A differential amplifier is designed to give the difference between two input signals. As shown in the circuit diagram, there are two inputs, I/P1 and I/P2 and two outputs \( V_{OUT1} \) and \( V_{OUT2} \). I/P1 is applied to the base of the transistor \( T_1 \) and IP2 is applied to the base of the transistor \( T_2 \). The emitters of both \( T_1 \) and \( T_2 \) are connected to a common emitter resistor so that the two output terminals \( V_{OUT1} \) and \( V_{OUT2} \) gets affected by the two input signals I/P1 and I/P2. \( V_{CC} \) and \( V_{EE} \) are the two supply voltages for the circuit. The circuit will also work fine using just a single voltage supply. You may have also noted that there is no ground terminal indicated in the circuit. Hence it must be automatically understood that the opposite points of both the positive and negative voltage supplies are understood to be connected to the ground.

When a differential amplifier is driven at one of the inputs, the output appears at both the collector outputs. When input signal I/P1 is applied to the transistor \( T_1 \), there will be a higher voltage drop across the collector resistance \( R_{COL1} \), and thus the collector of \( T_1 \) will be less positive. When I/P1 is negative \( T_1 \) is turned OFF, and the voltage drop across \( R_{COL1} \) becomes very low and thus the collector of \( T_1 \) will be more positive, almost at \( V_{CC} \). Thus we can conclude than an inverted output appears at \( T_1 \)'s collector for applying signal at I/P1.

When \( T_1 \) is turned ON by the positive value of I/P1, the current through the emitter resistance \( R_{EM} \) increases as the emitter current is almost equal to the collector current \( (I_E = I_C) \). Thus the voltage drop across \( R_{EM} \) increases and makes the emitter of both transistors going in a positive direction. Making \( T_2 \)'s emitter more positive is the same as making the base of \( T_2 \) more negative. In such a condition the transistor \( T_2 \) will conduct less current which in turn will cause less voltage drop in \( R_{COL2} \) and thus the collector of \( T_2 \) will go in a positive direction for positive input signal. Thus we can conclude that the non-inverting output appears at the collector of transistor \( T_2 \) for input at base of \( T_1 \).

The amplification can be driven differentially by taking output between the collector of \( T_1 \) and \( T_2 \). If the transistor \( T_1 \) and \( T_2 \) are identical in all characteristics, and if the voltages are equal \( (V_{BASE1} = V_{BASE2}) \), then the emitter current can also be said to be equal

\[
I_{EM1} = I_{EM2}
\]

Total Emitter Current, \( I_E = I_{EM1} + I_{EM2} \)

\[
V_{EM} = V_{BASE} - V_{BE}
\]

\[
I_{EM} = \left( V_{BASE} - V_{BE} \right) / R_{EM}
\]

The emitter current \( I_{EM} \) remains virtually constant regardless of the \( hFE \) value of the transistors. Since \( I_{COL1} = I_{EM1} \) and \( I_{COL2} = I_{EM2} \), \( I_{COL1} = I_{COL2} \). Also, \( V_{COL1} = V_{COL2} = V_{CC} - I_{COL} R_{COL} \), assuming collector resistance \( R_{COL1} = R_{COL2} = R_{COL} \). Differential amplifier is a closed loop amplifier circuit which amplifies the difference between two signals. Such a circuit is very useful in instrumentation systems. Differential amplifiers have high common mode rejection ratio (CMRR) and high input impedance. The front stage of an OP amp is typically a differential amplifier, which is followed by additional amplification stages.
Operational Amplifier

LM741 (8-pin dual-in-line package): Pin assignment and schematic diagram

Examples of Special IC’s for Medical Applications

**Analog Devices ADAS1000-2** (right)
Low power 5-electrode ECG analog front end companion chip
(~$20)

**Texas Instruments ADS1299** (above)
24-bit, 8-channel, analog-to-digital converter for electroencephalogram (EEG) and biopotential measurements
(~$60)

**Maxim MAX31723** (right)
Digital thermometers and thermostats with SPI/3-wire interface
(~$2)