

**Faculty of engineering - Shoubra**

**Benha University**

**Research Article / Research Project / Literature Review**

in fulfillment of the requirements of

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| **Department** |  |
| **Division** |  |
| **Academic Year** |  |
| **Course name** |  |
| **Course code** |  |

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**Research objectives**

Illustrate characteristics of some amplifiers to achieve desire application target like amplification or radio station.

State some real application using a design may be two of them together to have much more stable than any and low in cost rather using whole IC.

Deal with datasheets to some IC and, how to config them to have own target achieved.

Some filters like low pass filter is important for receive signal from emitter so it is important to embedded in our objectives.

**Abstract**

BJTs have wide range usage depend on its properties and stability so, we will deal with more than one BJT amplifier like CE, CC, CB to know what is the difference between then in many characteristics like gain, stability, input/output impedance, linearity, bandwidth, slew rate, power gain, and power efficiency.

Like CE is most used in application as voltage amplifier or amplitude,

CC or emitter follower used as buffer because it has high input impedance and no voltage gain it less than one, dealing with some real application and combine them together.

Datasheet important to understand and achieve desire design, know what volt should applied and what is the predicted output and etc.

**Table of contents**

|  |  |
| --- | --- |
| **Subject / section** | **Page** |
| **Common Emitter Amplifier** |  |
| **Common Collector Amplifier** |  |
| **Common Base Amplifier** |  |
|  |  |
|  |  |
|  |  |

**List of Figures (If any)**

|  |  |  |
| --- | --- | --- |
| **Figure I.D** | **Description** | **Page** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

**List of Tables (If any)**

|  |  |  |
| --- | --- | --- |
| **Table I.D** | **Description** | **Page** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

**Introduction**

A picture containing clock

Description automatically generated1-2 DC Analysis

A DC equivalent circuit is developed by removing the coupling and bypass capacitors cause they appear open when DC bias is concerned. Also removing the load resistor and signal source.

Figure 1-2 show the equivalent circuit.

βRE ≥ 10R2

(150) (.560k) ≥ (10) (6.8k)

84k ≥ 68k (satisfied)

We have option to solve with approximate solution.

Exact solution

Theveninizing the bias circuit and applying Kirchhoff’s voltage law to base-emitter circuit,

**RTH** = = 5.19 kΩ

Figure 1‑ A DC equivalent circuit for the amplifier.

**VTH** = = 2.83 V

**IE** = = 3.58 mA

**IC** ≈ IE  = 3.58 mA

**VE**  = IE RE  = 2.00 V

**VB** = VE + 0.7 V = 2.70 V

**VC**  = VCC  - IC RC  = 8.42 V

**VCE =** VC  - VE  = 6.42 V

1-3 AC Analysis

An ac equivalent circuit figure 1-3 is developed as follows:

1. The capacitors C1, C2 and C3 are replaced by short circuit. Cause their values are selected so that XC  is negligible at the signal frequency and can be considered to be 0 Ω.
2. A close up of a clock

   Description automatically generatedThe dc source is replaced by ground.

First determine the ac emitter resistance.

Figure 1‑**Error! No text of specified style in document.**‑ ac developed equivalent circuit.

**rꞌe** = = 6.98 Ω

then**,**

**Rin(base)** = βac rꞌe  = 1.12KΩ

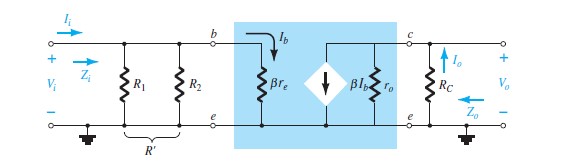
Next, determine the total input resistance viewed from the source.

