Amplifier Teaching Aid

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Preface

Nearly two years ago − the German Development Service (DED) offered me the possibility to assist a technical college in the Philippines.

I had finished my studies in electronic engineering in Germany and had gained several years of working experience in the development of medical electronic equipment and the organization of telecommunication units.

Since I have been assigned with the Don Bosco Technical College, I have been teaching in electronics/ computer science, and have been working in the training for instructors.

One of the mayor problems I encountered was the lack of preparation time for the lessons. Many teachers are under steady time pressure because they have to serve two or more jobs in order to earn the adequate income. That gave me the idea to develop a ready−made lesson preparation for teachers.

Based on my experience and also due to the visit of many other schools I edited and compiled this Teaching Aid. I tried to integrate practice and theory which is the best way to provide a solid foundation. I hope this will support the teachers as well as it can improve the quality of classes.

Andreas Lange

Canlubang, Philippines
November 1993

Introduction

Amplifier Teaching Aid is a teaching module made for teachers. It. is a ready−made lesson preparation and not a textbook. Therefore, you (the teacher) should already have some background knowledge on analog electronics. This module gives you all the material you need to run a course in basic analog electronics.

The module is divided into lessons/ each lesson is headed by a lesson plan followed by boardscripts, worksheets, and experiments. It also contains three evaluations which you can use as tests/exams or as advanced exercises. The lesson plans are not only containing the contents of the lesson, but also gives you the objectives and suggested methods and ways to carry out the lesson.

The following informs you about the purpose of every lesson plan column:

Time	−The 'Time' column is still blank, it is up to you to decide how much time you would like to spend on each topic. The average time per lesson is approximately 90 minutes.
Method	−The 'Method' column suggests a sample of teaching methods. Lesson plan 1 and 2 are already filled up to give you an example on how to use this column. I recommend the use of abbreviations, the meaning of every abbreviation is given at the bottom of every method column.
Topic	

	−The 'Topic' column gives you a brief description of the contents of every lesson. Feel free to add or drop some topics. Every topic is handled in the following boardscript pages.
Way	−The 'Way' column suggests a sample of teaching tools. Lesson plan 1 and 2 are already filled up . The explanation for the abbreviation used is given at the bottom of every way column. The boardscript pages of every lesson contain examples (EX) and hands−on (HO) exercises. The HO's should be carried out by the students during the lesson.
Remark	− The 'Remark' column provides you with space for additional information. (i.e.: Where can I find the transparency/ picture which I decided to use, or: What is the filename of the demo program which I already prepared)

This analog electronic course is designed for students with prerequisite knowledge in electronics. At least, they should know how to use Ohm's and Kirchhoff's law. Also some laboratory experience (how to measure voltage .current and resistance) is needed.

Lesson 1 − Semiconductor Review

Lesson Plan

Title: Semiconductor Review
Objectives:

- − Know the difference between conductor and semiconductor
- − Able to describe N− and P type semiconductor
- − Understand the diode principle

Time	Method	Topic	Way	Remark
	S	*Introduction - Conductor - Semiconductor - Silicon crystal - Types of flow	B P	 Fig. 1-1
	Q/A	Review		
	S,D	*Doping a semiconductor - N type - P type		
	S	*Diode - Unbiased diode - Biased diode	 P	 Fig. 1-2, 1-3
	E	*Review exercise	WS	Worksheet No. 1
	E	*Experiment - Diode Principle -		Experiment No. 1

S : Speech
D : Discussion
Q/A : Question/Answer
E : Exercise

B : Boardscript
P : Picture
Ex : Example
HO : Hands-On
WS : Worksheet
HT : Hand-Out

Introduction

Conductor

A neutral copper atom has only one electron in its outer orbit. Since the single electron can be easily dislodged from its atom, it is called a free electron.

Semiconductor

Silicon is the most widely used semiconductor material. The number of electrons in the valence orbit is the key to conductivity. Conductors have one valence electron, semiconductors have four valence electrons, and insulators have eight valence electrons.

Silicon Crystals

Each silicon atom in a crystal has its four valence electrons plus four more electrons that are shared by the neighboring atoms. At room temperature, a pure silicon crystal has only a few thermally–produced free electrons and holes.

Intrinsic Semiconductor

An intrinsic semiconductor is a pure semiconductor. Intrinsic silicon acts as an insulator at room temperature.

Two Types of Flow

Flow of free electrons, flow of holes

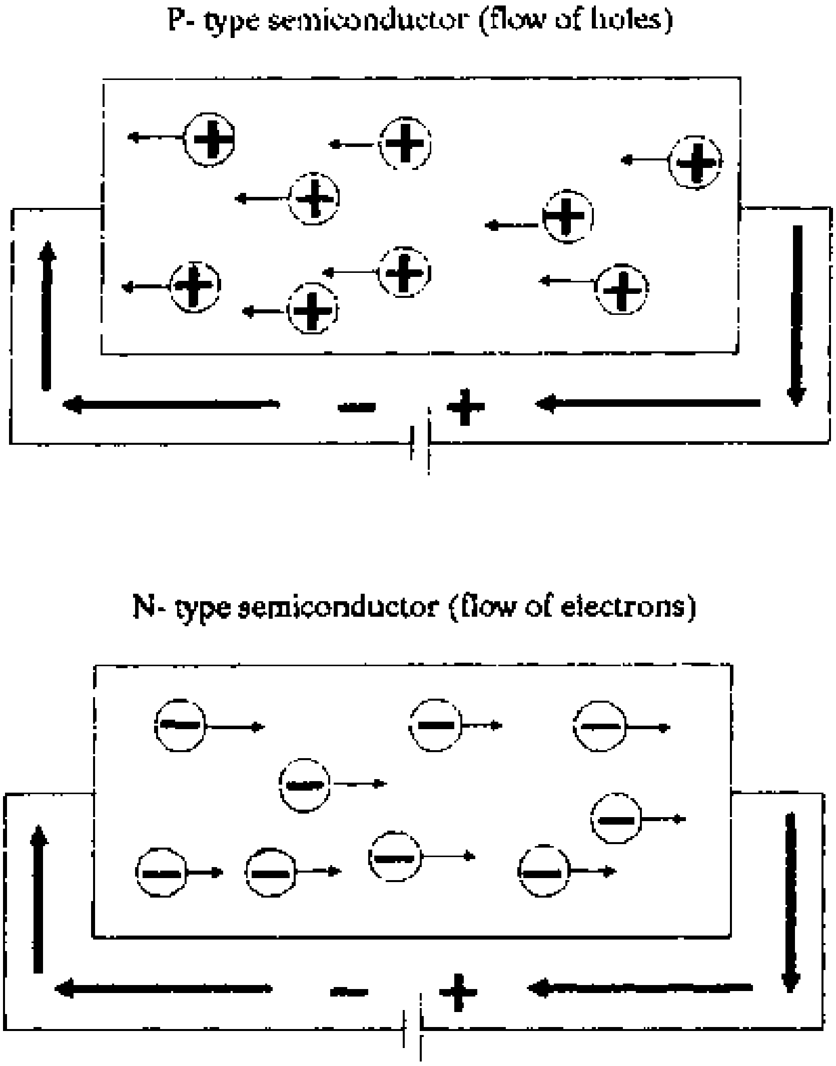


Fig. 1–1: Types of Flow

Doping a semiconductor

Doping increases the conductivity of a semiconductor. A doped semiconductor is called an extrinsic semiconductor. When an intrinsic semiconductor is doped with pentvalent (donor) atoms (i.e. Arsenic atoms donates one free electron to the crystal), it has more free electrons than holes.

–––> N–type semiconductor

When an intrinsic semiconductor is doped with trivalent (acceptor) atoms (i.e. Baron atoms in the crystal will create a hole which is capable of accepting an electron), it has more holes than free electrons.

–––> P–type semiconductor

Diode

<u>Unbiased Diode</u>

An unbiased diode has a depletion layer at the PN–junction. The ions in this deplation layer produce a barrier potential. At room temperature, this barrier potential is approximately 0.7V for a silicon diode.

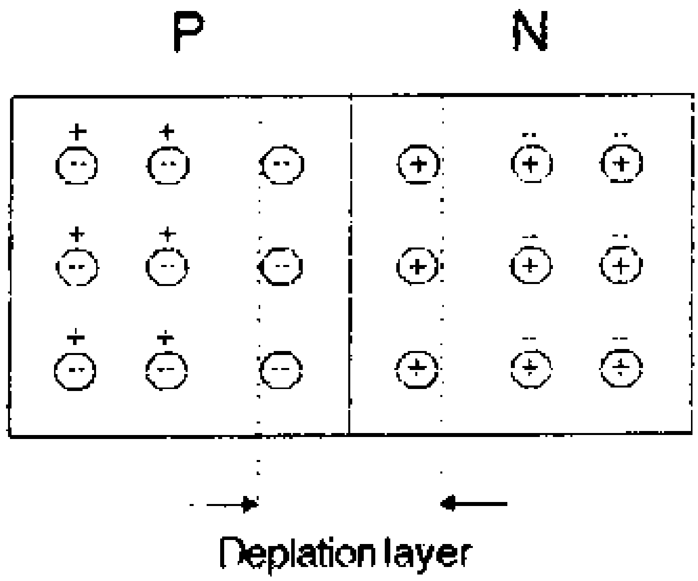


Fig. 1−2: Unbiased diode

Biased Diode

When an external voltage opposes the barrier potential, the diode is forward−biased. If the applied voltage is greater than the barrier potential, the current is large. In other words, current flows easily in a forward−biased diode.

When an external voltage aids the barrier potential, the diode is reverse biased. The width of the depletion layer increases when the reverse voltage increases. The current is approximately zero. The reverse biased diode acts like an open switch.

Breakdown

Too much reverse voltage will produce either avalanche or zener effect. Then, the large breakdown current destroys the diode.

Recap

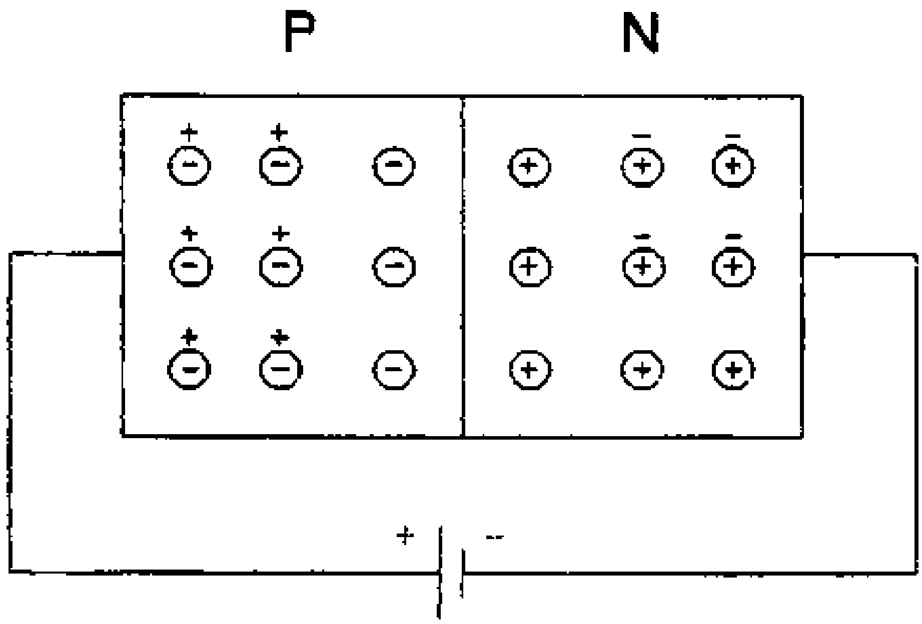


Fig. 1−3: Forward biased diode

What happens to an electron in this circuit?

1. After leaving the source terminal, it enters the right end of the crystal.
2. It travels through the N−region as a free electron.
3. At the junction it recombines with a hole and becomes a valence electron.
4. It travels through the P−region as a valence electron.
5. After leaving the left end of the crystal, it flows into the positive source terminal.

Worksheet No. 1

No. 1 How many valence electrons does a silicon atom have?

No. 2 Silicon atoms combine into an orderly pattern. What is it called?

No. 3 If you wanted to produce a P−type semiconductor which of these would you use?

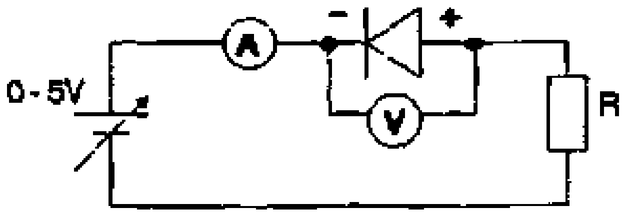
Acceptor atoms
Donor atoms
Pentavalent impurity
Silicon

No. 4 Holes are minority carriers in which type of semiconductor?

No. 5 What is the barrier potential of a silicon diode at room temperature?

No. 6 What happens to an electron travelling through a forward biased diode?

Experiment No. 1

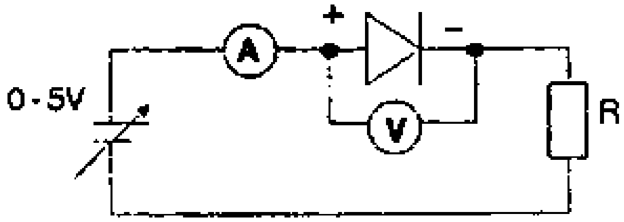


Procedure

Increase the voltage starting at 0V up to 5V. Observe voltmeter and ammeter.

Result

____



Procedure

Increase the voltage starting at 0V until the ammeter show a reading.

Result

____

Lesson 2 – Bipolar Transistor

Lesson Plan

Title: Bipolar Transistor

Objectives:

- Know the structure and symbols of bipolar transistors
- Able to calculate the current gain
- Understand how the currents in a transistor are split

Time	Method	Topic	Way	Remark
	Q/A	* Review Lesson 1		
	S,D	* Introduction		
		-Amplifier principle	P	Fig.2-1,2-2
	E	-Small and large signal amplifier - Power gain	Ex	
	S,D	* Transistor structures and symbols	P	Fig.2-3
	Q/A	Review		
	S	* Transistor currents	B,P	Fig.2-4,2-5
	S,E	*Current gain	B,Ex	
	S	* Transistor connections - CE connection	P,B	Fig.2-6,2-7
	E	* Review exercise	WS	Worksheet No.2
	E	* Experiment - Current Gain in a CE Configuration -		Experiment No. 2
	S : Speach D : Diskussion Q/A : Question/Answer E : Exercise		B : Boardscript P : Picture Ex : Example HO : Hands-On WS : Worksheet HT : Hand-Out	

Introduction

Amplifier Principle

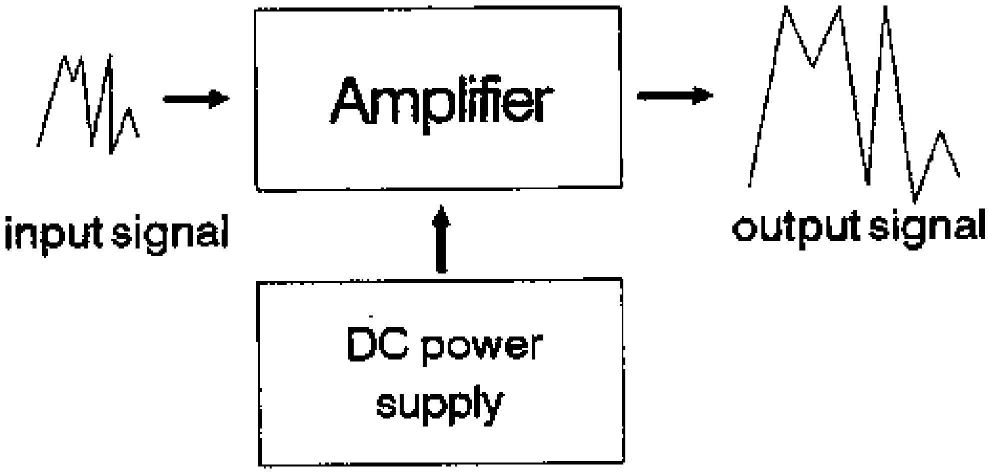


Fig. 2–1: Amplifier– principle

Small– and Large Signal Amplifier

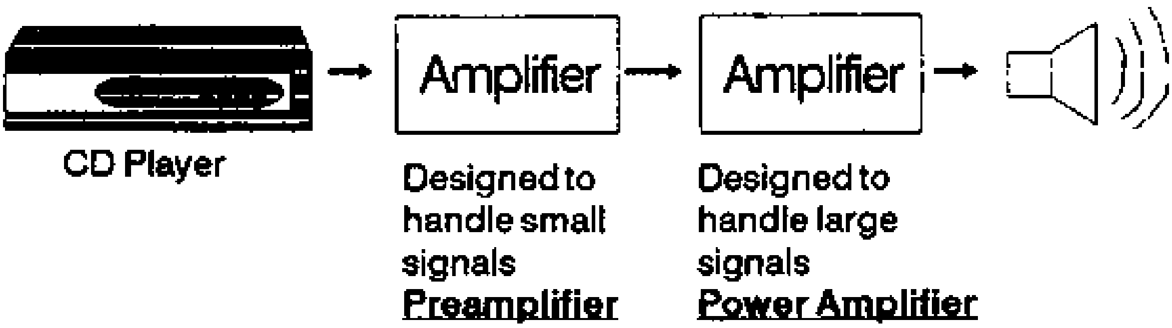


Fig. 2–2: Pre– and power amplifier

Amplifier circuits provide power gain.

Ex: P input– = 5 mW, P output = 50 W

$$P\,gain = \frac{50\,W}{5\,mW} = 10000$$

Transistor structures and symbols

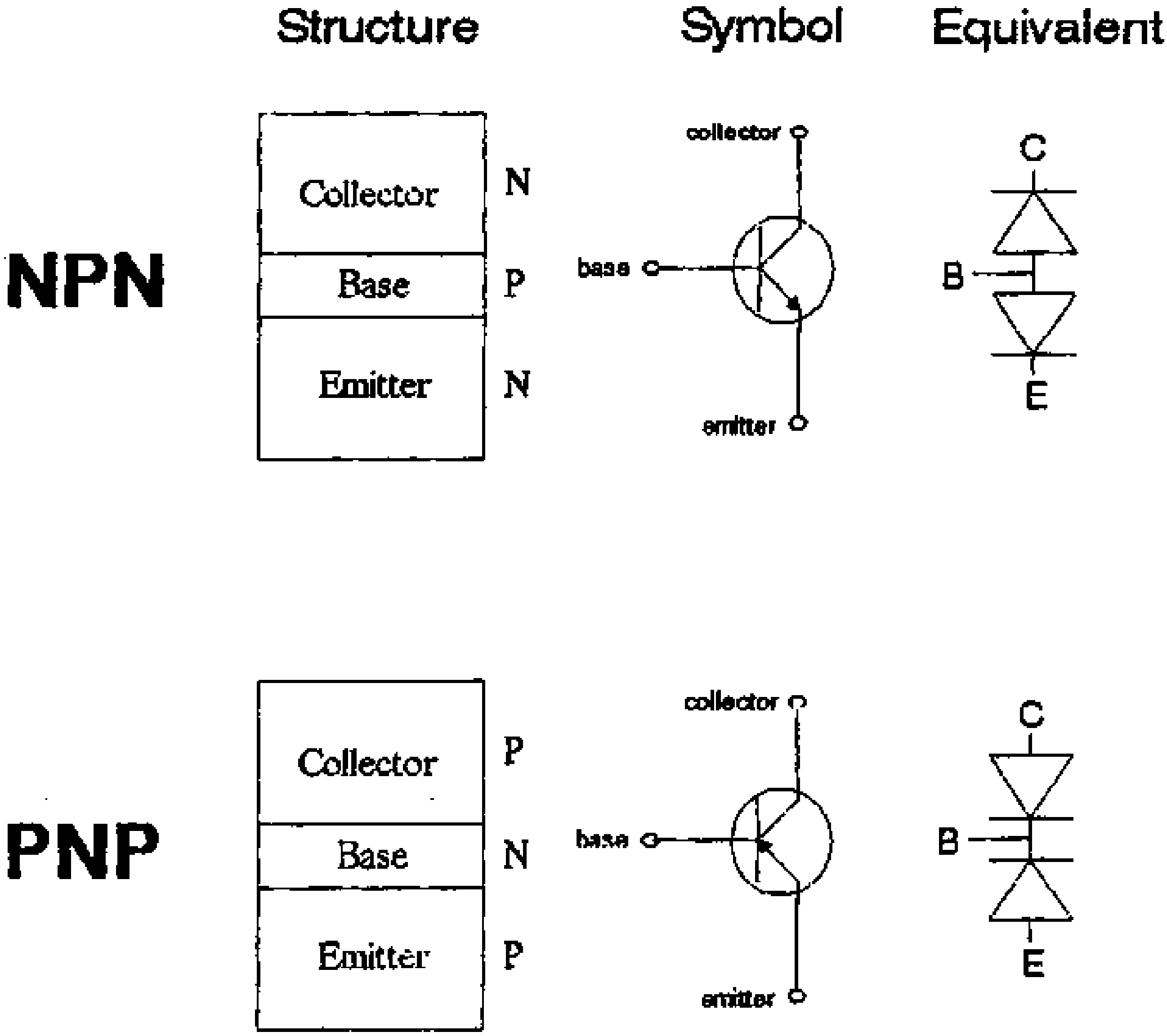


Fig. 2–3: NPN and PNP structure

Transistor currents

(see Fig. 2–4)

V_{BB} forward biases the emitter diode, forcing the free electrons in the emitter to enter the base. The thin and lightly doped base gives almost all these electrons enough time to diffuse into the collector. These electrons flow through the collector, through R_C, and into the positive terminal of the V_{CC} voltage source. In most transistors, more than 95% of the emitter electrons flow to the collector, less than 5% flow out the external base lead.

