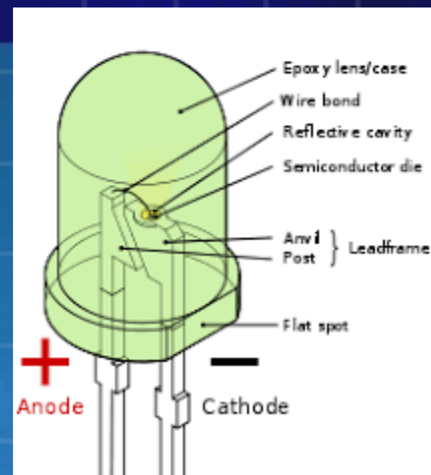
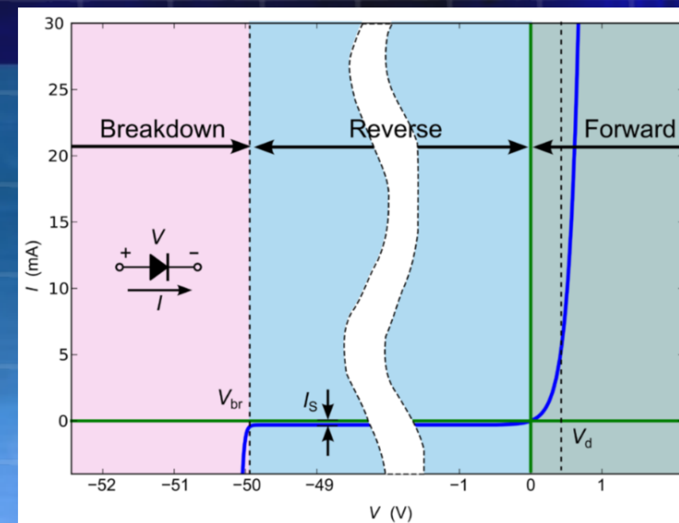




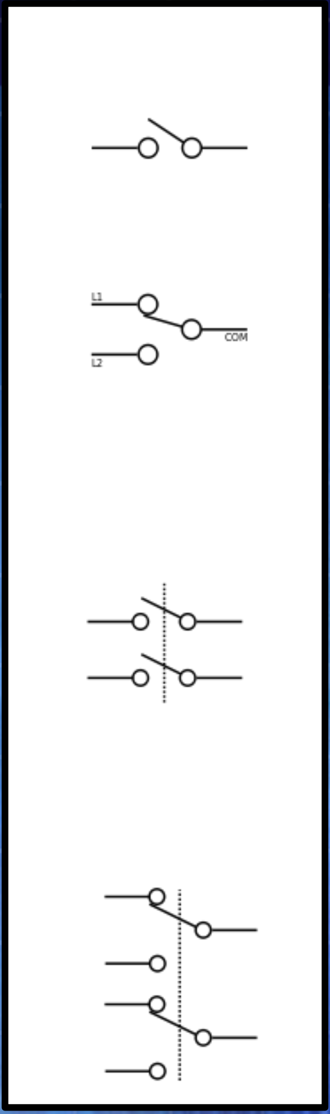
Circuit Lab

Practice #12—LEDs, Diodes, and Operational Amplifiers

Mr. Burleson
geaux15@hotmail.com

Types of switches

- Single Pole Single Throw (SPST)—a simple on/off switch. Light switch.
- Single Pole, Double Throw (SPDT)—a simple change over switch. Turns on one thing or another, not both.
- Double pole, Single Throw (DPST)—equal to two SPST switches controlled by a single mechanism. Like flipping two light switches at once.
- Double Pole, Double Throw (DPDT)—equivalent to two SPDT switches controlled by a single mechanism.



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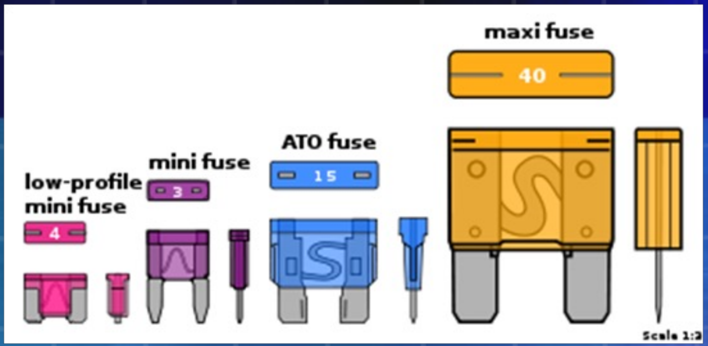
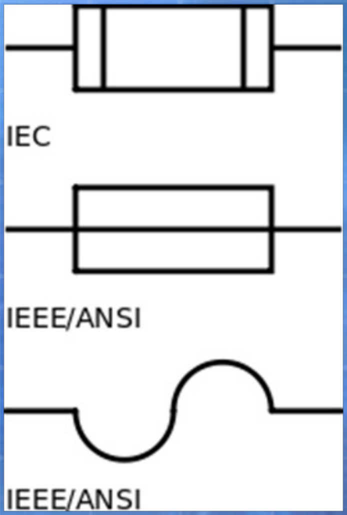
Fuses

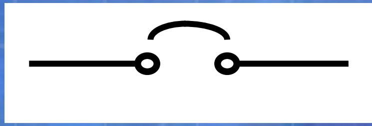
- A safety device which "burns out" at a given current
  - Prevents a short or high current from damaging other systems, melting wires, etc. from a short or other problem
  - Fuses must be replaced after burn out, <u>but not before the problem is resolved</u>.
  - Usually faster than circuit breakers.





