

**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) Oscillograph 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) Identifying 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) Identifying 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) Select DAC or ADC scaling components for given analog range and count value
- ☐ (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

**Digital Networking and Computing section** – questions 81 through 90

- ☐ (Q81) Interpret RS-232 encoded data
- ☐ (Q82) Sketch serial network wire connections
- ☐ (Q83) Identifying effects of faults in data network
- ☐ (Q84) Identifying possible faults in a wireless data network
- ☐ (Q85) Identifying possible faults in a wired data network
- ☐ (Q86) Sketch connections to expand addresses or data lines for RAM/ROM ICs
- ☐ (Q87) Predict outcome of a simple assembly-language program
- ☐ (Q88) Modify an assembly-language program to fulfill a specified function
- ☐ (Q89) Calculate electrical parameters in a microcontroller I/O circuit
- ☐ (Q90) Identifying possible faults in a microcontroller I/O circuit

## IETTI-236 Comprehensive exam

### RF section – questions 91 through 100

- ☐ (Q91) Calculate gains/losses in RF systems using decibels
- ☐ (Q92) Calculate transmission line length and pulse timing parameters
- ☐ (Q93) Determine how to impedance-match feedlines to RF components
- ☐ (Q94) Identifying component functions within RF amplifier circuits
- ☐ (Q95) Identifying signal frequencies within mixer circuits
- ☐ (Q96) Plot simple RC/RL/LC network impedance values on a Smith chart
- ☐ (Q97) Plot effects of component changes on a Smith chart
- ☐ (Q98) Calculate antenna dimensions/frequency
- ☐ (Q99) Identifying signal modulation type from oscillograph or spectrum display
- ☐ (Q100) Identifying effect of fault in radio transmitter or receiver circuit

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 100-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 current source and a resistor connected together with copper wire has the following properties:

- Temperature = 20 degrees Celsius
- Wire lengths = the red wire is twice as long as the black wire
- Source current = 5 milliAmperes
- Resistor color code = Brown, Grey, Red, Gold

Calculate the amount of voltage dropped by the resistor as well as the amount of power it will dissipate in this circuit assuming the resistor’s actual value *precisely* follows its color code (i.e. assume zero error rather than the customary  $\pm 5\%$ ):

$V =$

$P =$

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**Question 2**

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

**Brown - Blue - Orange - Silver**

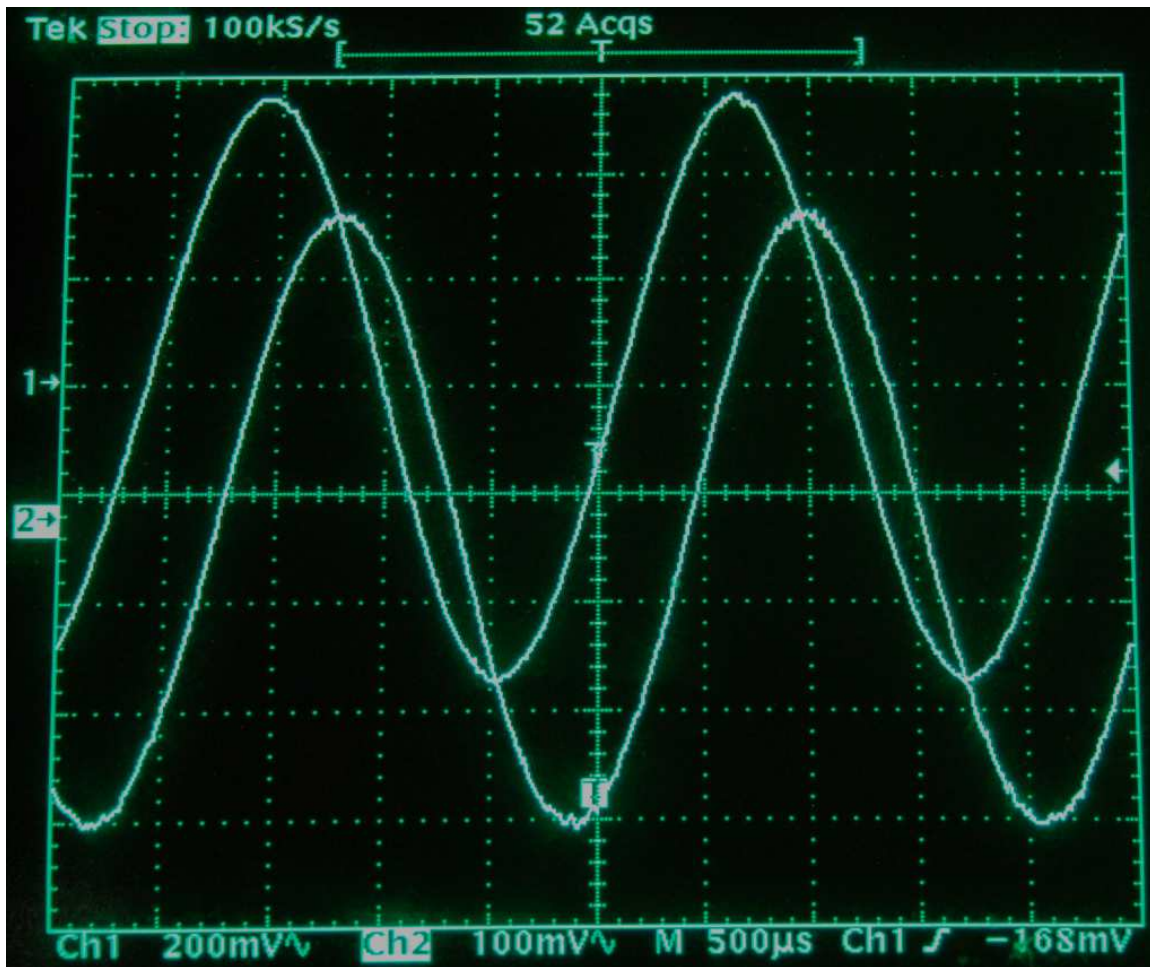
- Nominal (ideal) value = \_\_\_\_\_ Ohms
- Lowest tolerable value = \_\_\_\_\_ Ohms
- Highest tolerable value = \_\_\_\_\_ Ohms

**Yellow - Black - Red - 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 1  $V_{pk} =$  \_\_\_\_\_
- Channel 2  $V_{pk-pk} =$  \_\_\_\_\_
- Frequency = \_\_\_\_\_
- Phase shift = \_\_\_\_\_
- Channel 2 leads or lags? Channel 1

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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.  $\angle 0^\circ$ ):

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

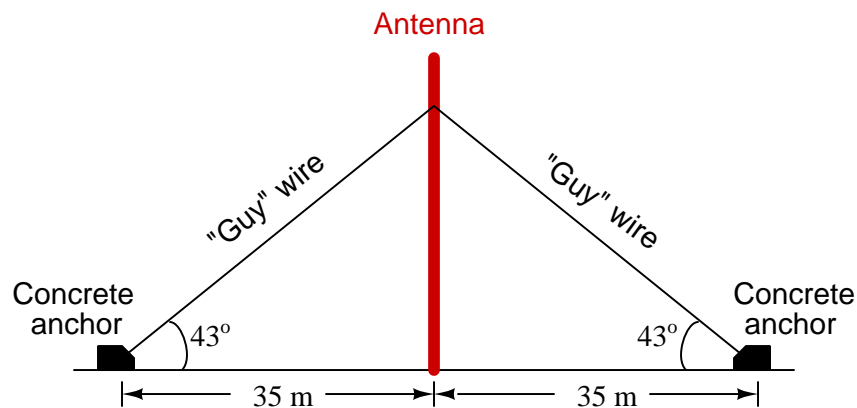
A 16 Volt RMS AC source with a frequency of 1 kHz connects to a 75 mH inductor. Calculate current in this circuit, expressing your answer in either rectangular or polar form, assuming the source is the phase reference (e.g.  $\angle 0^\circ$ ):

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

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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.

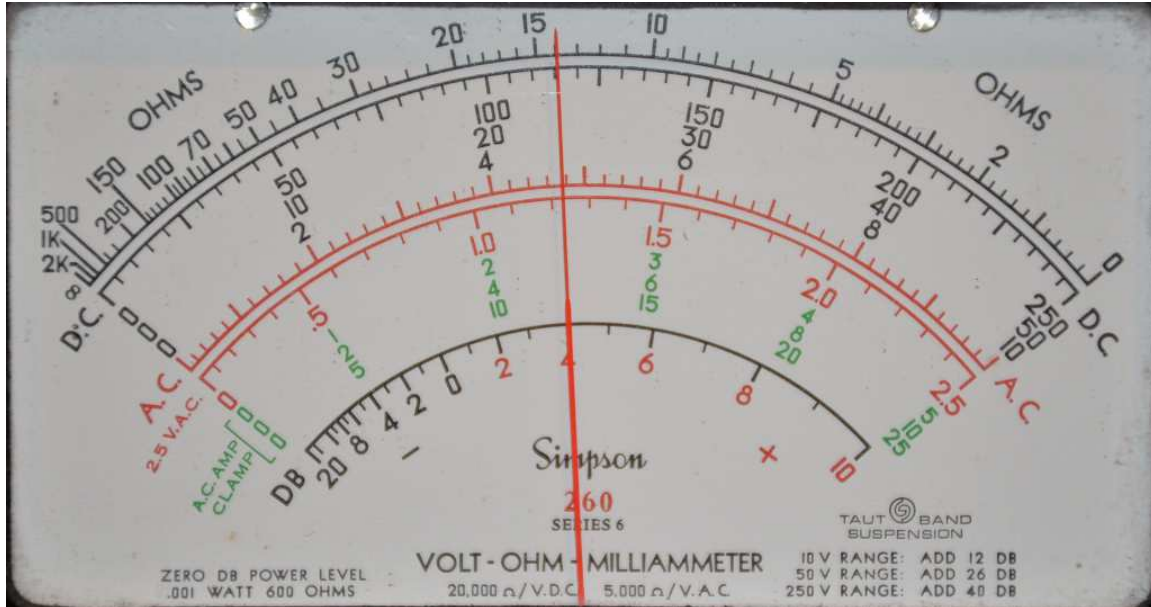
$$\text{Guy wire length} = \underline{\hspace{2cm}}$$

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

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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 bipolar junction transistor in its “active” operating mode passes 73 mA of collector current while being driven by 1.1 mA of base current, how much current will pass through its collector if base current decreases to 0.9 mA?

$I_C$  = \_\_\_\_\_

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**Question 8**

Convert the velocity **450 feet per second** into **centimeters per hour**. The following equivalents are given as a helpful reference, though you may not need to use all of them:

- 1 foot = 12 inches
- 1 minute = 60 seconds
- 1 inch = 2.54 centimeters
- 1 hour = 60 minutes



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**Question 9**

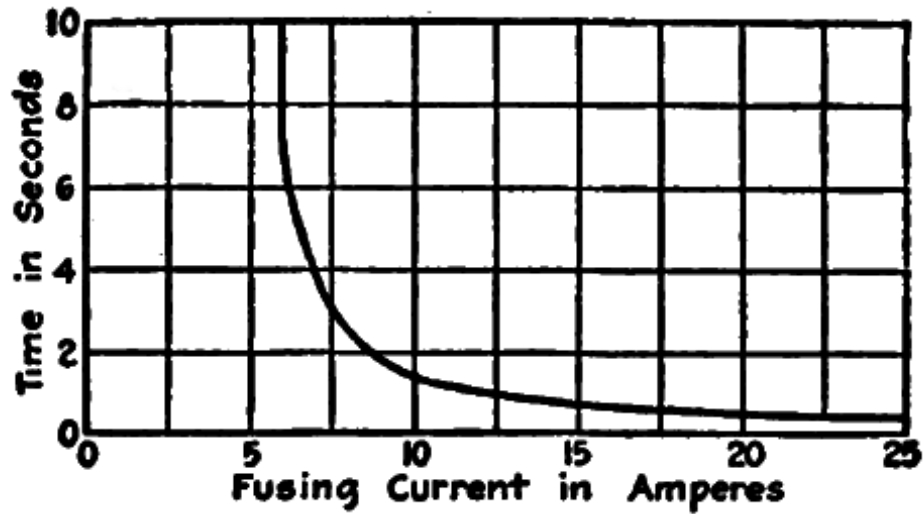
Solve for  $x$  in this equation:

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

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**Question 10**

Identify the approximate amount of time a fuse will blow if suddenly subjected to 12.5 Amperes of current, according to this fuse curve:



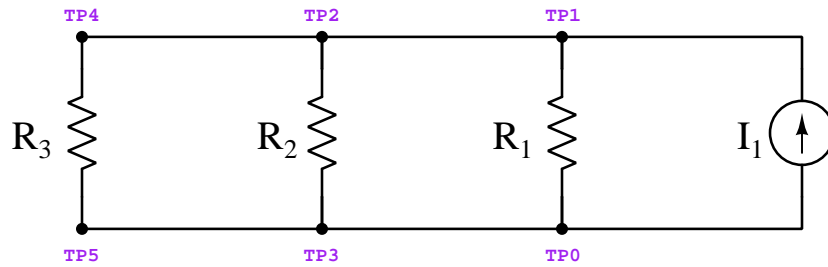
**FIG. 18.—Characteristic time-load curve of a 6-ampere fuse.**

Time = \_\_\_\_\_

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**Question 11**

Calculate the following parameters for this circuit, assuming  $I_1 = 410 \text{ mA}$ ,  $R_1 = 930 \Omega$ ,  $R_2 = 550 \Omega$ , and  $R_3 = 1.3 \text{ k}\Omega$ :

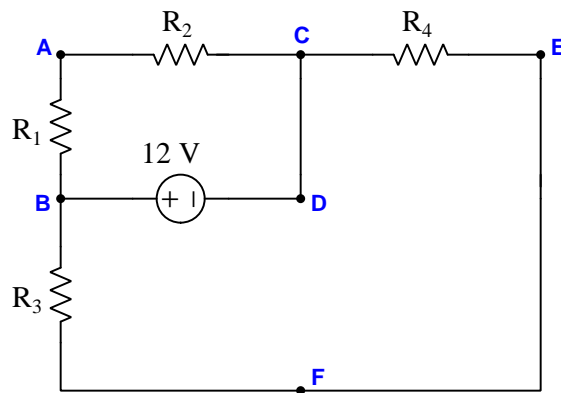


- $I_{R2} =$
- $I_{R1} =$
- $V_{TP2-TP1} =$
- $P_{R3} =$

---

**Question 12**

Calculate the amount of current through  $R_1$  in this series-parallel circuit, as well as the voltage between points D and F. Annotate the direction of current with an arrow pointing in the direction of conventional flow, and annotate voltage using + and - symbols, both annotations shown in the original diagram. Assume all resistors are  $1 \text{ k}\Omega$  in resistance:

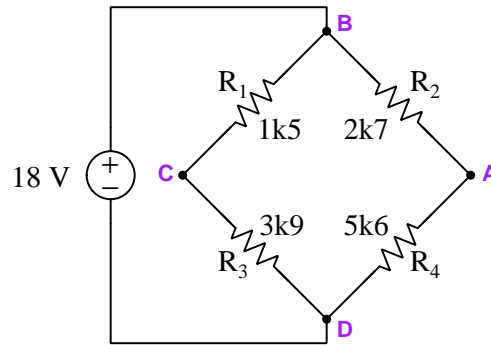


- $I_{R1} =$  (Also draw arrow on diagram)
- $V_{DF} =$  (Also draw + and - polarity marks on diagram)

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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* containing that new resistor value:

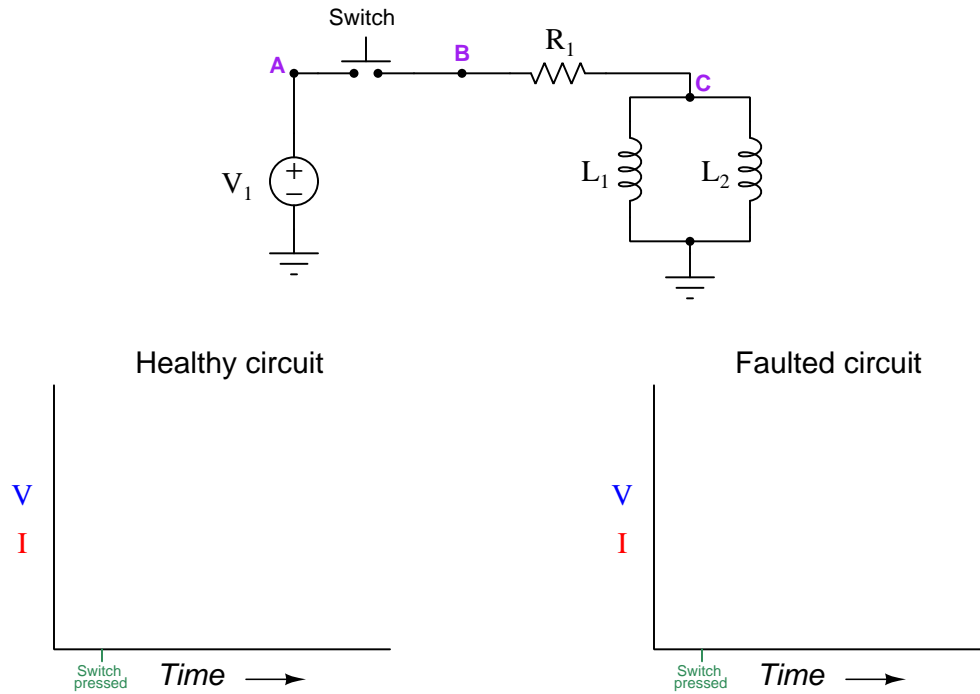


- $R_1 =$
- $V_{CB} =$
- $V_{BA} =$
- $I_{R3} =$
- $I_{source} =$

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:

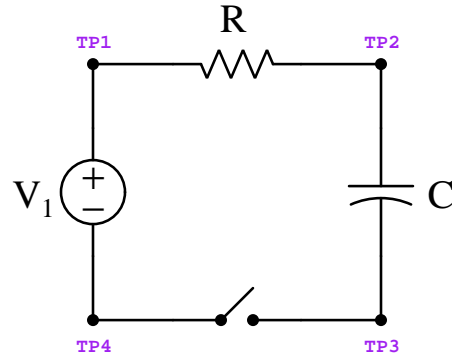


Sketch graphs for  $L_2$  voltage and current in the circuit assuming no faults (left) and again with the failed component (right).

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**Question 15**

Calculate the following parameters for this circuit, assuming  $V_1 = 12\text{ V}$ ,  $C = 3300\text{ }\mu\text{F}$ ,  $R = 5\text{ k}\Omega$ , and that the circuit begins with the switch open and with the capacitor completely de-energized (i.e. no stored charge):

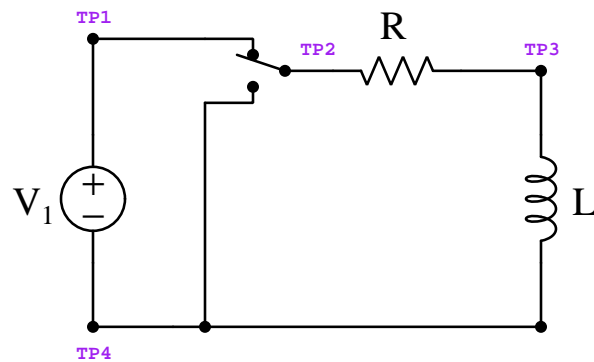


- $V_C$  14 seconds following switch closure =
- $V_{TP1-TP4}$  30 seconds following switch closure =
- $I_R$  at the moment the switch closes =

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**Question 16**

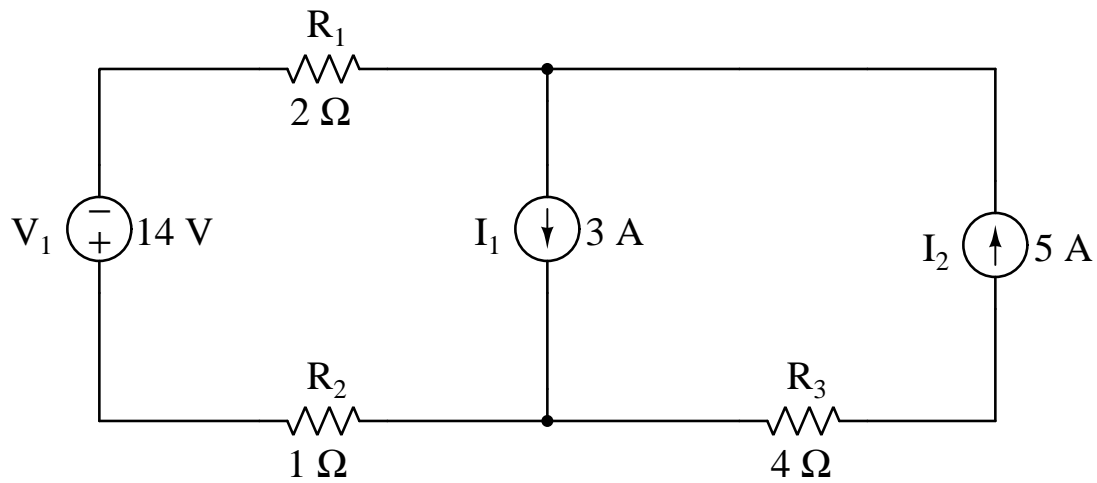
Calculate the following parameters for this circuit, assuming  $V_1 = 12\text{ V}$ ,  $L = 3\text{ H}$ ,  $R = 75\text{ }\Omega$ , and that the inductor's current happens to be 90 mA at the time the switch is flipped to the “down” position:



- $V_{TP2-TP4}$  20 milliseconds following switch flip =
- $I_R$  100 milliseconds following switch flip =
- $V_L$  70 milliseconds following switch flip =

### Question 17

Determine the circuit parameters listed below in this multi-source circuit. All numerical values as well as voltage polarities (+, -) and current arrow symbols for the requested voltages and currents must be shown annotated on the diagram near the specified components. Use conventional flow notation for current arrows.

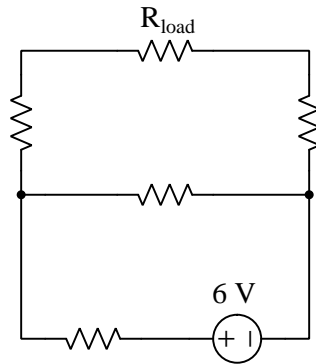


- Voltage across  $R_1$
- Voltage across  $I_2$
- Current through  $V_1$
- $I_1$  acting as a *source* or as a *load*?

