SNS COLLEGE OF TECHNOLOGY

(An Autonomous Institution)

23EET104 / ANALOG ELECTRONICS

I YEAR / II SEMESTER

UNIT-4: DIFFERENTIAL AMPLIFIERS AND MULTIVIBRATORS

Differential Amplifiers

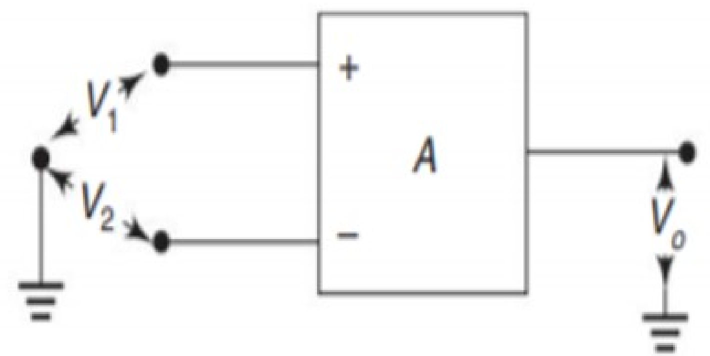
What We'll Discuss

TOPIC OUTLINE

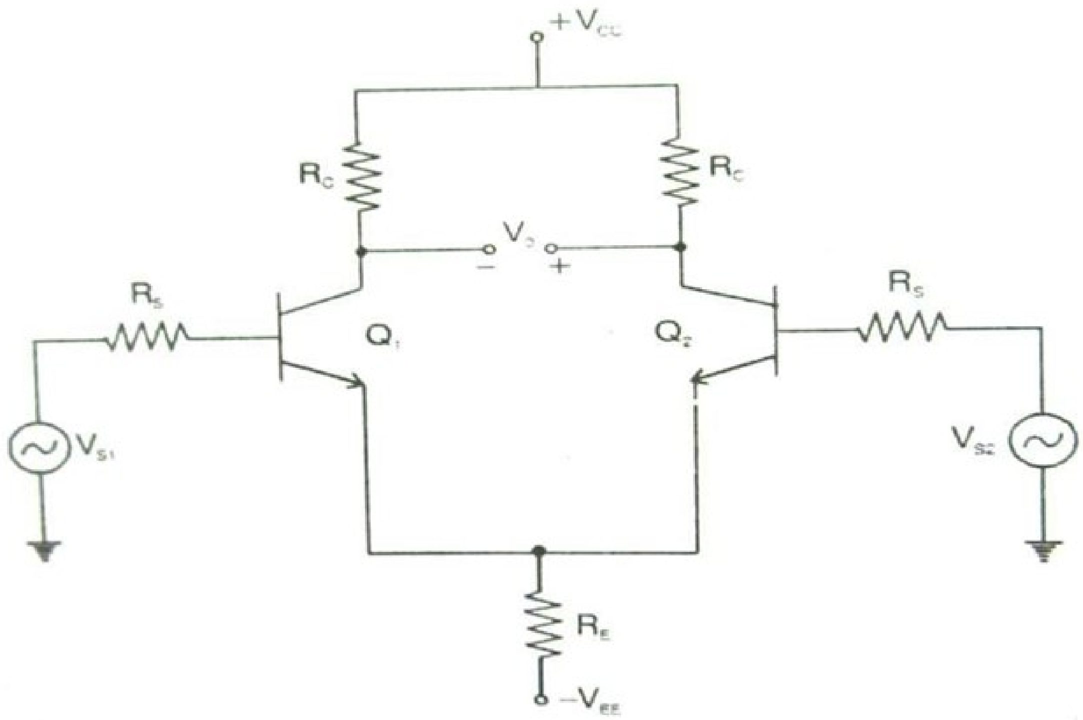
Introduction
Construction
Working
Applications
Advantages
Disadvantages

Introduction

- The function of a differential amplifier is to amplify the difference between two signals.
- The basic block diagram of a differential amplifier consists of two input terminals and one output terminal.



