Gain Analysis for LM386 Audio Amplifer

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Contents

Abstract—**This manual provides the gain analysis for the LM386 audio amplifier.**

1 Equivalent Circuit of LM386

2 Common Collector(Emitter Follower) Buffer

2.1 What is the gain of Common collector transistor amplifier?
Solution: The voltage gain of amplifier in CC state is a little less than 1.

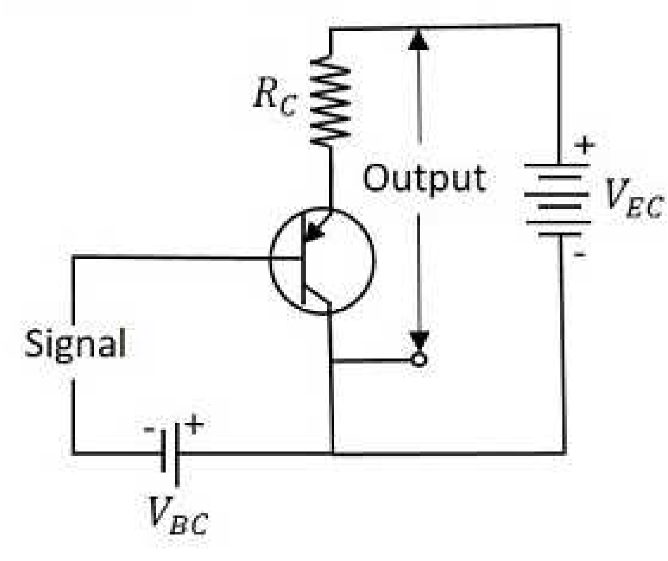

Fig. 2.1

2.2 What is the use of Q1 and Q2 in the internal circuit?
Solution: The first block is a PNP Emitter Follower amplifier (Q1, Q2), it sets the input impedance and defines the DC operation points, raising the input voltages off the ground so the circuit will accept negative input signal down to -0.4 V. Both 50k input resistors (R1, R3) create the path to ground of the base current, the input needs to be coupled so not to disturb the internal biasing, hence the input impedance is dominated by these resistors and set to 50K.

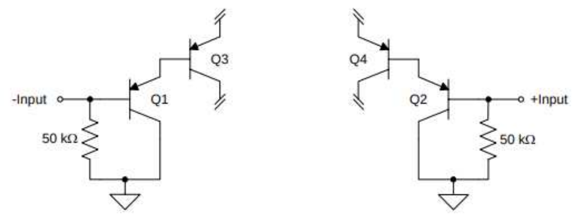

Fig. 2.2

3 Differential amplifier

3.1 What is a differential amplifier?
Solution: The differential amplifier can be considered as an analog circuit which consists of two inputs and one output. The differential amplifier circuit can be represented as shown in the figure below.

3.2 What is the output of a differential amplifier?
Solution: The output voltage of a differential amplifier is proportional to the difference between the two input voltages. This can be represented in equation form as follows: Differential Amplifier Gain

$$G = A(V_{b3} - V_{b4})$$

where V_{b3} and V_{b3} are input base voltages to Q3 and Q4 of differential amplifier and A is the gain of individual amplifiers,assuming them to be identical.

3.3 What is the output of the differential amplifier in the above circuit?

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Solution: The gain is 1 in this case because voltage drop across base-emitter of transistors Q1,Q2,Q3 ad Q4 is same and all are CC transistors.Therefoere, the voltage drop across R_e will be same as difference between the input voltages.
(Note :Section 1 we mentioned gain of CC transistor amplifier is almost 1.)

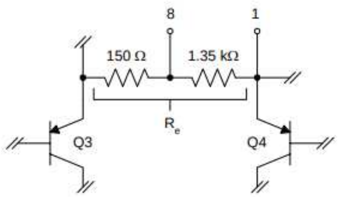

Fig. 3.3

4 Current Mirror

4.1 What is a Current mirror?
Solution: Current mirror circuits generally consist two main transistor, although other devices such as FETs can be used. The current mirror circuit gains its name because it copies or mirrors the current flowing in one active device in another, keeping the output current constant regardless of loading.

