A differential amplifier

- Both transistors are identical
A differential amplifier with single-ended output

Block symbol

\( v_{\text{out}} = A(v_1 - v_2) \)

(A is one-half the differential output value)
Single-ended output and single-ended input.

\[ v_{out} = Av_1 \]

Diagram:
- \( v_1 \)
- \( +V_{CC} \)
- \( R_C \)
- \( R_E \)
- \( -V_{EE} \)
**dc analysis**

$I_T$, the *tail current*, flows in $R_E$

$I_T = \frac{V_{EE} - V_{BE}}{R_E}$

$I_E = \frac{I_T}{2}$

$V_C = V_{CC} - I_E R_C$

$R_E$

$-V_{EE}$

$+V_{CC}$

$R_C$

$R_C$

$R_C$
**Common-mode gain**

\[ A_{CM} = \frac{R_C}{2R_E} \]

Diagram:

- Input: \( V_{in(CM)} \)
- Output: \( V_{out} \)
- Power supply: \( +V_{CC} \)
- Resistors: \( R_C \) and \( R_E \)
- Grounds: \( -V_{EE} \)
Common-mode rejection ratio

- $\text{CMRR} = \frac{A}{A_{\text{CM}}}$
- $\text{CMRR}_{\text{dB}} = 20\log \text{CMRR}$
- The higher the CMRR, the better
- A typical op amp has $\text{CMRR}_{\text{dB}} = 90 \text{ dB}$
- Much interference is common-mode and a high CMRR means an amplifier will be effective in rejecting interference
When $V_I$ is more negative than $V_{REF}$, $V_D$ is greater than 0V, and $V_0$ switches to $+V_{SAT}$. 
In this circuit, a zener diode (CR1) completes the feedback path for U1.

U1 is zero based because its noninverting terminal is connected to circuit common. Therefore, the circuit reference voltage is 0V.
If $V_I$ is positive (greater than 0V), $V_o$ swings in a negative direction towards $-V_{SAT}$.

When $V_o$ approximately equals the zener breakdown voltage ($V_z$), CR1 conducts and provides negative feedback. The feedback clamps $V_o$ to the value of $V_z$ and prevents negative saturation.
In this circuit, $V_0$ equals

a. $-V_{\text{SAT}}$

b. 0.7 Vdc.

c. 0V.

d. $+V_{\text{SAT}}$. 
In this circuit, $V_0$ equals

a. $-V_{\text{SAT}}$.  
b. 0.7 Vdc.  
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...
Based on the placement of CR1 (anode lead to U1 output terminal) into the circuit, $V_0$ switches between $-V_Z$ and $+V_F$.

**NOTE:** $V_Z$ is the zener diode breakdown voltage, and $V_F$ is the forward voltage drop of CR1.
In this circuit, the cathode of CR1 is connected to the U1 output terminal. As a result, $V_0$ switches between

a. $+V_Z$ and $-V_F$

b. $-V_Z$ and $+V_F$

c. $+V_{SAT}$ and $-V_{SAT}$.
In this circuit, the cathode of CR1 is connected to the U1 output terminal. As a result, $V_0$ switches between

a. $+V_Z$ and $-V_F$.
b. $-V_Z$ and $+V_F$.
c. $+V_{SAT}$ and $-V_{SAT}$.

Correct. $V_0$ is clamped at $+5\, \text{Vdc}$ and $-0.7\, \text{Vdc}$. 
If $V_0$ equals +5.1 Vdc, $V_I$

a. is negative.
b. is positive.
c. can be either negative or positive.
If $V_0$ equals +5.1 Vdc, $V_I$

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Correct. If $V_I$ is negative, $V_0$ switches toward $+V_{SAT}$ until the clamping action of CR1 occurs.
A zener diode clamped circuit controls the levels of a sine wave or square wave input signal.

For this circuit, either input waveform is clamped at \(-V_Z\) and \(+V_F\). If the CR1 connections are reversed, clamping occurs at \(+V_Z\) and \(-V_F\).
In this circuit (note $V_i$ and $V_Z$),

a. U1 is saturated.
b. CR1 cannot conduct.
c. $V_o$ switches between -5.1 Vdc and +0.7 Vdc.
d. All of the above.
In this circuit (note $V_i$ and $V_o$),

a. $U_1$ is saturated.
b. $CR_1$ cannot conduct.
c. $V_o$ switches between $-5.1 \ \text{Vdc}$ and $+0.7 \ \text{Vdc}$.
d. All of the above.

Correct. $CR_1$ conducts as a zener diode when $V_o$ is positive and as a diode when $V_o$ is negative.
- $V_o$ switches between $+V_F$ and $-V_Z$.

- If CR1 is reversed, $V_o$ switches between $-V_F$ and $+V_Z$. 
In this circuit, $V_I$ alternates between $-4\, V_{dc}$ and $-6\, V_{dc}$. $V_O$ switches between

a. negative and positive saturation, respectively.

b. positive and negative saturation, respectively.
In this circuit, $V_I$ alternates between -4 Vdc and -6 Vdc. $V_o$ switches between

a. negative and positive saturation, respectively.

b. positive and negative saturation, respectively.

Correct. If the noninverting input is negative with respect to the inverting input, $V_o$ is negative; if it is positive, $V_o$ is positive.
END