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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:

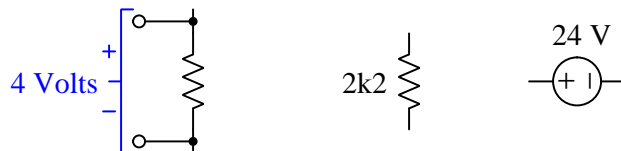


- $V_{Th} =$
- $R_{Th} =$
- $V_{load} =$

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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 resistor that is connected in series with a  $2.2\text{ k}\Omega$  resistor, being sure to specify any necessary component value(s).



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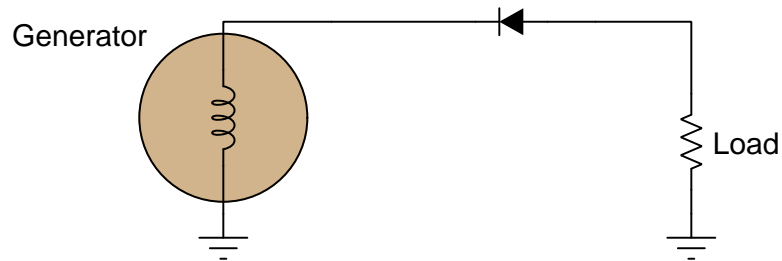
**Question 20**

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 10 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 the direction of load current in this circuit, assuming the use of a standard silicon rectifying diode and a generator voltage of 115 Volts RMS:



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

$$I_{load} = \text{(sketch arrows in the direction of conventional flow)}$$



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**Question 22**

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

- $I_{source} = 3$  Amperes RMS
- $f_{source} = 60$  Hz
- $R = 28 \Omega$
- $L = 250$  mH
- $C = 39 \mu\text{F}$

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

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

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

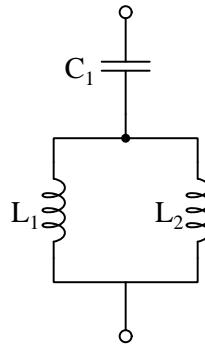
$$V_{source} = \underline{\hspace{2cm}}$$

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  $L_1$  to make this network resonate at a frequency of 2 kHz assuming  $L_2$  is 4 mH and  $C_1$  is 3.3  $\mu\text{F}$ , and determine whether the total impedance at that resonant frequency will be extremely high or extremely low:



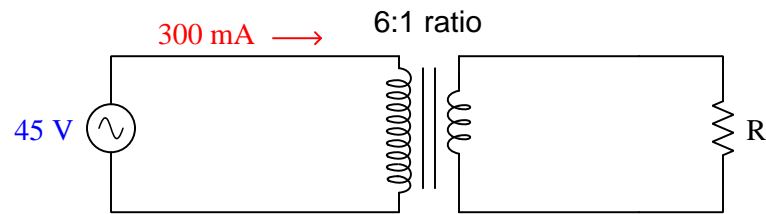
$$L_1 = \underline{\hspace{2cm}}$$

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

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**Question 24**

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



$$V_{load} =$$

$$R_{load} =$$

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**Question 25**

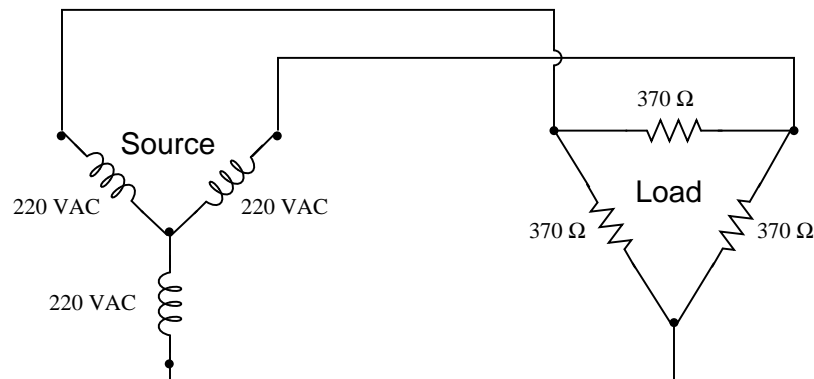
Predict the effects on the following voltages and currents in a series RC network with constant source voltage if the capacitor is replaced with another having a larger value (i.e. more microFarads):

- Current through source (*increases, decreases, or remains the same*)
- Voltage across  $C$  (*increases, decreases, or remains the same*)
- Voltage across  $R$  (*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 220 VAC and a load phase resistance of 370 Ohms:



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

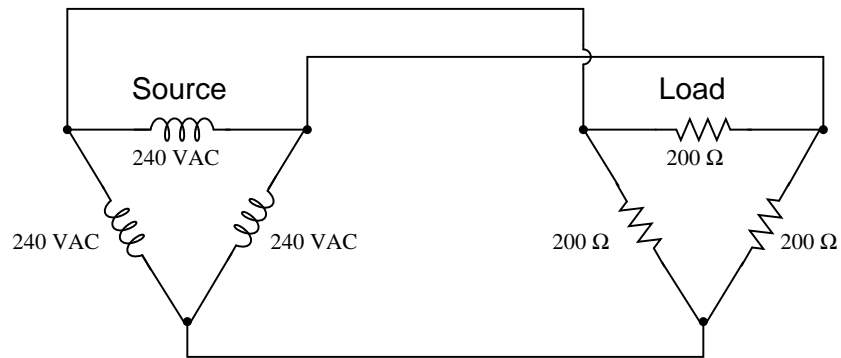
$$I_{line} = \text{_____ Amperes}$$

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

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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:



$$V_{line} = \underline{\hspace{2cm}} \text{ Volts}$$

$$I_{line} = \underline{\hspace{2cm}} \text{ Amperes}$$

$$I_{phase} \text{ (source)} = \underline{\hspace{2cm}} \text{ Amperes}$$

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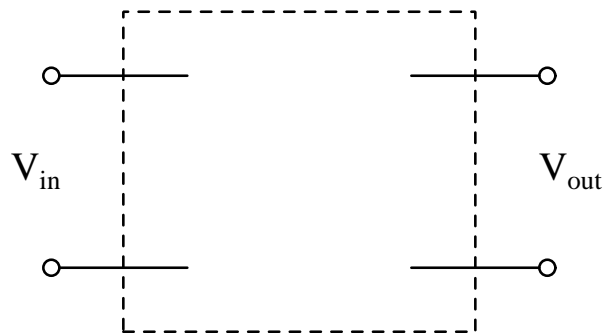
**Question 28**

A 15 horsepower, three-phase electric motor runs on a line voltage of 208 Volts. Calculate the line current for this motor while operating at its rated power, assuming 100% efficiency and a perfect power factor (1.0).

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**Question 29**

Design a high-pass filter with a cutoff frequency of 6 kHz, using either a 55 mH, 100 mH, or 175 mH inductor. Sketch the components between the terminals shown below:



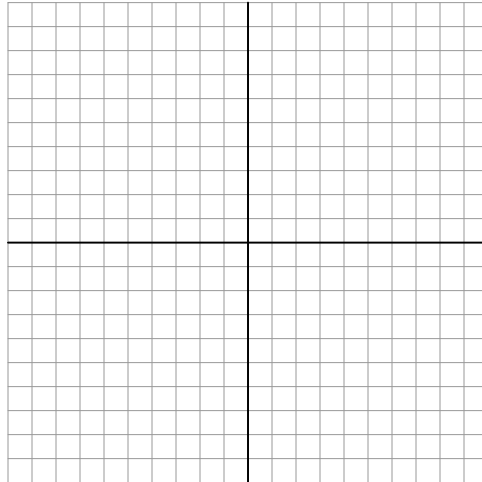
Be sure to show all component values within your diagram.

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**Question 30**

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

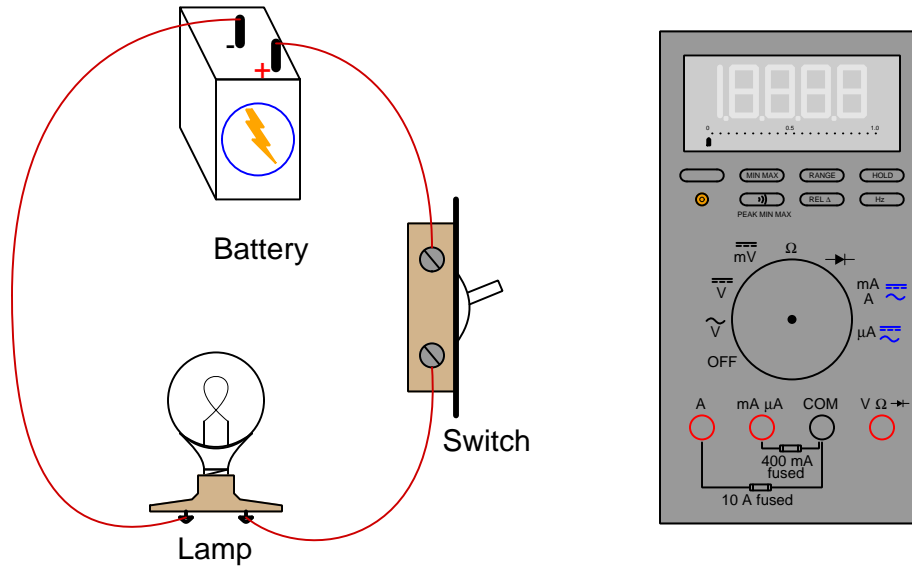
- $I_{source} = 5$  Amperes RMS  $\angle 0^\circ$
- $f_{source} = 200$  Hz
- $R = 8.1 \Omega$
- $L = 10$  mH



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!).

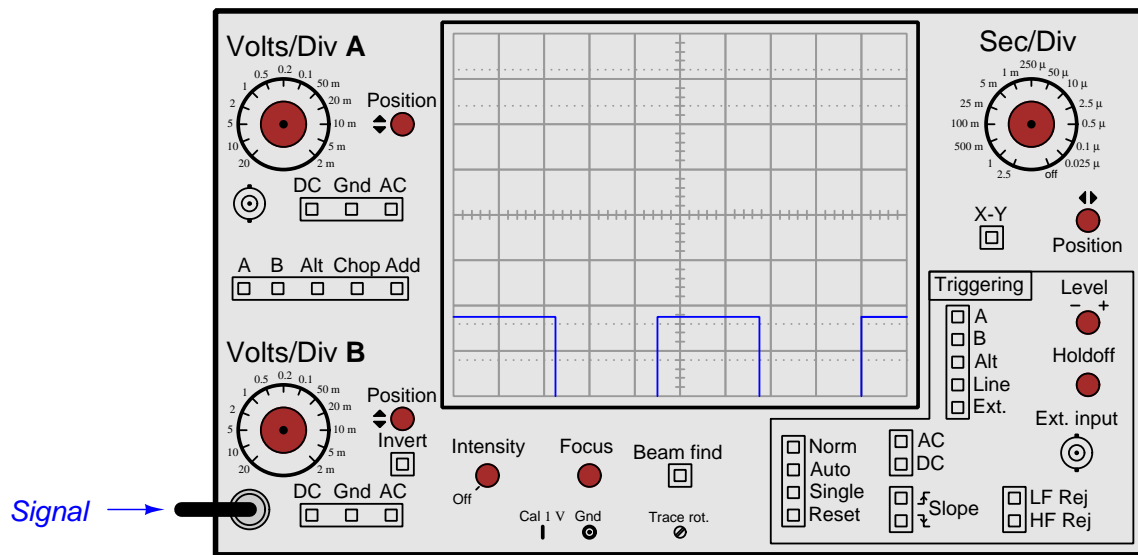
### Question 31

Show how this digital multimeter should connect to the circuit in order to measure the **switch's resistance**, anticipating practically zero when “on” and infinite when “off”. 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

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



Identify the front-panel control(s) on this oscilloscope you would use to select the type of signal *coupling* on the input of Channel 1:



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**Question 34**

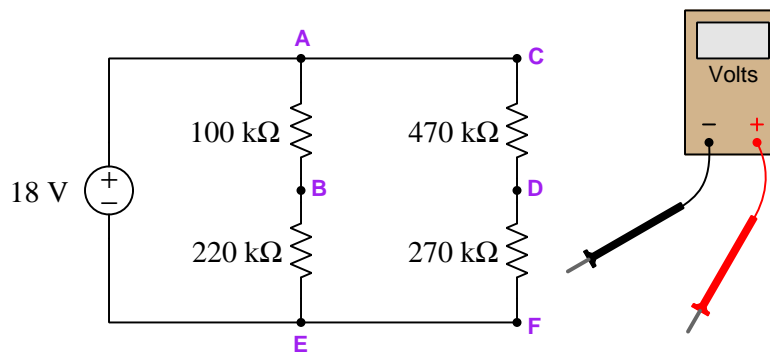
Identify the purpose of this test instrument, and also identify one practical application for it:



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**Question 35**

Sketch how to connect this digital multimeter (DMM) to measure voltage between points **B** and **E** in this circuit so that it will register a negative 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  $2\text{ M}\Omega$ .

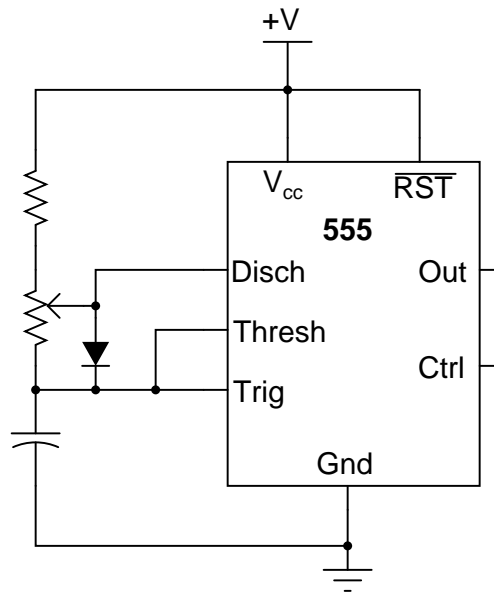
Voltage measurement = \_\_\_\_\_ Volts



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**Question 36**

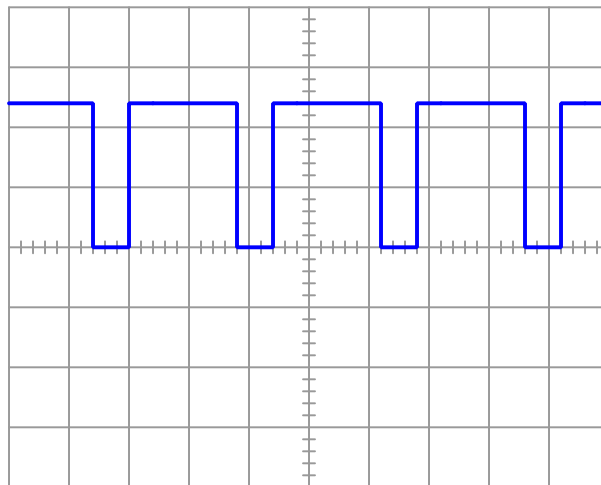
Identify where an oscilloscope probe could be connected in this circuit to measure the square-wave signal's *duty cycle*:



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**Question 37**

An oscilloscope measures pulsed DC voltage across a  $5\ \Omega$  load resistance that is known to be dissipating an average power of 81 Watts. Determine the peak voltage of this PWM waveform:



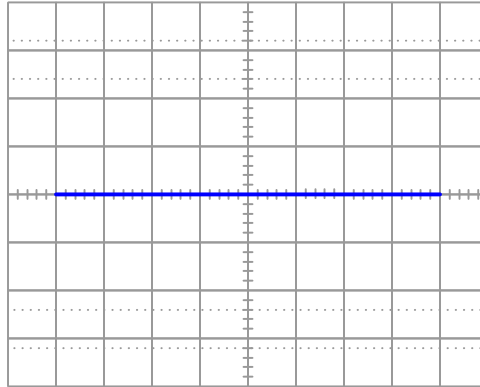
$$V_{pk} = \underline{\hspace{2cm}}$$

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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.

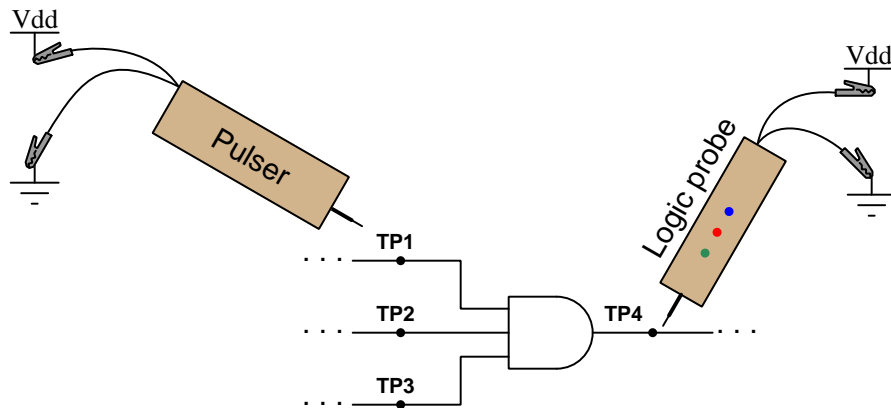
Identify both the component connected to this curve tracer as well as any defects in that component as evidenced by the instrument’s display:



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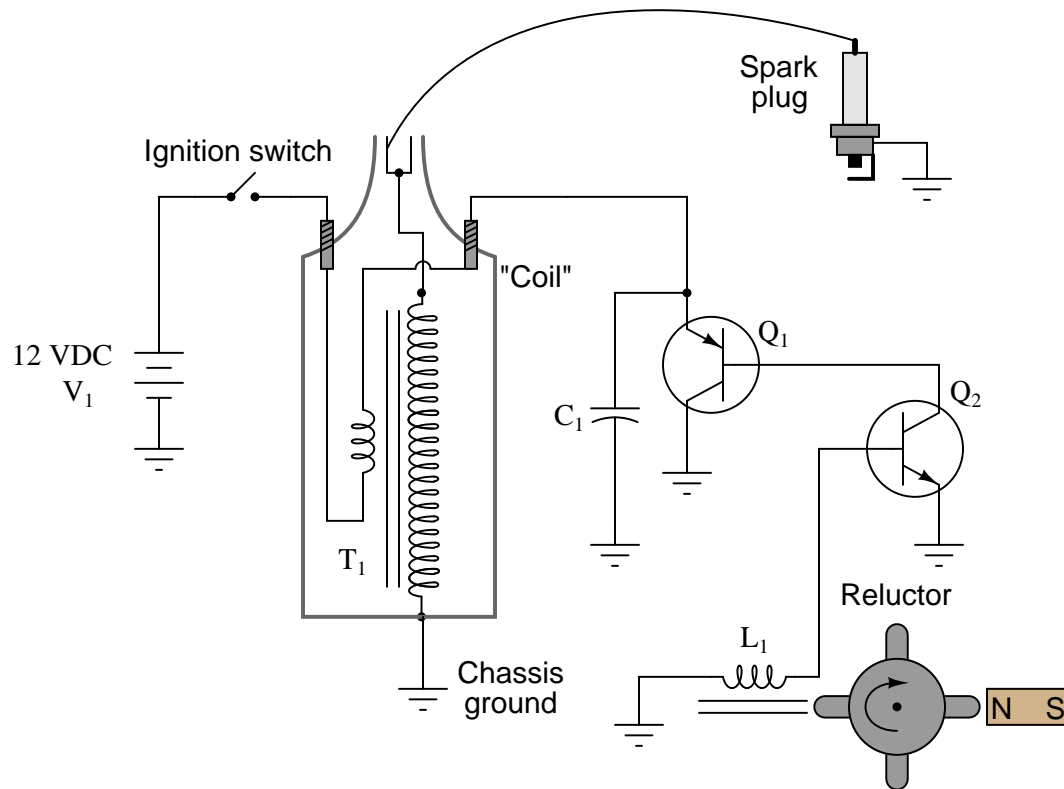
**Question 39**

Describe how to test the functionality of this logic gate using a logic pulser and a logic probe. Be sure to identify the logic states necessary at the non-pulsed inputs during your test:



#### Question 40

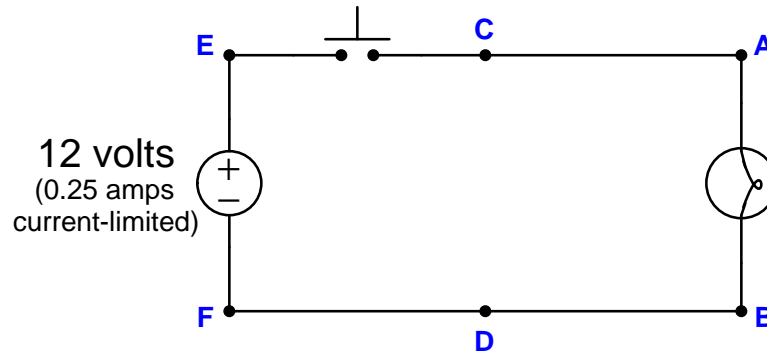
This is an electronic spark-ignition circuit for an internal-combustion engine. Its purpose is to generate high-voltage impulses to “fire” a *spark plug* (an air-gap spark discharge device used to ignite the air/fuel mixture within the engine). A *reluctor* device rotated by the engine’s camshaft provides the triggering signal necessary to generate these impulses to “fire” the spark plug at the right times:



Identify where you would connect a multimeter to measure a signal diagnosing whether or not transistor  $Q_2$  was turning on and off as the reluctor rotates. 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 0 Volts between test points **F** and **B** in the circuit while the pushbutton is pressed:



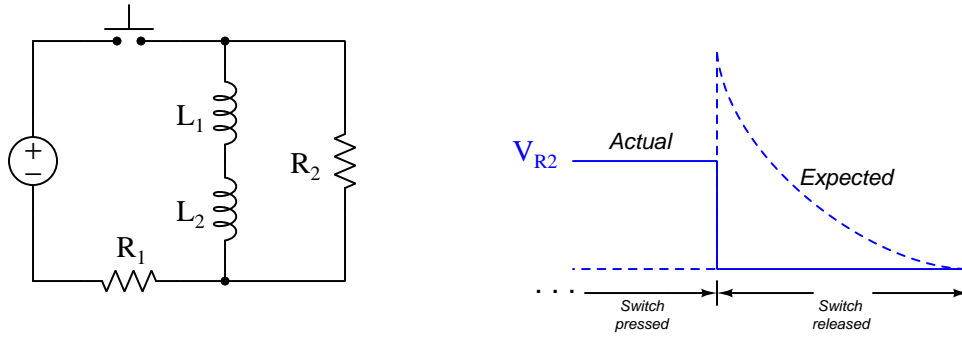
Note that a “current-limited” voltage source behaves like a normal voltage source when the load draws less than its current rating (i.e. constant voltage), but when faced with a load that would draw more current than its rating it switches into current-source mode and limits current to that rated value 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 follows a “step” pattern rather than an inverse-exponential decays 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.