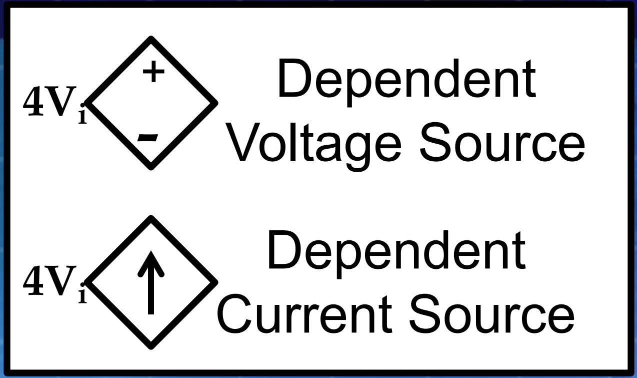
Circuit Breaker

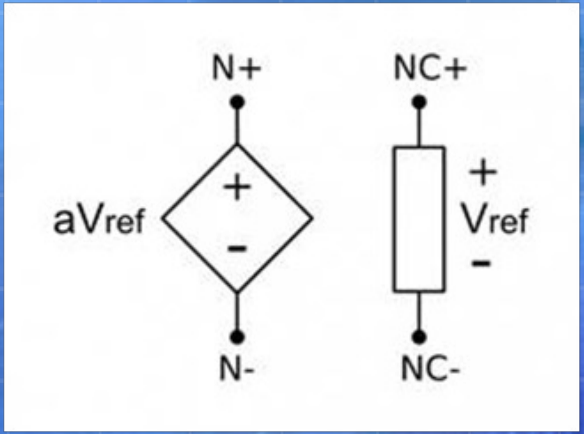
- A safety device which “trips” at a given current
  - Prevents a short or high current from damaging other systems, melting wires, etc. from a short or other problem
  - Circuit Breakers may be reset after tripping, but should not be reset unless the problem has been resolved.
  - Usually a little slower than fuses.



Dependent Sources

- Shown by diamond shape
- Sources that are dependent upon another element or measurement in a circuit.
  - Could reference other devices like an amplifier
- Use KVL and KCL to develop an equation and then solve





Superposition

- The superposition theorem for electrical circuits states that for a linear system the response (Voltage or Current) in any branch of a circuit having more than one <u>independent</u> source equals the algebraic sum of the responses caused by each independent source acting alone, while all other independent sources are replaced by their internal impedances.
- To ascertain the contribution of each individual source, all of the other sources first must be "turned off" (set to zero) by:
  - Replacing all other <u>independent</u> voltage sources with a short circuit (thereby eliminating difference of potential. i.e. V=0, internal impedance of ideal voltage source is ZERO (short circuit)).
  - Replacing all other <u>independent</u> current sources with an open circuit (thereby eliminating current. i.e. I=0, internal impedance of ideal current source is infinite (open circuit).
- <u>Does NOT work with DEPENDENT SOURCES or POWER</u>
- Will cover this in more detail later.

Diode

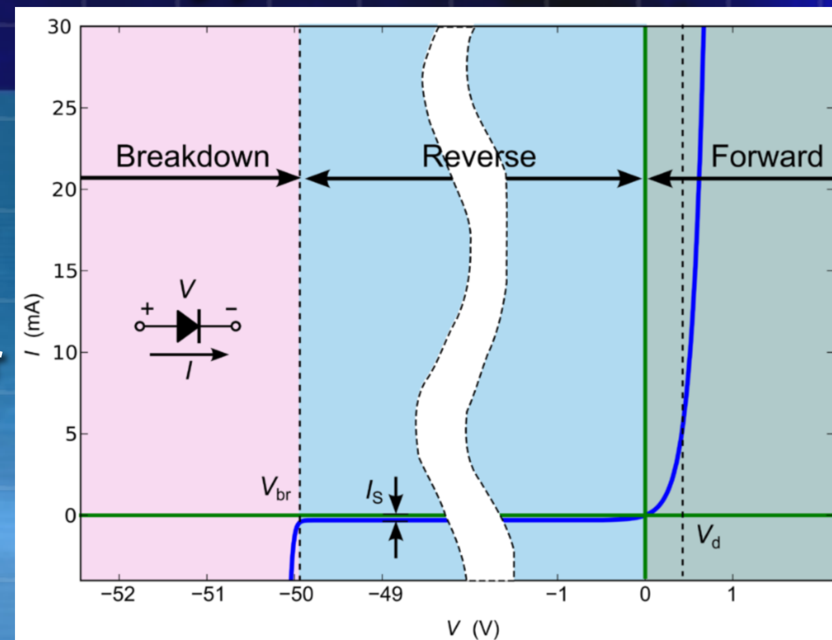
(Division C Only)