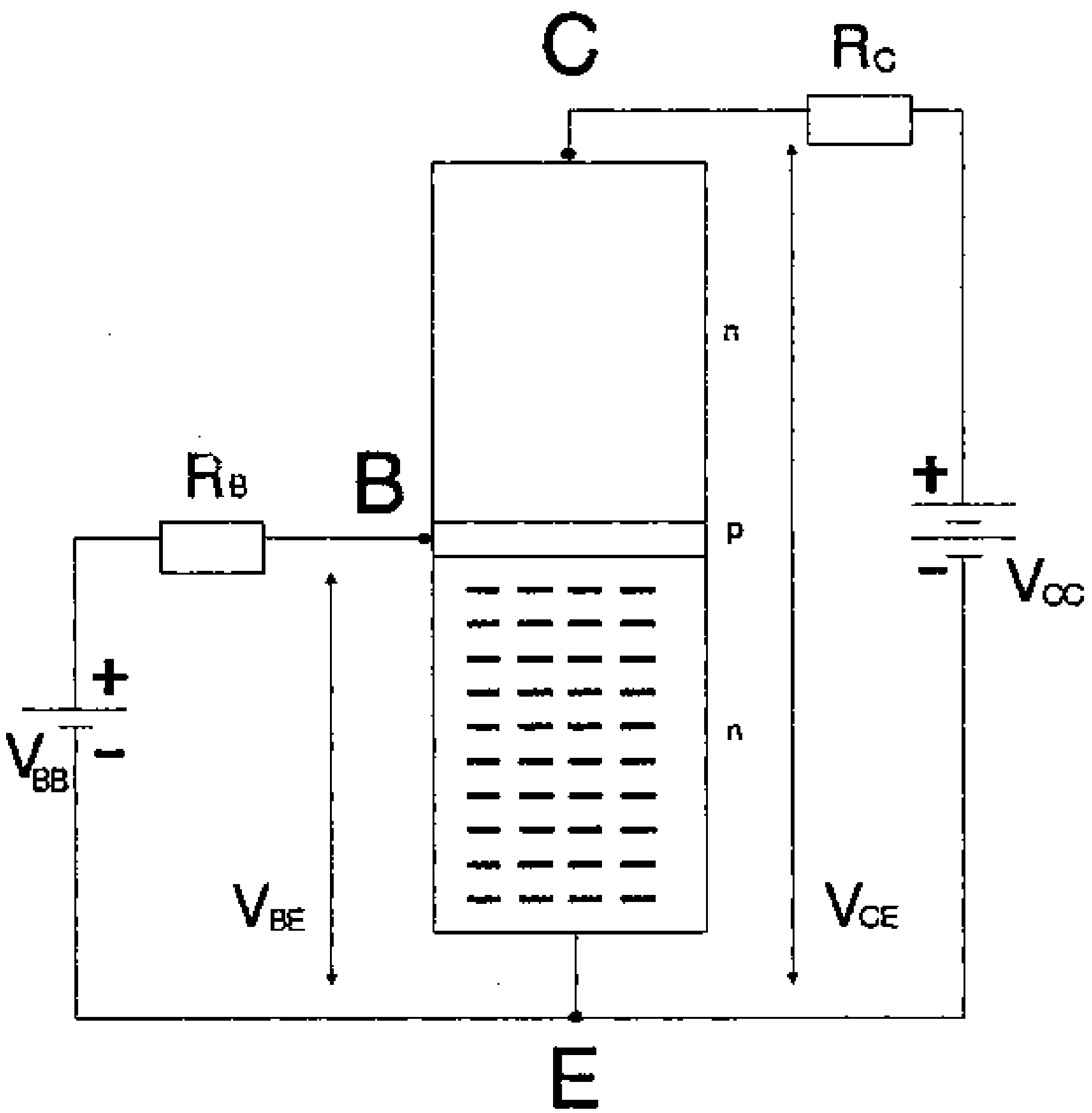


Fig. 2–4: NPN Transistor

Recall Kirchhoff's current law:

=> $I_E = I_C + I_B$

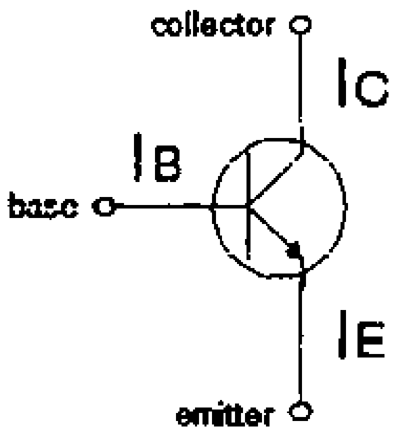


Fig. 2–5: Transistor currents

Because I_B is very small, for circuit analysis, we can do the following approximation:

I_C is equal to I_E

Current gain

Transistor circuits provide the power gain that is needed in electronic applications. They also provide voltage gain and current gain (?dc). Current gain ?dc of a transistor is defined as:

$$\beta_{dc} = \frac{I_C}{I_B}$$

Ex:

I_C = 10 mA

I_B = 40 ?A

$$\beta_{dc} = \frac{I_C}{I_B} = \frac{10mA}{14\mu A} = 250$$

Transistor connections

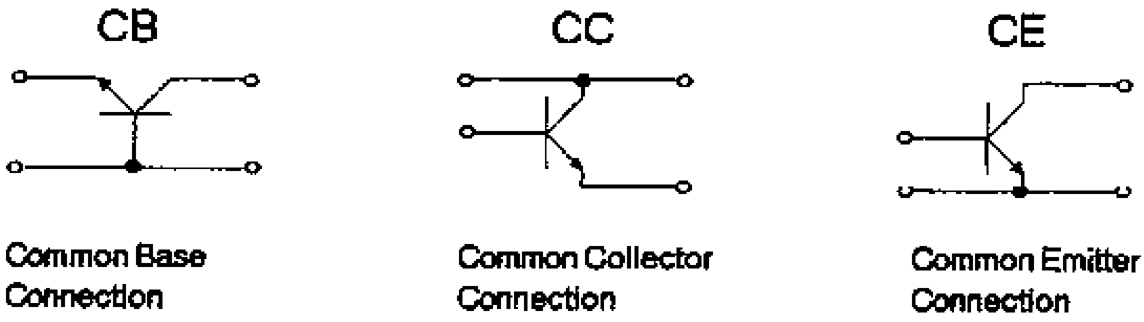


Fig. 2–6: Transistor connections

CE CONNECTION

The common emitter (CE) connection is the most widly used transistor connection.

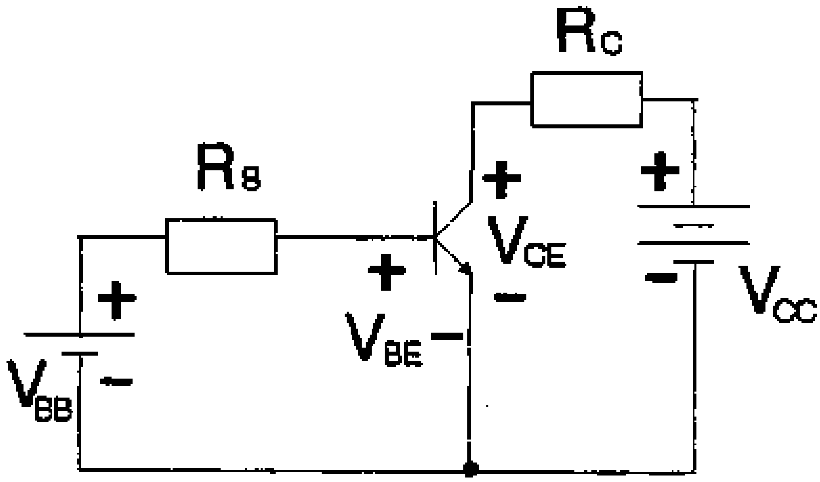


Fig. 2–7: CE amplifier, base biased

Base supply voltage: V_{BB}
Collector supply voltage: V_{CC}
Voltage base to ground: V_B
Voltage emitter to ground : V_E
Voltage collector to ground : V_C

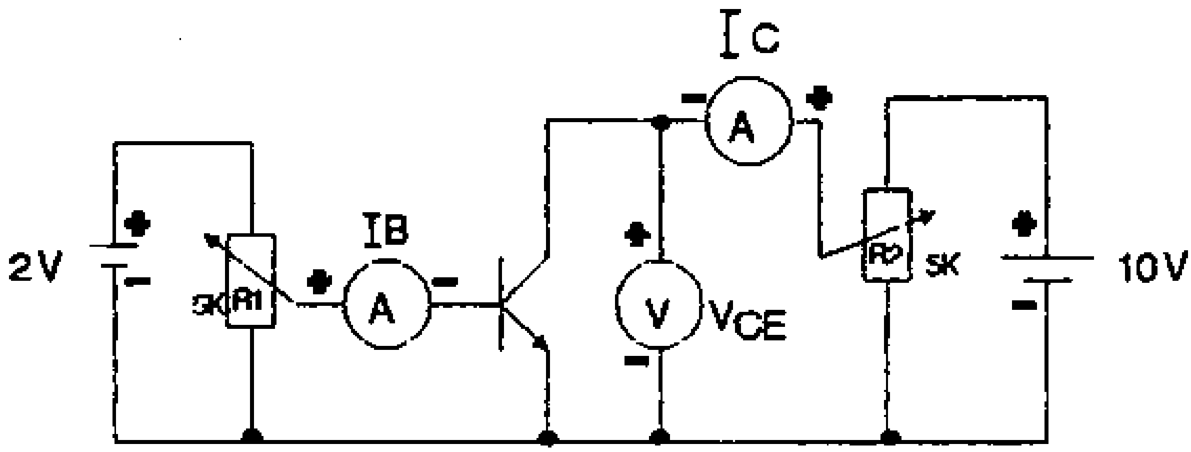
Worksheet No. 2

No. 1 A transistor has an emitter current of 10 mA and a collector current of 9.95 mA. What is the base current?

No. 2 A transistor has a current gain of 150 and a base current of 30 ?A. What is the collector current?

No. 3 If the collector current is 50 mA and the current gain is 75, what is the base current?

Experiment No. 2



Procedure

* Connect the circuit. R1 and R2 must be set for maximum resistance before power is supplied.

* Connect the power supply, adjust R1 for 10 ?A base current and adjust R2 to maintain V_{CE} at 6V, Measure and record I_C in the table below.

* Repeat the measurement for every value of I_B given in the table.

* Calculate the current gain (beta) for every measurement.

Step	I_B?A	I_C mA	beta	V_{CE} volt
1	10			6
2	20			6
3	30			6
4	40			6
5	50			6

Bipolar Transistor II

Lesson Plan

Title: Bipolar Transistor II

Objectives:

– Able to analyze a base biased CE configuration
– Able to name the regions of operation in a collector curve
– Know how to test a transistor

Time	Method	Topic	Way	Remark
		* Review Lesson 2		
		*Introduction - Base curve - Calculation off the base current		
		* Collector curve - Difference NPN-PNP - Voltage analyzis - Regions of operations		
		* Transistor power dissipation		
		* Transistor test - Out of circuit - In circuit		
		*Review exercise	WS	Worksheet No. 3
		*Experiment - Collector Characteristic Curve -		Experiment No. 3
	S : Speech D: Diskussion Q/A : Question/Answer F : Exercise		B : Boardscript P : Picture Ex : Example HO : Hands-On WS : Worksheet HT : Hand-Out	

Introduction

Base Curve (Input)

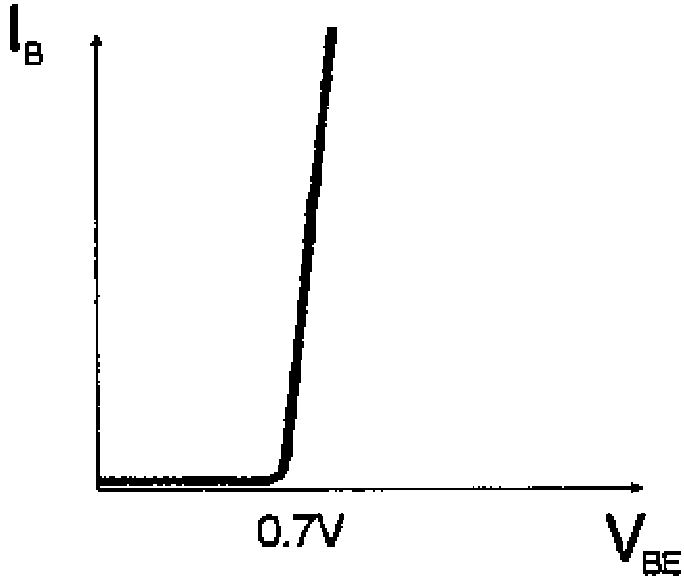


Fig. 3 – 1: Input curve, base biased CE connection

Calculate the Base Current: (see Fig. 2–7)

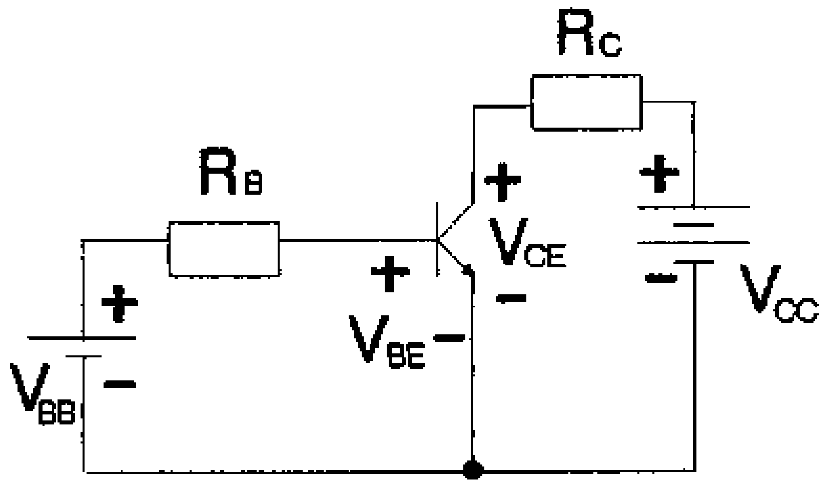


Fig. 3 – 2: Base biased CE connection

Approximation: V_{BE} = 0.7 V

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

Ex: Silicon Transistor

V_{BE} = 0.7V, V_{BB} = 10V, R_B = 100 K?

$$I_B = \frac{10V - 0.7V}{100K\Omega} = \frac{9.3V}{100K\Omega} = 93\mu A$$

Collector curves (output)

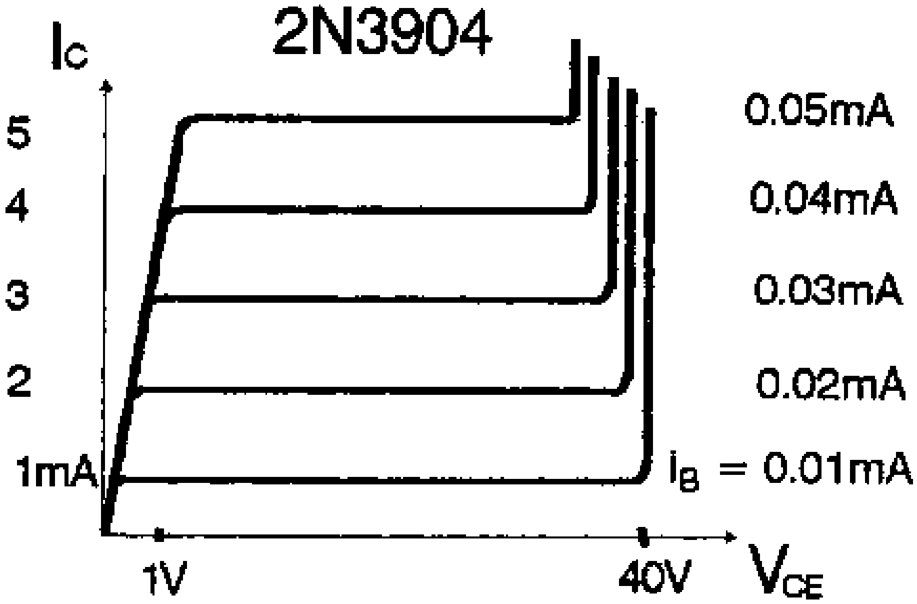


Fig. 3–3: NPN transistor collector curve (2N3904)

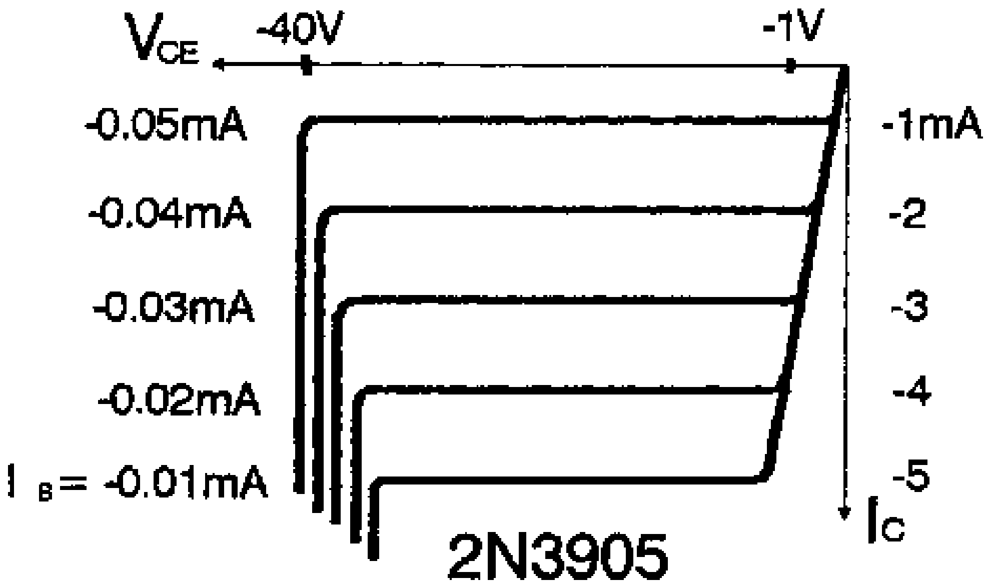


Fig. 3–4: PNP transistor collector curve (2N3905)

