ANALOGUE ELECTRONICS

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For Ian and Adam,

'A moment's insight is sometimes worth a lifetime's experience'

Oliver Wendell Holmes

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Preface

This book is intended for people with some basic knowledge of electronic principles, who wish to continue to develop an understanding of slightly more complex electronic devices and concepts.

The non-mathematical text commences with decibel notation, which is a sub-plot that runs through electrical and electronic engineering. Familiar analogue electronic topics such as signal amplifiers, power amplifiers and oscillators are discussed in detail. The important, but slightly mysterious concept of electrical noise has been introduced at this level in order to promote an understanding of its real significance in the world of electronics. Feedback is presented in a manner that illustrates its use when designing practical circuits, particularly those using operational amplifiers. Power electronic components like the thyristor and triac are today rapidly replacing electro-mechanical controllers. The operation of these devices together with the design and triggering of circuits is given thorough treatment. An individual, skilled and knowledgeable in the field of electronics should be able to repair faulty equipment. In an effort to be fully comprehensive, the final chapter briefly introduces this subject, showing how basic instruments can be used to diagnose faults in a circuit down to component level.

Discovery-based, student-centred methods are adopted throughout the book that make use of manufacturers' data sheets, self assessment questions and design assignments to reinforce theoretical concepts. In addition to this, hands-on experience can be gained by working through the 24 Practical Investigations. These are designed to help forge the all important link between *knowing* and *doing*. Each chapter includes a review section that allows the salient points to be recapped without excessive *hunting* through the text.

The material covers the principal objectives of the BTEC Level NIII Analogue Electronics Syllabus while sharing common ground with the City and Guilds 224, 271 and GCSE courses. Background information if required can be found in the companion volume *Electronics: Practical Applications and Design* (Morris, 1989). It is my intention that the step-by-step approach to the subject will make this book a source of interest to enthusiasts, technicians and teachers as well as the student of electronics.

The pages within represent the collective efforts of a number of people. I would like, therefore, to acknowledge Farnell Electronic Components Ltd., R.S. Components Ltd. and Maplin Electronics PLC for permission to reproduce extracts from their current catalogues. I shall always be most grateful for the kindness, wit and support of my colleagues, particularly Ben Byrne, Mike Lenard and Chas Taylor whose careful proof reading and helpful suggestions have led to many real improvements.

A project such as this involves a certain family commitment. In this respect Ian and Adam deserve my appreciation for their patience and understanding. To Lin, my wife, I offer a special *thank you* for her skilled help, warm encouragement and masterly typing of the manuscript.

John C. Morris
Billericay, Essex. June 1990

Introduction

The chapters are laid out in a sequence that I consider to be 'natural' for a programmed learning approach. However, if required, each topic can be readily studied in isolation.

In an effort to ensure a thorough understanding I recommend that the associated practical investigations for each topic are carried out. These use proven circuits and can be performed using common components with the minimum amount of normal laboratory equipment. For reasons of safety all a.c. circuits are designed to operate at a low voltage supplied via a mains step-down transformer. Under no circumstances must the specified supply voltage be exceeded. The method of circuit construction used is left to the reader, but the use of a *breadboard* is highly recommended for speed and reusability of components.

Please remember that a 'pioneering spirit' should be evident and that the specified components are only recommendations. If you do not have the appropriate semiconductor — use an equivalent or if a particular resistor is not available — use the nearest value you have. When carrying out the investigations work methodically and pay heed to the following points:

1 Check that the circuit is correct before switching on the supply.
2 Check the supply voltage with a meter when setting to a specified value (meters on power supplies are there for guidance only).
3 Make sure you record everything.
4 Plot graphs *as you go*.
5 *Do not* dismantle your circuit immediately you have finished but check through what you have written and what is yet required so that if you have to repeat part of the procedure the anger and frustration will be minimized.

Contents

1

The Decibel and its use

The decibel is a logarithmic ratio between two power levels.

It is usual in the world of electronics to concern ourselves with the gain or attenuation of a circuit, i.e. how much a signal level is increased or decreased as it passes through a circuit or cable. This is often achieved by expressing values of gain or attenuation as ratios, e.g. *in the case of an amplifier* (Fig. 1.1) or *for an attenuating circuit* (Fig. 1.2).