Figure 1-4 re modeling instead of transistor. equivalent

Figure **Error! No text of specified style in document.**‑ Substituting the r e equivalent circuit

**Literature Review**

1. The Common-Emitter Amplifier

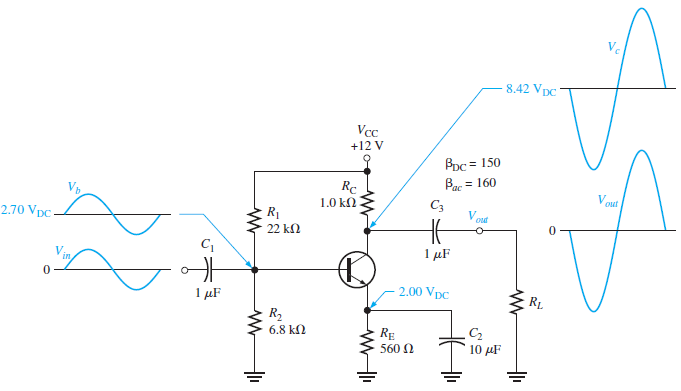


Figure ‑ -1 (A common-emitter amplifier)

Figure 1-1 shows a common-emitter amplifier with voltage divider bias and coupling capacitors C1 and C3 at input and output and bypass capacitor C2 from emitter to ground.

The input signal Vin is capacitively coupled to the base terminal, the output signal Vout is coupled from the collector to the load. The output is 180° out of phase with the input. No signal at the emitter because the bypass capacitor effectively shorts the emitter to ground .

All amplifiers have a combination of ac ad dc analysis(operation). But common emitter specially refers to ac operation.

Phase inversion: As any change in input signal cause change in base current resulting in change in the collector current from its Q-point. If the base current increases, the collector current increase above its Q-point, means voltage drop over RC . increase in voltage drop means decrease the voltage drop across collector.so any change in input voltage result in inverse change in collector signal voltage.

**Input impedance**

**Zin** = R1 || R2 || Rin(base) = 920 Ω

**Output impedance**

**Zout =** RC  || ro ≈ RC  = 1.0 kΩ if ro  ≥ 10 RC

**Voltage Gain**

**AV** = ,

where,

**Vout**  = -(β Ib ) (RC || ro)

and,

**Vin**  = Ib βre.

Then,

**Av** = ( for ro ≥ 10 RC ) = - = 143

**Stability**

Stability measure how amplifier respond to any change form input voltage or temperature or different transistor with different β. RE does maximum voltage gain, there is stability problem it depend on re since Av  = . also re  depend on IE and on temperature. When re increase gain also increase and vice versa.

With no bypass capacitor gain stable but so small, since Av = Rc  / (re + RE).

If RE >> re, the gain essentially independent of re, Av  = RC / RE .

**A close up of a clock

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Figure 1‑**Error! No text of specified style in document.**‑ signals current for +ve half cycle.

**Current gain && power gain/efficient**

Current gain Ai  = Ic  / Is, where Is is the total input current and equal to

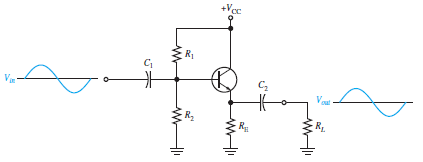
**Is**  = , Rin(ot)  = R1 || R2.

Ib part, and Ibias go through Rin.

Ic is composed of current in collector resistor and load resistor, Rc and RL.

**AP**  = Av Ai  , power gain produced by overall current voltage and overall voltage gain.

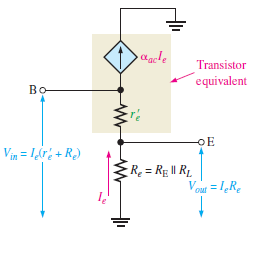
2- The Common-Collector Amplifier

 Common collector (CC) amplifier is usually referred to as an emitter follower (EF). The input is applied to the base through a coupling capacitor, and the output is at the emitter. The voltage gain is approximately 1, the main advantages are is high input impedance and current gain.

a voltage divider bias is shown in figure 2-1, signal input is coupled to the base, the output is coupled from emitter, and collector at ac ground.

Figure a common collector circuit.

The is no phase inversion and the output is approximately the same amplitude as the input.



**Voltage gain**

**Av** = Vout / Vin ,

**Vout** = Ie  Re, Vin = Ie (re + Re)

Then,

Figure Emitter-follower model for voltage gain derivation.