Recall Kirchhoffs voltage law: (see Fig. 2–7)

$$V_{CE} = V_{CC} - I_C * R_C$$

Ex: Analyse the following circuit

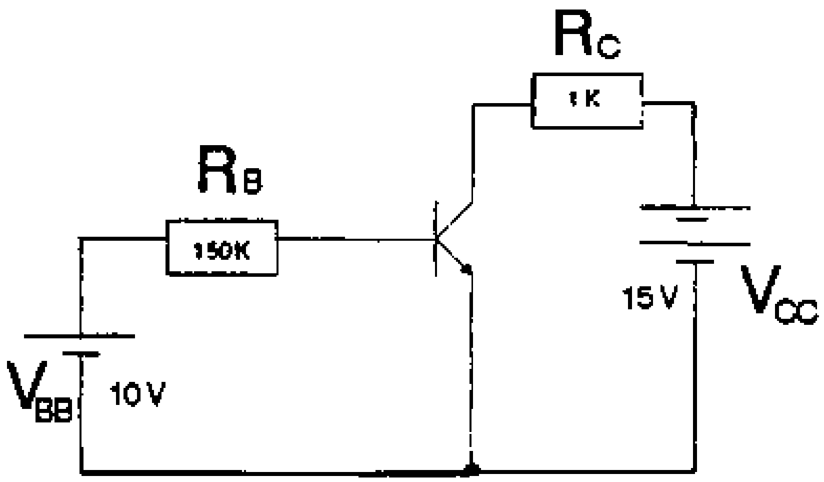


Fig. 3–5: Base biased CE connection, ?=100

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{9.3V}{150K\Omega} = 62\mu A$$

I_C = $?_{dc}$ * I_B = 6.2 mA

V_{CE} = V_{CC} – I_C * R_C = 15V – (6.2 mA * 1 K?) = 8.8V

<u>Regions of Operation</u>

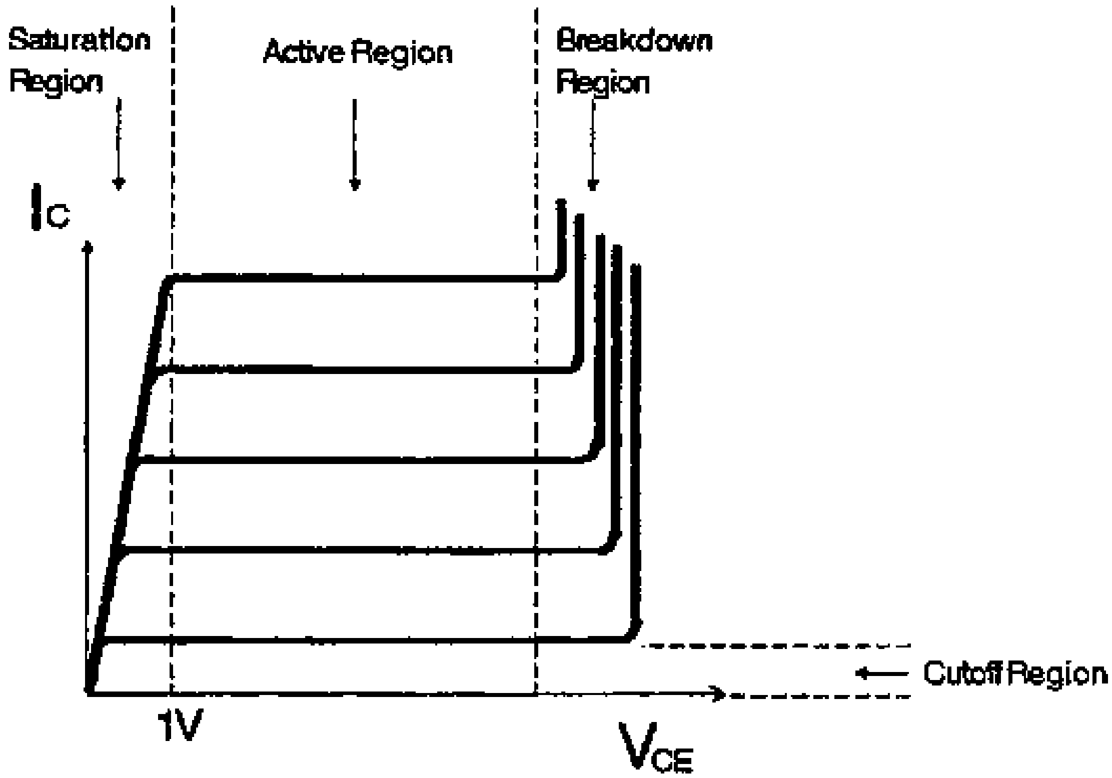


Fig. 3–5: Regions of operation

Active region : Normal operation
Emitter diode forward biased
Collector diode reverse biased
===> horizontal part of the curve

Breakdown region: Transistor should never operate in this region

Saturation region: V_{CE} between 0V ––––> 1V
===> rising part of the curve

Cutoff region: I_C approximately zero

Transistor power dissipation

$P_D = V_{CE} * I_C$

This power causes the junction temperature of the collector diode.

Important information from a data sheet:

Maximum power rating: $P_{D\ (max.)}$

Transistor test

– Out of circuit: With an ohmmeter.

* resistance between collector and emitter should be high in both direction.

===> diodes are back to back in series (see also Fig. 2–3)

* reverse and forward resistance of emitter collector diode (reverse/forward ratio) should be more than 1000: 1 (silicon)

– In circuit: With a voltmeter

* measure V_E and V_C, the difference V_E – V_E should be more than 1V but less than V_{CC}.

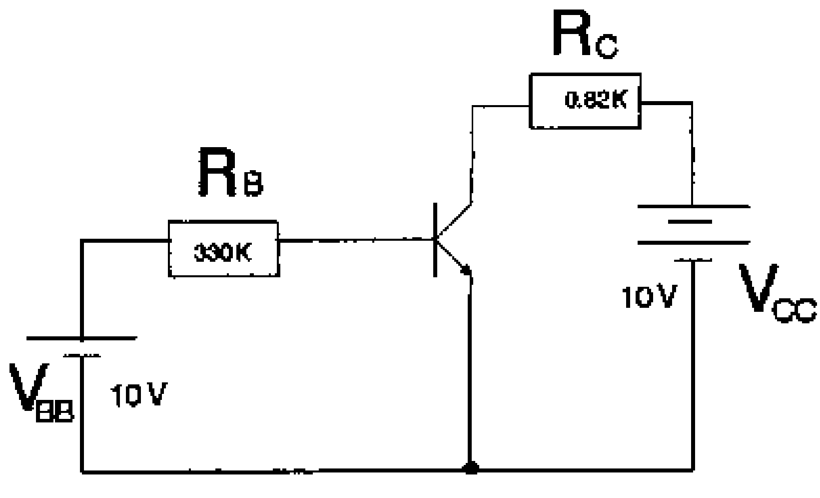
If V_{CE} is less than 1V:

––––> transistor may be shorted

If V_{CE} equals V_{CC}:

–––– > transistor may be open

Worksheet No. 3



β = 200

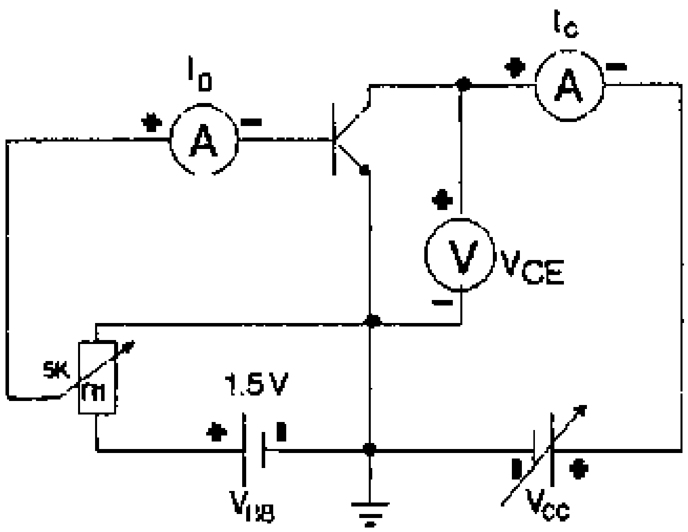
No. 1 What is the base current ?

No. 2 If the current gain decreases from 200 to 100 what is the base current?

No. 3 What are the collector–emitter voltage and the transistor power dissipation?

No. 4 Suppose we connect a LED in series with the collector resistor. What does the LED current equal?

Experiment No. 3



Procedure:

Adjust V_{CC} in turn to every value of V_{CE} shown in the table. Observe and record the value of I_C for each value of V_{CE}. Monitor I_B, and readjust R1 if necessary.

From the data in the table, plot the collector characteristic curve (I_C over V_{CE}).

I_B?A	**I_C mA**								
	V_{CE} volt								
	0	2.5	5	7.5	10	15	20	25	30

10									
20									
30									
40									
50									

First Evaluation

No. 1 Define extrinsic semiconductor and intrinsic semiconductor.

No. 2 At room temperature an intrinsic silicon crystal acts approximately like a ....

No. 3 The current in a transistor is split into parts. Which is the highest and how is it split?

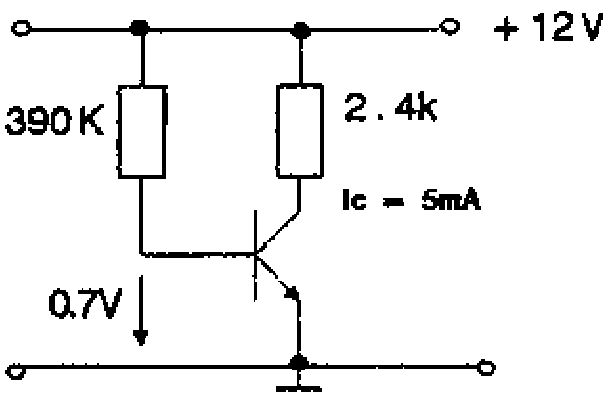
No. 4 Please sketch the basic transistor connections.

No. 5 If the base current is 100 mA and the current gain is 30, what is the collector current?

No. 6 Sketch a typical set of collector curves, label the graph and mark the regions of operation.

No. 7 a) Please calculate the current gain ?.

b)What is the voltage between collector and ground?



No. 8 Describe how you can find the base lead of an unknown transistor with the help of an ohmmeter.

Lesson 4 – Transistor Fundamentals

Lesson Plan

Title: Transistor Fundamentals

Objectives:

- Understand the meaning of load line and Q–point
- Able to do the calculation for load line and Q–point
- Know the principle of a transistor switch

Time	Method	Topic	Way	Remark
		* Review Lesson 3		
		* Introduction - Line		
		* Load line - Saturation point - Cutoff point - Load line calculation		
		* Operating point (Q-point) - Q-point calculation		
		* Recognizing saturation		
		* Transistor switch		
		* Review exercise	WS	Worksheet No. 4

S : Speech
D : Diskussion
Q/A : Question/Answer
F : Exercise

B : Boardscript
P : Picture
Ex : Example
HO : Hands-On
WS : Worksheet
HT : Hand-Out

The load line

The load line contains every possible operating point for the circuit. A line is defined by two points. To draw the load line you have to get. the saturation point and the cutoff point:

Saturation point: Tells you the maximum possible collector current for the circuit.

Calculate: Visualize a short between the collector and emitter.

V_{CE} --- > 0

$$I_{C(sat)} = \frac{V_{CC}}{R_C}$$

Cutoff point : Tells you the maximum possible collector emitter voltage for the circuit. Calculate: Visualize the transistor internally open between collector and emitter.

V_{CE} -- > V_{CC}

$V_{CE\,(cut)} = V_{CC}$

Ex: Draw the load line for the given circuit.

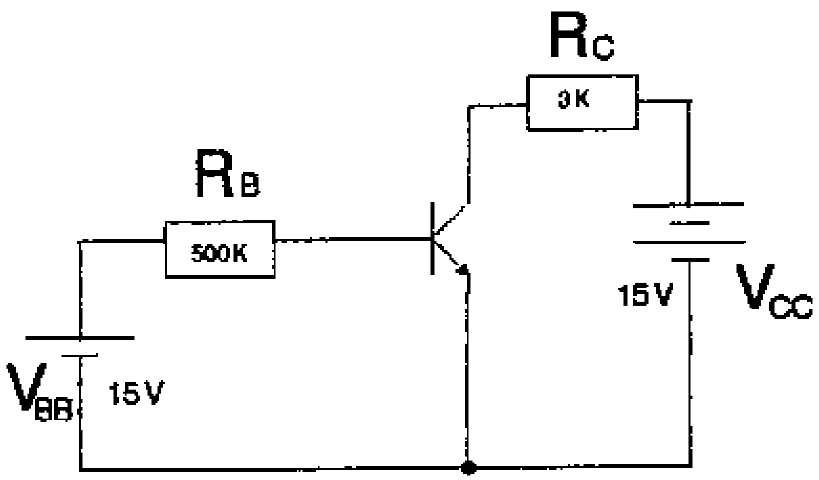


Fig. 4–1: CE amplifier base biased

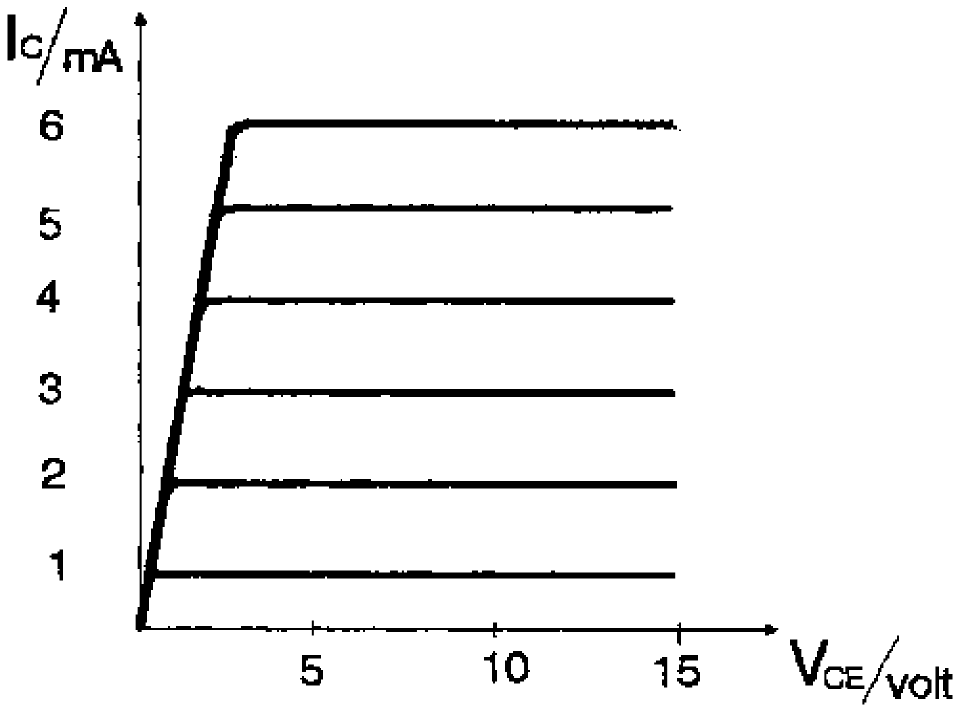


Fig. 4−2: Output curve

Saturation point:

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{15V}{3K\Omega} = 5mA$$

Cutoff point:

$V_{CE\ (cut)} = V_{CC} = 15V$

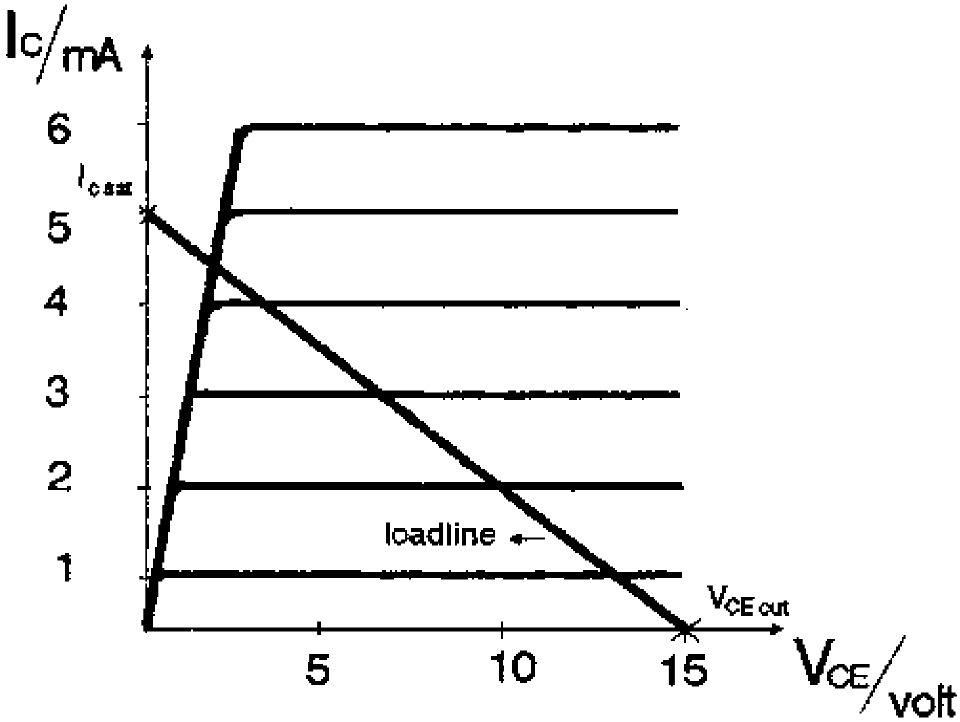


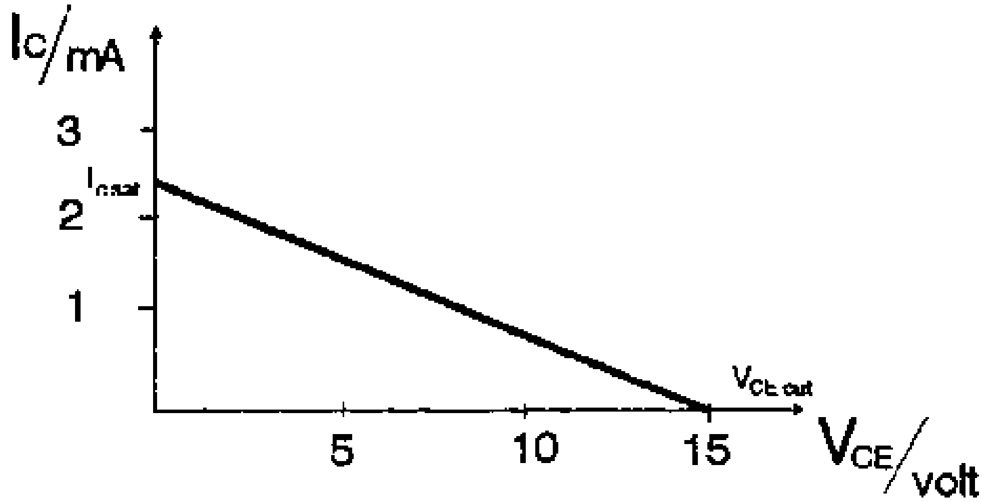
Fig. 4−3: Output curve with loadline

<u>HO:</u> Suppose the collector resistance (in Fig. 4−1) is increased to 6K?. What happens to the dc load line?

Solution:

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{15V}{6K\Omega} = 2.5mA$$

$V_{CE\ (cut)} = 15V$



The operating point

Every transistor circuit has a load line. If the base resistance is given you can also calculate the current and voltage for the operating point.

Ex: Calculate the operating point (Q–point)

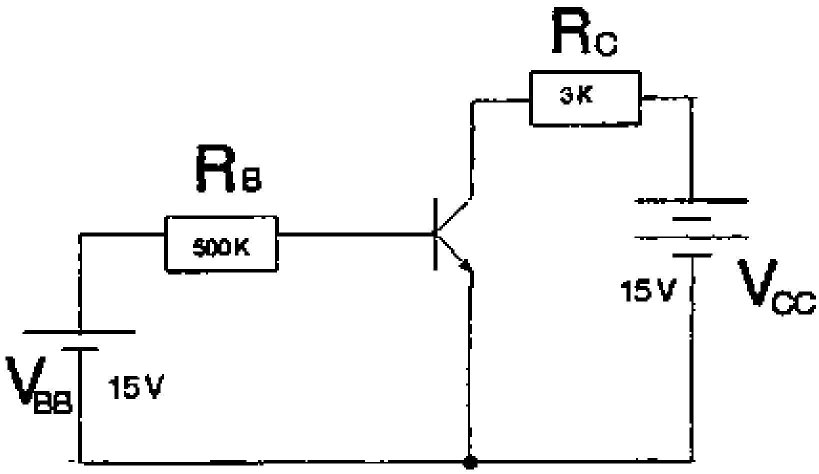


Fig. 4–4: Base biased CE connection

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{14.3V}{500K\Omega} = 29\mu A$$

$I_C = ?_{dc} * I_B = 100 * 29?A = 2.9$ mA

$V_{CE} = V_{CC} – (I_C * R_C) = 15V – (2.9$ mA $* 3K?) = 6.3V$

By plotting I_C (2.9 mA) and V_{CE} (6.3V), we get the operation point ––––> Q–point (quiescent point).