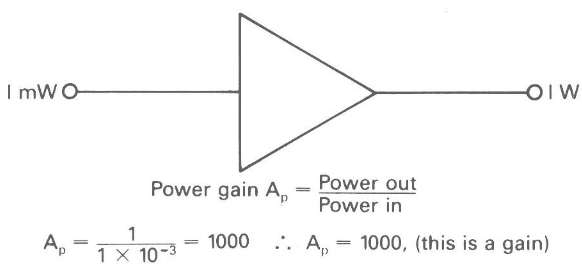


Fig. 1.1 An amplifying circuit

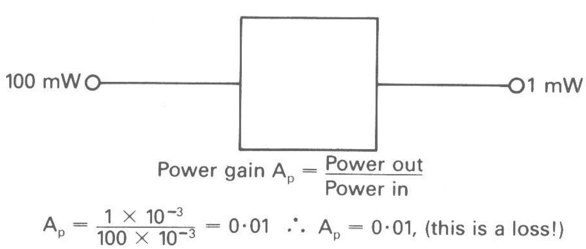


Fig. 1.2 An attenuating circuit

This use of ratios is handy because it tells at a glance exactly what the overall effect of a circuit is; in the case of the amplifier circuit, since it has a power gain of 1000, an input signal emerges 1000 times greater at the output. The attenuating circuit, however, gives an output that is 100 times lower than the input. This concept of a ratio is so informative that there may appear to be little or no reason for using anything other than ratios; but let us consider the practical realities that exist.

Amplifiers can have very large gain values, furthermore they are often connected in cascade (series) to form a complete system. This system

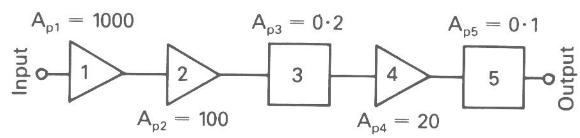


Fig. 1.3 Circuits in cascade

may well include sections that will reduce or attenuate the signal level. We are now in the position of having to calculate the overall effect of a complete circuit. Consider Fig. 1.3 that contains both amplifiers and attenuators. Circuits 1, 2 and 4 are amplifiers, while 3 and 5 are attenuating circuits.

The overall gain

$$(A_p) = A_{p1} \times A_{p2} \times A_{p3} \times A_{p4} \times A_{p5}$$

$$= 1000 \times 100 \times 0.2 \times 20 \times 0.1 = 40\,000$$

The overall result is a power gain $A_p = 40\,000$.

From this some major points emerge:

1 Large and unwieldy values are often involved with circuits having gains of 2×10^9 or losses of 2×10^{-5}.

2 Where circuits are interconnected to form systems, the overall result may involve multiplications of large values, increasing the possibility of error.
3 Often the final result is a number that is so large (or small) that it has little meaning, i.e. we cannot comprehend its *real* value. For example a gain of 40 000 sounds impressive, but what does it really tell us?

To express these numerical ratios in a more practical way, logarithmic ratios can be used. The use of logarithms results in a non-linear or compressed scale. This you may recall if you have ever used logarithmic graph paper in order to fit a large frequency range on a small sheet of paper.

It is also worth noting that many systems respond logarithmically to changes in power levels. The use of logarithmic ratios allows us to linearize this non-linear response. The logarithmic ratio between two power levels is expressed in bels (B), after Alexander Graham Bell.

$$A_p = \mathrm{Log}_{10}\left(\frac{\text{Output power}}{\text{Input power}}\right) \text{ Bels}$$

($\log_{10}$ indicates that logarithms to the base 10 are used).

If $P_{in} = 1\text{ mW}$ and $P_{out} = 1\text{ W}$

$$A_p = \log_{10}\left(\frac{1}{1 \times 10^{-3}}\right) = \mathrm{Log}\ 1000 = 3 \text{ Bels}$$

The bel is a very large unit so for convenience the decibel (abbreviation dB) is commonly used.

1 dB = 0.1 B. (1 dB is one tenth of a Bel!)

This gives the following equation:

$$A_p = 10\ \mathrm{Log}_{10}\left(\frac{P_{out}}{P_{in}}\right) \text{ dB.}$$

Note Once it is understood that logarithms to the base 10 are used the suffix 10 can be omitted.

If we now use the two previous examples, the power gains can be expressed in their dB form.

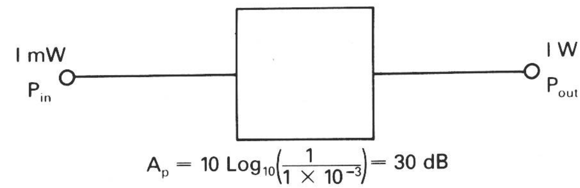


Fig. 1.4 A power gain of 30 dB

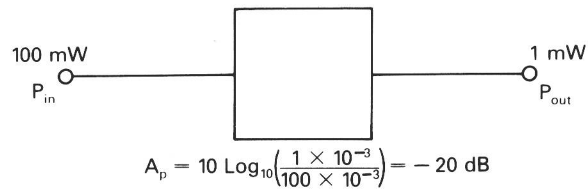


Fig. 1.5 A power gain of −20 dB (a loss in fact!)

THOUGHT

So loss or attenuation is always indicated by a minus sign?

