Omega$
- $C = 68\ \mu\text{F}$



Draw the phasor lengths and angles as close to scale as you can, being sure to document your calculated values for the phasor quantities (i.e. show your work!).

### Question 31

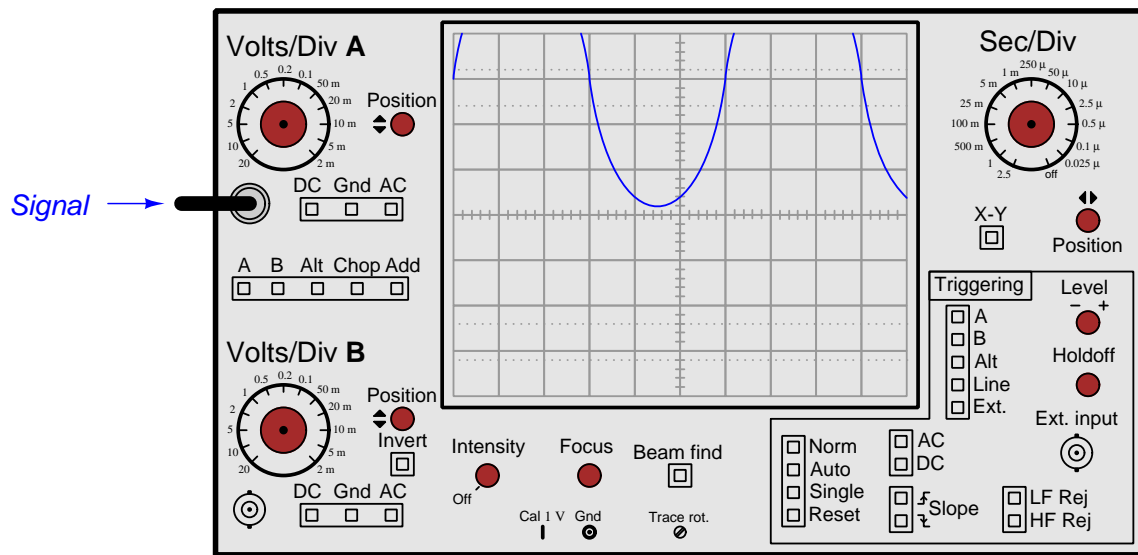
Show how this digital multimeter should connect to the circuit in order to measure the **resistor's resistance**, anticipating between 2.5 Ohms and 3.7 Ohms. If you must break continuity anywhere in the circuit, please mark each broken connection with an "X" symbol:



- Sketch proper connections for the red and black test leads
- Show proper setting of the meter's rotary selector

### Question 32

Identify the front-panel control(s) on this oscilloscope you would use to view the waveform in its entirety:



### Question 33

Identify the front-panel control(s) on this oscilloscope you would use to “capture” a transient signal and freeze it on the screen for further analysis:



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**Question 34**

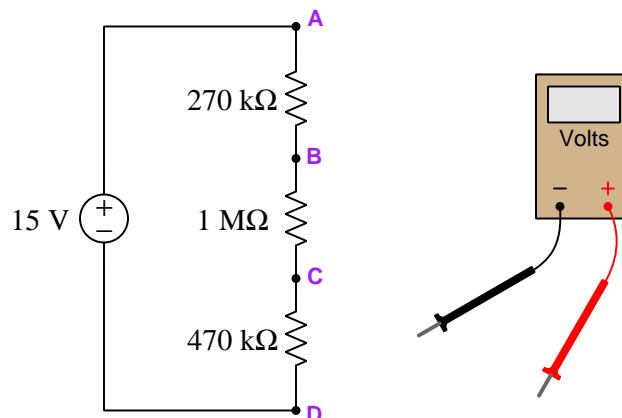
Identify the purpose of this test instrument, and also identify one practical application for it:



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**Question 35**

Sketch how to connect this digital multimeter (DMM) to measure voltage between points **A** and **C** in this circuit so that it will register a positive value. If you need to break any existing wire connections to do so, mark those breaks with “X” symbols.



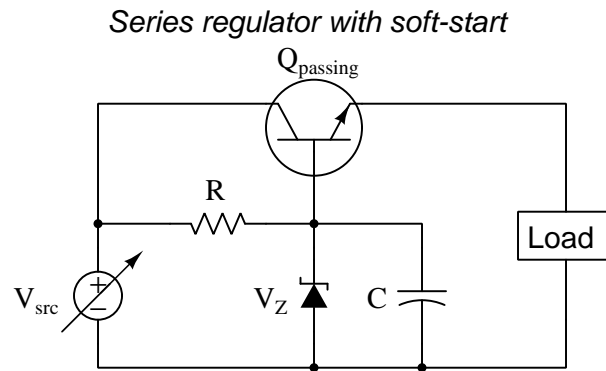
Next, determine how much voltage this DMM will register when connected between those points, assuming the meter has an internal (insertion) resistance of  $2\text{ M}\Omega$ .

Voltage measurement = \_\_\_\_\_ Volts

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**Question 36**

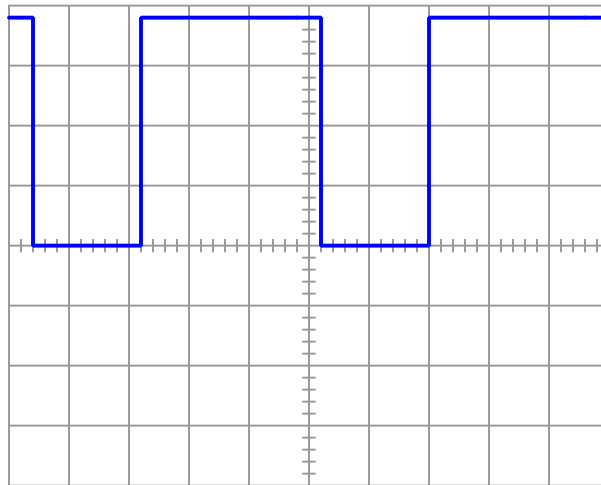
Identify where a dual-channel oscilloscope (configured for single-sweep trigger operation) could be connected in this circuit to measure the time delay between power-up and the attainment of full load voltage:



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**Question 37**

An oscilloscope measures pulsed DC current through a  $22\ \Omega$  load resistance that is known to be dissipating an average power of 129 Watts. Determine the peak current of this PWM waveform:



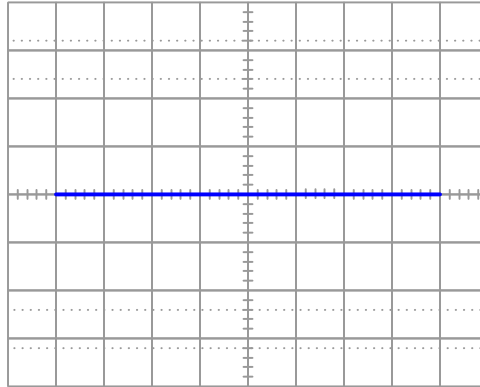
$$I_{pk} = \underline{\hspace{2cm}}$$

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**Question 38**

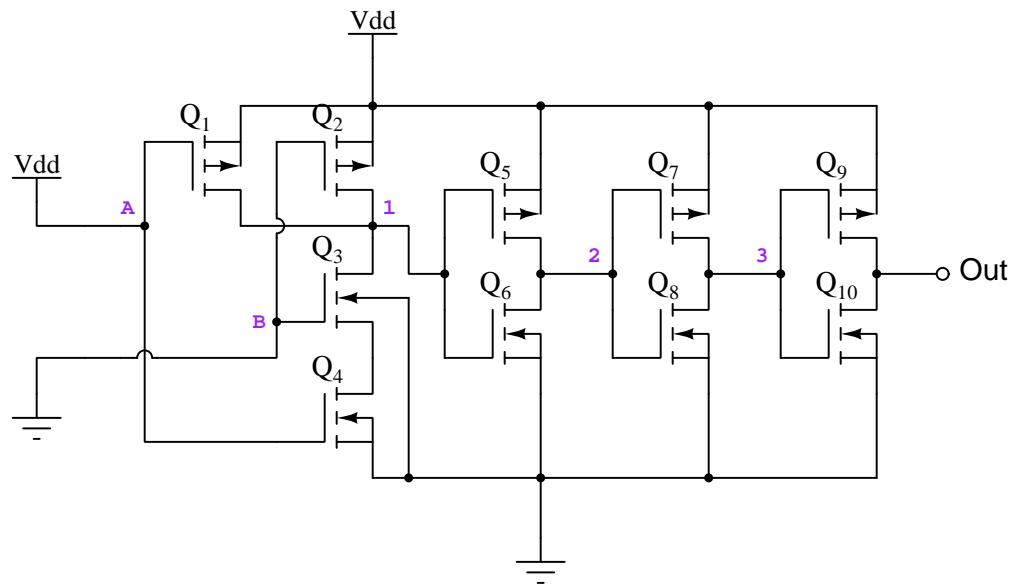
Interpret this display shown by a *curve tracer* instrument which works by exciting a component with an AC or “swept” DC voltage (horizontal axis) and measuring device current (vertical axis), yielding a current/voltage characteristic curve for the device under test.

Identify both the component connected to this curve tracer as well as any defects in that component as evidenced by the instrument’s display:



### Question 39

Determine the states that would be measured at various test points in this digital circuit using a logic probe:



Logic state at test point 1 = (high) or (low)

Logic state at test point 3 = (high) or (low)

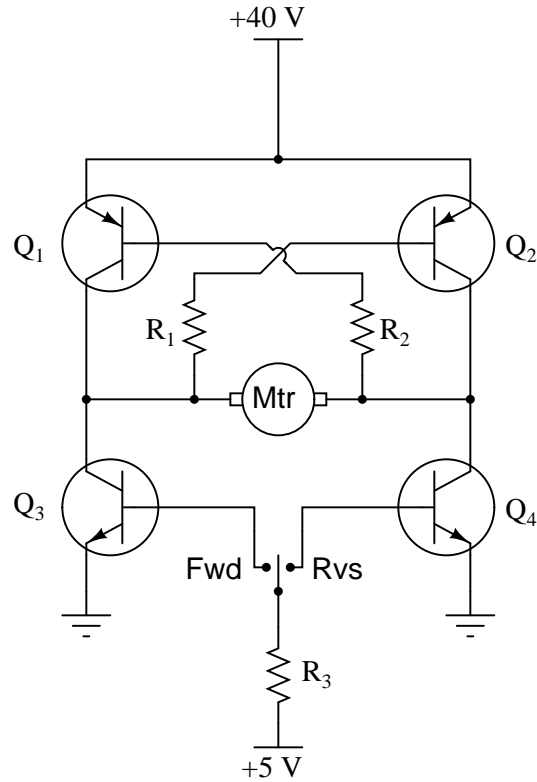
Logic state at output = (high) or (low)



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**Question 40**

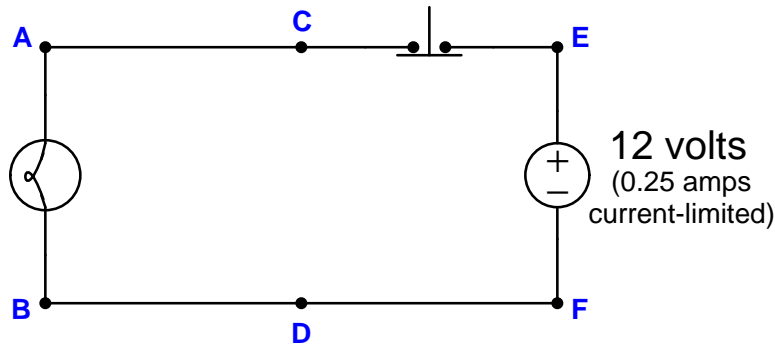
This set of transistors controls the direction of a DC electric motor:



Identify where at one of the transistor terminals you could connect a multimeter to measure motor *inrush current* at the moment in time when the SPDT switch moves to the appropriate position to spin the motor the “forward” direction. It is important that the meter only register motor current, and not any additional current, during this test! In addition to identifying the connection points, also specify which function (voltage, current, resistance) the multimeter should be configured for during this test.

### Question 41

Suppose the lamp refuses to light up regardless if the pushbutton switch is pressed or not. A voltmeter registers 12 Volts between test points **E** and **B** in the circuit while the pushbutton is pressed:



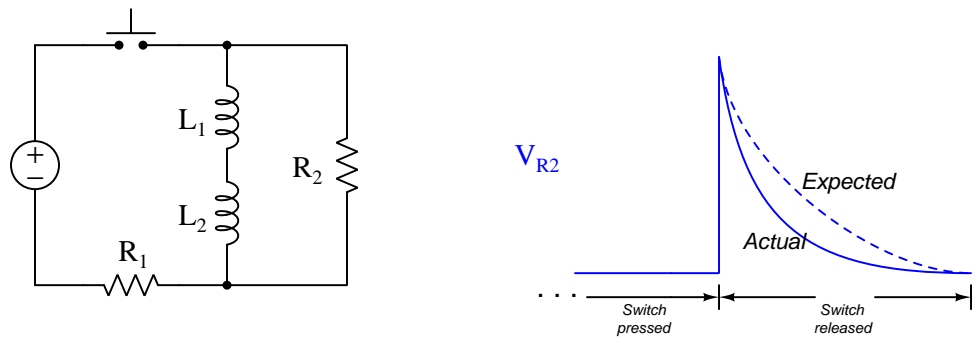
Note that a “current-limited” voltage source behaves like a normal voltage source when the load draws less than its current rating (i.e. constant voltage), but when faced with a load that would draw more current than its rating it switches into current-source mode and limits current to that rated value while letting the voltage sag below its normal value. For example, when shorted, a current-limited source will output its rated current at zero Volts.

Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Open wire between A and C		
Open wire between B and D		
Open wire between D and F		
Lamp failed open		
Switch failed open		
Lamp failed shorted		
Switch failed shorted		

Question 42

Suppose the voltage dropped across resistor  $R_2$  when the pushbutton switch is released decays at a more rapid rate than it should, as shown in the graph to the right of the schematic diagram. The dashed graph shows what the circuit ought to do, while the solid graph shows what it actually does:



Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

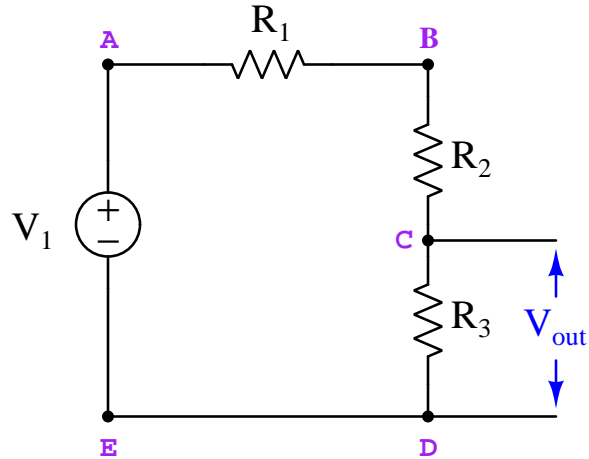
Fault	Possible	Impossible
Resistor $R_1$ failed open		
Resistor $R_2$ failed open		
Inductor $L_1$ failed open		
Inductor $L_2$ failed open		
Inductor $L_1$ failed shorted		
Inductor $L_2$ failed shorted		

### Question 43

The following voltage divider circuit has a problem, as it is found to output 0 Volts. The components are rated as follows:

- $V_1 = 30$  Volts
- $R_1 = 7.1 \text{ k}\Omega$
- $R_2 = 7.1 \text{ k}\Omega$
- $R_3 = 7.1 \text{ k}\Omega$

A diagnostic test performed using a voltmeter registers 30 Volts between test points **B** and **C**.

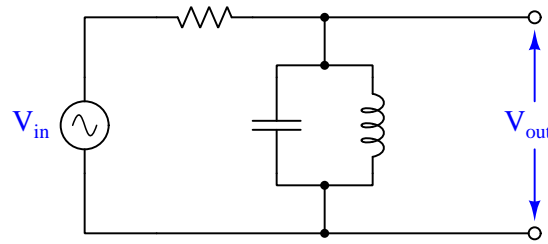


Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Open wire between E and D		
R1 failed open		
R2 failed open		
R3 failed open		
R1 failed shorted		
R2 failed shorted		
R3 failed shorted		
Voltage source dead		

### Question 44

Identify the type of filtering behavior of the circuit shown in this diagram:

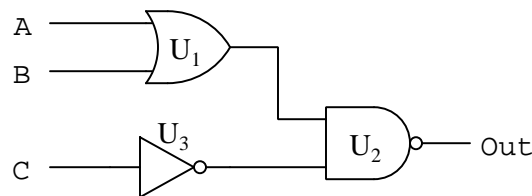


Next, identify the filtering behavior of this same circuit supposing the inductor fails *shorted*. Place two check-marks in the table below to identify each filtering characteristic (one check-mark identifying the healthy circuit's characteristic and another check-mark identifying the faulted circuit's characteristic):

Filter type	Healthy circuit	Faulted circuit
Low-pass		
High-pass		
Band-pass		
Band-stop		
Passes all frequencies		
Blocks all frequencies		

### Question 45

The following logic gate circuit has a problem. Its output state is always low (0) regardless of the input states:

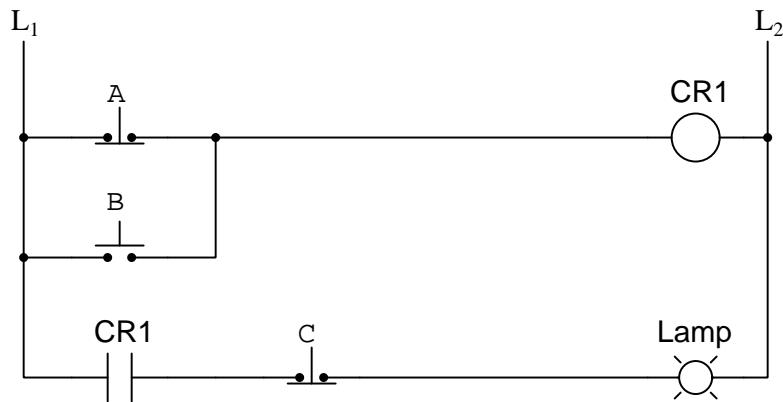


Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
$U_1$ output failed low		
$U_1$ output failed high		
$U_2$ output failed low		
$U_2$ output failed high		
$U_3$ output failed low		
$U_3$ output failed high		

### Question 46

The following relay ladder logic circuit has a problem. The lamp is always off regardless of the switch states:



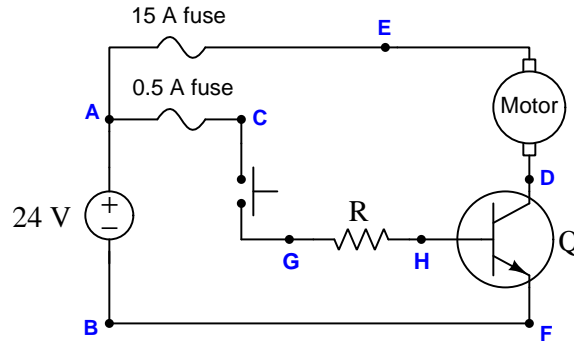
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Switch <i>A</i> failed open		
Switch <i>A</i> failed shorted		
Switch <i>B</i> failed open		
Switch <i>B</i> failed shorted		
Switch <i>C</i> failed open		
Switch <i>C</i> failed shorted		
CR1 contact failed open		
CR1 contact failed shorted		

---

**Question 47**

Suppose this DC electric motor refuses to run when the pushbutton switch is pressed. A voltmeter subsequently connected between test points **G** and **B** in this circuit registers 24 Volts when the switch is pressed:



Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Pushbutton switch failed open		
Pushbutton switch failed shorted		
Motor failed open		
Resistor failed open		
15 amp fuse blown		
0.5 amp fuse blown		

---

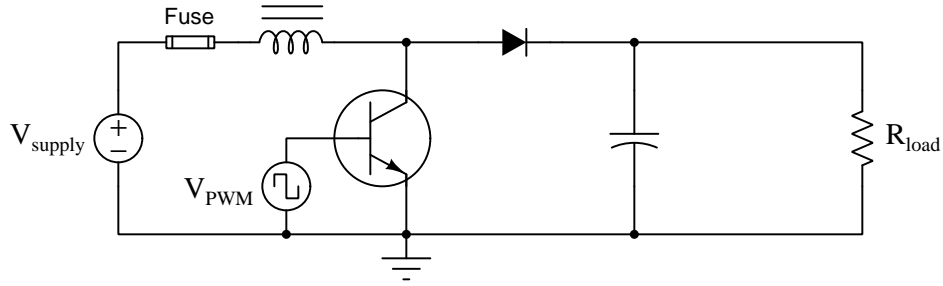
**Question 48**

An analog ohmmeter is used to test a rectifying diode:

- Red lead on striped terminal and black lead on non-striped terminal = (infinite) Ohms
- Black lead on striped terminal and red lead on non-striped terminal = 0.8 Ohms

Identify which end of this diode is the anode and which end is the cathode. Also determine whether or not this diode is healthy, and if not what type of fault it has.

Identify the effects of a *failed-open inductor* in this boost converter circuit:



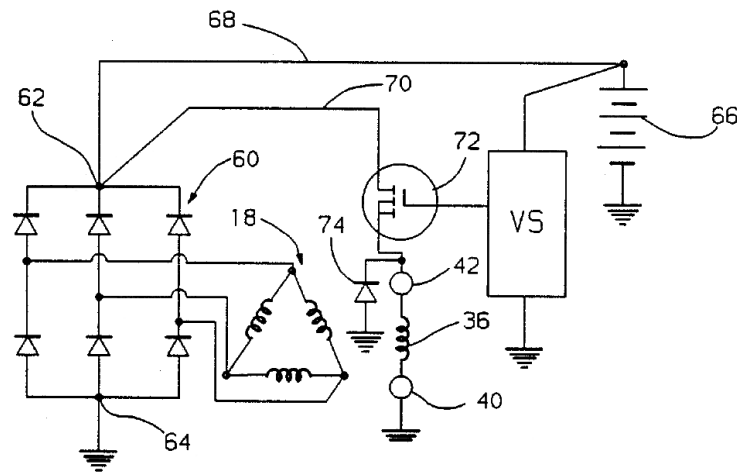
Assume the PWM signal's duty cycle remains constant before and after the fault (i.e. no automatic adjustment in an attempt to regulate load voltage or current).

- Fuse will blow (*yes or no?*)
- Load voltage (*increase or decrease or unchanged?*)
- Supply current (*increase or decrease or unchanged?*)

---

Question 50

Identify the purpose of component #60 in this alternator schematic:

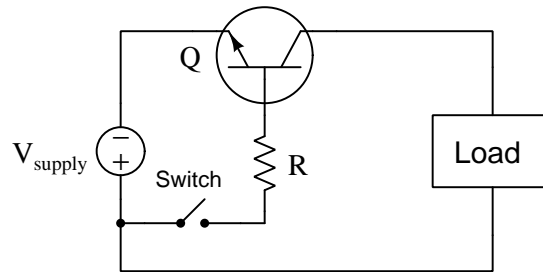




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**Question 51**

Calculate the following parameters in this switching circuit, assuming a source voltage of 22 Volts, a resistor value of  $470\ \Omega$ , a load resistance of  $75\ \Omega$ , and a silicon transistor with a  $\beta$  value of at least 90:



**With switch closed**

$$V_{load} = \underline{\hspace{2cm}}$$

$$I_{switch} = \underline{\hspace{2cm}}$$

**With switch open**

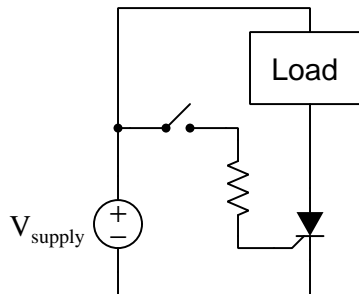
$$V_{load} = \underline{\hspace{2cm}}$$

$$I_{switch} = \underline{\hspace{2cm}}$$

---

**Question 52**

Calculate the maximum allowable load current for an SCR assuming a supply voltage of 220 Volts, an SCR power rating of 100 Watts, and a maximum forward on-state voltage  $V_{AK(max)}$  rating of 1.3 Volts:

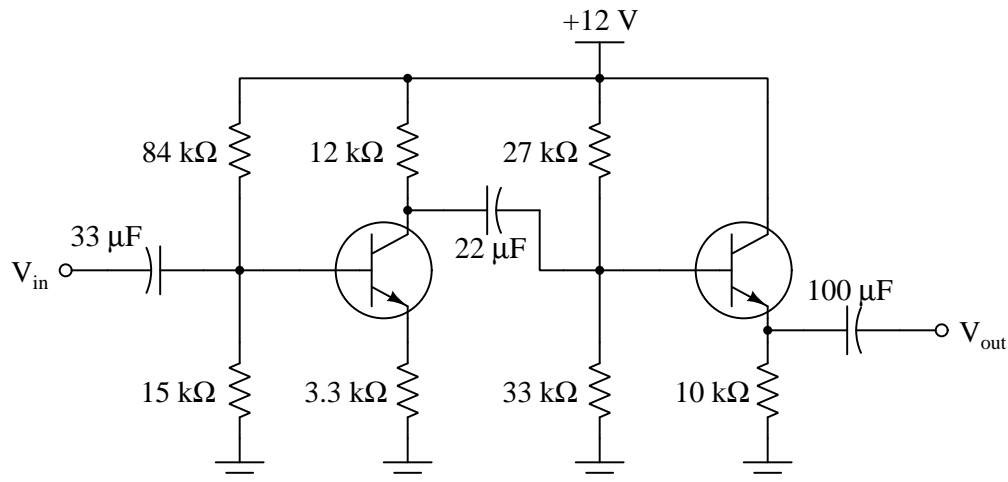


$$I_{load} = \underline{\hspace{2cm}}$$

---

**Question 53**

Predict the amount of AC voltage gain that will be exhibited by the following amplifier circuit:



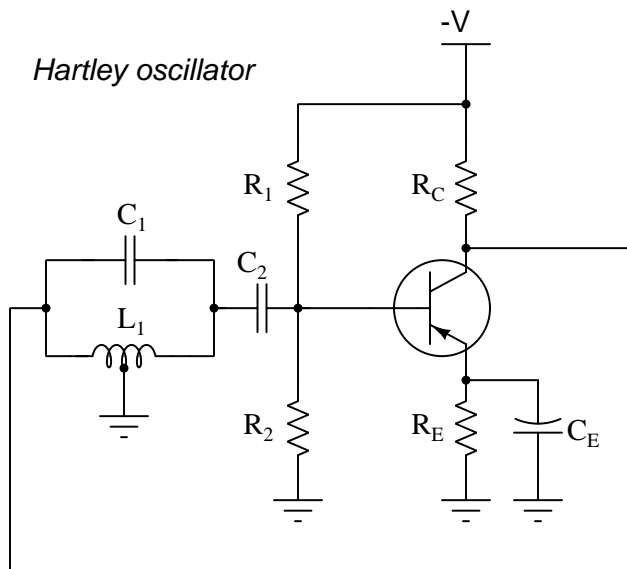
You may express your answer either as a gain ratio or as a decibel figure. If you answer in both formats, both of your answers must be correct! If you choose to answer in decibels you must write “dB” as the unit, as any unit-less answer will be assumed a gain ratio.