Basic configuration of a differential amplifier



Differential Amplifiers

- The output signal in a differential amplifier is proportional to the difference between the two input signals.

$$V_o \,\alpha\, V_1 - V_2$$

- If V1 = V2, the output voltage is zero.
- A non-zero output voltage is obtained if V1 and V2 are not equal

Vo – Single ended output

Differential Amplifiers

- The difference-mode input voltage is defined as

$$V_d = (V_1 - V_2)$$

- The common-mode input voltage is defined as

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$$V_{cm} = \frac{(V_1 + V_2)}{2}$$

Differential Gain (Ad)

Where, Ad is the constant of proportionality.

- Ad is the gain with which differential amplifier amplifies the difference of two input signals.

$$V_o = A_d \ (V_1 - V_2)$$

- Hence it is known as 'differential gain of the differential amplifier'.

$$A_d = \frac{V_o}{V_d} = -g_m R_C$$

- V1-V2= Difference of two voltage

Common Mode Gain (Ad)

An average of the two input signals is called common mode signal denoted as Vc.

$$V_{cm} = \frac{(V_1 + V_2)}{2}$$

Hence, the differential amplifier also produces the output voltage proportional to common mode signals.

Where Ac = - RC / RE , is the common mode gain. Therefore, there exists some finite output for V1 = V2 due to common mode gain Ac.

Hence the total output of any differential amplifier can be given as,

$$V_o = A_d V_d + A_c V_c$$

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Common Mode Rejection Ratio (CMRR)

The ability of a differential amplifier to reject a common mode signal is defined by a ratio called 'Common Mode Rejection Ratio' denoted as CMRR. •

CMRR is defined as the ratio of the differential voltage gain Ad to common mode gain Ac and is expresses in dB.

$$\mathbf{CMRR = Ad/Ac = g_m R_E}$$

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$$\mathrm{CMRR} = 20\log\left(\frac{A_d}{A_{cm}}\right)$$

$$CMRR = 20\log\left|\frac{A_d}{A_c}\right| dB$$

Differential Amplifiers-Characteristics

Differential Gain:

The gain applied to the difference between the input signals.

Common-Mode Rejection Ratio (CMRR):

The ability of the amplifier to reject input signals common to both inputs.

A high CMRR is desirable.

Input Impedance: The impedance seen by the input signals.

Output Impedance: The impedance seen at the output.

Features of Differential Amplifier

- High differential voltage gain
- Low common mode gain
- High CMRR
- High Input impedance
- Large bandwidth
- Low output impedance

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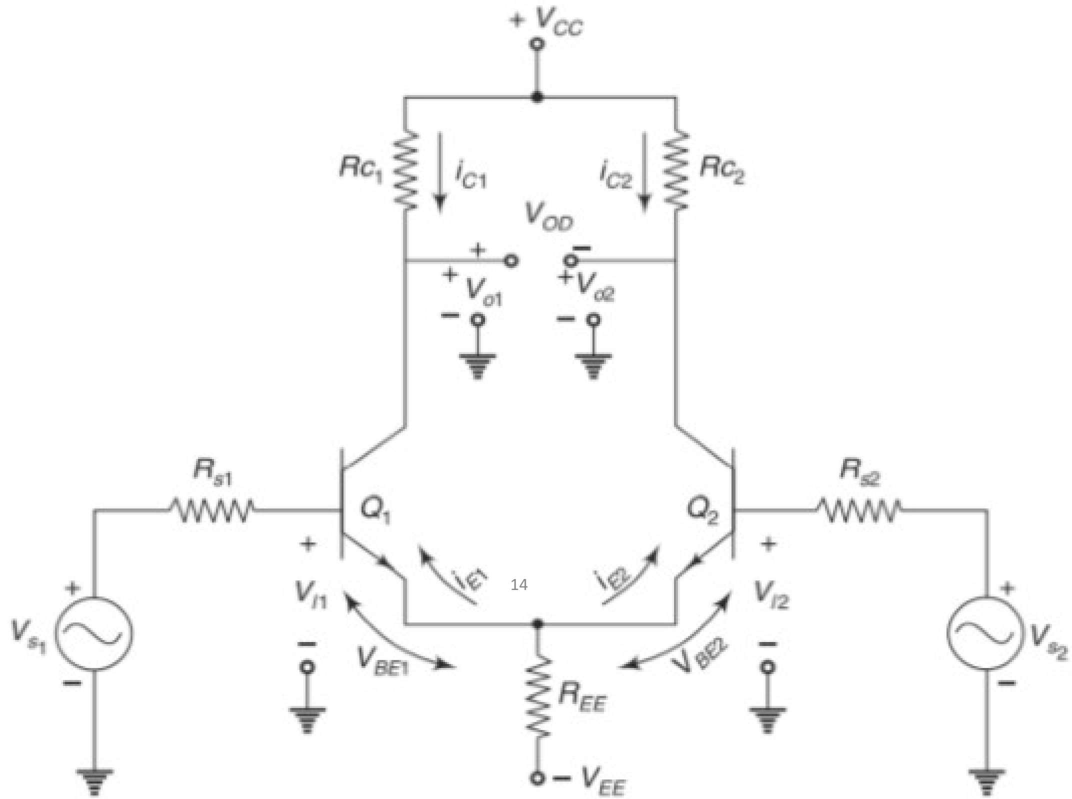
Construction