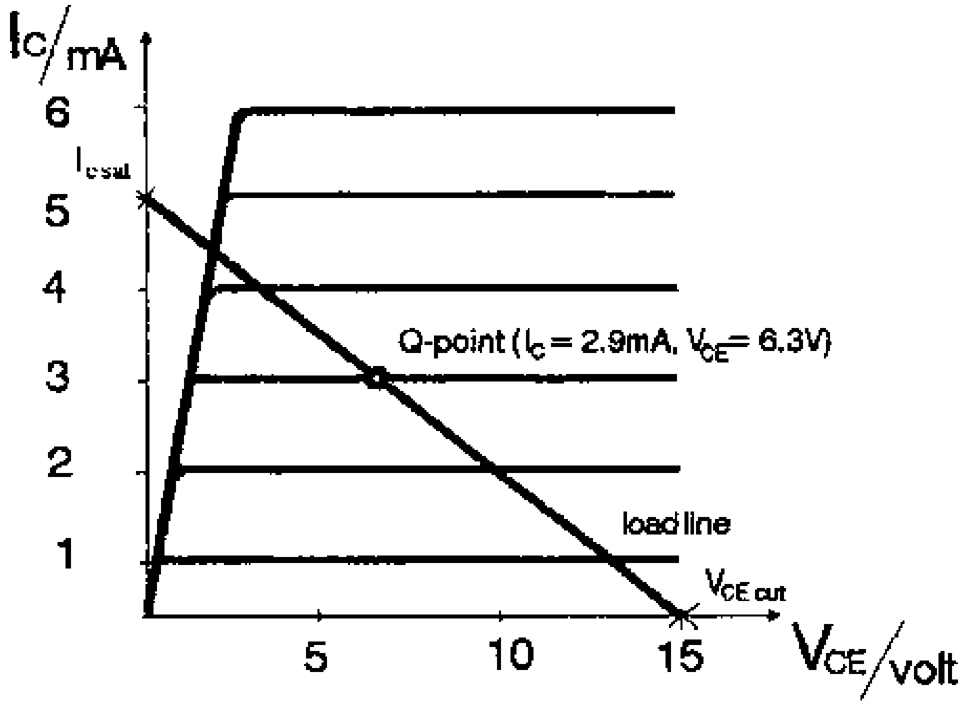


Fig. 4 – 5: Collector curve with load line and Q – point

<u>HO:</u> Draw the load line and Q–point.

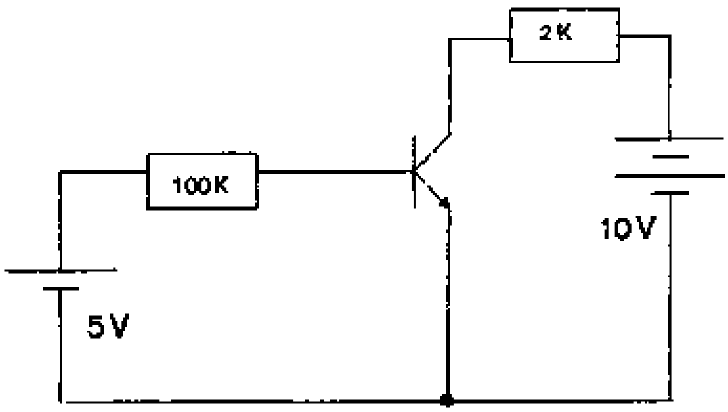


Fig. 4–6: base biased CE connection, ?=50

<u>Solution:</u>

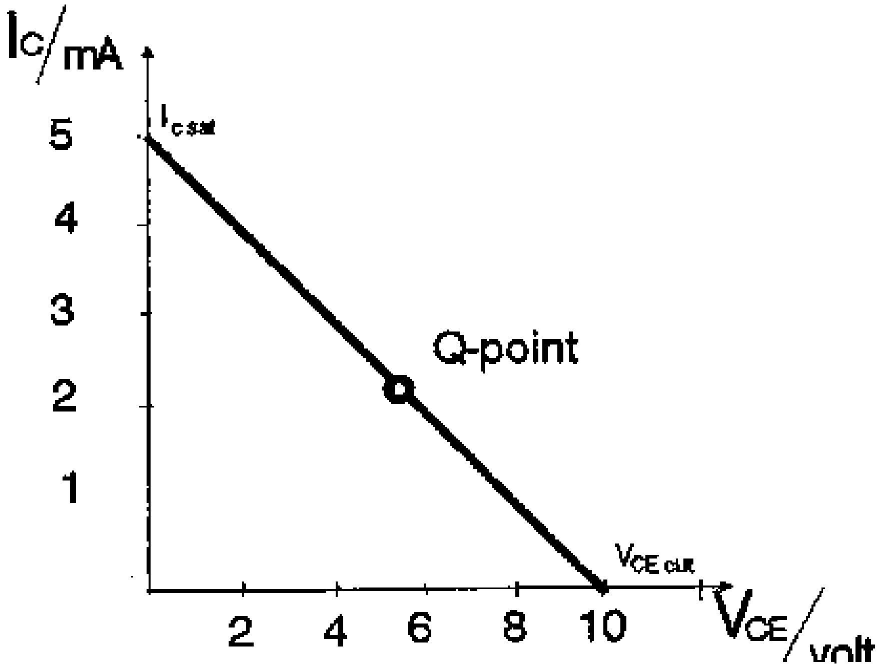
$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = 0.043mA$$

$I_C = I_B * ? = 2.15$ mA

$V_{CE} = V_{CC} – (R_C * I_C)= 5.7V$

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = 5mA$$

$V_{CE\ (cut)} = V_{CC} = 3.0V$



Recognizing saturation

When you first look at a transistor circuit, you usually cannot tell if it is saturated or operating in the active region.

1. calculate $I_{C\ (sat)}$

2. calculate I_C

If I_C is greater than $I_{C\ (sat)}$ the transistor is saturated.

Note: Current gain is less in saturation region.

The transistor switch

Ex: Circuit example for a transistor switch:

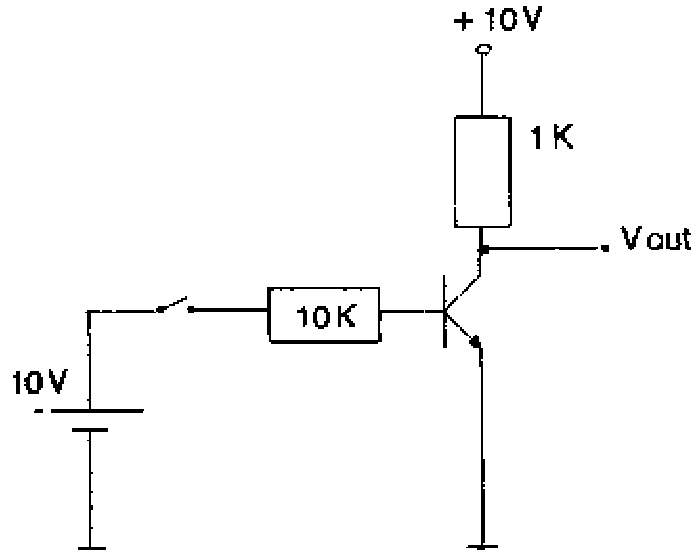


Fig. 4–7: Transistor switch

The transistor operate only at saturation and cutoff

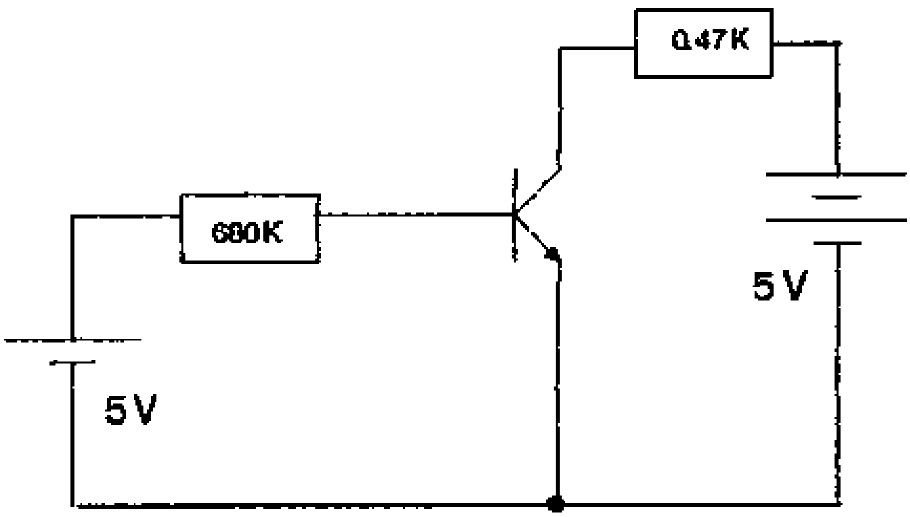
Switch closed: Transistor in hard saturation V_{out}? 0V

Switch open : Transistor in cutoff

I_C drops to zero

V_{out}? 10V

Worksheet No. 4



No. 1 Draw the load line!

No. 2 If the collector resistance is increased to 1K, what happens to the load line?

No. 3 What is the voltage between the collector and ground if the current gain is 100?

Lesson 5 – Transistor Biasing

Lesson Plan

Title: Transistor Biasing

Objectives:

– Understand the purpose of biasing
– Able to analyze an emitter biased circuit

Time	Method	Topic	Way	Remark
		* Review Lesson 4		
		* Introduction - Emitter bias		
		* Analyzis of emitter biased circuits - Q-point calculation - Exercises - Effect of small changes		
		* Review exercise	WS	Worksheet No. 5
	S : Speech D : Diskussion Q/A : Question/Answer F : Exercise		B : Boardscript P : Picture Ex : Example HO : Hands-On WS : Worksheet HT : Hand-Out	

Transistor biasing

<u>Emitter Bias</u>

The analysis of base biased circuits depends on the current gain which can vary in a wide range. In an amplifier we need circuits whose Q−points are immune to changes in current gain. The solution for this problem is the emitter biased circuit:

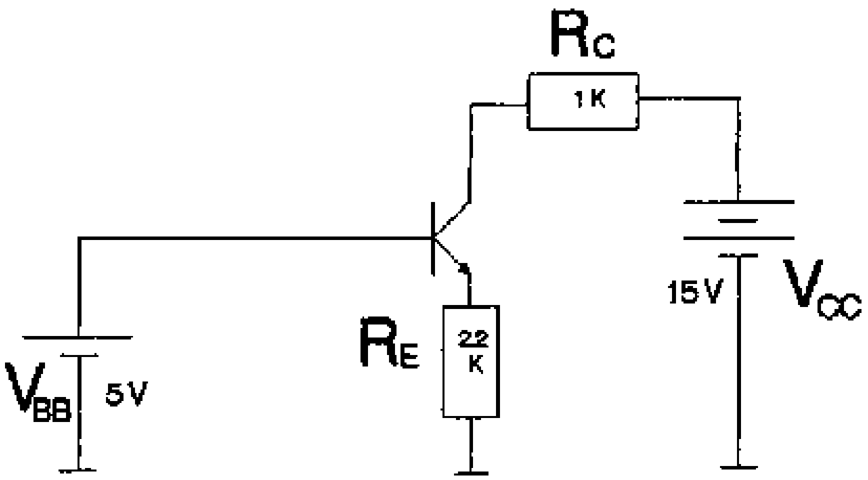


Fig. 5−1: Emitter biased circuit, ? = 100

<u>Find the Q−point:</u>

Given : V_{BB} = 5V, V_{BE} = 0.7V, V_{CE} = 15V

R_E = 2.2K?, R_C = 1K?

Calculation:

$V_E = V_{BB} - V_{BE}$ = 5V − 0.7V = 4.3V

$$I_E = \frac{V_E}{R_E} = \frac{4.3V}{2.2K\Omega} = 195mA$$

$I_E = I_C$ (close approximation)

V_C = VCC − (RC * IC)

= 15V − (1K? − 1.95 mA)

= 13.1V

$V_{CE} = V_C - V_E$ = 13.1V − 4.3V = 8.8V

Q−point coordinates:

>

I_C = 1.95 mA

V_{CE} = 8.8V

An emitter biased circuit is immune to changes in current gain. Analysing summary:

1. get V_E
2. calculate IE
3. find V_C
4. V_{CE} = V_C – V_E[SFARSIT]

At no time we need the current gain!

Tip for troubleshooter:

Don't measure direct V_{CE}, because the common lead of the voltmeter is grounded, so you will short the emitter to ground.

[inceput284]1. Measure V_C
2. Measure V_E
3. Subtract V_{CE} = V_C – V_E

HO: What is the collector voltage?

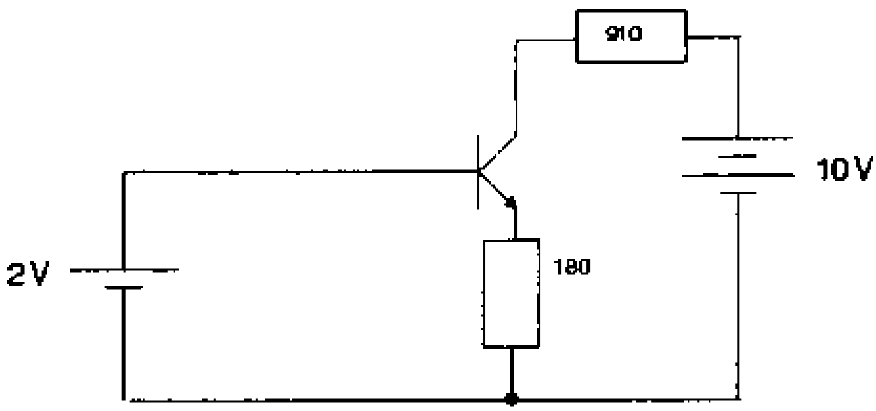


Fig. 5–2: Emitter biased CE connection

Solution:

$V_E = V_{BB} - V_{BE}$ = 2V – 0.7V = 1.3V

$$I_E = \frac{V_E}{R_E} = \frac{1.3V}{180\Omega} = 7.2mA$$

$I_E = I_C$ (approx.)

$V_C = V_{CC} - (R_C * I_C)$ = 10V – (910 ? * 7.2 mA) = 3.4V

HO: What is the collector–emitter voltage?

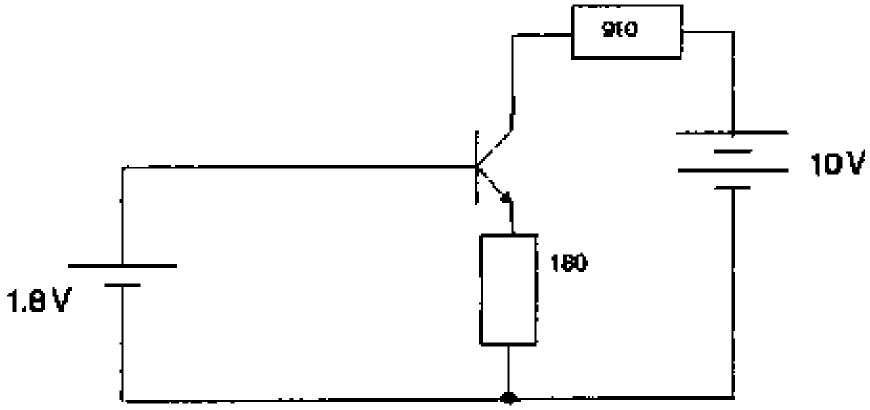


Fig. 5–3: Emitter biased CE connection

Solution:

$V_E = V_{BB} – V_{BE} = 1.1V$

$$I_E = \frac{V_E}{R_E} = 6.1mA$$

$I_E = I_C$ (approx.)

$V_C = V_{CC} – (R_C * I_C) = 9.4V$

$V_{CE} = V_C – V_E = 8.35V$

Effect of Small Changes

For example, tolerances of resistors (+/– 10%) are small changes.

See Fig. 5–4 on the next page.

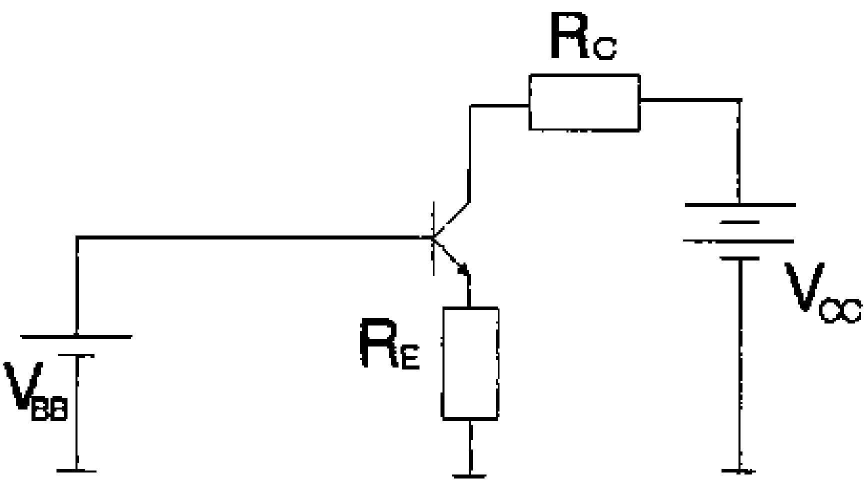


Fig. 5–4: Emitter biased CE connection

Before we can analyse the effects of small changes we have to find out which values are dependent or independent.

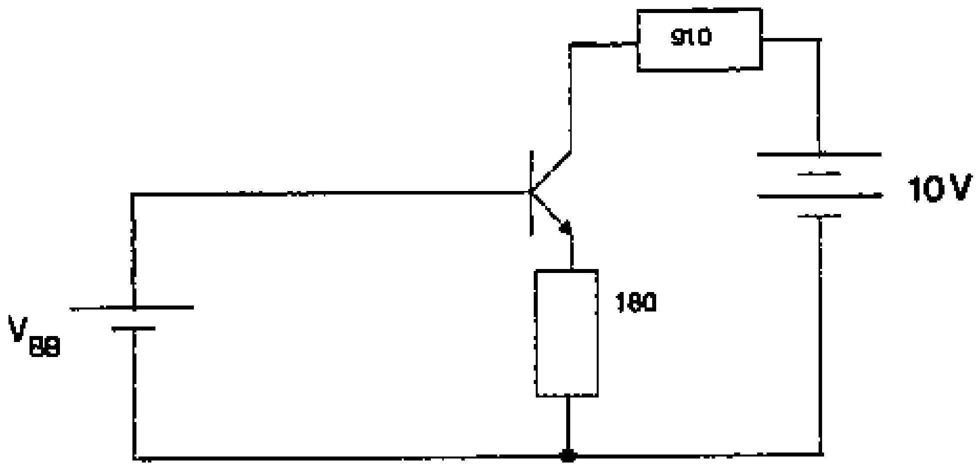
independent values: V_{BB}, V_{CC}, $?_{dc}$, R_E, R_C
dependent values : V_E , V_C, I_B, I_C, I_E

Suppose the independent values will increase one after another. What will be the effect on the dependent values:

increase ?		**dependent**					
		V_E	I_E	I_B	I_C	V_C	V_{CE}
	V_{BB}	U	U	U	U	D	D
	V_{CC}	N	N	N	N	U	U
independent	R_E	N	D	D	D	U	U
	R_C	N	N	N	N	D	D
	h_{fe}	N	N	D	N	N	N

U = up
D = down
N = no change

Worksheet No. 5



No. 1 What is –the collector voltage if V_{BB} = 2V?

No. 2 If the collector resistor is doubled, what is the collector emitter voltage for a base supply voltage of 2.3V?

No. 3 If the collector supply voltage is increased to 15V, what is the collector emitter voltage for V_{BB} = 1.8V?

No. 4 The base supply voltage (2V) increases by 10%. What happens to the base current, collector current, and collector voltage?

Lesson 6 – Transistor Biasing II

Lesson Plan

Title: Transistor Biasing II

Objectives:

– Know the advantage of voltage divider bias
– Able to analyse VDB circuits

Time	Method	Topic	Way	Remark
		* Review Lesson 5		
		*Introduction - Voltage divider bias (VDB)		
		*VDB analyzis - Example - Summary of formulas and process - Load line and Q-point - Q-point in the middle of the load line		
		*Review exercise	WS	Worksheet No. 6

S : Speach
D : Diskussion
Q/A : Question/Answer
E : Exercise

B : Boardscript
P : Picture
Ex : Example
HO : Hands-On
WS : Worksheet
HT : Hand-Out

Transistor biasing II

Voltage Divider Bias

The most famous circuit based on −the prototype of emitter bias is called the voltage divider bias (VDB).