$A_V =$

---

**Question 54**

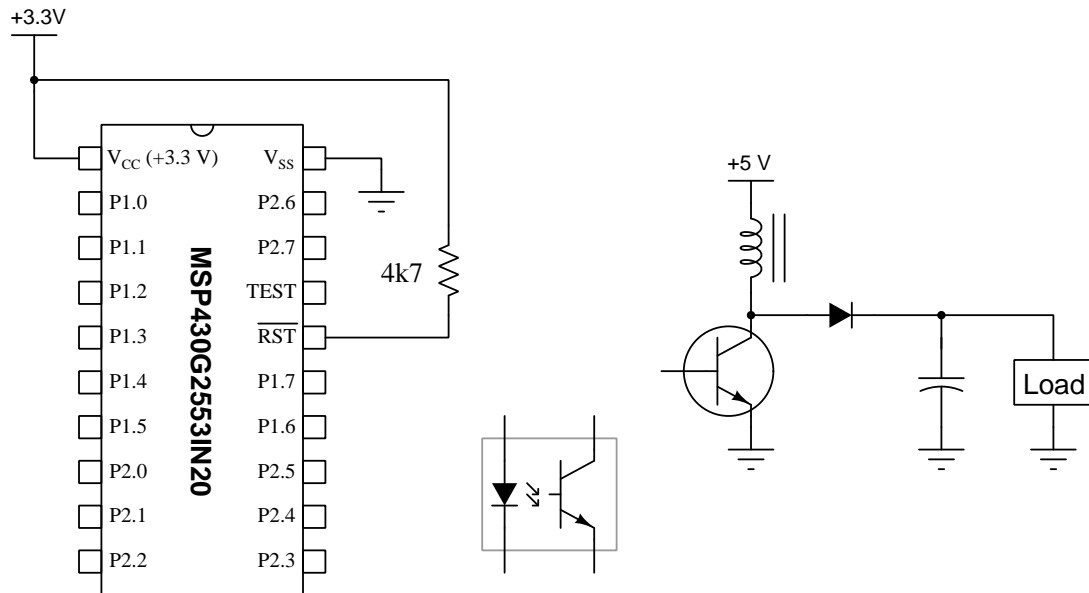
Determine the necessary size of  $L_1$  for this oscillator circuit to produce an output frequency of 500 kHz given  $C_1 = 0.001\ \mu\text{F}$ :



$L_1 =$  \_\_\_\_\_

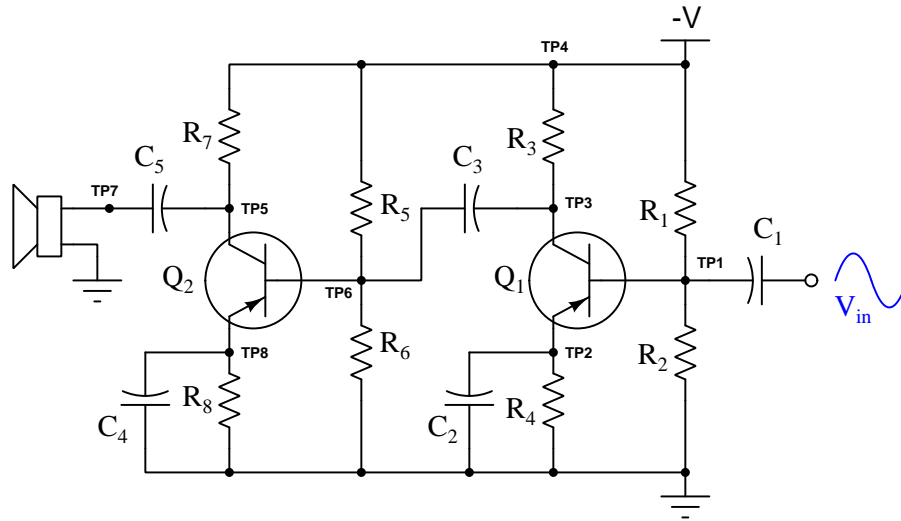
### Question 55

Sketch a circuit to interface output port P1.5 of the microcontroller to the power converter's transistor, so that a PWM signal generated by the MCU will control the power conversion. You are free to include additional components as necessary:



### Question 56

Suppose the following amplifier circuit produces a weak sound at the speaker despite the presence of a strong input signal (as verified by an oscilloscope measurement at TP1). AC voltage measured between TP6 and ground is weaker than normal as well:



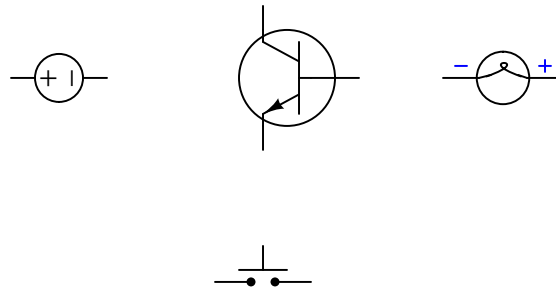
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
$R_1$ failed shorted		
$R_7$ failed open		
$R_8$ failed shorted		
$C_2$ failed open		
$C_3$ failed shorted		
$C_4$ failed open		

---

**Question 57**

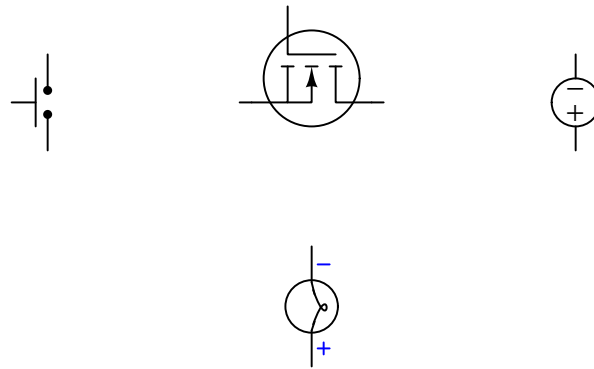
Sketch wires connecting these components together to form a circuit where pressing the pushbutton switch causes the transistor to turn on and send power to the lamp (with DC polarity shown). The pushbutton switch should carry only as much current as is necessary to trigger the transistor, and not carry full lamp current. Feel free to add other basic components as necessary to make your circuit reliably functional, but do not include anything unnecessary in your design (e.g. resistors that don't serve a purpose, or a second source).



---

**Question 58**

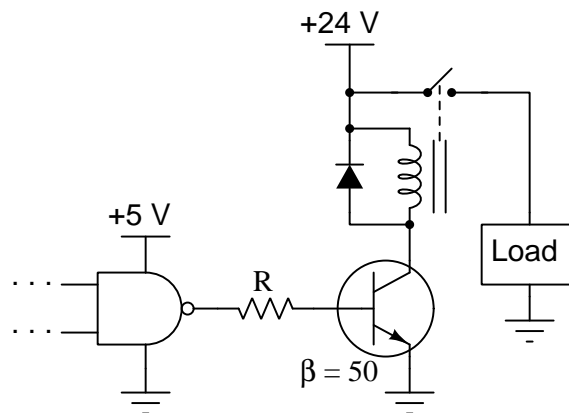
Sketch wires connecting these components together to form a circuit where pressing the pushbutton switch causes the transistor to turn on and send power to the lamp (with DC polarity shown). The pushbutton switch should carry only as much current as is necessary to trigger the transistor, and not carry full lamp current. Feel free to add other basic components as necessary to make your circuit reliably functional, but do not include anything unnecessary in your design (e.g. resistors that don't serve a purpose, or a second source).



---

**Question 59**

Calculate the resistor value necessary for the silicon transistor to reliably switch the load on and off, assuming we need it to be saturated when turned on by the output signal from the logic gate:



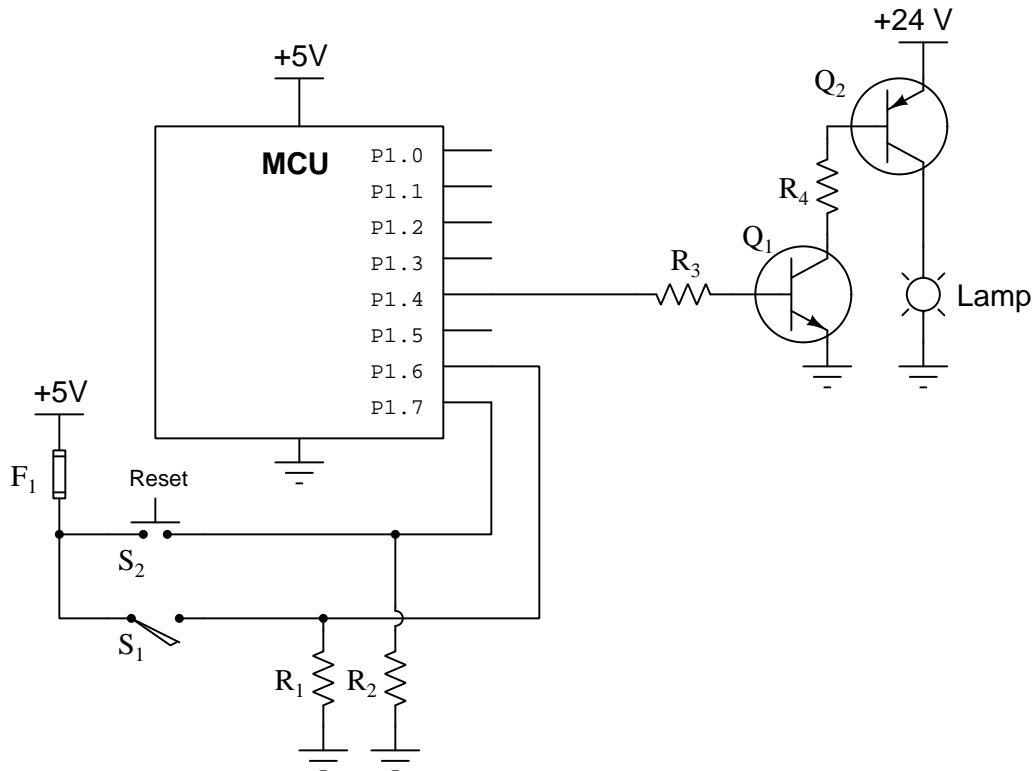
Assume the relay coil draws 100 milliAmperes of current when energized, and that the logic gate is CMOS with the ability to swing its output terminal voltage fully to the DC “rail” values (i.e. all the way down to 0 Volts and all the way up to +5 Volts).

$$R = \underline{\hspace{2cm}}$$

### Question 60

The following microcontroller is programmed to control the illumination of a lamp based on the number of vehicles counted passing by along a particular road. A pressure-actuated switch installed in the road ( $S_1$ ) detects the passage of vehicles (one pulse per vehicle) while a pushbutton switch ( $S_2$ ) manually resets the microcontroller's internal count back to zero. If this count value exceeds 1500, the lamp is supposed to energize. Otherwise, the lamp is supposed to remain de-energized.

However, something is wrong in this system because the lamp never illuminates even when many cars have passed and no one has pressed the reset pushbutton. Output pin P1.4 on the microcontroller consistently reads "high" using a logic probe.



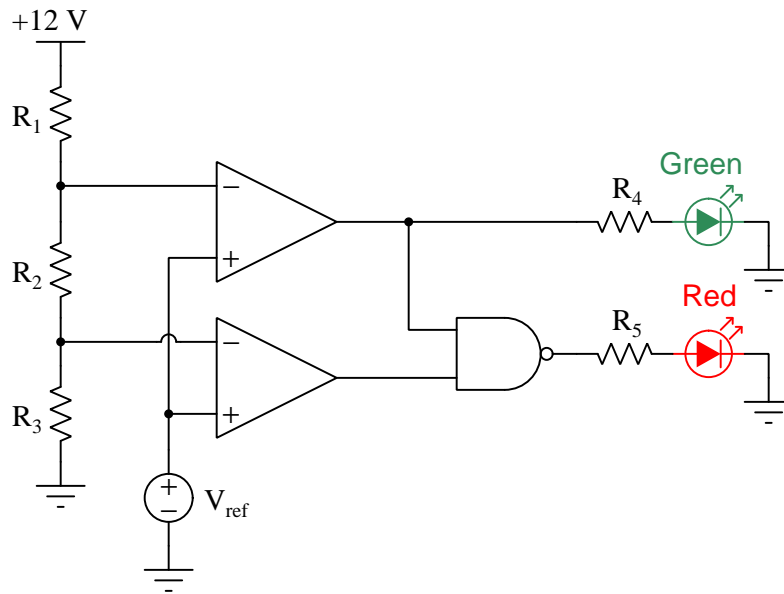
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Switch $S_1$ failed open		
Transistor $Q_1$ failed open collector-emitter		
Transistor $Q_2$ failed open collector-emitter		
Fuse $F_1$ blown		
Transistor $Q_1$ failed shorted collector-emitter		
Transistor $Q_2$ failed shorted collector-emitter		
Resistor $R_3$ failed open		

---

**Question 61**

Choose a value for  $V_{ref}$  that will absolutely guarantee the red LED is on *and* the green LED is off, assuming  $R_1$  through  $R_3$  are  $1.2\text{ k}\Omega$  each, and both  $R_4$  and  $R_5$  are  $630\text{ }\Omega$  each:



$V_{ref} = \underline{\hspace{2cm}}$

---

**Question 62**

Design a voltage amplifier circuit using an operational amplifier (“opamp”) where the over-all voltage gain (ratio) is equal to  $-5$ :

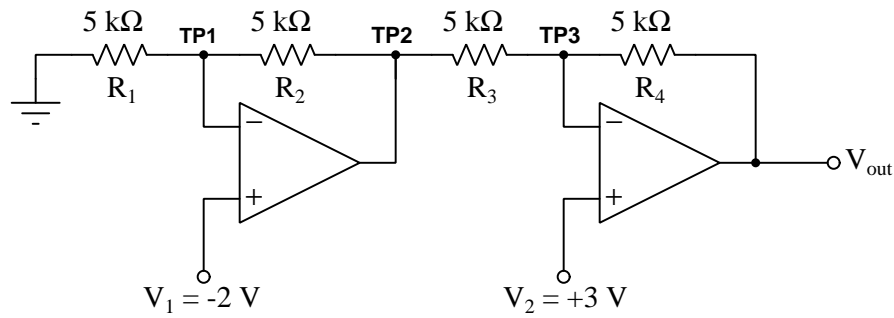
Be sure to show all component values within your diagram, as well as clearly labeling the “input” and “output” signal terminals.



