Exam 1

Practice Problems

Q1

0 points possible (ungraded)

The power distribution network in a particular apparatus can be modeled by the circuit below.

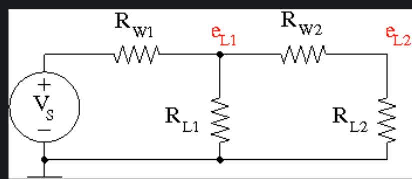


Figure 1-1

The power comes from a voltage source and is delivered to two loads. The loads are modeled by the resistors R_{L1} and R_{L2}. The resistances of the interconnects are modeled by the resistors R_{W1} and R_{W2}. The values of the element parameters are $V_S = 4.0$V, $R_{L1} = 15.0\Omega$, $R_{L2} = 20.0\Omega$, $R_{W1} = 1.0\Omega$, $R_{W2} = 2.0\Omega$.

Determine the node potentials e_{L1} and e_{L2}, assuming a ground node as indicated in the figure. Write your answers in the spaces provided below. Express your answers in Volts.

$e_{L1} =$

1320/367 ✔ **Answer:** 3.5967302452316074

$e_{L2} =$

1200/367 ✔ **Answer:** 3.2697547683923704

Determine the power dissipated in each of the resistors and the power entering the source. Express your powers in Watts. Remember that the power entering a two-terminal device is the product of the voltage across the device and the current through it in the associated reference directions. Write your answers in the spaces provided below.

$P_{R_{W1}} =$

0.162626 ✔ **Answer:** 0.16262649511095947

$P_{R_{L1}} =$

0.862431 ✔ **Answer:** 0.8624312304642546

$P_{R_{W2}} =$

0.0534565 ✔ **Answer:** 0.05345648122712321

$P_{R_{L2}} =$

0.534565 ✔ **Answer:** 0.5345648122712322

$P_{V_S} =$

-1.61308 ✔ **Answer:** -1.6130790190735702

Note: If you did everything correctly the sum of the powers should be zero!

In[∘]:=
```
vs = 4; rl1 = 15; rl2 = 20; rw1 = 1; rw2 = 2;
(*Node method with current going into nodes el1 &
  el2. When we enter the answers we enter them as +ve*)
```

$$\text{Solve}\left[\frac{-\text{vs}-\text{el1}}{\text{rw1}}+\frac{-\text{el1}}{\text{rl1}}+\frac{-\text{el1}}{\text{rw2}+\text{rl2}}==0,\ \text{el1}\right]$$

$$\text{Solve}\left[\frac{\text{el1}-\text{el2}}{\text{rw2}}+\frac{-\text{el2}}{\text{rl2}}==0,\ \text{el2}\right]\ /.\ \left\{\text{el1}\to-\frac{1320}{367}\right\}$$

$$\text{el1}=-\frac{1320}{367};\ \text{el2}=-\frac{1200}{367};$$

$$\text{prw1}=\frac{(-\text{vs}-\text{el1})^2}{\text{rw1}}\ //\ \text{N}$$

$$\text{prl1}=\frac{\text{el1}^2}{\text{rl1}}\ //\ \text{N}$$

$$\text{prw2}=\frac{(\text{el1}-\text{el2})^2}{\text{rw2}}\ //\ \text{N}$$

$$\text{prl2}=\frac{\text{el2}^2}{\text{rl2}}\ //\ \text{N}$$

$$\text{is}=\frac{-\text{vs}-\text{el1}}{\text{rw1}};$$

```
pvs = vs * is // N
```

Out[∘]= $\left\{\left\{\text{el1}\to-\frac{1320}{367}\right\}\right\}$

Out[∘]= $\left\{\left\{\text{el2}\to-\frac{1200}{367}\right\}\right\}$

Out[∘]= 0.162626

Out[∘]= 0.862431

Out[∘]= 0.0534565

Out[∘]= 0.534565

Out[∘]= -1.61308

Q2

0 points possible (ungraded)

A resistive load is attached to a two-terminal "black box".

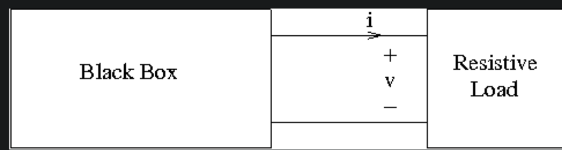


Figure 2-1

The "black box" contains only linear resistors and independent sources.
The voltage across the load is measured to be $v = 3.0V$ when the current through the load is measured to be $i = 22.0A$.

The load is then changed and the voltage across the new load is measured to be $v = 18.0V$ when the current through the load is measured to be $i = 17.0A$.

If the resistive load is replaced by a short circuit, what is the current, in Amperes, that flows through the short circuit?

23 ✔ **Answer:** 23.0

If the resistive load is replaced by an open circuit, what is the voltage, in Volts, that appears across the open circuit?

69 ✔ **Answer:** 69.0

```
v1 = 3; i1 = 22; v2 = 18; i2 = 17;
(*Open circuit voltage is Thevenin
 voltage. Short circuit current is Norton current*)
Solve[v1 == vth - i1 rth && v2 == vth - i2 rth, {vth, rth}]
in = vth / rth /. {vth → 69, rth → 3}
```

Out[•]= {{vth → 69, rth → 3}}

Out[•]= 23

Q3

0 points possible (ungraded)

The circuit below contains two dependent sources: a voltage controlled voltage source and a voltage controlled current source.

