Voltage Sources

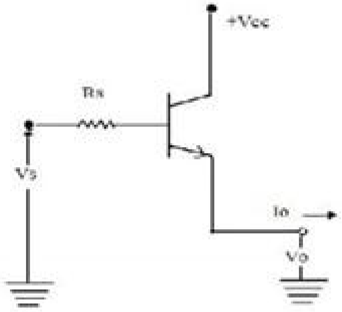
A voltage source is a circuit that produces an output voltage V_0, which is independent of the load driven by the voltage source, or the output current supplied to the load. The voltage source is the circuit dual of the constant current source.

A number of IC applications require a voltage reference point with very low ac impedance and a stable dc voltage that is not affected by power supply and temperature variations. There are two methods which can be used to produce a voltage source, namely,

1. Using the impedance transforming properties of the transistor, which in turn determines the current gain of the transistor and
2. Using an amplifier with negative feedback.

Voltage source circuit using Impedance transformation:

The voltage source circuit using the impedance transforming property of the transistor is shown in figure. The source voltage Vs drives the base of the transistor through a series resistance R_S and the output is taken across the emitter. From the circuit, the output ac resistance looking Into emitter is given by



Voltage source circuit using Impedance transformation:

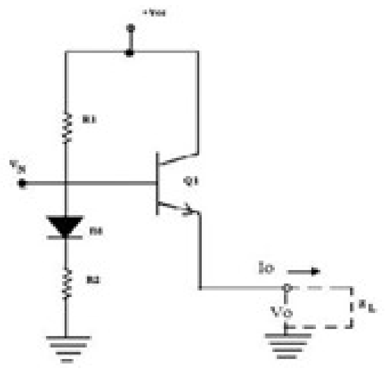
$$\frac{d_o}{dI_o} = R_0 = \frac{R_s}{\beta+1} + r_{eb} \;;$$

With β >> 100, $R_0 = \frac{R_s}{\beta+1}$

It is to be noted that, equation is applicable only for small changes in the output current. The load regulation parameter indicates the changes in V_0 resulting from large changes in output current I_0 , Reduction in V_0 occurs as I_0 goes from no-load current to full-load current and this factor determines the output impedance of the voltage sources.

Emitter– follower or Common Collector Type Voltage source:

The figure shows an emitter follower or common collector type voltage source.



Emitter– follower or Common Collector Type Voltage source

This voltage source is suitable for the differential gain stage used in op-amps. This circuit has the advantages of

A. Producing low ac impedance and

B. Resulting in effective decoupling of adjacent gain stages.

The low output impedance of the common-collector stage simulates a low impedance voltage source with an output voltage level of V0 represented= by

$$V_0 = V_{CC}\frac{R_2}{R_1 + R_2}$$

The diode D1 is used for offsetting the effect of dc value V_{BE} , across the E-B junction of the transistor, and for compensating the temperature dependence of V_{BE} drop of Q_1. The load Z_L shown in dotted line represents the circuit biased by the current through Q_1.

The impedance R_0 looking into the emitter= of Q_1 derived from the hybrid π model is given by

$$R_o = \frac{V_T}{I_1} + \frac{R_1 R_2}{\beta(R_1+R_2)}$$

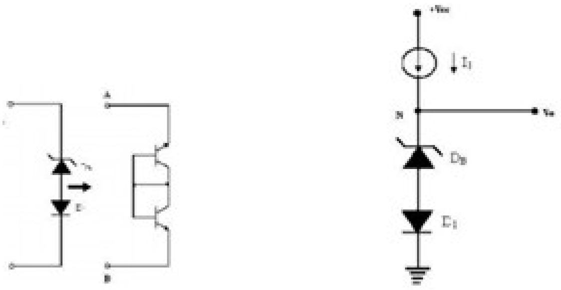
Voltage Source Using Temperature compensated Avalanche Diode

The voltage source using common collector stage has the limitations of its vulnerability for changes in bias voltage V_N and the output voltage V0 with respect to changes in supply voltage Vcc. This is overcome in the voltage source circuit using the breakdown voltage of the base- emitter junction shown below.

The emitter – follower stage of common – collector is eliminated in this circuit, since the impedance seen looking into the bias terminal N is very low. The current source I_1 is normally simulated by a resistor connected between Vcc and node n. Then, the output voltage level V0 at node N is given by

$V_0 = V_B + V_{BE}$ Where V_B is the breakdown voltage of diode D_B and V_{BE} is the diode drop across D_1.

The breakdown diode D_B is normally realized using the base-emitter junction of the transistor. The diode D_1 provides partial compensation for the positive temperature coefficient effect of V_B. In a monolithic I_C structure, D_B and D_1 can be conveniently realized as a single transistor with two individual emitters as shown in figure.



Temperature Compensated avalanche diode

The structure consists of composite connection of two transistors which are diode-connected back-to back. Since the transistors have their base to collector terminals common, they can be designed as a single transistor with two emitters.

The output resistance R0 looking into the output terminal in figure is given by

$$R_0 = R_B + \frac{V_T}{I_1}$$

where R_B and V_T/I_1 are the ac resistances of the base–emitter resistance of diode D_B and D_1 respectively. Typically RB is in the range of 40Ω to 100Ω, and V0 in the range of 6.5V to 9V.

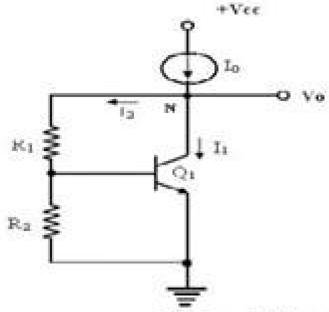
Voltage Source using VBE as a reference:

The output stage of op-amp requires stabilized bias voltage source, which can be obtained using a forward-biased diode connected transistor. The forward voltage drop for such a connection is approximately 0.7V, and it changes slightly with current.

When a voltage level greater than 0.7V, is needed, several diodes can be connected in series, which can offer integral multiples of 0.7V. Alternatively, the figure shows a multiplier circuit, which can offer voltage levels that need not be integral multiplied of 0.7V. The drop across R2 equals VBE drop of Q_1. Considering negligible base current for Q_1, current through R2 is the same as that flowing through R1.

Therefore, the output voltage V_0 can be expressed as

$$V_0 = I_2(R_1 + R_2) = \frac{V_{BE}}{R_2}(R_1 + R_2) = V_{BE}\left(\frac{R_1}{R_2} + 1\right)$$



VBE multiplier Circuit

Hence, the voltage V_0 can be any multiple of V_{BE} by properly selecting the resistors $R_1$and R_2. Due to the shunt feedback provided by R_1, the transistor current I1 automatically adjusts itself, towards maintaining I_2 and V_0 relatively independent of the changes in supply voltage.

The ac output resistance of the circuit R_0 is given= by,

$$R_O = \frac{dV_0}{dI_o} = \frac{R_1+R_2}{1+g_mR_2} \simeq \frac{(R_1+R_2)}{R_2 g_m} \quad \text{When } g_mR_2 >> 1$$

$$R_O = \frac{V_0}{V_{BE}}\frac{1}{g_m} = \frac{V_O}{V_{BE}}\frac{V_1}{I_C} \quad \text{as } \frac{V_O}{V_{BE}} = \frac{(R_1+R_2)}{R_2}$$