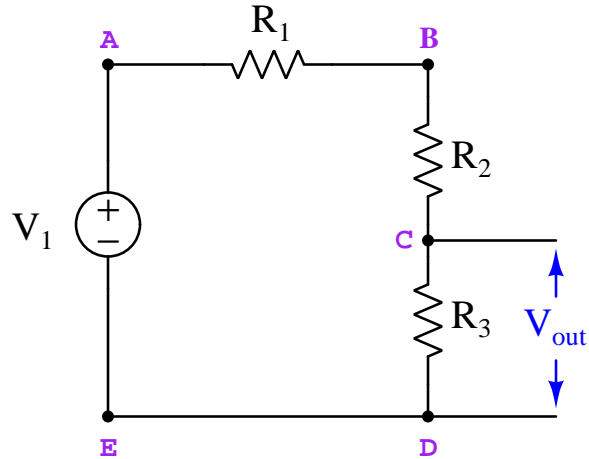
Fault	Possible	Impossible
Resistor $R_1$ failed open		
Resistor $R_2$ failed open		
Inductor $L_1$ failed open		
Inductor $L_2$ failed open		
Inductor $L_1$ failed shorted		
Inductor $L_2$ failed shorted		

### 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
- $R_1 = 7.1$  k $\Omega$
- $R_2 = 7.1$  k $\Omega$
- $R_3 = 7.1$  k $\Omega$

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



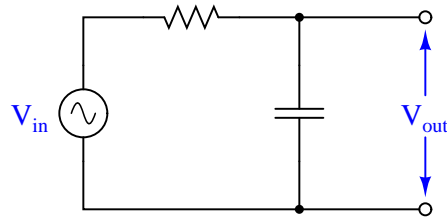
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

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:



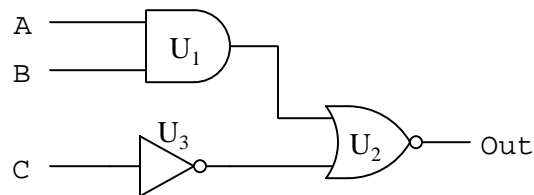
Next, identify the filtering behavior of this same circuit supposing the resistor fails *open*. Place two check-marks in the table below to identify each filtering characteristic (one check-mark identifying the healthy circuit's characteristic and another check-mark identifying the faulted circuit's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

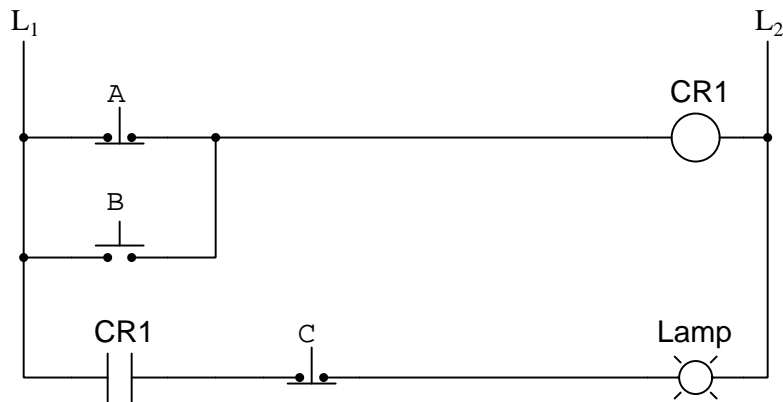


Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

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:



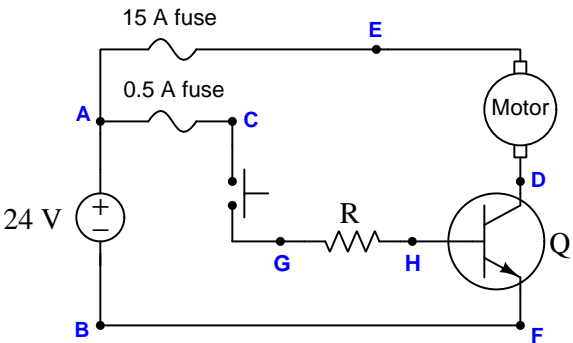
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

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 **A** and **C** in this circuit registers 0 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.

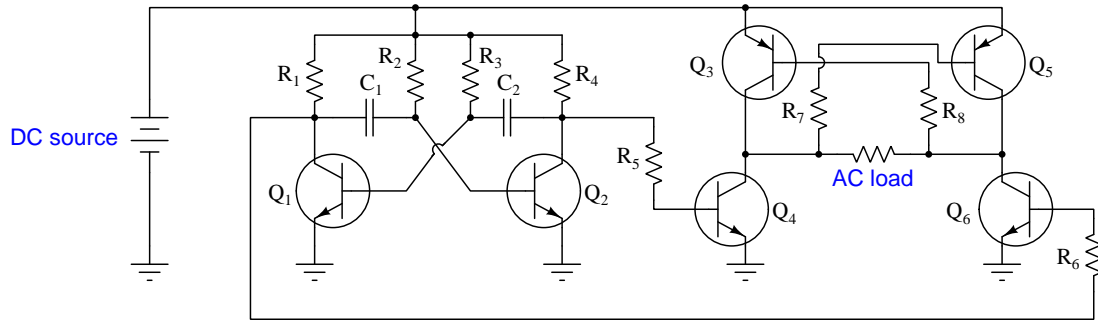
Fault	Possible	Impossible
Pushbutton switch failed open		
Pushbutton switch failed shorted		
Motor failed open		
Resistor failed open		
15 amp fuse blown		
0.5 amp fuse blown		

Question 48

A resistor with color code Red-Red-Brn-Gld measures 205 Ohms when tested with an ohmmeter. Determine whether or not this resistor’s resistance is within tolerance.

### Question 49

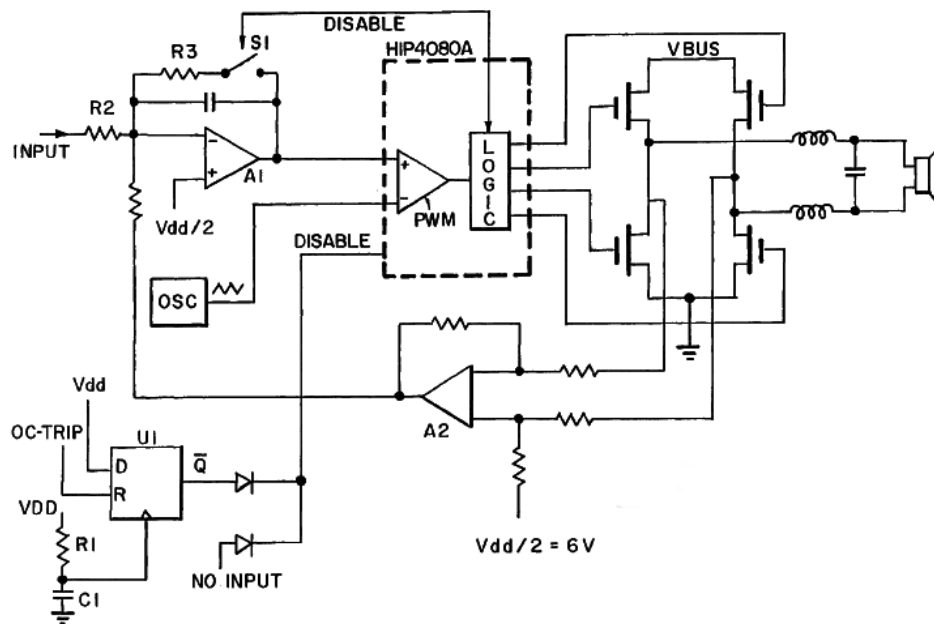
Identify the effect that a failed-open resistor  $R_6$  will have on this power converter circuit's output to the AC load:



Please be as specific as you can in your answer!

### Question 50

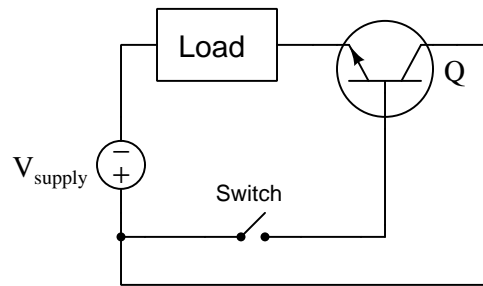
Identify the purpose of the inductors and capacitor near the loudspeaker of this subwoofer audio amplifier schematic:



---

**Question 51**

Calculate the following parameters in this switching circuit, assuming a source voltage of 18 Volts, a load resistance of  $50\ \Omega$ , and a silicon transistor with a  $\beta$  value of at least 75:



**With switch closed**

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

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

**With switch open**

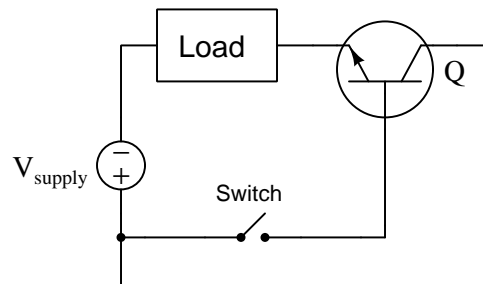
$$V_{load} = \underline{\hspace{2cm}}$$

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

---

**Question 52**

Calculate an appropriate power dissipation rating for a silicon transistor assuming a supply voltage of 20 Volts and an expected load current of 4.1 Amperes:

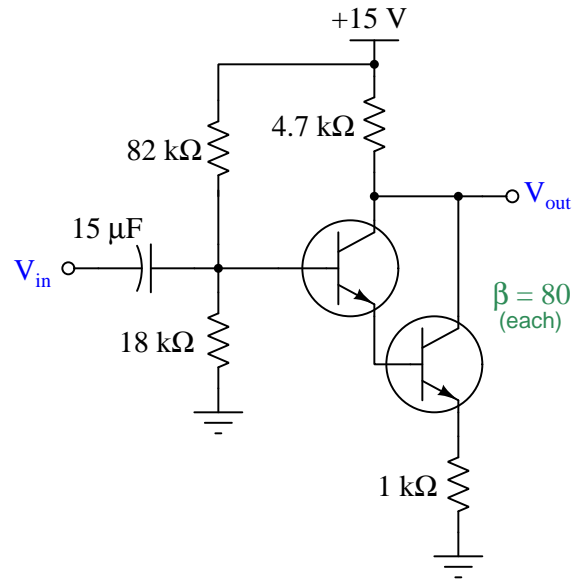


$$P_Q = \underline{\hspace{2cm}}$$

---

**Question 53**

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

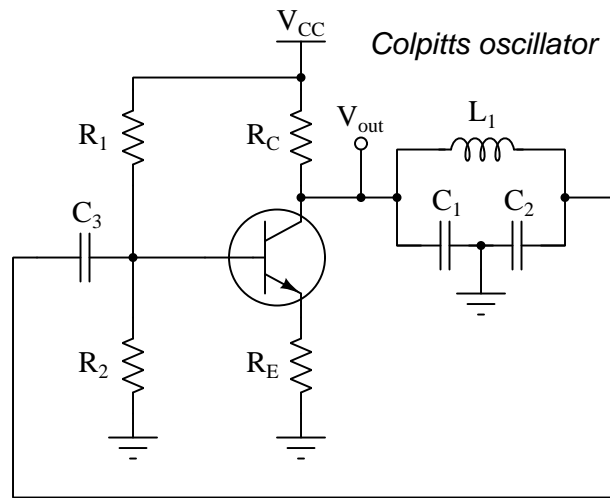


You may express your answer either as a gain ratio or as a decibel figure. If you answer in both formats, both of your answers must be correct! If you choose to answer in decibels you must write “dB” as the unit, as any unit-less answer will be assumed a gain ratio.

$A_V =$

### Question 54

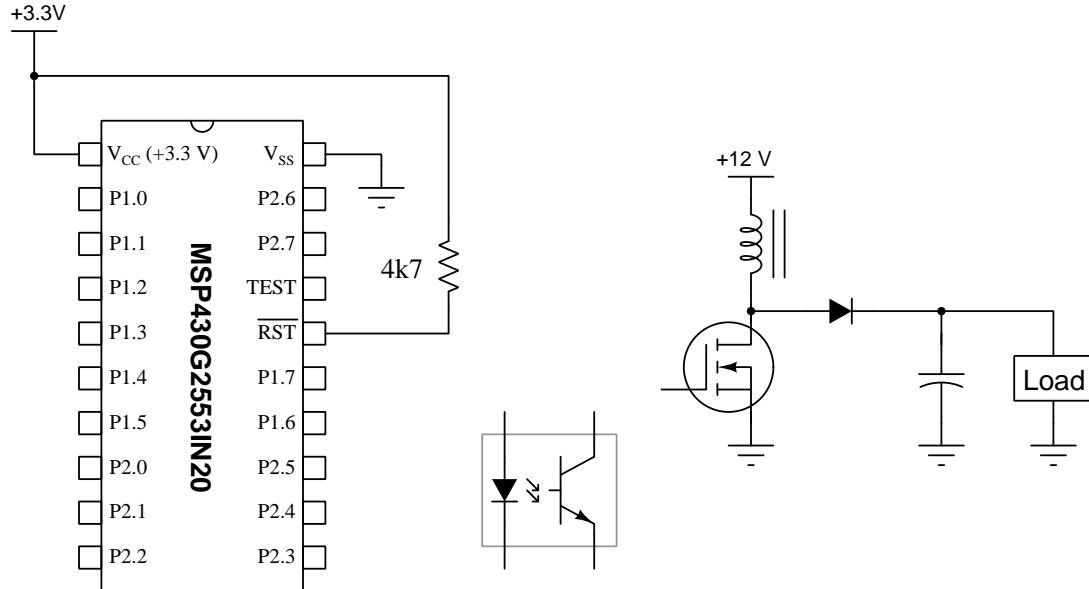
Identify the proper value for both  $C_1$  and  $C_2$  (i.e. both capacitors being equal-valued) to make this circuit oscillate at 35 kHz, assuming  $L_1 = 5$  mH.



$$C_1 = C_2 = \underline{\hspace{2cm}}$$

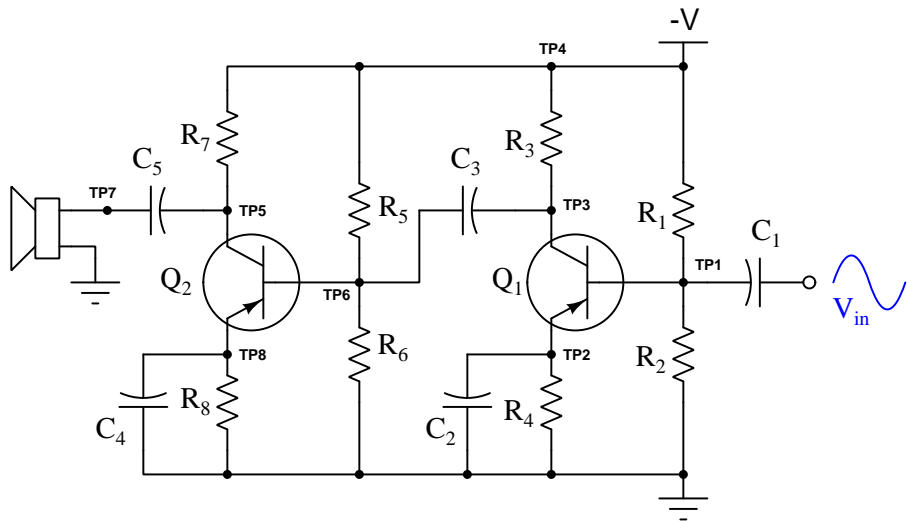
### Question 55

Sketch a circuit to interface output port P1.3 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:



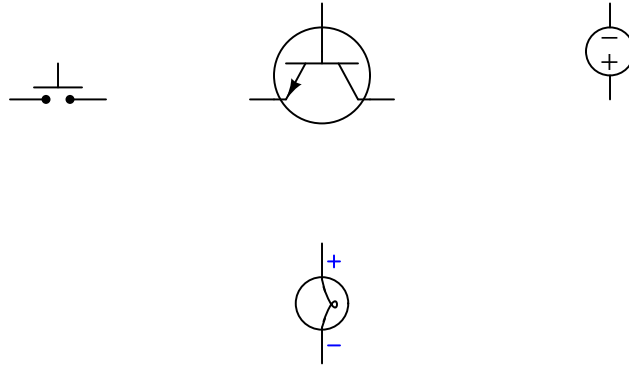
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

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**

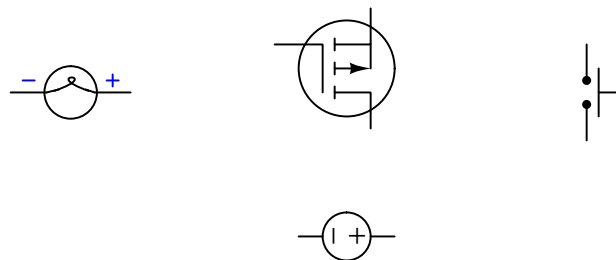
Sketch wires connecting these components together to form a circuit where pressing the pushbutton switch causes the transistor to turn on and send power to the lamp (with DC polarity shown). The pushbutton switch should carry only as much current as is necessary to trigger the transistor, and not carry 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**

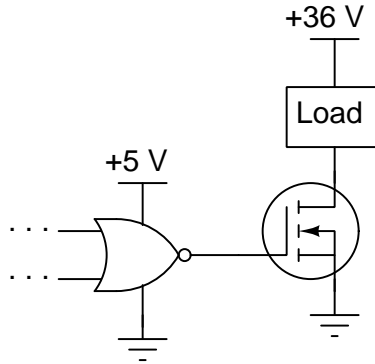
Sketch wires connecting these components together to form a circuit where pressing the pushbutton switch causes the transistor to turn on and send power to the lamp (with DC polarity shown). The pushbutton switch should carry only as much current as is necessary to trigger the transistor, and not carry 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 maximum drain-source “on” resistance for the transistor to reliably switch the load on and off, assuming the transistor is saturated when turned on by the output signal from the logic gate and it has a maximum power dissipation rating of 50 Watts:



Assume the load passes 14 Amperes of current when energized.

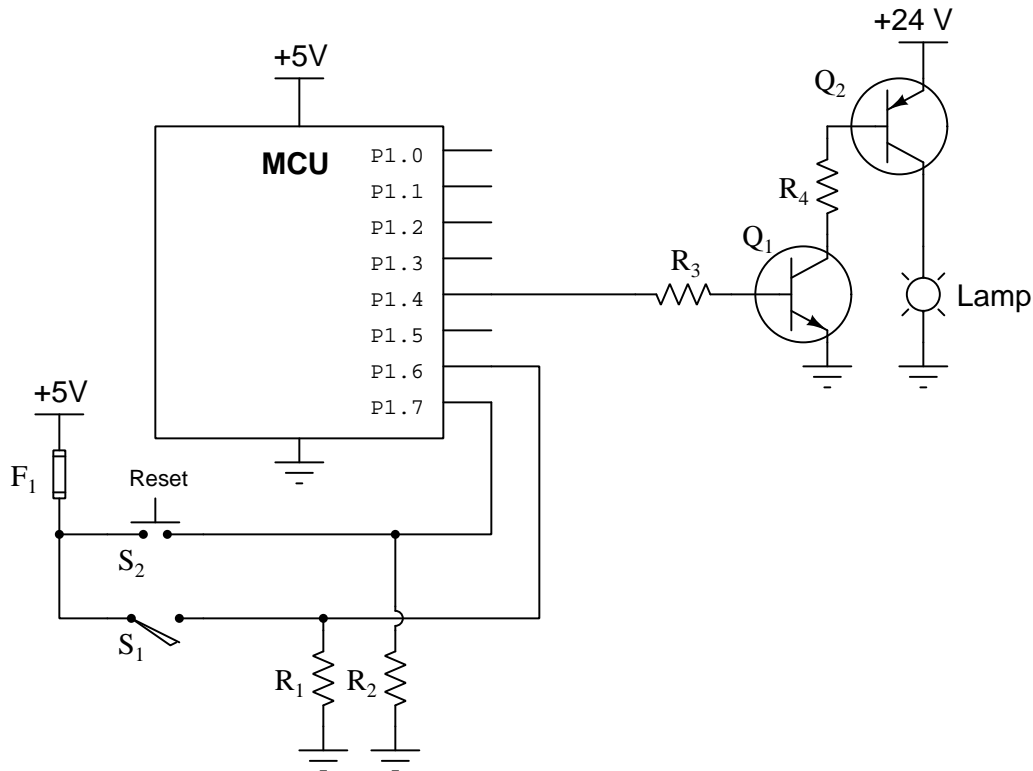
$$R_{DS(on)} = \underline{\hspace{2cm}}$$



### 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.



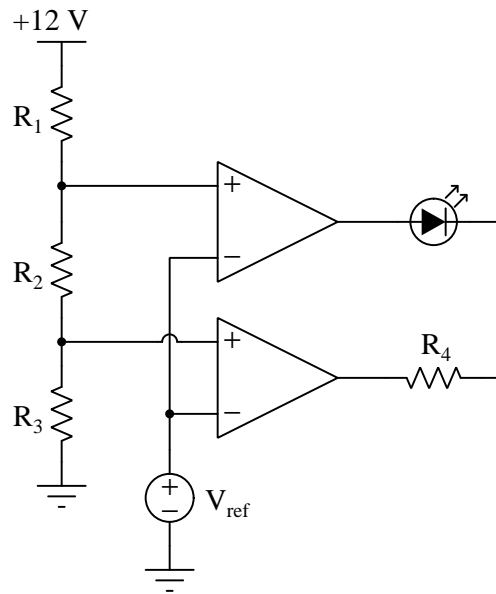
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

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 LED is energized, assuming  $R_1$  is 5 k $\Omega$ ,  $R_2$  and  $R_3$  are both 2.5 k $\Omega$ , and  $R_4$  is 330  $\Omega$ :