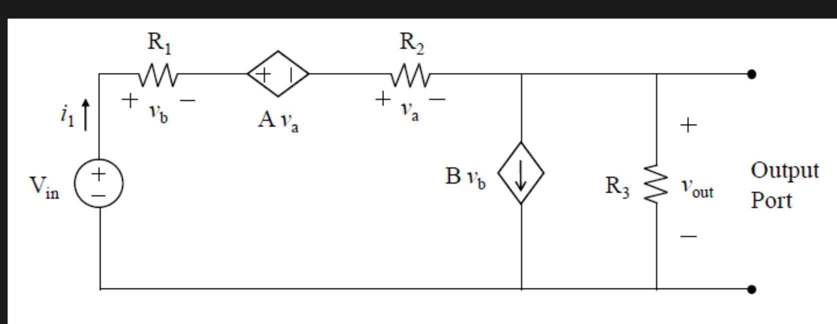


Figure 3-1

The circuit elements have the following values: $V_{in} = 15V$, $R_1 = 0.5\Omega$, $R_2 = 1.5\Omega$, $R_3 = 5\Omega$, $A = 2V/V$ and $B = 1.5A/V$.

What is the value of the current i_1 (in Amps)?

2.4 ✔ **Answer:** 2.4

What is the value of the output voltage v_{out} (in Volts)?

3 ✔ **Answer:** 3

We wish to create a Thevenin equivalent model of the above shown circuit as seen from its Output Port.

What is the value of the Thevenin equivalent voltage as seen from the Output Port (in Volts)?

3 ✔ **Answer:** 3

What is the value of the Thevenin equivalent resistance (in Ohms) as seen from the Output Port?

4 ✔ **Answer:** 4

Explanation:
The first three parts of this problem are solved by applying either the node method or the loop method to find the currents and voltages in the circuit. In these solutions we use both methods.

Node Method

From the circuit, we can identify four nodes that we label V_{in}, e_1, e_2, e_3. One node voltage, V_{in}, is known while the other three are unknown. We can use KCL to find relationships between the three unknown variables.
The first equation arises by equating current through resistors R_1 and R_2. This gves:

$$\frac{V_{in} - e_1}{R_1} = \frac{e_2 - e_3}{R_2}$$

The second equation is obtained by calculating the voltage difference across the voltage controlled voltage source:

$$e_1 - e_2 = A \cdot v_a$$

Finally, the third equation is obtained by equating the sum of currents going into node e_3 to the sum of currents going out of it. This gives:

$$\frac{e_2 - e_3}{R_2} = \frac{e_3}{R_3} + B \cdot v_b$$

Although we have three equations, the dependent sources introduced two new variables, namely v_a and v_b. The relationship of these two new variables with the original three variables (e_1, e_2, e_3) is given in the circuit:

$$v_a = e_2 - e_3$$
$$v_b = V_{in} - e_1$$

Using the expressions for v_a and v_b, we can write three equations for our original three unknowns:

$$\left(-\frac{1}{R_1}\right) e_1 + \left(-\frac{1}{R_2}\right) e_2 + \left(\frac{1}{R_2}\right) e_3 = \left(-\frac{1}{R_1}\right) V_{in}$$
$$e_1 + (-1 - A)\, e_2 + (A)\, e_3 = 0$$
$$(B)\, e_1 + \left(\frac{1}{R_2}\right) e_2 + \left(-\frac{1}{R_2} - \frac{1}{R_3}\right) e_3 = (B)\, V_{in}$$

This is a system of three equation and three unknowns. There are many ways to solve a system of equations (for example, matrix method) and it is not necessary to find the expressions for e_1, e_2, e_3. The matrix formulation for this problem is the following:

$$\begin{pmatrix} \frac{-1}{R_1} & \frac{-1}{R_2} & \frac{1}{R_2} \\ 1 & -(1+A) & A \\ B & \frac{1}{R_2} & -\frac{1}{R_2}-\frac{1}{R_3} \end{pmatrix} \cdot \begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix} = \begin{pmatrix} -\frac{V_{in}}{R_1} \\ 0 \\ B \cdot V_{in} \end{pmatrix}$$

Solving for this matrix equation implies taking the inverse of the coefficient matrix, so that:

$$\begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix} = \begin{pmatrix} \frac{-1}{R_1} & \frac{-1}{R_2} & \frac{1}{R_2} \\ 1 & -(1+A) & A \\ B & \frac{1}{R_2} & -\frac{1}{R_2}-\frac{1}{R_3} \end{pmatrix}^{-1} \cdot \begin{pmatrix} -\frac{V_{in}}{R_1} \\ 0 \\ B \cdot V_{in} \end{pmatrix}$$

Solving this matrix equation (perhaps using [Wolfram Alpha]) gives:

$$\begin{pmatrix} e_1 \\ e_2 \\ e_3 \end{pmatrix} = \begin{pmatrix} 13.799999999999999V \\ 6.599999999999994V \\ 2.999999999999986V \end{pmatrix}$$

- The current i_1 is given by:

$$i_1 = \frac{V_{in}-e_1}{R_1} = \frac{15V - 13.799999999999999V}{0.5\Omega} = 2.4A$$