Yes *but* be careful! A gain of −*x* dB is a loss of *x* dB. You cannot have a loss of −*x* dB because this would be a double negative!

The use of dBs to express ratios certainly makes the situation much neater. Should there be any doubts about this, a comparison between the numerical gain and decibel gain values will help to dispel them.

A_p (numerical)	A_p in dB
1	0
10	10
100	20
1000	30
1×10^4	40
1×10^6	60
1×10^{10}	100

Use the equation and check these values for yourself.

Circuits in Cascade

If we consider again our original series circuit this time using gain values in dB (Fig. 1.6).

$$\begin{aligned}\text{Overall gain } (A_p) &= A_{p1} + A_{p2} - A_{p3} + A_{p4} - A_{p5} \\ &= 30\text{ dB} + 20\text{ dB} - 6.98\text{ dB} + 13\text{ dB} - 10\text{ dB} \\ &= 46.02\text{ dB}\end{aligned}$$

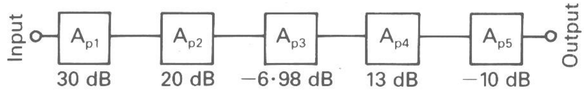


Fig. 1.6 Circuits in cascade

Overall gain (A_p) = 46.02 dB. As a check let's convert this to a numerical gain value and see how it compares with our original result of 40 000: since A_p in dB = 10 Log (numerical gain).

(Note: *A*.log = *Antilog*.)

$$\text{numerical gain} = A.\log\left(\frac{A_p(\text{in dB})}{10}\right)$$

$$= A.\log\left(\frac{46.02}{10}\right)$$

$$= A.\log 4.602$$

$$= 39\,994, \text{ i.e. } 40\,000 - \text{QED!}$$

So where gain values are quoted in dB the overall system gain is simply a matter of adding together all the gains and subtracting the losses.

Change in Signal Level Using Decibels

Another application of the decibel is when a change of signal level needs to be indicated. If a system has an input of 5 mW and an output of 5 mW then clearly neither amplification nor attenuation has taken place. In dB, this is given by:

$$A_p = 10\,\text{Log}\left(\frac{5\text{ mW}}{5\text{ mW}}\right) = 0\text{ dB}$$

So 0 dB indicates no change has occurred!!

Note You must get used to the fact that zero dB does not mean zero gain or zero output, it simply means unity gain.

unity = 1 = No change!

Reference levels

If the input and output powers are known, then a gain or loss in dB can easily be found since the decibel is simply a means of comparing the two power levels; however a reference level is sometimes useful for the following reasons:

1 It gives an indication of the practical realities of a circuit, i.e. it is meaningless to say that an amplifier has a power gain of 60 dB unless some reference power is stated or understood. A power gain of 60 dB represents a numerical gain of 1×10^6 ∴ if the input to such an amplifier was 1 μW the output would be 1 W, fine! But if the input was 1 W the output would be 1 MW — hardly likely! A stated reference level helps to remove any misunderstanding.

2 If the reference level is known, a change in signal level can be readily understood. Once a reference power is used any power level can be considered with respect to this reference level

$$A_p = 10\,\text{Log}\left(\frac{\text{Power level}}{\text{ref. level}}\right)\text{dB}$$

This reference level is indicated by a subscript to the abbreviation for decibel.

dB_m: reference level = 1 mW (1×10^{-3} W)

$$A_p = 10\,\text{Log}\left(\frac{\text{Power}}{1 \times 10^{-3}}\right)\text{dB}_m$$

dB_w: reference level = 1 W.

$$A_p = 10\,\text{Log}\left(\frac{\text{Power}}{1}\right)\text{dB}_w$$

Example 1
Express in dB_m the following power levels:

(a) 1.5 W (b) 1 μW (c) 1 mW

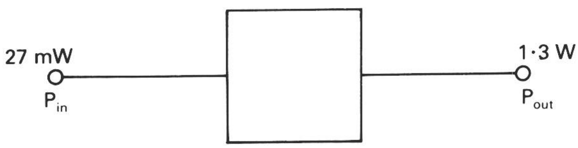
(a) $A_p = 10\log\left(\frac{1.5}{1 \times 10^{-3}}\right)\text{dB}_m$
$= 32\ \text{dB}_m$ (a gain of 32 dB_m)

(b) $A_p = 10\log\left(\frac{1 \times 10^{-6}}{1 \times 10^{-3}}\right)\text{dB}_m$
$= -32\ \text{dB}_m$ (a loss of 32 dB_m)

(c) $A_p = 10\log\left(\frac{1 \times 10^{-3}}{1 \times 10^{-3}}\right)\text{dB}_m$
$= 0\ \text{dB}_m$ (no change)

Self Assessment 1

1 Calculate the power gain in dB_m



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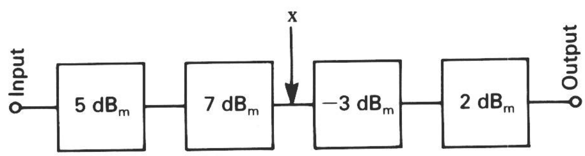

Calculate
(a) The overall system gain in dB_m.
(b) The signal power level at point x.
(c) The system output signal power.