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

---

**Question 62**

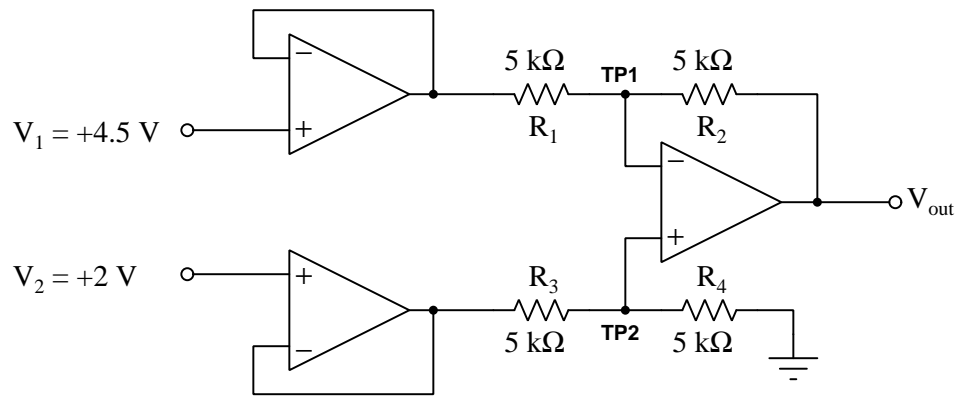
Design a voltage amplifier circuit using an operational amplifier (“opamp”) where the over-all voltage gain (ratio) is equal to  $-9$ :

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!):



$$V_{TP1} =$$

$$V_{TP2} =$$

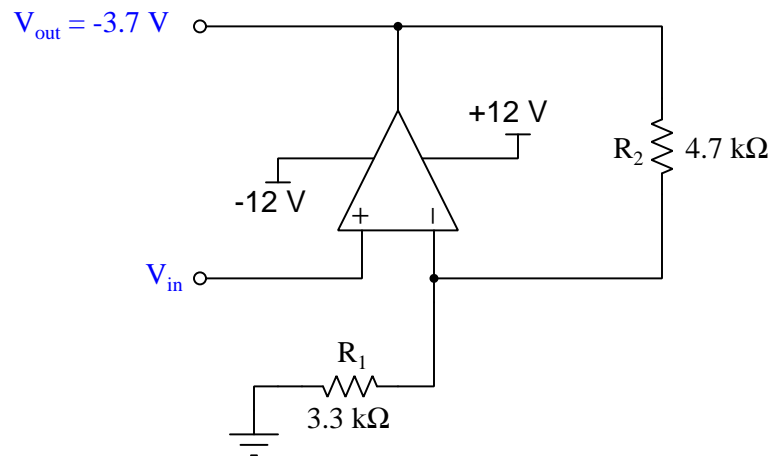
$$I_{R3} =$$

$$V_{out} =$$

---

**Question 64**

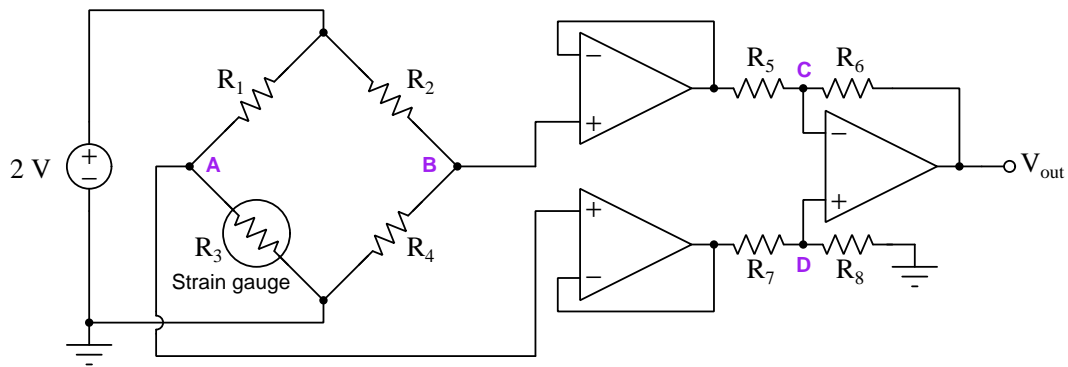
Calculate the amount and direction of current through resistor  $R_2$  in this opamp circuit, given the output voltage and resistor values shown. Note that the voltage source for  $V_{in}$  is not shown. Assume the opamp is capable of “rail-to-rail” output voltage swings, and that the output voltage 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:



- $R_1 = 2 \text{ k}\Omega$
- $R_2 = 2 \text{ k}\Omega$
- $R_3 = 3.1 \text{ k}\Omega$  (strain gauge sensor)
- $R_4 = 2 \text{ k}\Omega$
- $R_5 = 1 \text{ k}\Omega$
- $R_6 = 5 \text{ k}\Omega$
- $R_7 = 1 \text{ k}\Omega$
- $R_8 = 5 \text{ k}\Omega$

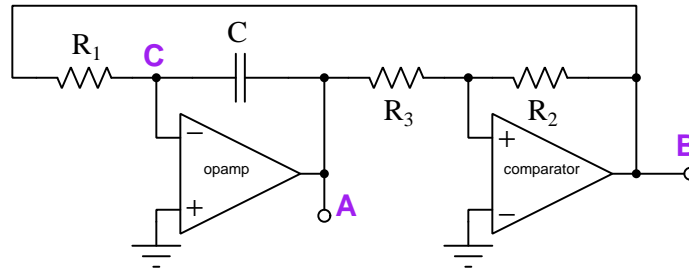
$$V_{out} = \underline{\hspace{2cm}}$$

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

---

**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*:

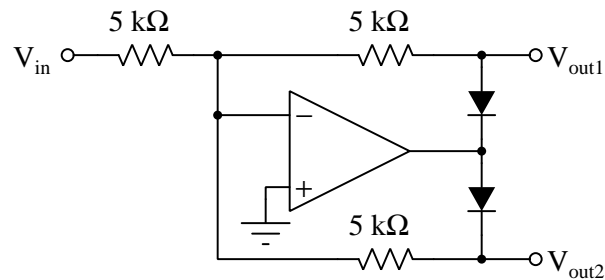


- Test point **A** =
- Test point **B** =
- Test point **C** =

---

**Question 67**

Determine the voltages at this circuit's output terminals (each with respect to ground) assuming the ground-referenced voltage applied to its input terminal is  $-4$  Volts, and that the operational amplifier's power supply rail voltages are  $+10$  Volts and  $-10$  Volts, respectively:



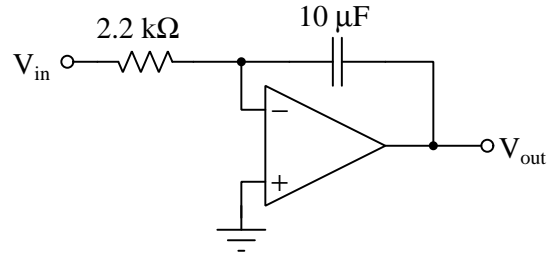
$V_{out1}$  = \_\_\_\_\_ Volts

$V_{out2}$  = \_\_\_\_\_ Volts

---

**Question 68**

Determine the rate-of-change for the voltage at this circuit's output terminal (with respect to ground) assuming the ground-referenced voltage applied to its input terminal is a constant +1.2 Volts, and that the operational amplifier's power supply rail voltages are +15 Volts and −15 Volts, respectively:

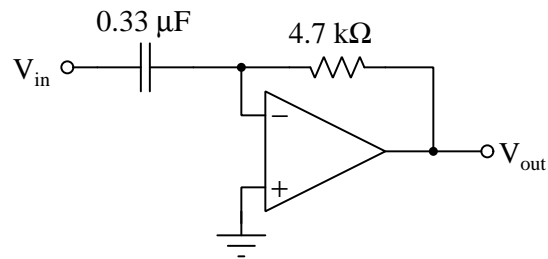


$$\frac{dV_{out}}{dt} = \text{_____ Volts/second}$$

---

**Question 69**

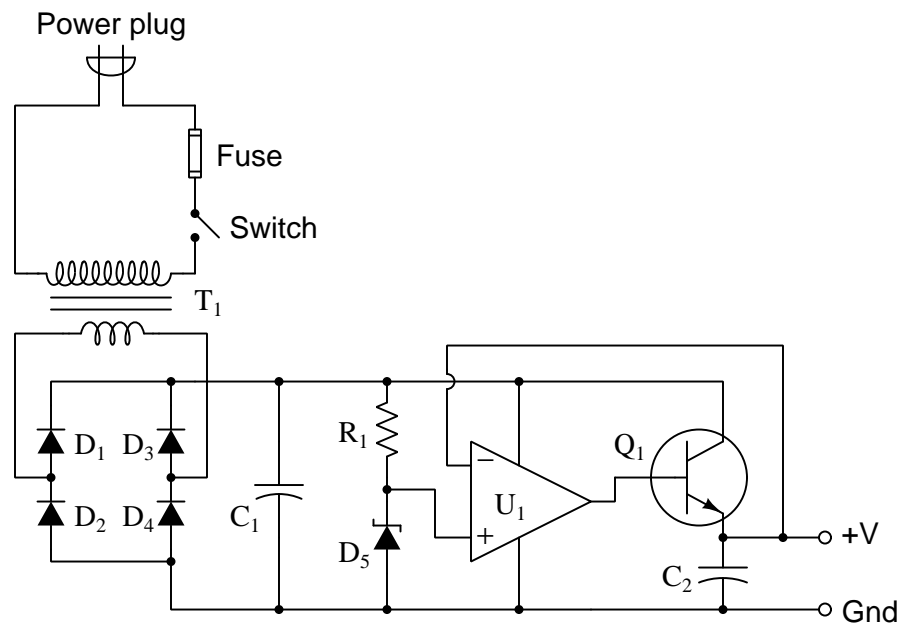
Determine the voltage at this circuit's output terminal (with respect to ground) assuming the ground-referenced voltage applied to its input terminal falls at a rate of −10 Volts per second, and that the operational amplifier's power supply rail voltages are +12 Volts and −12 Volts, respectively:



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

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 0 Volts:



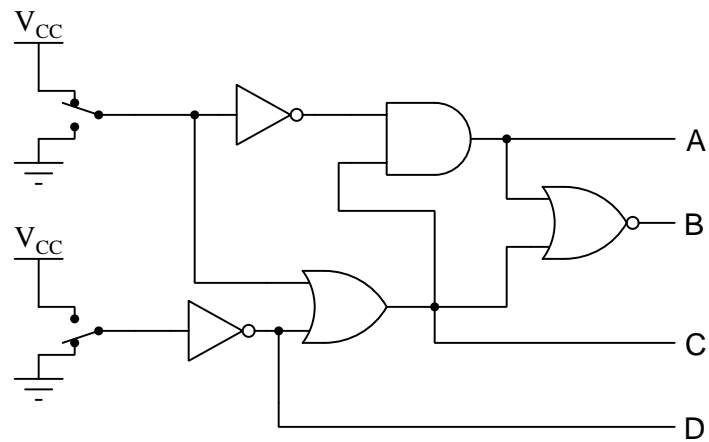
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

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:



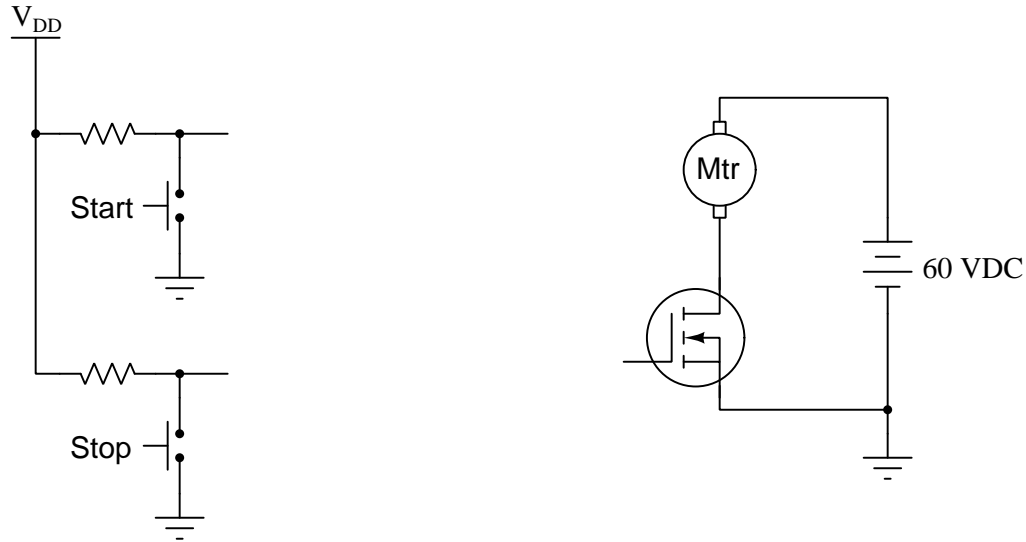
Place one check-mark in each row of the table, identifying the state of each output line:

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



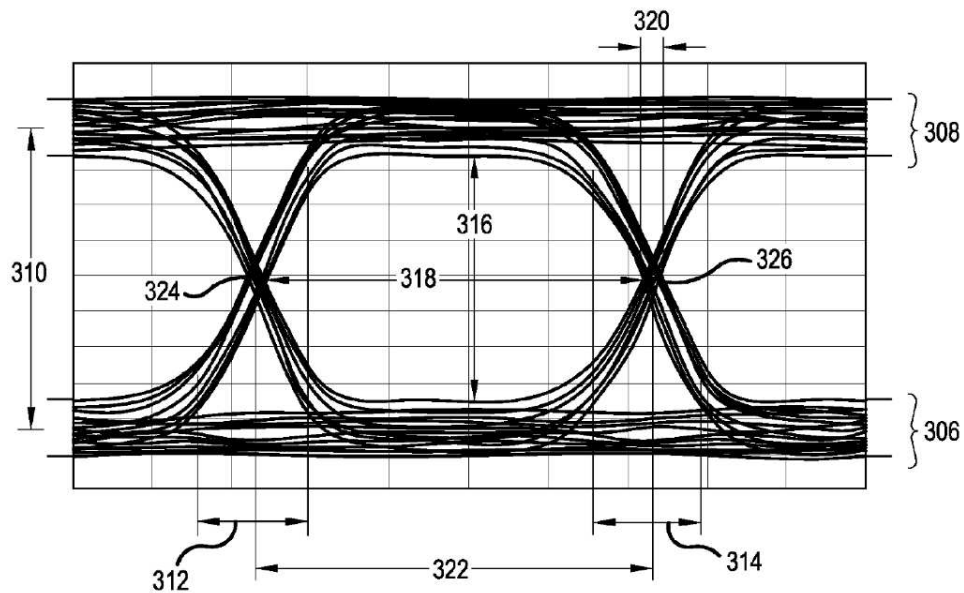
### Question 72

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

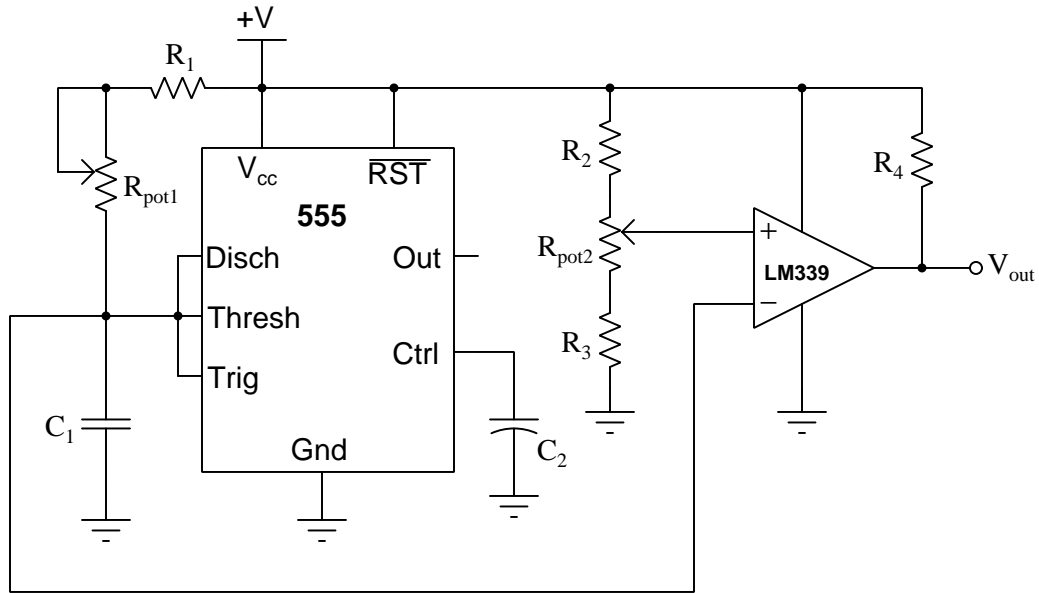
Identify examples of *fall time* in this eye diagram:



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 a new value for capacitor  $C_1$  to cause this PWM circuit's output frequency to be 1.5 kHz instead of 730 Hz at the exact same potentiometer position(s). All original component values (producing 730 Hz at that potentiometer position) are listed below:



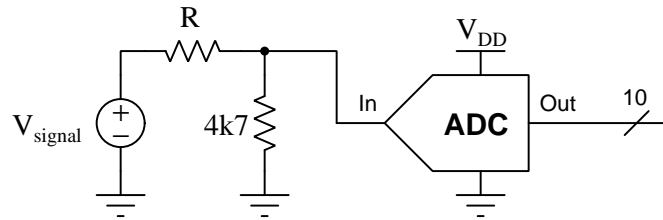
- $R_1 = 220 \text{ k}\Omega$
- $R_2 = 15 \text{ k}\Omega$
- $R_3 = 15 \text{ k}\Omega$
- $R_4 = 1 \text{ k}\Omega$
- $R_{pot1} = 1 \text{ k}\Omega$
- $R_{pot2} = 10 \text{ k}\Omega$
- $C_1 = 4.7 \text{ }\mu\text{F}$
- $C_2 = 33 \text{ }\mu\text{F}$

$C_1$  (new) = \_\_\_\_\_

---

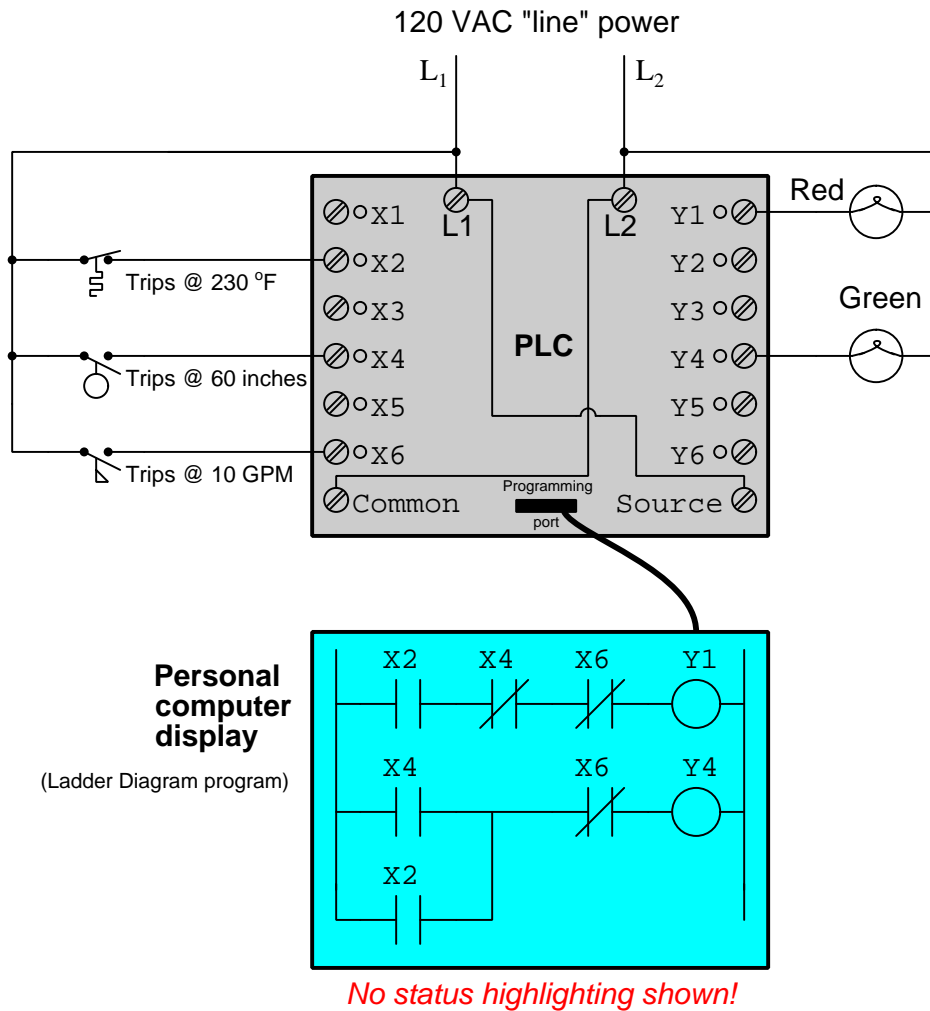
**Question 75**

Calculate the necessary value for  $R$  to make this 10-bit ADC output a count value of  $0x1A3$  given a signal source voltage of 12.8 Volts DC. The ADC's raw (unscaled) input voltage range is 0 to 5 Volts, corresponding to a count range of  $0x000$  to  $0x3FF$ :



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

Bit X2 will be: (1 or 0)

Bit X4 will be: (1 or 0)