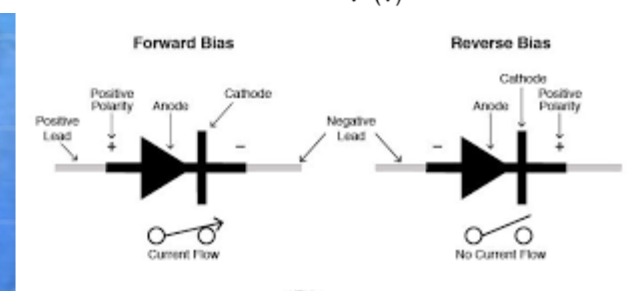
- A diode is a two-terminal electronic component that conducts current primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other

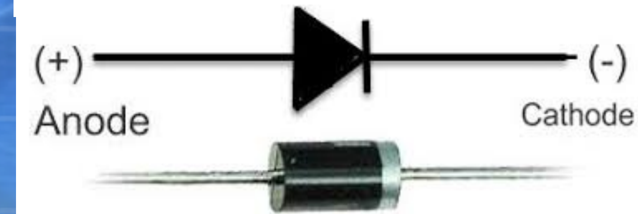
- Ideally can be replaced with
  - A short (0Ω) when forward biased or closed switch
  - An open (∞Ω) when reverse biased or open switch

- When forward biased has a small resistance and a bias depending upon semiconductor material
  - 0.6-0.7V for Si Diodes
  - 0.25 to 0.3V for Ge Diodes
  - LEDs can be as high as 4.0V

https://en.wikipedia.org/wiki/Diode







Ideal Diode

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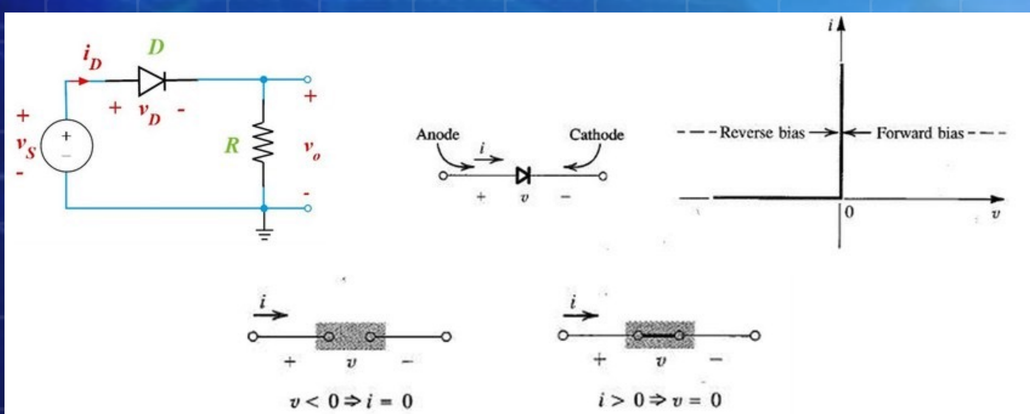
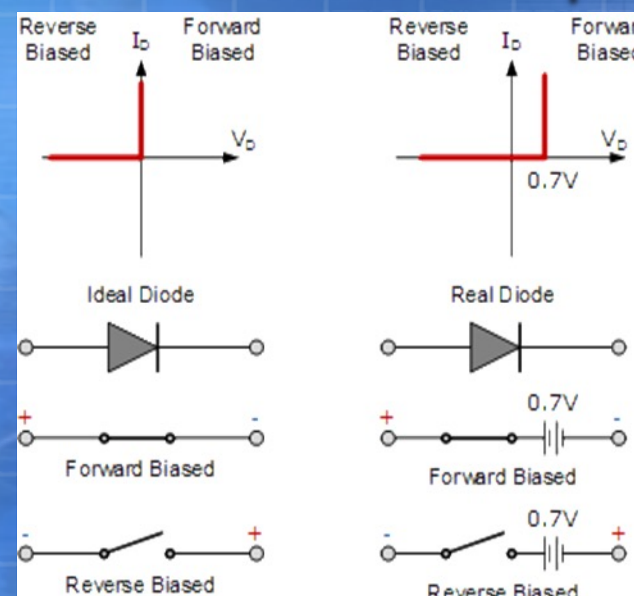
- Ideal diode has zero resistance in Forward Bias with the forward bias voltage and infinite resistance in Reverse Bias.
- Note that normally they assume the bias voltage is for Si ~0.7V

