IC LM3900 Projects

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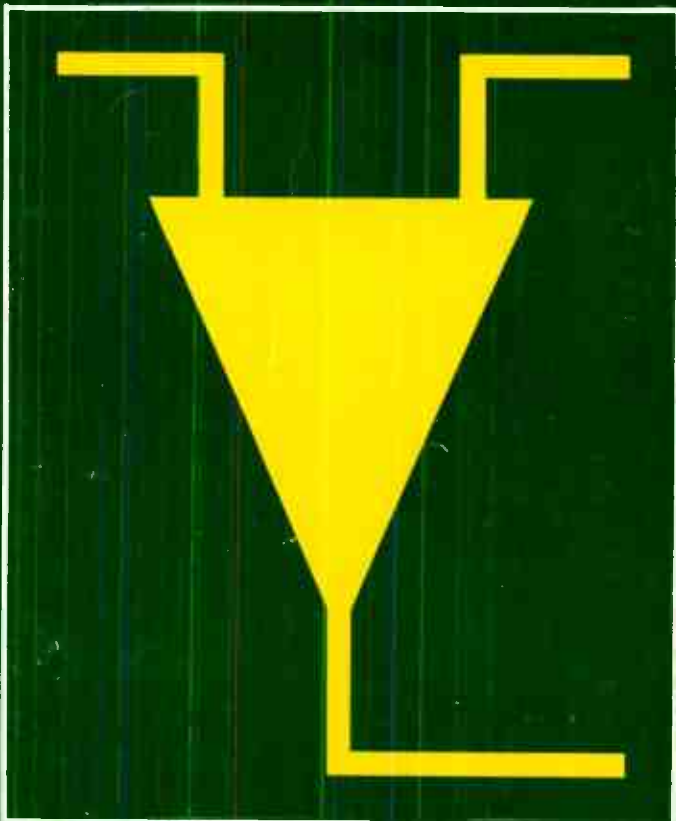

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INTRODUCTION TO BOOK

The purpose of this book is to introduce the LM 3900 to the technician, experimenter and the hobbyist. It provides the groundwork for both simple and advanced uses, and is more than just a collection of simple circuits or projects.

The LM3900 is different from the conventional Op-amp, but it can be used for many of the same applications as well as many new ones.

Simple basic working circuits are used to introduce this IC, and the reader should set up each of these for himself. It is essential the reader gain familiarity with these simple circuits if he wishes to fully understand this device, as these are the basis of many more complicated circuits and advanced uses.

The LM3900 can do much more than is shown here. This is just an introduction. Imagination is the only limit with this useful and versatile device. But first the reader must know its basics. That is what this book is about.

SECTION 1: INTRODUCTION TO THE LM 3900

The circuits in this section serve to introduce the LM 3900 as a circuit element. It is first compared with the conventional Op-amp so that its similarities and differences can be noted, and then several basic uses are shown. These lay the foundations needed to build the ideas in the following sections.

This section contains a few simple experiments which will help to introduce the device to the new user and give a good idea of its basic behaviour. It is strongly recommended the reader set these up and work through them.

The Basic IC Op-Amp

The common IC Op-Amp is a very high gain amplifier which finds widespread use in all areas of electronics, with applications in both linear and digital circuits. Several different types are available, but all have certain common characteristics. Briefly these can be listed as:–

An inverting input
A non-inverting input
A high impedance at both inputs
A low output impedance
DC output voltage of Ov
High open loop gain
Wide frequency response
Use of both an equal positive and negative power supply.

The basic circuit configuration for the op-amp is shown in Fig 1.1, but this can be modified slightly to fit specific applications. In most cases the internal construction of the device includes a differential amplifier as the input stage, and this provides the high gain and both the inverting and non inverting inputs.

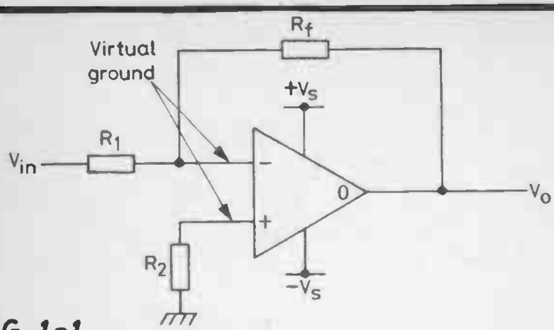


FIG. 1-1

In operation both inputs are a 'virtual ground' and ideally no input current flows in the quiescent condition, thus preserving the very high input impedance to the device. In contrast, the input impedance of the overall circuit, as seen by the generator supplying the input signal, is much lower, being given by the value of R_1.

The overall closed loop gain is given by the formula:–

$$A_v = \frac{R_f}{R_1}$$

Biasing the op-amp is the process of setting the DC output voltage level to Ov, which is half way between the + and – power supply voltages. This is the function of R_2, which is chosen to be equal to the parallel equivalent of R_1 and R_f.

i.e. $$\frac{1}{R_2} = \frac{1}{R_1} + \frac{1}{R_f}$$

Note that R_2 is connected to ground or Ov, and not to either power supply.

The op-amp has a few disadvantages, such as input and output offset voltages, temperature drift, it often requires frequency compensation, etc. but these can be fairly easily overcome in practice. Many other fine texts explain these techniques and cover op-amps in more detail than here.

There is however, one disadvantage which cannot be easily overcome. Two power supplies must be used, they must have equal positive and negative values with very little difference between them, they must be well regulated, and the range of supply values is limited.

The Different Op-Amp.

An Introduction to the LM 3900

The LM 3900 is a different type of Op-Amp. It has all the characteristics, advantages and disadvantages of the conventional type, plus a few of its own.

A radically different internal circuit design is used, and this has led to some important differences in the external circuit arrangements.

The result is an op-amp which can be used in a variety of simple and complex circuit and with a range of uses as wide as the conventional op-amp, but not directly interchangeable with it.

The LM 3900 retains several characteristics of the conventional op-amp. Included in these are:–

An inverting input
A non inverting input
A single output
A very high open loop gain
A controllable closed loop gain

But it also exhibits some very important differences:–

Only one supply voltage is needed.
A wide range of supply voltages can be used.
The DC output level is not Ov but half the supply voltage (in most applications)
The input stage is not a differential amplifier
The output impedance is higher than the conventional op-amp

Because the LM 3900 can be used with only one power supply, which can be anything between 4v and 36v, the LM 3900 will fit into a wide variety of existing circuits and systems. It can also be used with conventional op-amps as it will work with + and – or dual 15v power supplies. An interesting corollary is that the power supply for the LM 3900 need not be an exact value, but it should be well filtered.

Its normal DC output voltage is half the power supply voltage, and it is very easy to bias it to this. The DC and AC output voltage can swing from about 100 mv above ground and go as high as 1v less than the supply. (Compare this to the poorer voltage swing of the conventional op-amp with one power supply.). Any power supply ripple appears at the output halved in value.

The reason for this wide power supply range is the unusual circuit of the device. The input is not a differential amplifier, as found in the conventional op-amp, but a 'current mirror' amp which is shown simplified in Fig 1.2. Because of this peculiar input circuit the device is often referred to as a 'Norton' or 'Current Differencing' amplifier. A DC input current flows into each input under normal operating conditions, and the output voltage level is a function of their difference.

The accepted circuit symbol is shown in Fig 1.3. but in many circuit drawings it is usually simplified to a standard symbol, as in Fig. 1.3. but in this case it should always be labelled as an LM 3900 to prevent confusion.

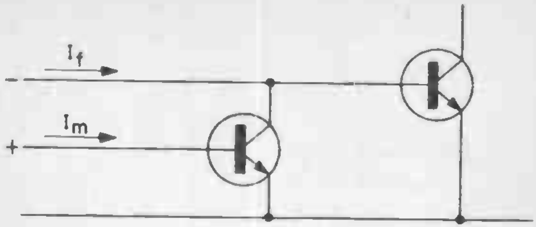


FIG. 1-2

The details of using the LM 3900 are given in the sect paragraphs, and many practical circuits are shown throughout this book. In most cases a 9 v power supply is used, but any other value between 4v and 36v can be chosen. The reason for using 9v is that it allows the reader to assemble the circuits using a standard 9v transistor radio battery.

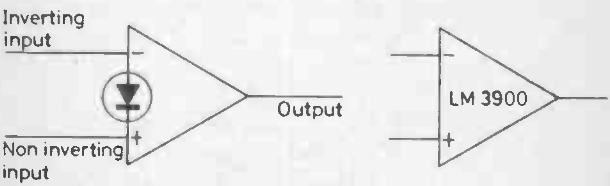


FIG. 1-3

Using the LM 3900

The LM 3900 is very easy to use as an AC amplifier and this is the best introduction to it as an electronic component. Its use as a DC amplifier requires a little more care, as does its use in digital circuits.

In normal use as an amplifier the output DC level is biased to be half the supply voltage. Two resistors are used for this, as in Fig. 1.4.

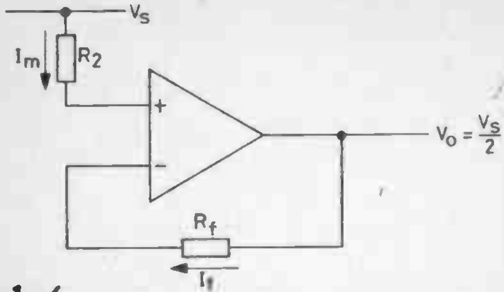


FIG. 1-4

Two DC currents flow. Feedback current – I_f – flows into the – ve input; and 'mirror current' – I_m – flows into the +ve input. When these are equal the DC output will be half the supply voltage. The choice of the resistors to achieve this is covered in the next paragraph.

Fig. 1.2. shows a simplified input circuit. From this it is easy to see that the DC voltage level at each input is always about 0.5v – or 'one V_{be}' – above ground.

The input impedance to the **LM 3900** is thus quite low, and varies between 1k and 10k, depending upon the input currents; but the input impedance to the actual circuit is set by external resistors which are usually much higher than this.

One important point is that the LM 3900 is not a low noise device, and its noise performance is further degraded by the input resistors.

It has a very high open loop gain, and the closed loop gain is controlled by external resistors, as explained in a later paragraph.

Biasing the LM 3900

Most linear applications of the LM 3900 require the output DC level to be half the supply voltage. This allows maximum output signal swing in both directions before clipping and distortion occur.

This condition is obtained by the common electronic process known as 'biasing'. Biasing the LM 3900 is very easy.

Fig. 1.4 shows a circuit which will bias the output DC level to half the power supply voltage for any value of power supply used.

All that is needed is to set R_2 to be twice the value of R_f.

i.e. $R_2 = 2 \times R_f$

When biasing the LM 3900, there is only one restriction to observe, and that is the mirror current should be between 5 μa and 100 μa.

i.e. $5\ \mu a \leqslant I_m \leqslant 100\ \mu a$

Some applications notes state that I_m can go up to 200 μa with out harm.

In practice 50 μa is a good working figure and is often quoted as an optimum value or a 'design centre'.

This restriction on I_m leads to a very easy biasing procedure:—

1. Choose R_2 so that the input current I_m is within the range given above. Ideally choose $I_m = 50\ \mu a$.

2. Choose R_f to be half R_2.

i.e. $R_2 = 2 \times R_f$

Connecting the two resistors found by this procedure will set the DC output of the LM 3900 to half way between ground and the supply voltage. If the supply voltage is changed, these two resistors will still work, but I_m will change.

This procedure is justified in the appendix.

An absolute maximum for I_m is quoted in the spec sheet as 5ma or 6ma. However, it is not recommended that high currents like this should be used continuously. In some digital applications, where the output is often not at half the supply level, then short duration pulsed I_m values can approach these maximum values.

Calculation of the Bias Resistors

The mirror current is very easy to calculate.

$$I_m = \frac{V_s - 0.5}{R_2}$$

If V_s is 9v or more, then the input V_{be} of 0.5v can be ignored, and this simpler formula can be used.

$$I_m = \frac{V_s}{R_2}$$

The value of the mirror current is now chosen by the designer, and in practice 50 μa is a good starting value.

The supply voltage is either chosen by the designer or imposed by existing conditions, such as the availability of power supplies, or the power source in a circuit to which the LM 3900 will be added.

So R_2 is simply calculated from:–

$$R_2 = \frac{V_s}{I_m}$$

A few simple examples will illustrate this procedure. Later the reader is advised to set these up in an experiment and check the values for output voltage.

Ex.1. Using a 9v supply, bias the output to 4.5v. Assume $I_m = 50\ \mu a$.

$$R_2 = \frac{V_s}{I_m} = \frac{9v}{50\ \mu a} = 180K$$

so $R_f = ½ \times R_2 = ½ \times 180 = 90K$

Ex.2. Repeat Ex. 1, but use $I_m = 5\ \mu a$.

$$R_2 = \frac{9v}{5\ \mu a} = 1.8\ M$$

so $R_f = ½ \times 1.8\ M = 900K$

Ex.3. Repeat Ex.1, but use $I_m = 100\ \mu a$

$$R_2 = \frac{9v}{100\ \mu a} = 90K$$

so $R_f = ½ \times 90K = 45K$

Ex.4. Repeat Ex. 1 with $I_m = 200\ \mu a$

$$R_2 = \frac{9v}{200\ \mu a} = 45K$$

so $R_f = ½ \times 47K = 22.5K$

These examples demonstrate the extremes of resistor values which can be used with a 9v supply.

$45K < R_2 < 1.8M$
$22.5K < R_f < 910K$

This wide range is very useful, as it allows considerable latutude in the choice of both gain and input impedance. This is explained more fully later.

To gain further experience in biasing the LM 3900 the reader should work these examples, which use different power supply values.

Ex.5. Use a 15v supply, and bias the output to be 7.5v.

Use $I_m = 5\ \mu a$.

$$R_2 = \frac{15v}{5\ \mu a} = 3\ M$$

$$R_f = 1.5\ M$$

Ex.6. Repeat Ex. 5., using $I_m = 100\ \mu a$.

$$R_2 = \frac{15v}{100\ \mu a} = 150\ K$$

$$R_f = 75\ K$$

Ex. 7. With an 18v supply and $I_m = 50\ \mu a$, bias the output to 9v.

$$R_2 = \frac{18v}{50\ \mu a} = 360\ K$$

$$R_f = 180\ K$$

Compare these values with those in Ex. 1. These are twice the value of Ex.1. That is because the supply voltage here is twice that used in Ex.1.

Before leaving these examples, it should be pointed out that any intermediate value. of I_m can be chosen by the circuit designer. The calculations are just the same as shown here. One example will suffice.

Ex.8. With a 15v supply, bias the output to 7.5v using I_m = 20 μa.

$$R_2 = \frac{15v}{20\ \mu a} = 750\ K$$

$$R_f = 375\ K$$

Other values of output DC level can be chosen, but that is covered later.

Biasing Experiments

The reader should set up these experiments and make careful measurements of the DC output voltage.

Expt. 1.

Set up this circuit in Fig. 1.5.
Perform these steps

1. Let Point A float – do not connect it to anything.
2. Measure the output DC voltage.
   It should be approximately 4.5v
   Slight variations from this will be due to component tolerances.
3. Connect Point A to Ov.
   Observe the DC output will go to about 8.5v
4. Connect Point A to the 9v supply.
   Observe the output will go to about 0.5v – 'one V_{be}– above ground.

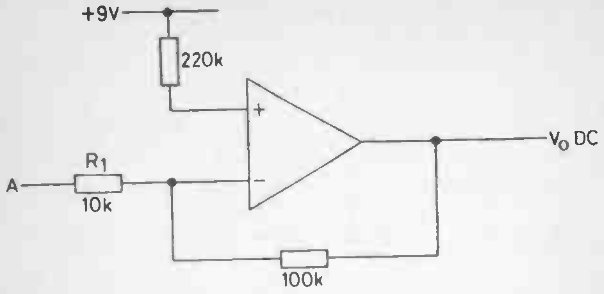


FIG. 1-5

Expt. 2.

Modify the circuit to that in Fig. 1.6.
i.e. change R_1 to the other input.
Perform these steps:–

1. Let Point B float – do not connect it to anything.
2. Measure the output DC voltage. It should be approx 4.5v
3. Connect Point B to Ov.
   Observe the DC output will go to about 0.5v
4. Connect Point B to the 9v supply.
   Observe the DC output will go to about 8.5v.

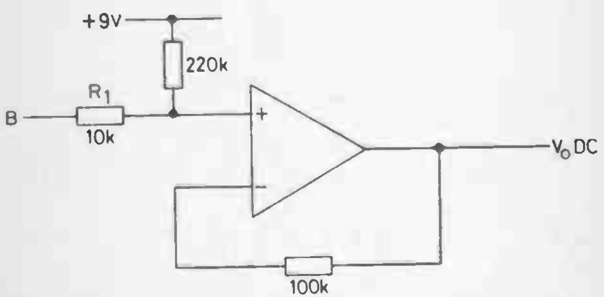


FIG. 1-6

These two experiments demonstrate an important point: Connecting either A or B to either the supply voltage or ground introduces extra currents into the input circuits, and these upset the bias conditions. This is why the output DC level goes to near ground or the supply voltage level.

Input signals are connected to points A and B in the next sections, but a capacitor is used to prevent upsetting the biasing.

Expt. 3.

Connect the resistor values and supply voltages used in the worked examples to the LM 3900.
In each case measure the DC output voltage.

In most cases the actual calculated resistor value will not be available, so the nearest standard value must be used. These slight variations from the ideal values will cause slight offsets in the DC output level. These should be observed and noted. Two general rules will be observed:–

1. If R_2 is increased relative to R_f, then V_o decreases.

2. If R_2 is decreased relative to R_f, then V_o increases.

Expt. 4.

Set up the simple circuit shown in Fig. 1.7.
Measure the DC output level.
It will be about 0.5v – or 'one V_{be}' – above ground.

The important point here is that the output voltage is not 'hard clamped' to this level, and it is capable of following minor AC input swings.

An AC output of less than 0.5v p-p will be quite undistorted, and can be coupled to the next stage and used.

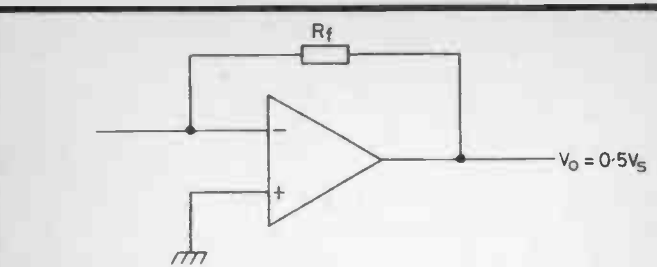


FIG. 1-7

This simple biasing technique is used in several later circuits where the AC output swing is very small.

This is presented in the manufacturers literature as an alternative biasing circuit.

Physical Layout

The LM 3900 is delivered as four IC Op-amps in one 14 pin 'dual-in-line' package (DIP). A top view of the pins and their functions is shown in Fig. 1.8. Each amplifier can be used independently in different external circuits with no interaction between them.

