Electronics 2 homework

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Design a break point circuit given by following parameters.

Reference voltage	Break points	Slope
$U_{ref1} = 6.4V$	$U_{inBrk1} = -5V$	$Slope_1 = 1$
$U_{ref2} = -6.4V$	$U_{inBrk2} = 5V$	$Slope_2 = 1$
$U_{ref3} = 1V$	$U_{outBrk1} = -9V$	
	$U_{outBrk2} = 11V$	

Graph

With there parameter we are able to plot a graph of input and output voltage.

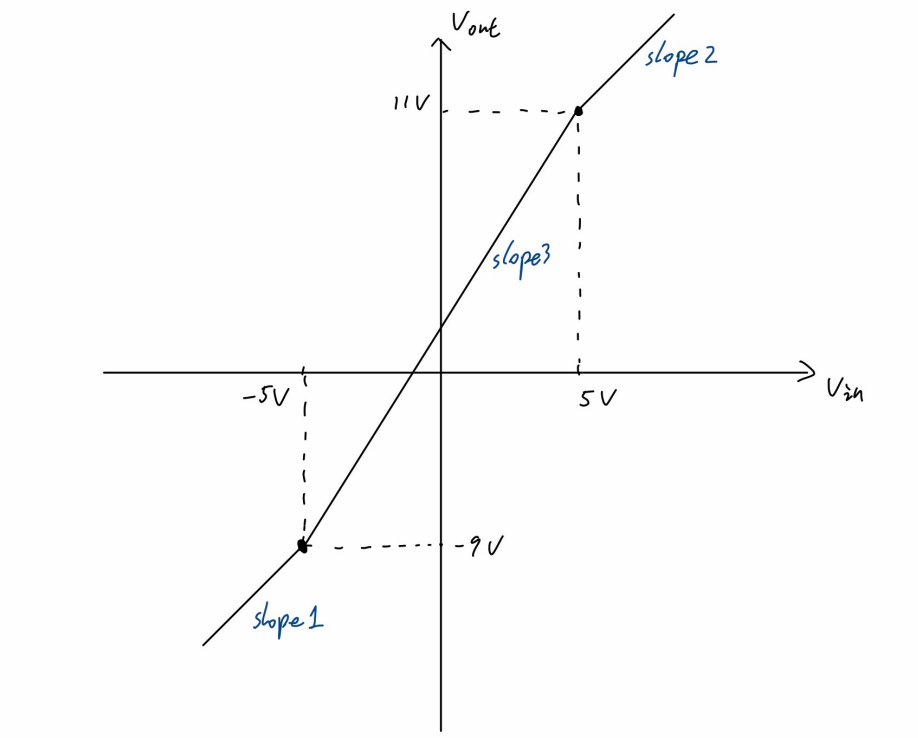

Figure 1: graph

My approch

1. Analyize the graph

We can notice that if we shift the graph by 1 unit down. $U_{outBrk1}$ becomes 10V and $U_{outBrk2}$ becomes -10V. We can then obtain a perface symmetrical graph.

There are two break points with the same slop beforw the fiest breakpoint and after the second breakpoint. We can also calculate the slope between breakpoints as:

$$Slope_3 = \frac{11 - (-9)}{5 - (-5)} = 2$$

This happens to be double of slope 1 and 2.

2. Analyize the circuit

We can seperate the circuit to three parts:

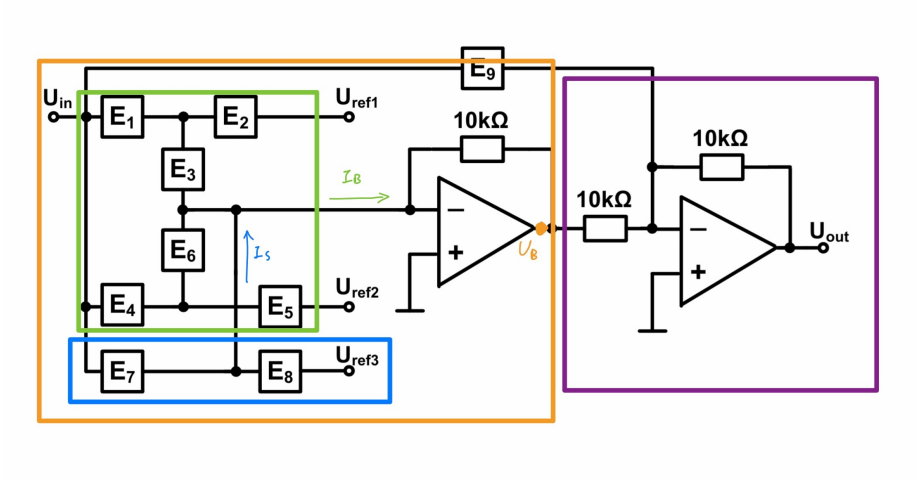

Figure 2: circuit

Part1(Purple) This is a inverting amplifier which invert the voltage output. Graphically the graph will be "fliped" along the horizontal axis.

Part2(Orange) This is a breakpoint circuit it self. The voltage U_B depends on current I_B

$$U_B = -10k\Omega * I_B \tag{1}$$

Part3(Green) The two 3-pole circuit we need to generate two break points.

Part4(Blue) This is not a three pole. But we can shift the graph by supplying a current I_s here.

3. Circuit design

First we assume E9 is open circuit. In which case part1 invert the voltage.

$$U_{out} = -U_B$$

Because of equation 1 and inverting amplifier we need to shift the voltage graph at U_B **up** by 1V. This is done by I_s

$$I_s = \frac{1V}{-10k\Omega} = 0.1mA \tag{2}$$

Now we need to design a break point circuit to match a symmetrical graph. We can see that by adding the two function marked by purple we can get the desired characteristic. The two function have turning points at 5V and -5V. And same slope befor or after the turning point.

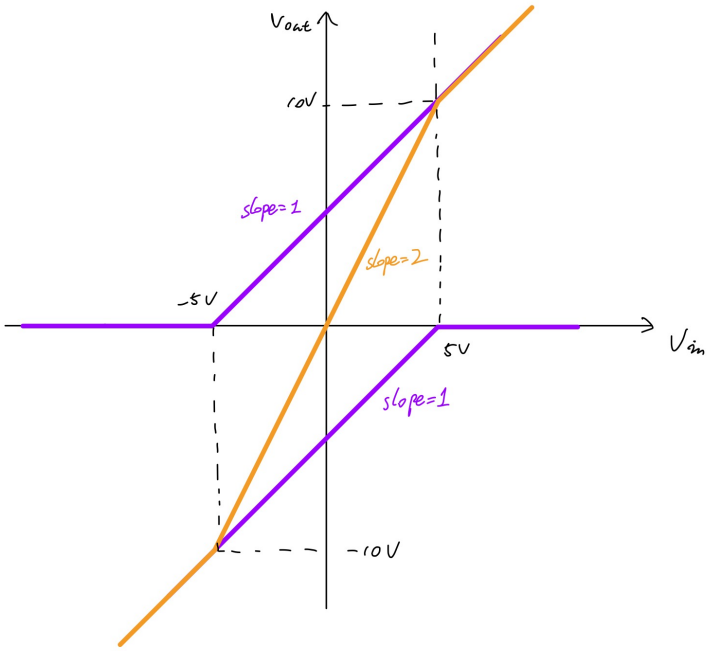

Figure 3: graph2

To achive this characteristic we pick these two 3-pole circuit.