Voltage and Current Ratios Expressed in Decibels

So far power levels only have been considered, often however only input and output voltage and current levels are quoted see Fig. 1.7.

Power (P) can be calculated using:

$$P = I^2R \quad or \quad I \times V \quad or \quad \frac{V^2}{R}$$

from this it is easy to see that for any circuit

$$P_{in} = V_{in} \times I_{in} \quad or \quad {I_{in}}^2 \times R_{in} \quad or \quad \frac{{V_{in}}^2}{R_{in}}$$

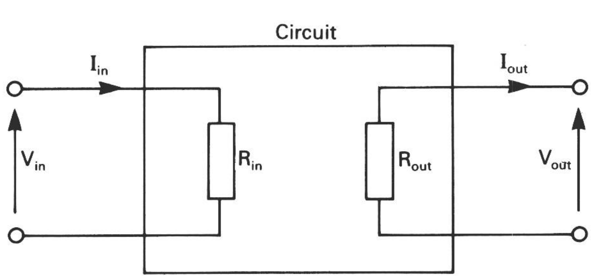

Fig. 1.7 Input and output signals

and

$$P_{out} = V_{out} \times I_{out} \quad \text{or} \quad {I_{out}}^2 \times R_{out} \quad \text{or} \quad \frac{{V_{out}}^2}{R_{out}}$$

Now if the input and output resistances of a circuit are *identical* ($R_{in} = R_{out}$) and if the input and output current or voltage is known, the power ratio can be found using:

$$A_p = 10 \text{ Log}\left(\frac{(V_{out})^2/R_{out}}{(V_{in})^2/R_{in}}\right) \text{dB}$$

since $R_{in} = R_{out}$ they cancel

To give:

$$A_p = 10 \log\left(\frac{V_{out}}{V_{in}}\right)^2 = 20 \text{ Log}\left(\frac{V_{out}}{V_{in}}\right) \text{dB.}$$

THOUGHT

So the power gain $A_p = 20 \text{ Log}\left(\frac{V_{out}}{V_{in}}\right)$ *dB?*

True but *only* if R_{in} and R_{out} are identical.
Likewise it could be shown that

$$A_p = 20 \log\left(\frac{I_{out}}{I_{in}}\right) \text{dB when } R_{in} = R_{out}$$

Note Unfortunately R_{in} and R_{out} are seldom identical in real life.

However, it is quite acceptable to express voltage and current ratios in dB, provided it is made clear that they are *not* power ratios. Then:

Power gain $A_p = 10 \log\left(\frac{P_{out}}{P_{in}}\right)$ dB

Voltage gain $A_v = 20 \log\left(\frac{V_{out}}{V_{in}}\right)$ dB

Current gain $A_i = 20 \log\left(\frac{I_{out}}{I_{in}}\right)$ dB

Unfortunately technical literature often quotes a gain in dB without considering R_{in} and R_{out}, we have to put up with this!

Bandwidth

All circuits, transmission lines and cables have a frequency range over which they will perform satisfactorily, this is defined as the bandwidth (B). You may have been used to this being defined as the frequency range over which the current or voltage gain does not fall below 0.707 of its mid-band value. Where numerical ratios are concerned this is absolutely true. However, once decibels are used to express gain the bandwidth is defined as *the frequency range over which the gain falls by no more than 3 dB from its mid-band value*. If the gain/frequency response curve has been plotted using dBs, the bandwidth can be readily defined. This is shown in Fig. 1.8.