- In Examples below:
  - If $v_S >= 0.7V$, then the diode is in forward bias, no resistance by still account for $v_D = 0.7V$, therefore $v_o = v_S - 0.7V$
  - If $v_s < 0.7V$, the diode is in reverse bias and can be treated as open





https://www.researchgate.net/figure/A-circuit-with-Ideal-Diode-its-i-v-characteristic-and-equivalent-circuits-in-the_fig12_316098112
https://www.electronics-tutorials.ws/diode/diode_3.html

Light Emitting Diodes (LEDs)

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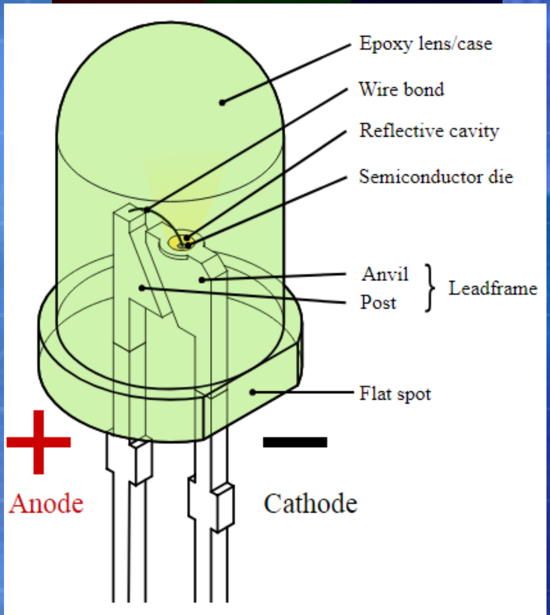
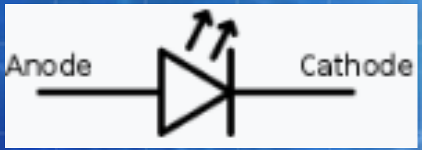
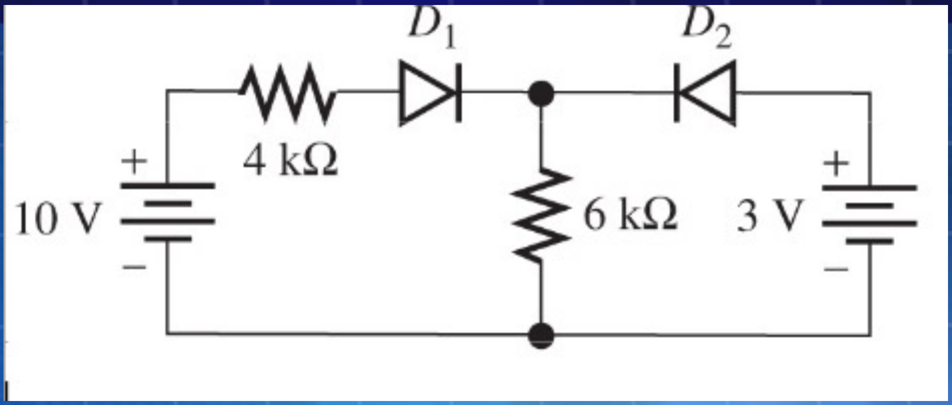
- A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated
- Color is determined by the energy band gap of the semiconductor, which also affects the voltage drop
  - Full table has been put in the Homework Generator, LED Datasheet tab
  - https://en.wikipedia.org/wiki/Light-emitting_diode#cite_note-79