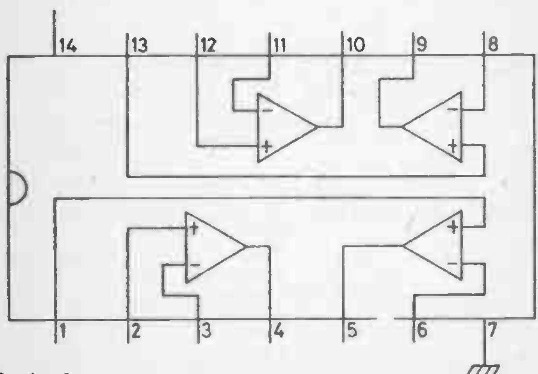


FIG. 1-8

Fig. 1.9 also shows a useful layout for a PC board or experimental pegobard. This layout is quite suitable for circuit evaluations, experiments and final designs. It allows the maximum space for the input and output capacitors and keeps the input and output connections away from each other. It also has free space for modifying the feedback circuit, which is important in many applications where the external components are needed to set the frequency response characteristics. Other layouts are possible of course, should the reader wish to use one.

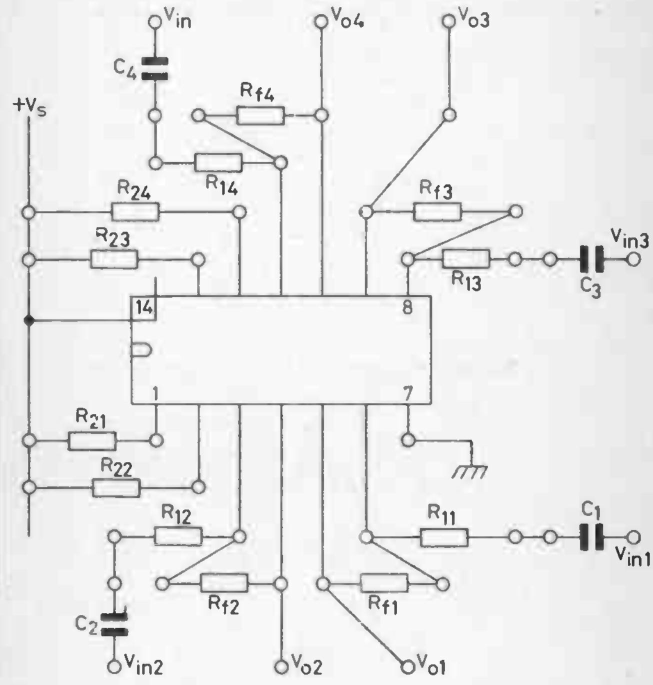


FIG. 1-9

The LM 3900 Amplifier

The AC Amplifier

The LM 3900 can be used as an inverting, non-inverting, and differential amplifier. All three forms use the basic circuit shown in the last sections, and an AC signal is introduced via an input capacitor and resistor R_1.

The amplifier is first biased so that the output DC level is half the supply voltage, and then R_1 and the capacitor are added. See Fig. 1.10.

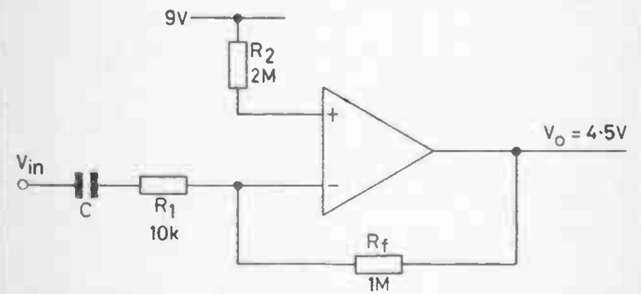


FIG. 1-10

By definition an amplifier has 'gain'.

The LM 3900 has a large 'open loop' gain, and its 'closed loop' gain is controlled by the ratio of the input resistor to the feedback resistor.

i.e. $$A_v = \frac{R_f}{R_1}$$

As R_f has already been chosen in the biasing procedure R_1 is now chosen to set the desired gain.

R_1 also determines the input impedance – Z_{in} – to the circuit.

In this circuit, the gain is 100, and the input impedance is 10k.

The Inverting Amplifier

To use the LM 3900 as an inverting AC amplifier, the input signal is applied to the inverting input, as shown in Fig. 1.10.

The output will be inverted when compared to the input.

The amplifier should first be biased, so that R_2 and R_f will be known, and then R_1 chosen to set the desired gain. R_1 will also set the input impedance.

A few simple examples will demonstrate this whole procedure. In these examples this circuit is used, a 9v supply is used in each case, and the resistors R_2 and R_f have already been set to give a DC output of 4.5v.

In each case the required gain is given.

Find R_1 and the AC output voltage with a 10 mv p-p input.

Ex. 1.	Av	=	10	Ans.	R_1	=	10K
	V_o	=	100 mv.				
Ex. 2.	A_v	=	20	Ans.	R_1	=	5K
	V_o	=	200 mv.				
Ex. 3.	A_v	=	50	Ans.	R_1	=	2K
	V_o	=	500 mv.				
Ex.4.	A_v	=	100	Ans.	R_1	=	1K
	V_o	=	1 v				
Ex.5.	A_v	=	200	Ans.	R_1	=	500 ohms
	V_o	=	2 v				

Check each of these in an experiment. Use a 1Khz input frequency. Check the output is inverted from the input.

Check also that $A_v = \frac{V_f}{V_{in}} = \frac{R_f}{R_1}$

Note that the widest variation will be found in the last two examples. This is because of the higher gain and the low input impedance.

In these next examples the same circuit configuration is used, but different values of R_2 and R_f and A_v are used in each case. In each example find R_1 and the AC p-p output voltage for a 10 mv p-p input. Also check that I_m falls within the specified range.

				Ans.	
Ex.	R_2	R_f	A_v	R_1	I_m
1.	3M	1.5M	100	15K	3μa
2.	150K	75K	10	7.5K	60μa
3.	750K	390K	10	39K	12μa
4.	470K	220K	20	11K	20μa

Verify these experimentally.

The Non Inverting Amplifier

The LM 3900 can be used as a non inverting amplifier by applying the input signal to the + ve input. Fig. 1.11. shows this, and again AC coupling is used.

All the resistors values are chosen exactly as for the inverting case, and all the previous experiments should be repeated with the non inverting input used.

Note: In the more exact parts of the manufacturers literature the gain for the non inverting case is quoted as being slightly different from the inverting case. A more accurate formula is given.

$$A_v = \frac{R_f}{R_1 + r_i}$$

where r_i = the input impedance to the + ve terminal.

and $r_i = 26/I_m$

But the next line states that 20% variation must be expected, and as this can be found in the external components, the same simple formula should be used for both inverting and non inverting amplifiers.

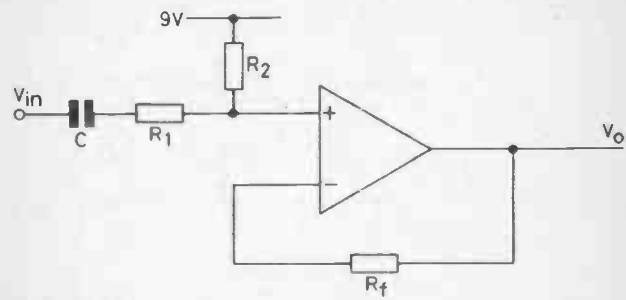


FIG. 1-11

The Voltage Follower

This is a special case of the non inverting amplifier. It has a gain of 1 and the output is in phase with the input. Thus the output is an exact copy of the input, or it follows the input; hence the term 'voltage follower'.

The circuit is shown in Fig. 1.12.

The resistors values can be anything consistent with I_m restrictions and desired Z_{in}.

The circuit shown here should be set up and examined.

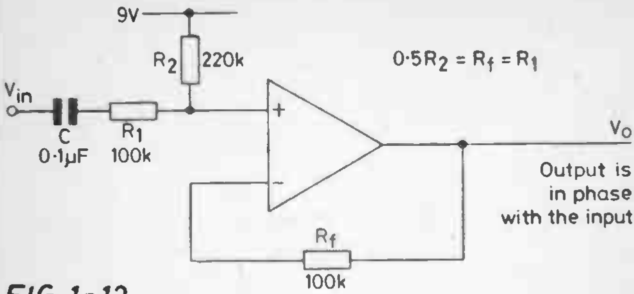


FIG. 1-12

The X1 Inverting Amplifier.

By feeding the input signal to the inverting input, an out of phase output can be obtained with no amplification.

See up the circuit in Fig. 1.13 and check this.

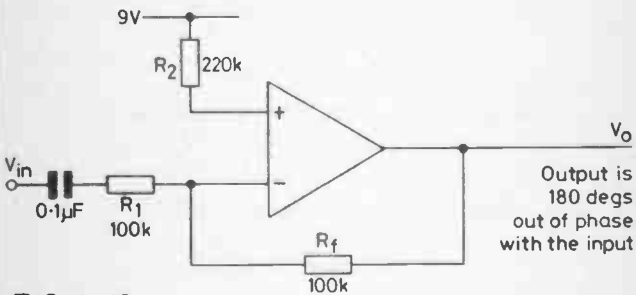


FIG. 1-13

The Active Attenuator

By making R_1 larger than R_f the output will be an attenuated version of the input. Both inverted and non inverted forms can be used. Fig. 1.14 shows both.

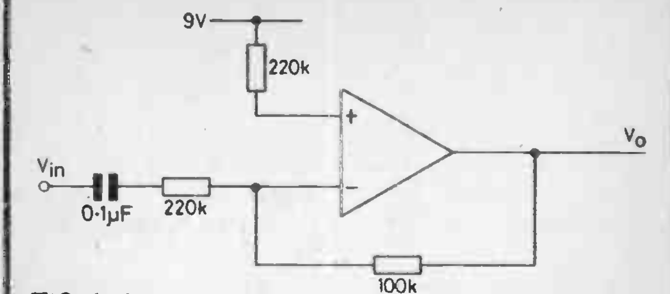


FIG. 1-14

The Differential Amplifier

Although the LM 3900 is not a conventional op-amp and does not have standard differential amplifier input, it can be used in a differential mode.

A circuit for this is given in Fig. 1.15. To get a good CMRR a input impedance is required, which makes a high gain difficult. The circuit given here has a gain of 1, and a following amplifier is required to get more gain.

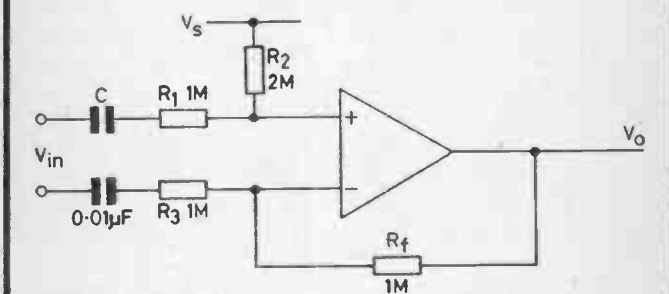


FIG. 1-15

The DC Amplifier

Using the LM 3900 as a DC amplifier is a little more difficult than use as an AC amplifier.

The reason for this is a DC signal source will supply a DC input current which will affect the biasing. This can be avoided to some extent by having a signal source with as low an impedance as possible and with a very low input swing.

The easiest DC use of the LM 3900 is as a DC voltage follower. This requires a slightly simpler circuit than before, as in Fig.1.16. It has a gain of 1, and the biasing current is actually supplied by the DC signal source.

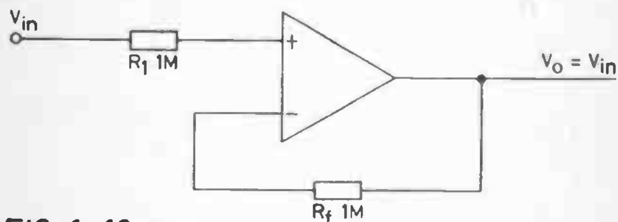


FIG. 1-16

The only condition to be observed is that the input voltage must overcome the input V_{be}.

i.e. $V_{in} > 0.5v$ DC

DC circuits are covered more fully later.

The Input Impedance

The input impedance to the actual LM 3900 amplifier depends very much on the value of the mirror current. Fig. 1.17. gives an idea of the range of values to be expected.

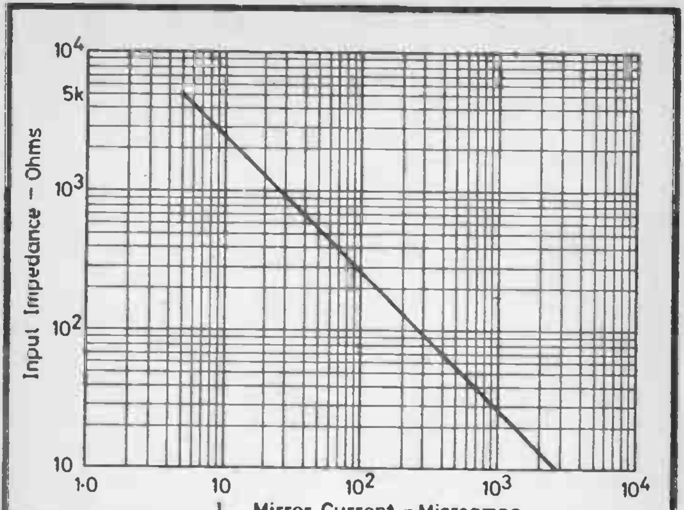


FIG. 1-17

However, the input resistance to the overall circuit is also determined by R_1.R_1 is determined by the gain required and is calculated from the value of R_f, which in turn was calculated from R_2 and the chosen mirror current.

In practice it turns out that the input impedance to the LM 3900 is usually about 20% or less than R_1, and R_1 dominates the input to the circuit. So R_1 is taken as the input impedance.

It is difficult to get both a high input impedance and a high gain, but techniques for this are beyond the scope of this book.

The Input Capacitor

The choice of C_1 is quite easy. Its value is calculated from the formula:–

$$X_c = \frac{1}{2 \pi f C}$$

The procedure is to choose the reactance value to be equal to R_1 at the lowest frequency of interest, and calculate the capacitor value from this. In fact, it is no different than any other amplifier situation.

More About the LM 3900

The most important of the specifications are given in this table.

Power Supply Range	4v to 36v
Open loop Gain	70 db
Unity Gain Frequency	2.5 Mhz
Input Impedance to AC	1 Meg
Output Impedance to AC	8K
Maximum Output Voltage	$V_s - 1v$
Minimum Output Voltage	100 mv approx
Input Bias current	50 μa nominal
Slew Rate	0.5v/usec

A most useful parameter, not in the above table, is the DC output current. When the output voltage is high, then the LM 3900 will source or supply about 10 ma maximum. When the output voltage is low, then it will sink about 30 ma maximum under normal operating conditions. But if the negative input is overdriven it will sink a maximum of 80 ma.

The restirctions on the range of I_m places upper and lower limits on the values of R_2. This in turn places limits on the values of R_f.

If R_1 is now chosen to set the required gain, then the resulting input impedance to the circuit must be accepted.

If R_1 is chosen instead to give a required input impedance, then the resulting gain must be accepted.

If either the Gain or input impedance are outside the bounds of acceptability, then R_f and R_2 must be rechosen. But they must still obey the I_m restrictions.

The practical problem which arises from this conflict is that it is very difficult to obtain a high input impedance and a high gain simulataneously.

A few examples will make this clear.

Ex.1.
Consider a standard inverting amplifier circuit.

$V_s = 9v.$ Choose $R_2 = 200K$

$$\text{Then } I_m = \frac{9v}{200\ K} = 45\ \mu a,$$ which is acceptable.

then $R_f = 100\ K$

Now, suppose a gain of 100 is required. Then $R_1 = 1k$.
So the input impedance is 1k.

However, suppose an input impedance of 5k is required. Then $R_1 = 5k$, and the gain will be 20.

Ex.2.
Again an amplifier with 15v power supply, and $R_2 = 270\ K$.

Then $I_m = 53\ \mu a.$ and $R_f = 130\ K$

If a gain of 50 is required, the $R_1 = 2.4\ K$

But if the input impedance is to be 5K, then $R_1 = 5K$ and a gain of 26 approx must be accepted.

If a definite input impedance and a definite gain are required, then a different approach is required.

In this case, R_1 and R_f are now determined; and R_2 must be calculated. Although this is easy, it is not always possible to maintain the I_m range with a given power supply.

Some examples will explain this.

Ex.1.
An input impedance of 10K and a gain of 10 are needed.

so R_1 = 10K and R_f = 100K
thus R_2 = 200K.

Now the problem is to keep I_m within its limits.

For $I_m = 5\ \mu a$ V_s = $5\ \mu a \times 200K$
= 1 v

For $I_m = 100\ \mu a$ V_s = $100\ \mu a \times 200K$
= 20 v

So provided the power supply is between 1v and 20v the I_m values will be acceptable and this circuit can be used.

Can this circuit be used in a 28v system.

$$I_m = \frac{28v}{200K} = 140\ \mu a$$

This exceeds the I_m limit, and so 28v should not be used.

Ex.2.
An impedance of 1K and a gain of 50 are required. Can this be achieved in a 15v system.

R_1 = 1K

R_f = 50K

R_2 = 100K

$$I_m = \frac{15v}{100K} = 150\ \mu a$$

So a lower supply voltage is needed.

What would be a good supply voltage.

For $I_m = 100\ \mu a$ $\quad V_s = 100\ \mu a \times 100K$

$= 10v$

So 10v is the maximum supply voltage which can be used.

If a 10v supply in unavailable and the original 15v supply must be used, the two other alternative choices remain:—

i. Keep the same Z_{in} but raise the gain.

ii. Keep the same gain but settle for a larger Z_{in}.

Ex.3.
An LM 3900 is to be used in a TTL system to condition an input signal. Z_{in} is to be 1K, and A_v to be 50. Can this be achieved.

$$R_1 = 1K \quad R_f = 50K \quad R_2 = 100K \quad I_m = \frac{5v}{100K} = 50\ \mu a$$

It is almost a perfect set-up.

Summary

The point of the last few examples was to show the LM 3900 can be used with a wide range of input impedance, gain, and power supplies; and that when one factor is varied then the others usually adjust to accommodate the new situation.

To close this section a few application hints are in order:—

1. Although the limited range of I_m has been stressed in these examples, it can be exceeded slightly without undue damage to the LM 3900.

2. When driving either input from a low impedance source, a limiting resistor must be placed in series to limit the peak

current. This is usually R_1 in the circuits we have been using. Currents as large as 20 ma will not damage the device but they will saturate it and thus it will not work.

3. Unintentional signal coupling from output to the + input can cause oscillations.

This usually occurs in breadboards and experimental set ups.

4. The overall performance is not as precise as a conventional op-amp using split power supplies, but it is good enough for most industrial applications.

5. Output shorts to the power supply of ground should be of short duration. The current will not actually damage the LM 3900, but the internal heating it will cause will produce excessive dissipation which will eventually destroy the chip.