**Av** = Ie Re / Ie (re + Re)

**Av** = Re  / re + Re

Where,

**Re**  = RL || RE  if no load then, Re = RE

And,

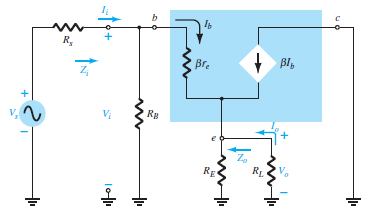
**Av** ≈ 1 If (Re >> re)

**Input resistance**

the common emitter has a high input impedance and low output impedance. Could used ad buffer to minimize loading effects, when it is driving a low-resistance load.

Rin(base) = = = , Ie ≈ Ic = βacIb

Rin(base) = = βac ( re + Re ) ≈ βac Re, if ( Re  >> re ).

**** Rin(total) = R1 || R2 || Rin(base).

**Output resistance**

Rout  = Re || re .

**Current gain**

Gain voltage may be less than 1 but current gain is equal

Ai = Ie  / Iin  ,

Where,

Ie include both emitter and load currents.

Iin = Vin / Rin(total).

**Power gain**

is the product of current gain and voltage gain.

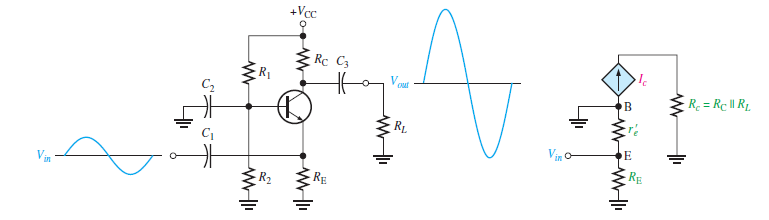
Ap  = Av Ai

Ap ≈ Ai

You can use current divider to determine load current.

**Stability**

More stable cause no bypass capacitor so the gain does not change through change in base current it approximately equal to 1.



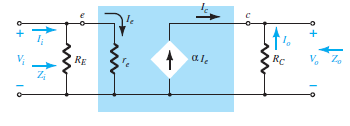


Figure re model for common base amplifier

Figure Common-base amplifier with voltage-divider bias.

3- The Common-Base Amplifier

A typical common base amplifier is shown in the figure. The base is in common terminal and is at ac ground because of capacitor C2.

Input signal is capacitively coupled to the emitter. The output is capacitively coupled from the collector to a load resistor.

Vout = Vc = Ie (Rc)

Vin = Ie ( Re + re ), Re = RL || RE

**Voltage gain**

Av = Rc / (Re||re), Rc >> re

Av = Rc / re

Gain expression is the same as common emitter but no inversion.

**Input Resistance**

Rin(emitter)  = = =

If, RE  >> re, then

Rin(emitter) ≈ re

The input resistance can be set to a desired value within limits by using a swamping resistor. This is useful in communication systems and other applications where you need to match a source impedance to prevent a reflected signal.

We always neglect the ro resistance cause it exceed more than 100 kΩ, so

ro || Rc  ≈ Rc , Rout  = Rc where Rc = RC || RL

**Current gain**

The current gain is the output current divided by the input current.

Icis the ac output current, and Ieis the ac input current.

Since Ic > Ie, the current gain is approximately 1.

Ai ≈ 1

**Power gain**

The common base amplifier is primarily a voltage amplifier, so power gain is not too important.

The total power gain is approximately equal to the voltage gain.

AP ≈ Av

The power gain includes both load and collector resistor, if you want to calculate power gain only to the load, then divide V2out / RL by the input power.