4.2 Comment about how the current mirror works in the IC.
Solution: Q5 and Q6 form a current mirror.The differential amplifier is biased by the current mirror.A current mirror is a circuit block which functions to produce a copy of the current flowing into or out of an input terminal by replicating the current in an output terminal.
This can be proved by,

$$V_{be(Q5)} = V_{be(Q6)} = V_b$$

$$I_c = I_{cs}e^{V_b/V_t}$$

$$I_{c5} = I_{c6}$$

Since the two transistors are matched,

$$I_{E5} = I_{E6}$$

Neglecting the base currents by assuming large β .

$$I_5 = I_6$$

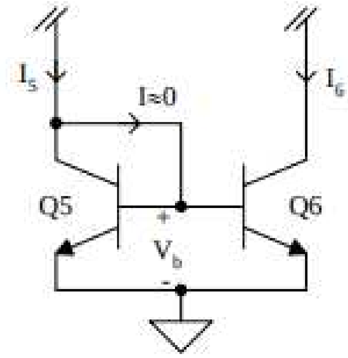

Fig. 4.2

5 Small Signal Analysis

5.1 Draw the small signal equivalent of the internal circuit excluding the BJTs.

Solution: Fig. 5.1

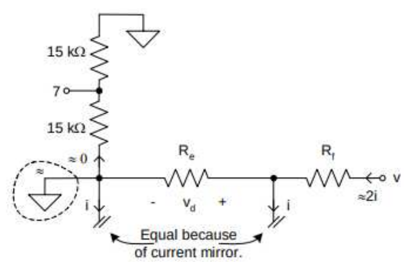

Fig. 5.1

5.2 Derive the relation between input voltage(across differential amplifier) and output voltage.
Solution: The current mirror forces the currents on both halves of the differential amplifier to be equal: both dc and ac components.
Consequently, the currents i at the emitters of Q3 and Q4 must be the same, as shown in Fig.5.6.
Due to the mirror, the current through $R_f = 2i$(approx) , neglecting the current in the two $15k\Omega$ resistors (which are large impedances relative to the other parts of the

circuit). Therefore,

$$\frac{v - v_d}{R_f} = 2i$$

5.3 Given the class AB amplifier what will be the β for the compund pnp transistor in terms of individual β?

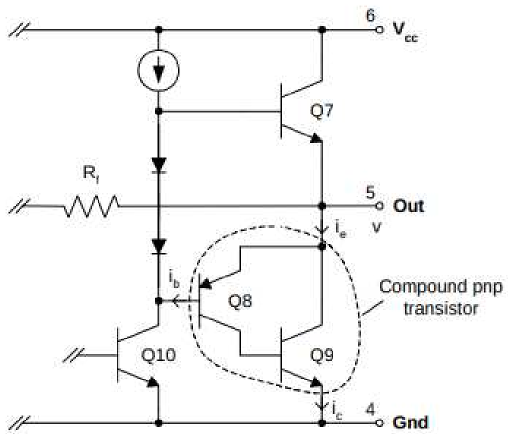

Fig. 5.3

Solution: Here,

$$\beta = \beta_{Q8}\beta_{Q9}$$

which is easy to show starting with $i_{c8} = \beta_{Q8} i_{b8}$ and $i_{c9} = \beta_{Q9} i_{b9}$. Compounding pnp's was done in early IC's to improve the traditionally poor performance of pnp transistors wrt frequency response, etc.

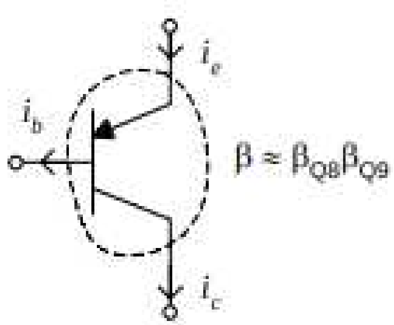

Fig. 5.3

6 Gain Calculation

6.1 The class amplifier will amplify v such that we can assume $v >> v_d$. Derive the gain of the IC assuming the values of resistors given in the internal circuit.

Solution:

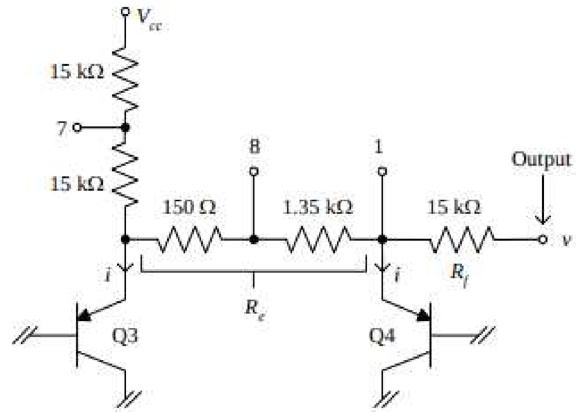

Fig. 6.1

After amplification by class AB amplifier,since we can assume $v >> v_d$

Therefore ,

$$\frac{v}{R_f} = 2i$$

Also from small signal model we got,

$$\frac{v_d}{R_e} = 2i$$

From the above equations we get Gain,

$$G = \frac{2R_f}{R_e}$$

Substituting values from the IC we get

$$G = \frac{2 \times 15k}{150 + 1350} = 20$$