- Output voltage is simply $e_3 = 3V$
- Thevenin voltage is the open circuit voltage which is the same as the output voltage found above, therefore $V_{th} = e_3 = 3V$
- The Thevenin resistance can be calculated by finding the Norton current I_{nt} and using the relationship: $R_{th} = \frac{V_{th}}{I_{nt}}$. Finding Norton current requires shorting the output terminals which esentially shorts the resistance R_3 and makes $e_3 = 0$. Making $e_3 = 0$ in the system of equations found above gives (for the first two equations):

$$\left(-\frac{1}{R_1}\right)e_1' + \left(-\frac{1}{R_2}\right)e_2' = \left(-\frac{1}{R_1}\right)V_{in}$$

$$e_1' + (-1-A)\,e_2' = 0$$

Solving these equations give:

$$e_1' = \frac{(1+A)\,V_{in}}{1+A+\frac{R_1}{R_2}}$$

$$e_2' = \frac{V_{in}}{1+A+\frac{R_1}{R_2}}$$

Therefore, we can calculate I_{nt} as:

$$I_{nt} = \frac{e_2'}{R_2} - B\,(V_{in} - e_1')$$

The Thevenin resistance is: $R_{th} = \frac{V_{th}}{I_{nt}} = 4\Omega$

Loop method

In this problem, the loop method (based on KVL) gives a simpler set of equations because we only have two unknown (current i_1 in loop 1, and current i_2 in loop 2). The two equations for these unknowns are found by equating to zero the sum of voltages around any two closed loops. If we use the exterior path of the circuit we get the first equation:

$$R_1 i_1 + A v_a + R_2 i_1 + R_3 i_2 = V_{in}$$

Using the current through the voltage control current source gives:

$$B v_b = i_1 - i_2$$

We can solve for i_1 and i_2 if we use the expressions for v_a and v_b given in the circuit, namely:

$$v_a = R_2 i_1$$

$$v_b = R_1 i_1$$

The set of two equations with two unknowns is:

$$(R_1 + A \cdot R_2 + R_2)\, i_1 + (R_3)\, i_2 = V_{in}$$

$$(1 - B \cdot R_1)\, i_1 + (-1)\, i_2 = 0$$

Solving for i_1 and i_2 by direct substitution gives:

$$i_1 = \frac{V_{in}}{R_1 + (A+1)\, R_2 + R_3 - B R_1 R_3}$$

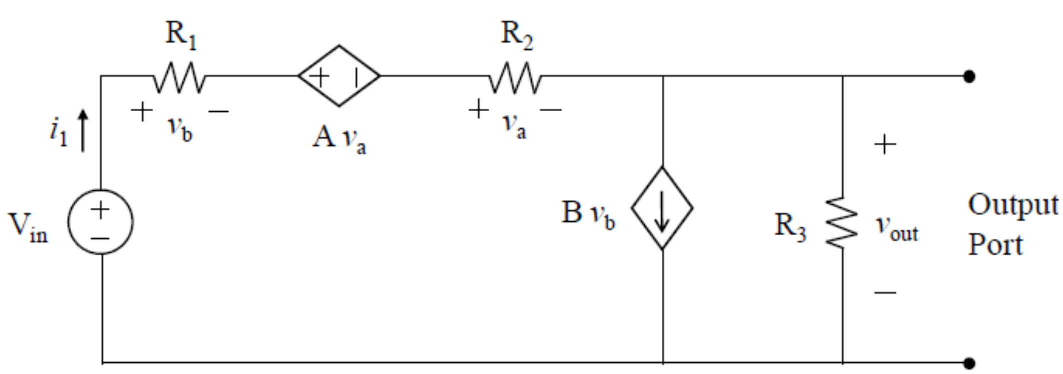
$$i_2 = \frac{(1 - B \cdot R_1)\,(V_{in})}{R_1 + (A+1)\, R_2 + R_3 - B R_1 R_3}$$

- The current i_{in} is simply $i_1 = 2.4A$
- Output voltage is given by $V_{out} = R_3 i_2 = 3V$
- Thevenin voltage is the output voltage found above $V_{th} = V_{out} = 3V$
- To find the Thevenin resistance we first find the Norton current I_{nt} and then apply the equation $R_{th} = \frac{V_{th}}{I_{nt}}$. We can apply the same equations found to solve part (a) to (c) but substituing $R_3 = 0$. Therefore:

$$i_1' = \frac{V_{in}}{R_1 + (A+1)\, R_2}$$

$$i_2' = \frac{(1 - B \cdot R_1)\,(V_{in})}{R_1 + (A+1)\, R_2}$$

The Norton current I_{nt} is i_2' and therefore the Thevenin resistance is $R_{th} = \frac{V_{th}}{I_{nt}} = 4\Omega$



```
In[•]:= vin = 15; r1 = 0.5; r2 = 1.5; r3 = 5;
        a = 2; b = 1.5;
        (*Loop method from the solution (KVL)*)
        Solve[(r1 + a r2 + r2) i1 + r3 i2 == vin &&
           (1 - b r1) i1 == i2, {i1, i2}]
        vout = r3 i2 /. {i2 → 0.6000000000000001`}
        vth = vout
        (*If we short the output port, current i2 will bypass the resistor r3*)
        in = ((1 - b r1) vin) / (r1 + (a + 1) r2);
        rth = vth / in

Out[•]= {{i1 → 2.4, i2 → 0.6}}

Out[•]= 3.

Out[•]= 3.

Out[•]= 4.
```

Q4

0 points possible (ungraded)

For many purposes of gate design, we can model a MOSFET used as a switch simply as as an ideal switch and an "on-state resistor" R_{ON}. This is the SR model.