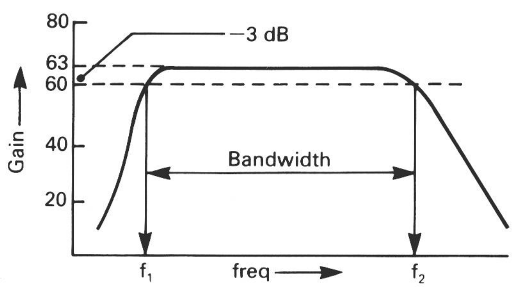

Fig. 1.8 Bandwidth using dBs

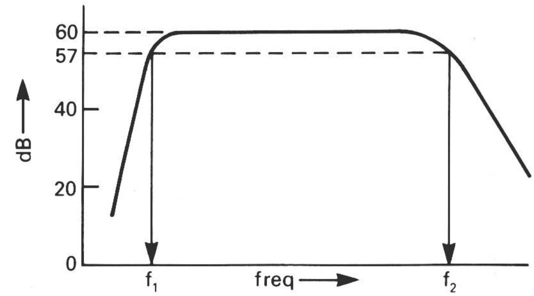

Fig. 1.9 Gain/frequency response

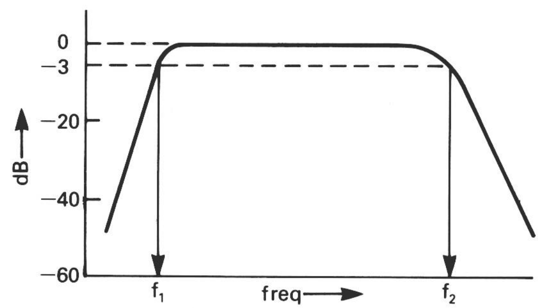

Fig. 1.10 Normalized gain/frequency response

Frequencies f_1 and f_2 are described using a variety of terms, common ones being: the −3 dB frequencies, the −3 dB points, the cut-off frequencies, the break points, the half-power points and the corner frequencies.

Once the frequency response has been plotted it seems reasonable to normalize it so that the mid-band value becomes 0 dB. The bandwidth is then enclosed by its *genuine* −3 dB points. See Figs 1.9 and 1.10.

What do these 3 dB points really mean for power and voltage gain?
Let us consider what a fall in 3 dB means for a power gain.

$$-3\text{ dB} = 10\log\left(\frac{P_{out}}{P_{in}}\right)$$

$$\therefore \text{As a ratio } A_p = \text{A. log}\left(\frac{-3}{10}\right) = 0.5$$

this represents fall in power gain to 50% of its mid-band value, hence the name *half-power* point.

For a voltage or current gain a loss of 3 dB means:

$$-3\text{ dB} = 20\log\left(\frac{V_{out}}{V_{in}}\right)$$

$$\therefore \text{As a ratio } A_v = \text{A. log}\left(\frac{-3}{20}\right) = 0.707.$$

representing a fall in voltage gain to 70.7% of its mid-band value.

Sound Intensity

If a survey was carried out the average person would say that the decibel is a measure of volume or level of sound. This is fundamentally untrue because we know that the dB is not an absolute unit, it is simply a logarithmic ratio between two power levels.

However, a sound can be expressed in decibels if a reference level is used.

A typical reference level is a sound so faint it can just be heard by the human ear (in good condition), i.e. a pin dropping or leaves rustling. This is taken to be an audible power level of 1×10^{-12} W/m^2 and then:

$$\text{Sound intensity} = 10 \log \left(\frac{\text{sound power}}{1 \times 10^{-12}} \right) \text{dB}_A$$

Where: sound power = noise or sound being measured
1×10^{-12} W/m^2 = reference power
dB_A = Intensity in dB. The subscript A indicating that the reference level is acoustic at 1×10^{-12} W/m^2.

THOUGHT

Why W/m² for the reference power level?
This is used because sound intensity decreases as the distance from the source increases and approximately follows the inverse square law, as shown in Fig. 1.11.

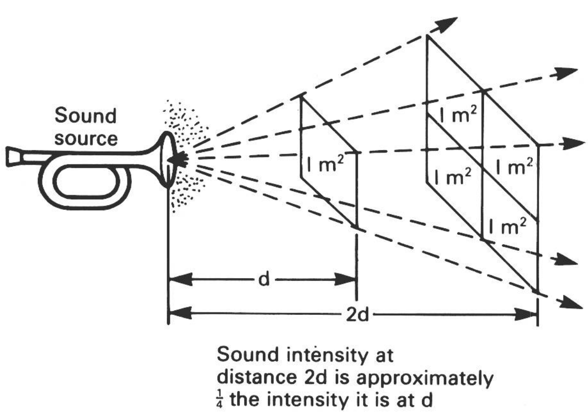

Fig. 1.11 Reduction of sound intensity with distance

We can now quote sound intensity in dB_A with typical values being:

Conversation	60 dB
Noisy factory	85 dB
Car horn at ½	90 dB
Threshold of pain	120 dB – above this level physical pain occurs and ear damage may result.

Note 1 dB is the smallest change in audio power that can be detected by the human ear, i.e. if you set the volume of your audio system to give a particular sound output and then increase the volume until your ears tell you the sound is louder, the output has now increased by 1 dB.