6. NEVER reverse the power supply leads or instal the LM 3900 backwards in a socket. The current will quickly fuse the internal wires.

The LM 3900 is a very versatile device, and is worth using in many applications. Now that the basics of its use have been shown, the following chapters will present solid proven circuits which can all be used as they appear, or can be the basis of other ideas – equally simple or more advanced.

SECTION 2: AUDIO APPLICATIONS

The LM 3900 can be used in several audio applications without introducing distortion. It is not considered a 'quality' audio amplifier as it is not a low noise device. For non critical work, such as in a cassette machine used for speech, intercoms, or in a PA system in a disco or a public hall it is quite suitable. It is probably most out of place when used as a tape head pre-amplifier, it is not good enough for the serious Hi-Fi enthusiast, and is out of the question for professional studio use.

If larger input signals are encountered, which have already been raised above noise level, then the LM 3900 is quite satisfactory. It does not have sufficient output power to directly drive a speaker, but as it can amplify an input voltage to almost any level desired it can be used as a pre-amplifier or driver for a power output stage.

In this section several pre-amplifiers are given, with an appropriate negative feedback network for shaping the frequency response for a few common audio applications.

The Basic Pre-Amplifier

The purpose of a simple pre-amplifier is to take a small original signal, such as from a microphone, tape head, record player pick-up, etc. and provide voltage amplification. As a gain or volume control is usually included at some point, the actual amount of gain realised from the pre-amplifier is often not important. What is important is to get as large an amplification of the signal as possible; now it will be above any noise or interference, and further power amplification and frequency shaping may be performed.

When using an op-amp as a high gain pre-amp, it usually has more than enough gain to raise the signal to a usable level. For example, an op-amp with an open loop gain of 100,000 would try to amplify the 1mv level from a tape head to 100 v. So to keep the output level within reasonable limits a large amount of feedback must be used.

Feedback with op-amps produces the same advantages found elsewhere; a lower controlled gain, reduced distortion, better frequency response characteristics, control of input and output impedance etc.

A simple pre-amp. suitable for amplifying an audio input is shown in Fig. 2.1. This is used as a building block for the remaining circuits in this section.

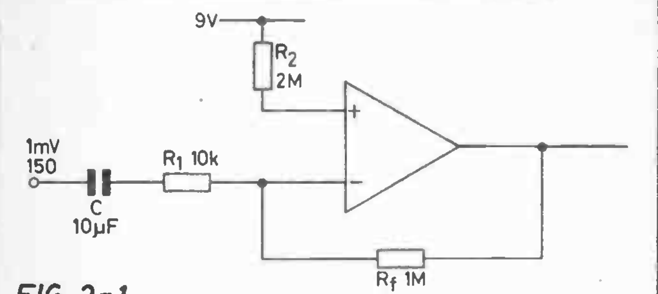


FIG. 2-1

Distortion

Distortion with the LM 3900 is very low, less than 0.3% can easily be obtained across the audio spectrum. Distortion usually occurs when the output signal approaches the maximum voltage swing. The positive and negative peaks tend to

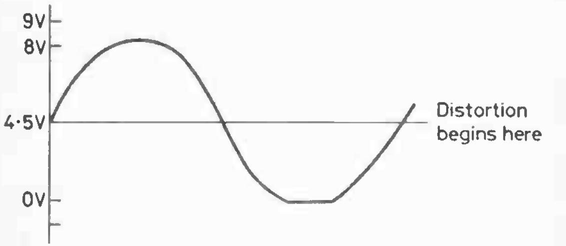


FIG. 2-2

distort before they clip, and this begins to occur about 1v from the power supply voltage levels.

Fig.2.2 makes this clear.

Note: The circuit of Fig. 2.3 will have a gain of 100, and the output will be biased at about 0.5v above earth or ground. With an input of 1 mv p-p, the output will be 100 mv p-p and will be practically undistorted. A larger input, or attempting to get more gain will quickly produce clipping and distortion of the negative part of the output waveform.

The advantage of this circuit is simplicity.

AC coupling to the next stage is advised.

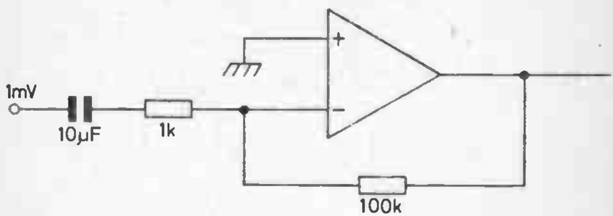


FIG. 2-3

Frequency Response of the LM 3900

If the LM 3900 was used as an open loop amplifier, it would have a frequency-gain characteristic curve as shown in Fig. 2.4. It has unity gain at about 2.5Mhz, and hence it is not good for video or fast pulse work.

At 20 Khz, the upper limit of the audio range, it has about 42 db of gain. The circuits of Fig 2.3 will produce a curve as shown in Fig. 2.5, giving the amplifier equal gain of 40 db across the audio spectrum. This should be set up and tested by the reader.

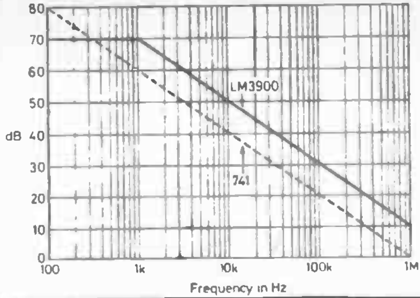


FIG. 2-4

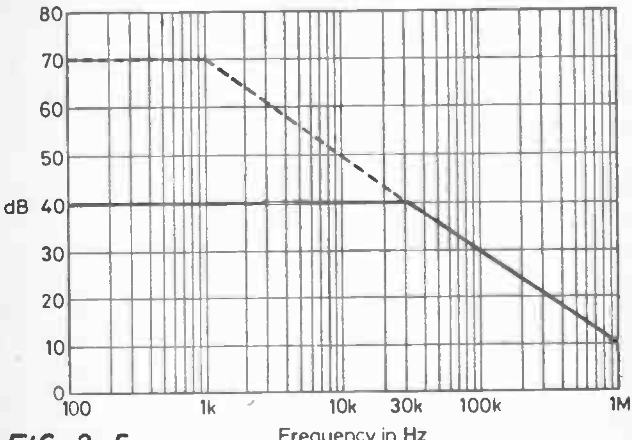


FIG. 2-5

However, in many audio application more gain is required at low frequencies than at the higher frequencies, and an amplifier with a basic gain of 60 db is needed. This is usually considered to be the gain required from an audio pre-amplifier prior to frequency shaping. The circuit of Fig. 2.6. will have a gain of 60 db, and the response curve is shown in Fig. 2.7.

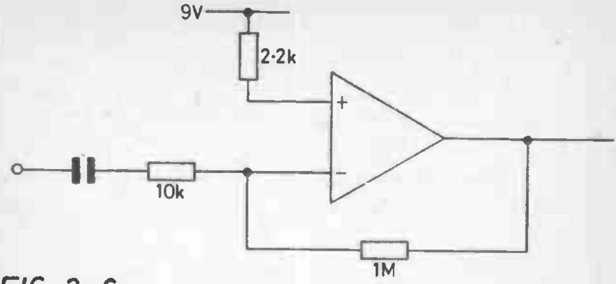


FIG. 2-6

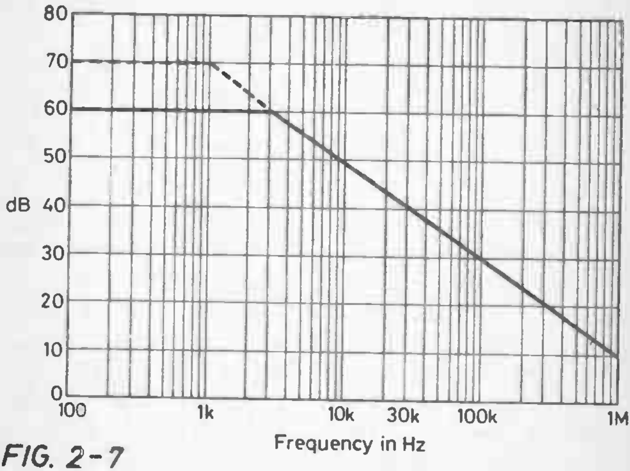


FIG. 2-7

Frequency Shaping

In most audio amplifiers gain is not the only thing required. The frequency response must follow a definite pre-determined curve.

Tapes and discs are recorded with a reduced bass response and increased high frequency response. The bass is attentuated to prevent overload distortion and the high are emphasised to overcome noise from disc surfaces etc.

So on playback the pre-amplifier must reverse this deliberately introduced non-linearity. This is achieved by having a combination of resistors and capacitors in the negative feedback network, which provide different gain at different frequencies. The general shape of the voltage output when plotted against frequency is shown in Fig. 2.8.

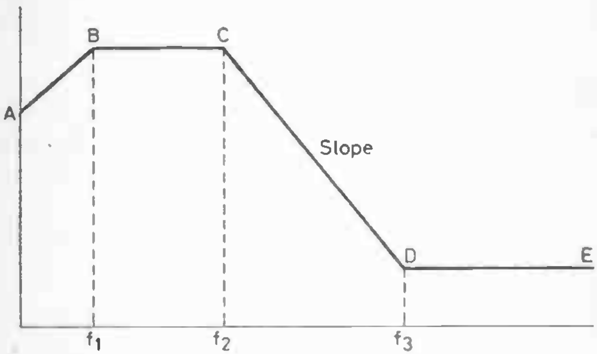


FIG. 2-8

The slope CD is a natural phenomenon, falling at 6 db per octave. All resistor and capacitor combinations provide this same shape. The choice of values determine at which frequencies f_2 and f_3 the slope will start and end. Once the frequencies have been chosen then the levels will also have been determined, due to the constant slope. Audio response curve like this are among the simplest and most natural found in electronics. What distinguishes one playback curve from another is the choice of frequencies for f_2 and f_3. Well known disc playback curves are RIAA, CCIR, DIN. Well known tape curves are NAB, CCIR, Philips Cassette.

A basic feedback circuit for an op-amp used in audio is given in Fig. 2.9.

The frequency shaping at the higher frequencies is accomplished by C_2, R_c and R_f. As long as the op-amp has an open loop gain that is greater than the desired closed loop frequency shaped gain then the overall performance will be determined by these external components. A roll off at very low frequencies will be provided by C_1, which adds to the input impedance provided by R_1. C_1 is simply chosen by making its reactance equal to R_1 at 50 hz.

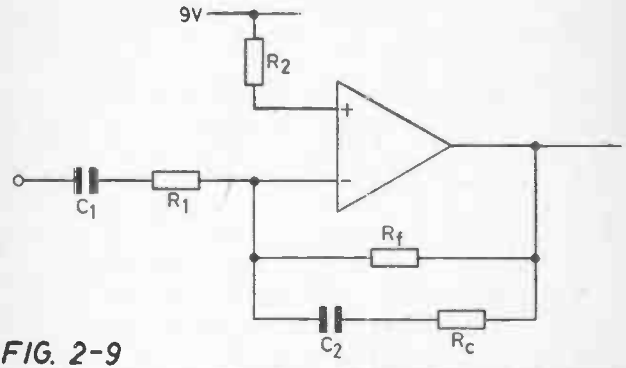


FIG. 2-9

As the gain setting R_f is part of the feedback network, the choice of the frequency shaping resistors and capacitors will be dependent on R_f. Hence the actual values seen in published circuits will vary, depending upon the gain and the input impedance. This is not the place for a discourse on how to design frequency shaping networks, and calculations involving the choice of these components will not be undertaken.

But, because of the low output impedance and high input impedance, a frequency network used for one op-amp will work with most others. So almost any op-amp can be substituted in any published circuit if the recommended one is unavailable. Although the LM 3900 is not a direct replacement for other types of op-amps the same frequency shaping feedback networks can be used. All the user need do is to choose R_2 so that the output DC biasing point falls close to the mid-range of the power supply voltage.

To demonstrate this, all the following circuits were 'lifted' from manufacturers published circuits which used other op-amps. An LM 3900 was used instead, with appropriate bias circuit changes; the feedback network was unchanged. The measurements to ascertain the frequency curves produced results within the variations normally found due to component tolerances.

High Frequency Roll Off

Because of their very high gain and extended frequency response, op-amp circuits often have trouble with spurious oscillations. These tend to occur at frequencies lower than the internal compensation of the op-amp, and are caused by wiring loops, board layout, etc. A simple method to obviate these is an RC roll off circuit. A suitable one for the LM 3900 audio pre-amp is shown in Fig. 2.10. Only use it when necessary. Often this oscillation problem arise with power amplifiers and the roll off circuit should be used there instead of at the LM 3900 output. Later circuits will show this.

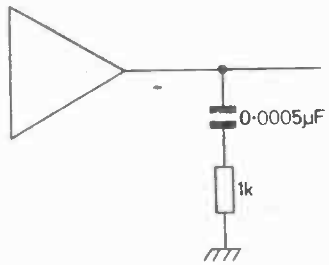


FIG. 2-10

Microphone Pre-Amplifier

Many top quality microphones have a very flat frequency response, and to amplify the output of a microphone faithfully a flat frequency response is required in a pre-amp. So a simple basic pre-amp circuit, with feedback to set the gain is satisfactory as a microphone pre-amp.

The output of a microphone can be anywhere from 70db to 40db. A pre-amp should raise this to around 20db as this is the minimum level suitable for the 'line' or 'auxiliary' input of many tape machines, PA amplifiers, etc.

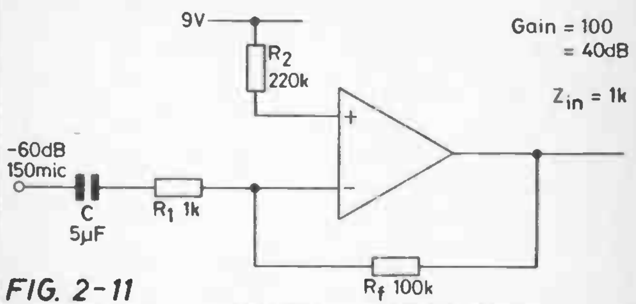


FIG. 2-11

A useful microphone pre-amp using the LM 3900 is given in Fig. 2.11. It has a gain of 40 db and an input impedance of 1K. Fig. 2.12 shows a pre-amp with a gain of 60db and an input impedance of 600 ohms.

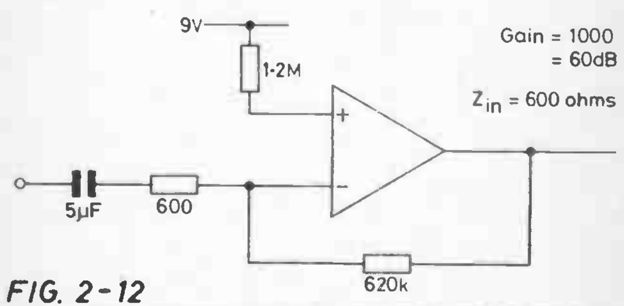


FIG. 2-12

It should be remembered that the LM 3900 is a 'noisy' amplifier and although it is suitable for intercom systems, paging, PAs, etc. it is not good enough for studios or other critical work.

Record Player or Disc Pre-Amplifiers

Most record pick-ups are magnetic in nature, with an output around 1 mv or more. A suitable disc pre-amp will have as

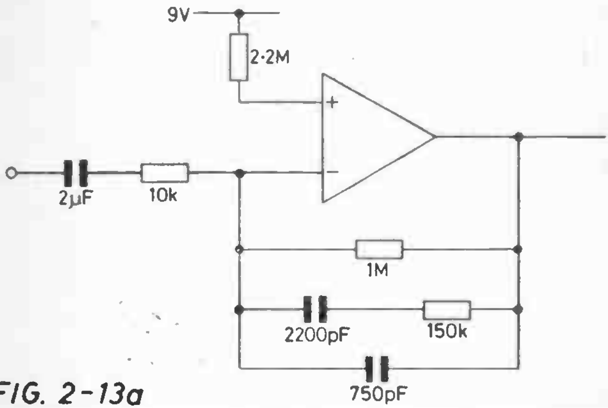


FIG. 2-13a

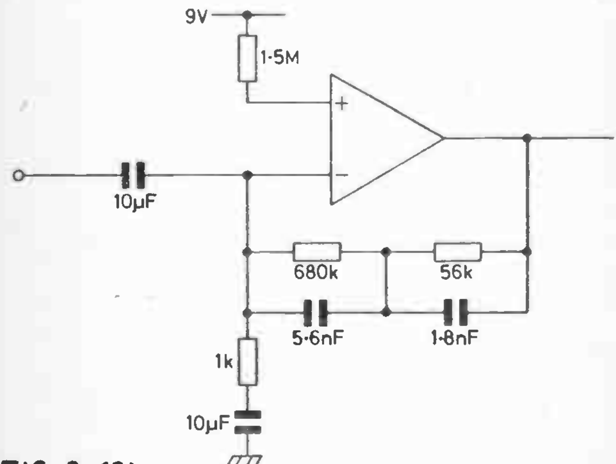


FIG. 2-13b

much gain as possible, and a frequency shaping network to compensate for the recording characteristics used. Although many characteristic record and playback curves have been used in the past, the RIAA (Recording Industry Association of America) curve has become almost a world standard. The pre-amps of Fig. 2.13 have an RIAA equalised playback curve, which is shown in Fig. 2.14.

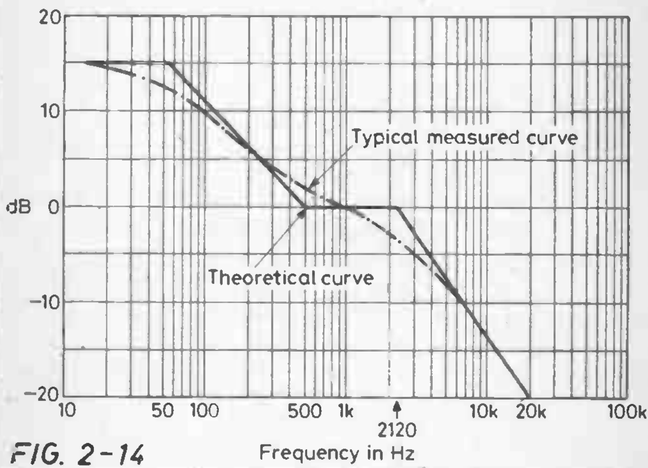


FIG. 2-14

Tape Pre-Amplifiers

Most tape heads are low impedance and have an output around 1 mv at 1 Khz. But when a tape is played back the head does not have a flat frequency response, it rises with frequency to some maximum point and then falls to zero. The curve is shown in Fig. 2.15. The playback characteristic of a tape pre-amp must compensate for both the recording characteristics and the head response. The range usually used is that marked AB on the curve. The frequencies F_p and F_h are both very dependent upon the head gap and the tape speed, and thus different playback curves are required from a pre-amp when the tape speed is changed.