---

**Question 63**

Calculate the following parameters in this circuit (be sure to specify the polarity of each voltage with respect to ground!):



$$V_{TP2} =$$

$$V_{TP3} =$$

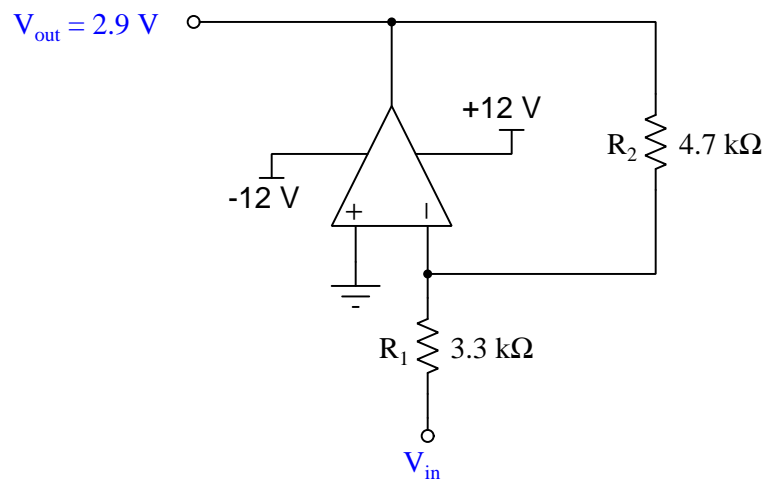
$$I_{R4} =$$

$$V_{out} =$$

---

**Question 64**

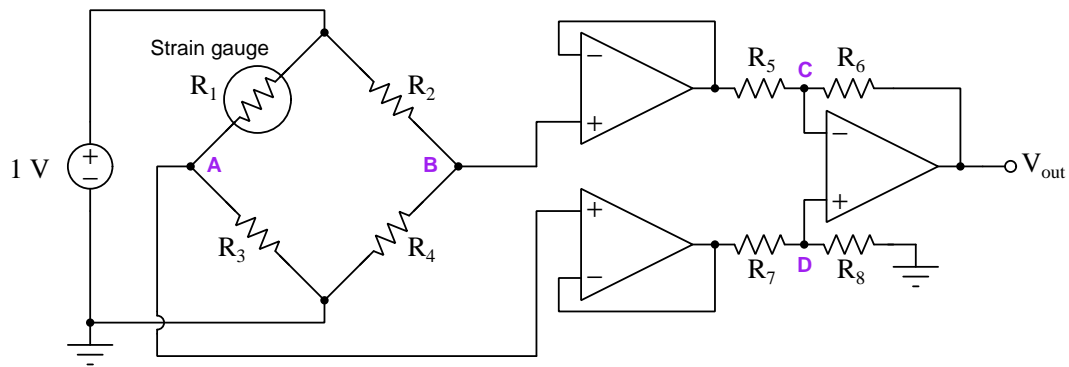
Calculate the amount and direction of current through resistor  $R_2$  in this opamp circuit, given the output voltage and resistor values shown. Note that the voltage source for  $V_{in}$  is not shown. Assume the opamp is capable of “rail-to-rail” output voltage swings, and that the output voltage is specified in reference to ground. Be sure to sketch your current arrow in the direction of *conventional* flow:



$$I_{R2} =$$

### Question 65

Calculate the following parameters for this circuit as shown, given the listed component values:



- $R_1 = 8 \text{ k}\Omega$  (strain gauge sensor)
- $R_2 = 10 \text{ k}\Omega$
- $R_3 = 10 \text{ k}\Omega$
- $R_4 = 10 \text{ k}\Omega$
- $R_5 = 1 \text{ k}\Omega$
- $R_6 = 3.3 \text{ k}\Omega$
- $R_7 = 1 \text{ k}\Omega$
- $R_8 = 3.3 \text{ k}\Omega$

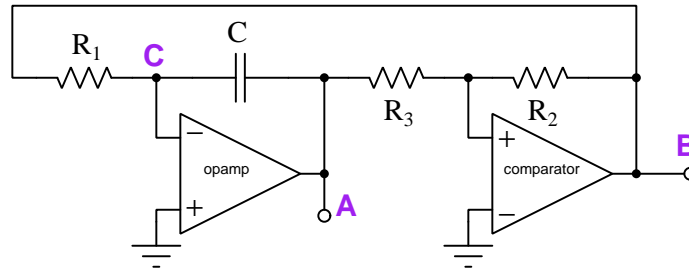
$$V_{out} = \underline{\hspace{2cm}}$$

$$I_{R7} = \underline{\hspace{2cm}}$$

---

**Question 66**

Identify the type of voltage signal expected at the following test points of this operational amplifier circuit, all measured with respect to ground. Your choices are *zero potential*, *steady DC potential*, *sinusoidal signal*, *triangle-wave signal*, *sawtooth-wave signal*, or *pulse or square-wave signal*:

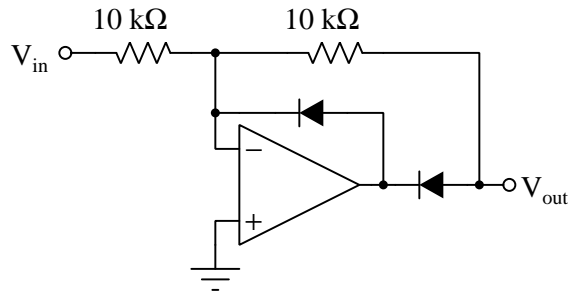


- Test point **A** =
- Test point **B** =
- Test point **C** =

---

**Question 67**

Determine the voltage at this circuit's output terminal (with respect to ground) assuming the ground-referenced voltage applied to its input terminal is  $-3$  Volts, and that the operational amplifier's power supply rail voltages are  $+12$  Volts and  $-12$  Volts, respectively:

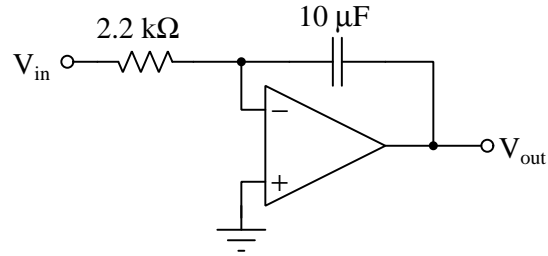


$V_{out} = \underline{\hspace{2cm}}$  Volts

---

**Question 68**

Determine the applied voltage necessary at the input terminal (with respect to ground) to cause the operational amplifier's output voltage to fall at a rate of  $-25$  Volts per second, assuming the operational amplifier's power supply rail voltages are  $+14$  Volts and  $-14$  Volts, respectively:

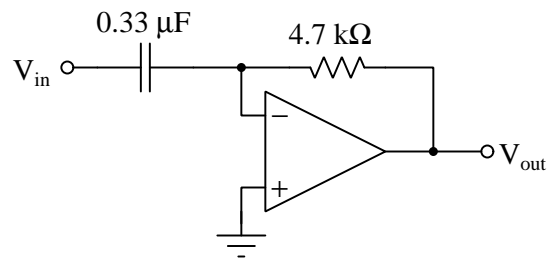


$$V_{in} = \text{_____ Volts}$$

---

**Question 69**

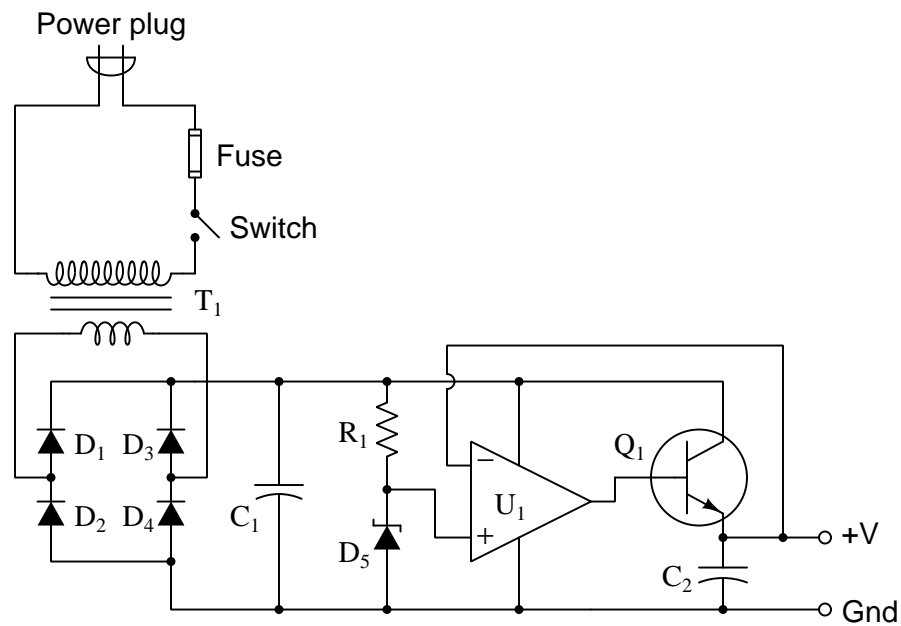
Determine the applied rate-of-change of voltage necessary at the input terminal (with respect to ground) to cause the operational amplifier's output voltage to be  $+30$  milliVolts, assuming the operational amplifier's power supply rail voltages are  $+15$  Volts and  $-15$  Volts, respectively:



$$V_{in} = \text{_____ Volts/second}$$

### Question 70

The following voltage regulator circuit has a problem. There is no DC voltage at all between the +V and Ground output terminals. A voltage measurement across  $C_1$  shows it to be dropping 16.9 Volts:



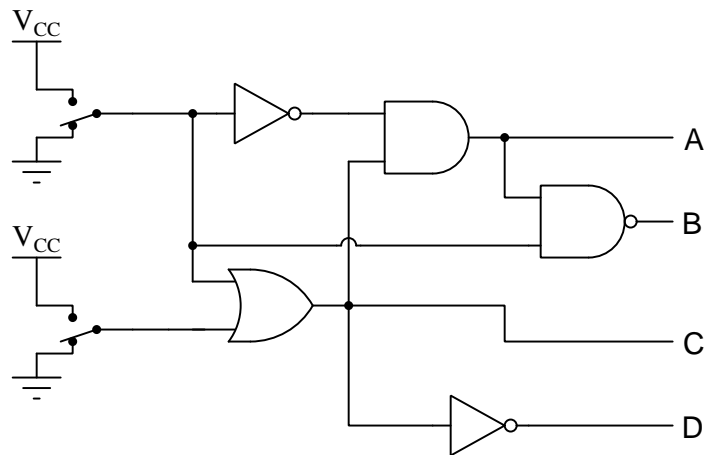
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Blown fuse		
$C_2$ failed open		
$R_1$ failed open		
$R_1$ failed shorted		
$U_1$ failed with low output		

---

**Question 71**

Determine the logic states of the four lettered outputs in this combinational gate circuit, given the input switch states shown in the diagram:

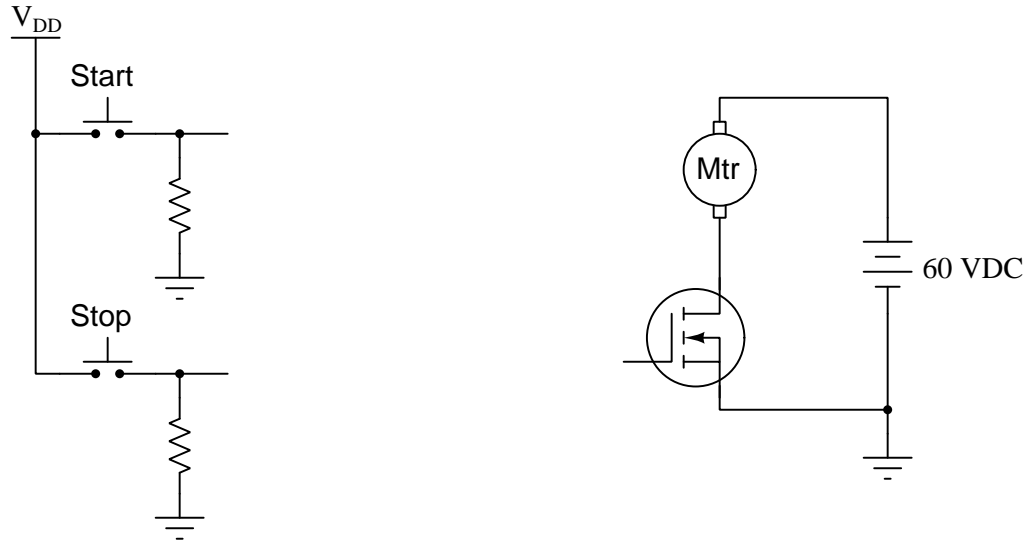


Place one check-mark in each row of the table, identifying the state of each output line:

Output	High	Low
<i>A</i>		
<i>B</i>		
<i>C</i>		
<i>D</i>		

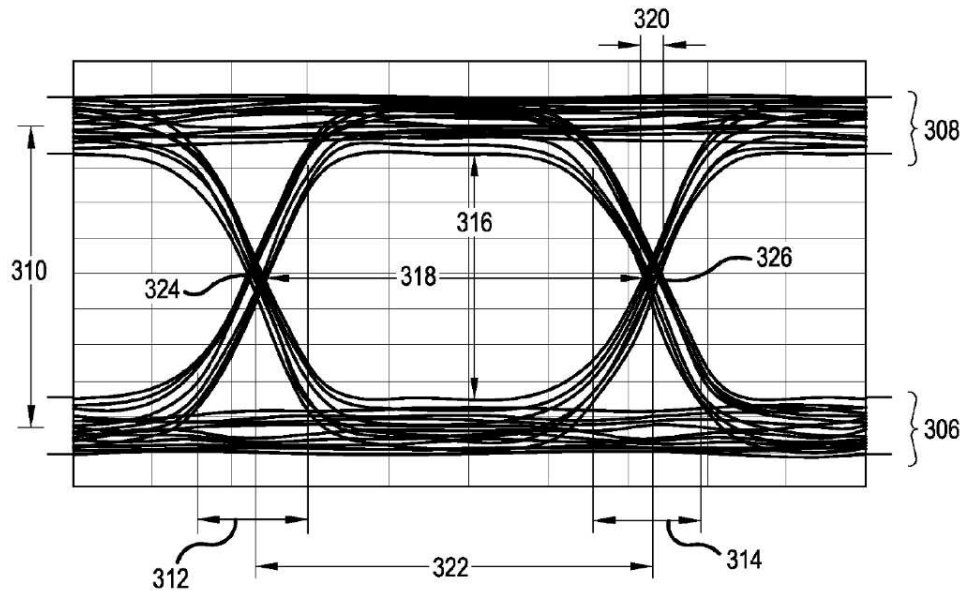
### Question 72

Sketch a latch or flip-flop as appropriate into this diagram to complete the motor start/stop control circuit. Feel free to add other components (e.g. logic gates, transistors, resistors, diodes, etc.) if you deem them necessary, and be sure to include proper power-supply pin connections to all logic ICs:



### Question 73

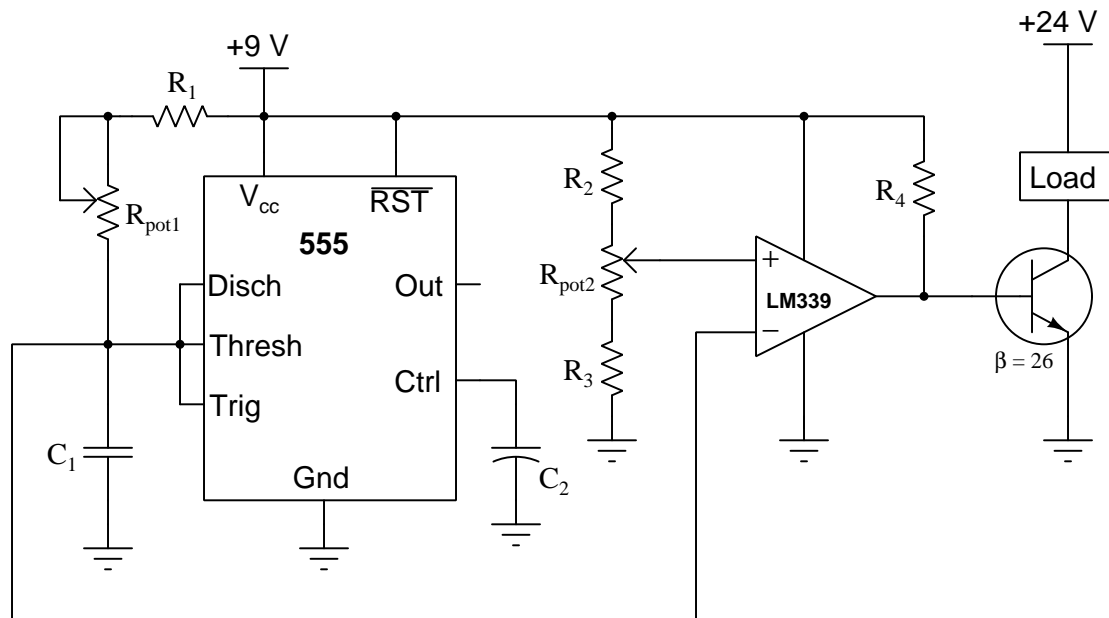
Identify examples of *jitter* in this eye diagram:



Feel free to draw arrows or circles or other identifying marks on the diagram highlighting the imperfections, or simply reference by number.