While these values are only approximate they do serve as a guide and indicate clearly the relative intensity levels of the environment in which we live. For audio equipment the dB is widely used, with most frequency response curves drawn to show maximum or mid-band gain as 0 dB. *VU meters* (Volume Units) show the maximum power output into loudspeakers or magnetic tape as 0 dB. Even volume controls have been renamed *gain* controls, having maximum output marked as 0 dB and everything below this as −dB. I suppose this almost universal use of the decibel should lead to a widespread understanding of its meaning, but alas I fear that for the most part it passes unnoticed; you, however, will become very familiar with the dB since it is also used for the measurement of signal-to-noise ratios in Chapter 6.

Decibel Review

1 The Decibel (dB) is not an absolute unit but the logarithmic ratio between two power levels.

2 Power gain $A_p = 10 \text{ Log}_{10} \left(\frac{P_{out}}{P_{in}} \right)$ dB.

(Suffix 10 indicates logarithms to the base 10 are used, its inclusion in the equation is optional)

3 A gain is indicated by positive dB values, a loss by negative dB values.

4 Voltage gain $A_v = 20 \log \left(\frac{V_{out}}{V_{in}} \right)$ dB.

5 Current gain $A_i = 20 \log \left(\frac{I_{out}}{I_{in}} \right)$ dB.

6 The bandwidth of a system is determined by the upper and lower frequencies at which the gain has fallen by 3 dB from its mid-band value.
7 −3 dB represents a fall to 0.707 of the mid-band voltage and current gain.
8 −3 dB represents a fall to 0.5 (half-power) of the mid-band power gain.
9 Reference levels can be used indicating the power that any gain or loss is compared to. The actual reference power level is expressed using a subscript letter:
$dB_m = 1$ mW $dB_w = 1$ watt
$dB_A = 1 \times 10^{-12}$ W.
(remember subscript A = acoustic)
10 For circuits in cascade the overall effect of the system can be found by adding (algebraically) the gains and losses.
11 It is usual to normalize a frequency response curve so that maximum output or mid-band gain is represented by 0 dB.
12 Sound intensity can be quoted in dB using:

$$\text{intensity} = 10 \log \left(\frac{\text{Power}}{1 \times 10^{-12}} \right) dB_A$$

13 1 dB is the smallest change in audio power that can be detected by the human ear.

Self Assessment Answers

Self Assessment 1

1 $$A_p = 10 \log \left(\frac{P_{out}}{P_{in}} \right) \text{dB}$$

$$= 10 \log \left(\frac{1.3}{27 \times 10^{-3}} \right) \text{dB} = 16.8 \text{ dB}$$

(a) Overall system gain $= 5 + 7 - 3 + 2\ dB_m$
$= 11\ dB_m$

(b) The signal power at x $= 12\ dB_m$ gain on input signal
input signal = 1 mW (dB_m implies a reference signal of 1 mW)

numerical value of gain for 12 dB

$$= A \log \left(\frac{12}{10} \right) = 15.85$$

output at x $= 1 \times 10^{-3} \times 15.85 = 15.85$ mW.

(c) Output signal level $= 11\ dB_m$ gain on input signal
input signal = 1 mW

numerical value of 11 dB

$$= A.\log \left(\frac{11}{10} \right) = 12.59$$

output signal $= 1 \times 10^{-3} \times 12.59 = 12.59$ mW.

2

Amplifiers

Amplifiers can really be divided into two types:

1 The small signal amplifier.
2 The power amplifier.

The small signal amplifier is used to increase a very low level voltage or current signal to a level that can be more easily handled. It must do this without introducing much distortion or noise. For this reason very small changes in voltage and current are employed in the amplifying device itself. Hence the name *small signal*. These amplifiers are often called pre-amplifiers because they boost very tiny signals to a level that can be used to drive a power amplifier.

The power amplifier is invariably a 'beast' that takes the output from a pre-amplifier and boosts it to such a level that it can do physical work. Examples of this include driving the cone of a loudspeaker in and out to produce an audible sound output, delivering power to a motor that is part of a control system, or providing radio frequency (rf) power to an aerial so that a signal may be transmitted. When considering such applications it is easy to see that the requirement of a power amplifier may be anything from a couple of watts to many kilowatts. Consequently very large changes in current and voltage occur in the amplifying device, hence the alternative name of *large signal amplifier*.