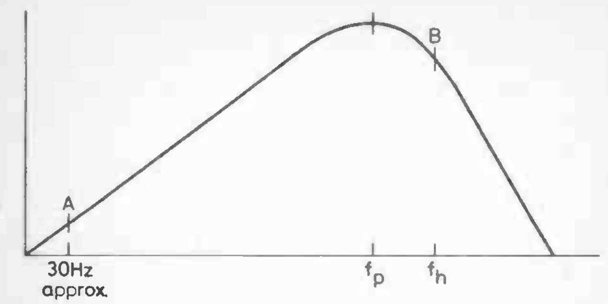


FIG. 2-15

Compensating for different tape speeds is quite easy, an alternative feedback path is used to provide the different frequency response required. As heads are seldom changed in tape machines, and as a correct replacement is usually installed, then altering the pre-amp is not required. Professional record-

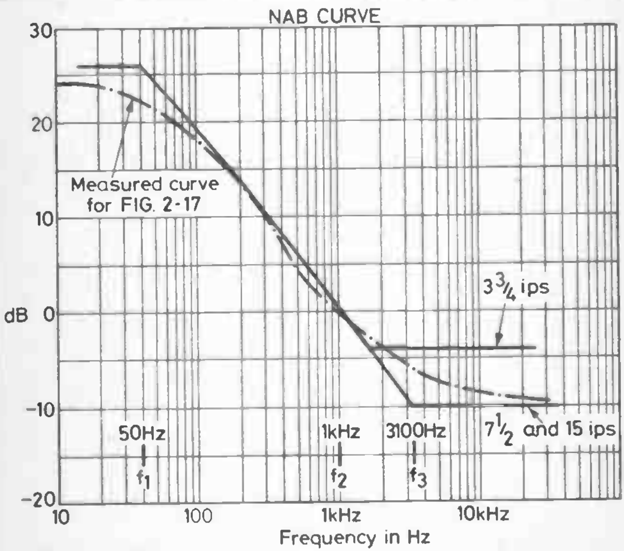


FIG. 2-16

ing machines have head matching and peaking circuits. These are not shown here as the LM 3900 is not recommended for studio machines; but it can be used with some success in speech only machines such as cassettes and educational A/V machines.

The basic NAB tape playback curve is shown in Fig. 2.16. The referrence frequency is 1 Khz (f_2) and this is arbitararily assigned a level of '0 db' and all other frequencies have levels above or below this. This is merely a convenience or convention so that measurements on different amplifiers and tape machines can be easily compared. The actual pre-amp gain at 1 Khz however is about 40 – 50 db.

Maximum gain is at 50 hz (f_1) and above this frequency the output drops at the 6 db/octave (20 db/decade) rate until the high frequency corner is reached. At this point the output is flat until the amplifier itself begins to roll off.

This corner frequency (f_3) can be anywhere between 1K and 5K, depending on the tape speed and the playback system (NAB, CCIR, DIN, JIS).

The low frequency roll off point (f_o) is usually left up to the circuit designer, and is determined by the input capacitor.

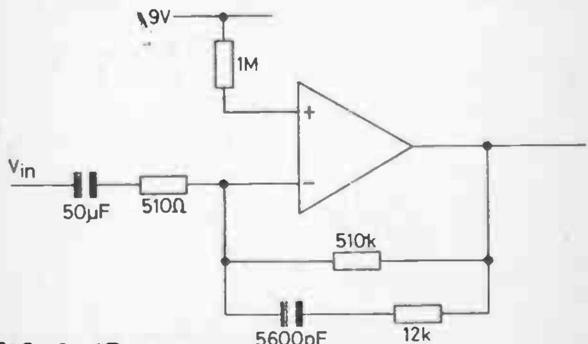


FIG. 2-17

Fig 2.17 shows a typical tape pre-amp for 7½ ips tape speed. The curve measured from this is also plotted on Fig. 2.16, showing the high frequency corner (f_3) of 3100 hz for this speed.

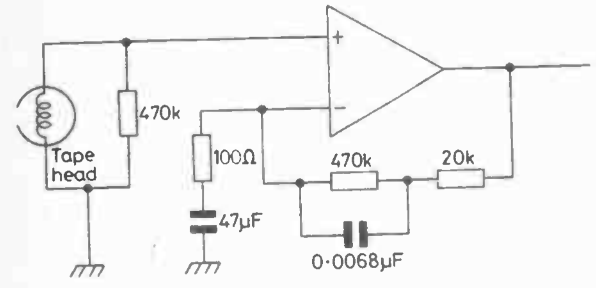


FIG. 2-18a

Fig. 2.18 shows several other suitable tape pre-amps which can be used.

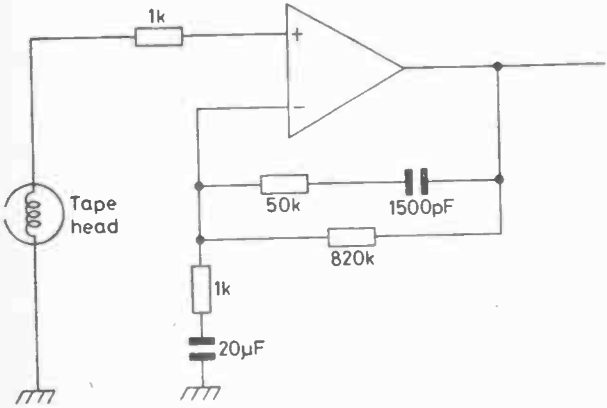


FIG. 2-18b

In general, for tape pre-amps, the LM 3900 can be substituted into any published circuit; provided the feedback path is preserved and the LM 3900 is biased properly. It will give results close enough for most non critical work.

Tone Control Circuits

Tone control circuits fall into two main types.

1. Passive components at the input or output of a pre-amp.

These shape the signal before or after the pre-amp, and the pre-amp merely provides gain.

2. Variable components in the pre-amp feedback network.

These actually alter the frequency response of the pre-amp.

Either can be used with the LM 3900, and typical examples can be 'lifted' from almost any other circuit.

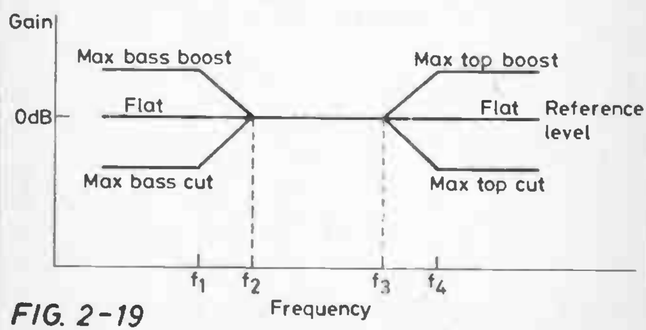


FIG. 2-19

The effect of these controls is to increase or decrease the gain over a narrow part of the frequency spectrum; Fig. 2.19 explains this. Fig. 2.20 to 2.22 show typical feedback tone controls. Control circuits like this will often affect the overall gain of the pre-amp, and the level heard in a speaker can go up and down as the tone control is altered. For critical purposes more complex circuits can be used, but then a better quality op-amp should also be used.

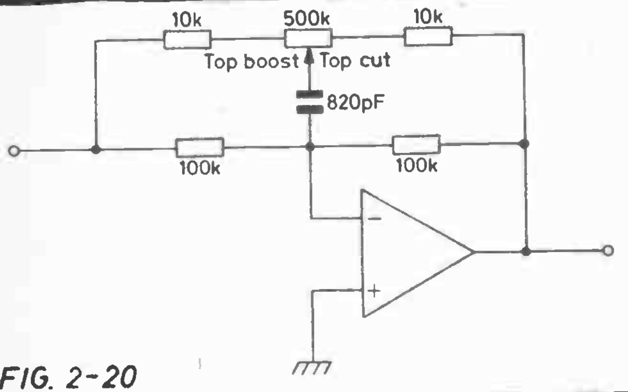


FIG. 2-20

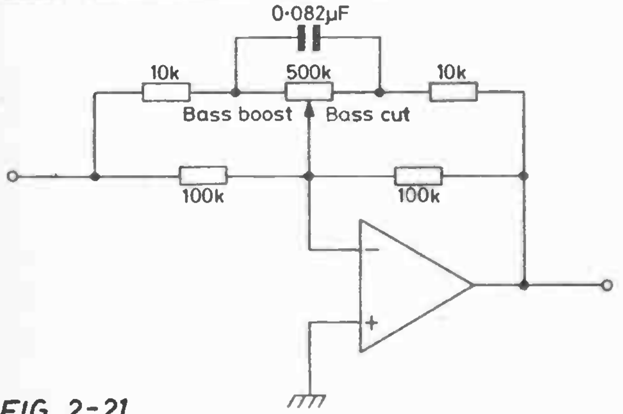


FIG. 2-21

Almost any other published tone control circuit can be 'lifted' from its specific op-amp and used when the LM 3900. However, when this happens the curve will not exactly fit the published or specified curve due to the relatively high output impedance of the LM 3900. But, it will be close enough for most purposes.

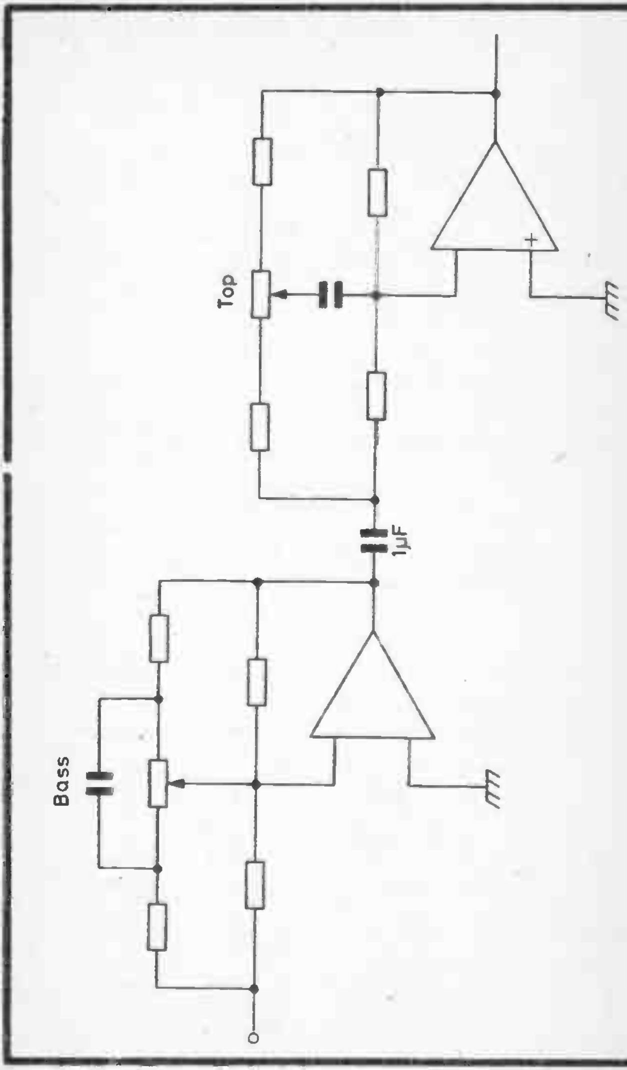


FIG. 2-22

Tape Recording Amplifier

Designing an amplifier suitable for recording on tape is not difficult; but giving a general purpose circuit is inadvisable as the signal source, tape head, and bias oscillator output can affect the performance.

Basically a tape a recording amplifier has equal gain over the whole frequency range, as the recording process is linear; but the high frequencies are pre-emphasised to compensate for noise and head losses. The amount of recording compensation differs depending on tape speed. Several recording characteristics have been used, but the most common are NAB, CCIR, and the Philips Cassette.

The LM 3900 is not the best choice for a recording amplifier, due to its relatively high output impedance and the fact it may not be able to deliver sufficient power to the heads.

It can be used as a pre-amp to drive a power stage which drives the heads. A simple circuit for this is shown here, but experimenting with the R_f and R_1 to provide sufficient gain may be necessary. For quality work, alternative op-amps should be used.

The circuit of Fig. 2.23 will have an output which will begin to rise around 5 Khz at a rate of about 3db/octave.

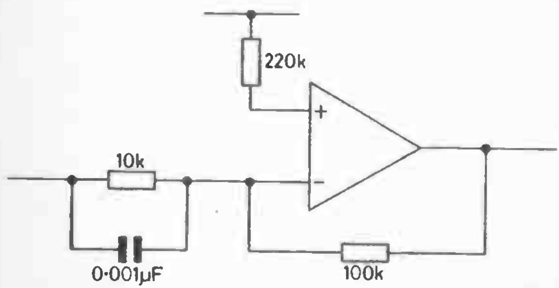


FIG. 2-23

Pre-Amplifier Gain Control

There are several places to place a gain or volume control in an LM 3900 pre-amp circuit.

1. The Input.
Although this is the obvious choice, it tends to add noise. In Fig. 2.24 note the use of C_2 to prevent upsetting the bias. The control R can be any desired value, and it will effectively set the input impedance of the circuit

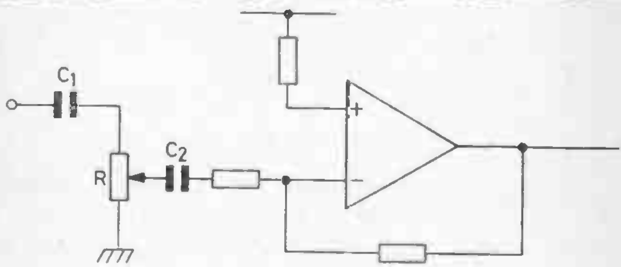


FIG. 2-24

2. The Output.
This has much to recommend it. Signal level is way above the noise. AC or DC coupling to the control can be used. Fig. 2.25 shows 4 common arrangements, the choice of which depends upon the input to the next stage. The control should be above 10 Kohms.

3. In the Feedback Loop.
An obvious choice is to use R_f, as the ratio of R_f to R_1 sets the gain. Although this works two serious disadvantages. Fig. 2.26.

A. It will change the output DC bias point, as R_2 is no longer $2 \times R_f$. If the maximum p-p voltage output is much less than the power supply, then this can be tolerated.

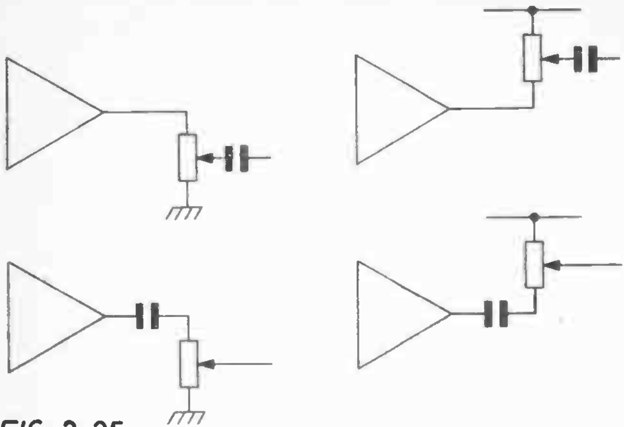


FIG. 2-25

If DC coupling is used to the next stage, the bias condition of the next stage will change with the gain. So it is best to use AC coupling if this approach is taken.

B. The gain setting will affect the frequency response, as it alters the feedback network.

In general, one of the ideas in the output circuit should be used.

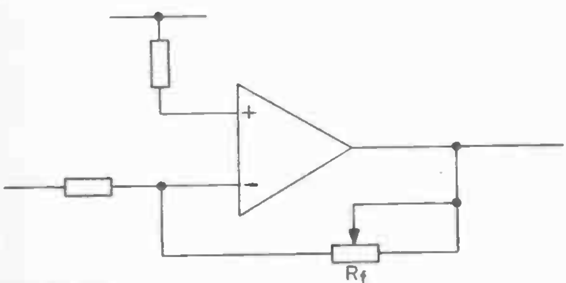


FIG. 2-26

Audio Power Amplifiers

The LM 3900 is not a power amplifier and it cannot drive low impedance phones or speakers directly. A power stage, providing current and power amplification is required. This can be entirely emitter followers, as the LM 3900 will provide all the voltage amplification required. Several simple power circuits are shown here, but many others can be used. The main requirement is that the input impedance to the power stage should be at least 10K.

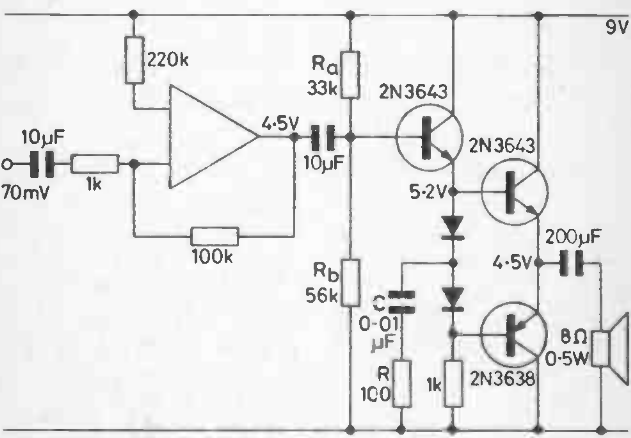


FIG. 2-27

Fig. 2.27 shows the LM 3900 AC coupled to the power stage. This allows the power stage to be biased by R_a and R_b so that the DC output stage can be midway between the power supply and ground. Fig. 2.28 shows the maximum output available before clipping occurs. Feedback is not usually necessary in the power amplifier, so it may introduce some distortion if the input level is too high. This circuit is suitable for intercoms and low power paging systems.

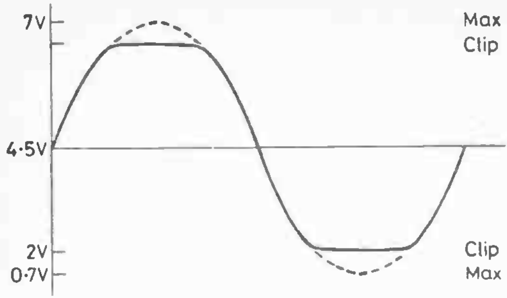
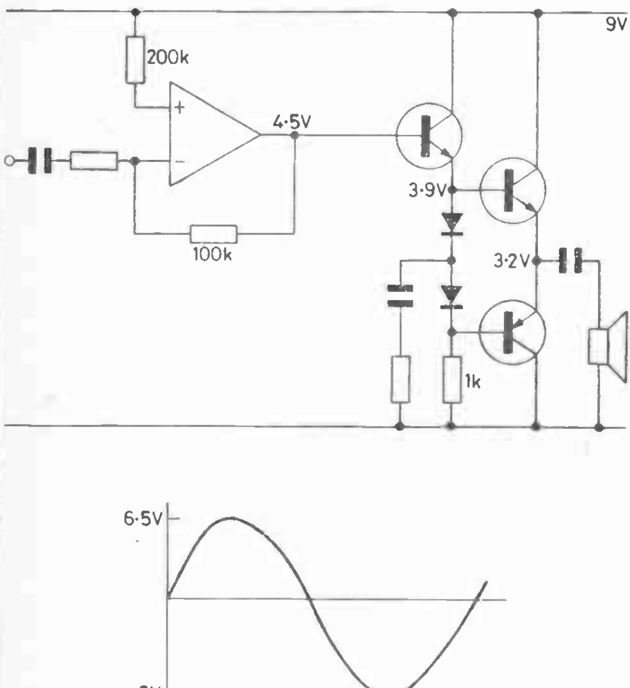


FIG. 2-28



Voltage clip levels at output

FIG. 2-29

Fig. 2.29 is similar to the previous circuit but direct coupling is used. Here the output of the LM 3900 is biased by R_2 to be 4.5v, and so the power amp DC is about 3.2v.