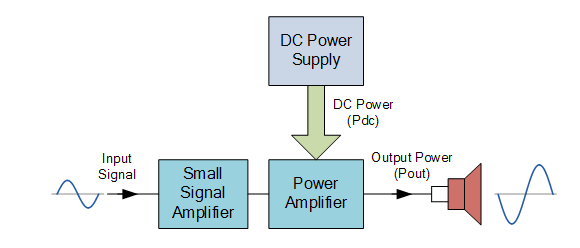
**Stability**

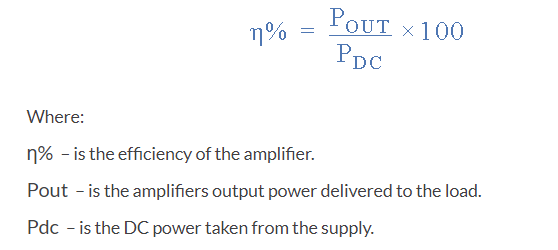
It like common emitter no stability cause the current if collector and emitter could change the value of re cause change in gain Av = Rc / re

**Power efficiency**

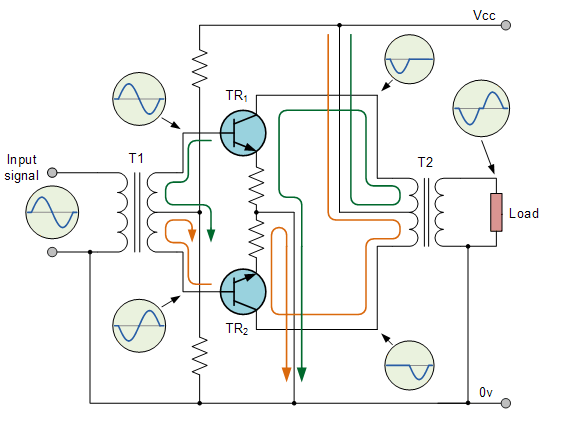
Since we are interested in delivering maximum AC power to the load, while consuming the minimum DC power possible from the supply we are mostly concerned with the “conversion efficiency” of the amplifier.

However, one of the main disadvantage of power amplifiers and especially the Class A(our example) amplifier is that their overall conversion efficiency is very low as large currents mean that a considerable amount of power is lost in the form of heat. Percentage efficiency in amplifiers is defined as the r.m.s. output power dissipated in the load divided by the total DC power taken from the supply source as shown below.





**Class B Amplifier**also known as a**push-pull amplifier**configuration.

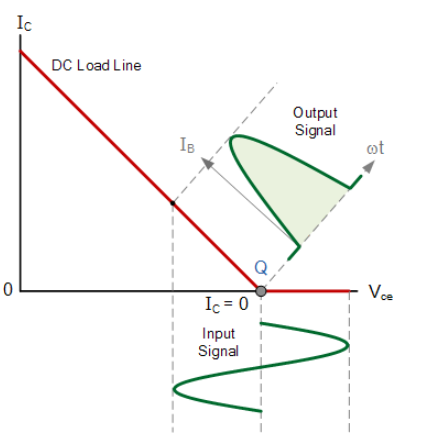


uses a balanced center-tapped input transformer, which splits the incoming waveform signal into two equal halves and which are 180o out of phase with each other.

operation has zero DC bias as the transistors are biased at the cut-off, so each transistor only conducts when the input signal is greater than the Base-emitter voltage. Therefore, at zero input there is zero output and no power is being consumed. This then means that the actual Q-point of a Class B amplifier is on the Vce part of the load line as shown below.

The **Class B Amplifier** has the big advantage over their Class A amplifier cousins in that no current flows through the transistors when they are in their quiescent state (ie, with no input signal), therefore no power is dissipated in the output transistors or transformer when there is no signal present unlike Class A amplifier stages that require significant base bias thereby dissipating lots of heat – even with no input signal present.

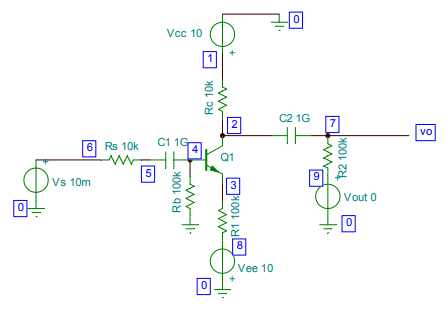
So the overall conversion efficiency ( η ) of the amplifier is greater than that of the equivalent Class A with efficiencies reaching as high as 70% possible resulting in nearly all modern types of push-pull amplifiers operated in this Class B mode.