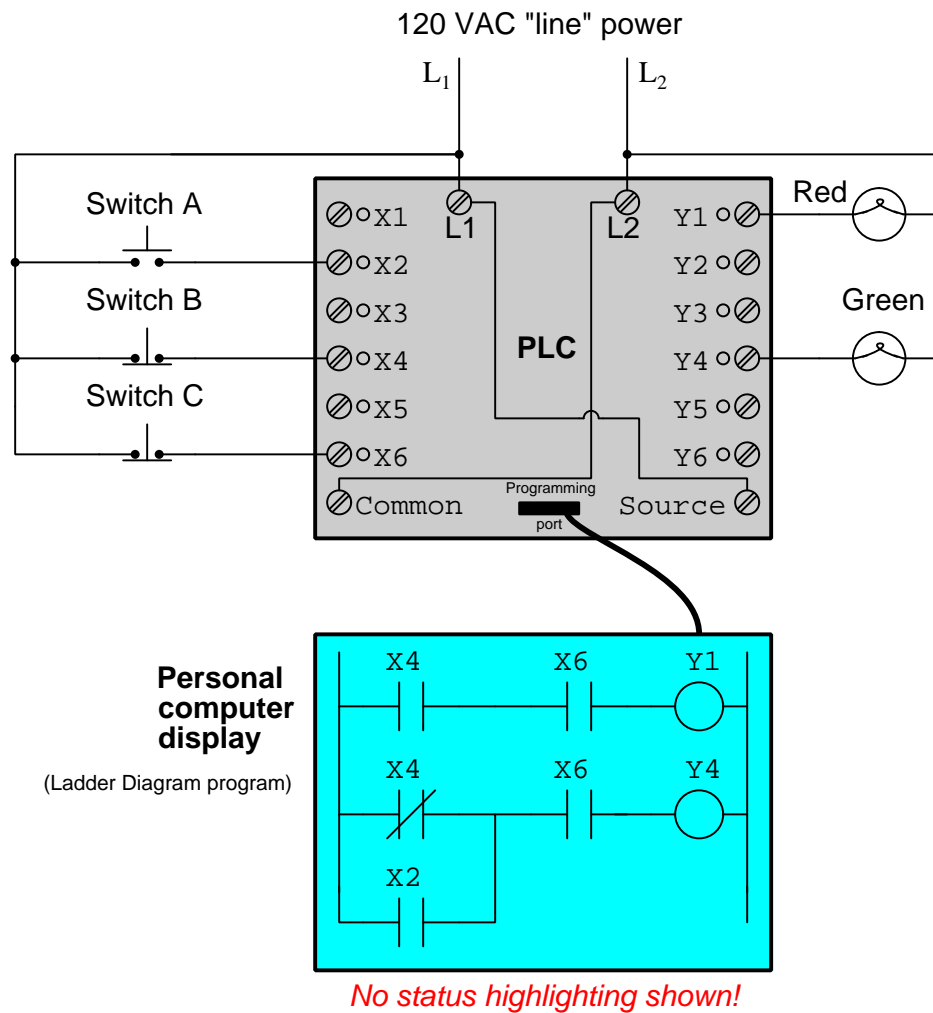
Bit X6 will be: (1 or 0)

The red lamp will be: (on or off)

The green lamp will be: (on or off)

### Question 77

Determine the status of the two lamps connected to this PLC. Assume only switch “A” is being pressed at the moment:

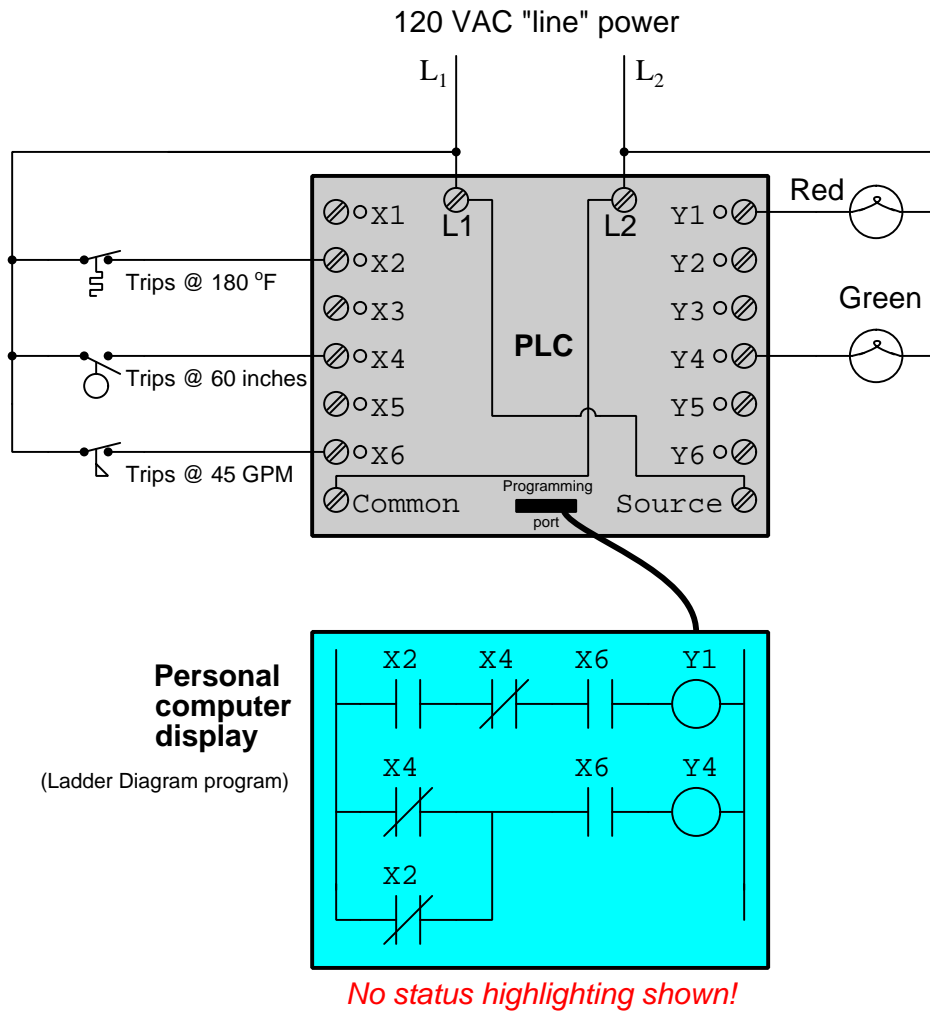


The red lamp will be: (*on* or *off*)

The green lamp will be: (*on* or *off*)

### 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 = 190 °F
- Liquid level = 23 inches
- Liquid flow = 75 GPM

Bit X2 will be: (1 or 0)

Bit X4 will be: (1 or 0)

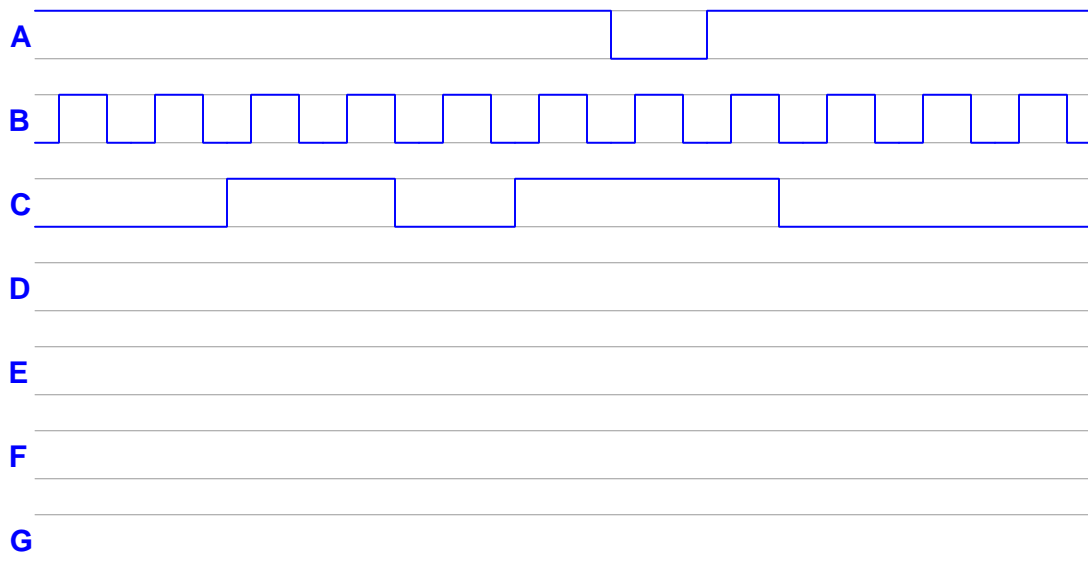
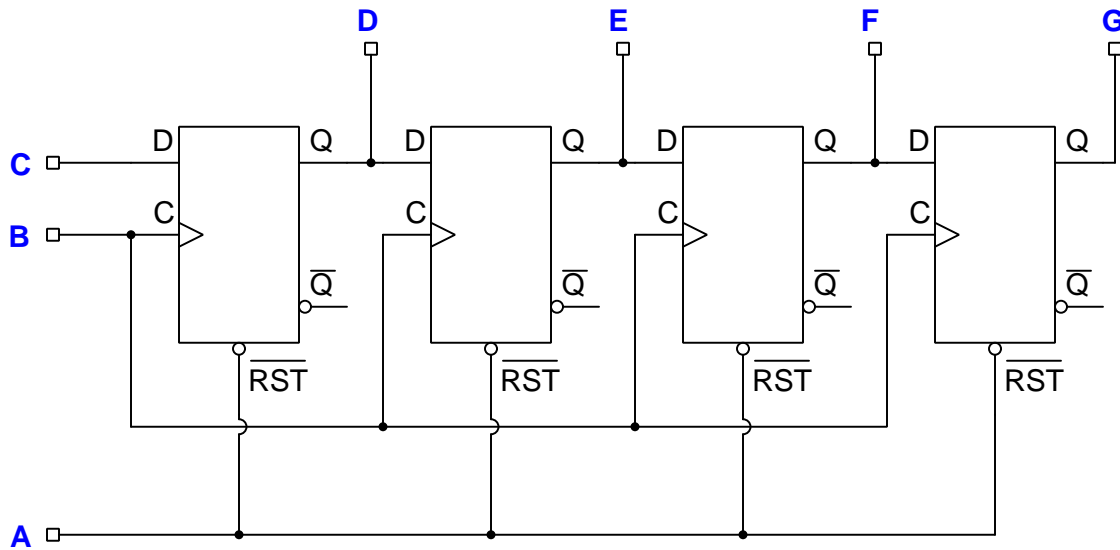
Bit X6 will be: (1 or 0)

The red lamp will be: (on or off)

The green lamp will be: (on or off)

### Question 79

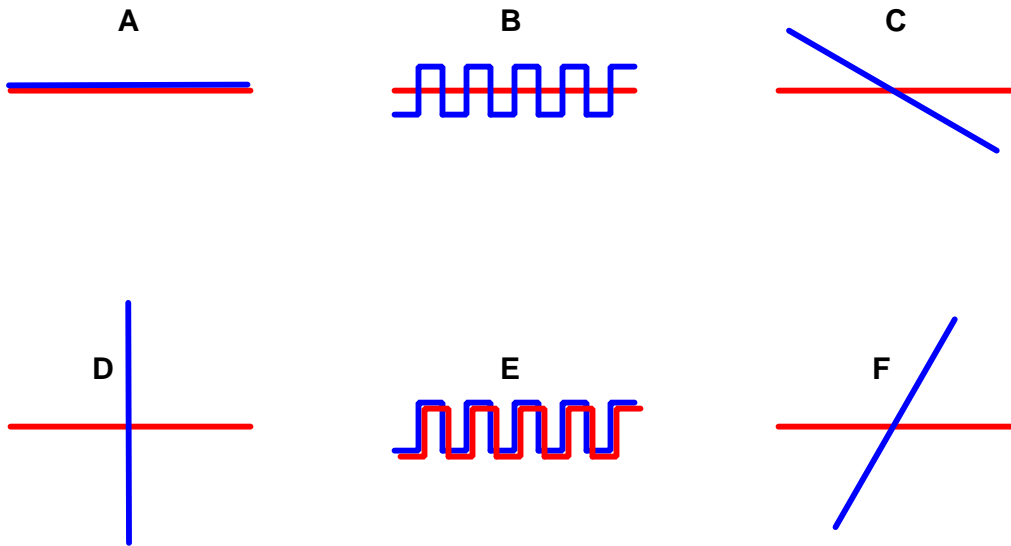
Complete the timing diagram below, assuming all outputs begin in their “low” states and that the shift register’s reset function is asynchronous:



---

**Question 80**

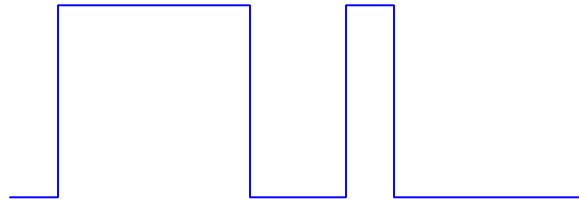
If two conductors must be in close proximity to one another, which arrangement will result in the least amount of capacitive coupling between the two?



---

**Question 81**

Analyze this RS-232 data frame with expected parameters of 8 data bits, odd parity, and 1 stop bit (801), determining the binary value of the data payload and whether or not the parity is correct:



Data = \_\_\_\_\_ (write in normal binary order, MSB left and LSB right)

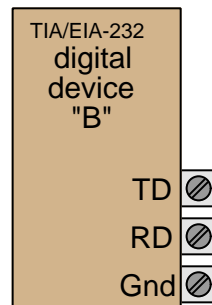
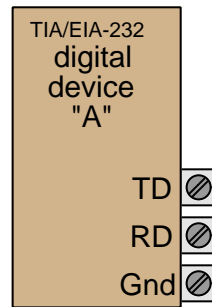
Parity = *correct* or *incorrect*



---

**Question 82**

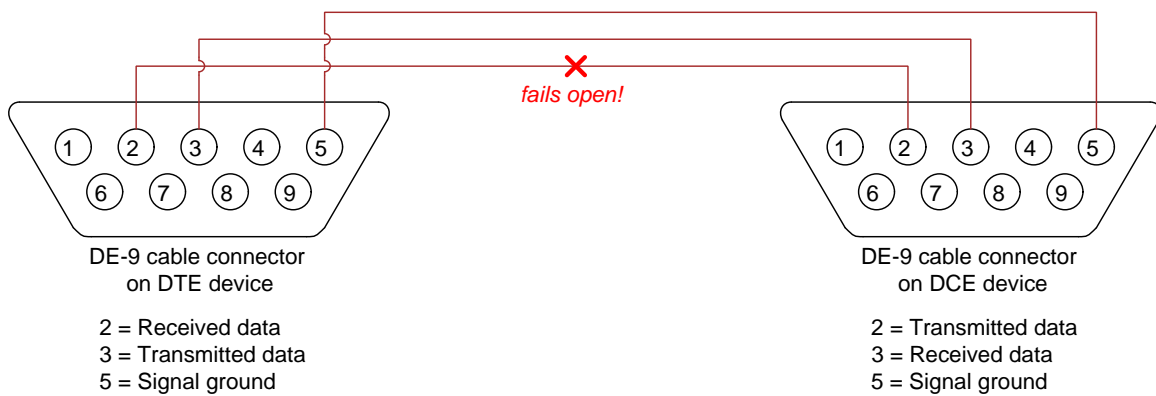
Sketch wire connections necessary to allow these two devices to communicate in full-duplex fashion:



---

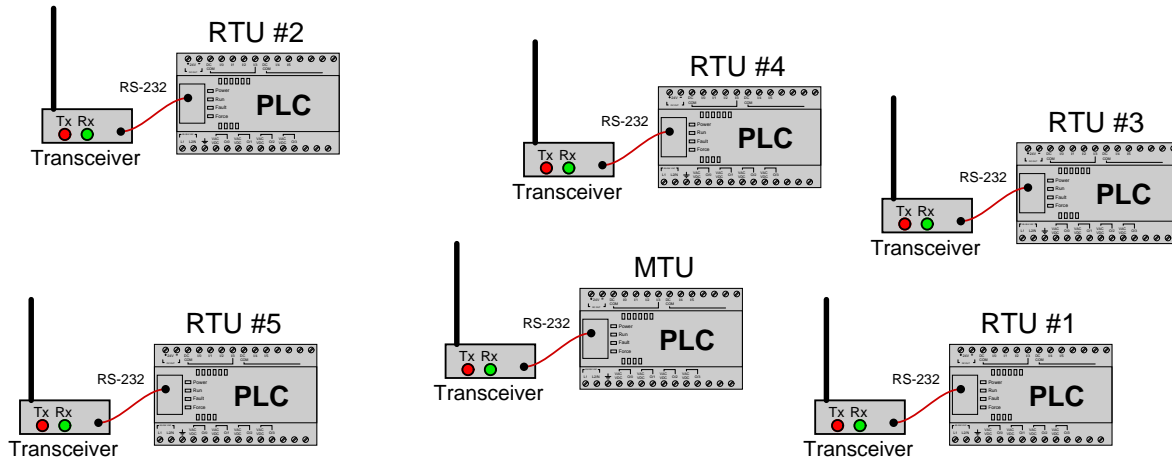
**Question 83**

Predict the likely effect(s) of a failed-open wire shown between two RS-232 devices:



### Question 84

In this SCADA system, a “master” PLC (MTU) communicates with multiple “slave” PLCs (RTUs) via radio using Modbus protocol. Each PLC communicates with its radio transceiver via a short RS-232 serial cable. All RTU radio transceiver units are identical, but the MTU transceiver has a greater power output (“transmit”) rating than the RTU transceivers:



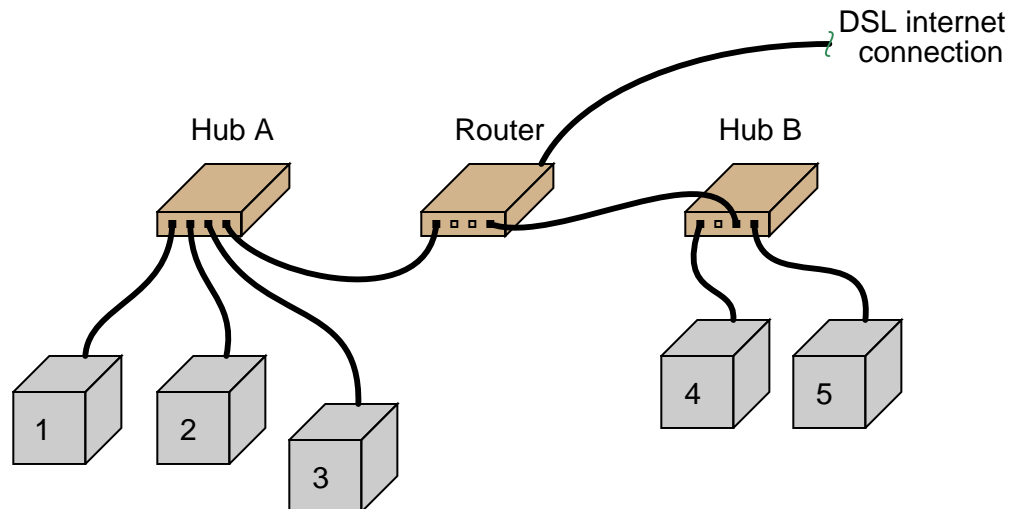
Unfortunately, there is a problem with this system. None of the RTUs are communicating with the MTU. Upon inspection, you find no blinking LED indicators on any of the RTU radio transceivers, and no blinking LED indicators on the MTU’s radio transceiver either.

Identify the likelihood of each specified fault for this system. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault could independently account for *all* measurements and symptoms in this SCADA network.

Fault	Possible	Impossible
Damaged antenna on MTU		
Damaged antenna on RTU #1		
PLC halted (not running) on MTU		
Conductor broken inside RS-232 cable on MTU		
PLC baud rate set incorrectly on MTU		
PLC baud rate set incorrectly on RTU #1		
Fresnel zone interference between MTU and RTU #1		

### Question 85

This Ethernet network has a problem in it somewhere:



- 1 can “ping” 3
- 5 can “ping” 2
- 4 cannot “ping” `www.bing.com`
- 3 cannot “ping” `www.google.com`

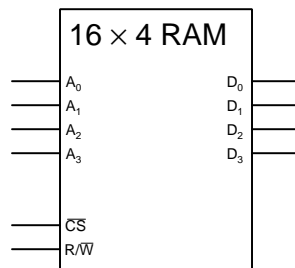
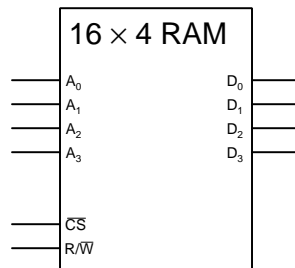
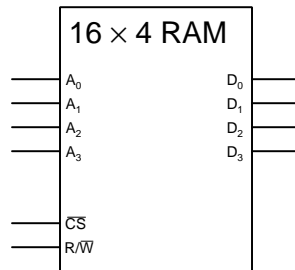
Identify the likelihood of each specified fault. Consider each fault one at a time (i.e. no coincidental faults), determining whether or not each fault is compatible with *all* measurements and symptoms in this system.

Fault	Possible	Impossible
Router failed		
Internet service provider failed		
Cable failed between computer #1 and Hub A		
Cable failed between computer #2 and Hub A		
Cable failed between computer #4 and Hub B		
Cable failed between computer #5 and Hub B		
Cable failed between Hub A and Router		
Cable failed between Hub B and Router		
Server failed at <code>www.google.com</code>		
Server failed at <code>www.bing.com</code>		

---

**Question 86**

Sketch the necessary address and data line connections to form a 16x12 memory array from these three 16x4 static RAM memory ICs:



Feel free to incorporate additional logic circuitry if necessary.

---

**Question 87**

Identify the numerical value stored in memory address 0x1004 after the third execution of the `staa` `PORTB` instruction in this Motorola 68HC11 assembly-language program:

```
PORTB equ $1004    ; Defines "PORTB" as memory address 0x1004
org $0100          ; Starting address for program
ldx PORTB          ; Loads x with address of Port B
ldaa #%00001111    ; Loads register A with the binary value 00001111

OuterLoop
    staa PORTB      ; Writes contents of register A to Port B
    ldy #$6f4d      ; Loads register Y with the hex value 0x6F4D

InnerLoop
    dey             ; decrements Y register
    bne InnerLoop   ; repeats "Loop" if Y not equal to 0

    deca            ; decrements A register
    bne OuterLoop   ; repeats OuterLoop if A not equal to 0
    bra OuterLoop   ; return
```

---

**Question 88**

This is a partial assembly-language program listing for a Microchip PIC 16F1719 microcontroller, intended to periodically blink a single LED (connected to pin 0 of Port B) on and off:

```
LOOP
    CALL DELAY1
    BSF PORTB,0 ; Set specified bit of Port B
    CALL DELAY1
    BCF PORTB,0 ; Clear specified bit of Port B
    GOTO LOOP

DELAY1
    MOVLW 0xa0 ; Delay time loaded into W
    MOVWF 0x20 ; Move from W to an address in General RAM (0x20)
INNERLOOP1
    CALL DELAY2
    DECFSZ 0x20, 1 ; Decrement and skip next instruction if zero
    GOTO INNERLOOP1
    RETURN

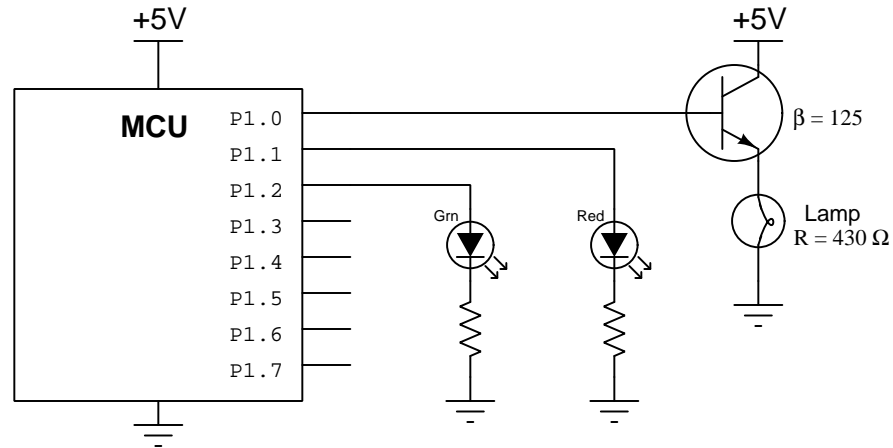
DELAY2
    MOVLW 0xff ; Delay time loaded into W
    MOVWF 0x21 ; Move from W to an address in General RAM (0x21)
INNERLOOP2
    DECFSZ 0x21, 1 ; Decrement and skip next instruction if zero
    GOTO INNERLOOP2
    RETURN

END
```

Identify *two* different modifications you could make to this to cause the LED to blink at a faster rate.

