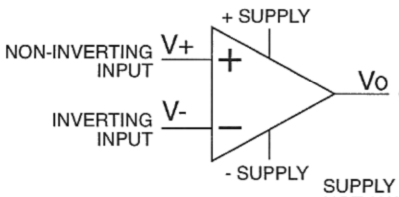
OP-AMP (OPERATIONAL AMPLIFIER) BASICS BY JOE BARBETTA REV.A 01/31/97

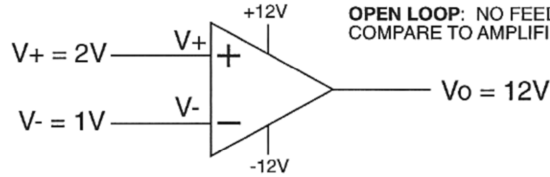


SUPPLY CONNECTIONS NOT ALWAYS SHOWN

INPUT RULE: Zin = INFINITY

OP-AMP INPUTS ARE ALWAYS HIGH **IMPEDANCE** (RESISTANCE). ZERO CURRENT IN OR OUT

USING THE OP-AMP AS A **COMPARATOR** (OPEN LOOP)



OPEN LOOP: NO FEEDBACK LOOP - COMPARE TO AMPLIFIER (CLOSED LOOP)

COMPARATOR RULE: IF V+ > V-, Vo = HIGH

OP-AMP COMPARES BOTH INPUTS. IF THE VOLTAGE AT THE +INPUT > - INPUT THE OUTPUT VOLTAGE GOES UP. IF -INPUT > +INPUT THE OUTPUT GOES DOWN. *REMEMBER THE SCALE ANALOGY: THE HEAVIER WEIGHT TIPS THE SCALE.*

THE OP-AMP IS BASICALLY A CONTROLLER. THESE TERMS AND IDEAS ARE APPLICABLE TO ANY TYPE OF CONTROLLER IN ANY FIELD OF ENGINEERING.

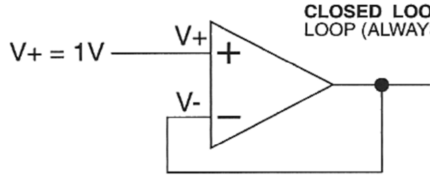
REMEBER THESE 3 BASIC RULES WHEN LOOKING AT OP- AMP CIRCUITS. OP-AMP'S ARE USUALLY USED AS AMPLIFIERS, SO ONE TYPICALLY NEEDS ONLY THE INPUT AND AMPLIFIER RULES.

TRY TO TACKLE AN OP-AMP PROBLEM PIECE BY PIECE. IDENTIFY THE FEEDBACK LOOP AND APPLY THE BASIC RULES. TRY NOT TO REMEMBER THESE RULES AND MANY OTHERS YOU COME ACCROSS AS EQUATIONS, BUT AS IDEAS IN PLAIN ENGLISH.

BELOW ARE SOME PROBLEMS THAT DEMONSTRATE THESE RULES. FOR EACH CIRCUIT DETERMINE THE UNKNOWN VALUES IN THE ORDER LISTED AND FOR AMPLIFIERS, DERIVE AN EQUATION RELATING Vo TO THE INPUT(S). YOU SHOULD ALSO TRY TO DERIVE AN EQUATION WITHOUT RESISTOR VALUES USING R1 AND R2, IF PRESENT. START WITH PROBLEM 1 AND PROCEED IN ORDER.

USING THE OP-AMP AS AN **AMPLIFIER** (CLOSED LOOP)

CLOSED LOOP: HERE WE HAVE A FEEDBACK LOOP (ALWAYS FROM OUTPUT TO - INPUT)

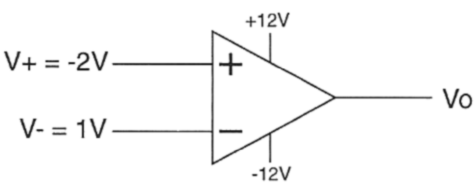


THIS AMPLIFIER HAS A **GAIN** OF 1: Vo = V+.

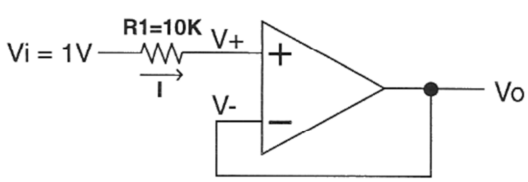
THINK OF THE AMPLIFIER AS A **CONTROLLER**. THE INPUT VOLTAGE IS CONTROLLING THE OUTPUT VOLTAGE. THE LOOP GIVES THIS CONTROLLER FEEDBACK. MOST CONTROLLERS NEED FEEDBACK TO CONTINUOUSLY CHECK THE CONTROLLED VARIABLE, IN THIS CASE THE OUTPUT VOLTAGE. THINK OF HOW THE OP-AMP IS STILL WORKING AS A COMPARATOR, BUT REACHING A STATE OF **EQUILIBRIUM** OR BALANCE. BECAUSE OF THIS WE GET THE BELOW RULE.