Recall the steps of analyzing the emitter bias circuit:

1. V_E
2. I_E
3. I_C
4. Voltage drop across R_C
5. V_C
6. V_{CE}[SFARSIT]

The three most important steps are:

[inceput284]1. I_E
2. V_C
3. V_{CE}

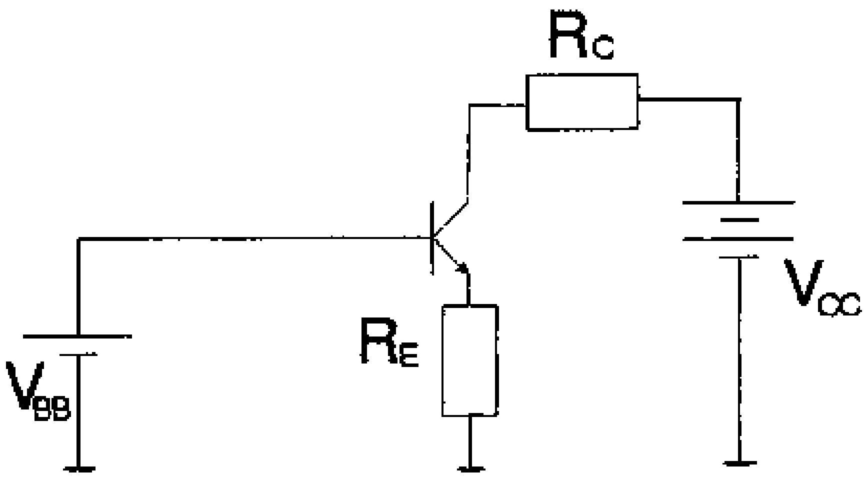


Fig. 6−1: Emitter biased circuit

Problem: Sometimes the voltage from the V_{CC} power supply is too large to apply directly at the base.

Solution:

− extra power supply for the base
− or ==> VDB

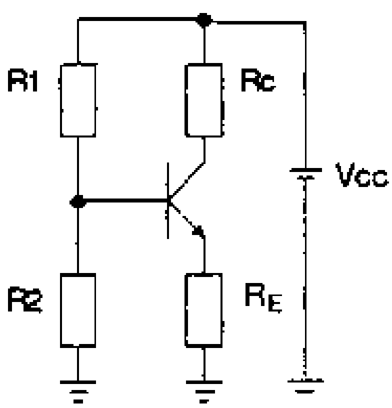


Fig. 6−2: VDB circuit

The voltage drop across R_2 is applied directly to the base, which means:

$V_2 = V_B$

1. step: find voltage drop across R_2
2. step: subtract 0.7V to get V_E

VDB analysis

Design errors of 5% or less are acceptable, because of resistor tolerances.

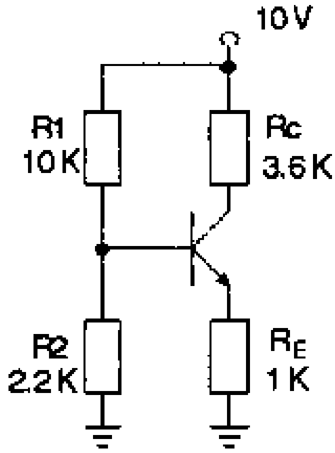


Fig. 6–3: VDB example circuit

Find the base voltage:

Assumption: Base current is so small that it has no effect on the voltage divider.

5% error – > base current is 20 times smaller than the divider current.

$$I = \frac{V_{CC}}{R_1 + R_2} = \frac{10V}{12.2K\Omega} = 0.82mA$$

$V_B = I * R_2 = 0.82\ mA * 2.2K? = 1.8V$

$V_E = V_B - V_{BE} = 1.8V - 0.7V = 1.1V$

$$I_E = \frac{V_E}{R_E} = \frac{1.1V}{1K\Omega} = 1.1mA$$

$V_C = V_{CC} - (R_C * I_C) = 10V - (3.6K? * 1.1\ mA) = 6.04V$

$V_{CE} = V_C - V_E = 6.04V - 1.1V = 4.94V$

Checking the assumption:

5% error ––> $I_B = \frac{I}{20} = \frac{0.82mA}{20} = 41\mu A$

The current gain can vary from 30 to 300.

$$I_B = \frac{I_C}{30} = \frac{1.1mA}{30} = 36\mu A$$

Even under the worst case condition the calculation is within the 5% limit, hence the assumption can be done.

Summary of Process and Formulas

Divider current	$I = \frac{V_{CC}}{R_1 + R_2}$
Base voltage	$V_B = I * R_2$
Emitter voltage	$V_E = V_B - V_{BE}$
Emitter current	$I_E = \frac{V_E}{R_E}$
Collector voltage	$V_C = V_{CC} - (I_C * R_C)$
Coll.– emitter voltage	$V_{CE} = V_C - V_E$

HO: What will change if the emitter resistor increases to 2K?? (unchanged voltage divider)

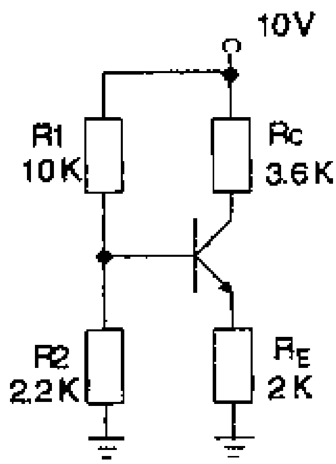


Fig. 6–4: VDB circuit

Solution:

$I = 0.82$ mA

$V_B = 1.8V$

$V_E = 1.1V$

$$I_E = \frac{V_E}{R_E} = 0.55mA$$

$V_C = V_{CC} - (R_C * I_C) = 8.02V$

$V_{CE} = V_C - V_E = 6.92V$

VDB Load–Line and Q–Point

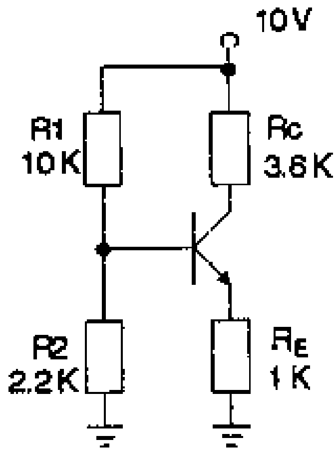


Fig. 6–5: VDB circuit

Saturation point:

Visualize short between collector and emitter

$V_{RC} = V_{CC} – V_E = 10V – 1.1V = 8.9V$

– – >

$$I_{c(sat)} = \frac{V_{RC}}{R_C} = \frac{8.9V}{3.6K\Omega} = 2.47mA$$

Cutoff point:

Visualize open between collector and emitter

– – > $V_{CE\ (cut)} = V_{CC} – V_E = 8.9V$

Q–point:

$$I_C \approx I_E = \frac{V_E}{R_E} = \frac{1.1V}{1K\Omega} = 1.1mA$$

$V_C = V_{CC} – (I_C * R_C) = 10V – (1.1 mA * 1K?) = 6.04V$

$V_{CE} = V_C – V_E = 6.04V – 1.1V = 4.94V$

Now we plot these values and get the load line and the Q–point:

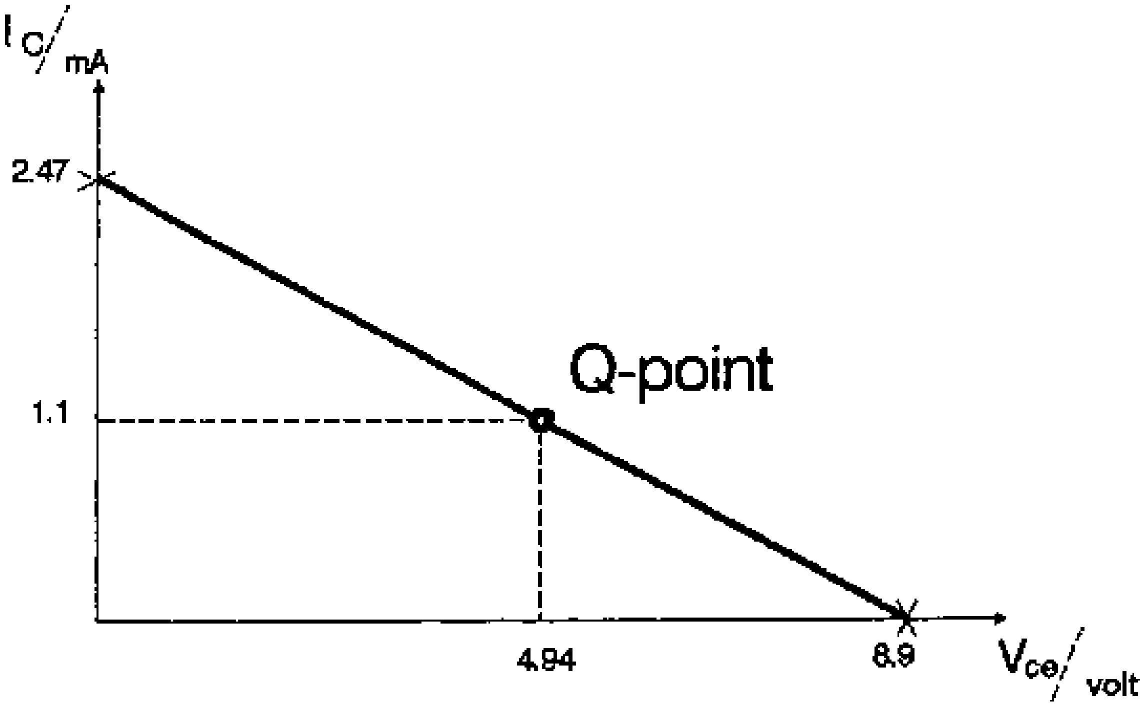


Fig. 6–6: Output curve with load line and Q–point

The values V_{CC}, R_C, R_1, and R_2 are controlling saturation current and cutoff voltage. To move the Q–point is possible by varying the emitter resistance (R_C).

<u>Get the Q–point in the Middle of the Load Line</u>

To set the Q–point is a important preparation as you will see later on.

Effect of R_E:

R_E too large –– > Q–point moves into cutoff
R_E too small ––> Q–point moves into saturation

Q – point in the middle of the load line:

Half the value of $I_{C\ (sat)}$ and redesign R_E

$I_{C\ (sat)}$ = 2.47 mA ==> 1.23 mA

$$R_E = \frac{V_E}{1.23mA} = 894\Omega$$

Look for the nearest standard value:

===> 910 ?

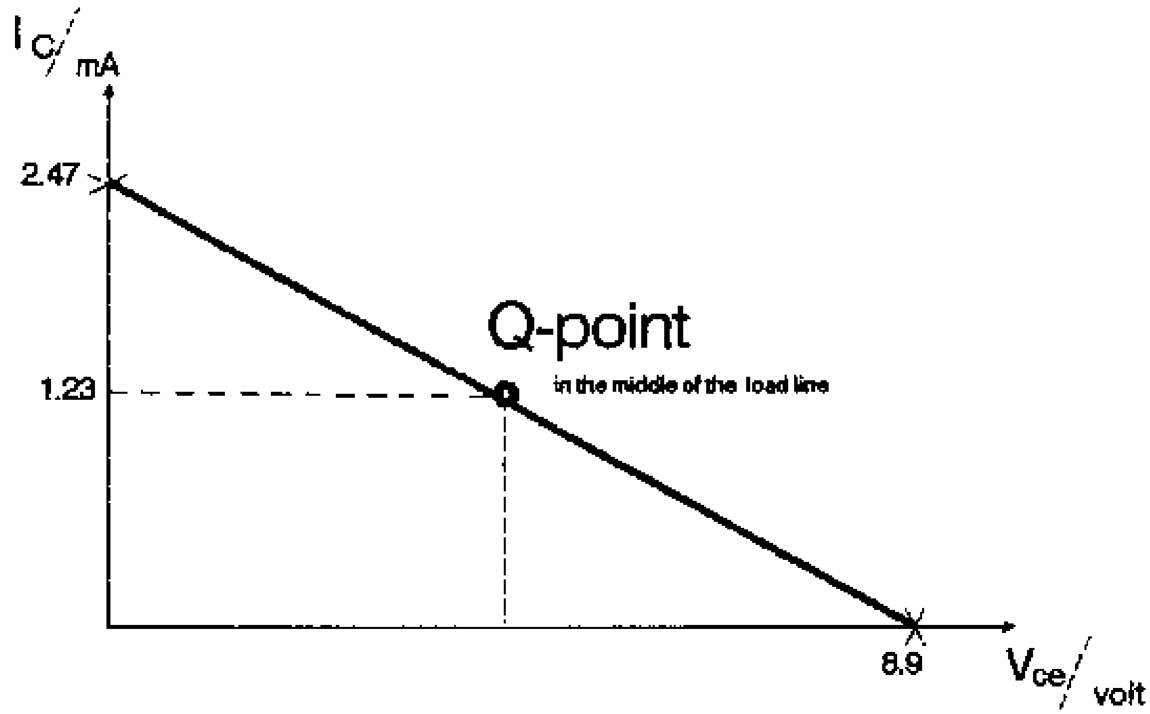
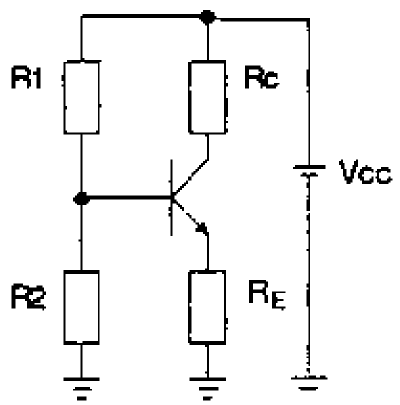


Fig. 6–7: Output curve, Q–point in the middle

Worksheet No. 6



No. 1 What is –the emitter voltage? The collector voltage? Given: R_1= 10k, R_2= 2.2k, R_C = 3.6k, R_E = 1k, V_{CC} = 25V

Draw the load–line, plot the Q point!

No. 2 What is the emitter voltage? The collector voltage?

Given: R_1= 330k, R_2= 100k, R_C = 150k, R_E = 51k, V_{CC} = 10V

Draw the load–line, plot the Q point!

No. 3 What is the emitter voltage? The collector voltage? Given: R_1 = 10k, R_2 = 2.2k, R_C = 2.7k, R_E = 1k, V_{CC} = 10V

Draw the load–line, plot the Q point!

Redesign the circuit to get the Q–point in the middle of the loadline!

Second Evaluation

No. 1 If the base resistor is very small, −the −transistor will operate in the a. cutoff region b. active region c. saturation region d. breakdown region

No. 2 If a transistor operates in the middle of the load line, an increase in the base resistance will move the Q−point a. up b. down c. nowhere d. off the load line

No. 3 The saturation point is approximately the same as a. cutoff point b. lower end of the load line c. upper end of the load line

No. 4 When the collector resistance decrease in a base biased circuit, the load line becomes a. more horizontal b. more vertical c. fixed

No. 5 The first step in analyzing emitter biased circuits is to find the a. base current b. emitter voltage c. emitter current d. collector current

No. 6 If the emitter resistance decreases, the collector voltage a. decreases b. stays the same c. increases d. breaks down the transistor

No. 7 If the emitter resistance doubles in a VDB circuit, the collector current will a. double b. drop in half c. remain the same d. increase

No. 8

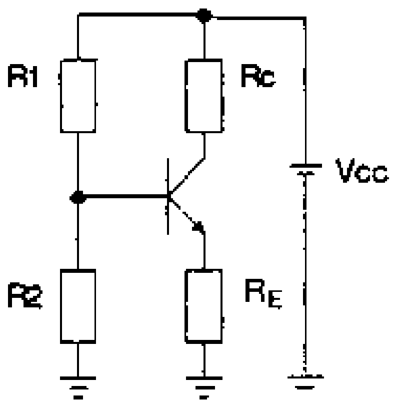
a) What is the emitter voltage?

b) The collector voltage?

c) Draw the load line, plot the Q−point!

d) Redesign the circuit to get the Q−point in the middle of the load line.

Given: R_1 = 12K?, R_2 = 3K?, R_C = 3.2 K?, R_E = 1K?, V_{CE} = 10V



Lesson 7 – Small Signal Amplifier

Lesson Plan

Title: Small Signal Amplifier

Objectives:

- Know the purpose of capacitors in amplifier circuits
- Able to calculate the voltage gain in an CE amplifier

Time	Method	Topic	Way	Remark
		* Review Lesson 6		
		*Introduction - AC signals		
		*Coupling capacitors		
		*Bypass capacitors		
		*Amplifier analyzing method - DC equivalent circuit - AC equivalent circuit - Voltage gain AC emitter resistance AC collector resistance		
		*Review exercise	WS	Worksheet No. 7
		*Experiment - CE Amplifier, Biasing and Gain -		Experiment No. 4
	S : Speach D: Diskussion Q/A : Question/Answer E : Exercise		B : Boardscript P : Picture Ex : Example HO : Hands-On WS : Worksheet HT : Hand-Out	

Small signal amplifier

<u>AC Signals</u>

After the transistor has been biased with the Q−point near the middle of the load line, we can put a small ac−voltage on the base (V_{in}). That procedures a large ac voltage at the collector (V_{out}). This increase is called amplification. For two reasons we have to use capacitors. First, to couple or transmit ac signals (coupling). Second, to short ac signals to ground (bypass).

Coupling capacitor

A capacitor is open at low frequencies and shorted at high frequencies.

$$X_C = \frac{1}{2\pi \times f \times C}$$

Capacitive reactance (X_C) is inversely proportional to frequency (f) and to capacitance (C). For a coupling capacitor to work properly, it has to act like an ac short at the lowest frequency that the ac source can have. To realize that we can use the following rule:

$X_C < 10\ R$

Make the reactance at least 10 times smaller than the total resistance in series with the capacitor.

Ex: Calculate the capacitance of C_1 for a proper ac transmittance. Frequency range: 20−20000 Hz

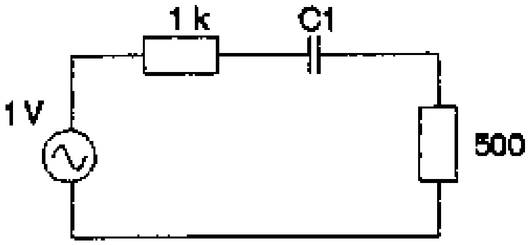


Fig. 7−1: Use of coupling capacitor

Total resistance: 1K? + 500? = 1.5K?

$X_C <= 10 * R$ −− >

$$X_C = \frac{1.5K\Omega}{10} = 150\Omega$$

$$X_C = \frac{1}{2\pi \times f \times C} \quad -- > \quad C = \frac{1}{2\pi \times f \times X_C}$$

$$C = \frac{1}{2 \times 3.14 \times 20Hz \times 15K\Omega}$$

C = 53?F

The capacitor to choose should be bigger than 53?F. The next standard value is:

C = 56?F

Bypass capacitor

It is connected in parallel across a resistor. The reason for doing this is to bypass an ac current away from the resistor. The capacitor provides a short for the ac. You can use the following rule to calculate the capacitance:

Make the reactance at least 10 times smaller than the total resistance in parallel with the capacitor.

Amplifier analyzing method

From a given amplifier circuit first do –the dc analysis (recall lesson 6) and than do the ac analysis.