https://en.wikipedia.org/wiki/Light-emitting_diode

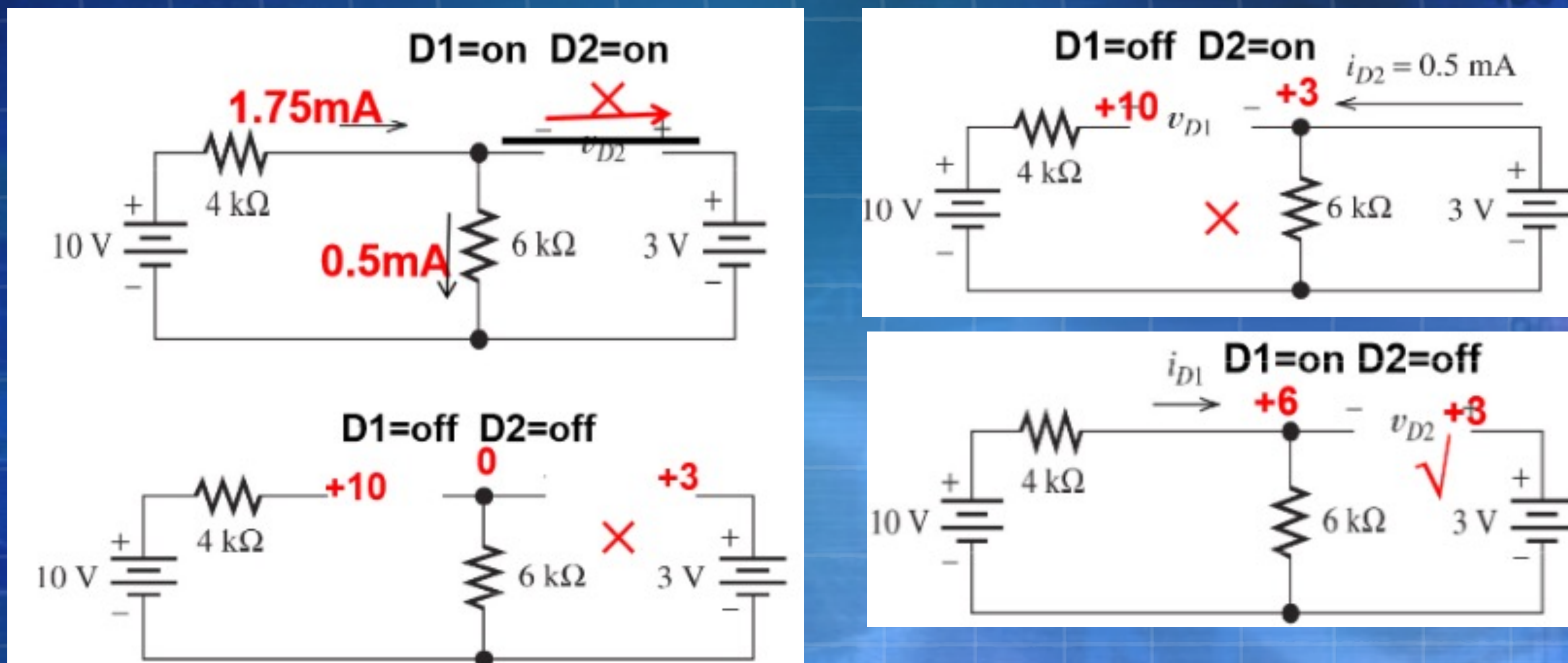
Diode Practice



- For this circuit with ideal diodes, which diodes are on and which diodes are off? (assume no forward bias voltage)
- D_1 is on and D_2 is off

https://math.stackexchange.com/questions/1448477/how-to-determine-the-states-of-ideal-diodes-in-simple-circuits-with-only-dc-sour

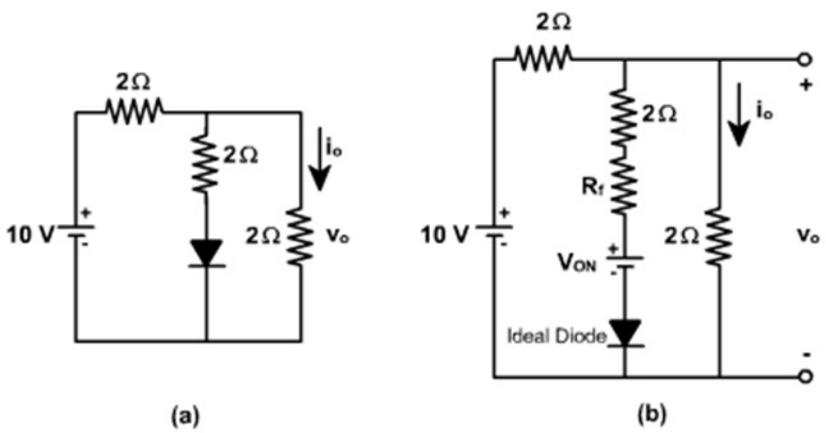
Diode Practice Solution



- Try the four different combinations to see which ones are valid
- D_1 is on and D_2 is off

http://tuttle.merc.iastate.edu/ee201/homework/hw_N/hw_N1.pdf

Real Diode Problem using Ideal Diodes

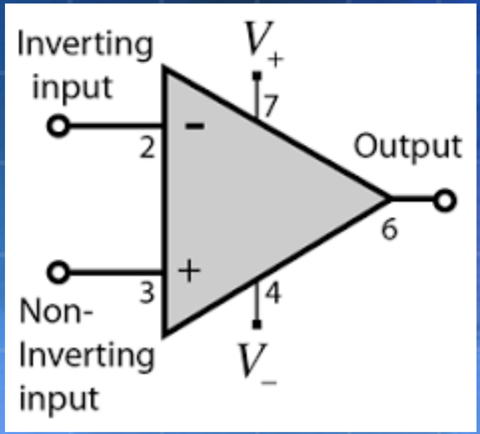


- Transform the real diode into an ideal diode with an ideal diode with the forward biased voltage and R_f (very small) resistance
  - However, if you determine that after solving the problem the current flows in the wrong direction, then it never was in forward bias and was off

https://nptel.ac.in/courses/117107095/3

Operational Amplifiers
(Division C Only)