AMPLIFIER RULE: V+ = V-

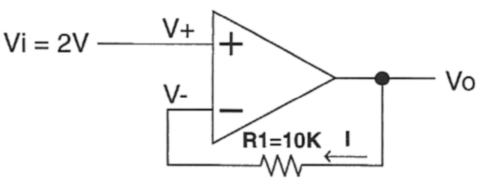
BOTH OP-AMP INPUTS HAVE THE SAME VOLTAGE.



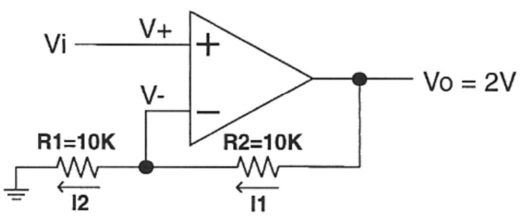
PROBLEM 1: Vo = ?



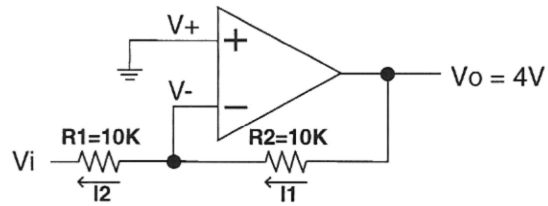
PROBLEM 2: I = ?, V+ = ?, V- = ?, Vo = ?, GAIN = ?



PROBLEM 3: I = ?, V+ = ?, V- = ?, Vo = ?, GAIN = ?

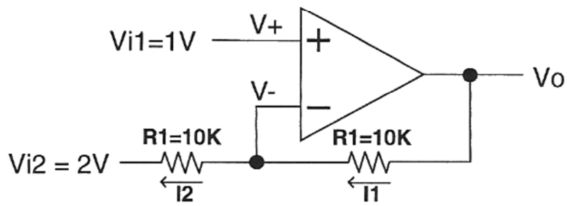


PROBLEM 4: I1 = ?, I2 = ?, V- = ?, V+ = ?, Vi = ?, GAIN = ?

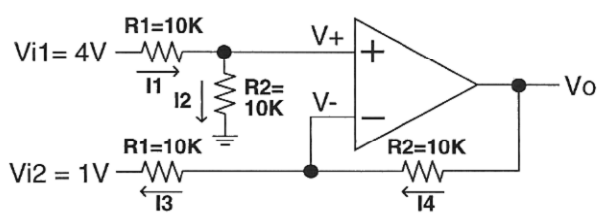


PROBLEM 5: V+ = ?, V- = ?, I1 = ?, I2 = ?, Vi = ?, GAIN = ?

THE NEXT 2 PROBLEMS HAVE 2 INPUTS INSTEAD OF ONE. SOLVE THEM AS YOU DID FOR THE OTHER PROBLEMS, BUT REMEBER THAT THE EQUATIONS FOR THE BELOW AMPLIFIERS SHOULD HAVE 2 INPUT VARIABLES.



PROBLEM 6: V- = ?, I2 = ?, I1 = ?, Vo = ?



PROBLEM 7: I1 = ?, I2 = ?, V+ = ?, V- = ?, I3 = ?, I4 = ?, Vo = ?

AFTER COMPLETING THESE PROBLEMS TRY CHANGING SOME RESISTOR VALUES. ONCE YOU DERIVE AN EQUATION FOR EACH, TRY PLUGGING IN NEW VALUES AND SEE HOW THEY AFFECT GAIN, BUT DON'T RELY ON MEMORIZING THESE EQUATIONS. YOU SHOULD ALWAYS BE ABLE TO DERIVE THEM.

1: Vo=-12V 2: I=0A, V+=1V, V-=1V, Vo=1V, G=1, Vo=Vi 3: I=0A, V+=2V, V-=2V, Vo=2V, G=1, Vo=Vi 4: I1=0.1mA, I2=0.1mA, V-=1V, V+=1V, Vi=1V, G=2, Vo=2Vi, Vo=Vi(1+R2/R1) 5: V+=0V, V-=0V, I1=0.4mA, I2=0.4mA, Vi=-4V, G=-1, Vo=-Vi, Vo=-Vi R2/R1 6: V-=1V, I2=-0.1mA, I1=-0.1mA, Vo=0V, Vo=-Vi2+2Vi1 7: I1=0.2mA, I2=0.2mA, V+=2V, V-=2V, I3=0.1mA, I4=0.1mA, Vo=3V, Vo=Vi1-Vi2, Vo=(Vi1-Vi2)R2/R1