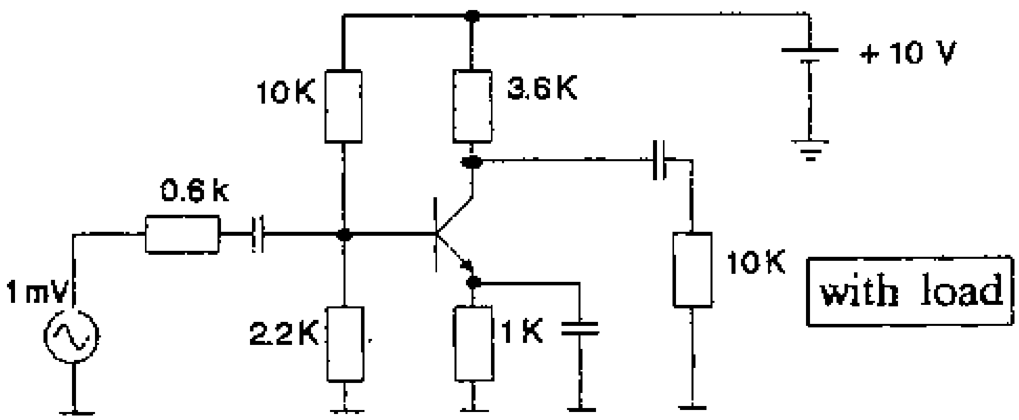


Fig. 7–2: CE amplifier circuit

DC equivalent circuit

For dc, all capacitors are acting like open switches; therefore we can draw the following dc equivalent circuit:

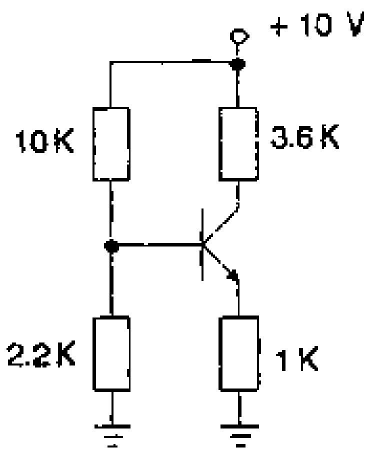


Fig. 7–3: DC equivalent circuit

Now the dc analysis can easily be done: (see Lesson 6)

V_B = 1.8V
V_E = 1.1V

$I_E = 1.1$ mA
$V_C = 6.04$V
$V_{CE} = 4.94$V

<u>AC equivalent circuit</u>

For the ac all capacitors are shorted and the dc sources are reduced to zero:

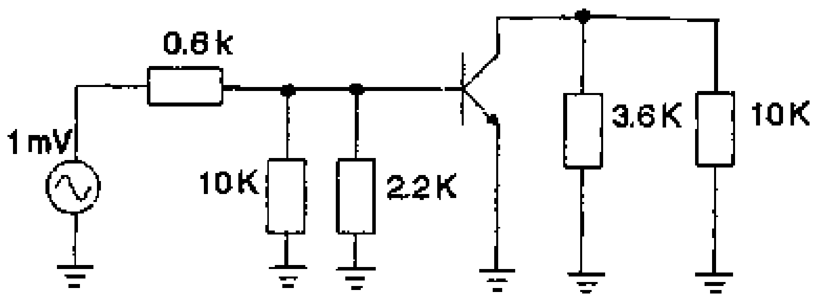


Fig. 7–4: Ac equivalent, circuit

The top of the 10K and 3.6K resistors are grounded. The resistors 10K/2.2K and 3.6K/10K are in parallel so we can combine them:

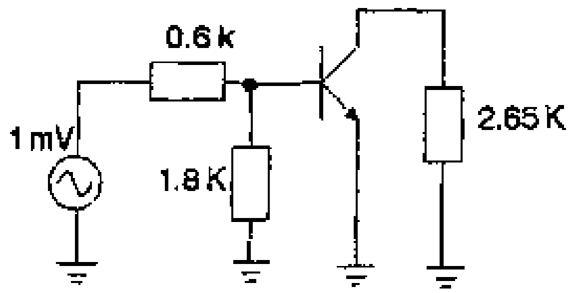


Fig. 7–4: Simplified ac equivalent circuit

Now we got a really simple circuit for the ac analysis.

<u>Voltage Gain</u>

One of the most important characteristics for small signal amplifiers is the voltage gain (A_V).

$$A_V = \frac{V_{out}}{V_{in}}$$

The lowercase letters are used to indicate ac values. The output voltage is given by:

$V_{out} = i_c * r_c$

The input voltage is given by:

$V_{in} = i_e * r_e$

Substitute of these two expressions:

$$A_V = \frac{i_c \times r_c}{i_e \times r_e}$$

Because i_c approximately equals i_e:

$$A_V = \frac{r_c}{r_e}$$

<u>AC emitter resistance (r_e)</u>

The first step in calculating the voltage gain is to estimate the ac emitter resistance (r_e).

$$r_e = \frac{25mV}{I_E}$$ (formula derived by using calculus)

This relation applies to all transistors that means it is a universal formula.

Let's remember our example circuit (Fig. 7–4):

$$r_e = \frac{25mV}{I_E} = \frac{25mV}{1.1mA} = 22.7\Omega$$

<u>AC collector resistance</u>

Due to the ac analyzing method we easily get the ac collector resistance (re). See Fig. 7–4:

r_c = 2.65K?

So now we are ready to calculate the voltage gain:

$$A_V = \frac{r_c}{r_e} = \frac{2.65K\Omega}{22.7\Omega} = 117$$

<u>HO:</u> What will be the voltage gain for the following circuit?

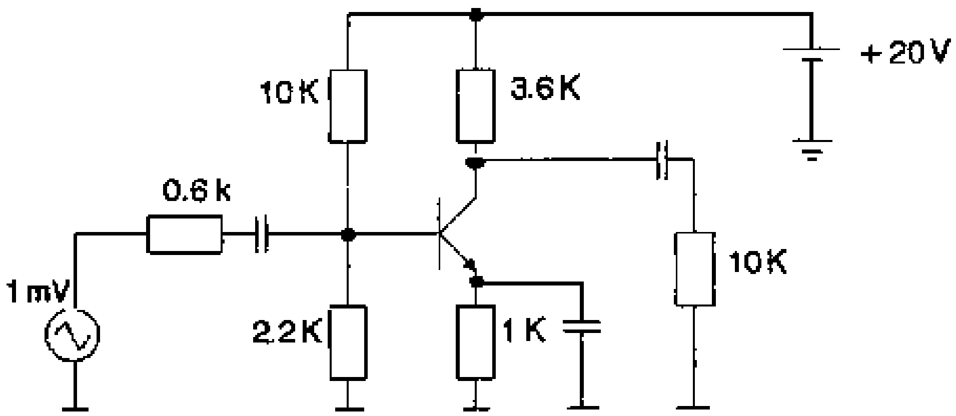


Fig. 7–5: CE amplifier circuit

<u>Solution:</u>

DC analysis

V_B = 3.6K?, V_E = 2.9 K?, I_E = 2.9 mA

V_C = 9.5V, V_{CE} = 6.6V

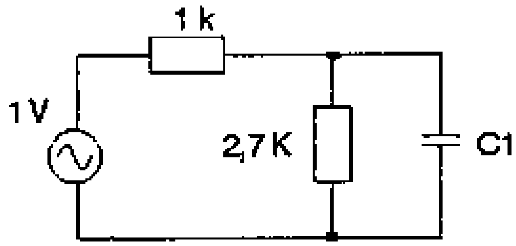
AC analysis

r_c = 2.65K?

$$r_e = \frac{25mV}{I_E} = \frac{25mV}{2.9mA} = 8.62\Omega$$

$$A_V = \frac{r_c}{r_e} = \frac{2.65K\Omega}{8.62\Omega} = 307$$

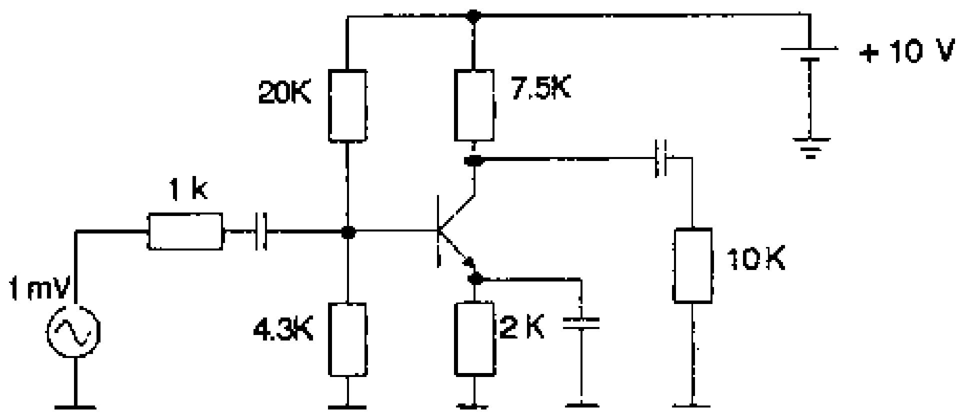
Worksheet No. 7



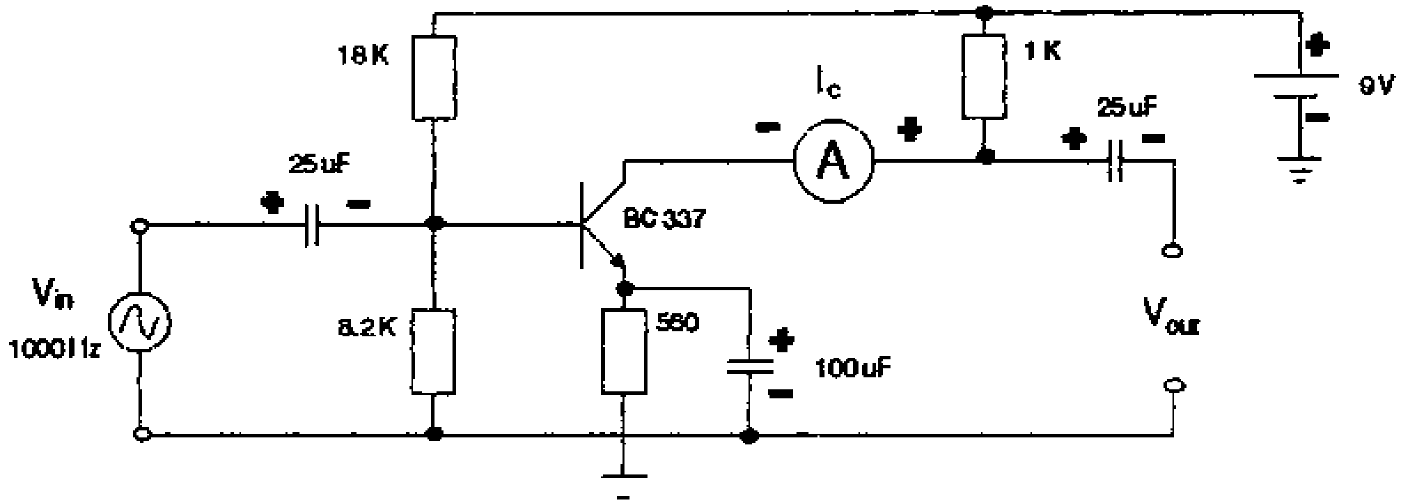
No. 1 (circuit above) Calculate the capacitance of C_1, to design a proper working bypass capacitor for the load R_L. Frequency range: 20 – 20000 Hz

No. 2 (circuit below)

a) Draw the dc equivalent circuit.
b) Calculate the following dc values: I_C, V_{CE}
c) Draw the ac equivalent circuit.
d) Calculate the ac emitter resistance (r_e) and the ac collector resistance (r_c).
e) What is the voltage gain A_V?
f) What happens to the voltage gain if the supply voltage doubles?



Experiment No. 4



Procedure:

1. Connect the circuit

2. Connect an signal generator to the input. Set it to 1000 Hz (sinewave) and minimum output. Connect an oscilloscope to the output terminals of the amplifier. Adjust the oscilloscope for proper viewing.

3. Set the output of the generator to the maximum undistorted amplifier output.
Measure the peak to peak input and output amplitude and record it in the table. Draw the input and output waveforms in the table.

4. Set the generator to the minimum undistorted amplifier output.
Measure the peak to peak input and output amplitude and record it in the table. Sketch the input and output waveforms in the table.

Step		**Input**		**Output**	
	I_C	V_{p-p}	**Waveform**	V_{p-p}	**Waveform**
3					
4					

Lesson 8 – Small Signal Amplifier II

Lesson Plan

Title: Small Signal Amplifier II

Objectives:

– Able to calculate the input impedance
– Understand the purpose of impedance matching

Time	Method	Topic	Way	Remark
		* Review Lesson 7		
		* Introduction - Signals in a CE amplifier		Handout No. 1
		* Input impedance		
		* Impedance matching - Voltage optimum - Power optimum		
		* Review exercise		Worksheet No. 8
	S : Speech D : Diskussion Q/A : Question/Answer F : Exercise		B : Boardscript P : Picture Ex : Example HO : Hands-On WS : Worksheet HT : Hand-Out	

Signals in a CE amplifier

One characteristic of the CE amplifier is the phase inversion.

See Handout No. 1 (let the students complete)

For a better understanding the different voltage signals are plotted in four graphs:

Graph 1: A small ac signal is applied at the amplifier input.
Graph 2: The small ac signal is topping the biasing dc.
Graph 3: The amplified and inverted ac signal is topping the biasing dc.
Graph 4: The output capacitor C_2 is blocking the dc, the amplified inverted ac signal is applied at the load.

Input impedance

Another important value to analyze is the input impedance of an amplifier circuit.

Recall the ac equivalent circuit in Lesson 7:

(see Fig. 8–1 on the next page)

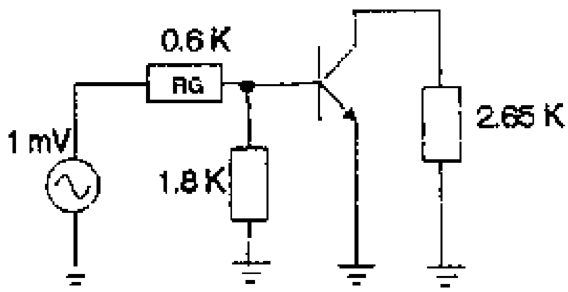


Fig. 8–1: AC equivalent circuit

R_G is equal to the internal resistance of the signal source. Input impedance looking into the base:

$$z_b = \frac{V_b}{i_b} = \frac{i_e \times r_e}{i_b}$$

i_e/i_b is approximately equal to ?:

z_b = ? * r_e

The input impedance of a amplifier stage is the combination of base impedance and biasing resistance:

z_{in} = R_1//R_2//? * r_e

Ex: What is the input impedance in Fig. 8–1?

re = 22.7 ?, ? = 100

z_{in} = 1.8 K?//22.7 ? * 100

$$= \frac{18K\Omega \times 227\Omega}{18K\Omega + 227\Omega}$$

= 202 ?

Impedance matching

When you couple some amplifier stages or connect electronic appliances, the input/output impedance of every stage will effect the efficiency.

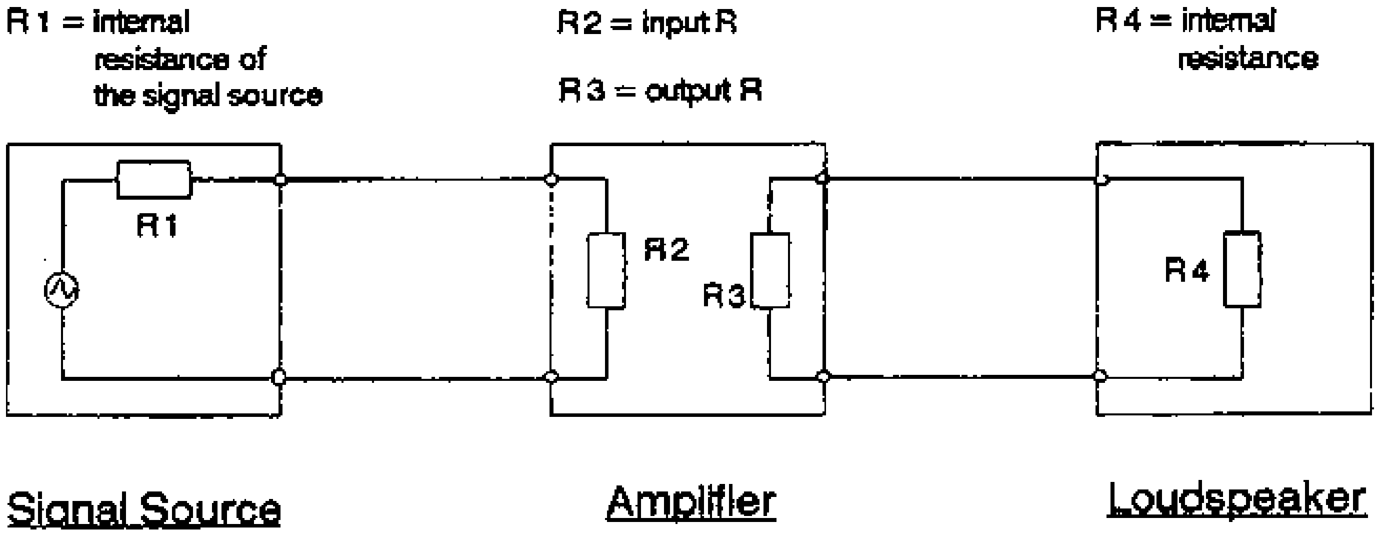


Fig. 8–2: Impedance matching

The internal resistance/impedance of the signal source (R_1) and the loudspeaker (R_4) is fixed. Only R_2 and R_3 can be designed to match the impedance.

<u>Voltage optimum</u>

Between signal source and amplifier it is important to transfer the highest possible voltage.

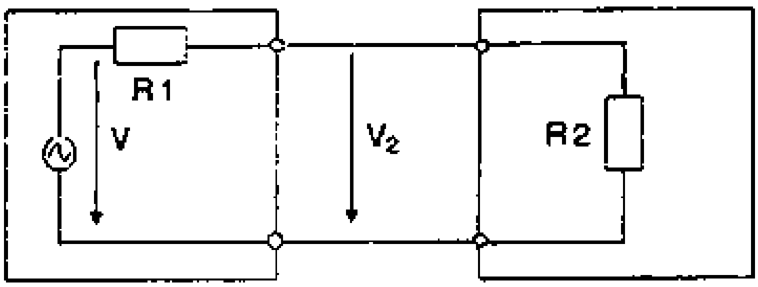


Fig. 8–3: Voltage optimum

$$V_2 = \frac{R_2}{R_1 + R_2 \times V}$$

In order to get the highest, possible voltage (V_2) let's try several values for R_2.

Ex: V = 10V, R_1 = 100 ?

R_2 = 0.1 * R_1 --- >

$$V_2 = \frac{0.1 \times R_1}{R_1 + R_1 \times 0.1 \times V} = 9.09\% V$$

$R_2 = R_1$ --- >

$$V_2 = \frac{1}{1 + 1 \times V} = 50\% V$$

$R_2 = 10 * R_1$ --- >

$$V_2 = \frac{10 \times R_1}{R_1 + R_1 \times 10 \times V} = 90.9\% V$$

$R_2 = 100 * R_1$ --- >

$$V_2 = \frac{100 \times R_1}{R_1 + R_1 \times 100 \times V} = 99\% V$$

The input impedance of an amplifier should be much bigger than the internal resistance of the signal source.

Power Optimum

Between amplifier and loudspeaker it is most important to transfer the highest possible power.

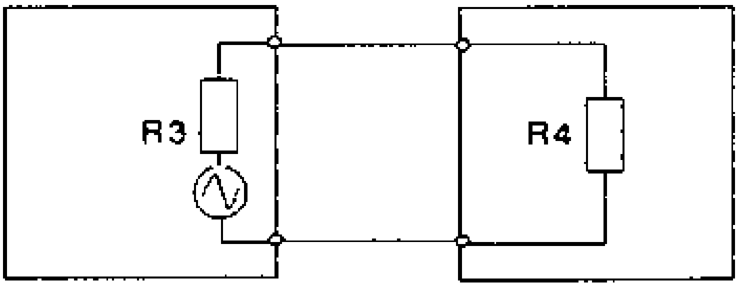


Fig. 8–4: Power optimum

Ex: Power in the load under different values of R4.