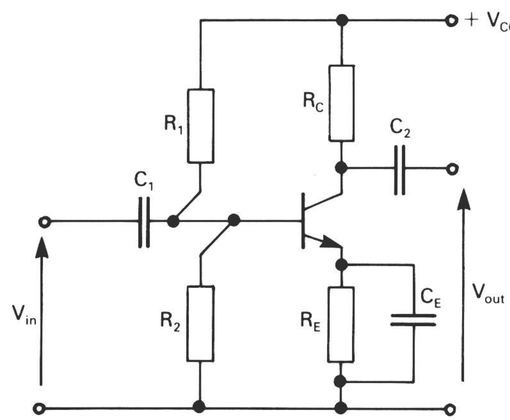

Fig. 2.1 Common emitter amplifier

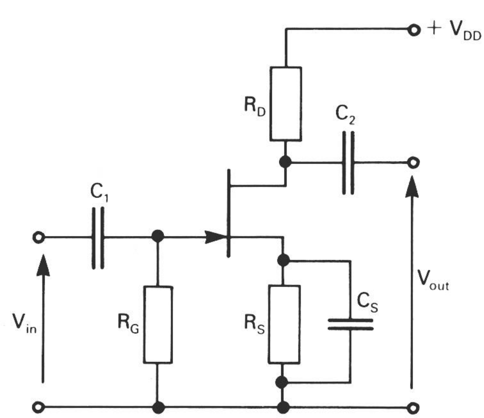

Fig. 2.2 Common source amplifier

Transistor Biasing

From previous encounters you may have had with electronics you will be aware that perhaps the most popular circuits are the common emitter and its FET equivalent the common source amplifier, shown in Figs 2.1 and 2.2.

You may also know that such amplifiers are usually operated in Class A bias. We need now to examine more closely what this term biasing means.

Biasing a transistor means establishing potential differences across its electrodes. These will cause currents to flow in the device. Voltages and currents set up by the biasing establish the d.c. or static conditions, referred to as the *quiescent* or *quiet* state: so called because there is no input signal connected to the amplifier. The transistor itself is at *quiescence,* it is d.c. biased and so has voltages and currents present but is not actually amplifying any input signals. Obviously the size of the d.c. bias voltages will determine the quiescent current flowing in the device. To help determine the actual bias points required under quiescent conditions a load line is drawn on the output characteristics as shown in Figs 2.3 and 2.4.

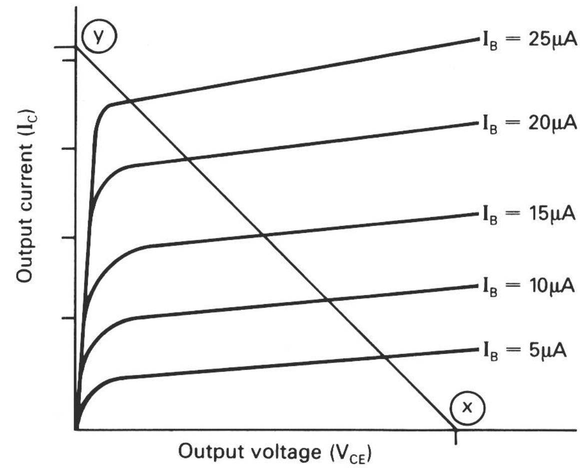

Fig. 2.3 Common emitter load line

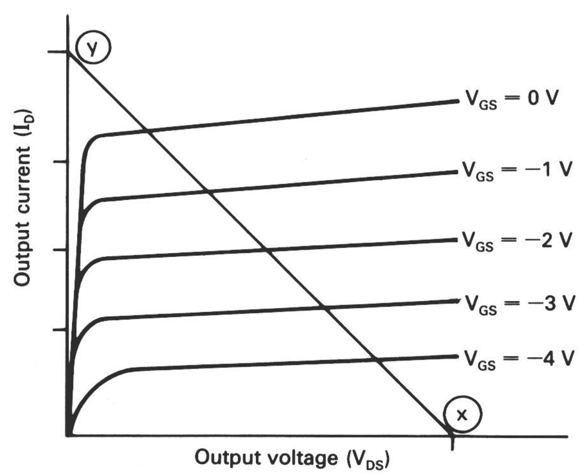

Fig. 2.4 Common source load line

From this it appears that the transistor could be biased at *cut-off* (point x) or *saturation* (point y) or anywhere in between these two points.

Once the bias point has been fixed it becomes known as the *quiescent* or Q point. If an input signal is now applied it will drive the Q point up and down the load line as it swings positive and negative, this in turn will produce changes in the output current and voltage. The position chosen for the Q point on the load line is critical for the following reasons:

1 It will determine the maximum possible change in output current and voltage, i.e. if the Q point is fixed near the top of the line any input signal will not be able to drive the point very far up the line before the transistor saturates. Likewise, a bias point near the bottom will mean that when the input signal swings negative the Q point will not have far to move before the transistor is *cut off.*
2 The Q point determines the quiescent current that flows in the device. Consequently, if the transistor is biased near the top of the line, the d.c. current flowing in the device will be high and this means that power is being consumed even though there is no input signal to the amplifier. Conversely a Q point near the bottom of the line will ensure that a low d.c. current will flow under quiescent conditions.

It is the d.c. biasing that determines the Q point, the Q point that determines the *class* of amplifier and the amount of distortion produced.