### Question 74

Select an appropriate value for resistor  $R_4$  to drive  $Q_1$  into saturation, given the fact that the LM339 comparator is open-collector and therefore can only sink current, and assuming the load should draw 1.1 Amperes of current when the transistor turns on:

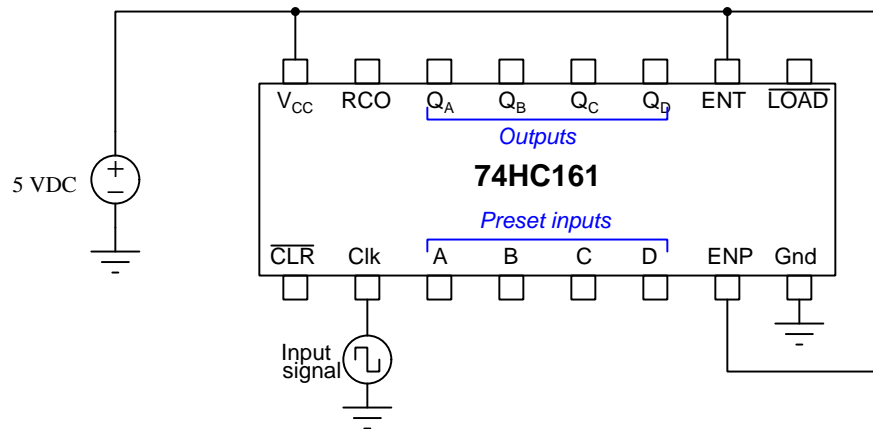


$R_4 =$  \_\_\_\_\_



### Question 75

Sketch wire connections to the pins of this 74HC161 counter IC to make it divide an input frequency by *five*, adding any other components as necessary to fulfill this function:

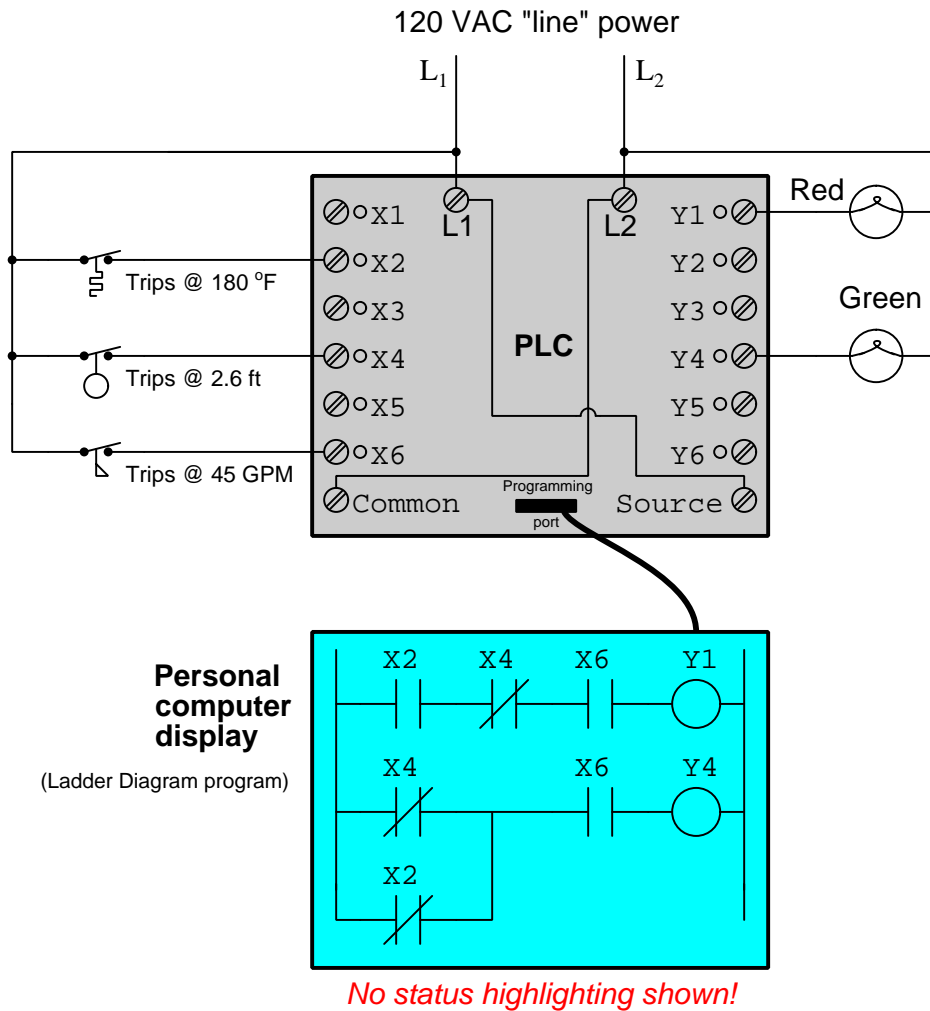


This counter IC's active-low clear function is asynchronous, and its active-low load (preset) function is synchronous. The RCO terminal is a "ripple carry output" which goes to a high state when the counter reaches its maximum count value of fifteen (0b1111).

*Note: there is more than one correct solution!*

### Question 76

Determine the status of the two lamps connected to this PLC, the bit states (either 1 or 0) for each of the connected inputs, and the color-highlighting of each element of the ladder-logic program inside the running PLC.



Assume the following process conditions sensed by the switches:

- Temperature = 109 °F
- Liquid level = 4.0 ft
- Liquid flow = 31 GPM

Bit X2 will be: (1 or 0)

Bit X4 will be: (1 or 0)

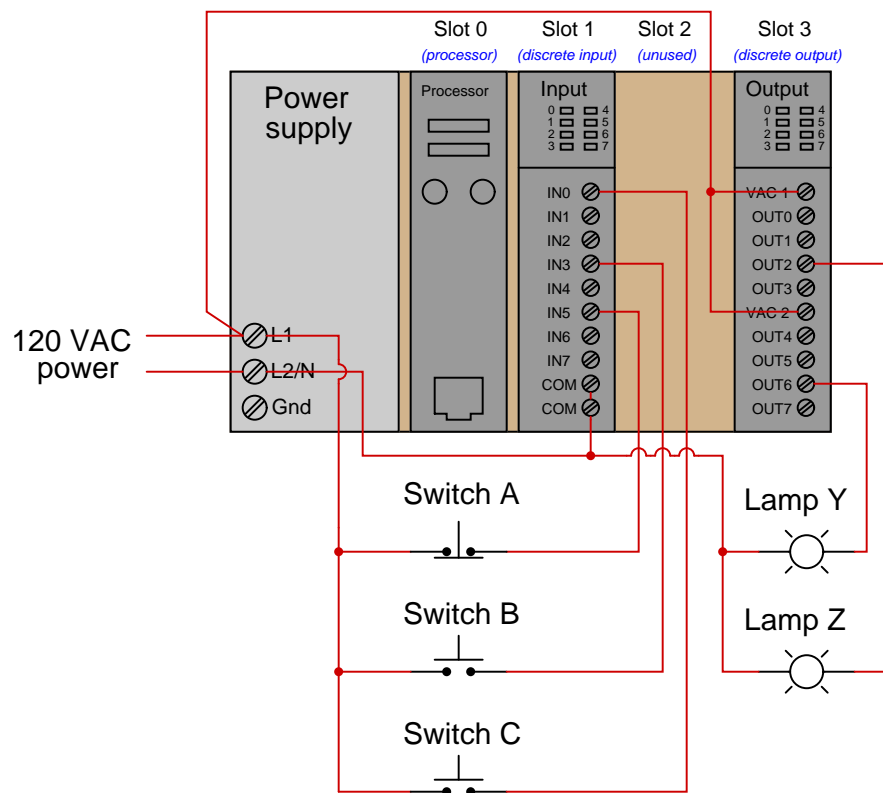
Bit X6 will be: (1 or 0)

The red lamp will be: (on or off)

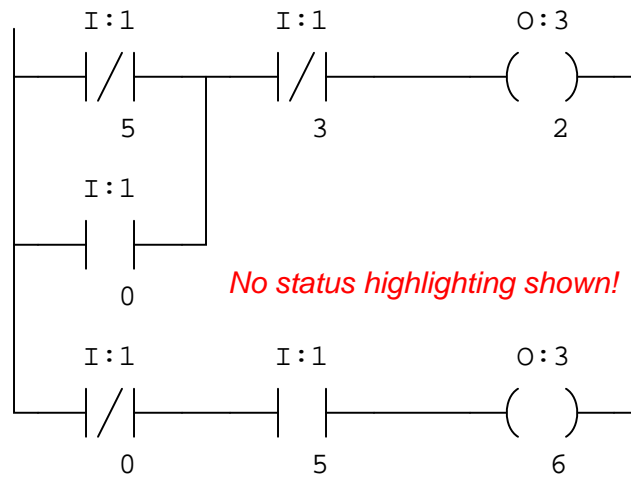
The green lamp will be: (on or off)

## Question 77

Suppose we have an Allen-Bradley model “SLC 500” PLC connected to three pushbutton switches and two lamps as shown in this illustration:

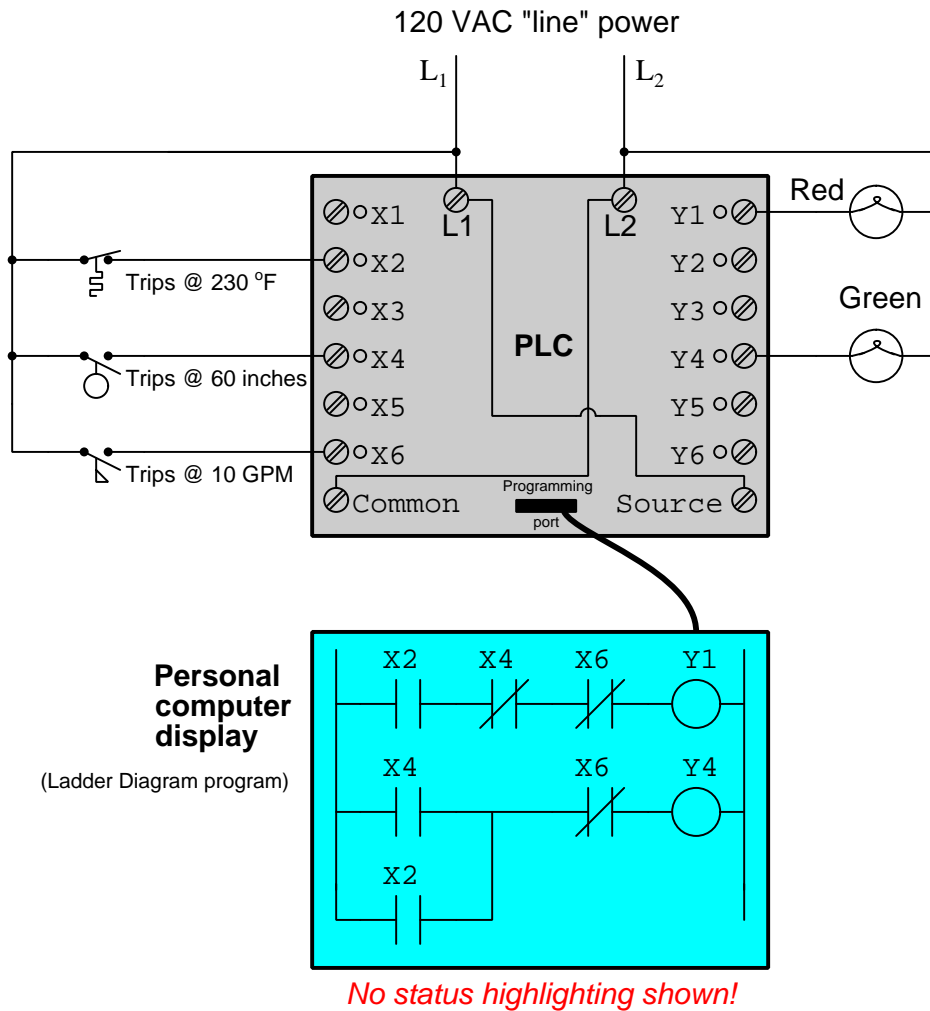


Examine the following relay ladder logic (RLL) program for this Allen-Bradley PLC, determining the statuses of the two lamps provided switches A and C are pressed, and switch B is unpressed:



### Question 78

Determine the status of the two lamps connected to this PLC, the bit states (either 1 or 0) for each of the connected inputs, and the color-highlighting of each element of the ladder-logic program inside the running PLC.