V = 10V, R3 = 8?

$$I = \frac{V}{R_3 + R_4}$$

$P_L = R_4 * I^2$

R_4 = 16? I = 24? = 0.42A P_L = 2.78W

R_4 = 8? I = 16? = 0.63A P_L = 3.125W

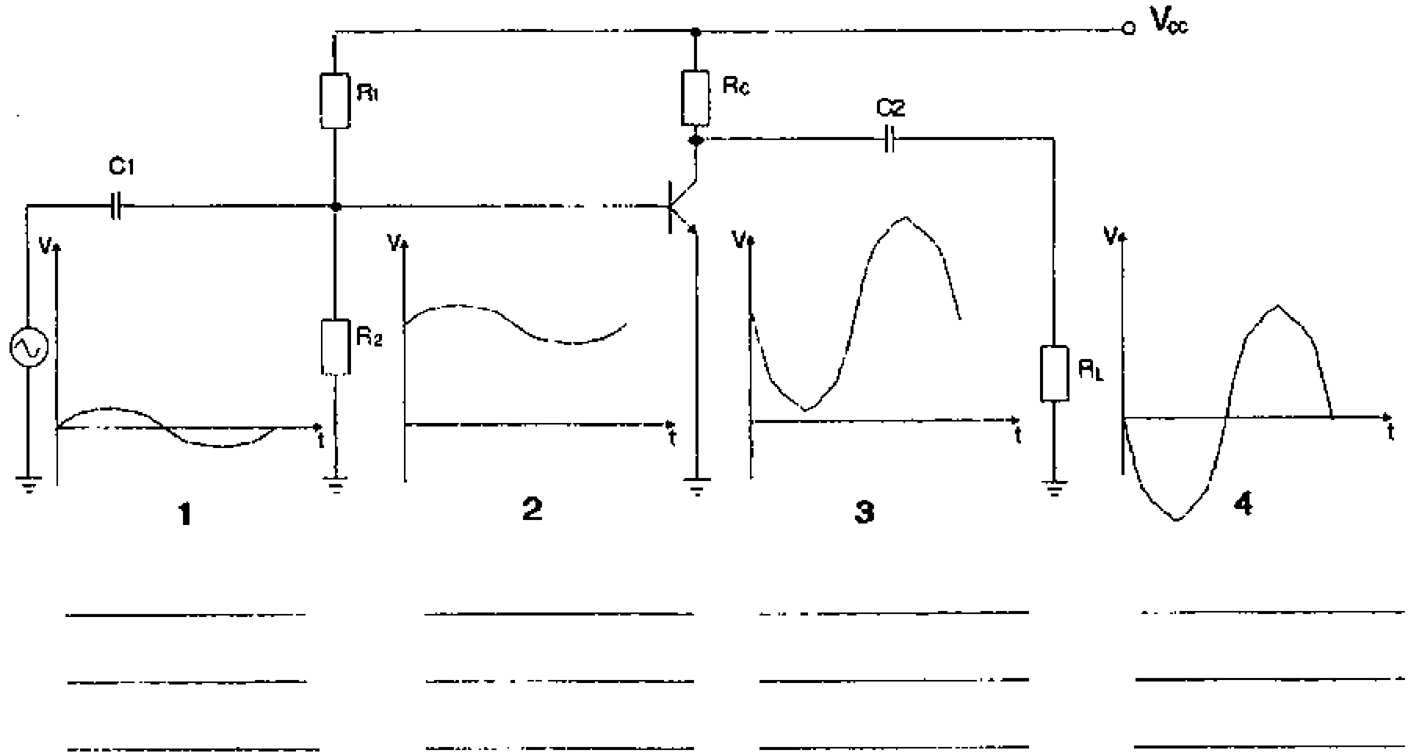
R_4 = 4?   I = 12? = 1.14A P_L = 1 .03W

Input impedance of the load and the output impedance of the amplifier should have the same value.

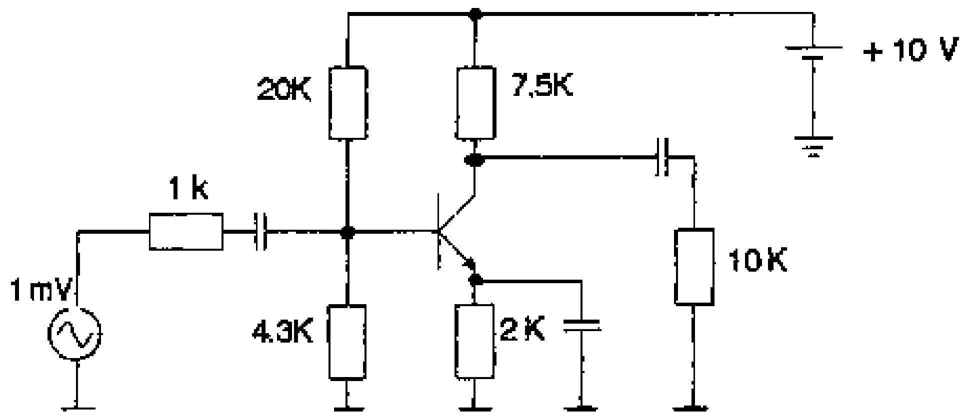
$R_3 = R_4$

$R_i = R_L$

Handout No. 1



Worksheet No. 8



No. 1 a) The generator voltage doubles. What is the input impedance?

>b) The generator resistance R_G doubles. What is the input impedance?

No. 2 You like to connect a microphone (R = 100K?) to an amplifier. What should be the input impedance of the amplifier to get a voltage optimum?

Microphone output voltage V_{out} = 10 mV

No. 3 The output impedance of your amplifier is 6?. What kind of loudspeaker (4? or 8?) do you choose to get the best power transfer?

Lesson 9 – Small Signal Amplifier III

Lesson Plan

Title: Small Signal Amplifier III

Objectives:

- Know the characteristics of CE, CB, and CC configurations
- Understand why the output voltage depends on the frequency
- Able to construct the ac load line

Time	Method	Topic	Way	Remark
		* Review Lesson 8		
		* Introduction - Other cofigurations		Hand out No. 2
		* Frequency response of an amplifier		
		* AC load line - AC load line construction		
		* Review exercise		Worksheet No. 9
	S : Speach D : Diskussion Q/A : Question/Answer F : Exercise		B : Boardscript P : Picture Ex : Example HO : Hands-On WS : Worksheet HT : Hand-Out	

Other configurations

Up to now we discussed only the common emitter configuration, which is widely used. But for some circuit conditions the common base or the common collector configuration may be a better choice.

As we had already seen, the input/output impedance of an amplifier is a very important characteristic, because the internal impedance of signal sources vary widely:

Ex:

Antenna ––– > approx. 50 ?
Microphone ––– > approx. 100000 ?

To choose the best configuration let's have a look at its characteristics.

See Handout No. 2 (let the students complete)

Common base CB

- High voltage gain
- No current gain
- Low input impedance
- High output impedance
- No phase inversion

Common collector CC

- No voltage gain
- High current gain
- High input impedance
- Low output impedance
- No phase inversion

Common emitter CE

- High voltage gain
- High current gain
- Medium input impedance
- Medium output impedance
- Phase inversion

Frequency response of an amplifier

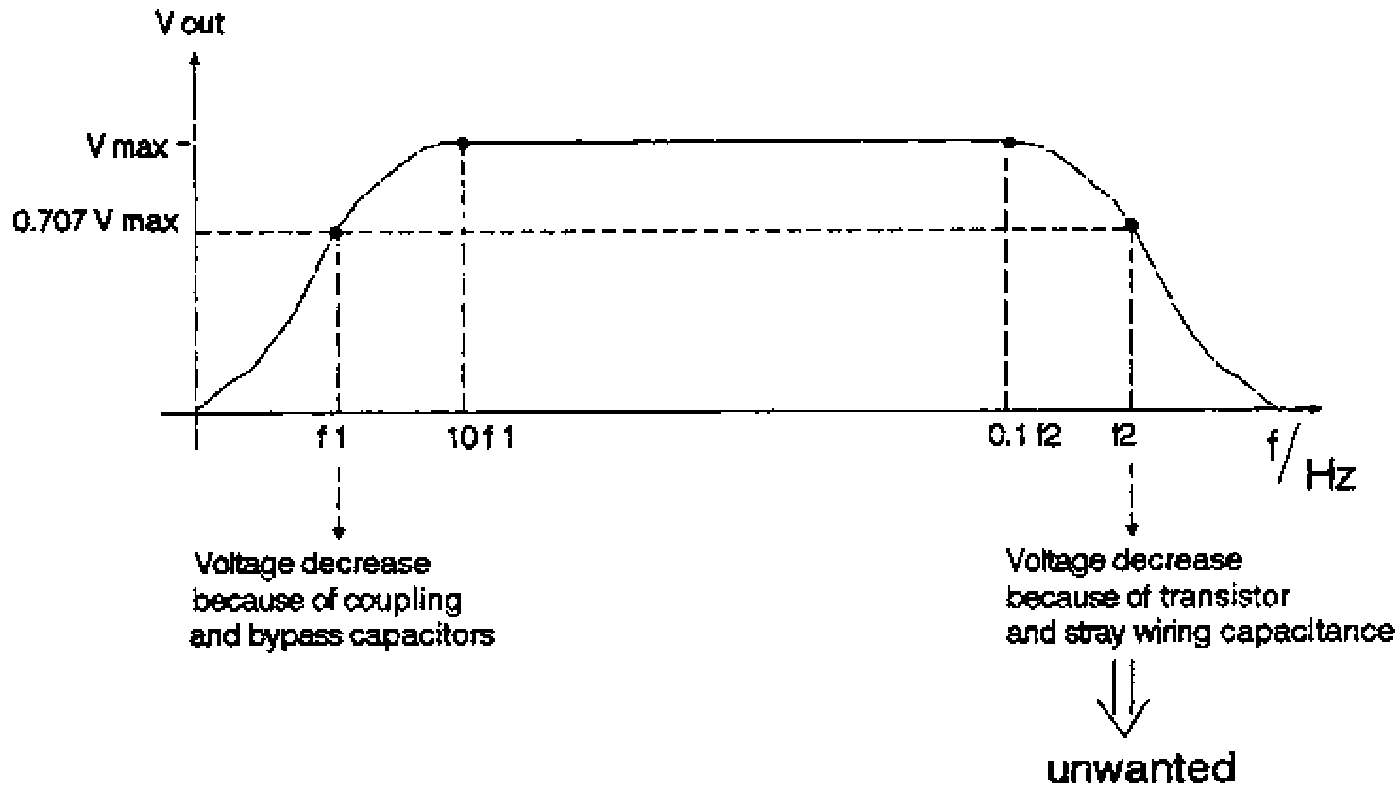


Fig. 9–1: Amplifier output voltage in terms of frequency

Fig. 9–1 shows the typical frequency response of an amplifier. At low frequencies the output voltage decreases because of coupling and bypass capacitors. At high frequencies, the output voltage decreases because of transistor and stray wiring capacitance.

Critical frequencies:

Where the output voltage is 0.707 of V_{max}.
Two critical frequencies –> f_1, f_2

Midband:

Is the band of frequencies between 10 * f_1 and 0.1 * f_2.
The midband is where an amplifier is supposed to be operated.

Ex: Find the midband of an amplifier with f_1 = 5 Hz and f_2 = 100 KHz.

10 * f_1 = 10 * 5 Hz = 50 Hz –– > lower end

0.1 * f_2 = 0.1 * 100 KHz = 10 KHz –– > upper end

Midband: 50 Hz – 10 KHz

The AC load line

In previous lessons we used the dc load line to analyze biasing circuits. But an amplifier sees two loads, a dc load and a ac load. Now we will use the ac load line to understand the large signal operations.

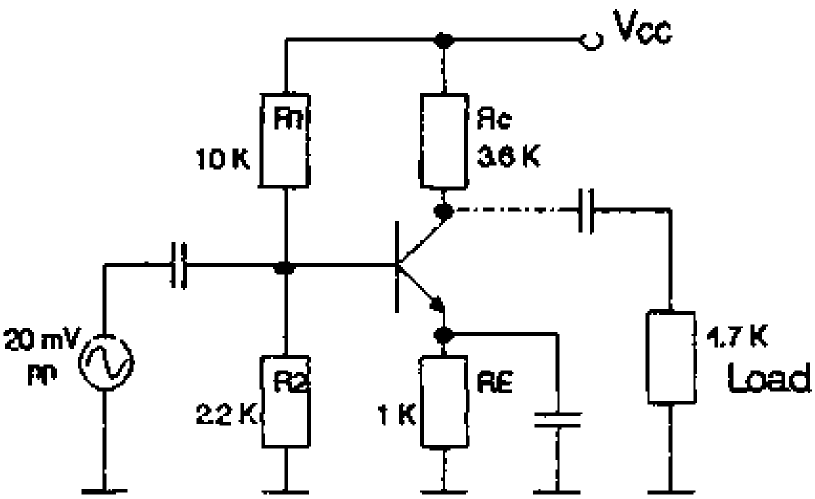


Fig. 9–2: CE amplifier

DC values: V_B = 1.8V, V_E = 1.1V, I_E = 1.1 mA, V_C = 6.04V V_{CC} = 10V, V_{CE} = 4.94V

Without load: DC an ac load line are the same.

With load: r_c = RC//RL

$$r_c = \frac{3.6K\Omega \times 4.7K\Omega}{3.6K\Omega + 4.7K\Omega} = 2.04K\Omega$$

<u>AC Load Line Construction</u>

The following process shows you an easy method to get the ac load line:

1. Draw the dc load line

$$I_{C(sat)} = \frac{V_{RC}}{R_C} = 2.5mA$$

$V_{CE\ (cut)} = V_{CC} - V_E = 8.9V$

2. Calculate and draw the Q point

I_C = 1.1 mA

V_{CE} = 6.04V

3. Draw a –temporary ac load line

$V_{CE\ (cut)} = V_{CC}$

$$I_{C(sat)} = \frac{V_{RC}}{r_c} = 4.9mA$$

4. Construct the ac load line

– parallel to the temporary ac load line
– passing the Q point

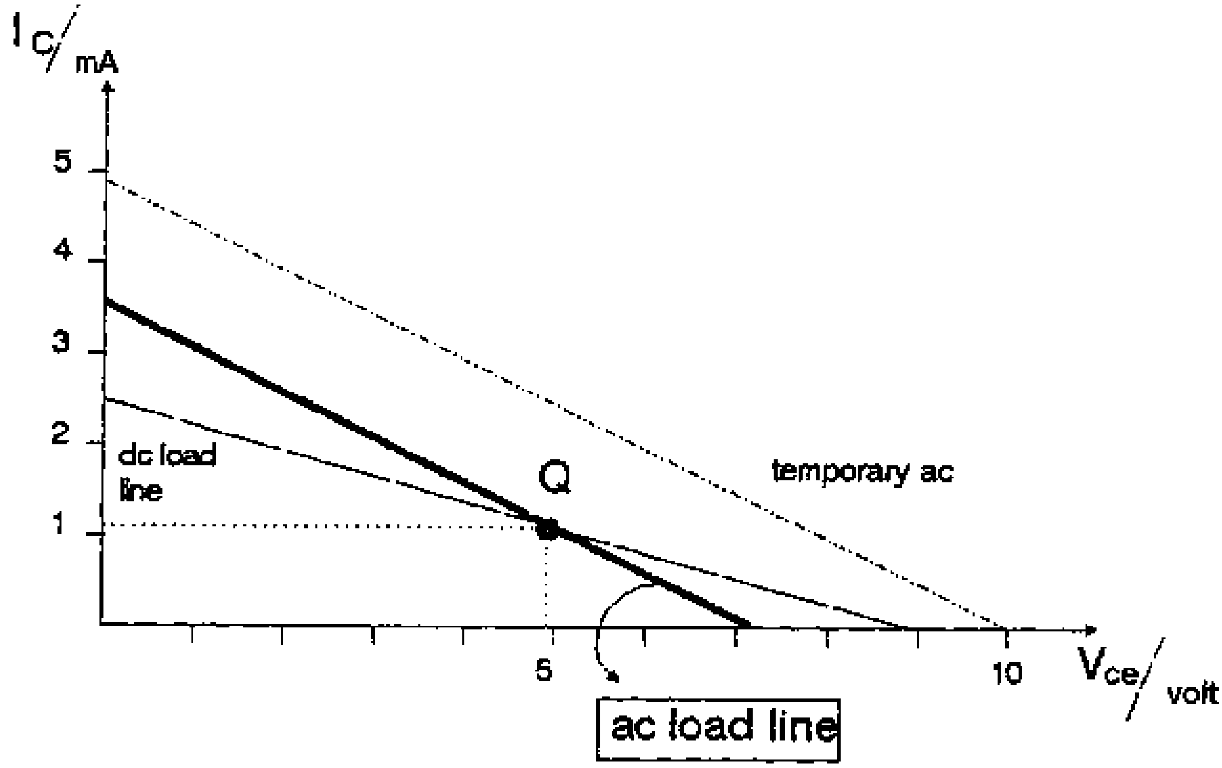
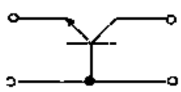


Fig. 9–3: Construction of an ac load line

Handout No. 2

Common Base CB



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* ________________
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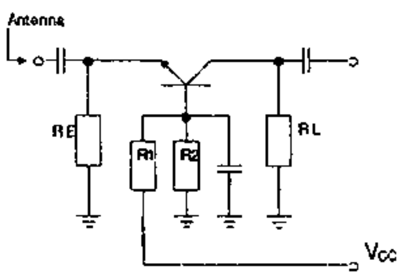
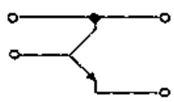
Application:
RF Amplifier



Common Collector CC



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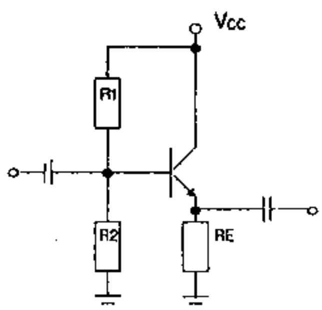
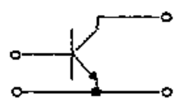
Application:
Impedance changer



Common Emitter CE



* ________________
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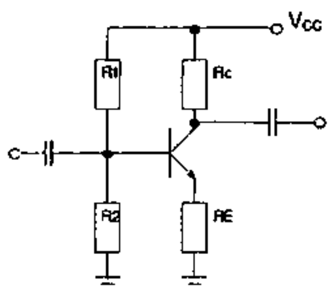
Application:
Mainly used, i.e. Audio amplifier



Worksheet No. 9

<u>No. 1</u> An amplifier has –this critical frequencies:

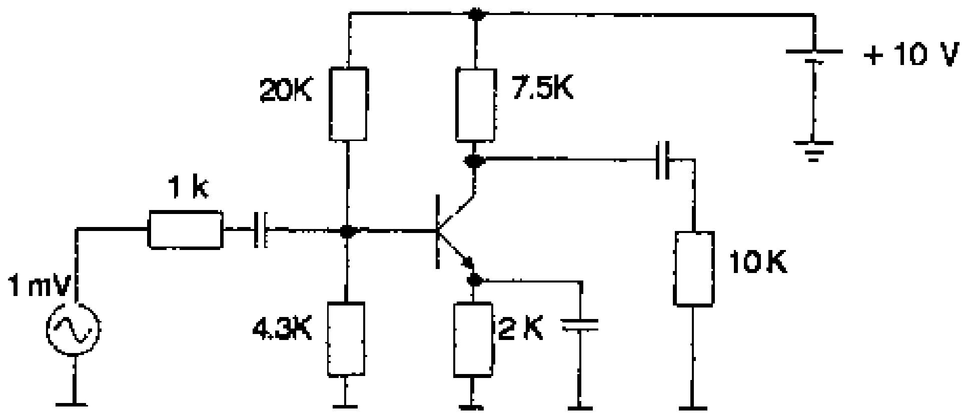
f_1 = 2 Hz, f_2 = 200 KHz

What is the midband?

<u>No. 2</u> See Worksheet No. 8, Problem No. 3.

What kind of transistor connection would you choose for the first stage of the amplifier? Explain!

<u>No. 3</u> Construct the ac load line for the following circuit.



Lesson 10 – Large Signal Amplifier

Lesson Plan

Title: Large Signal Amplifier

Objectives:

– Understand the importance of amplifier efficiency
– Know the most common classes of power amplifier and their basic characteristics

Time	Method	Topic	Way	Remark
		* Review Lesson 9		
		* Intrduction - Large signal amplfication		
		* Classes		
		* Class A power amplifier		
		* Class B power amplifier		
		* Class AB power amplifier		
		* Review exercises		Worksheet No. 10

S : Speach
D : Diskussion
Q/A : Question/Answer
F : Exercise

B : Boardscript
P : Picture
Ex : Example
HO : Hands-On
WS : Worksheet
HT : Hand-Out

Large signal amplifier

The early stages of amplifier systems are dealing with small signals. These stages are designed to give good voltage gain. Small signal transistors have a power rating of less than half a watt and power transistors have a power rating of more than half a watt.

The later stages of an amplifier system have much larger collector currents, because the load impedances are much smaller (i.e.: Loudspeaker 1?, 4?, 8?, 16?).