Assuming this model for the MOSFET, consider the inverter in the figure. This inverter is intended to be used as an element in a logic family with NAND and NOR gates.

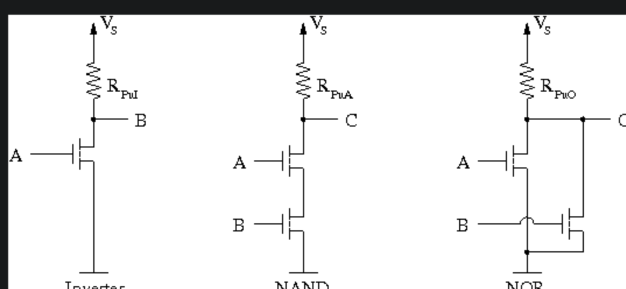


Figure 4-1

The static discipline required for this family is:

$$V_S = 5.0V, V_{OH} = 4.5V, V_{IH} = 4.0V, V_{IL} = 1.5V, V_{OL} = 1.0V.$$

What is the low noise margin (in Volts)?

0.5 ✔ **Answer:** 0.5

What is the high noise margin (in Volts)?

0.5 ✔ **Answer:** 0.5

What is the width of the forbidden region (in Volts)?

2.5

✔ **Answer:** 2.5

Suppose that the threshold voltage for the MOSFET is $V_T = 2.0V$ and $R_{ON} = 7000.0\Omega$.

What is the minimum value of the pullup resistor R_{PuI} (in Ohms) for which this inverter can obey the required static discipline?

28000

✔ **Answer:** 28000.0

Now, consider the NAND gate of this family. What is the minimum value of the pullup resistor R_{PuA} (in Ohms) for which this inverter can obey the required static discipline?

56000

✔ **Answer:** 56000.0

How about the NOR gate of this family. What is the minimum value of the pullup resistor R_{PuO} (in Ohms) for which this inverter can obey the required static discipline?

28000

✔ **Answer:** 28000.0

Assume that we implemented this family with the minimum pullup resistors that you have already calculated.

What is the maximum power (in milli-Watts, $mW = 0.001W$) consumed by the inverter?

0.71428

✔ **Answer:** 0.7142857142857143

What is the maximum power (in milli-Watts, $mW = 0.001W$) consumed by the NAND?

0.35714

✔ **Answer:** 0.35714285714285715

What is the maximum power (in milli-Watts, $mW = 0.001W$) consumed by the NOR?

0.79365

✔ **Answer:** 0.7936507936507936

Explanation:

$$V_S = 5.0 \; V_{OH} = 4.5 \; V_{IH} = 4.0 \; V_{IL} = 1.5 \; V_{OL} = 1.0$$

The low noise margin is defined as $V_{IL} - V_{OL}$. For this problem, it is $0.5V$. As an example, if an inverter outputs a valid voltage signal of $1.0V$ (V_{OL}) to another inverter, then that signal can rise by $0.5V$ all the way to V_{IL}, before it becomes an invalid logical 0 input to the second inverter.
The high noise margin is defined as $V_{OH} - V_{IH}$. For this problem, it is $0.5V$. Again, if an inverter outputs a valid voltage signal of $4.5V$ (V_{OH}) to another inverter, then that signal can fall by $0.5V$, all the way to V_{IH} before it becomes an invalid logical 1 input to the second inverter.
The width of the forbidden region is defined as $V_{IH} - V_{IL}$. For this problem, it is $2.5V$. Valid inputs to our logic family are not allowed to fall between V_{IH} and V_{IL}.
When V_{GS} for the MOSFET is below V_T, the MOSFET behaves like an open circuit, and $i_{DS} = 0$. That means no voltage drops over R_{PUI} and the output voltage of our inverter is V_S, so this case is fine with out static discipline, since the output voltage is above V_{OH}. For $V_{GS} \geq V_T$, the MOSFET is on and behaves like a resistor with resistance R_{ON} with our model.
To find R_{PUI}:

$$V_{OL} = \frac{V_S\,(R_{ON})}{R_{ON} + R_{PUI}}$$

$$1 = \frac{5\,(7000.0)}{(7000.0 + R_{PUI})} \rightarrow R_{PUI} = 28000.0\Omega$$

Similar to the inverter case, when either MOSFET is off, no current can flow through the pullup resistor because the MOSFETs and pullup resistor are in series. So V_{OUT} for the NAND gate is simply V_S when either MOSFET is off. When both MOSFETs are on, they behave like resistors with resistance R_{ON}. The two MOSFETs are in series, so we calculate:
To find R_{PUA}:

$$V_{OL} = \frac{V_S\,(2R_{ON})}{2R_{ON} + R_{PUA}}$$

5 (14000.0)

$$1 = \frac{[illegible]}{(14000.0 + R_{PUA})} \rightarrow R_{PUA} = 56000.0\Omega$$