Assume the following process conditions sensed by the switches:

- Temperature = 105 °F
- Liquid level = 48 inches
- Liquid flow = 2 GPM

Bit X2 will be: (1 or 0)

Bit X4 will be: (1 or 0)

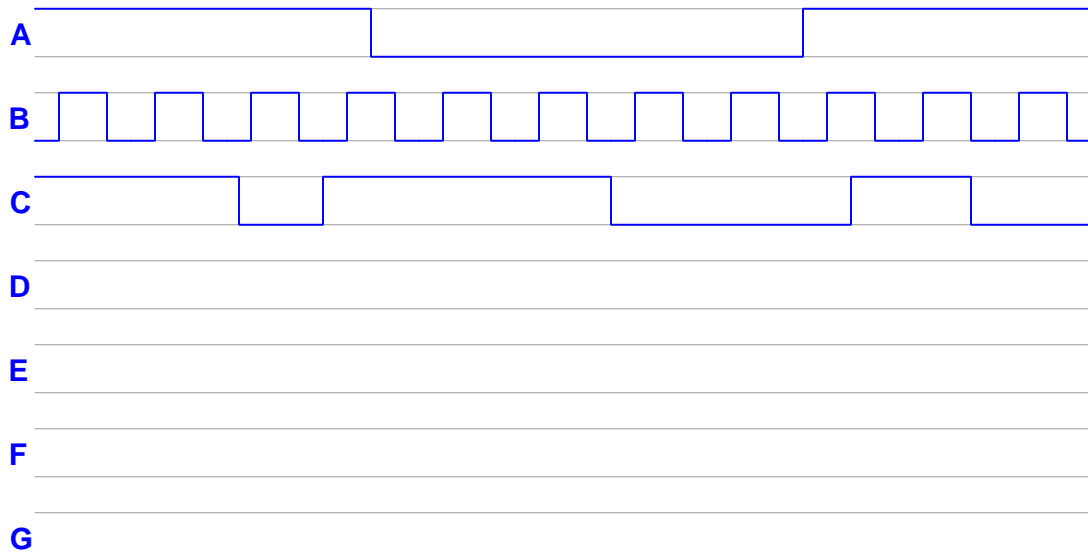
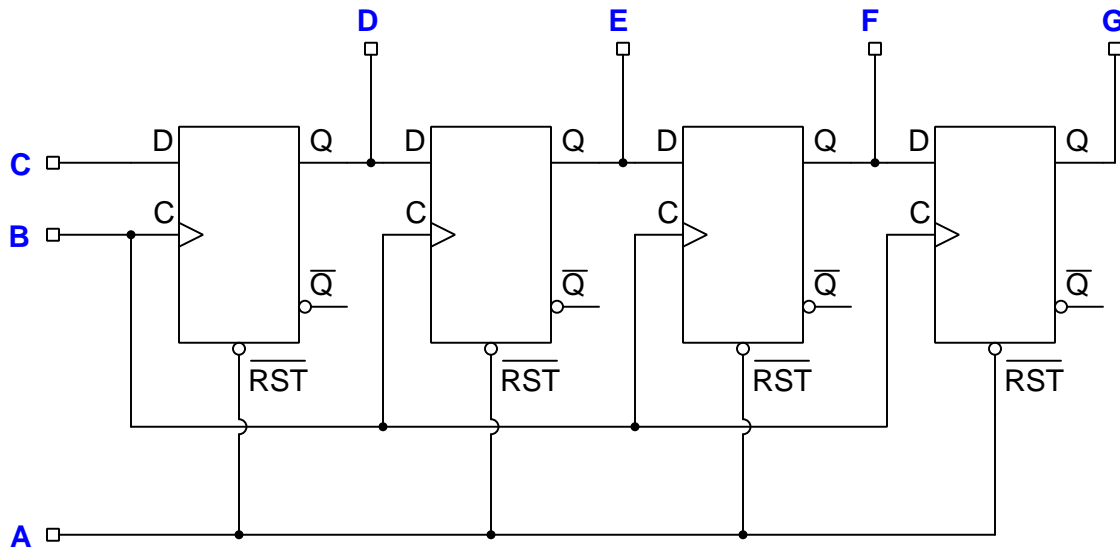
Bit X6 will be: (1 or 0)

The red lamp will be: (on or off)

The green lamp will be: (on or off)

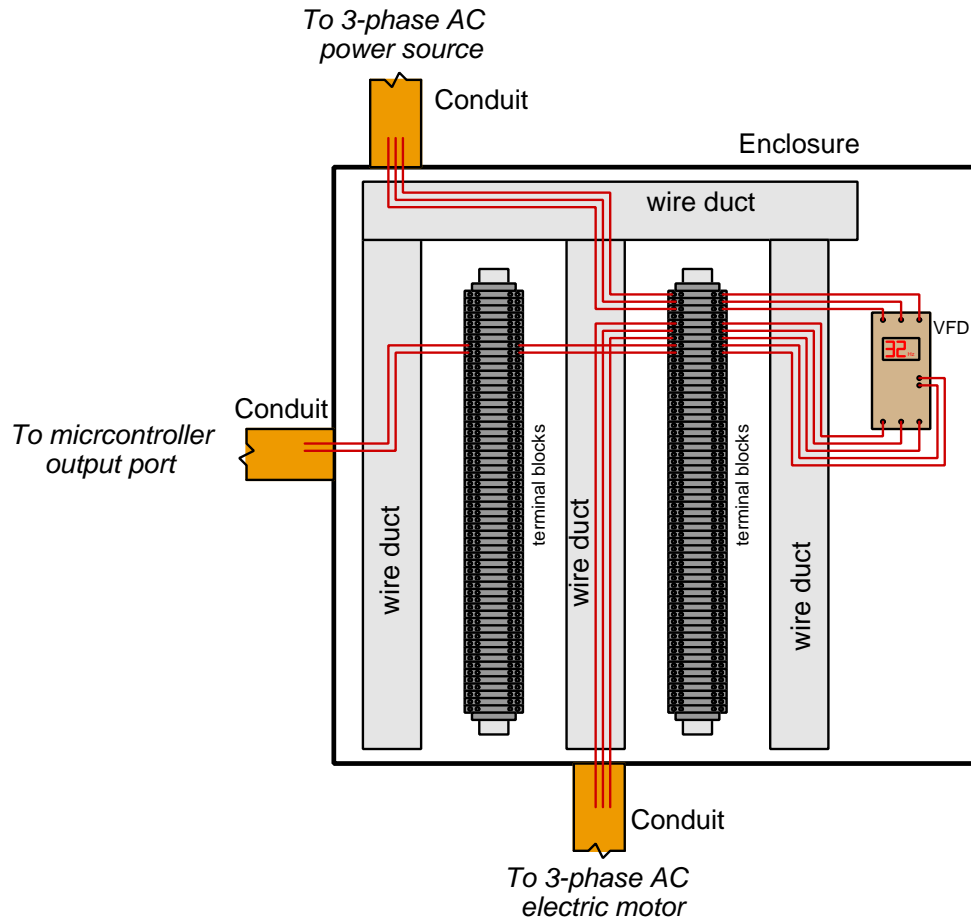
### Question 79

Complete the timing diagram below, assuming all outputs begin in their “low” states and that the shift register’s reset function is asynchronous:



### Question 80

The following illustration shows wiring inside of a metal electrical enclosure, connecting a VFD (Variable-Frequency Drive) to a three-phase AC power source and three-phase AC motor for motor speed control, the VFD receiving a DC voltage speed-command signal from the output of a microcontroller:



Unfortunately, the VFD's control of motor speed is unstable. When the microcontroller outputs a constant speed signal, the motor speed ends up varying up and down in a seemingly random pattern. An electrician has swapped out the VFD for a new unit (multiple times) but the problem persists. You are called to investigate, and using an oscilloscope connected to the VFD's command signal input terminals you determine the strong presence of AC noise on what should be a constant DC signal.

Describe a practical way to mitigate this noise so that the motor will run at the speed commanded by the microcontroller.

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**Answer 1**

$$R = 1437.5 \, \Omega$$
$$P = 92.0 \, \text{mW}$$

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**Answer 2****Violet - Green - Red - Silver**

- Nominal (ideal) value = **7,500** Ohms
- Lowest tolerable value = **6,750** Ohms
- Highest tolerable value = **8,250** Ohms

**Grey - Red - Yellow - Gold**

- Nominal (ideal) value = **820,000** Ohms
- Lowest tolerable value = **779,000** Ohms
- Highest tolerable value = **861,000** Ohms

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**Answer 3**

*Note: allow for  $\pm 10\%$  tolerance on all answers ( $\pm 10^\circ$  on phase) to account for uncertainties of the display.*

- Channel 2  $V_{pk} = \mathbf{\underline{280 \, \text{mV}}}$
- Channel 1  $V_{pk-pk} = \mathbf{\underline{1.1 \, \text{V}}}$
- Period = **2.195 ms**
- Phase shift = **55.8^\circ**
- Channel 1 **leads** Channel 2

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**Answer 4**

$$V = 9.6458 \, \text{V} \angle -90^\circ \quad 0 - j9.6458 \, \text{V}$$

$$I = 33.953 \, \text{mA} \angle -90^\circ \quad 0 - j33.953 \, \text{mA}$$

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**Answer 5**

Guy wire length = **47.856**

Height of attachment point = **32.638 meters**

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**Answer 6**

(Answer rounded to the nearest minor division)

Meter indication = **14 Ohms**

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**Answer 7**

$$I_{\text{primary}} = \mathbf{\underline{133.55 \, \text{AAC}}}$$

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**Answer 8**

$$81 \, \text{pounds/minute} = 21.6 \, \text{ounces/second}$$



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**Answer 9**

$$x = 10^c + 4b$$

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**Answer 10**

$\lambda = \underline{0.9}$  microns (any answer between 0.85 microns and 0.95 microns is acceptable)

**Credit for graph:**

US Patent 3,293,513 (“Semiconductor Radiant Diode”) by James R. Biard and Gary E. Pittman.

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**Answer 11**

- $I_{R1} = 11.46 \text{ mA}$
- $P_{total} = 0.7221 \text{ W}$
- $I_{R3} = 20.63 \text{ mA}$
- $V_{TP2-TP5} = 20.63 \text{ V}$

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**Answer 12**

$$P_{R1} = 38.36 \text{ mW}$$

$$V_{BC} = 19.77 \text{ V} - B \text{ negative } (-) \text{ and } C \text{ positive } (+)$$

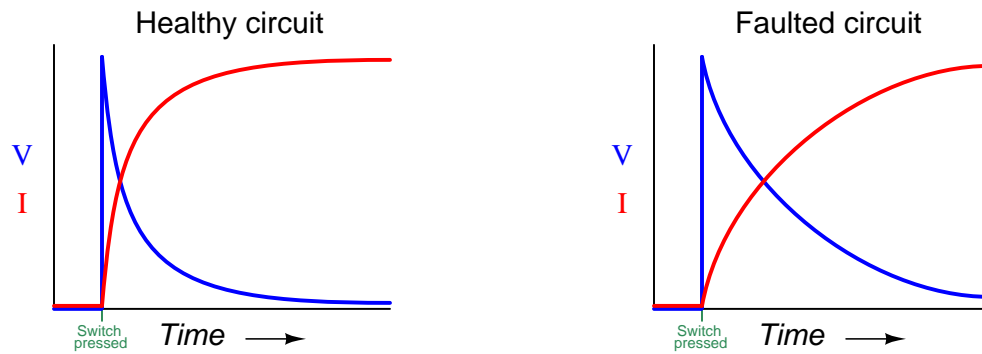
$$V_{EF} \text{ polarity} - \mathbf{E} \text{ positive } (+) \text{ and } \mathbf{F} \text{ negative } (-)$$

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**Answer 13**

- $R_1 = 1880.36 \Omega$
- $V_{CB} = -5.8554 \text{ V}$
- $V_{BA} = 5.8554 \text{ V}$
- $I_{R3} = 3.114 \text{ mA}$
- $I_{source} = 5.283 \text{ mA}$

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**Answer 14**

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**Answer 15**

- $V_C$  10 seconds following switch closure = **3.921 V**
- $V_{TP4-TP3}$  18 seconds following switch closure = **0 V**
- $I_R$  20 seconds following switch closure = **0.24795 mA**

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**Answer 16**

- $I_R$  50 milliseconds following switch closure = **87.35 mA**
- $V_L$  25 milliseconds following switch closure = **8.232 V**
- $V_{TP4-TP3}$  100 milliseconds following switch closure = **0 V**

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**Answer 17**

$$V_{generator} = \mathbf{13.367 \text{ Volts}}$$

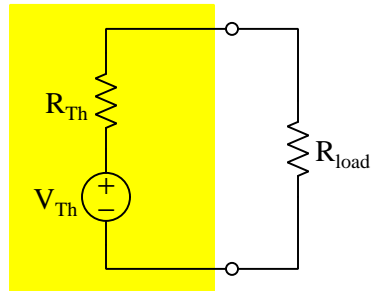
$$V_{loads} = \mathbf{12.936 \text{ Volts}}$$

Current from **right to left** through both wires ; current **up** through the battery.

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**Answer 18**

*Thevenin equivalent network*



- $V_{Th} = 3$  Volts
- $R_{Th} = 2.5$  k $\Omega$
- $V_{load} = 1.125$  V

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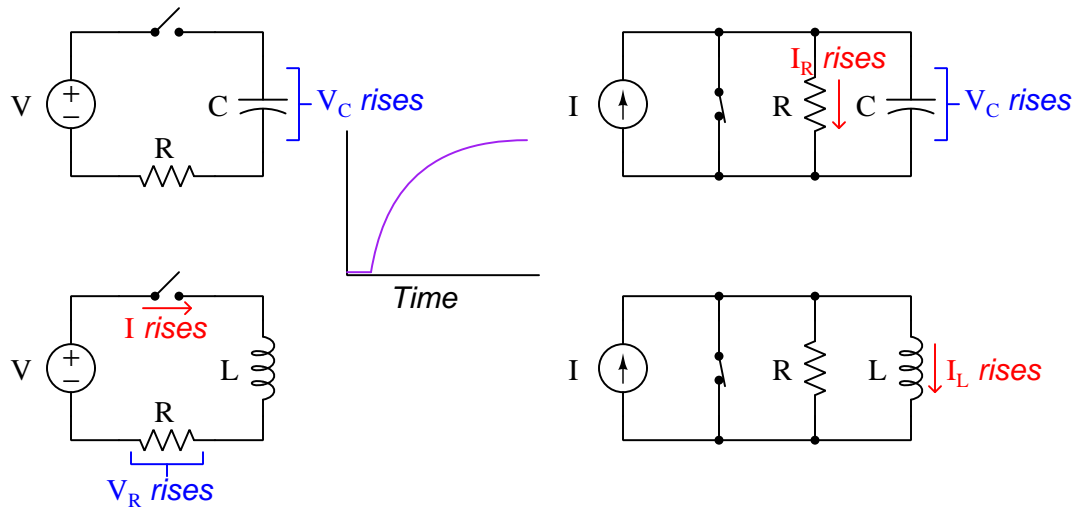
**Answer 19**

11 k $\Omega$  connected in series with the 2.2 k $\Omega$  resistor.