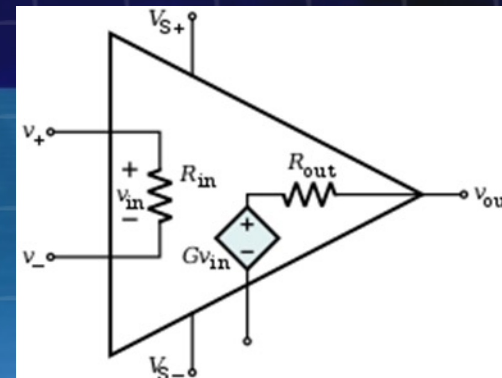
- An operational amplifier (often op-amp or opamp) is a DC-coupled high-gain electronic voltage amplifier with a differential input and, usually, a single-ended output
- Very popular due to its versatility as a differential amplifier.
- Can be set up easily as a comparator, inverting amplifier, or non-inverting amplifier
- <u>NEVER, EVER use a KCL at the output of an Op-Amp</u>

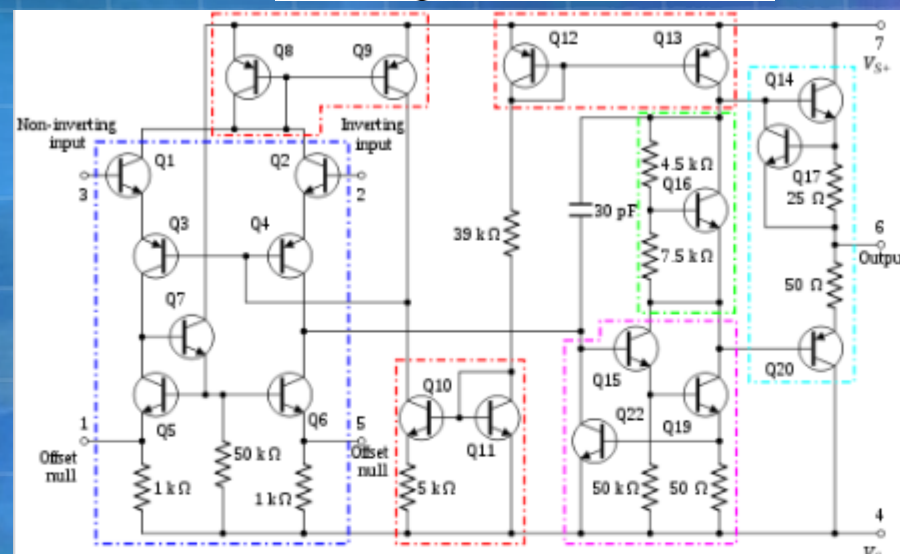


https://en.wikipedia.org/wiki/Operational_amplifier

Ideal Op-Amps

- Full List for Ideal Op-Amps
  - Infinite Open-Loop Gain (G)
  - Infinite Input Impedance (R_{in})
  - Infinite Out Voltage Range (v_{out} max)
  - Infinite Common-Mode Rejection Ratio
  - Infinite Power Supply Reject Ratio
  - Zero Input Offset Voltage
  - Zero Output Impedance (R_{out})
  - Zero Noise
  - Zero Input Current (v_{in}/R_{in})
  - None of these are actual
- Two Golden Rules
  - $V_+ = V_-$
  - Current is zero at V_+ and V_-





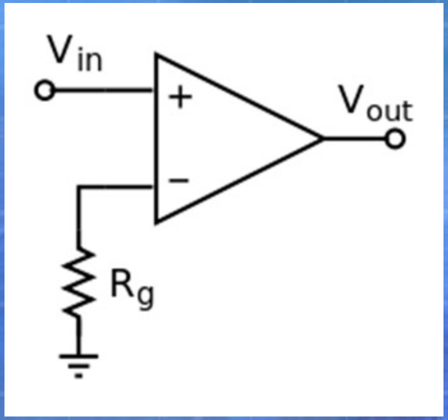
A component-level diagram of the common 741 op-amp. Dotted lines outline: current mirrors; differential amplifier; class A gain stage; voltage level shifter; output stage.

https://en.wikipedia.org/wiki/Operational_amplifier

Op-Amp Uses

Comparator

- Since the Gain is normally 100,000 or more for Op-Amps, a small difference between V_+ and V_- will cause the Output (V_{out}) to go to very near the supply voltage (called Saturation)
  - If $V_+ > V_-$, then maximum output voltage
  - If $V_- < V_+$, the maximum negative output voltage
- Also called a Comparator

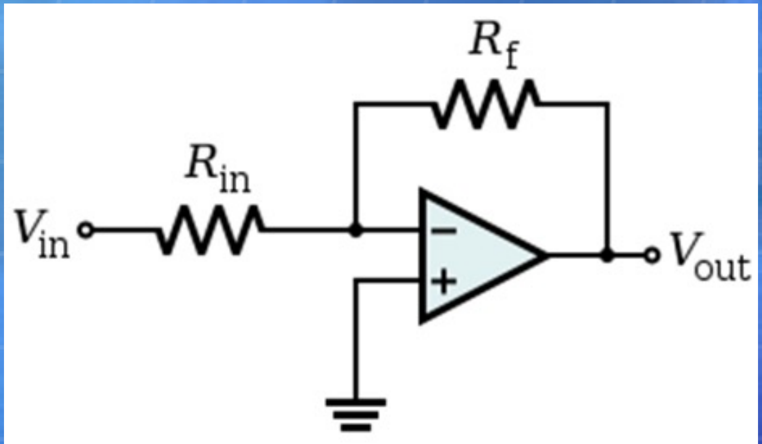


https://en.wikipedia.org/wiki/Operational_amplifier

Op-Amp Uses

Inverting Amplifier

- Inverting Amplifiers can give a large amplification (up to near the Source voltages) and can be easily adjusted—but the polarity is swapped (the inversion)
  - If V_{in} is negative, V_{out} will be positive or vice versa
- Gain is equal to $-R_f/R_{in}$