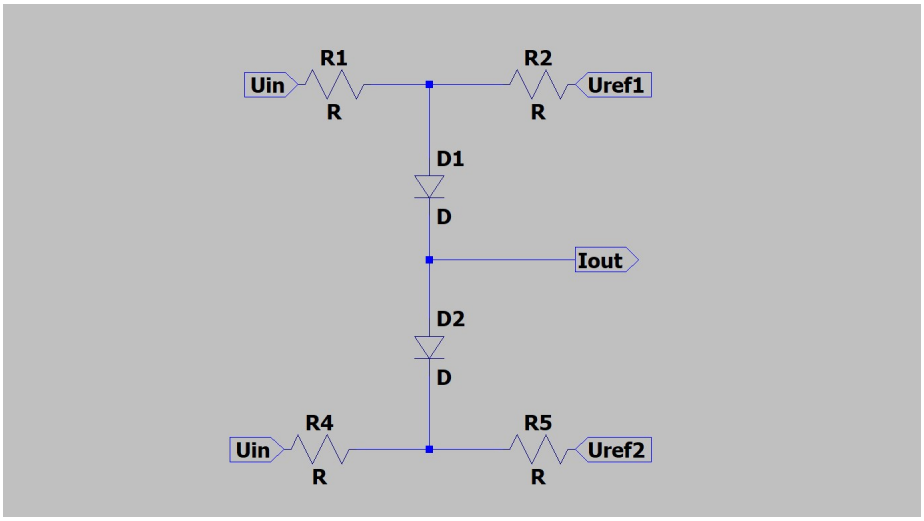

Figure 4: 3-pole circuits

The upper and lower circuit have a turning point at

$$U_{t1} = -\frac{R_1}{R_2}U_{ref1} + \frac{R_1 + R_2}{R_2}U_d = -5V$$

$$U_{t2} = -\frac{R_4}{R_5}U_{ref2} - \frac{R_4 + R_5}{R_5}U_d = 5V$$

The slope of two circuits are the same. We are looking for a slope of $-1\frac{V}{V}$ at U_B point. Consider the relation described at equation 1 the slope of I_B should be.

$$slope_{I_B} = \frac{1}{R_1} = \frac{1}{R_4} = \frac{-1}{-10k} = 0.1\frac{mA}{V}$$

Inorder to supply current I_s we can make E7 an open circuit and E8 a resistor R_8. This way current will flow from U_{ref3} to virtual ground point through R_8. Previously in equation 2 we calculated the current required to shift the graph by 1V. We can then list this equation about I_s

$$I_s = \frac{U_{ref3}}{R_8} = 0.1mA$$

Now we can establish a system of equation

$$\begin{cases} -\frac{R_1}{R_2}6.4V + \frac{R_1+R_2}{R_2}0.7V = -5V \\ -\frac{R_4}{R_5}(-6.4V) - \frac{R_4+R_5}{R_5}0.7V = 5V \\ \frac{1}{R_1} = 10^{-4} \\ \frac{1}{R_4} = 10^{-4} \\ \frac{1V}{R_8} = 0.1mA \end{cases}$$

5 equations and 5 unknowns this is solvable. Results are

$$R_1 = R_2 = R_4 = R_5 = R_8 = 10k\Omega$$

Final design

Component	Value	Component	Value
E1	10k resistor	E6	diode
E2	10k resistor	E7	open circuit
E3	diode	E8	10k resistor
E4	10k resistor	E9	open circuit
E5	10k resistor		

Opreational amplifier supply voltage is hidden from the diagram for the clarity.

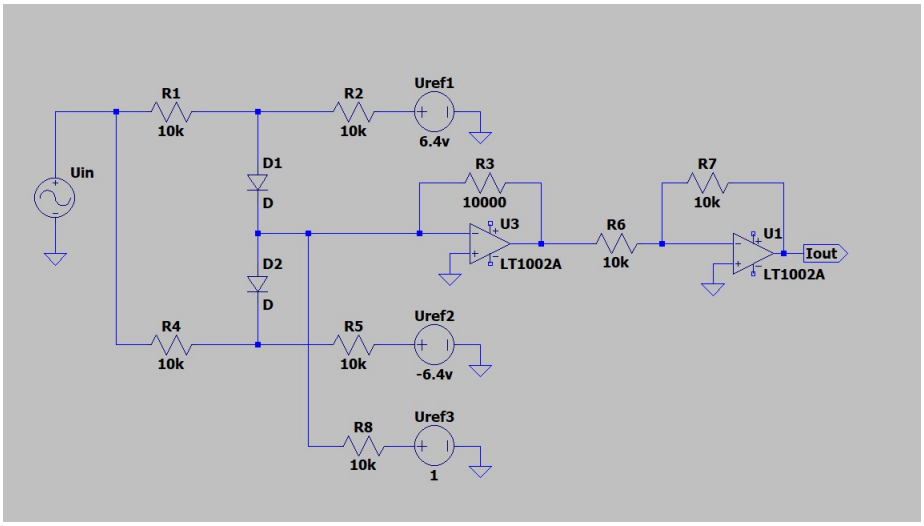

Figure 5: circuit diagram

Simulation

Simulation is done using LTspice. LT1002A opreational amplifier is used for this simulation. Also we need to specify the forward voltage of diodes in the diode model to be 0.7V.

As showen in the simulation two break points meets the desired parameter with around 5% error. We can also calculate the slope of graph.