When both MOSFETs are off, V_{OUT} for the NOR gate is simply V_S because no current can flow through either MOSFET or R_{PUO}. When one MOSFET is on, V_{OUT} is:

$$V_S \cdot \frac{(0.5)\,R_{ON}}{(0.5)\,R_{ON} + R_{PUO}}$$

because the MOSFETs are in parallel with each other. For the cases with one MOSFET on or both MOSFETs on, V_{OUT} must be at least as small as V_{OL}. For the case with one MOSFET on, R_{PUO} must be at least 28000.0 Ω. For the case with both MOSFETs on, R_{PUO} must be at least 14000.0 Ω. So for our NOR gate to satisfy the static discipline, R_{PUO} must be at least 28000.0 Ω.
When the MOSFET in the inverter is off, no power is consumed because no current can flow as the MOSFET behaves like an open circuit. When it is on, V_S must drop over R_{PUI} and R_{ON}, so the power consumed is:

$$\frac{(V_S)^2}{R_{PUI} + R_{ON}}$$

Power consumed by inverter:

$$\frac{25V}{7000.0 + 28000.0\Omega} = 0.000714W = 0.714mW$$

When either MOSFET is off, no current flows through the MOSFETs or R_{PUA}, so there is no power consumed. When both MOSFETs are on, V_S must drop over R_{PUA} and $2R_{ON}$ because the MOSFETs are in series with each other. The power consumed in this case is:

$$\frac{(V_S)^2}{R_{PUA} + 2R_{ON}}$$

Power consumed by NAND:

$$\frac{25V}{2 \cdot 7000.0 + 56000.0\Omega} = 0.000357W = 0.357mW$$

When both MOSFETs are off, no curernt can flow, so no power is consumed. When one MOSFET is on, V_S must drop over R_{PUO} and R_{ON}, so the power consumed is:

$$\frac{(V_S)^2}{R_{PUO} + R_{ON}}$$

When both MOSFETs are on, V_S must drop over R_{PUO} and $\frac{1}{2}\,R_{ON}$ because the MOSFETs are in parallel, so the power consumed is:

$$\frac{(V_S)^2}{R_{PUO} + 0.5\,(R_O N)}$$

The maximum power is consumed by the NOR gate in the latter case:

$$\frac{25V}{(7000.0 \parallel 7000.0) + 28000.0\Omega} = 0.000794W = 0.794mW$$

Q5

0 points possible (ungraded)

Consider the circuit in Figure 5-1 below.

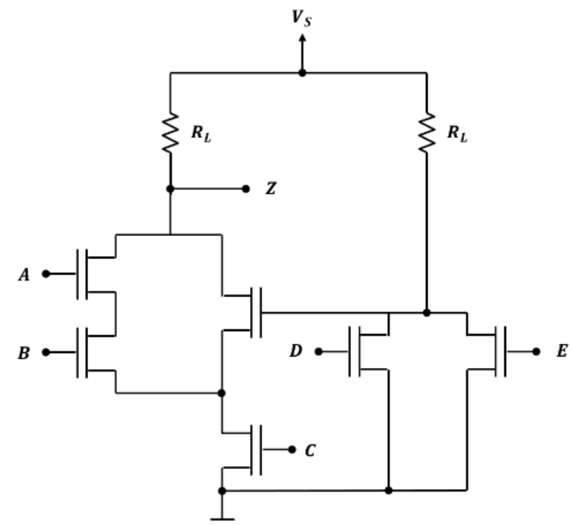


Figure 5-1

Write a boolean expression for Z in terms of A, B, C, D, and E. You need not simplify your expression. Use your expression to fill out the truth table below.

A	B	C	D	E	Z
1	0	1	0	1	z_0
1	1	1	1	1	z_1
0	0	1	1	0	z_2
0	1	1	0	0	z_3

Enter the unknown values for the ouputs as one stream of bits in the form $z_0 z_1 z_2 z_3$

1010

Answer: 1010

How many distinct boolean-valued functions are there of n boolean-valued signals? Write an expression in terms of n.

2^(2^n)

Answer: 2^(2^n)

Explanation:
a) The output Z is defined by the boolean expression

$$\overline{((A \cdot B) + \overline{(D+E)}) \cdot C}$$

So we can plug our inputs into this expression to get our outputs. Given our truth table, the answer should be 1010
b) There are 2^n possible combination of inputs. And each of these combinations can take on 2 possible values. Hence, we have a total of 2^{2^n} possibilities

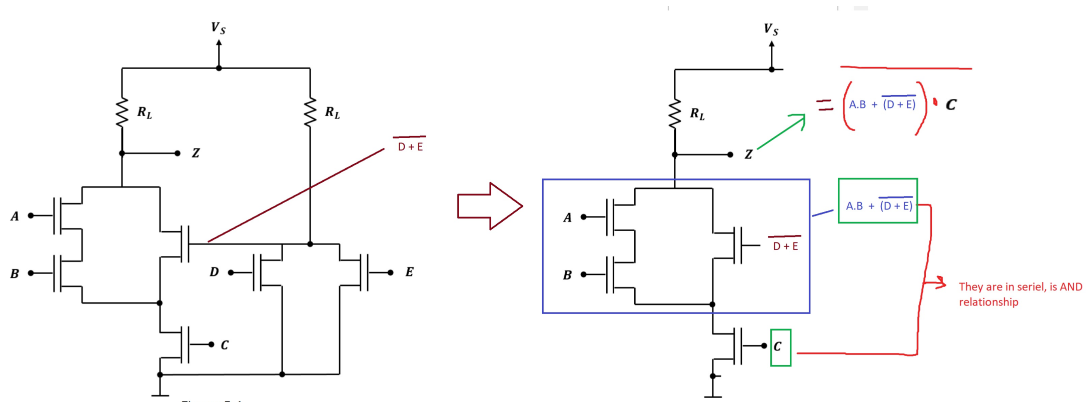


Figure 5-1

```
(*Basically what I got from the below comment is that inversion happens when we
 take a signal from output port (Z and !(D+E) here) below the load resistor (Rl)
```