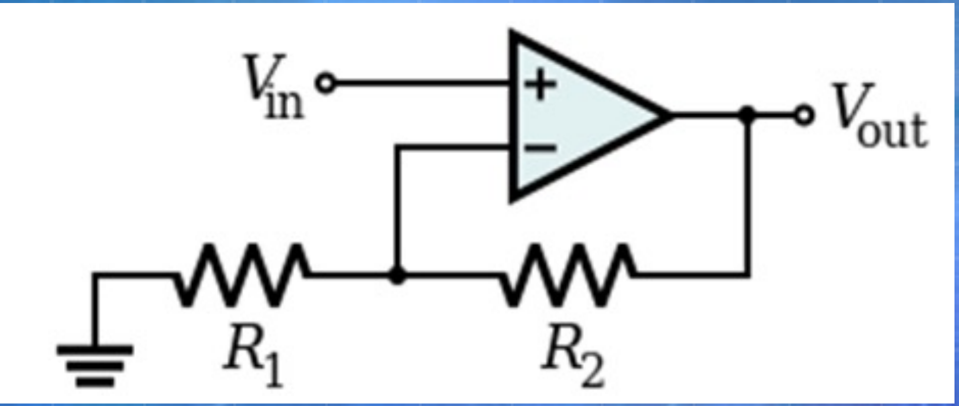


https://en.wikipedia.org/wiki/Operational_amplifier

Op-Amp Uses

Non-Inverting Amplifier

- Non-Inverting Amplifiers can give a large amplification (up to near the Source voltages) and can be easily adjusted—the polarity is remains the same (no inversion)
  - If V_{in} is negative, V_{out} will be negative or the same for positive
- Gain is equal to $(1+ R_2/R_1)$



https://en.wikipedia.org/wiki/Operational_amplifier

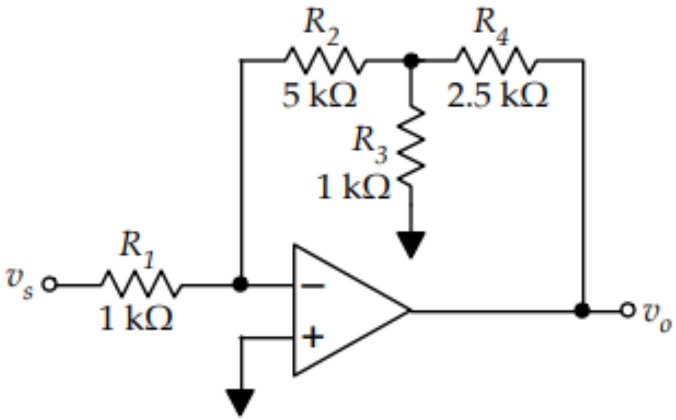
What to do if it is a more complex Op-Amp Circuit

- Simplify by redrawing to make it easier to see (or make it obviously one of the common types
- Simplify by combining resistors as you have seen previously with combining those in parallel, those in series and repeating
- Simplify using the same circuit analysis tools such as KVLs, KCLs, voltage division, current division
- Use the golden rules of OpAmp
- **NEVER, EVER use a KCL at the output of an Op-Amp**

Op-Amp Practice

EE 201 Name________________________________ Sec ______________
Homework N1

Calculate the gain for the inverting-type circuit shown at right.



$G = v_o/v_s =$ ____

- Show you work and how you got to G= -20

http://tuttle.merc.iastate.edu/ee201/homework/hw_N/hw_N1.pdf

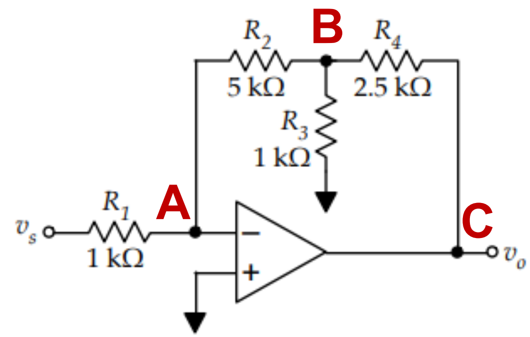
Op-Amp Practice Solution

Exploring the World of Science

EE 201 Name________________________________ Sec _____________

Homework N1

Calculate the gain for the inverting-type circuit shown at right.