Class A Biasing

From a study of the output characteristics of Figs 2.3 and 2.4 the best place to bias the device appears to be so that the Q point is in the middle of the line. This is Class A biasing and offers the advantage that maximum changes in output current and voltage are possible because the Q point can move an equal amount up and down the line as indicated in Fig. 2.5(a). Let us consider the voltage and current changes that occur when an input signal is applied. Study Figs 2.3, 2.4 and 2.5(a) in conjunction with the tables below.

Table 1.1 Common emitter amplifier (using an n-p-n transistor)

Input Signal Swings positive	Input Signal Swings negative
I_B increases I_C increases V_{CE} decreases	I_B decreases I_C decreases V_{CE} increases

Table 1.2 Common source amplifier (using an n channel transistor)

Input Signal Swings positive	Input Signal Swings negative
V_{GS} becomes less negative I_D increases V_{DS} decreases	V_{GS} becomes more negative I_D decreases V_{DS} increases

A further advantage of Class A bias is that the transistor will be operating over the most linear region of its characteristic. This cannot be seen from the output characteristic but is quite obvious from the input characteristic for a BJT (Fig. 2.5(b)) and the transfer characteristics of an FET (Fig. 2.5(c)).

It would appear that Class A bias is the only sensible one from all standpoints. There are, however, other considerations:

(a) Supposing the signal to be amplified was one polarity only, i.e. a negative or positive pulse — Class A bias would not then allow the maximum input signal to be applied since the device is already half turned on (or off according to your point of view).

(b) Bias current is flowing in the transistor even when there is *no* input signal!! Consider Fig. 2.5(a) without an input signal applied. The quiescent current flowing is 5 mA; this means that the Class A amplifier is consuming power doing nothing — hardly efficient!

When considering an input signal, a device is said to be biased in Class A when output current

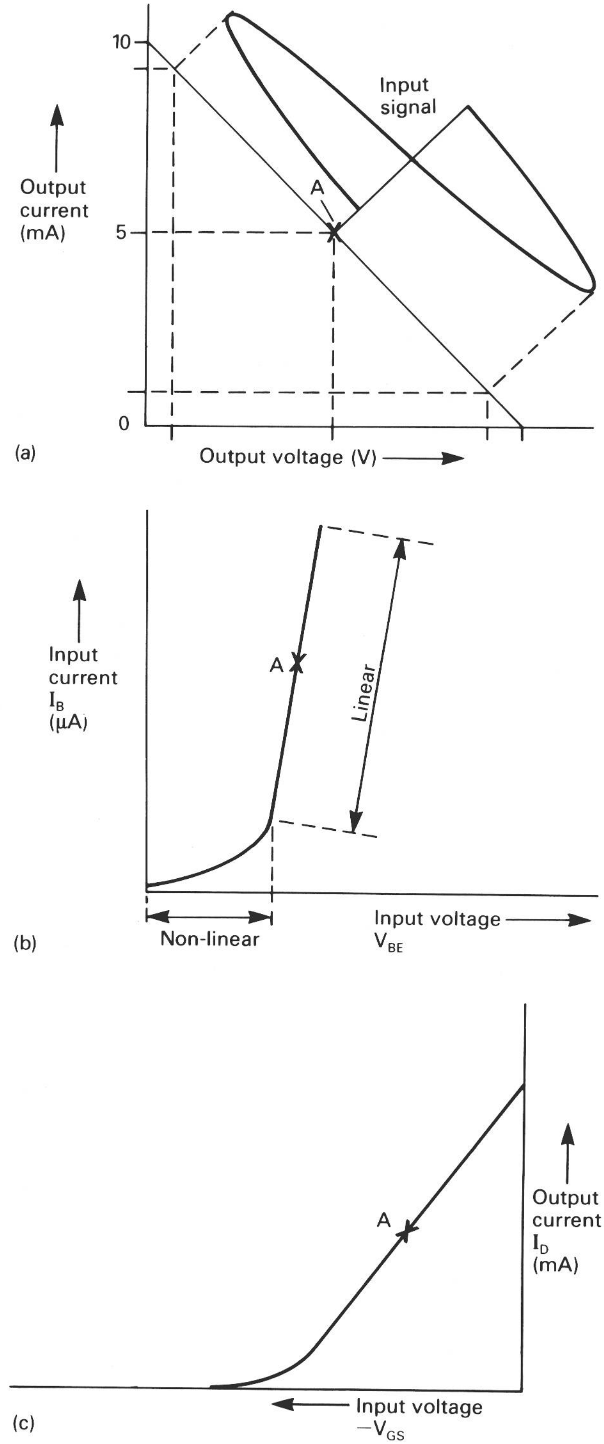

Fig. 2.5 (a) Class A bias; (b) BJT input characteristic; (c) FET transfer characteristic