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**Answer 20**

*Variables that **rise** in inverse-exponential fashion when switch is toggled to the opposite state*



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**Answer 21**

$$V_{load(pk)} = \underline{169.13 \text{ V}}$$

$$I_{load(pk)} = \underline{8.4566 \text{ A}}$$

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**Answer 22**

$$Z_C = \underline{47.3675 \text{ } \Omega \text{ } \angle -90^\circ}$$

$$I_R = \underline{88.6076 \text{ mA } \angle 0^\circ}$$

$$Z_{total} = \underline{76.2539 \text{ } \Omega \text{ } \angle -15.1513^\circ}$$

$$I_{source} = \underline{91.7986 \text{ mA @ } 15.1513^\circ}$$

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**Answer 23**

$$C_2 = \underline{2.6186 \text{ } \mu\text{F}}$$

$$Z_{total} \text{ @ resonance} = \underline{\text{high}}$$

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**Answer 24**

$$V_{source} = 94.5 \text{ V}$$

$$I_{source} = 42.0 \text{ mA}$$

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**Answer 25**

- Current through source **decreases**
  - Current through  $C$  **decreases**
  - Current through  $R$  **remains the same**
- 

**Answer 26**

$$V_{line} = \underline{398.37 \text{ Volts}}$$

$$I_{line} = \underline{13.800 \text{ Amperes}}$$

$$I_{phase} \text{ (source)} = \underline{13.800 \text{ Amperes}}$$

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**Answer 27**

$$V_{line} = \underline{240 \text{ Volts}}$$

$$I_{line} = \underline{2.08 \text{ Amperes}}$$

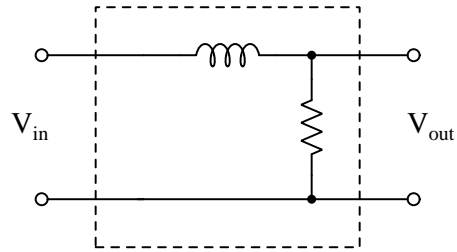
$$I_{phase} \text{ (source)} = \underline{1.2 \text{ Amperes}}$$

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**Answer 28**

$$P = 2.559 \text{ horsepower}$$

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**Answer 29**

$$L = 1 \text{ H} ; R = 6.283 \text{ k}\Omega$$

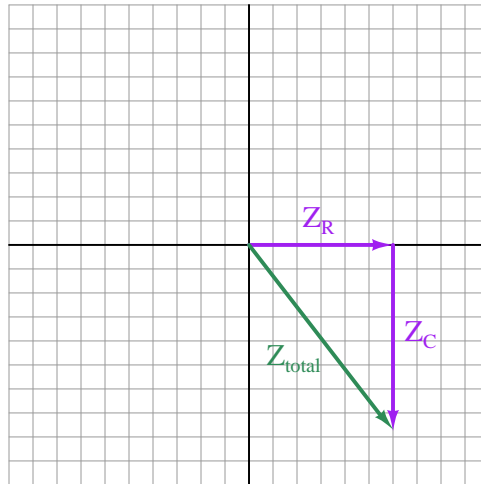
$$L = 1.5 \text{ H} ; R = 9.425 \text{ k}\Omega$$

$$L = 2 \text{ H} ; R = 12.566 \text{ k}\Omega$$

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**Answer 30**

Note: the order of the phasors is arbitrary, but the resultant (shown as a green vector) is not.



$$Z_R = 30.0000 \, \Omega \angle 0^\circ$$

$$Z_C = 39.0086 \, \Omega \angle -90^\circ$$

$$Z_{total} = 49.2104 \, \Omega \angle -52.4375^\circ$$

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**Answer 31**

- Sketch proper connections for the red and black test leads
  - Break circuit somewhere
  - Red ( $V\Omega D$ ) to one resistor terminal, Black ( $COM$ ) to the other resistor terminal
- Show proper setting of the meter's rotary selector
  - Set to  $\Omega$  position

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**Answer 32**

The “Position” control for Channel A needs to be moved to shift the waveform down on the display.

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**Answer 33**

Within the “TRIGGER” controls section there is a button marked “SINGLE” that is used to configure triggering for single-trace mode. After setting this mode as well as the trigger level (the “LEVEL” knob) and perhaps some of the menu options, the oscilloscope will be ready to capture a transient waveform.

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**Answer 34**

This is a benchtop digital multimeter (DMM), used for measuring voltage, current, resistance, etc.

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**Answer 35**

Connect the red test probe to test point **A** and the black probe to point **C**.

Voltage measurement = 9.34534 Volts

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**Answer 36**

One probe tip connected to the positive terminal of  $V_{src}$  and the other probe tip to the positive terminal of the load, with either channel’s ground clip connected to the negative terminal of  $V_{src}$ .

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**Answer 37**

$t_{on} = 3 \text{ div}$        $t_{off} = 1.8 \text{ div}$       Duty cycle = 62.5%       $P_{pk} = 206.4 \text{ W}$

$I_{pk} = \underline{3.0630 \text{ Amperes}}$

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**Answer 38**

This curve matches the characteristics of an *open component*, as there is voltage (horizontal) but no current (vertical).

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**Answer 39**

Logic state at test point 1 = high

Logic state at test point 3 = high

Logic state at output = low

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**Answer 40**

Measure DC current at  $Q_2$ ’s collector terminal, with the switch moving to the *forward* position to trigger current through  $Q_1$  and to the motor.

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**Answer 41**

Fault	Possible	Impossible
Open wire between A and C	✓	
Open wire between B and D		✓
Open wire between D and F		✓
Lamp failed open	✓	
Switch failed open	✓	
Lamp failed shorted	✓	
Switch failed shorted		✓

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**Answer 42**

Fault	Possible	Impossible
Resistor $R_1$ failed open		✓
Resistor $R_2$ failed open	✓	✓
Inductor $L_1$ failed open		✓
Inductor $L_2$ failed open		✓
Inductor $L_1$ failed shorted	✓	
Inductor $L_2$ failed shorted	✓	

$R_2$  failed open is possible if you simply consider the time-decay and not the amplitude of the initial transient (when the switch is released). Since the question did not specifically mention anything about the magnitude of this voltage surge, either answer will be accepted.

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**Answer 43**

Fault	Possible	Impossible
Open wire between E and D		✓
R1 failed open		✓
R2 failed open	✓	
R3 failed open		✓
R1 failed shorted		✓
R2 failed shorted		✓
R3 failed shorted		✓
Voltage source dead		✓

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**Answer 44**

Filter type	Healthy circuit	Faulted circuit
Low-pass		
High-pass		
Band-pass	✓	
Band-stop		
Passes all frequencies		
Blocks all frequencies		✓

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**Answer 45**

Fault	Possible	Impossible
$U_1$ output failed low		✓
$U_1$ output failed high		✓
$U_2$ output failed low	✓	
$U_2$ output failed high		✓
$U_3$ output failed low		✓
$U_3$ output failed high		✓

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**Answer 46**

Fault	Possible	Impossible
Switch $A$ failed open		✓
Switch $A$ failed shorted		✓
Switch $B$ failed open		✓
Switch $B$ failed shorted		✓
Switch $C$ failed open	✓	
Switch $C$ failed shorted		✓
CR1 contact failed open	✓	
CR1 contact failed shorted		✓

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**Answer 47**

Fault	Possible	Impossible
Pushbutton switch failed open		✓
Pushbutton switch failed shorted		✓
Motor failed open	✓	
Resistor failed open	✓	
15 amp fuse blown	✓	
0.5 amp fuse blown		✓

---

**Answer 48**

The striped end is the cathode, and the non-striped end is the anode. This diode is healthy.

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**Answer 49**

- Fuse will blow (**no**)
- Load voltage (**decrease**)
- Supply current (**decrease**)



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**Answer 50**

Component #60 is one of the diodes in the three-phase bridge rectifier used to convert AC into DC for the alternator's output.

**Credit for schematic:**

US Patent 4,959,577 ("Alternating Current Generator") by Thomas A. Radomski.

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**Answer 51**

**With switch closed**

$$V_{load} = \underline{21.7 \text{ V}}$$

$$I_{switch} = \underline{45.319 \text{ mA}}$$

**With switch open**

$$V_{load} = \underline{0 \text{ V}}$$

$$I_{switch} = \underline{0 \text{ mA}}$$

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**Answer 52**

$$I_{load} = \underline{76.923 \text{ Amperes (maximum)}}$$

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**Answer 53**

$$A_V = 3.636 \text{ (unitless ratio)}$$

$$A_V = 11.21 \text{ dB}$$

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**Answer 54**

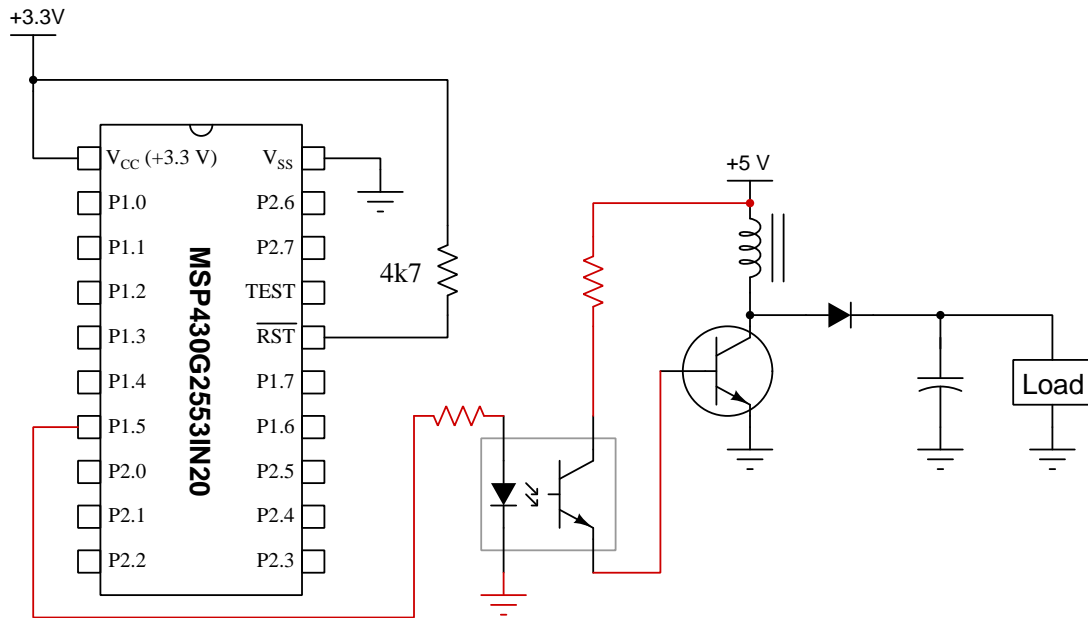
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$L_1 = \underline{101.32 \text{ }\mu\text{H}}$$

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**Answer 55**

This is one possible solution:



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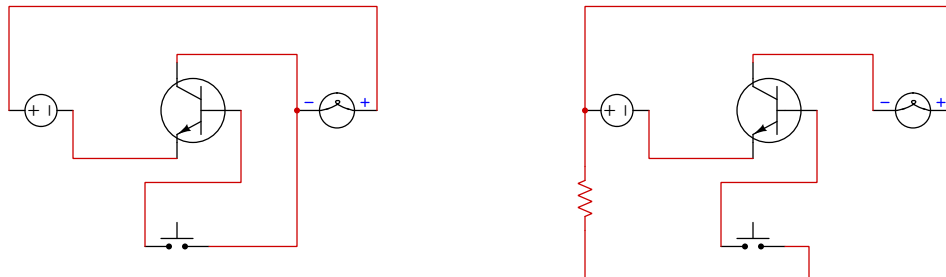
**Answer 56**

Fault	Possible	Impossible
$R_1$ failed shorted		✓
$R_7$ failed open		✓
$R_8$ failed shorted		✓
$C_2$ failed open	✓	
$C_3$ failed shorted		✓
$C_4$ failed open		✓

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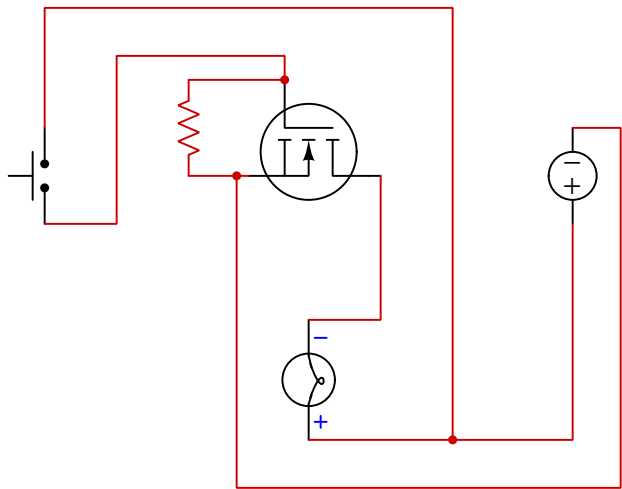
**Answer 57**

Two possible solutions, one requiring a resistor and one not requiring a resistor, are shown below. Note that solutions other than these may be possible!