Fig. 2.30 is the same as the previous circuit, but here R_2 has been changed so that the power amp output is at 4.5v DC. This puts the LM 3900 output at approx. 6v.

Note that in these circuits the full output voltage swing of the LM 3900 cannot be used. For low power applications this does not cause problems.

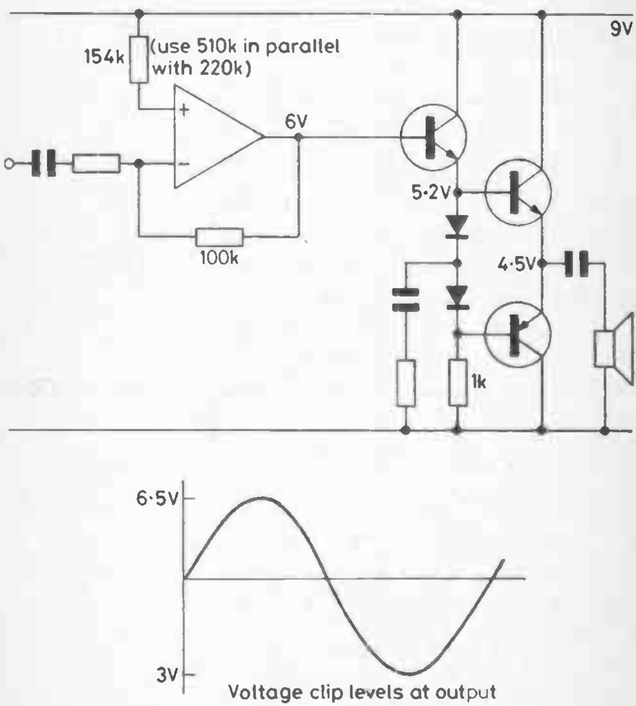


FIG. 2-30

Fig. 2.31 uses a transistor to provide extra gain after the pre-amp and uses transformer coupling to drive the speaker. The relevant values are shown in the drawing.

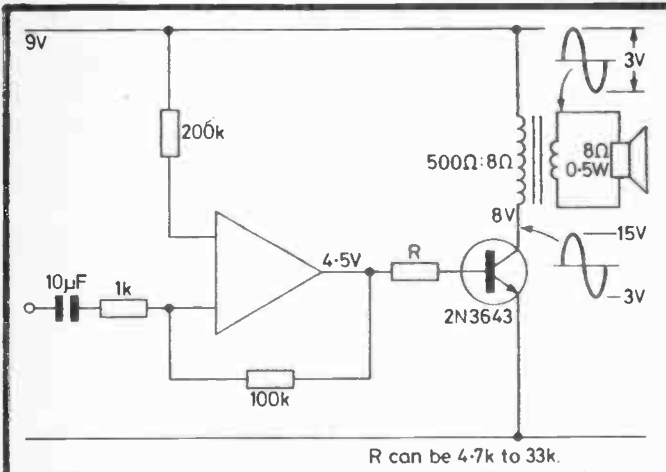


FIG. 2-31

If a high impedance low power earpiece is to be used, then the LM 3900 and a small transformer will suffice. The pre-amp will not drive an earpiece satisfactorily. Figs. 2.32. shows two possible arrangements.

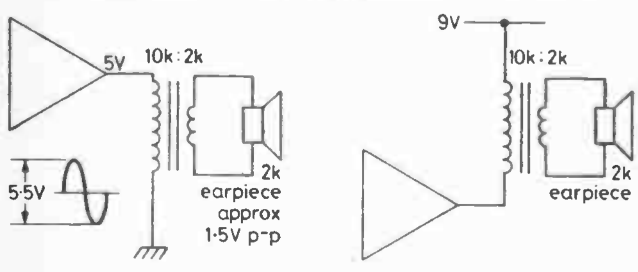


FIG. 2-32

SECTION 3 : SIMPLE LINEAR APPLICATIONS

The term 'linear', when applied to Op-amps, covers a wide range of diverse uses. Originally it referred to arithmetic and algebraic operations such as the summing, differencing, etc. of analogue or continuous signals; but it now includes other applications such as video, RF, LF, biomedical, frequency shaping, active filters, etc. Although audio is a linear application, it is usually treated separately under its own heading, due to the specialised and individual nature of its use.

There are two main ways to categorise linear applications; either by the circuit or the input signal. Neither are perfect as an op-amp can perform very similar operations with equal ability on both a slowly changing AC signal or a digital input. Linear circuits often tread the mid ground between sinusoidal AC, non-sinusoidal AC, and discrete level digital. In fact, many of the circuits in the wave form generator section could easily be placed here.

The circuits presented here in this section are those which are most often called linear in the engineering profession. Very few linear circuits use one amplifier only, usually several are used; but here we commence only with simple one amplifier circuits.

The Summing Amplifier

This is probably the original use of the op-amp and is usually the starting point in most text books. The output is simply the arithmetic sum of the input voltages; and this works for as many inputs as required provided the output does not reach or exceed the supply voltage or ground.

The LM 3900 can be used in this circuit, as shown in Fig. 3.1.

This is not really a good example for here, as its use outside of special applications is limited, but it does make a good introduction to the audio mixer circuit, which is shown later.

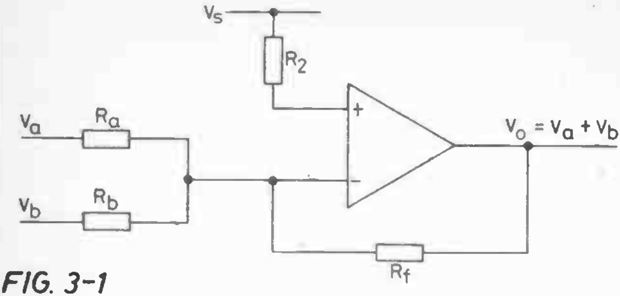


FIG. 3-1

The Differentiator

The circuit in Fig. 3.2 will convert a pulse train into a series of sharp output spikes. This amplifier is biased to half the supply voltage and the gain is ½.

This is useful when fast trigger spikes may be needed to drive another circuit.

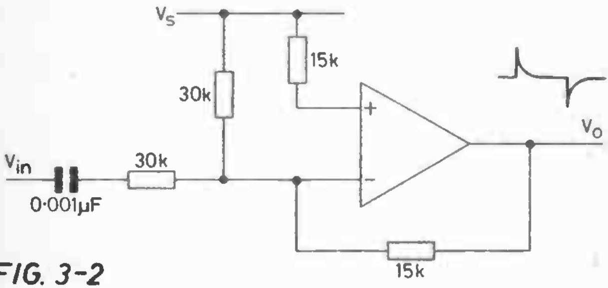


FIG. 3-2

Integrator Circuits and Ramp Generators

These circuits are used for a variety of timing and other purposes. The output is the time integral of the input current. In practice, a DC level at the input will produce a ramp at the output.

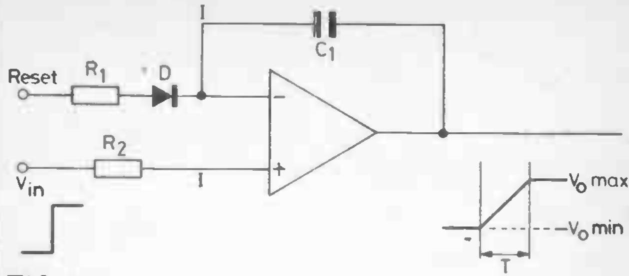


FIG. 3-3

The circuit of Fig. 3.3 will generate a positive going ramp. If the reset voltage is low, then a positive going ramp will occur at the output when V_{in} is positive. The output will go from minimum to maximum and remain at the maximum until it is reset by a positive pulse at the –ve input.

The ramp time is given by:–

$$T = V.\frac{C}{I}$$

But in practice capacitor values are usually chosen on the basis of observation and measurement.

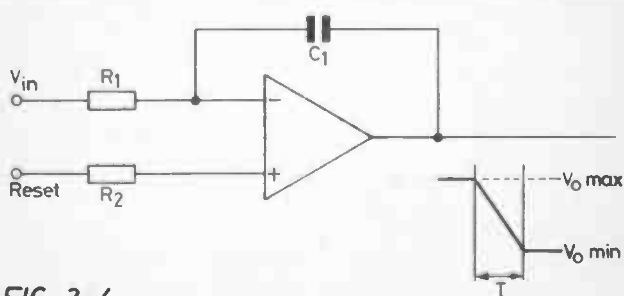


FIG. 3-4

The diode is to prevent R_1 and the reset source from loading down the –ve input affecting the integrating current and the timing. As R_1 is very small, the reset current is quite large, and so the reset time is very fast.

The circuit of Fig. 3.4 will give a negative going ramp. This goes from maximum to minimum and stays there until it is reset.

In both of the above circuits, practical values are often determined by experimentation.

An important variation in the use of the circuit is to apply the input DC voltage for a time less than the total ramp time. In this case the output will not reach maximum or minimum, but only part way. So a short pulse at the input will produce only part of the ramp. The output will then remain at its intermediate value until reset. Fig. 3.5 explains this. This idea has been used in timers, D/A converters, and other circuits.

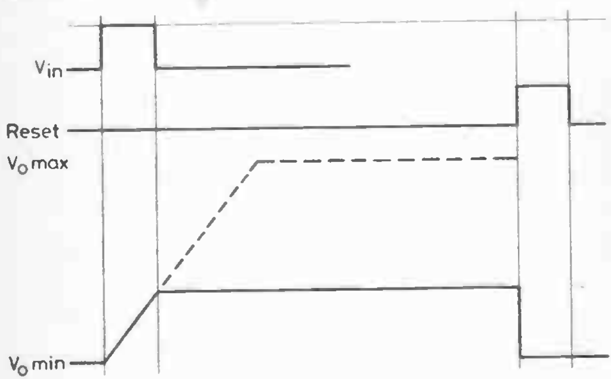


FIG. 3-5

Another variation in the use of this circuit is to keep V_{in} at a constant DC level and to apply a train of pulses to the reset input. All the while the pulses are low, the output will ramp up, and it will reset quickly when the pulses are high. Fig. 3.6 shows a simple circuit using this idea, and the sawtooth output waveform which results.

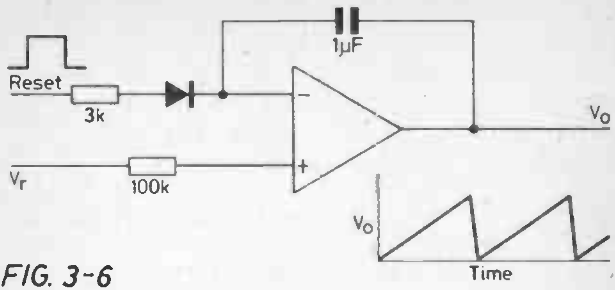


FIG. 3-6

Active Filters

The LM 3900 makes a good active filter. An active filter is a frequency selective circuit which uses an op-amp with resistors and capacitors. The op-amp replaces the inductor found in normal passive filters, and this confers the advantages of gain and a high Q.

Active filters are used for many purposes across the entire electro-magnetic spectrum. Typical examples are biomedical circuits, audio frequency response shapers, tone decoders, etc. Standard active filters are the low pass, high pass, bandpass, and notch configurations; and all types can be made with the LM 3900.

Simple active filters can be made with one LM 3900. This gives a second order filter with a roll off rate of 12 db/octave (40 dv/decade) with Qs and gain values generally less than 10.

This is not the place for a discussion on active filter design, so simple circuits and formulae only will be given.

However, a few comments are in order at this time. Active filters provide an excellent example of the difference between theoretical circuits analysis and practical design.Theoretical analysis gives formula which relate the centre frequency f_o to the resistors, capacitors, the Q and the gain; but which provide little help in actual component selection.

In practice the f_o, gain and Q are decided upon by the requirements to be set. These fill in many places in the formulae, but still leaves them in a state where an infinity of component values will work. This explains why, in theory and practice, the component values can be 'scaled' without effecting the filter characteristics. (i.e. double the R values and halve the C values, and the same filter results).

To get working circuits the capacitor values are usually decided arbitrarily – or picked out of the air – and then the corresponding resistor values are calculated. Hopefully these will be within the limits required by the biasing and loading rules. If not, then the capacitor values are rechosen and suitable new resistors calculated.

A good general rule or observation is made clear by this procedure. Electronics is NOT an exact mathematical science. Do not try to do everything by mathematics and be textbook correct. If a simple shortcut exists – then take it. If experience and common sense dictates some action – then take it. If the circuit works, then you were right, and usually theory will bear this out. If it does not work – try something else.

These examples will illustrate these points.

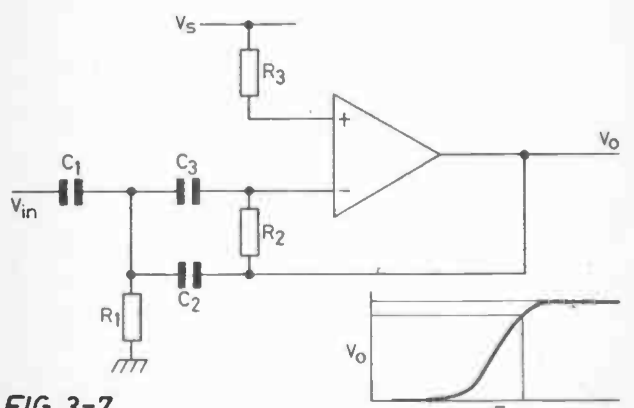


FIG. 3-7

A High Pass Active Filter

A single amplifier high pass filter is shown in Fig. 3.7.

To explain the component values, the design procedure will be presented and followed:–

1. Decide upon values for Q, f_o, and H_o (gain at f_o) The rest of this procedure is to calculate R_1, R_2, R_3, C_1, C_2, C_3.

2. This is the first step in the actual design. Let $C_1 = C_3$ and choose some convenient value. Why do this – it makes life easy.

3. Calculate R_1, using:–

$$R_1 = \frac{1}{2\pi f\, Q\, C_1\, k}$$

where $k = 2H_o + 1$

4. Calculate R_2 using:–

$$R_2 = \frac{Q\, k}{2\pi f\, C_1}$$

5. Calculate C_2 from:–

$$H_o = \frac{C_1}{C_2}$$

6. Calculate R_3.

This is the biasing resistor, so $R_3 = 2 \times R_2$.

This practical example will illustrate the procedure.

1. Decide upon the requirements. These are typical values.

$H_o = 1 \quad Q = 10 \quad f_o = 1$ Khz

If an input of constant amplitude across the audio spectrum is fed into the filter, the output will be that of Fig. 3.7.

2. Choose 300 pf for C_1 and C_3.

Why this value – this is where experience tells. The more you design, the more you get a feeling for the range of values which will work. Try a few examples of this circuit with a 10 uf capacitor and see where you get.

3. Calculate R_1.

$$R_1 = \frac{1}{2 \times \pi \times 10^3 \times 10 \times 300 \times 10^{-12} \times 3}$$

$$= 17.7K$$

$$k = 2 \times 1 + 1 = 3$$

4. Calculate R_2.

$$R_2 = \frac{10 \times 3}{2 \times \pi \times 10^3 \times 300 \times 10^{-12}}$$

$$= 15.9 \text{ M}$$

5. Calculate C_2.

$$C_2 = \frac{C_1}{H_o} = \frac{300}{1} = 300 \text{ pf}$$

6. $R_3 = 2 \times R_2 = 2 \times 15.9 = 32$ M approx.

Obviously R_2 and R_3 are too large for practical circuits. So now the component values are scaled. We will reduce the resistor values and increase the capacitor values.

Reduce R_2 to 10 M. This is a factor of 1/1.59, and now R_1 must be reduced by the same factor. So:–

$$R_1 = \frac{17.7\ K}{1.59} = 11\ K$$

Similarly the capacitors must be multiplied by this amount:–

$$C_1 = 300\ pf \times 1.59 = 477\ pf$$

To complete the circuit R_3 becomes 20 M.

This is still too high for R_3, so try a further scaling. Divide all resistors by 4, and multiply all capacitors by 4. The values are now shown in this Fig. 3.8.

Check all these final values in the equations.

Finally, use the nearest standard values of all components.

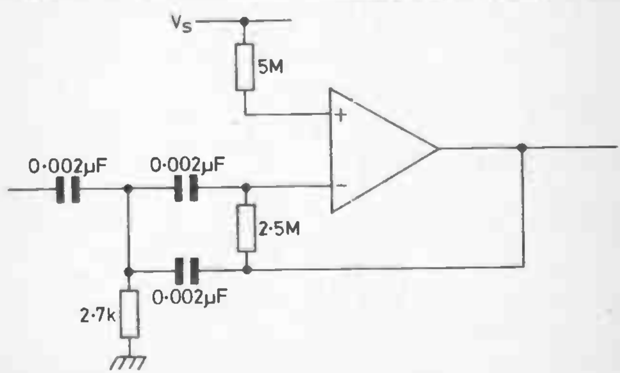


FIG. 3-8

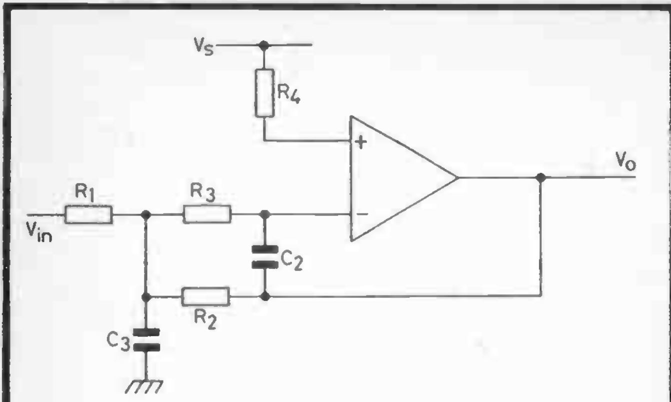


FIG. 3-9

A Low Pass Active Filter

A circuit for this is given in Fig. 3.9. Note that the signal is not AC connected to the input. The design procedure is similar to the previous case; it will be presented here simultaneously with the practical values and the calculations will be performed immediately.

1. Chose values for Q, f_o, and H_o (gain)

$Q = 1$ $\quad f_o = 1$ Khz $\quad H_o = 1$

Typical easy values.