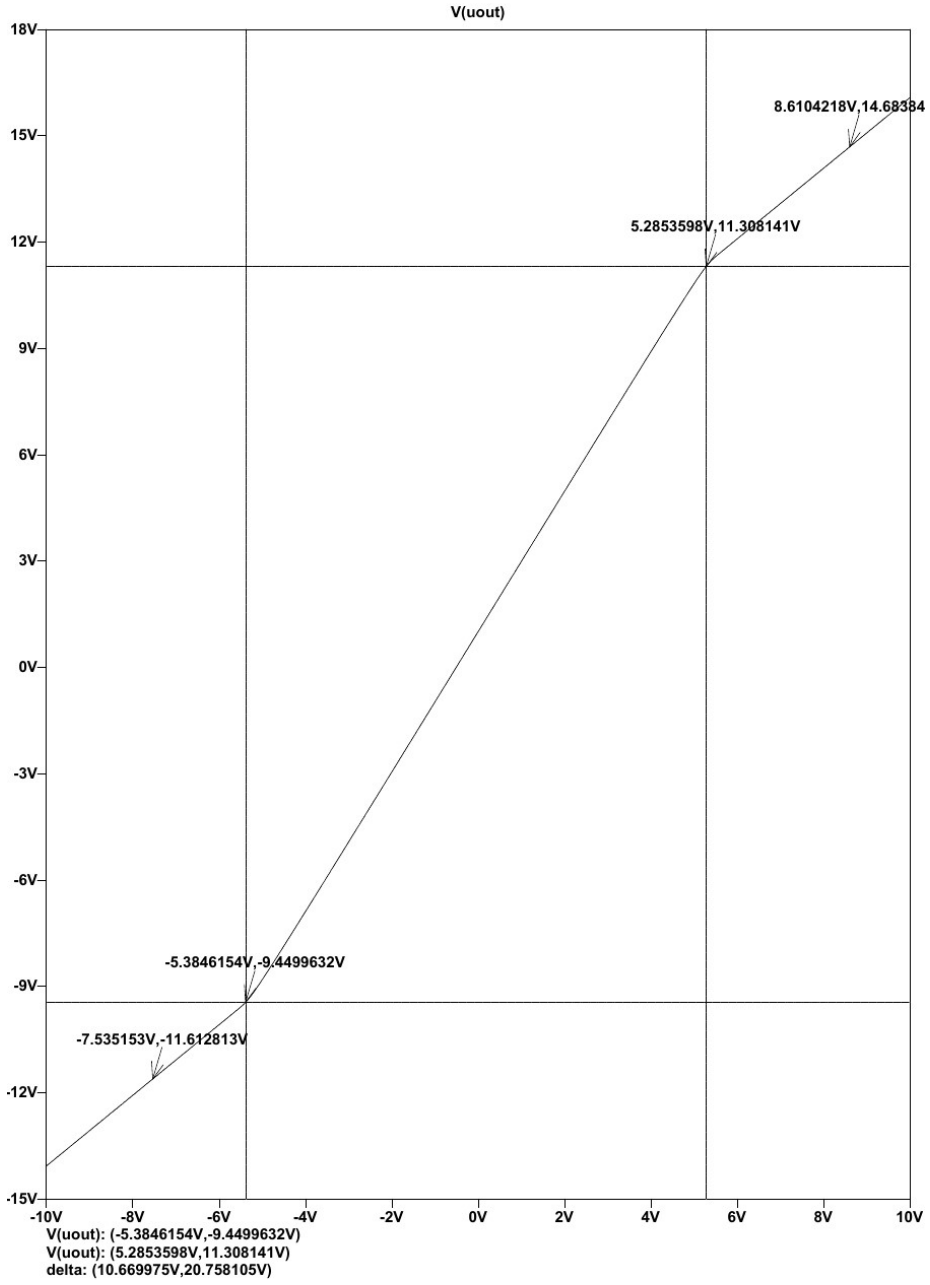

Figure 6: simulation result

$$slope_1 = \frac{-9.45 + 11.61}{-5.38 + 7.54} = 1$$
$$slope_2 = \frac{14.68 - 11.31}{8.61 - 5.29} = 1.02$$
$$slope_3 = \frac{11.31 + 9.45}{5.29 + 5.37} = 1.95$$