### Question 89

This microcontroller drives multiple load devices using pins associated with Port 1:



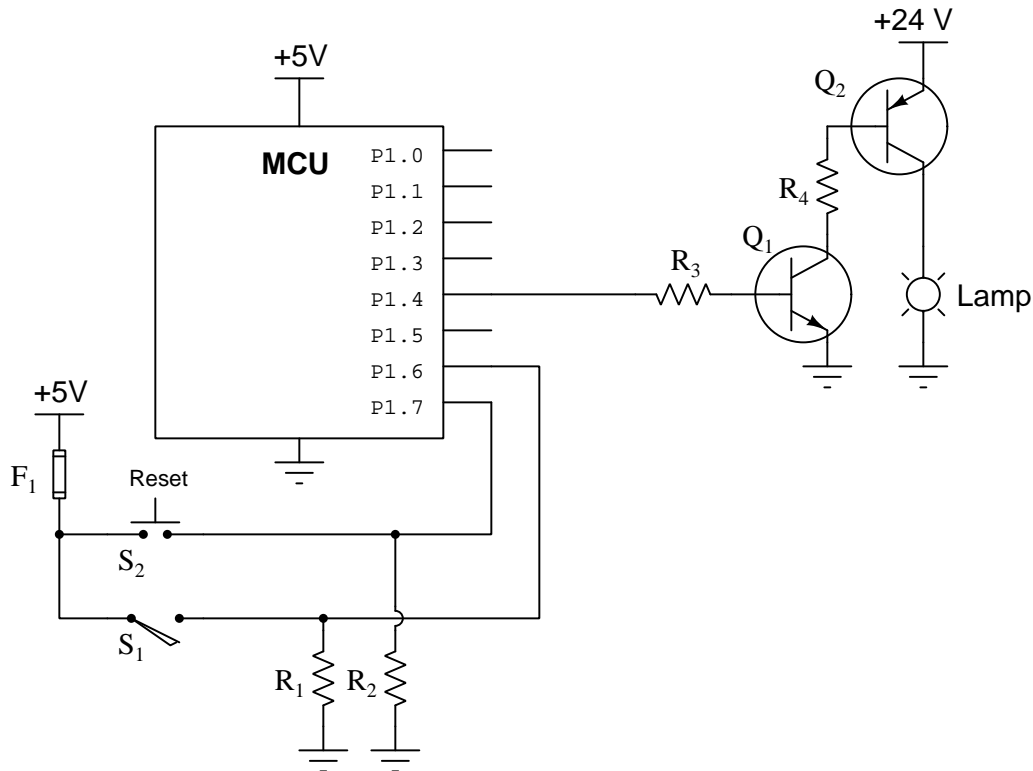
Assuming the output word for port 1 is 0x05, the microcontroller's output lines are capable of full +5 and 0 Volt output (i.e. swinging rail-to-rail), a forward voltage drop of 1.7 Volts for the red LED, and a forward voltage drop of 1.8 Volts for the green LED, calculate the following:

- Current through the transistor's collector terminal =
- Current through the transistor's emitter terminal =
- Proper resistor size to limit current through the red LED to 5 mA when on =
- Voltage between base and emitter terminals of the transistor =

### Question 90

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 "low" 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.

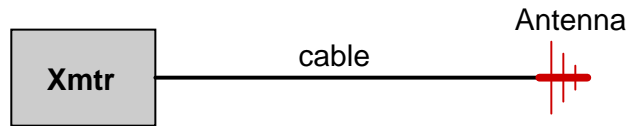
Fault	Possible	Impossible
Switch $S_1$ failed open		
Transistor $Q_1$ failed open collector-emitter		
Transistor $Q_2$ failed open collector-emitter		
Fuse $F_1$ blown		
Transistor $Q_1$ failed shorted collector-emitter		
Transistor $Q_2$ failed shorted collector-emitter		
Resistor $R_3$ failed open		



---

**Question 91**

A radio transmitter connects to an antenna through a coaxial cable. The output of the transmitter (measured at the beginning of the cable) is 130 Watts. The cable is 12 feet long, and has a loss rating of 0.05 dB per foot. Calculate the amount of RF power available at the end of the cable where it connects to the antenna:

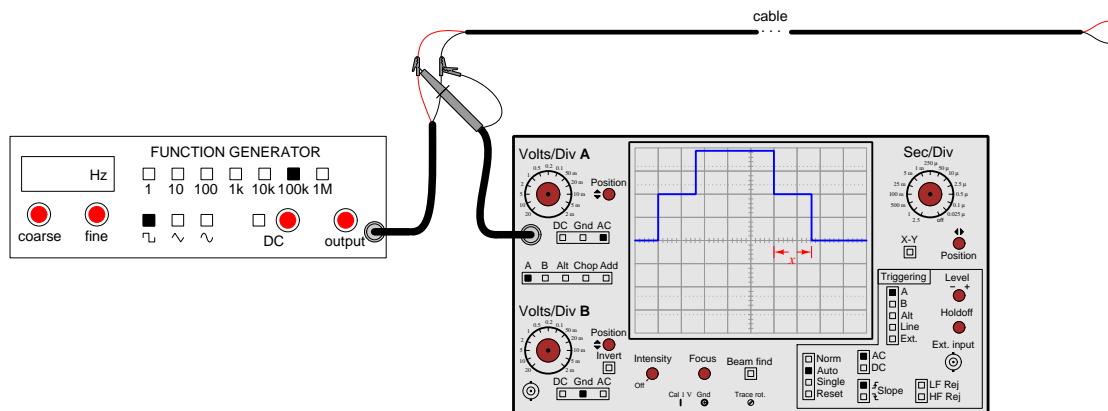


$P_{antenna} = \underline{\hspace{2cm}}$  Watts

---

**Question 92**

The following cable is 25 meters in length with a characteristic impedance of 100 Ohms, and the pulse waveform's "step" ( $x$ ) is 0.22 microseconds in duration:



Given this information, calculate the cable's velocity factor:

Velocity factor =

---

**Question 93**

Specify a pair of primary and secondary turns values for an impedance-matching transformer intended to match a 600 Ohm feedline to a 73 Ohm antenna. Note that multiple correct answers exist for this problem!

$N_p$  (feedline side) = \_\_\_\_\_ turns

$N_s$  (antenna side) = \_\_\_\_\_ turns

Miscellaneous reference formulae:

$$\Gamma = \frac{V_r}{V_f} = \frac{Z_{term} - Z_{line}}{Z_{term} + Z_{line}} \qquad \text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

$$\frac{Z_p}{Z_s} = \left( \frac{N_p}{N_s} \right)^2 \qquad \text{Velocity factor} = \frac{v}{c} = \frac{1}{\sqrt{\epsilon_r}}$$

$$Z_{section} = \sqrt{Z_{feedline} Z_{antenna}} \qquad \text{VSWR} = \frac{V_{max}}{V_{min}}$$

$$c = \lambda f \approx 2.9979 \times 10^8 \text{ m/s} \qquad f_r = \frac{1}{2\pi\sqrt{LC}}$$

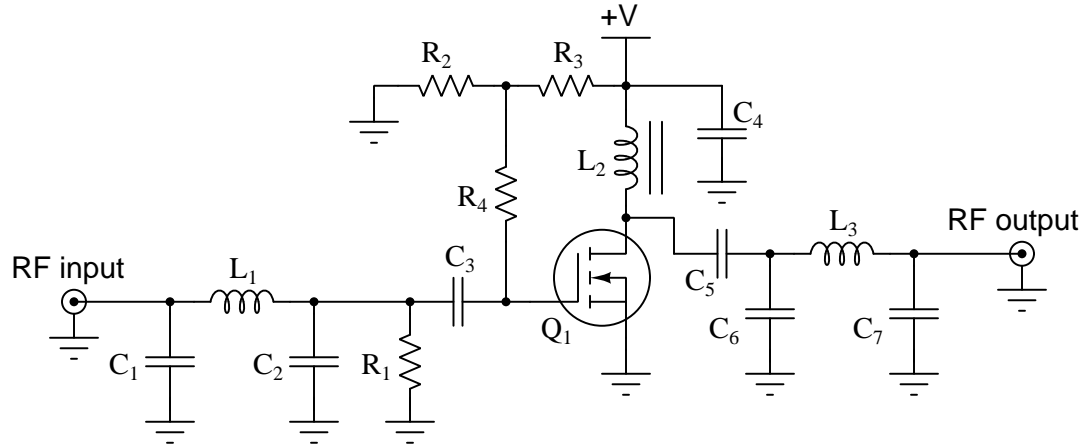
$$L_p = -20 \log \left( \frac{4\pi D}{\lambda} \right) \qquad P_{tx(min)} = P_{rx(min)} - (G_{total} + L_{total})$$

$$r = \sqrt{\frac{n\lambda d_1 d_2}{D}} \qquad 1 \text{ inch} = 2.54 \text{ cm} \qquad 1 \text{ foot} = 12 \text{ inches}$$

---

**Question 94**

Identify the purpose of the first three listed components and also identify the component(s) fulfilling the listed function in the following RF amplifier circuit:



- $L_2$
- $R_2$  and  $R_3$
- $C_5$
- Component(s) tuning the amplifier to a desired frequency

---

**Question 95**

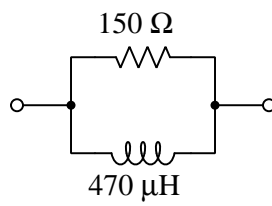
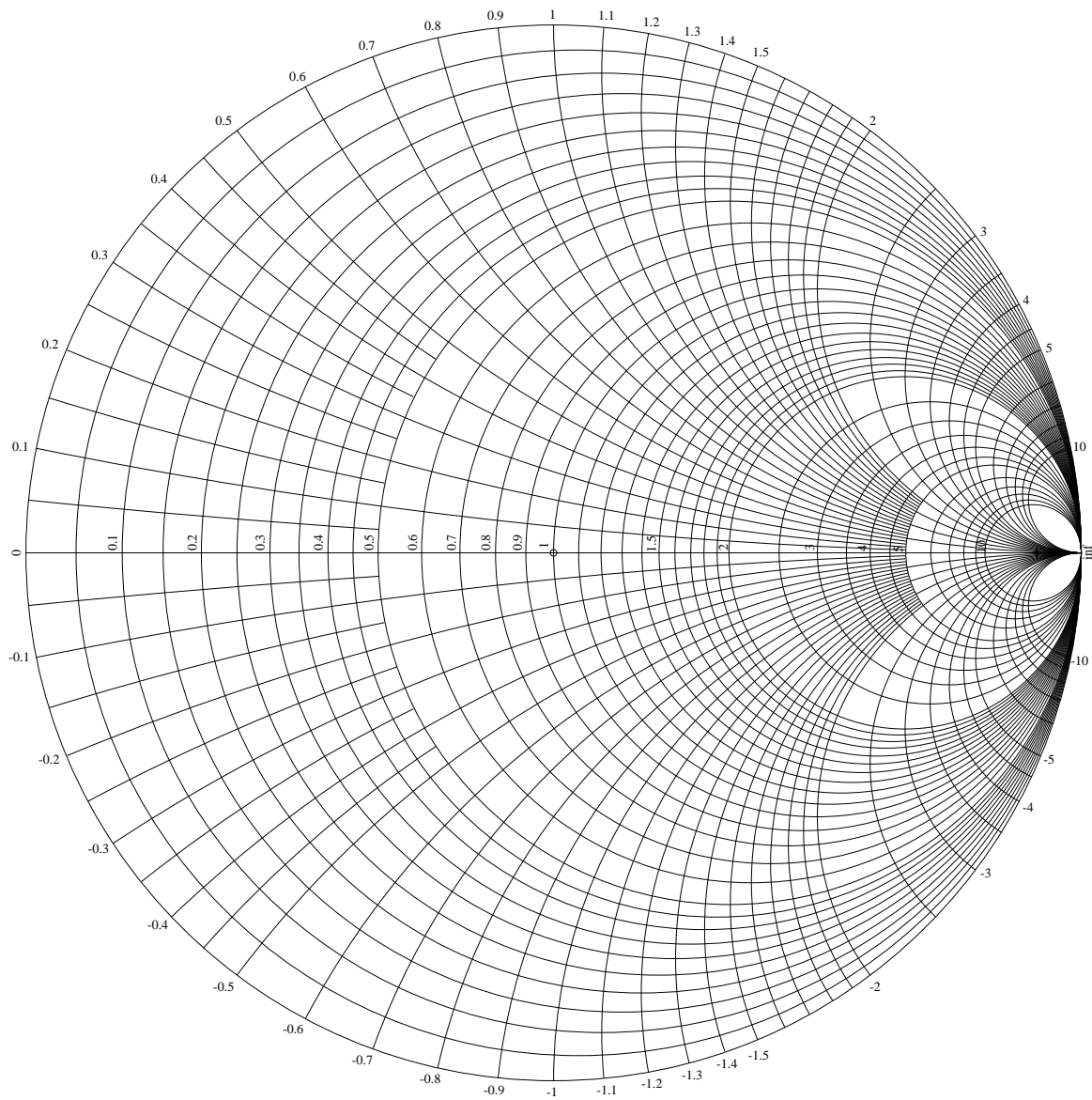
List three distinct frequencies that will be present at the output of an unbalanced mixer circuit given the following input signals:

- **Input signal A** – 2.5 kHz square wave
- **Input signal B** – 1 kHz sine wave

Note that there may be more than three distinct frequencies present in the output signal's spectrum, but that you need only list three of them. *Every frequency you list must be correct in order for the answer to be correct!*

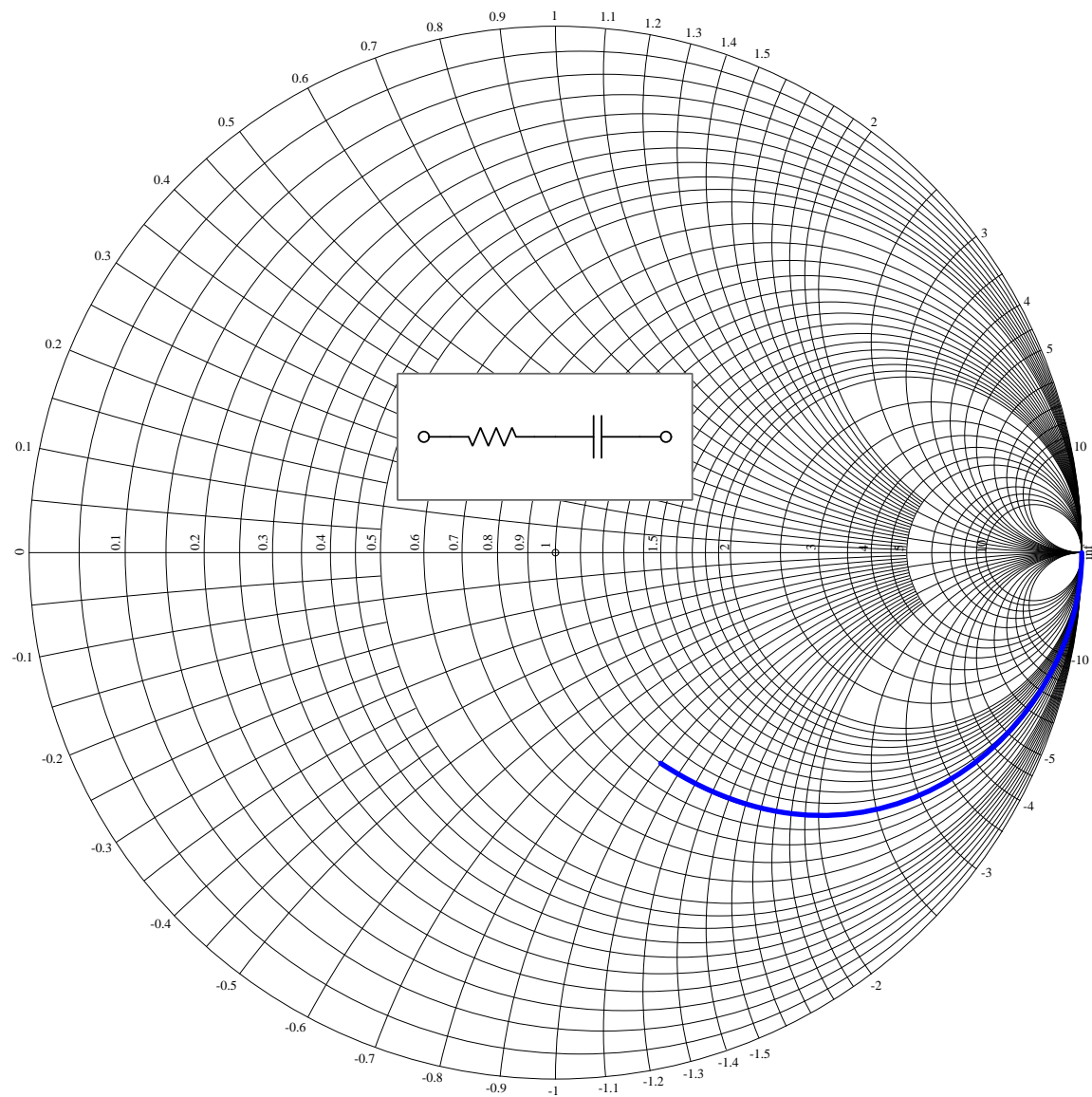
### Question 96

Mark a point on the Smith chart below representing the impedance of the network shown at a frequency of 30 kHz, assuming the chart is normalized to 50 Ohms:



### Question 97

The following Smith chart shows the frequency-sweep analysis for a simple network's total impedance ( $Z_{total}$ ):



Sketch a new curve on the chart showing another impedance analysis over the same frequency sweep range, assuming a second resistor of the same value as the original resistor has been added in series.

---

**Question 98**

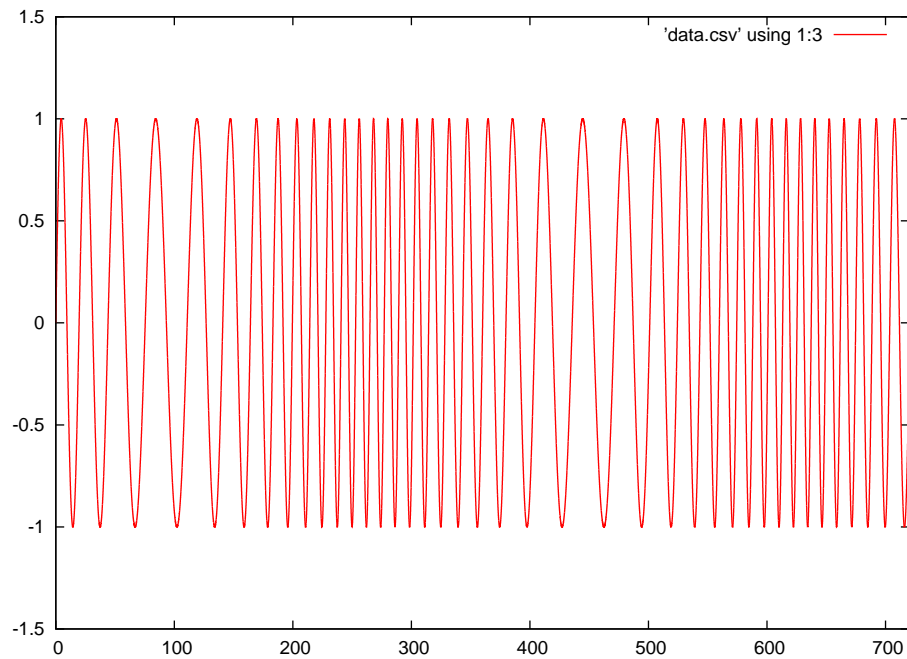
Sketch an illustration of a half-wave loop antenna, and calculate its ideal perimeter length in both meters and inches if designed to resonate at a fundamental frequency of 250 kHz.

Length = \_\_\_\_\_ meters = \_\_\_\_\_ inches

---

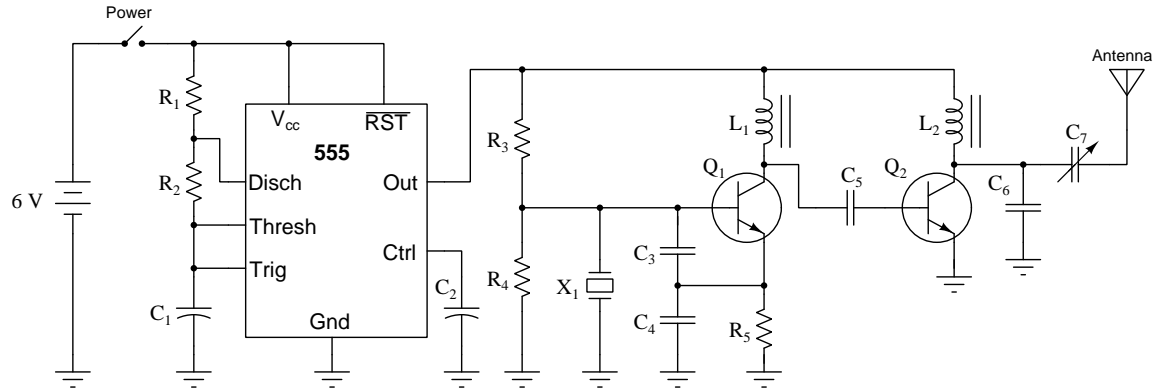
**Question 99**

Identify the type of modulation evident in this oscillograph, being as specific as you can (e.g. modulation format and also whether it is digital or analog):



### Question 100

Identify the effect that a failed-shorted capacitor  $C_1$  will have on this beacon transmitter's output to the antenna:



Be sure to explain *why* the fault has the effect that it does!