2. Select $C_1 = C_2 = 300$ pf.

3. Calculate R_2 from:–

$$R_2 = \frac{1}{2\pi f\ 2Q\ C_1}\left[1 \pm \sqrt{1 + \frac{4Q^2 (H_o + 1)}{k}}\right]$$

[where $k = \dfrac{C_2}{C_1}$]

Here, in this example k = 1 by choice of capacitors.

$$\text{so } R_2 = \frac{1}{2 \times \pi \times 10^3 \times 2 \times 1 \times 300 \times 10^{-12}} \left[1 + \sqrt{1+4(2)} \right]$$

$$= 1.06 \text{ M}$$

4. Calculate R_1 from:–

$$R_1 = \frac{R_2}{H_o} = \frac{1.06 \text{ M}}{1} = 1.06\text{M}$$

5. Calculate R_3 using:–

$$R_3 = \frac{1}{(2\pi f)^2 \; C_1^2 \; R_2 \; k}$$

$$= \frac{1}{(2 \times \pi \times 10^3)^2 \times (300 \times 10^{-12})^2 \times 1.06 \times 10^6 \times 1}$$

$$= 266 \text{ K}$$

6. Finally find the biasing resistor R_4 from:–

$$R_4 = 2 \left(\frac{R_1}{2} + R_3 \right)$$

$$\text{so } R_4 = 2 \left(\frac{106 \text{ M}}{2} + 266 \text{ K} \right)$$

$$= 1.5 \text{ M}$$

If the input is AC coupled, then R4 is given by:–

$$R_4 = 2 \; (R_2 + R_3)$$

$$= 2 \; (1.06 \text{ M} + 266 \text{ K})$$

$$= 2.7 \text{ M}$$

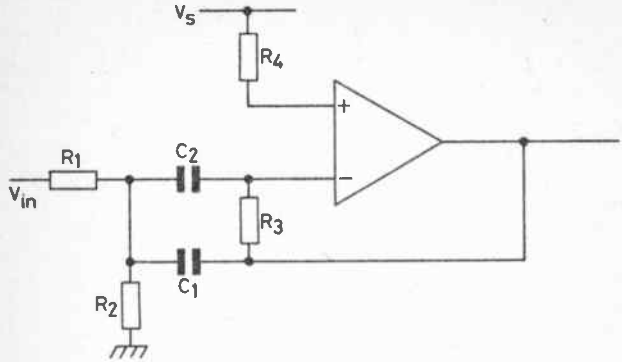


FIG. 3-10

A Band Pass Filter

For low frequencies, low gain, and low Q, (all under 10) a single amplifier can be used. The circuit is shown in Fig. 3.10.

The procedure will again be shown concurrent with the calculations.

1. Choose values for Q, f_o, and H_o.

   $Q = 5, \quad f_o = 1$ Khz $\quad H_o = 1$

2. Select $C_1 = C_2 = 510$ pf.

3. Calculate R_1 from:–

$$R_1 = \frac{Q}{H_o \; 2 \pi f \; C_1}$$

$$= \frac{5}{2 \times \pi \times 10^3 \times 510 \times 10^{-12}}$$

$$= 1.57 \text{ M}$$

4. Calculate R_2 from:–

$$R_2 = \frac{Q}{(2Q^2 - H_o)\ 2\pi f C_1}$$

$$= \frac{5}{(2 \times 25 - 1) \times 2 \times \pi \times 10^3 \times 510 \times 10^{-12}}$$

$$= 32\ K$$

5. Calculate R_3 from:–

$$R_3 = \frac{2Q}{2\pi f C_1}$$

$$= \frac{2 \times 5}{2 \times \pi \times 10^3 \times 510 \times 10^{-12}}$$

$$= 3.13\ M$$

6. Finally, to bias the amplifier, use:–

$$R_4 = 2R_3$$

$$= 2 \times 3.13M$$

$$= 6.2\ M$$

The performance of active filters is relatively insensitive to the components used. But for temperature stability the resistors should be metal film or wirewound and not carbon, and the capacitors should not be the disc ceramic type.

The current restrictions on the LM 3900 must be observed. This means the output loads must be kept above 10K to prevent loss of gain and excessive output current; and the input resistors should be less than 10 M so that sufficient bias current flows. In general, relatively low values of components give the best results.

More complex circuits can be made with more than one amplifier. As the basis of active filters is a gain stage, then the more amplifiers the better. This also means less component selection and trimming, and less performance disturbance by tolerances and temperature drifts.

SECTION 4 : SIMPLE DIGITAL APPLICATIONS

By overdriving the LM 3900 it can be used for several simple digital circuits and switching applications.

It has several useful features and advantages which make it a useful digital device. Briefly these are:–

1. It can be used from the low TTL voltage levels up to about 36v. Thus it is compatible with all the common digital IC families.

2. Its large output voltage swing will enable it to interface with almost any circuit.

3. It has a relatively low speed, and thus is free from the problems of high speed devices, especially noise. Its slew rate is 0.5v/μs.

4. It requires a very small input current, so large values of resistors can be used. This means that small capacitors can be used in timing circuits.

5. Its output circuit has an active pull up and pull down. So it can deliver and sink larger output currents than resistive pull up devices and circuits.

(The output current is nominally 10 ma when V_O is high; and it can go to 80 ma when V_O is low).

These features make it ideal where circuits must be tailored to an existing situation and where high speeds are not necessary. In both cases it obviates the need for expensive interface circuits which often require standard digital ICs and many discrete components and more than one power supply.

In this section the common digital applications and circuits are covered, and then following section gives more advanced uses.

In all digital circuits using the LM 3900 the key to how and why they work is the currents into the two input terminals. In a given output state – high or low – one input terminal will have more current than the other, and this will be a stable condition to make the output change state, extra current is introduced into the other input. This is usually effected by a change in an input voltage, which provides the current through a large value input resistor. The resistor must be chosen so that the input current remains within the limits of 5μa if possible, especially if the LM 3900 will remain in one state for any length of time.

If the output change is to be very short, or the input voltage is a short pulse, then a much larger input current can be tolerated. It is here that the absolute maximum of 5 ma can be reached, but in general the current should be no higher than will make the circuit work reliably. Often a little experimenting is required.

The OR Gate

The simple OR function can be achieved with the simple circuit of Fig. 4.1.

When all the inputs are high, the total current I_2 must not

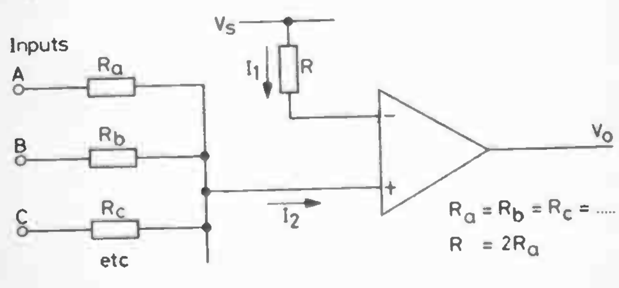


FIG. 4-1

exceed I_m limits, so the input resistors R_a, R_b, etc. must be chosen to ensure this.

The value of R is chosen to be twice the value of the input resistors. In this case, when all the inputs are low, the current I_1 through R will keep the output voltage low, at logical O. If any one input goes high, to logical 1, then the input current I_2 will be twice I_1 and the output will go to a logical 1.

If one input only is high the others are all low, then the current through that input resistor flows into the + ve input of the LM 3900 and also through the other input resistors. Due to the small input current required by the LM 3900 this usually causes no problems.

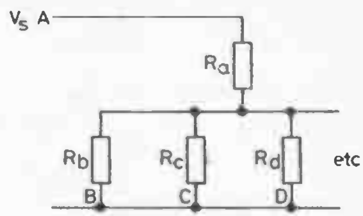


FIG. 4-2

An easy way to ensure the circuit will work is to follow this procedure:–

1. Disconnect the LM 3900 from the input resistors.

2. Ground all the inputs except A.

3. Put point A to + ve, so the situation is that of Fig. 4.2.

4. Find the parallel equivalent resistance R_p of all the other input resistors.

(This is easy, divide the resistance value by the number of resistors used.)

5. The situation is now shown in Fig. 4.3.

6. Use the voltage divider formula to find V_X.

$$V_X = V. \frac{R_p}{R_p + R_a}$$

7. If V_X is greater than 1v, then the OR gate will work.

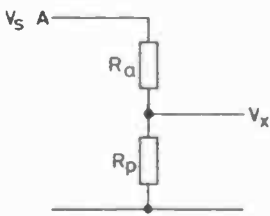


FIG. 4-3

A practical OR gate is shown in Fig. 4.4. A good working range for the resistors is 100K to 1M.

The NOR Gate

The LM 3900 can also be used as a NOR gate. This can easily

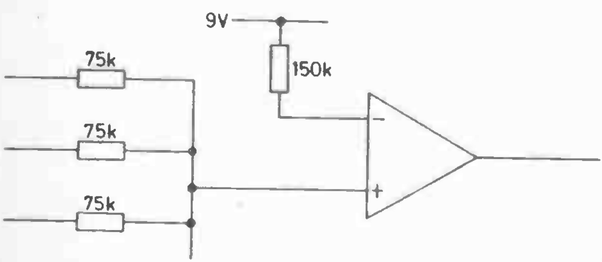


FIG. 4-4

be obtained by simple reversing or interchanging the inputs. See Fig. 4.5.

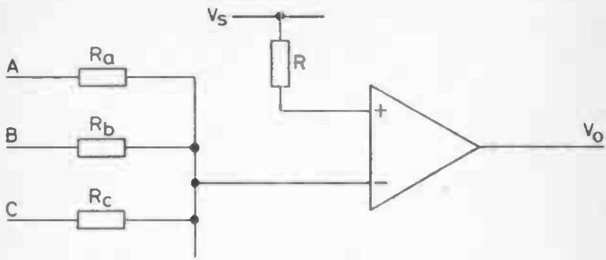


FIG. 4-5

The AND Gate

To use the LM 3900 as an AND gate, connect it as shown in Fig. 4.6. In this circuit all three inputs voltages must be at logical 1 for the output to go to logical 1. Only when this is so will I_2 be greater than I_1.

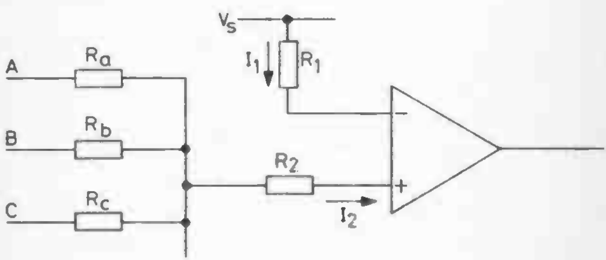


FIG. 4-6

The resistor values must again be chosen to set input currents within the I_m range. The relationship between the resistor values is given by:–

$$\frac{R_a}{3} + R_2 < R_1 < 1.5 \left(\frac{R_a}{3} + R_2 \right)$$

If any one of the inputs is at 0, then I_2 will be less than I_1 and the output will be 0.

Fig. 4.7 shows a practical 3 input circuit.

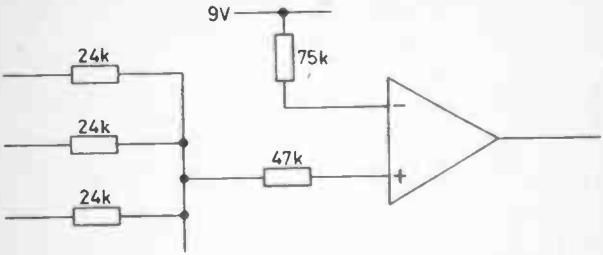


FIG. 4-7

A two input AND gate, as in Fig. 4.8, has the resistor relationship given here:–

$$\frac{R_a}{2} + R_2 < R_1 < 1.5 \left(\frac{R_a}{2} + R_2 \right)$$

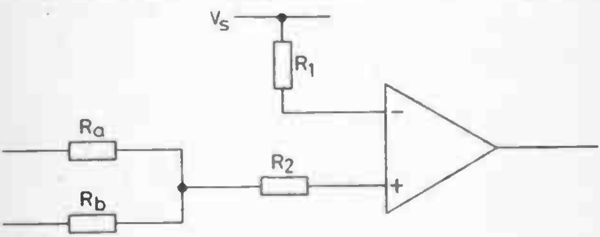


FIG. 4-8

Fig. 4.9 shows two circuits which can be used.

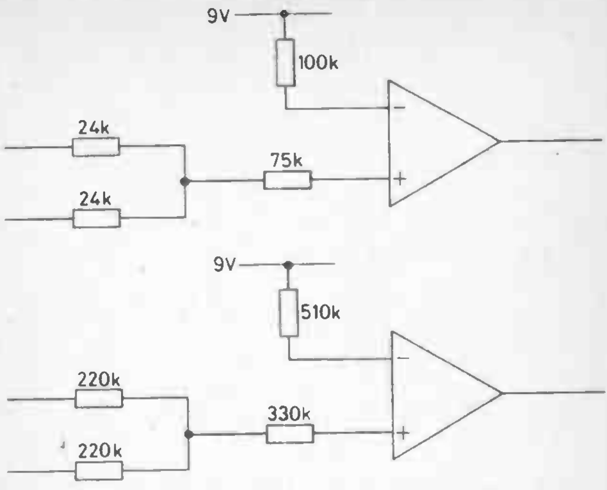


FIG. 4-9

For circuits which have 3 or more inputs – large fan in – this circuit of Fig. 4.10 is preferred. It avoids the problems of resistive summing. R_1 should be about half R_2.

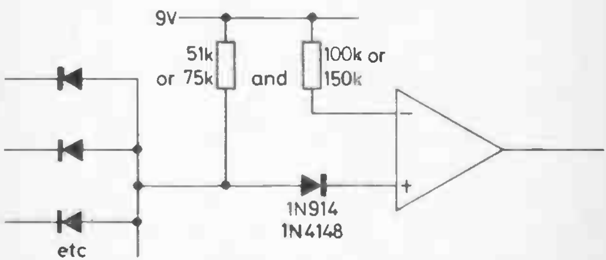


FIG. 4-10

The NAND Gate

AND gate can easily be made with the LM 3900. Simple interchange the connections on the AND gate. Fig. 4.11 is a multiple input NAND gate.

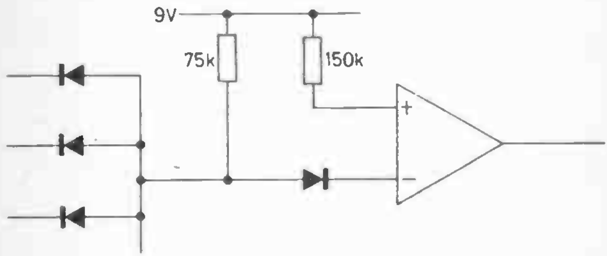


FIG. 4-11

Fan Out

In all logical circuits using the LM 3900 the logical drive capability or FAN OUT is very large. This is best shown with an example. See. Fig. 4.12.

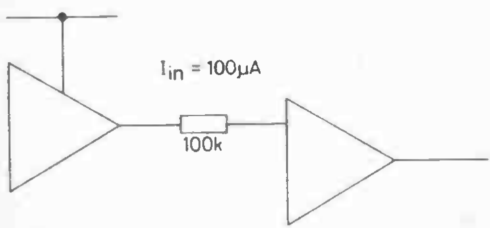


FIG. 4-12

Assume the output of the LM 3900 will rise to 10v, and that 100K resistors are used in the inputs. Then the input current will be 100μa – the maximum permitted.

As the output can deliver 10 ma, then it can supply enough current for 100 inputs.

Other input resistors and voltage levels will give equally large FAN OUT numbers. This is part of the usefulness of the LM 3900 in digital applications.

When its output goes low, then it can sink up to 80 ma if its inputs are overdriven, giving even larger FAN OUT capability.

The Bi-Stable Multivibrator.

This is also known as an asynchronous RS flip-flop, or latch. The LM 3900 can be used in this function by connecting it in this simple circuit. See Fig. 4.13. Note carefully that R_4 provides positive feedback to the + ve input, and that its value is half that of R_1. It is this which causes the latching action.

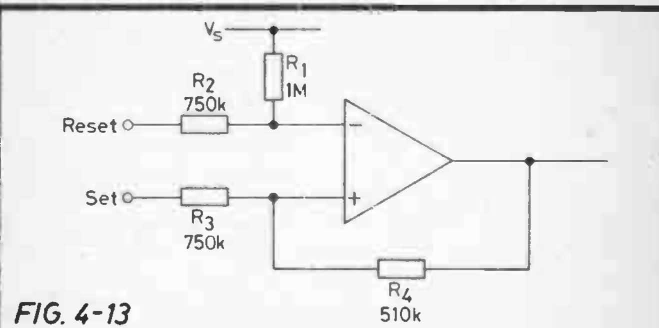


FIG. 4-13

A positive pulse at the set input will cause the output to go high, and the latching action will keep the circuit in this steady state after the input pulse is removed.

A positive pulse at the reset input will send the output low, where it will remain until another positive pulse is received at the set input.

The amplitude of the input pulse must be above the 0.5v DC level of the inputs to the LM 3900, and it must be sufficiently above this to cause minimum I_m to flow into the inputs. Usually this is not a problem as the input pulses meet this condition. If they do not, another LM 3900 can be used as a simple amplifier to obtain pulses which will work. For the values given in Fig. 4.13, the input pulse needs to be about 3.75v for the circuit to work.

Although this will work with pulses as short as a miscrosecond, it is intended for pulses of much longer duration.

The Comparator

A comparator is a circuit which compares the relative levels of two inputs signals. The output then changes very fast from one digital state to the other when the input signal passes through some reference level.

Comparators are used extensively in D/A and A/D converters, and in many other industrial circuits, such as alarm sensors, etc. They provide a link between the analogue outside world and digital circuitry, which is their most important use.

The LM 3900 is a very good slow speed comparator. It has a very high open loop gain, which enables it to switch output states for very small input changes, and all it needs is only two resistors to make a complete comparator.

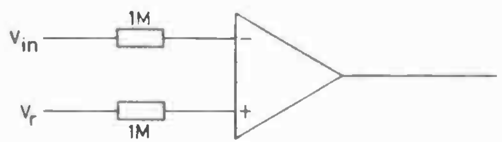


FIG. 4-14

In Fig. 4.14, all the while the input voltage is more positive than the reference voltage the output is low.

If the input drops below the reference level, then the output quickly jumps to a logical 1 – or very close to the supply voltage

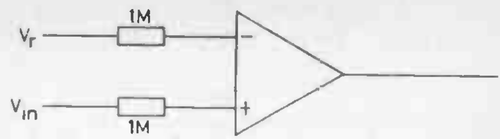


FIG. 4-15

In Fig. 4.15 the output is 0 as long as the input is below the reference. If it rises above this level, then the output jumps to a 1.

The reference voltage can be any chosen value between 1v above ground and about 1v less than the supply voltage. It should be very stable and well filtered.

The only restriction on this circuit is that the input voltage must overcome the 0.5v input to the LM 3900. Provided it will do this then the input resistors can be chosen to ensure the input currents remain within the 5-100 μa range.

A Negative Input Comparator

The previous comparator was restricted in that its input voltage has to be between about 1v and the supply voltage level. The circuit of Fig. 4.16 allows voltages between Ov and 1v at the input, and will also permit small negative input voltages.