Efficiency is most important when large amounts of signal power are required:

$$\text{Efficiency} = \frac{\text{Signal power output}}{\text{DC power input}}$$

Classes

This refers to how the amplifying device is biased. Amplifier can be biased for class A, B or AB operation.

Class A power amplifier

The amplifiers we have discussed have been class A amplifiers. Class A amplifier operate in the center of the load line. This gives the best possible output swing without clipping.

Efficiency: low, maximum 50%

> Even when no signal is applied, a high current is flowing (100 mA) and there is a power dissipation in the load.

Distortion: low

Applications: Few audio amplifier (high quality)

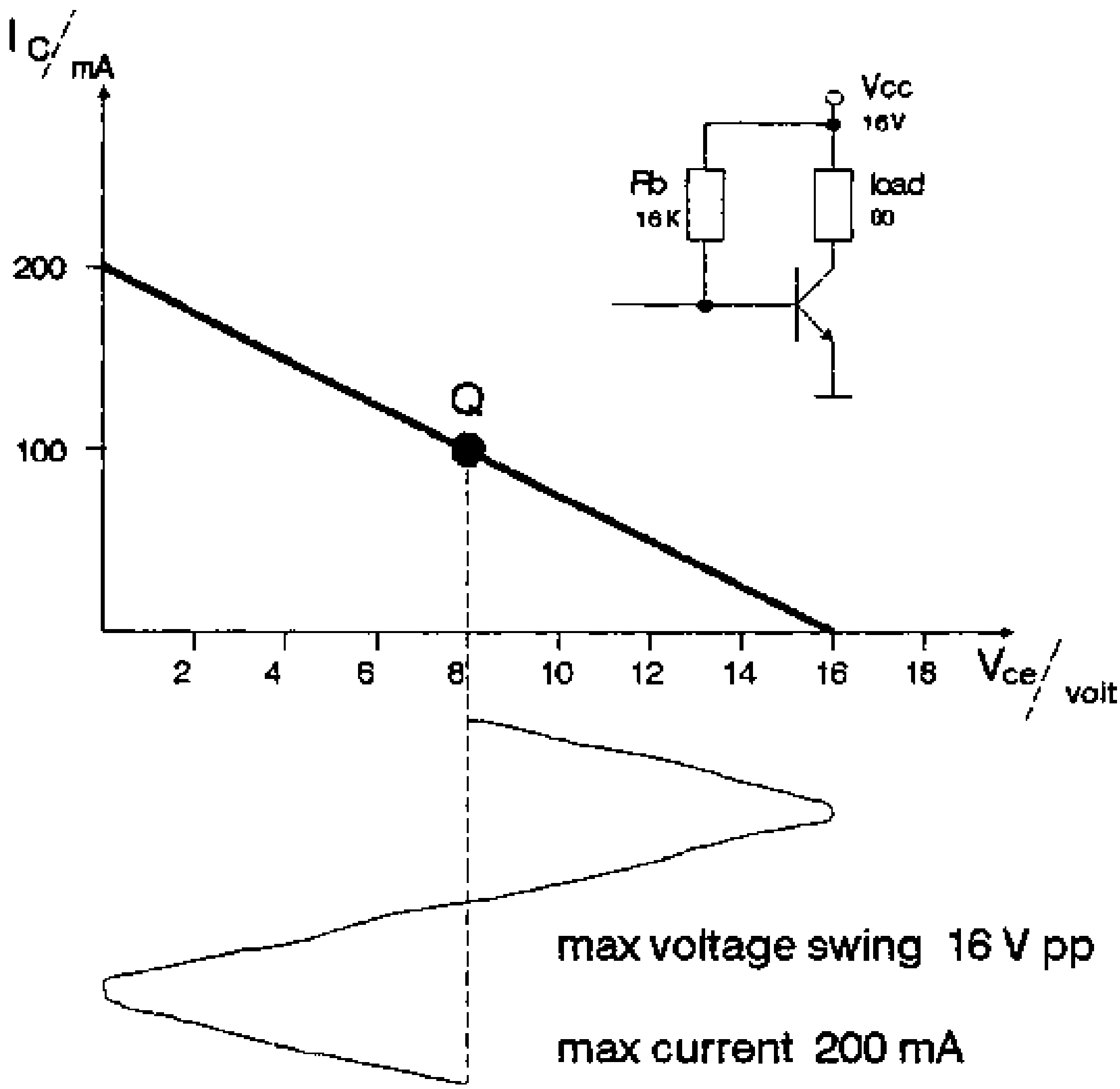


Fig. 10–1: Class A amplifier

Class B power amplifier

The class B amplifier is biased at cutoff. No current will flow until an input signal provides the bias to turn on the amplifier.

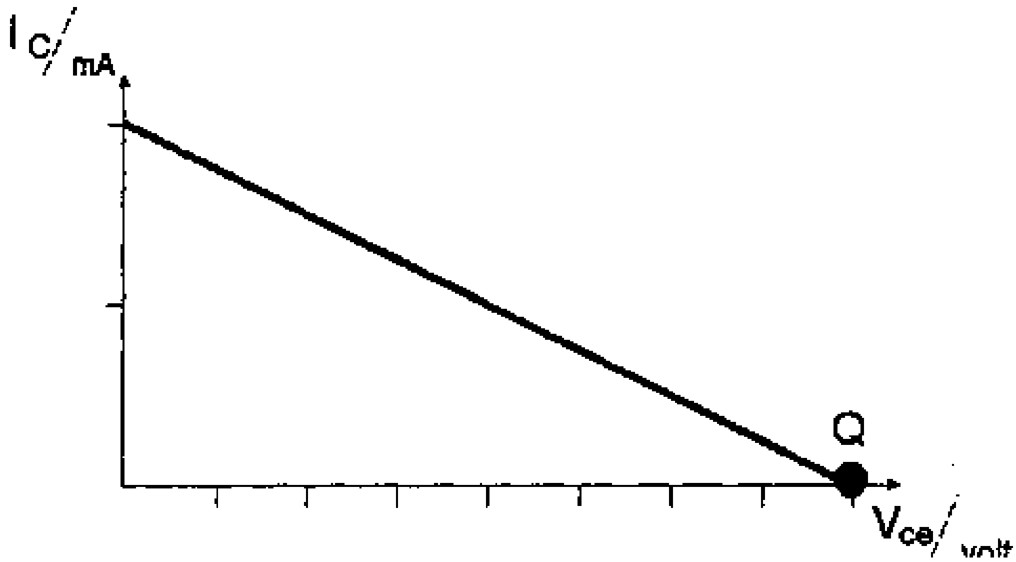


Fig. 10–2: Q point of a class B amplifier

Only one half of the input signal is amplified. Two transistors can be operate in class B together in one circuit, one transistor for the positive portion of the signal and one transistor for the negative portion of the signal (Push Pull):

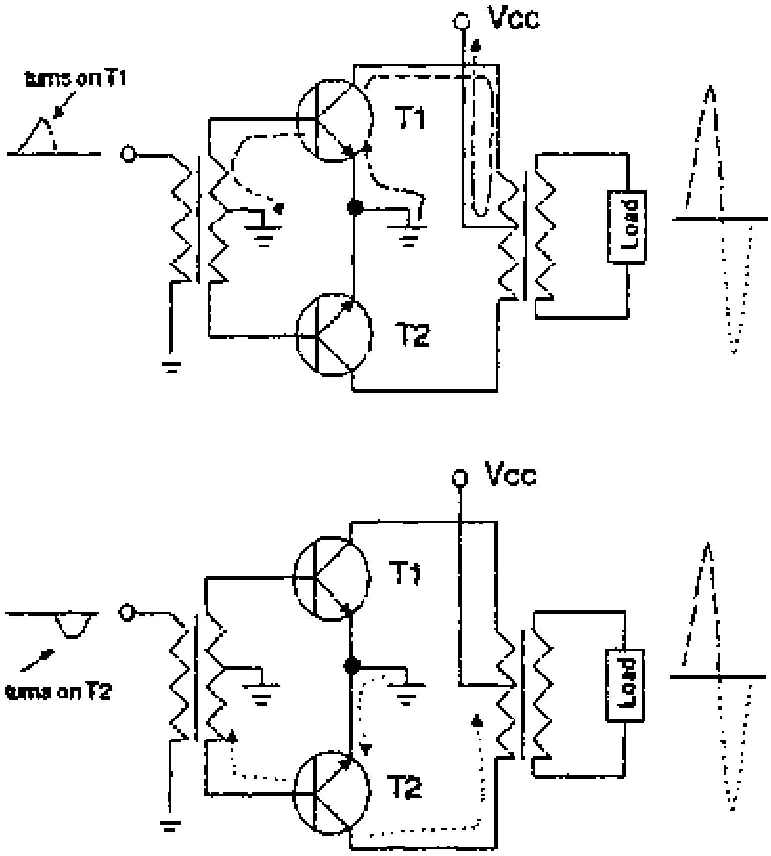


Fig. 10–3: Push Pull amplifier

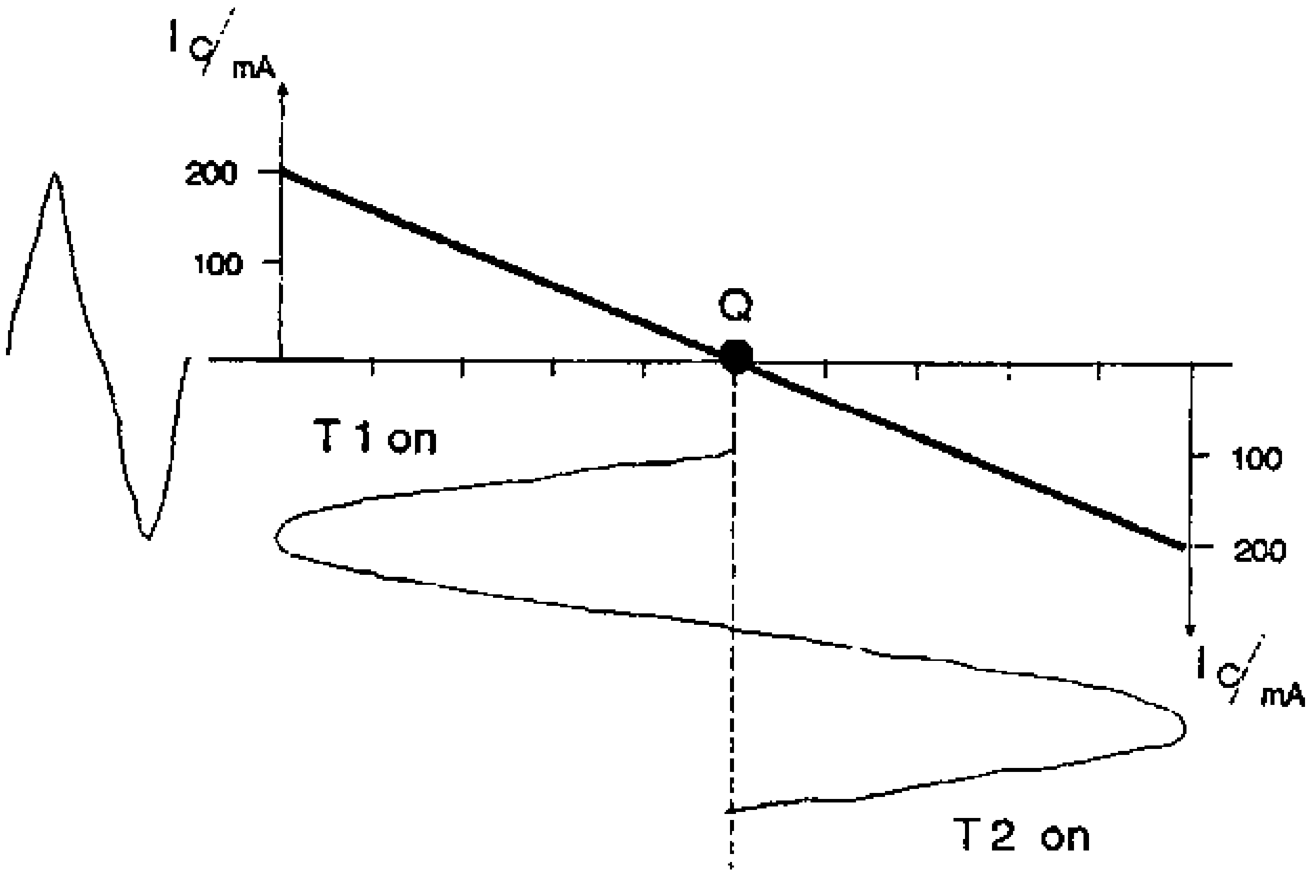


Fig. 10–4: Signal swing of a. push pull amplifier, Class B operation

Problem: Crossover distortion, the emitter diode takes 0,7V to turn on.

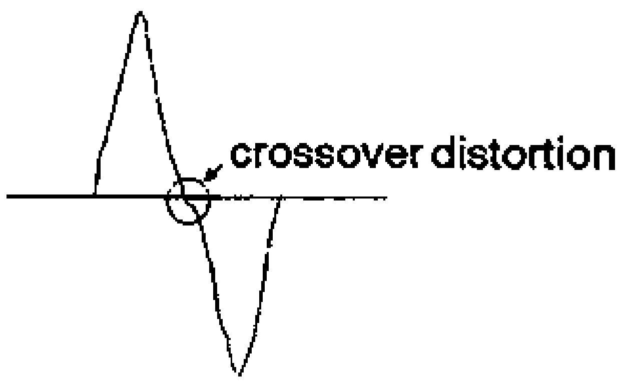


Fig. 10–5: Crossover distortion

Efficiency: 78.5%

Distortion: High

Application: High power stages, not used in audio applications.

Class AB power amplifier

Solution to the crossover distortion:

Provide some forward bias for the base emitter junction.

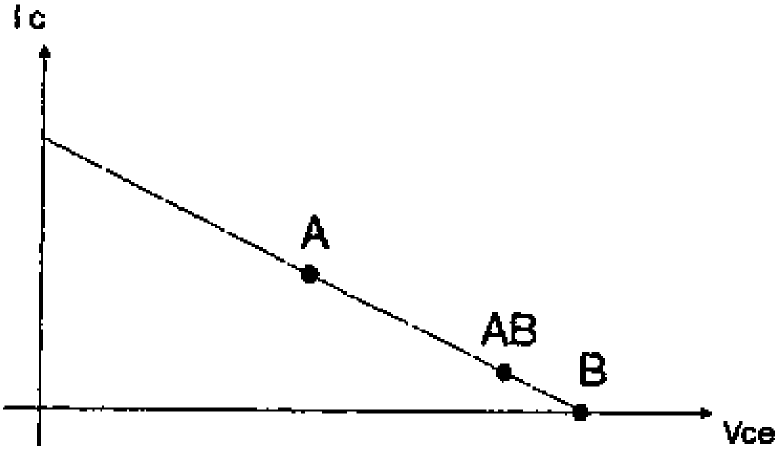


Fig. 10−6: Class AB amplifier

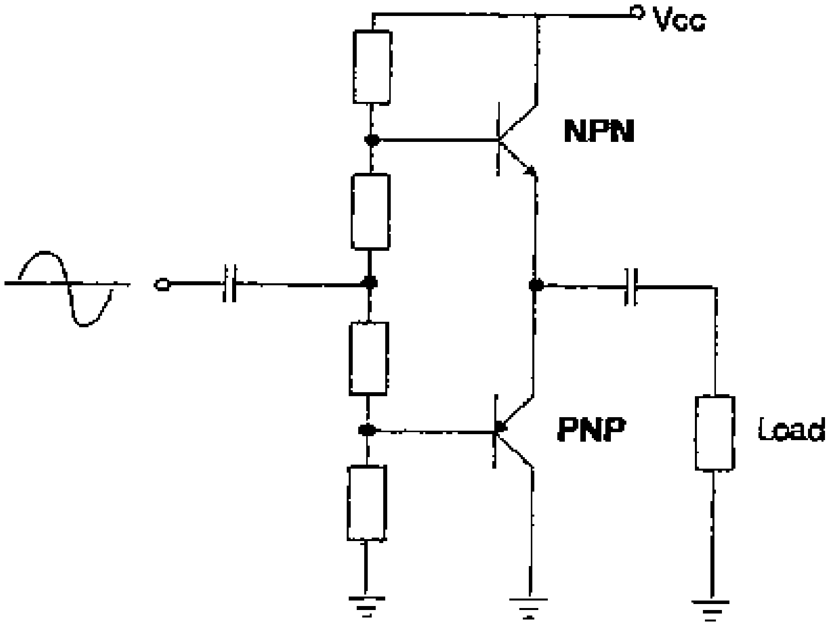


Fig. 10−7: Complementary push pull amplifier

Two complementary transistors are used (NPN + PNP) , so no transformer is needed any more.

Efficiency: between A and B

Distortion: Moderate

Application: High power stages in audio and radio−frequency applications.

Worksheet No. 10

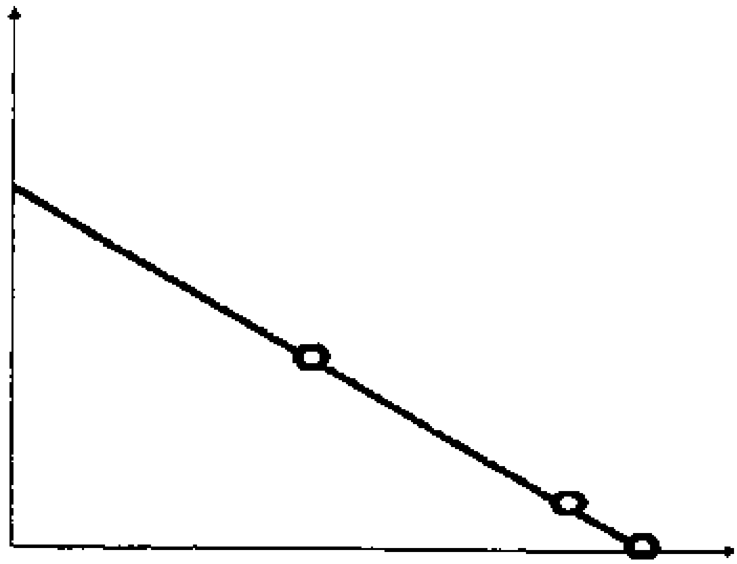
No. 1 Explain the difference between class A and class B power operation.

No. 2 Draw a circuit of a complementary push pull amplifier.

No. 3 Why is the efficiency of a class A power amplifier so low?

No. 4 In the graph below you see the Q points of different power amplifiers. Which Q point belongs to which type of power amplifier?

Label the graph!



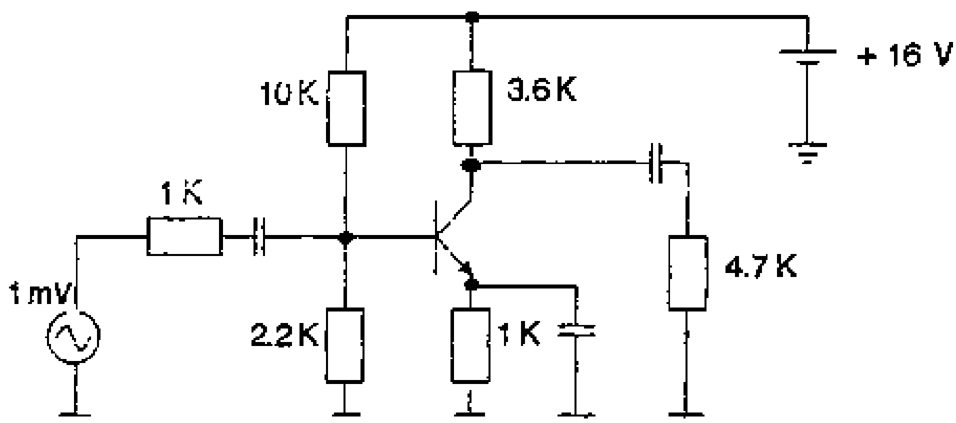
Third Evaluation

No. 1 Characteristic parameter of –the transistor connections. Fill in: yes/no/high/low/medium

	common base	common collector	common emitter
voltage gain			
current gain			
input impedance			
output impedance			
phase inversion			

No. 2

a) What is the voltage gain A_V?
b) What is the input impedance?
c) Construct the ac load line!



No. 3 a) What are the classes of power amplifiers? Discuss advantage and disadvantage of every class.

b) Sketch a circuit of a push pull amplifier.