Thank you! I got stuck thinking that any series combination of MOSFETs had to be NAND and that any parallel combination of MOSFETs had to be NOR (rather than them being AND or OR, respectively). I forgot that the placement of the R_L and the output, relative to the MOSFETs, dictates whether inversion occurs.

posted 2 years ago by **Calebzig**

In[ ]:=
```
z = ! ((a && b) || ! (d || e) && c);
t = Boole[BooleanTable[{a, b, c, d, e, z}, {a, b, c, d, e}]];
TableForm[t, TableHeadings → Automatic]
(*Shortened to what rows we need*)
tshort = {{a, b, c, d, e, "z"}};
tshort = Append[tshort, t[[11]]];
tshort = Append[tshort, t[[1]]];
tshort = Append[tshort, t[[26]]];
tshort = Append[tshort, t[[20]]];
tshort // TableForm
```

Out[ ]//TableForm=

	1	2	3	4	5	6
1	1	1	1	1	1	0
2	1	1	1	1	0	0
3	1	1	1	0	1	0
4	1	1	1	0	0	0
5	1	1	0	1	1	0
6	1	1	0	1	0	0
7	1	1	0	0	1	0
8	1	1	0	0	0	0
9	1	0	1	1	1	1
10	1	0	1	1	0	1
11	1	0	1	0	1	1
12	1	0	1	0	0	0
13	1	0	0	1	1	1
14	1	0	0	1	0	1
15	1	0	0	0	1	1
16	1	0	0	0	0	1
17	0	1	1	1	1	1
18	0	1	1	1	0	1
19	0	1	1	0	1	1
20	0	1	1	0	0	0
21	0	1	0	1	1	1
22	0	1	0	1	0	1
23	0	1	0	0	1	1
24	0	1	0	0	0	1
25	0	0	1	1	1	1
26	0	0	1	1	0	1
27	0	0	1	0	1	1
28	0	0	1	0	0	0
29	0	0	0	1	1	1
30	0	0	0	1	0	1
31	0	0	0	0	1	1
32	0	0	0	0	0	1

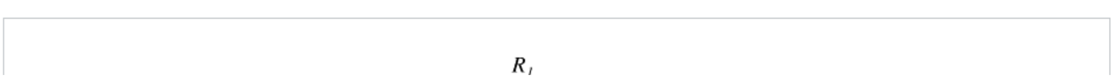
Out[ ]//TableForm=

a	b	c	d	e	z
1	0	1	0	1	1
1	1	1	1	1	0
0	0	1	1	0	1
0	1	1	0	0	0

Q6

0 points possible (ungraded)

A battery in combination with a dependent current source is connected to a lamp in the circuit shown below in Figure 6-1. The battery is modeled as a voltage source in series with a resistor, R_{bat}, and has an open circuit voltage of $4V$. The lamp turns on if the voltage across the lamp is greater than $2V$. When the lamp is on it has an internal resistance of 10Ω, and when it is off it acts like an open circuit.



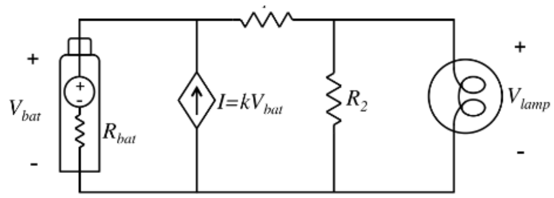


Figure 6-1

The elements in this circuit have the following values: $R_1 = 5\Omega$, $R_2 = 5\Omega$, and $k = 0.2$.

Assume that the lamp is on and $V_{lamp} = 2V$, what is the battery's internal resistance, R_{bat} (in Ohms)?

2.5 ✔ **Answer:** 2.5000000000000004

What is the power (in Watts) dissipated in the lamp?

0.4 ✔ **Answer:** 0.4

What is the power (in Watts) dissipated in R_1?

1.8 ✔ **Answer:** 1.8000000000000007

What is the power (in Watts) dissipated in R_2?

0.8 ✔ **Answer:** 0.8

What is the power (in Watts) coming out of the voltage controlled current source, I?

5 ✔ **Answer:** 5.0

What is the power (in Watts) coming out of the battery?

-2 ✔ **Answer:** -1.9999999999999996

We start by finding V_{BAT}. By KVL, it is equal to V_{LAMP} plus the voltage across R_1. By KCL, the current through R_1 is equal to the sum of the currents in the R_2 and V_{LAMP} branches, so:

$$V_{BAT} = V_{LAMP} + R_1 \left(\frac{V_{LAMP}}{R_{LAMP}} + \frac{V_2}{R_2} \right)$$

Substituting in our known values give us $V_{BAT} = 5.0V$.