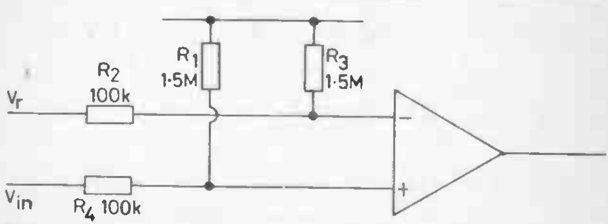


FIG. 4-16

When a negative input voltage is used, the current supplied by R_2 must satisfy the current requirements of the negative voltage source as well as the input to the LM 3900

Negative Comparator Design Procedure

The design of a negative comparator is quite easy. It is merely a matter of balancing the input currents and it also provides a good approach to digital circuit design using the LM 3900.

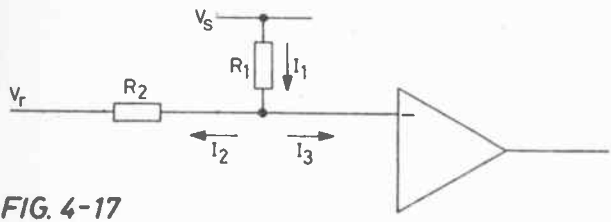


FIG. 4-17

In Fig. 4.17, V_r is the negative reference voltage. To design the circuit the currents shown can be any convenient value. To make things easy, we will make $I_2 = I_3 = 50\ \mu a$, as a good design centre value. Please understand that any other values can be used.

now, $I_1 = I_2 + I_3$

so $I_1 = 100\ \mu a$

The resistors can be easily found from:–

$$R_1 = \frac{V_s}{100\ \mu a} \qquad R_2 = \frac{V_r + 0.5v}{50\ \mu a}$$

Now install 4 resistors in the circuit with $R_1 = R_3$ and $R_2 = R_4$ This will balance the input currents, and the output will change when V_{in} passes through V_r.

A simple example will illustrate this procedure.

With a 9v supply, design a comparator which will change state at – 3v input.

If – 3v is to be trigger level, then it is a good idea to make this the reference level also.

Then:–

$$R_1 = \frac{9v}{100\,\mu a} = 90\,K$$

$$R_2 = \frac{3v + 0.5v}{50\,\mu a} = 75\,K$$

Use 91K and 75K as these are the nearest standard values.

Using the nearest standard values will alter the input currents slightly from the chosen value, and due to resistor tolerances the output will change at an input voltage which may be a little different from the chosen level. If accuracy is essential then one of the input resistors must be variable or trimmed, or precision resistors must be used. Fig. 4.18 shows this circuit.

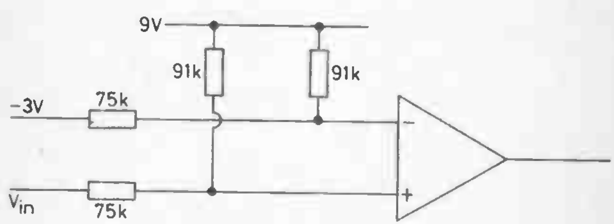


FIG. 4-18

The Phase Comparator

The previous comparators were all working with a static DC reference voltage and a varying DC input voltage. A phase comparator is the same circuit, but which has two pulse trains as its inputs. The output is a pulse width modulated waveform. This can be filtered to provide a DC level which is a measure of the phase difference on the two inputs.

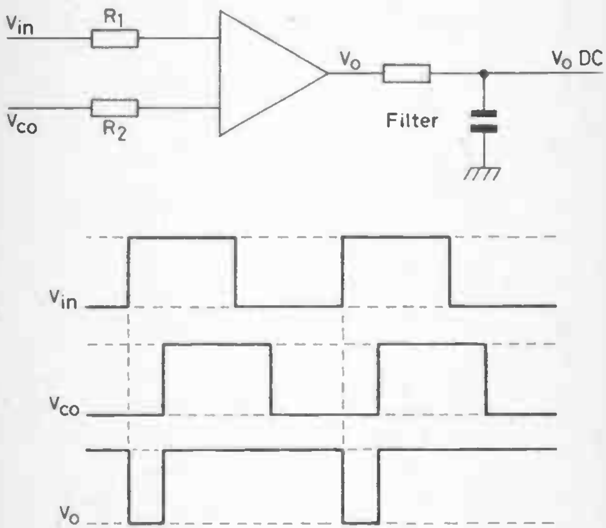


FIG. 4-19

In Fig. 4.19, R_2 is smaller than R_1, so that the + input inhibits the – input. The waveforms are shown in Fig. 4.19. When filtered, the DC output will range from $V_s/2$ up to V_s as the phase difference changes from 0 to 180 degrees.

These are most important circuits in modern electronics, and are an essential part of the phase locked loop.

The Schmitt Trigger

A Schmitt Trigger can be viewed as a comparator with hysteresis – in other words, the upper and lower trip points are at different voltage levels.

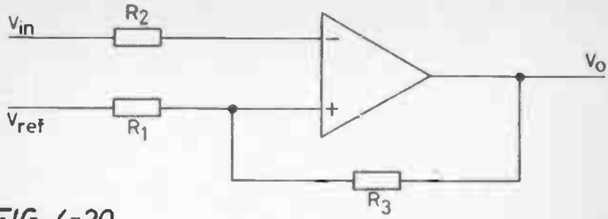


FIG. 4-20

Fig. 4.20 shows an inverting Schmitt trigger using an LM 3900. The reference voltage can be almost anything desired, but in order for the upper trip voltage to be reached the sum of I_1 and I_2 must be less than I_3.

Simple formulae for the upper and lower trips points are:–

$$L = V_r \cdot \frac{R_2}{R_1}$$

$$U = V_r \cdot \frac{R_2}{R_1} + V_o \cdot \frac{R_2}{R_3}$$

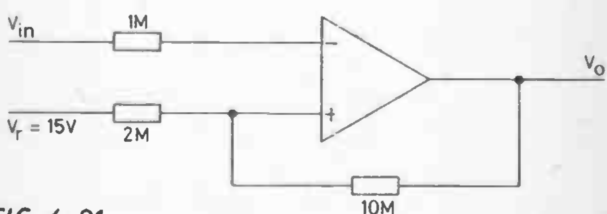


FIG. 4-21

The circuit of Fig. 4.21 gives practical values with L = 8v and U = 9.5v.

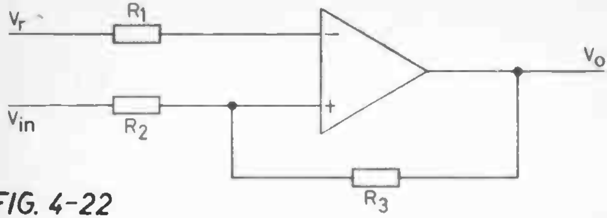


FIG. 4-22

In contrast, Fig. 4.22 is a non inverting Schnitt trigger. It is slightly different from the above version. In this I_3 must always be less than I_1, otherwise V_{in} will not reach the lower trip point. Again simple formula give the trip points:–

$$U = V_r \cdot \frac{R_2}{R_1}$$

$$L = V_r \cdot \frac{R_2}{R_1} - V_o \cdot \frac{R_2}{R_3}$$

The values in Fig. 4.23 give L = 2v and U = 13v.

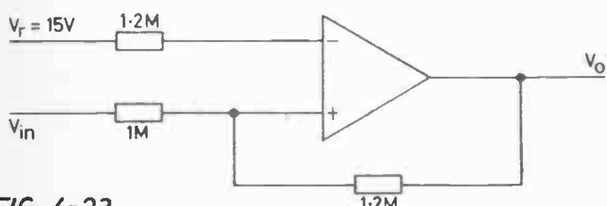


FIG. 4-23

Outside World Interfacing and Power Circuits

The LM 3900 is not a power device.

Because of its input current limitations and its high output impedance it is unsuitable for connecting to or directly driving many other devices or circuits.

It can be used as a low power buffer, where only a small microamp range current may be drawn from a source, and where the load requires a few milliamps.

Although it will illuminate a low current lamp or an LED directly, the LM 3900 must be buffered with one or more transistors when driving a device which needs more power. A similar situation exists in audio circuits where an output stage is required between the LM 3900 and a speaker.

Typical output currents for the LM 3900 at 25°C are:–

10 ma with V_O high
30 ma with V_O low
80 ma with V_O low and the – input overdriven.

For higher chip temperatures, these currents must be derated.

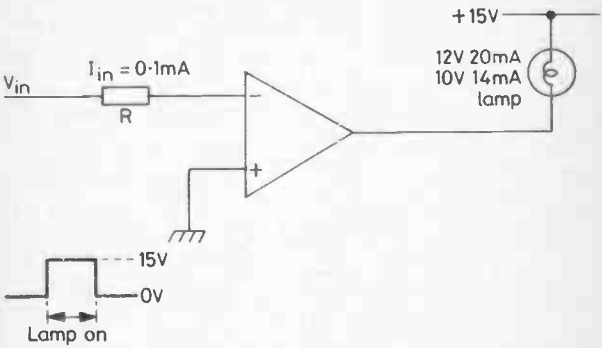


FIG. 4-24

A simple lamp driver is shown in Fig. 4.24, and this is also suitable for a low power reed relay, For a larger power lamp or heavy duty relay, an external driver is needed.

Fig. 4.25 is a typical simple circuit, with usable values.

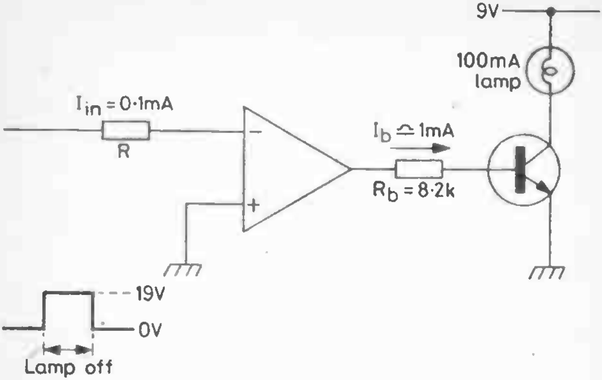


FIG. 4-25

In this circuit, when the output of the LM 3900 goes low, it does not quite reach ground – typically it is 0.5v. This should turn the transistor off and extinguish the lamp, but it is a borderline case which is very susceptible to nosie. A silicon diode in the emitter lead will improve matters. Fig. 4.26.

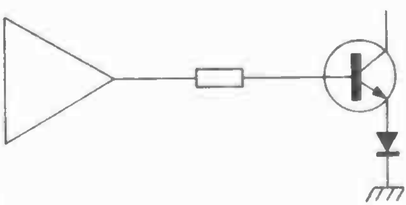


FIG. 4-26

This circuit will work for a wide range of supply voltages and many lamps. The table gives some common lamps (Chicago Miniature Lamp Numbers), and the operating voltages and currents. Assuming a transistor with a B = 100 and which will safely pass about 300 ma (2N3643) is used, then the final column shows the value of R_b which will work.

Lamp	V	ma	Lamp res	R_b
1471	12	260	46	4.6 K
328	6	200	30	3 K
330	14	80	175	16 K
344	10	14	714	70 K
327	28	40	700	68 K

A slightly different but very useful circuit is that in Fig. 4.27.

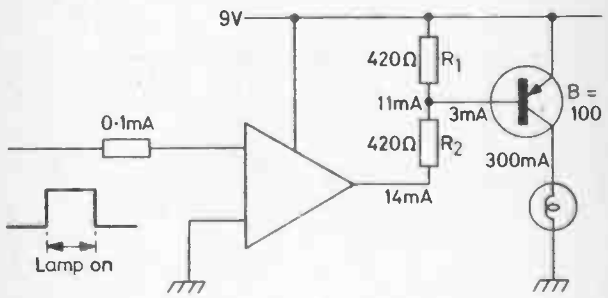


FIG. 4-27

When the LM 3900 output is high the R_1 and R_2 will both hold the transistor off. When the LM 3900 output is low, R_2 limits the base drive but still allows the transistor to turn on. Note that Pin 14 of the LM 3900 is tied to the same voltage which supplies the emitter. It must be at least this high for reliable operation.

Fig. 4.28 is an alternative connection of the two resistors. Different values are given so that when these two circuits are tried, it will broaden the users experience. Both circuits can be improved by a diode in the emitter lead.

Suitable transistors for these circuits are:–

NPN:	2N2219	2N3643	2N3904
PNP:	2N2905	2N3638	2N3906

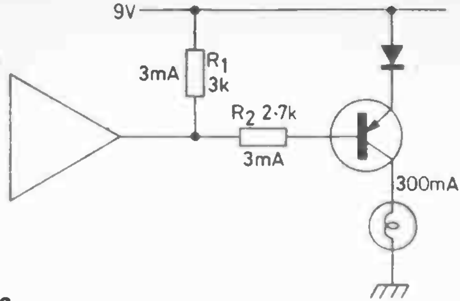


FIG. 4-28

SECTION 5 : SIGNAL GENERATOR CIRCUITS

These are digital and linear circuits which produce a variety of output waveforms. The circuits of the previous two sections operated on input signals; those here will both operate on input signals and generate outputs without an input signal. In all cases, only one LM 3900 amplifier is used, the circuits are a little more advanced than those seen up to now. In most cases the output is independent of the supply voltage, and in all cases the output frequency is limited by the slew rate of the LM 3900 (0.5 v/μsec).

The Positive Output One-Shot

A simple 'one-shot' with a positive pulse output can be made with one LM 3900. Fig. 5.1 shows the circuit.

R_2 keeps the output low until a positive pulse arrives at the input. This is differentiated by C_2 and the positive going edge

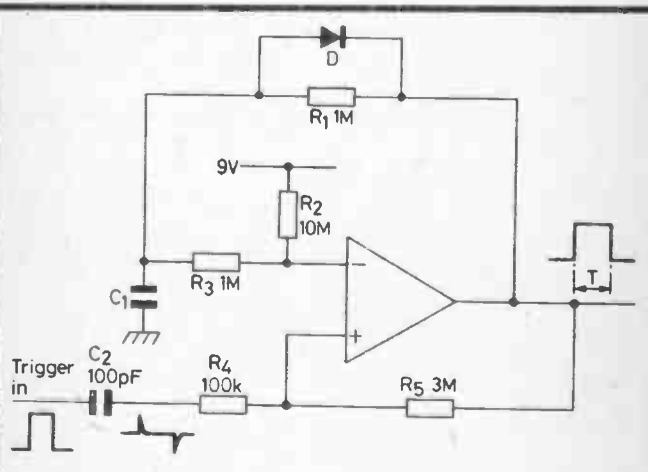


FIG. 5-1

triggers the circuit. When the output goes high it is latched in this condition by R_5.

The high output now begins to charge C_1 through R_1. When C_1 reaches about $V_s/4$, then the current through R_3 is sufficient to cause the output to go low again.

C_1 now discharges through D and the output circuit of the LM 3900. This is a very fast discharge, so re-triggering can be very rapid.

The output pulse width is approx:–

$$T = \frac{R_1 C_1}{3}$$

The Negative Output One-Shot

The circuit of the Fig. 5.2 is a simple one-shot with a negative going output pulse.

The sum of the currents through R_2 and R_3 keeps the output high, so C_1 is fully charge through D. A differentiated negative input pulse will cause the output to change.

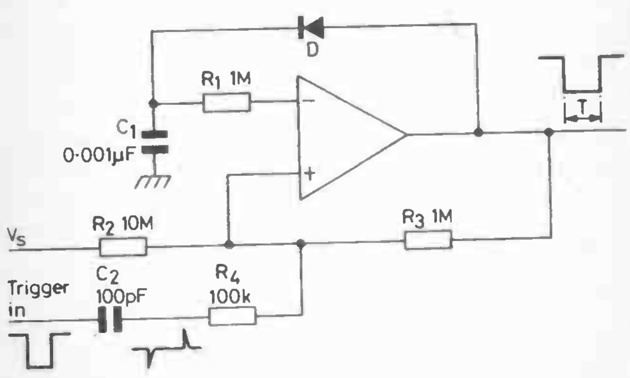


FIG. 5-2

C_1 now begins to discharge through R_1 into the – input. When its voltage drops to about 1/10 of the supply voltage it cannot then supply sufficient current to this input, and the output goes high again. The output remains stable until the next trigger, which can occur after the rapid charge of C_1 through D.

R_2 and C_4 can be moved to the – input so that this circuit can be triggered on a positive edge.

The output pulse durations is:–

$$T = 3 \cdot R_1C_1$$

An alternative circuit is given in Fig. 5.3.

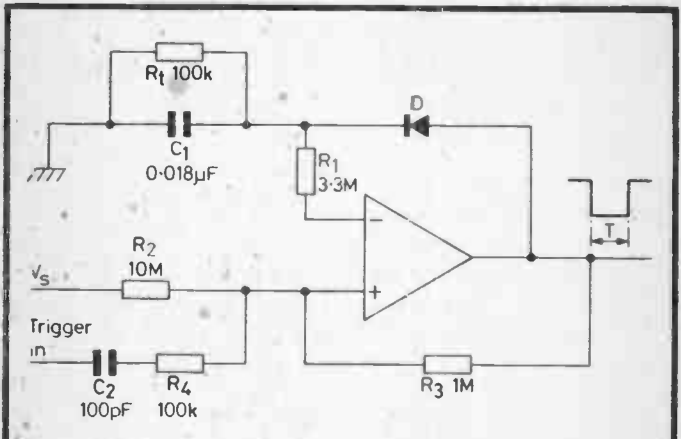


FIG. 5-3

The pulse duration here is given by:–

$$T = 1.1\ R_tC_1$$

The advantage of this circuit is that the time can be easily changed by varying R_t, which is not part of the LM 3900 biasing circuit. As one end is connected to ground the other end only need be switched to change values. This makes using a variable resistor or remote control very easy. See Fig. 5.4.

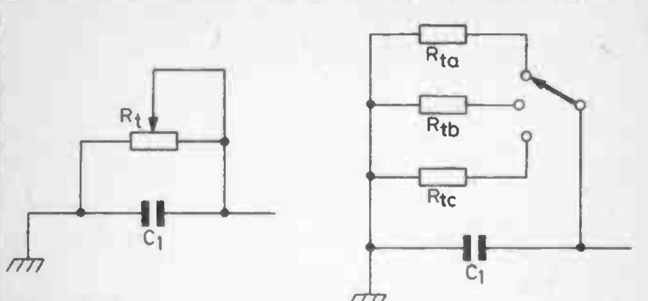


FIG. 5-4

The Astable Multivibrator.

The LM 3900 can be used as an astable multivibrator. There are two versions of this circuit; the first produces symmetrical – or square – waves, the other produces asymmetric pulses.