**Slew rate**

Slew rate (SR) It is defined as the maximum rate of change output voltage per unit of time and is expressed in volts per millisecond. In equation form

SR= dVo / dt maximum V / microsecond. The slew rate is found to be 20.45 (depend on figure 1-6 ) V/micro second, which is shown in figure 1-7.



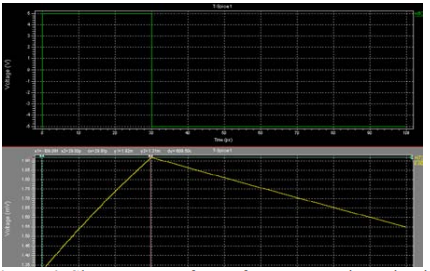
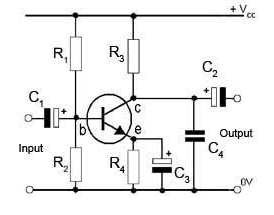


Figure 1‑ Comment emitter circuit with no feed-back.

Figure 1‑ Slew rate waveform of common emitter circuit

**Bandwidth**

Every amplifier should have range of frequencies, too narrow a bandwidth will be loss, too wide unwanted signals come.

The signal must pass through the input and output coupling capacitors C1 and C2 as it passes from input to output. The primary function of these capacitors is to provide DC isolation from voltages in preceding and following circuits. Also however, because the action of capacitors is frequency dependent they also can have an effect on the bandwidth of the amplifier.

Figure 1- abstract of CE voltage divider

C1, together with R1, R2 and the input resistance of the transistor forms a high pass filter, and C1 will normally have a quite large value of capacitance, making the corner frequency of the filter very low. At frequencies below this point however, amplifier gain will be reduced.

C2 will act in a similar manner with the input impedance of any following circuit, also contributing a fall off in gain at low frequencies.

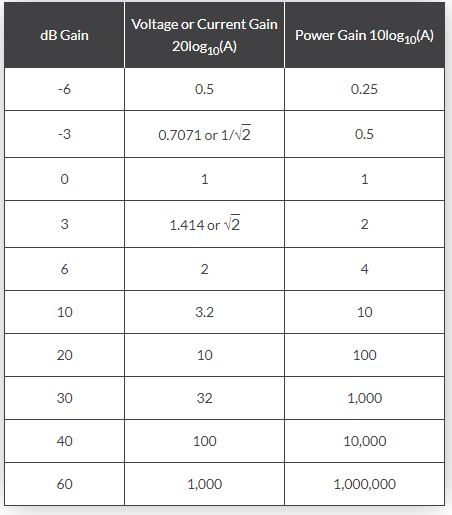
## 

Emitter Decoupling

The emitter decoupling capacitor C3, connected across the emitter stabilising resistor R4 is intended to prevent any AC signal appearing on the emitter, which would otherwise act as negative feedback, severely reducing the gain of the amplifier. The relatively large value of C3 almost entirely removes any AC from the emitter, but it will have some reactance at the lowest frequencies and so allow some very low frequency signals to appear on the emitter, (assuming that these frequencies have not been removed by the action of C1 and C2 as described above) and whilst C3 contributes to higher gain over most of the bandwidth, gain at very low frequencies may not be improved.

The values of C1, C2 and C3 are therefore chosen to give the required fall off in gain at the low frequency end of the bandwidth.

Table change in circuit behavior depend on its input frequencies change.

Each transistor therefore has a limit to its high frequency current gain, and this is normally listed in transistor data sheets as the cut-off frequency fT. This is the frequency at which the small signal current gain hfe falls to 1. As gain begins to fall off at 6dB per octave (a doubling in frequency) well before fT is reached, the transistor needs to be operated at frequencies considerably lower than fT. Because of the relationship between frequency and gain in transistors, fT is also commonly listed as

"Gain Bandwidth Product".

Bandwidth = FH – FL.

Vout / Vin  = 1 so, 20 log(1) = 0dB.

Common emitter amplifier has a narrow bandwidth cause the gain is high and relation between then is inverse.

PS: with no bypass capacitor C3, the gain is a lower but bandwidth get more wide.