A differential mode amplifier has two modes of operations

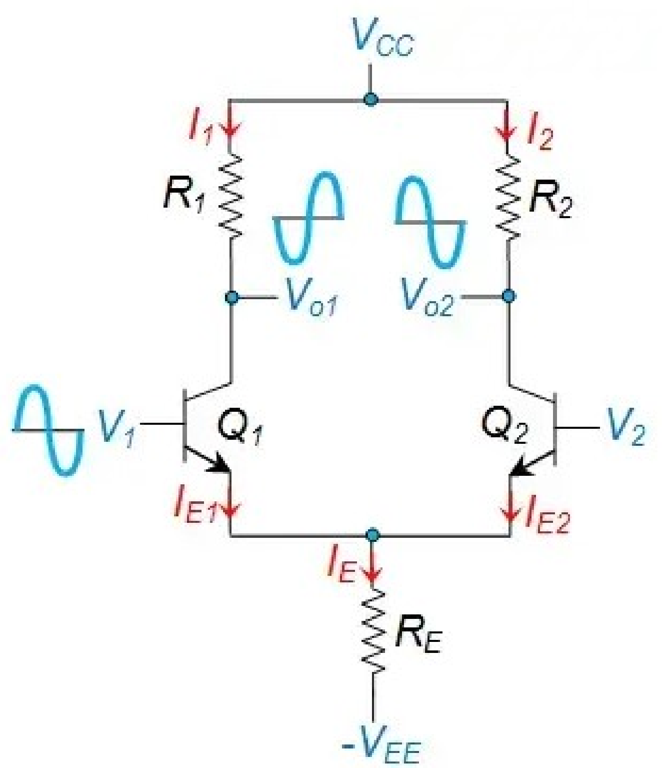
They are

- Differential mode operation
- Common mode operation

Differential Mode Operation



Differential Mode Operation



Operation

BJT differential amplifier circuit made of two BJTs (Q_1 and Q_2) and two power supplies of opposite polarity,

V_{CC} and $-V_{EE}$ which uses three resistors among which two are the collector resistors, R_{C1} and R_{C2} (one for each transistor) while one is the emitter resistor R_E common to both transistors.

Operation

The input signals (V_1 and V_2) are applied to the base of the transistors while the output is collected across their collector terminals (V_{o1} and V_{o2}).

In this case, if the V_1 at Q_1 is sinusoidal, then as V_1 goes on increasing, the transistor starts to conduct and this results in a heavy collector current I_{C1} increasing the voltage drop across R_{C1}, causing a decrease in V_{o1}.

Operation

Due to the same effect, even I_{E1} increases which increases the common emitter current, I_E resulting in an increase of voltage drop across R_E.