*This page intentionally blank*



---

**Answer 1**

Resistor color code = Brown, Grey, Red, Gold = 1.8 k $\Omega$

$$V = 9.0 \text{ V}$$

$$P = 45.0 \text{ mW}$$

---

**Answer 2**

**Brown - Blue - Orange - Silver**

- Nominal (ideal) value = 16,000 Ohms
- Lowest tolerable value = 14,400 Ohms
- Highest tolerable value = 17,600 Ohms

**Yellow - Black - Red - Gold**

- Nominal (ideal) value = 4,000 Ohms
  - Lowest tolerable value = 3,800 Ohms
  - Highest tolerable value = 4,200 Ohms
- 

**Answer 3**

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

- Channel 1  $V_{pk} = \underline{550 \text{ mV}}$
  - Channel 2  $V_{pk-pk} = \underline{560 \text{ mV}}$
  - Frequency = 455.6 Hz
  - Phase shift = 55.8 $^\circ$
  - Channel 2 lags Channel 1
- 

**Answer 4**

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

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

---

**Answer 5**

Guy wire length = 47.856

Height of attachment point = 32.638 meters

---

**Answer 6**

(Answer rounded to the nearest minor division)

Meter indication = 14 Ohms

---

**Answer 7**

$$I_C = \underline{59.727 \text{ mA}}$$

---

**Answer 8**

$$450 \text{ feet/second} = 493776 \text{ centimeters/hour}$$

---

**Answer 9**

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

---

**Answer 10**

Time = 1 second (any answer between 0.75 seconds and 1.25 seconds is acceptable)

**Credit for graph:**

Todd, Victor H., *Protective Relays – their theory, design, and practical operation*, First Edition, Fourth Impression, McGraw-Hill Book Company, Inc., New York, 1922.

---

**Answer 11**

- $I_{R2} = 203.5 \text{ mA}$
  - $I_{R1} = 120.4 \text{ mA}$
  - $V_{TP2-TP1} = 0 \text{ V}$
  - $P_{R3} = 9.639 \text{ W}$
- 

**Answer 12**

$I_{R1} = 6 \text{ mA}$  – arrow pointing up, from B to A

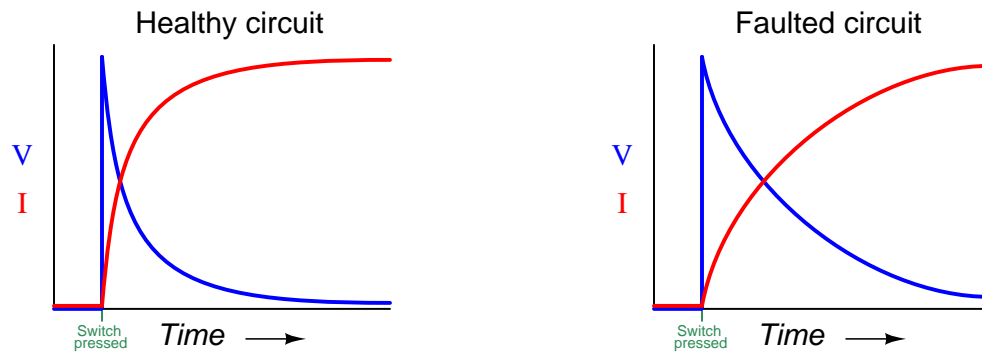
$V_{DF} = 6 \text{ V}$  – D negative (–) and F positive (+)

---

**Answer 13**

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

---

**Answer 14**

---

**Answer 15**

- $V_C$  14 seconds following switch closure = **6.863 V**
- $V_{TP1-TP4}$  30 seconds following switch closure = **12 V**
- $I_R$  at the moment the switch closes = **2.40 mA**

---

**Answer 16**

- $V_{TP2-TP4}$  20 milliseconds following switch flip = **0 V**
- $I_R$  100 milliseconds following switch flip = **7.388 mA**
- $V_L$  70 milliseconds following switch flip = **1.173 V**

---

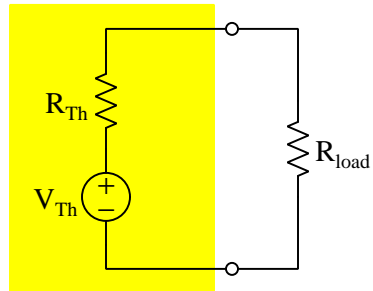
**Answer 17**

- Voltage across  $R_1$  = **4 Volts** + right and – left
- Voltage across  $I_2$  = **12 Volts** + top and – bottom
- Current through  $V_1$  = **2 Amperes** down
- $I_1$  acting as a **source**

---

**Answer 18**

*Thevenin equivalent network*



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

---

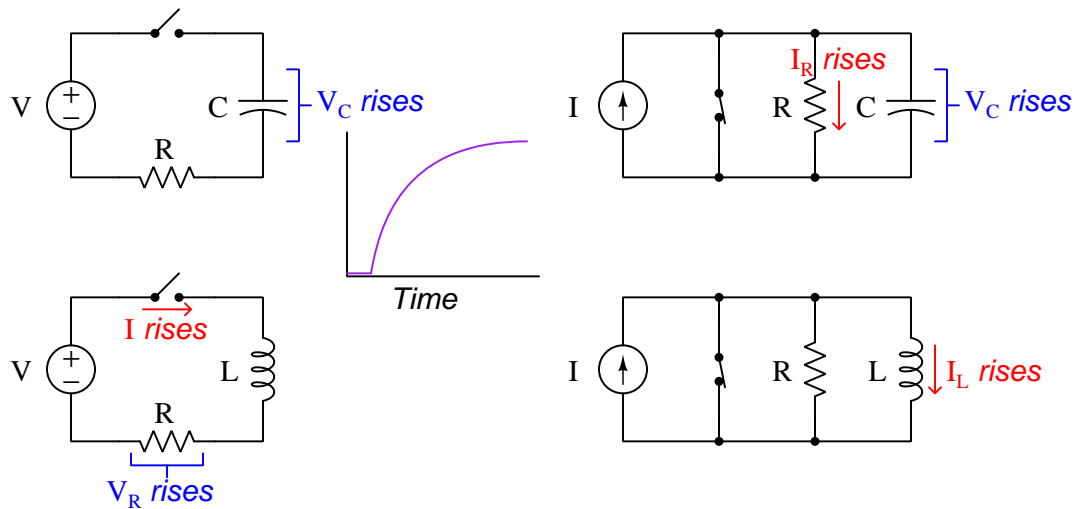
**Answer 19**

The resistor with the output terminals must be 440  $\Omega$ , connected in series with the 2.2 k $\Omega$  resistor.

---

**Answer 20**

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



---

**Answer 21**

$$V_{load(pk)} = \underline{161.94 \text{ V}}$$

$I_{load}$  = counter-clockwise through the circuit

---

**Answer 22**

$$V_R = \underline{84 \text{ V} \angle 0^\circ}$$

$$V_L = \underline{282.743 \text{ V} \angle 90^\circ}$$

$$Z_{total} = \underline{38.3688 \Omega \angle 43.1337^\circ}$$

$$V_{src} = \underline{115.106 \text{ V} \angle 43.1337^\circ}$$

---

**Answer 23**

$$L_1 = \underline{3.6885 \text{ mH}}$$

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

---

**Answer 24**

$$V_{load} = 7.5 \text{ V}$$

$$R_{load} = 4.167 \Omega$$

---

**Answer 25**

- Current through source **increases**
  - Voltage across  $C$  **decreases**
  - Voltage across  $R$  **increases**
- 

**Answer 26**

$$V_{line} = \underline{381.1} \text{ Volts}$$

$$I_{line} = \underline{1.784} \text{ Amperes}$$

$$I_{phase} \text{ (load)} = \underline{1.030} \text{ Amperes}$$

---

**Answer 27**

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

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

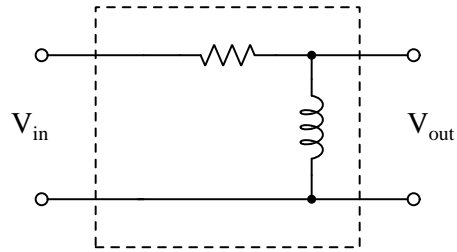
$$I_{phase} \text{ (source)} = \underline{1.2} \text{ Amperes}$$

---

**Answer 28**

$$I_{line} = 31.06 \text{ Amperes}$$

---

**Answer 29**

$$L = 55 \text{ mH} ; R = 2.073 \text{ k}\Omega$$

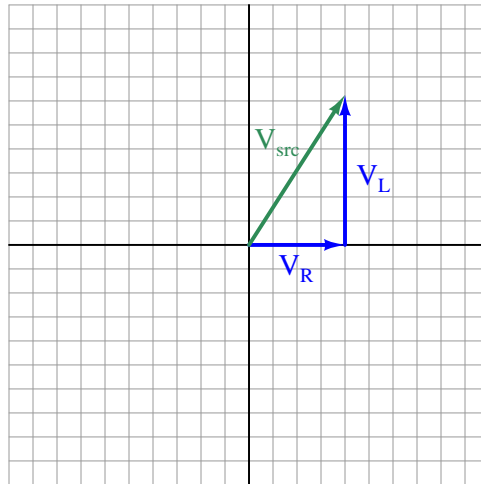
$$L = 100 \text{ mH} ; R = 3.770 \text{ k}\Omega$$

$$L = 175 \text{ mH} ; R = 6.597 \text{ k}\Omega$$

---

**Answer 30**

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



$$V_R = 40.5000 \text{ V} \angle 0^\circ$$

$$V_L = 62.8319 \text{ V} \angle 90^\circ$$

$$V_{total} = 74.7535 \text{ V} \angle 57.1951^\circ$$

---

**Answer 31**

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

---

**Answer 32**

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

---

**Answer 33**

The “AC/GND/DC” three-position lever switch above the Channel 1 BNC connector.

---

**Answer 34**

This is a logic probe, useful for detecting high/low states in digital logic circuits.

---

**Answer 35**

Connect the red test probe to test point **E** and the black probe to point **B**.

Voltage measurement = **11.96375** Volts

---

**Answer 36**

Connect the probe to the 555 timer’s Output terminal and the ground clip to ground.

---

**Answer 37**

$t_{on} = 1.8 \text{ div}$        $t_{off} = 0.6 \text{ div}$       Duty cycle = 75.0%       $P_{pk} = 108 \text{ W}$

$V_{pk} =$ **23.2379** Volts

---

**Answer 38**

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

---

**Answer 39**

Touch the pulser to each input, one at a time, while keeping the other inputs “high”. The logic probe should indicate pulses as soon as the pulser probe makes contact with a gate input terminal.

---

**Answer 40**

Measuring DC voltage between the collector of  $Q_2$  and ground should show a pulsing voltage as the retractor rotates. Alternatively, breaking the connection between the base of  $Q_1$  and the collector of  $Q_2$  and then measuring DC current between those disconnected points would prove the same.

---

**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		✓

---

**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		✓

---

**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		✓

---

**Answer 44**

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

---

**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	✓	



---

**Answer 46**

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		✓

---

**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**

Red-Red-Brn-Gld should be  $220\ \Omega \pm 5\%$ , allowing for a range of 209  $\Omega$  to 231  $\Omega$ . Thus 205  $\Omega$  is **too low**.

---

**Answer 49**

If  $R_6$  fails open, neither  $Q_3$  nor  $Q_6$  will be able to turn on, the result being that the AC load only receives pulsed DC when  $Q_4$  and  $Q_5$  turn on (positive on right and negative on left).

---

**Answer 50**

These form an  $LC$  low-pass filtering network for the speaker, which is only supposed to reproduce low-frequency tones.

**Credit for schematic:**

US Patent 5,973,368 (“Monolithic Class D Amplifier”) by Lawrence G. Pearce and Donald F. Hemmenway.

---

**Answer 51**

With switch closed

$$V_{load} = \underline{17.3 \text{ V}}$$

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

With switch open

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

$$V_{switch} = \underline{18 \text{ V}}$$

---

**Answer 52**

$$P_Q = \underline{2.87 \text{ Watts (minimum)}}$$

---

**Answer 53**

$$A_V = 4.7 \text{ (unitless ratio)}$$

$$A_V = 13.44 \text{ dB}$$

---

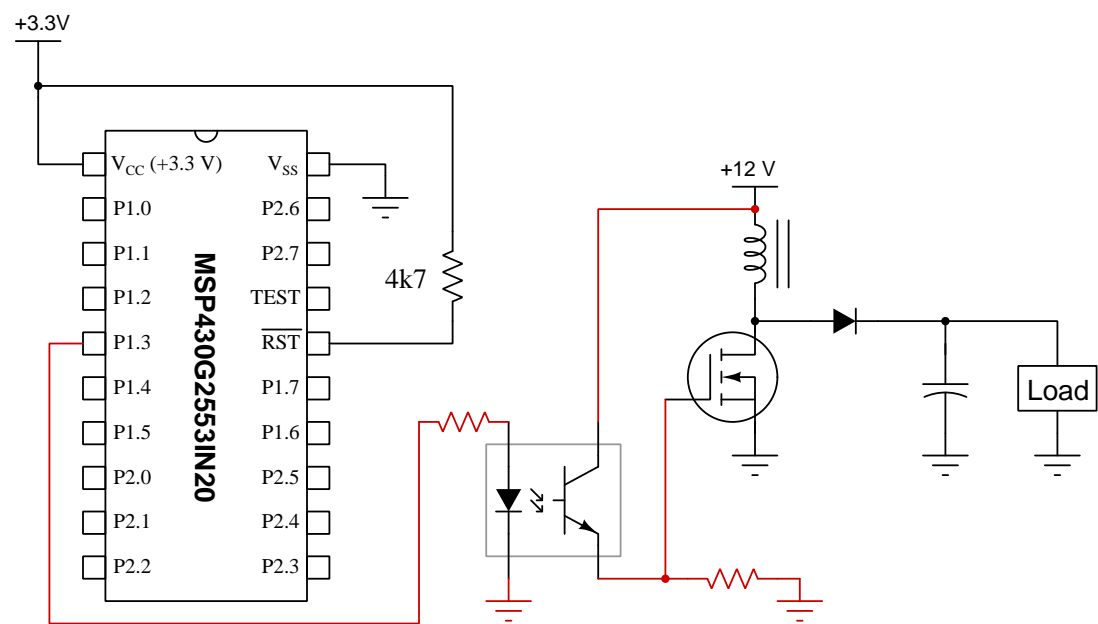
**Answer 54**

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

$$C_1 = C_2 = \underline{8.271 \text{ nF}}$$

Answer 55

This is one possible solution:



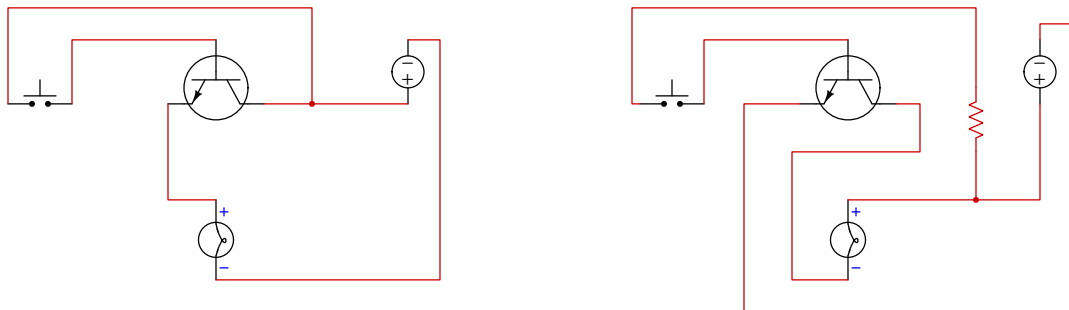
Answer 56

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		✓

---

**Answer 57**

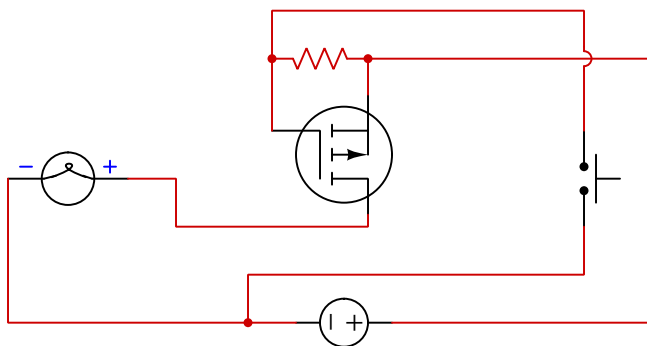
Two possible solutions, one requiring a resistor and one not requiring a resistor, are shown below. Note that solutions other than these may be possible!



---

**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**

$$R_{DS(on)} = \underline{\mathbf{0.2551\ Ohms\ (maximum)}}$$

---

**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	✓	

---

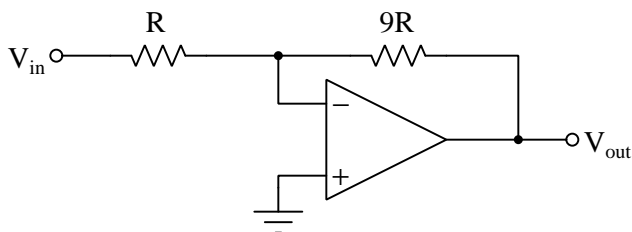
**Answer 61**

$$V_{ref} = \text{greater than 3 Volts and less than 6 Volts}$$

---

**Answer 62**

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



---

**Answer 63**

$$V_{TP1} = +1 \text{ V}$$

$$V_{TP2} = +1 \text{ V}$$

$$I_{R3} = 200 \text{ } \mu\text{A}$$

$$V_{out} = -2.5 \text{ V}$$

---

**Answer 64**

$$I_{R2} = 0.4625 \text{ mA (arrow pointing upwards)}$$

---

**Answer 65**

$$V_A = 1.21569 \text{ V} ; V_B = 1 \text{ V} ; V_D = 1.01307 \text{ V} ; I_C = 13.0719 \text{ } \mu\text{A (moving left)}$$

$$V_{out} = \underline{1.07843 \text{ Volts}}$$

$$V_{R7} = \underline{0.202614 \text{ Volts}}$$

---

**Answer 66**

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

**Answer 67**

$$V_{out1} = \underline{0} \text{ Volts}$$

$$V_{out2} = \underline{\pm 4} \text{ Volts}$$

---

**Answer 68**

$$\frac{dV_{out}}{dt} = \underline{-54.55} \text{ Volts/second}$$

---

**Answer 69**

$$V_{out} = \underline{\pm 0.01551} \text{ Volts}$$

---

**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		✓

---

**Answer 71**

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

---

**Answer 72**

One possible solution is an SR latch with active-low 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.

---

**Answer 73**

Fall time is seen at periods (312) and (314), on each of the negative slopes.

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.

---

**Answer 74**

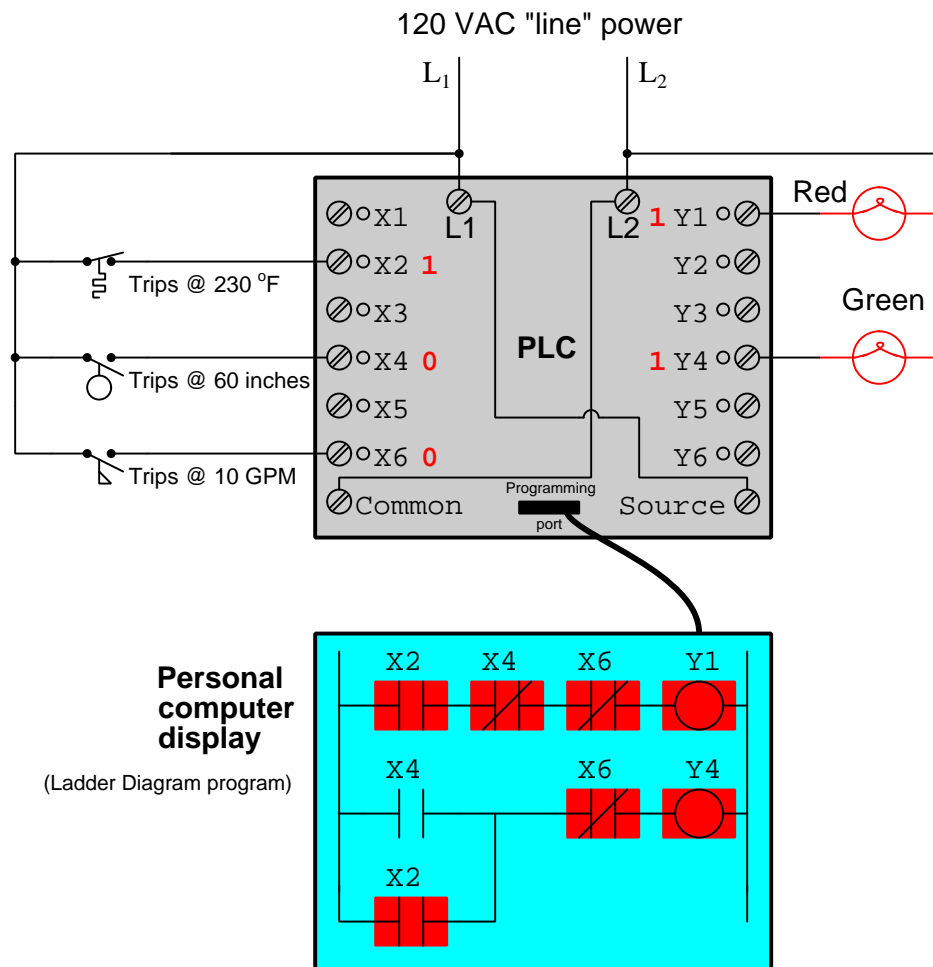
$$C_1 \text{ (new)} = \underline{\underline{2.287 \mu\text{F}}}$$

---

**Answer 75**

0x1A3 equates to 40.958% of the 0-5 VDC converter range, or 2.0479 Volts. This requires  $R$  to have a value of 24.6765 k $\Omega$ .