Once we have V_{BAT}, finding I_{BAT} and R_{BAT} is simple:

By KCL at the top of the battery node, $I_{BAT} = k \cdot V_{BAT} - \left(\frac{V_{Lamp}}{R_{Lamp}} + \frac{V_{LAMP}}{R_2} \right)$

and we can infer by the open circuit battery voltage that $R_{BAT} = \frac{V_{BAT} - V_{OC}}{I_{BAT}}$

Again, we substitute in our known values and get $I_{BAT} = 0.3999999999999999A$ and $R_{BAT} = 2.5000000000000004\Omega$.

Once we have these values and have essentially fully analyzed our circuit, finding the power values is straightforward:

$$P_{LAMP} = \frac{V_{LAMP}^2}{R_{LAMP}} = 0.4W$$

R_{LAMP}

$P_{R2} = \frac{V_{LAMP}^2}{R_2} = 0.8W$

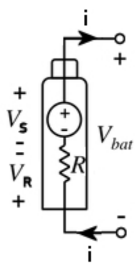
$P_{R1} = \frac{(V_{BAT}-V_{LAMP})^2}{R_1} = 1.8000000000000007W$

$P_I = k \cdot V_{BAT}^2 = 5.0W$

$P_{BAT} = -V_{BAT} \cdot I_{BAT} = -1.9999999999999996W$

Grove (Community TA)
2 years ago - marked as answer 2 years ago by **edxpub**

I have redrawn and relabelled the relevant part of the circuit.



V_S is the source voltage, which for a battery is sometimes called its emf, and R, labelled as V_{bat} in the question diagram, is the source resistance which is sometimes called the internal resistance.

Applying KVL to the loop gives $+V_R - V_S + V_{bat} = 0 \Rightarrow V_{bat} = V_S - V_R \Rightarrow V_{bat} = V_S - iR$

So with the current as shown in the diagram the potential difference across the terminals of the battery (terminal pd), V_{bat}, is less than the source voltage by an amount which is equal to the voltage across the internal resistance of the battery, iR.

Only if $i = 0$, which implies there is no connection across the terminals of the battery (open circuit) does $V_{bat} = V_S$ which is the value given in the question.

So in this question $V_S = 4\,\mathrm{V}$.

Page 36 → of the textbook might be worth a read?

```
r1 = 5; r2 = 5; k = 0.2;
Vlamp = 2; Rlamp = 10;
(*In the answer above, V2 = Vlamp*)
```

$$\text{Vbat} = \text{Vlamp} + \text{r1} * \text{Vlamp}\left(\frac{1}{\text{Rlamp}} + \frac{1}{\text{r2}}\right);$$

$$\text{Ibat} = \text{k Vbat} - \left(\frac{\text{Vlamp}}{\text{Rlamp}} + \frac{\text{Vlamp}}{\text{r2}}\right);$$

$$\text{Rbat} = \frac{\text{Vbat} - \text{Voc}}{\text{Ibat}} \text{ /. \{Voc} \to 4\}$$

```
(*Check answer for the power calculations*)
```

Out[ ]= 2.5

Q7

0 points possible (ungraded)

0 points possible (ungraded)

The circuit shown below is the linear equivalent model of a two-input single-output amplifier. Note that it contains a current dependent voltage source.

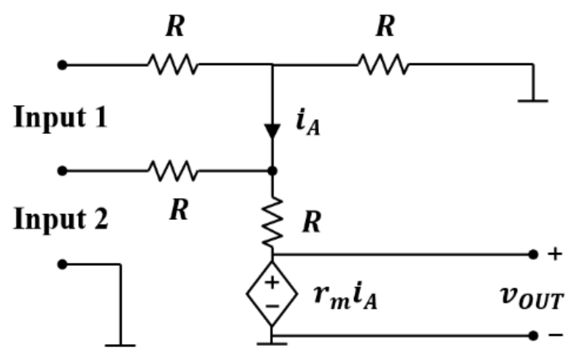


Figure 7-1

One application of this amplifier is in a communications circuit where its two inputs are driven by two antennas. We can model the two antennas as two current sources: i_{IN1} and i_{IN2}, as shown below.

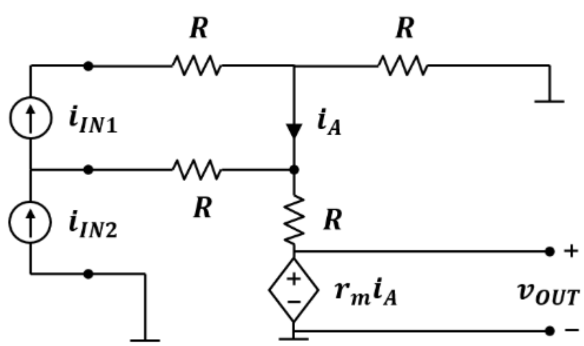


Figure 7-2

The elements in the circuit have the following values: $R = 3k\Omega$ and $r_m = 3k\Omega$

Assuming that $i_{N1} = 1mA$ and $i_{N2} = 0A$, what is the value of v_{OUT} in Volts?

2

✔ **Answer:** 2

Assuming that $i_{N1} = 0A$ and $i_{N2} = 1mA$, what is the value of v_{OUT} in Volts?