- This means that the emitters of both transistors are driven towards positive which in turn implies that the base of Q_2 would start to become more and more negative.
- This results in a decrease of collector current, I_{C2} which in turn decreases the voltage drop across the collector resistor R_{C2}, resulting in an increase in the output voltage V_{o2}.

Operation

This indicates that the changes in the sinusoidal signal observed at the input of transistor Q_1 are reflected as such across the collector terminal of Q_2 and appear with a phase difference of 180^o across the collector terminal of Q_1.

The differential amplification can be driven by considering the output in-between the collector terminals of the transistors, Q_1 and Q_2.

Output Equations

Output $V_o \alpha V_1 - V_2$

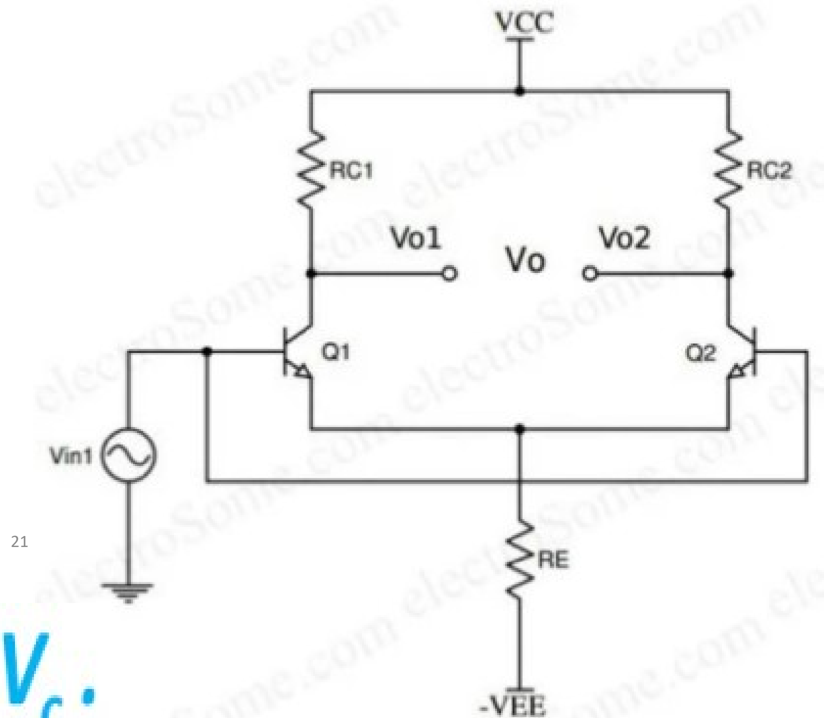
$$V_o = A_d (V_1 - V_2)$$

$$V_o = A_d V_d$$

Differential gain $A_d = V_o/V_d$

Common Mode Operation

differential amplifier is said to be in common mode when same signal is applied to both inputs and the expected output will be zero,ie ideally common mode gain is zero.



$$V_c = \frac{V_1+V_2}{2}.$$

$$V_o = A_c V_c .$$

Common Mode Rejection Ratio (CMRR)

- CMRR is introduced to define the ability of a differential amplifier to reject common mode signal.
- CMRR is defined as the ratio of the differential voltage gain Ad to common mode gain Ac and is generally expressed in dB.

$$CMRR = 20 \log_{10} \left| \frac{A_d}{A_c} \right|$$

Applications

- Differential amplifiers are vital in numerous electronic systems and devices, including but not limited to:
- **Operational Amplifiers (Op-Amps):** Most operational amplifiers employ a differential input stage, enhancing their performance by offering high input impedance and common-mode noise rejection.
- **Analog-to-Digital Converters (ADCs):** Differential amplifiers are crucial in the design of ADCs. They help in eliminating noise and other common-mode signals before the analog signal is converted into a digital one.
- **Audio Systems:** These systems often utilize differential amplifiers to minimize noise interference and maintain high-quality sound reproduction.

THANK YOU

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