Common Collector amplifier has wide bandwidth cause no bypass capacitor to prevent AC signal.

Common base amplifier has more wide bandwidth than common emitter with bypass capacitor.

**Conclusions**

A many characteristics sush as gain, stability, input/output impedance, linearity, bandwidth, slew rate, power gain, and power efficiency vary from one design to another, discussed with simplicity over some amplifier , Which are Common Emitter, Common Collector and Common base amplifiers.

Different amplifier have different purposes and more vary properties than other and

Most of their usage in real life.

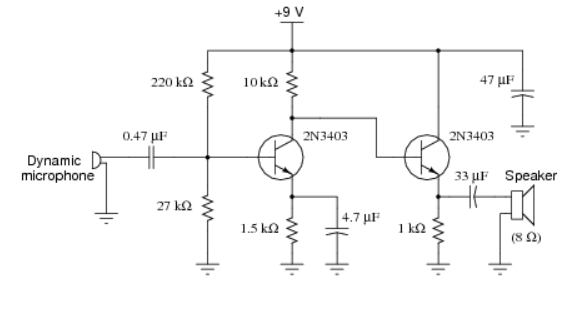
Operate some simulation for some application like RF, audio, Comparator.

Characteristics like bandwidth and power efficiency depend on some variation not a special designed circuit we made a small intro to how we can analysis any circuit with different approaches and what we want from each analysis.

Some new websites and references came out to support more details and replaced

Them with some knowledge to come like this.

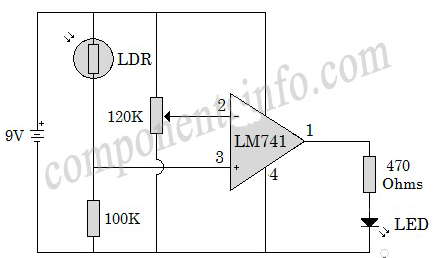
Many application should have its own design to achieve the desire purpose and it a trade off dealing cost gain power usage and frequency bandwidth.

Part 2

The following schematic shows a simple, two-stage audio amplifier circuit:

Signal of voice taken from microphone then coupled throw base(input) capacitor 0.47 µF gained with common emitter amplifier 2N3403, depend on its characteristics which have great gain when bypass capacitor is embedded and high input impedance so no wasted power or current.

and the output is produced at collector buffered throw the common collector amplifier to have no drop and delivered to the speaker after removing noised with the capacitor 33 µF.

light sensor using LM 741 IC mean while no light sticks LDR 3 will be more then 2 then the output will be 1 and the LED will be on.

Based on high input voltage range and short circuit protection. It sense the light so the negative 2 is bigger than ­positive 3 and the output is so small no amplification for current, but in reverse state the current will be amplified then the led will have quiet current. LM741 is single operation amplifier.

![A picture containing clock

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from ant1 and converted to audio wave, or a recever.

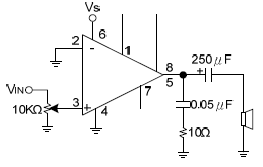
Common base amplifer is used here base on there is ability to make match circuit based on Coil L2 and Capacitors C6, C7 and C5.

With its low input impedance we will garenteed that no distorsion or bandwidth drop happened cause matching will adjust perfectly. Low input impedance to prevent a reflected signal.

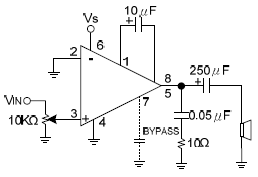
Current gain is almost equal 1 to get no more distorting in signal.

Audio amplifier system

Using LM386 to amplify input signal but with great adjustment on 2 pins pin 1 and pin 8.

Let them open circuit gain will be 20 out on internal resistor 1.35 KΩ (26bB).

If we bypass that resistor the gain will be 200(45dB).

combine them together with a variable resistor the gain could adjusted between 20 and 200.

LM741

LM386

**References**

Microelectronic Circuits 6th Edition, SEDRA/SMITH.

Electronic Devices and Circuit Theory, Robert L.BOYLESTAD & LOUIS NASHELSKY.

<https://www.ekb.eg>