**Answer 58**

One possible solution is shown below. Note that a resistor connected between gate and substrate (source) is necessary to bleed off any stored gate-capacitance charge to reliably turn the MOSFET off, but no resistor is ever necessary in series with the gate because MOSFET gates draw no current:



**Answer 59**

$I_B = \frac{0.1}{50} = 2.0 \text{ milliAmperes}$        $V_R = 5 - 0.7 = 4.3 \text{ Volts}$        $R = \frac{V}{I} = \frac{4.3}{0.002} = 2150.0 \text{ Ohms}$

$R = \text{less than } 2150 \text{ Ohms}$

**Answer 60**

Fault	Possible	Impossible
Switch $S_1$ failed open		✓
Transistor $Q_1$ failed open collector-emitter	✓	
Transistor $Q_2$ failed open collector-emitter	✓	
Fuse $F_1$ blown		✓
Transistor $Q_1$ failed shorted collector-emitter		✓
Transistor $Q_2$ failed shorted collector-emitter		✓
Resistor $R_3$ failed open	✓	

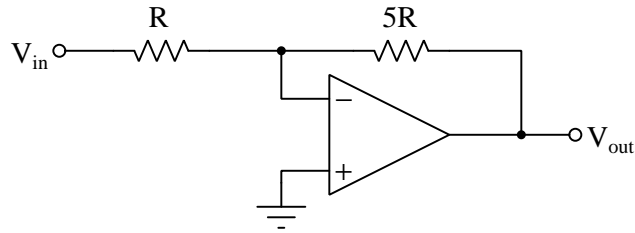
**Answer 61**

$V_{ref} = \text{greater than or equal to } 0 \text{ Volts and less than } 8 \text{ Volts}$

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**Answer 62**

Note: the following schematic shows resistor *ratios* rather than actual values:



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**Answer 63**

$$V_{TP2} = -4 \text{ V}$$

$$V_{TP3} = +3 \text{ V}$$

$$I_{R4} = 1.4 \text{ mA}$$

$$V_{out} = +10 \text{ V}$$

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**Answer 64**

$$I_{R2} = 0.6170 \text{ mA (arrow pointing downwards)}$$

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**Answer 65**

$$V_A = 555.55 \text{ mV} ; V_B = 500 \text{ mV} ; V_D = 0.426357 \text{ V} ; I_C = 73.6434 \text{ } \mu\text{A (moving right)}$$

$$V_{out} = \underline{\mathbf{0.183333 \text{ Volts}}}$$

$$I_{R7} = \underline{\mathbf{0.129199 \text{ milliAmperes}}}$$

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**Answer 66**

- Test point **A** = Triangle wave
- Test point **B** = Square wave
- Test point **C** = Zero potential

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**Answer 67**

$$V_{out} = \underline{\mathbf{0}} \text{ Volts}$$

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**Answer 68**

$$V_{in} = \underline{\mathbf{\pm 0.55}} \text{ Volts}$$

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**Answer 69**

$$V_{in} = \underline{\mathbf{-19.34}} \text{ Volts/second}$$

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**Answer 70**

Fault	Possible	Impossible
Blown fuse		✓
$C_2$ failed open		✓
$R_1$ failed open	✓	
$R_1$ failed shorted		✓
$U_1$ failed with low output	✓	

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**Answer 71**

Output	High	Low
$A$		✓
$B$	✓	
$C$		✓
$D$	✓	

---

**Answer 72**

One possible solution is an SR latch with active-high inputs, S=Start and R=Stop, the Q output driving the MOSFET's gate directly (no resistor required), with the latch powered by  $V_{DD}$  and Ground.

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**Answer 73**

Jitter is quantifiable by the width marked (320), showing time-varying points of signal crossing between high and low states.

NOTE: image taken from Duff, Christopher P. *US Patent 9,442,136*, "Real-Time Oscilloscope for Generating a Fast Real-Time Eye Diagram", application 1 September 2013, patent granted 13 September 2016.

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**Answer 74**

$$\beta = \frac{I_C}{I_B} \quad I_B = 42.31 \text{ mA}$$

$$R_4 = \underline{196.18 \text{ } \Omega \text{ (maximum)}}$$

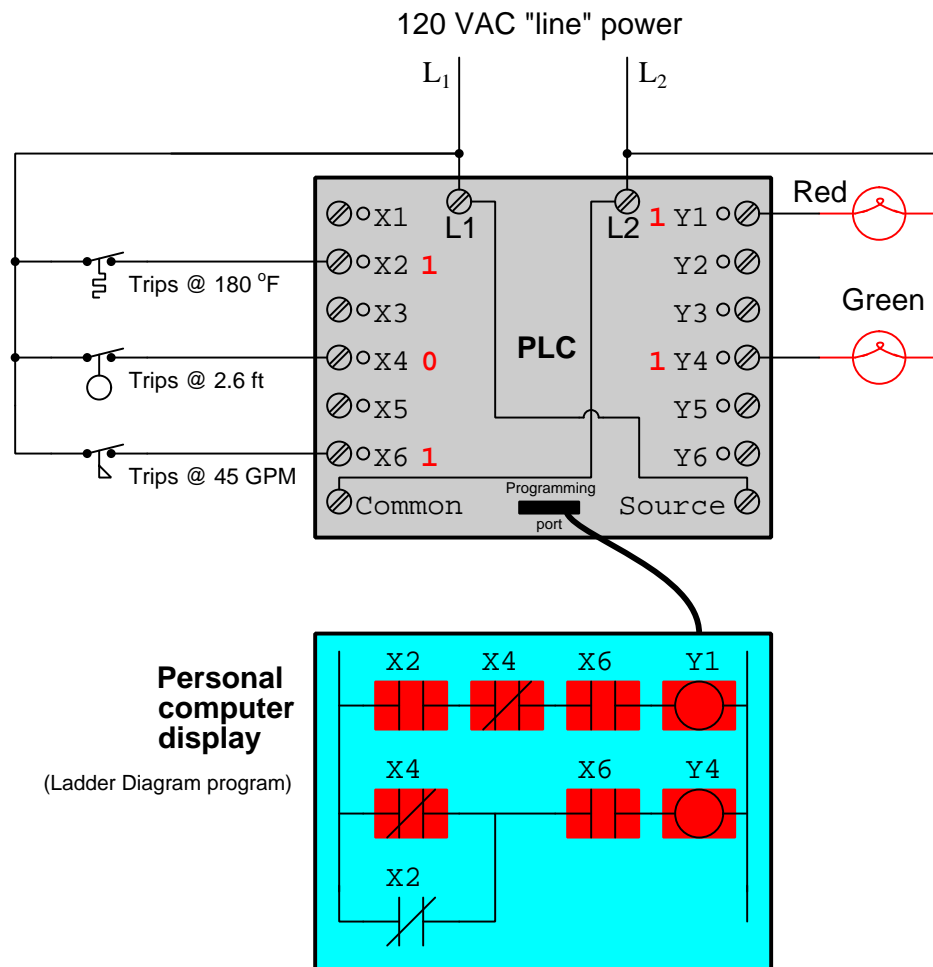
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**Answer 75**

One solution is to decode for a count value of five (0101) and send an active-low signal to the Clear input when this condition is met. This decoding may be done using a four-input NAND gate sampling the Q output lines, with  $Q_D$  and  $Q_B$  inverted; or it may be as simple as a two-input NAND gate sampling  $Q_C$  and  $Q_A$  and driving the Clear input. This circuit will force the counter to count in the following sequence: 0, 1, 2, 3, 4, 5 *immediately* clearing when the count of 5 is reached, resulting in five stable steps (0 through 4). The signal sent to the Clear input will have a frequency one-fifth that of the clock input signal.

Another solution is to wire an inverter gate between the RCO (ripple carry output) and the Load input, and then connect the D through A preset input terminals to 1011, respectively. This will force the counter to count in the following sequence: 11, 12, 13, 14, 15 which is five distinct steps. Both the RCO signal and the signal sent to the Load input will have a frequency one-fifth that of the clock input signal.

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**Answer 76**

Bit X2 will be: **1**

Bit X4 will be: **0**

Bit X6 will be: **1**

The red lamp will be: **on**

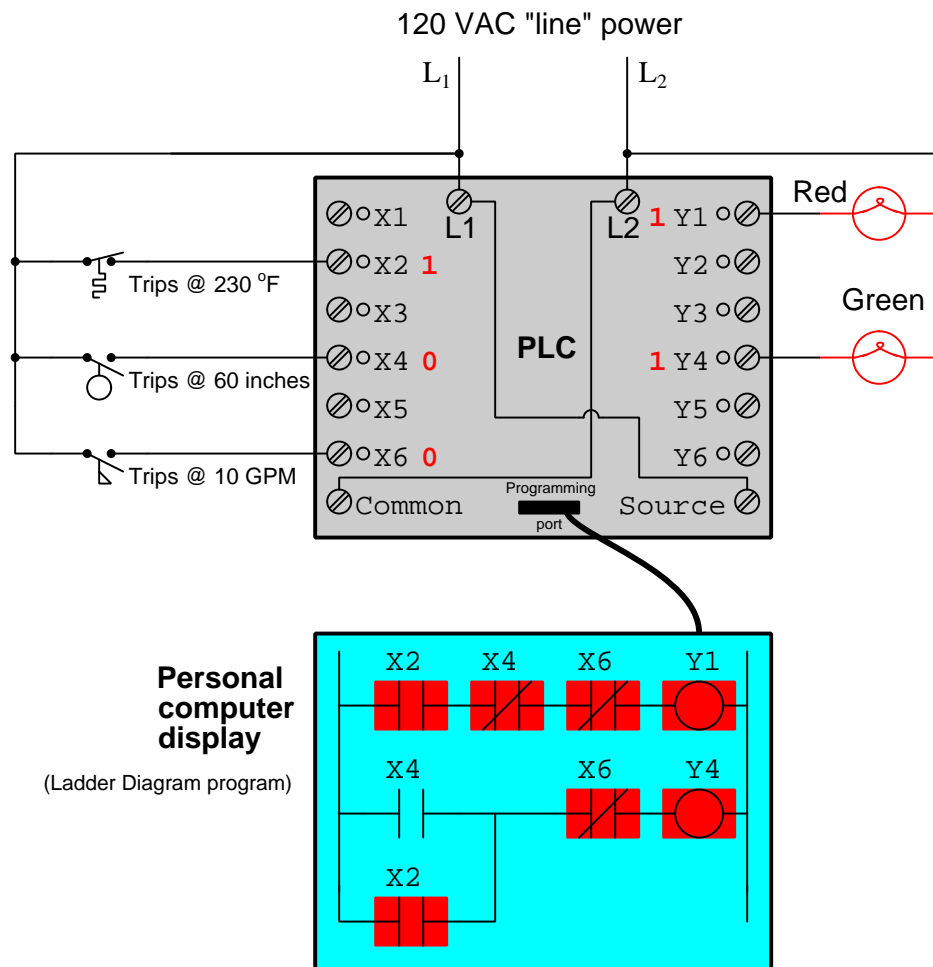
The green lamp will be: **on**

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**Answer 77**

Lamp Y is de-energized.

Lamp Z is energized.



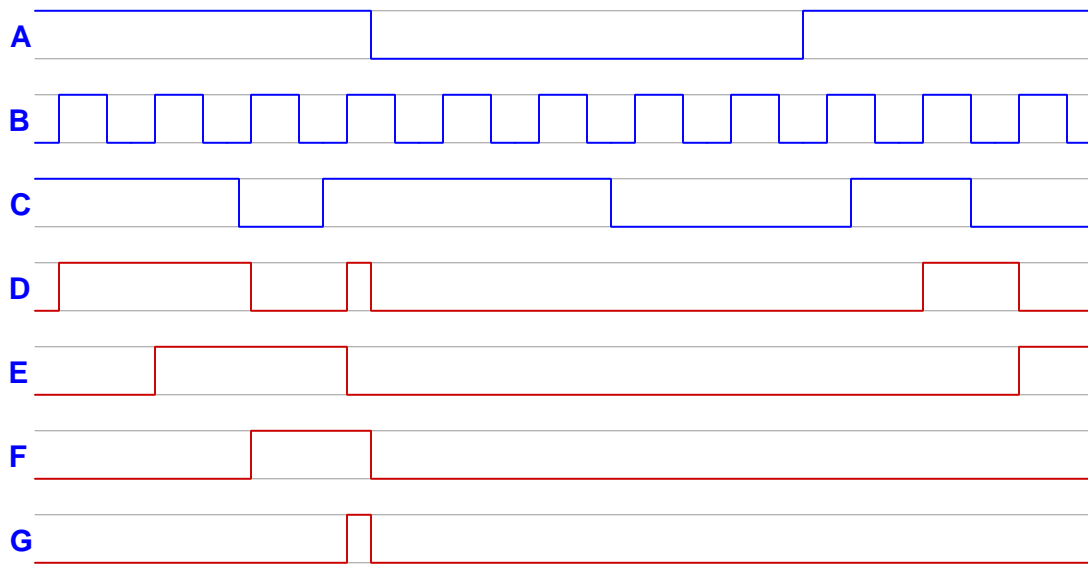
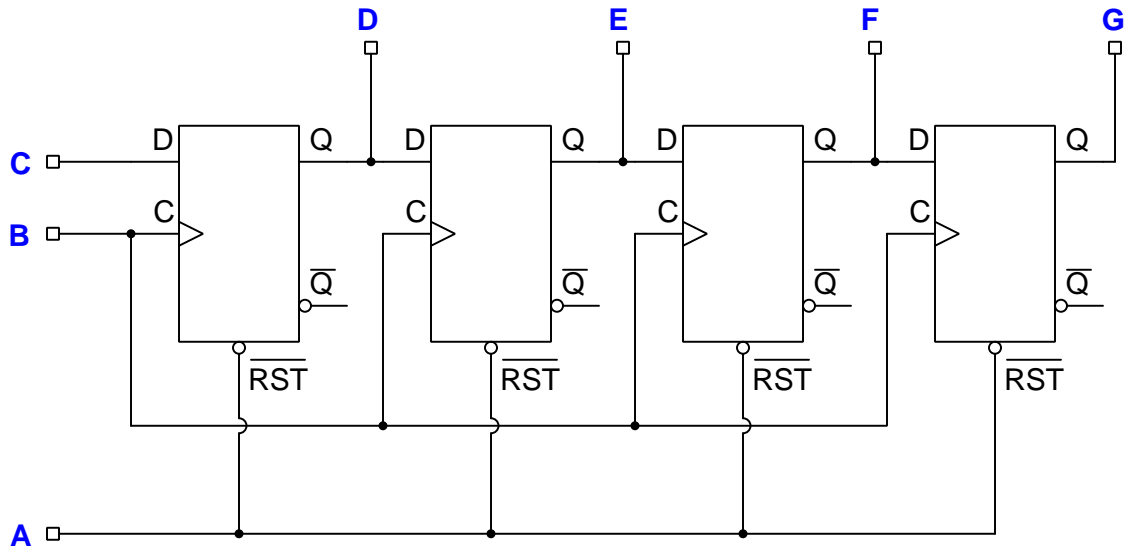
Bit X2 will be: **1**

Bit X4 will be: **0**

Bit X6 will be: **0**

The red lamp will be: **on**

The green lamp will be: **on**





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**Answer 80**

Multiple options exist, including:

- Run speed-command signal through a shielded, twisted-pair cable instead of through individual conductors
- Use a DC current signal rather than a DC voltage signal, connecting a resistor to the VFD's speed-command signal terminals to convert that current signal into a voltage signal
- Re-route the signal wiring so it only crosses power conductors at right-angles, and never runs parallel to power wiring
- Connect a low-pass filter network at the VFD's speed-command signal terminals to filter out any noise before entering the VFD