$G = v_o/v_s =$ ____

- Current is same through the 1kΩ and 5kΩ resistors, $I_{R1} = I_{R2}$ (from KCL @ A)
- V_- is the same as $V_A = V_- = 0V$
- $I_{R1} = (Vs - V_{1k\Omega})/ 1k\Omega = V_s/1k\Omega$
- $V_B = -I_{1k\Omega} * 5k\Omega = -5V_s$
- $I_{R3} = (V_B - 0)/1k\Omega = -5V_s/1k\Omega$
- KCL @ B– $I_{R2} = I_{R3} + I_{R4} \Rightarrow I_{R4} = 6V_s/1k\Omega$
- $V_C = V_o = V_B - I_{R4} R_4$
  - $Vo = -5Vs - (6Vs * 2.5k\Omega/1k\Omega) =$
  - $Vo = -20V_S$

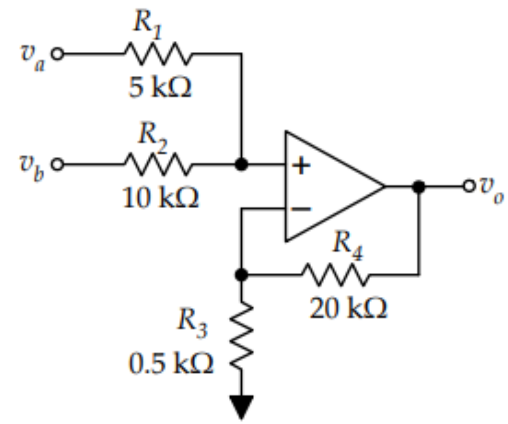
http://tuttle.merc.iastate.edu/ee201/homework/hw_N/hw_N1.pdf

Op-Amp Practice

EE 201 Name______________________________ Sec ____________

Homework N2

For the circuit shown, calculate the output v_o as a function of the inputs v_a and v_b. Assume that the op amp is ideal.



v_o = ____

- Show you work and how you got to $V_o = 13.67(2V_a + V_b)$

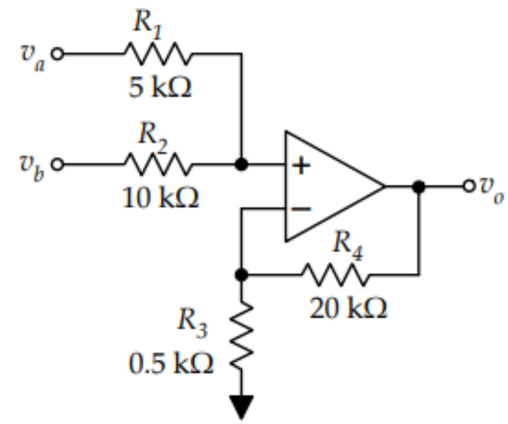
http://tuttle.merc.iastate.edu/ee201/homework/hw_N/hw_N2.pdf

Op-Amp Practice Solution

EE 201 Name________________________ Sec ___________

Homework N2

For the circuit shown, calculate the output v_o as a function of the inputs v_a and v_b. Assume that the op amp is ideal.



v_o = ______________________________

- Recognize that the sub-circuit Op-Amp, R_3 and R_4 is a non-inverting amplifier with a sub-circuit Gain of 41
- Recognize that V_a and V_b is a simple voltage divider where $V_+ = (2V_a + V_b)/3$
- Combine such that $V_o = G\,V_+ = 41\,(2V_a + V_b)/3 = 13.67(2V_a + V_b)$

http://tuttle.merc.iastate.edu/ee201/homework/hw_N/hw_N2.pdf

Arguing an Illegal Question

- Always make sure you read the question again to ensure it really is illegal.
  - Event supervisor might have old rules, but double check your rules first.
- Ask for how to implement the question within the rules.
  - Remove the illegal items like capacitors/inductors/LEDs/etc.
  - Operate it as DC instead of AC.
- Reference the specific rule, normally in section 3.d
- Semiconductors include diodes, LEDs, transistors, OpAmps, and integrated circuits. LEDs, Diodes and OpAmps are now allowed in certain circumstances.
- AC circuit theory includes frequency analysis, two or three phase power, capacitor/inductor reactance. But they can sometimes be made legal by switching to a DC system.
- AC devices include transformers, rectifiers, others. Most will not work with DC.
- Several items are only available for Division C and not for B

Homework

- Update your binder to get it competition ready
- Complete the circuit problems from the Homework Generator
  - Level 15 Diodes
  - Level 16 Operational Amplifiers
- Complete the in class practice problems using your own methods, showing all work. Make sure that your work can be followed by others.
- Design a inverting amplifier with a gain of -100, using 6 resistors and an ideal opamp
- Design a non-inverting amplifier with a gain of 3, using 5 resistors and an ideal opamp
- Design a circuit using diodes that will turn on a Green LED when the input voltage Vin is greater than 3V (assume forward bias voltages)
- Design a circuit using diodes that will only have positive voltage outputs, do not assume forward bias voltages