-1

✔ **Answer:** -1

Assuming that $i_{N1} = 1mA$ and $i_{N2} = 1mA$, what is the value of v_{OUT} in Volts?

1

✔ **Answer:** 1

Assuming that Input 2 is left as an open circuit, what is the Thevenin equivalent resistance (in kOhms) seen from Input 1?

6

✔ **Answer:** 6

Explanation:

Explanation:

(a) This question is best solved using mesh analysis. From the top of the dependent voltage source we can write the KVL loop equation:

$$r_m \cdot i_A - 2 \cdot R \cdot (i_{IN1} - i_A) = 0$$

rearranging this equation yields:

$$(r_m + 2 \cdot R) \cdot i_A = 2 \cdot R \cdot i_{IN1}$$
$$i_A = \frac{2 \cdot R}{r_m + 2 \cdot R} \cdot i_{IN1}$$

Since the output voltage is proportional to i_A by a factor of r_m, it must be:

$$v_{OUT} = \frac{2 \cdot R \cdot r_m}{r_m + 2 \cdot R} \cdot i_{IN1} = 2V$$

(b) This question is also best solved using mesh analysis. Again from the top of the dependent source we can write:

$$r_m \cdot i_A + R \cdot (i_{IN2} + i_A) + R \cdot i_A = 0$$

rearranging yields:

$$(r_m + 2 \cdot R) \cdot i_A = -R \cdot i_{IN2}$$
$$i_A = \frac{-R}{r_m + 2 \cdot R} \cdot i_{IN2}$$

And the output voltage is

$$v_{OUT} = \frac{-R \cdot r_m}{r_m + 2 \cdot R} \cdot i_{IN2} = -1V$$

(c) Using superposition,

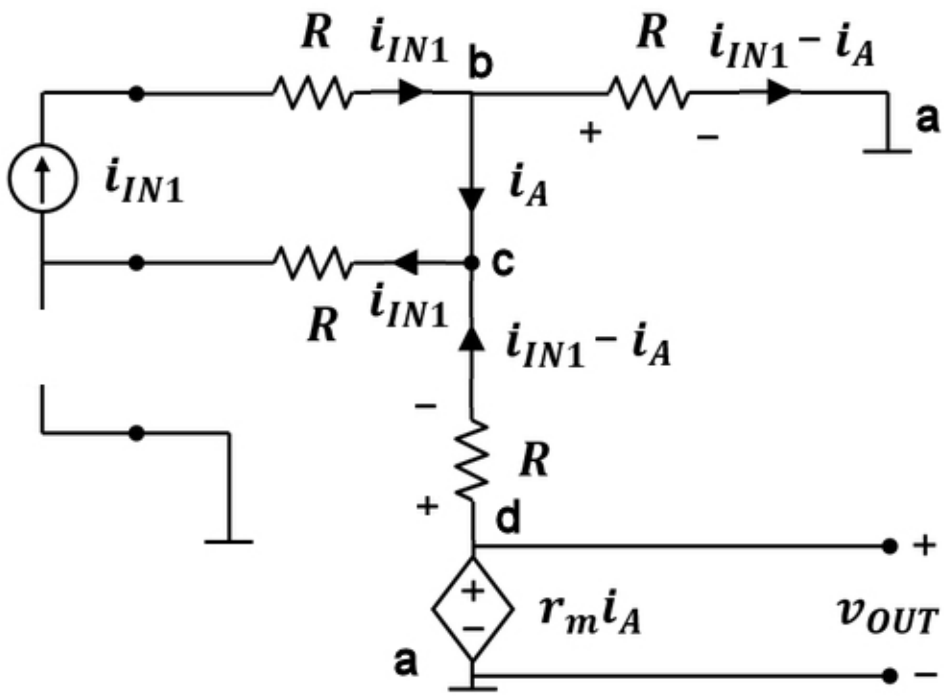
$$v_{OUT} = 2V + -1V = 1V$$

(d) This question has nothing to do with the output nor the dependent source. Form a mesh loop around the input terminals and we find that:

$$R_{IN} = 2 \cdot R = 6k\Omega$$

```
(*Very helpful diagram for first part, mildly helpful for second part.*)
```

Grove (Community TA)
about a year ago



Go for a KVL walk around loop **abcda**.

```
(*Helpful tip for last part*)
```

Grove (Community TA)
2 years ago

The question is really about the input resistance as seen looking into circuit flanked by the two terminals which are connected to current source i_{IN1}

```
R = 3*^3; rm = 3*^3;
Vout[Ia_] := rm * Ia;
(*Go for that KVL walk. TODO: Learn mesh analysis*)
In1 = 1*^-3; In2 = 0;
Solve[(Ia - In1) R + (Ia - In1) R + Vout[Ia] == 0, Ia];
Vout[Ia] /. {Ia → 1/1500} // N
(*Same KVL walk, different source,
note that Ia is still non-zero and open circuit changes to In1*)
In2 = 1*^-3; In1 = 0;
Solve[Ia R + (Ia + In2) R + Vout[Ia] == 0, Ia];
Vout[Ia] /. {Ia → -1/3000}
Vsuperpos = 2 + (-1)
2 R / 1*^3
```

Out[∘]= 2.

Out[∘]= -1

Out[∘]= 1

Out[∘]= 6