---

**Answer 76**

Bit X2 will be: **1**

Bit X4 will be: **0**

Bit X6 will be: **0**

The red lamp will be: **on**

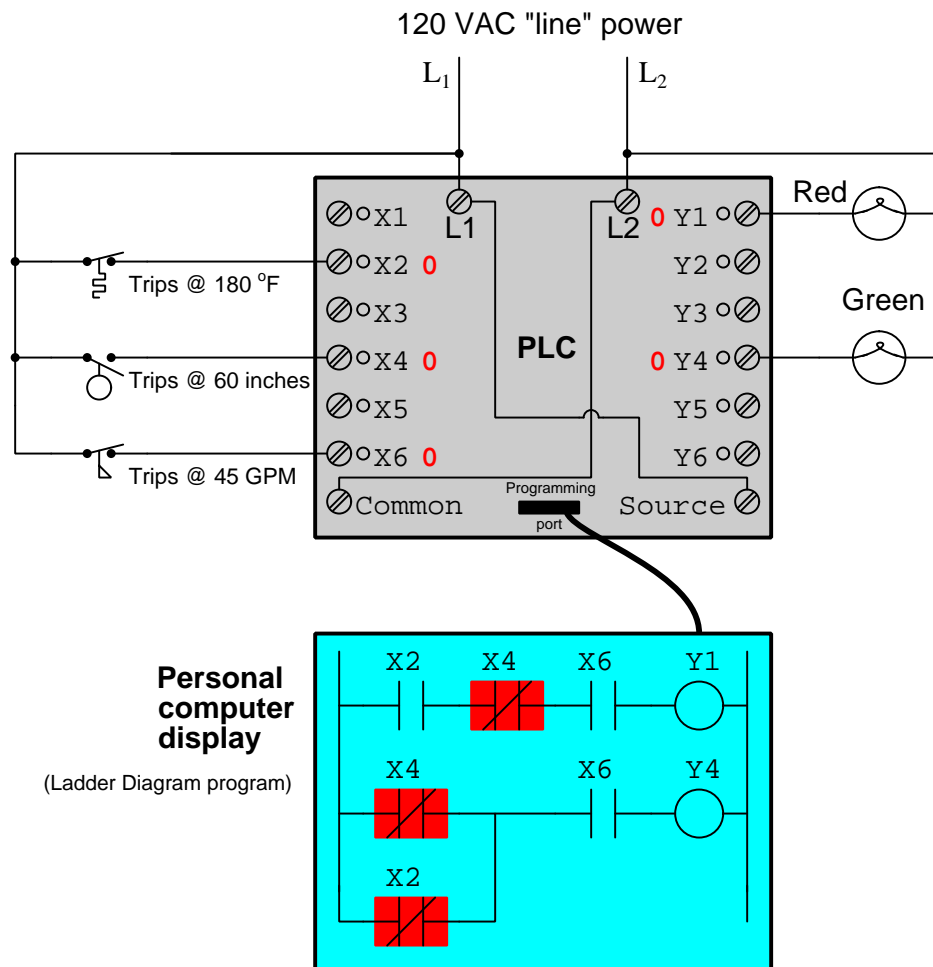
The green lamp will be: **on**

---

**Answer 77**

The red lamp will be: **on**

The green lamp will be: **on**



Bit X2 will be: **0**

Bit X4 will be: **0**

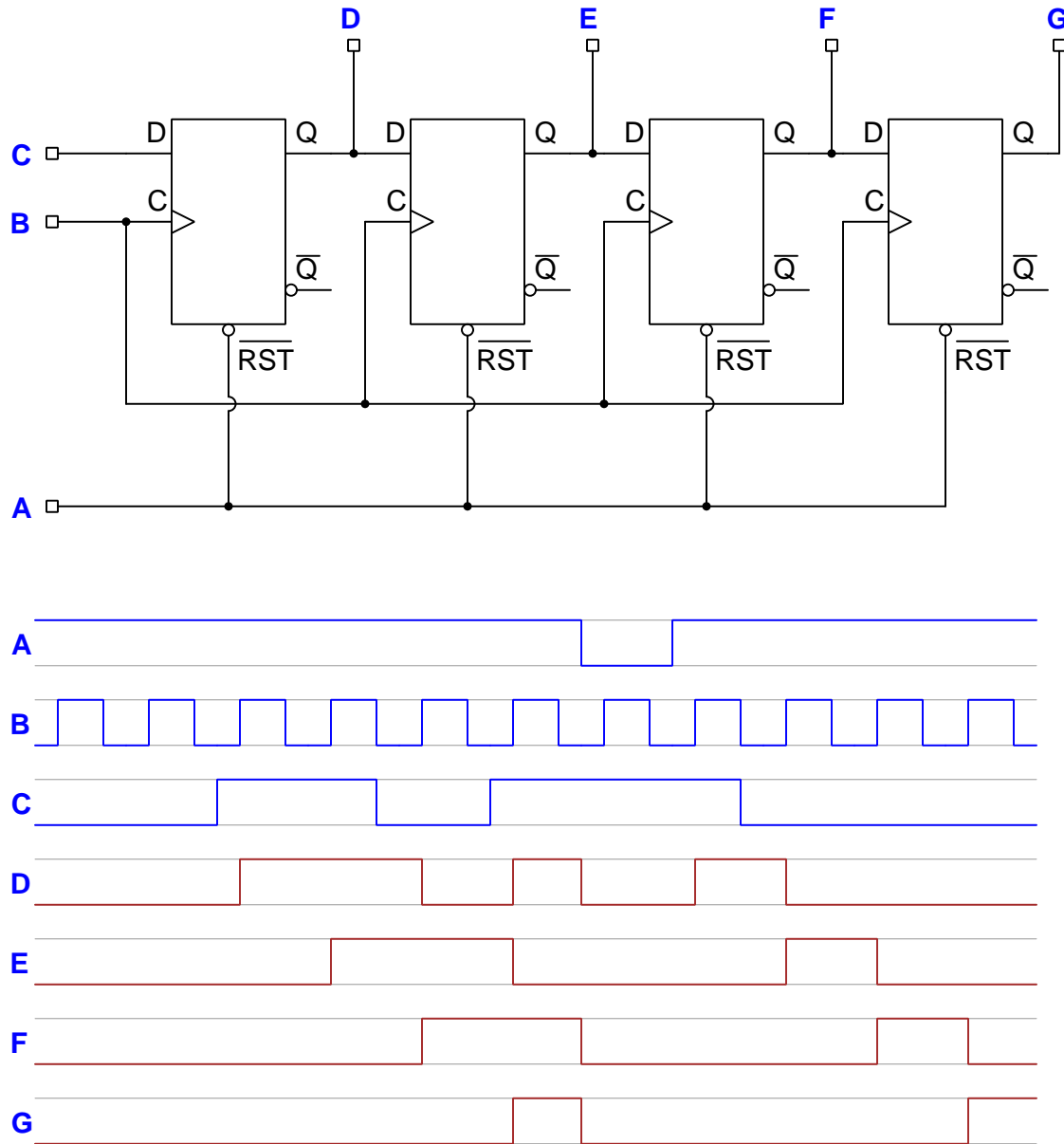
Bit X6 will be: **0**

The red lamp will be: **off**

The green lamp will be: **off**



---

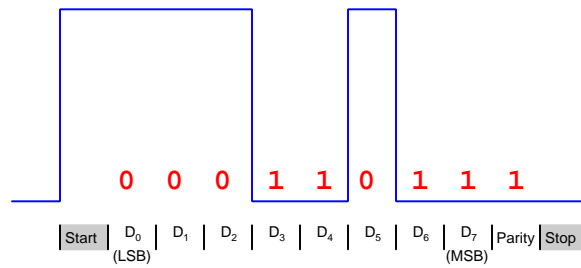
**Answer 79**

---

**Answer 80**

Figure **D** will result in the least amount of capacitive coupling.

---

**Answer 81**

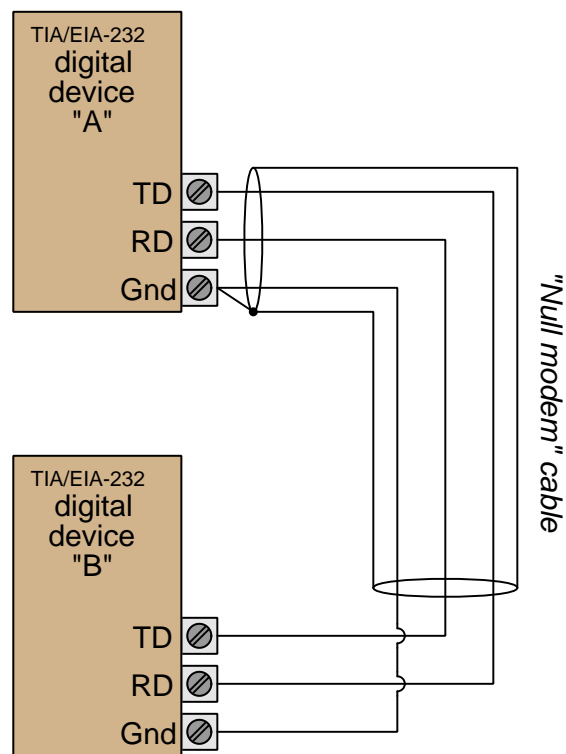
Data = 1101 1000 (write in normal binary order, MSB left and LSB right)

Parity = **correct**

---

**Answer 82**

What we need is a “null-modem” connection:



The shield and its connection to ground is optional.

---

**Answer 83**

The DTE device will no longer be able to receive data from the DCE device.

---

**Answer 84**

Fault	Possible	Impossible
Damaged antenna on MTU		✓
Damaged antenna on RTU #1		✓
PLC halted (not running) on MTU	✓	
Conductor broken inside RS-232 cable on MTU	✓	
PLC baud rate set incorrectly on MTU		✓
PLC baud rate set incorrectly on RTU #1		✓
Fresnel zone interference between MTU and RTU #1		✓

---

**Answer 85**

Fault	Possible	Impossible
Router failed	✓	✓
Internet service provider failed	✓	
Cable failed between computer #1 and Hub A		✓
Cable failed between computer #2 and Hub A		✓
Cable failed between computer #4 and Hub B		✓
Cable failed between computer #5 and Hub B		✓
Cable failed between Hub A and Router		✓
Cable failed between Hub B and Router		✓
Server failed at <a href="http://www.google.com">www.google.com</a>		✓
Server failed at <a href="http://www.bing.com">www.bing.com</a>		✓

A failed router is possible if only the DSL port is bad but the Ethernet ports are still working fine. However, if a student assumes a router “failure” means a complete failure then this is not possible.

---

**Answer 86**

Parallel address lines  $A_0$  through  $A_3$ , parallel the read/write lines, tie all chip select lines low, and let data lines  $D_0$  through  $D_3$  of one IC be the  $D_0$  through  $D_3$  of the array while letting lines  $D_0$  through  $D_3$  of the next IC be the  $D_4$  through  $D_7$  lines of the array and  $D_0$  through  $D_3$  of the last IC be the  $D_8$  through  $D_{11}$  of the array.

---

**Answer 87**

0x1004 = 0b00001101 after third execution

---

**Answer 88**

Either delay loop's delay time may be shortened. Thus, editing either of the following lines to have a smaller value loaded into the W register will suffice:

```
MOVLW 0xa0 ; Delay time loaded into W
```

```
MOVLW 0xff ; Delay time loaded into W
```

---

**Answer 89**

- Current through the transistor's collector terminal = **9.9206 mA**
  - Current through the transistor's emitter terminal = **10 mA**
  - Proper resistor size to limit current through the red LED to 5 mA when on = **660  $\Omega$**
  - Voltage between base and emitter terminals of the transistor = **0.7 V**
- 

**Answer 90**

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 91**

$$P_{\text{antenna}} = \underline{\underline{113.23}} \text{ Watts}$$

---

**Answer 92**

$$\text{Velocity factor} = \underline{\underline{0.75811}}$$

---

**Answer 93**

Any pair of values having the correct turns ratio (**2.8669 : 1**) is acceptable, including these:

$$N_p \text{ (feedline side)} = \underline{\underline{86}} \text{ turns}$$

$$N_s \text{ (antenna side)} = \underline{\underline{30}} \text{ turns}$$

---

**Answer 94**

- $L_2$  is a choke to block RF from getting to the DC bus
- $R_2$  and  $R_3$  together form a voltage divider to properly bias MOSFET  $Q_1$
- $C_5$  passes RF to the output while blocking DC – may also serve a minor role in impedance-matching to the feedline and antenna
- Component(s) tuning the amplifier to a desired frequency –  $C_1/L_1/L_2$  tune the input while  $C_6/L_3/C_7$  tune the output

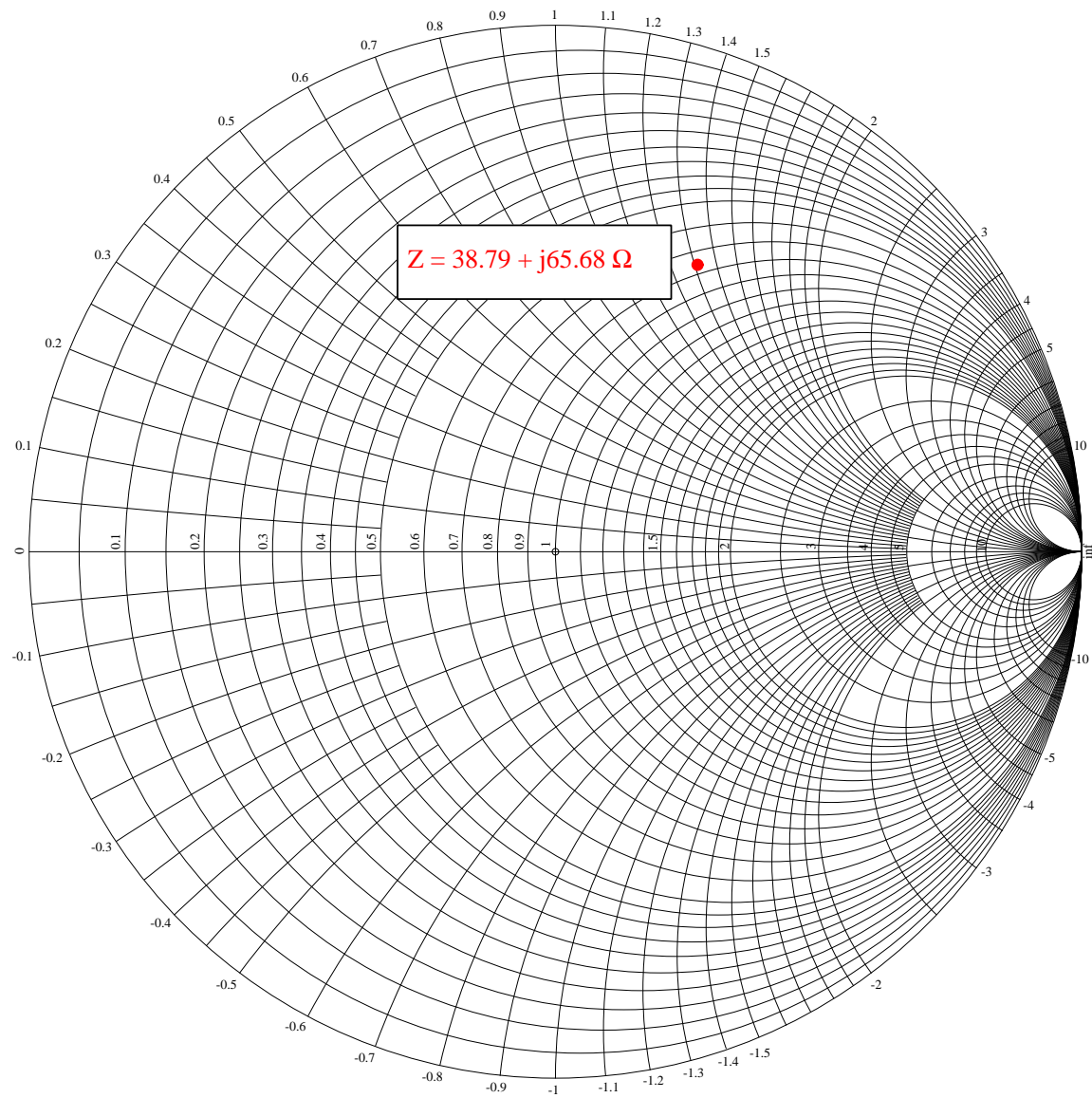
*Note: for the last question the minimal answer is to identify at least two components within one of those tuning networks.*

---

**Answer 95**

Just some of the frequencies present in the output signal spectrum (only considering the first three harmonics of signal A):

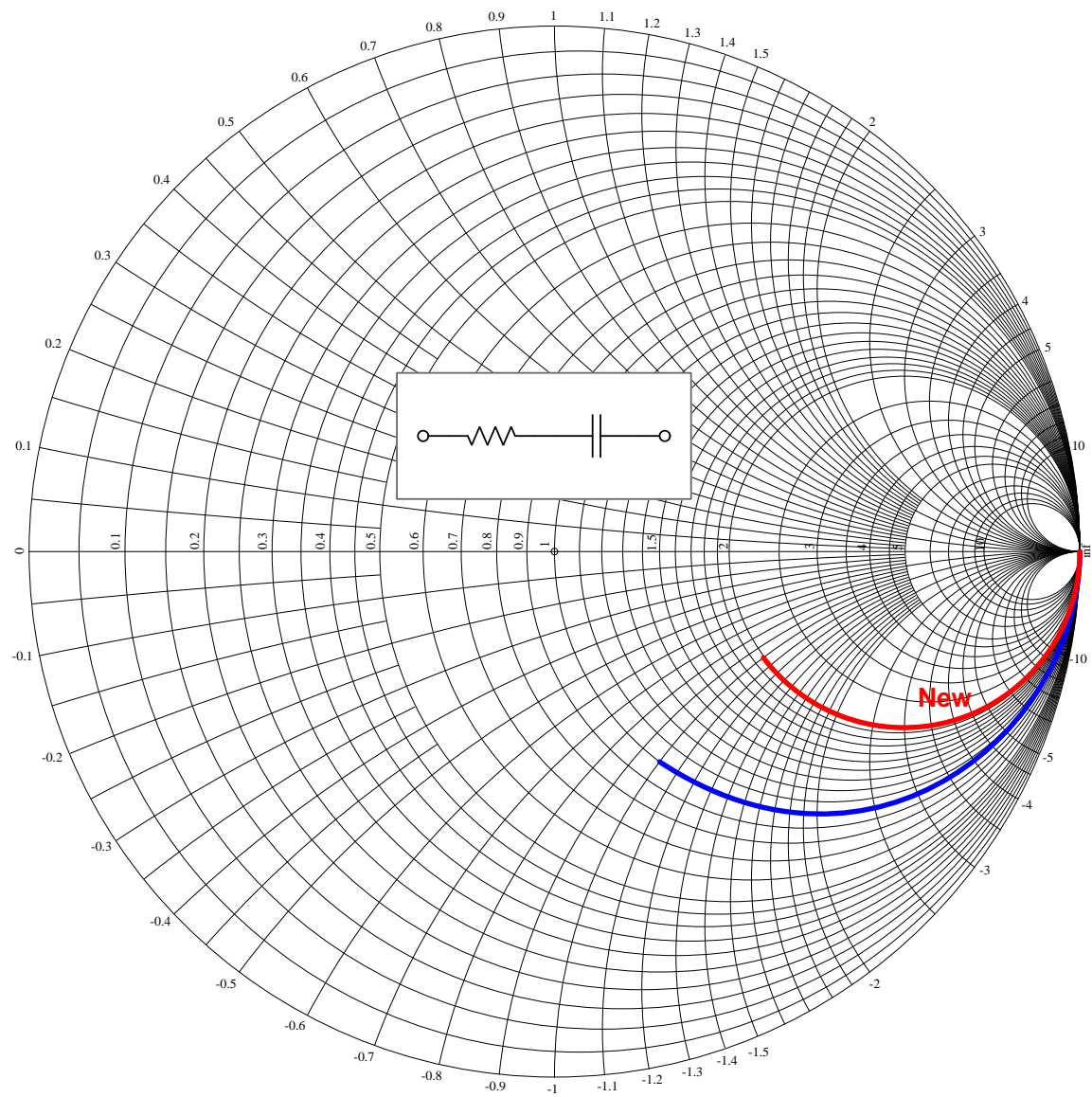
- **1 kHz** (leakage)
- **2.5 kHz** (leakage)
- **7.5 kHz** (leakage)
- **12.5 kHz** (leakage)
- **1.5 kHz** =  $2.5 \text{ kHz} - 1 \text{ kHz}$
- **3.5 kHz** =  $2.5 \text{ kHz} + 1 \text{ kHz}$
- **6.5 kHz** =  $7.5 \text{ kHz} - 1 \text{ kHz}$
- **8.5 kHz** =  $7.5 \text{ kHz} + 1 \text{ kHz}$
- **11.5 kHz** =  $12.5 \text{ kHz} - 1 \text{ kHz}$
- **13.5 kHz** =  $12.5 \text{ kHz} + 1 \text{ kHz}$



---

**Answer 97**

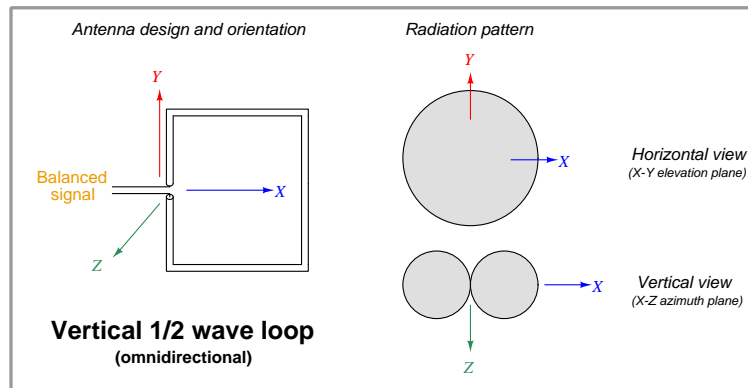
The modified-network frequency sweep is shown in red:



---

**Answer 98**

Calculations based on the assumption of the antenna operating at the fundamental frequency (antenna perimeter length =  $\frac{\lambda}{2}$ ), the speed of light being  $2.9979 \times 10^8$  meters per second, and there being exactly 2.54 centimeters to 1 inch.



$$\text{Length} = \underline{599.58} \text{ meters} = \underline{23605.5} \text{ inches}$$

---

**Answer 99**

This is **analog frequency modulation** or **analog phase modulation**, as it is impossible to differentiate the two from an oscilloscope.

---

**Answer 100**

The 555 timer will not oscillate, and its output pin (3) will be in a high state all the time. The transmitter will output a continuous carrier wave signal, but there will be no audio modulation and therefore no "tone" sent to the antenna.