The Square Wave Generator

Fig. 5.5 shows a simple circuit which will produce a continuous output. C_1 alternately charges and discharges through R_1. The output voltage DC limits are set by R_2, R_3, R_4, as

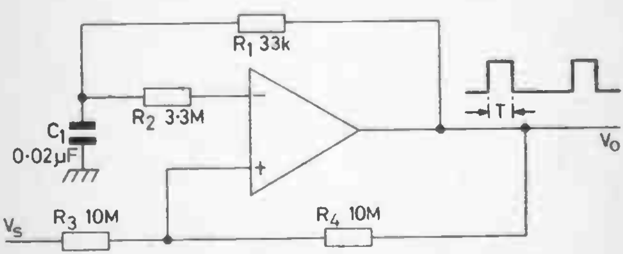


FIG. 5-5

they are in the Schmitt Trigger. Symmetry is obtained by adjusting the trip point voltages.

For symmetry, or a square wave output $R_2 = R_3/3$ and $R_3 = R_4$. For best results R_1 should be much less that R_2, then R_2 will not affect the timing.

The voltage output extremes are given by $V_s/3$ and $2V_s/3$.

The period is given by $T = 1.4\ R_1C_1$

This is a good circuit for low frequencies, but not for high. High frequencies are limited by the slew rate of the LM 3900.

With the values shown it will have an output of about 1 khz.

The Asymmetric Astable

By adding a diode to the previous circuit an asymmetric output can be obtained. The capacitor charges through the 39K and discharges through the 150K into the input of the LM 3900. This can be seen in Fig. 5.6.

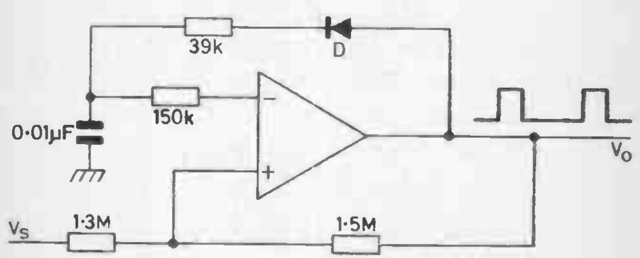


FIG. 5-6

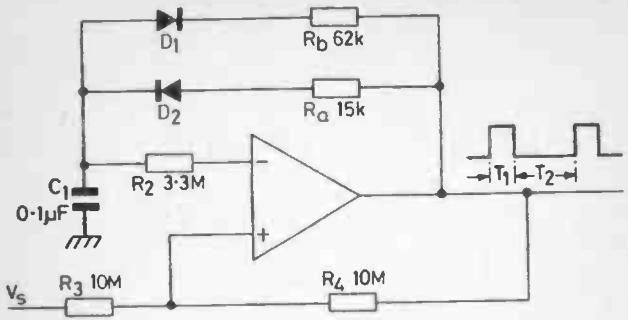


FIG. 5-7

Fig. 5.7 shows a more refined method of achieving an asymmetric output. The charge and discharge paths are controlled by the diodes, and R_a and R_b set the times. The periods are given by:–

$$T_1 = 0.7\, R_a\, C_1$$

$$T_2 = 0.7\, R_b\, C_1$$

With the values in this circuit, T_1 = 1 ms and T_2 = 4 ms.

The variation in Fig. 5.8 will alter the duty cycle of the output but will maintain the frequency constant.

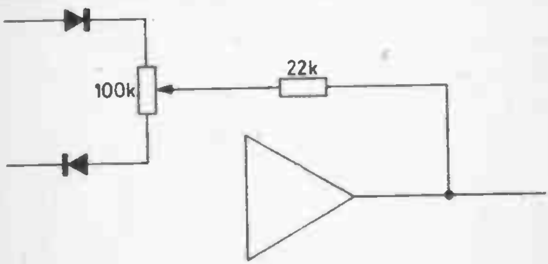


FIG. 5-8

A 'Programmable Unijunction'.

A programmable unijunction can be simulated with the LM 3900. Basically it is a Schmitt Trigger circuit with a diode added. Fig. 5.9 shows this.

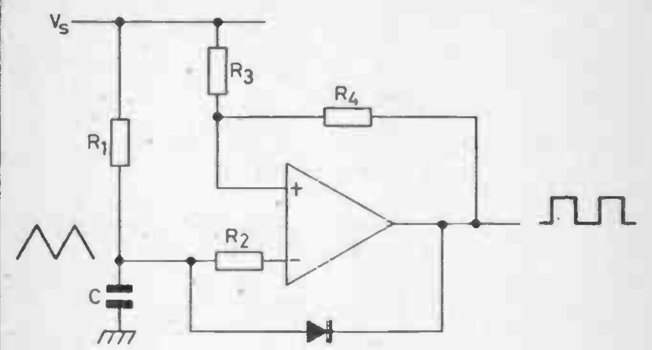


FIG. 5-9

When the input voltage is low, the output is high and the diode is back biased. When the input reaches the upper trip point the output falls to Ov and C discharges through D.

The low trip point must be above 1v to ensure the forward drop across the diode which is added to the output voltage will be less than the low trip voltage.

The discharge current can be increased by using lower values of R_2. The trip voltages are designed as shown in the Schmitt trigger paragraph.

The Trigger Flip-Flop

This circuit will divide an input frequency by 2. Fig. 5.10 shows a typical set of values. This is for asynchronous logic applications, as there is no clock pulse.

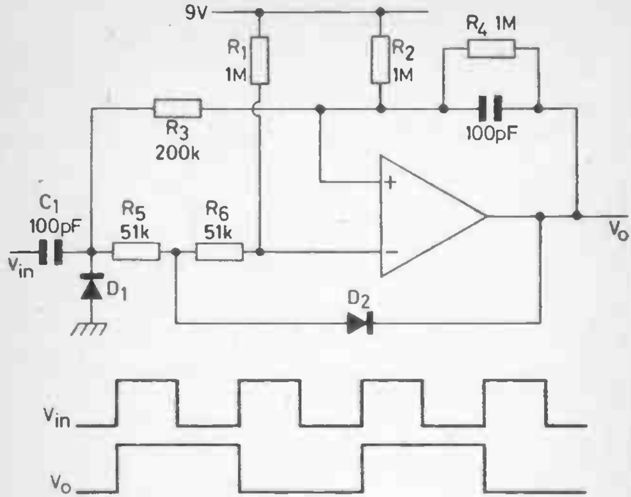


FIG. 5-10

The input pulse is differentiated, and then steered by D_2. When the output is low, the input pulse is steered to the + input. By comparing the input and output waveforms, it will be seen this circuit will transform an asymetric pulse train into a square wave.

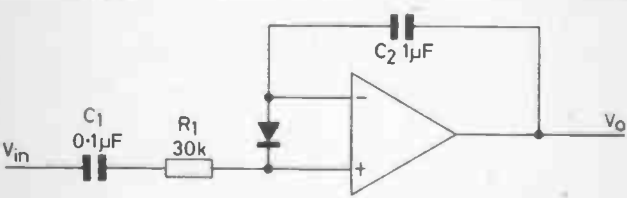


FIG. 5-11

The Staircase Generator

If the ramp or sawtooth circuit of the previous section is used, and the input is a short pulse, then the output will only have time to describe part of the full ramp voltage. Fig. 5.11 gives a typical circuit for this application.

If the input is a series of pulses, then the output will be several parts of the ramp, one on top of the other, and separated by the time interval between the pulses. Fig. 5.12 explains this. This will continue until the maximum output is reached. The staircase output can only be repeated after a reset pulse is applied and the output returns to ground.

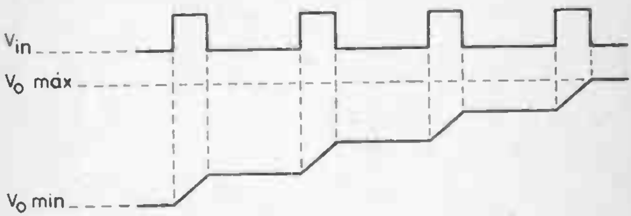


FIG. 5-12

R_1 must be a low value resistor so that C_2 charges rapidly, and the output steps rise in a short time. This allows short input pulses to be used.

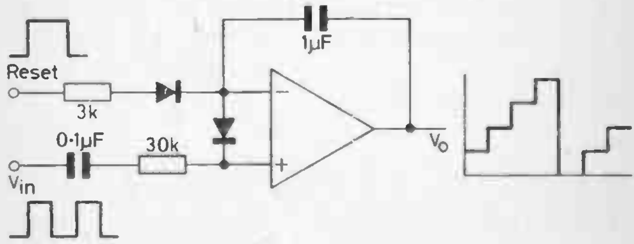


FIG. 5-13

Fig. 5.13 shows a staircase generator with reset.

The Basic Tachometer Circuit

This is a variation on the previous simple circuits. It is shown in Fig. 5.14.

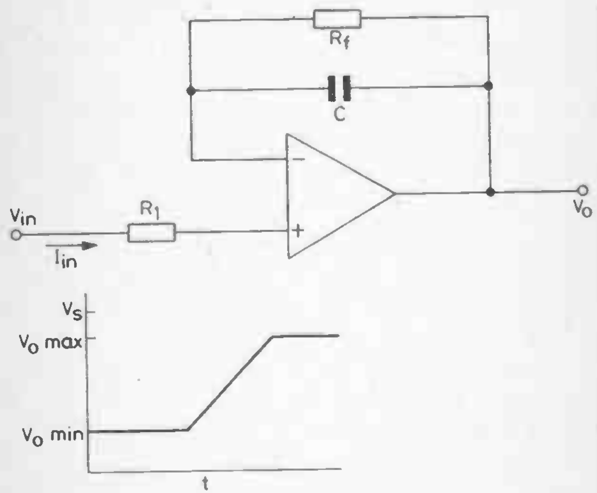


FIG. 5-14

The input can be either current or voltage pulses, or differentiated square waves. The DC output can be made to increase with increasing frequency; and it can be made proportional to twice the input frequency, or the sum or difference of two input frequencies.

Due to the small bias currents and the high gain, the output is a fairly linear function of the input.

Each input pulse causes a small change in the output, and this relationship is usually quoted:–

$$\Delta V_o = \frac{I \Delta t}{C}$$

The Resistor R gives a discharge path which prevents the output causing continued integration and it also provides a time dependency which is necessary to average the input pulses.

Inputs can be applied to the – input, but a diode must be placed in series, as in Fig. 5.15.

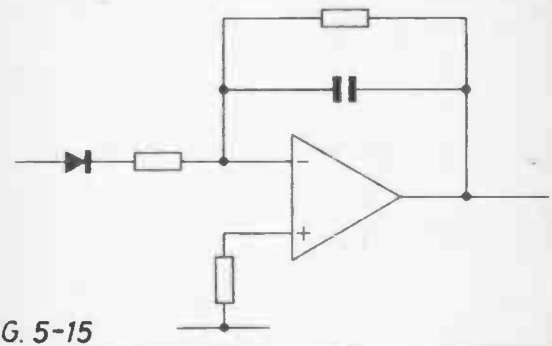


FIG. 5-15

In most cases the component values are best determined experimentally to fit the case in question.

SECTION 6 : SPECIAL APPLICATIONS

There are many applications for the LM 3900 which do not neatly fit any of the previous categories, but often are combinations of the ideas presented in them.

To design the LM 3900 into circuits for unusual or specific applications requires a good knowledge of how it works and behaves, and the circuits shown here should help the reader in widening the basic knowledge gained in the previous sections.

Any circuits the reader may design himself should, like those here, observe the restrictions on I_m and the output current.

All the circuits shown here should be built and made to work by the reader. Although those shown here may not be directly usable in anything the reader may by constructing them demonstrate principles which can be used in a wide variety of applications.

Amplifier with DC Gain Control

A DC gain control can be added to an LM 3900 amplifier as shown in Fig. 6.1.

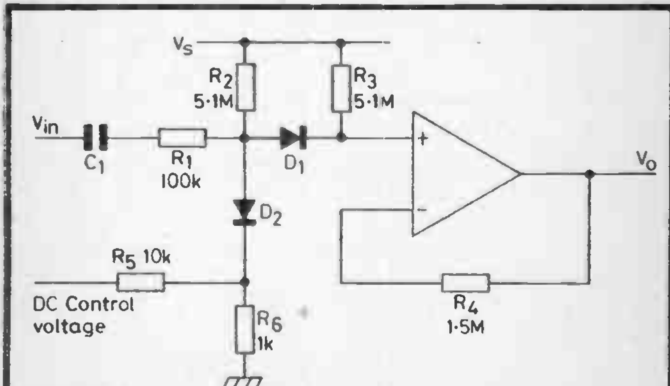


FIG. 6-1

Varying the DC gain control from Ov to near 10v will vary the gain from minimum to maximum. The maximum gain is about 15. At minimum gain the DC output voltage is near 0.3v, and at maximum gain it is near 0.6v. Because of this, this circuit is for small input signals only. The DC output level changes as the gain control is changed.

A Squaring Amplifier

This circuit, Fig. 6.2 is useful for various types of variable reluctance transducers. The input resistors convert the voltage outputs to currents, and common mode biasing is accomplished with R_{b1} and R_{b2}. R_f provides positive feedback and hysteresis.

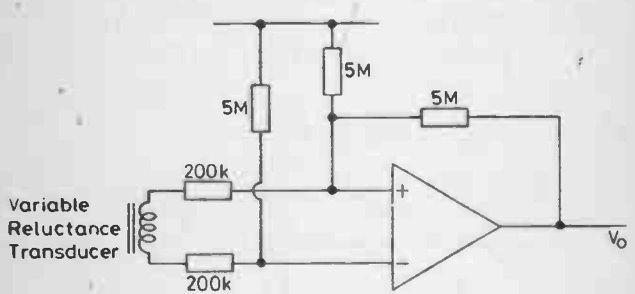


FIG. 6-2

The large source resistance and the 'Miller' input capacitance of the LM 3900 (approx 0.002 μf) provide high frequency roll off.

With the values shown the trip voltages are about ± 150 mv centred around zero.

A Peak Detector

Peak detectors are useful for many purposes. Fig. 6.3 shows a simple circuit using one LM 3900. The peak of the signal charges the capacitor to the peak value. The diode prevents loss due to temperature drifts in the output voltage. R_b allows DC voltage too exists across the capacitor. The value of R_1 can be selected to provide gain if required.

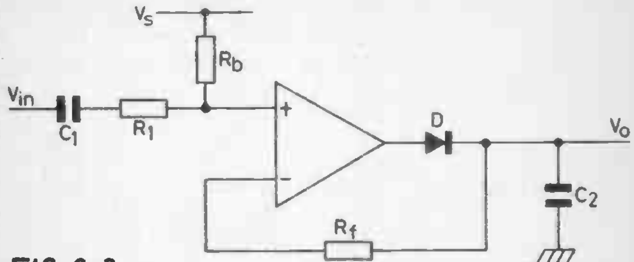


FIG. 6-3

A Differential Input Stage

A differential input stage can be added to the input of the LM 3900, Fig. 6.4 shows this. This will increase the gain and reduce the offset voltage. Frequency compensation can be added with a feedback capacitor, as shown. In many cases

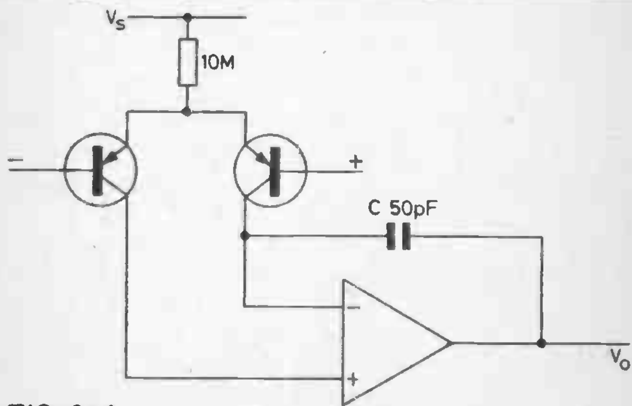


FIG. 6-4

where large input voltage swings are expected, large resistors should be added to the base circuits of the two input transistors.

The two transistors must not be allowed to saturate as this can cause a latching of the LM 3900.

Two variations to this circuit are to use FETs; and to use it with split 15v power supplies.

High Voltage Circuits

Although the maximum supply voltage of the LM 3900 is 36v, it can be used to control transistors which have higher power supply voltages. This is very useful in cathode ray tube deflection circuits, for example.

A High Voltage Inverting Amplifier

The output of this circuit Fig. 6.5, will swing from almost Ov to the full 300v. The biasing resistor R_3 is used to centre the transfer characteristic of the circuit for best linearity. The gain is given by the ratio of R_2 to R_1. To reduce current drain from the power supply R_c can be increased.

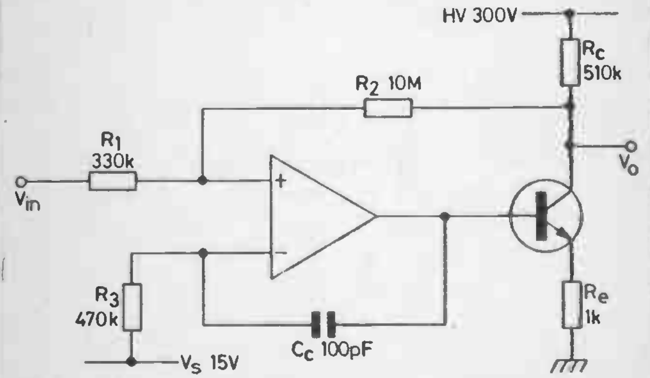


FIG. 6-5

A High Voltage Non Inverting Amplifier

This is shown in Fig. 6.6. Common mode biasing with R_2 (two of them) is used so that the input can go to Ov. R_E will prevent the output actually reaching Ov, but it will get to about 0.3v.

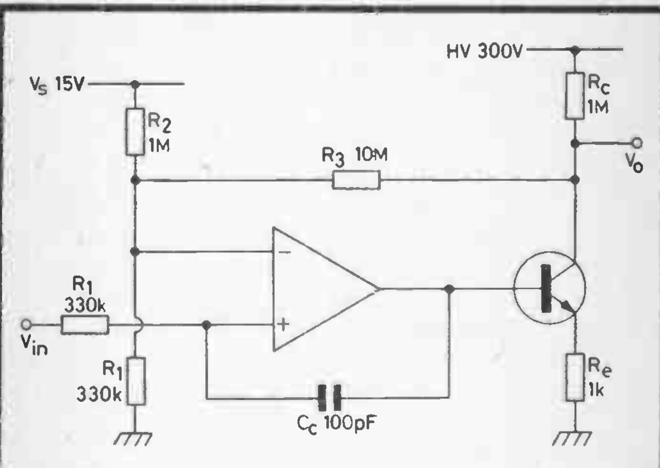


FIG. 6-6

The gain is 30 (ratio R_3 to R_1) and an input voltage range of 0v to 10v will drive the output from 0v to 300v.

A Low Frequency Mixer

Mixing two frequencies to produce sum, difference and other components is possible by using the diode at the + input for non linear mixing. Gain and filtering can also be accomplished with just one amplifier, as in the circuit of Fig. 6.7.

The two feedback components R_f and C_f form a low pass single pole filter. With the components shown here it has a corner frequency of 1Khz and a gain of 10.

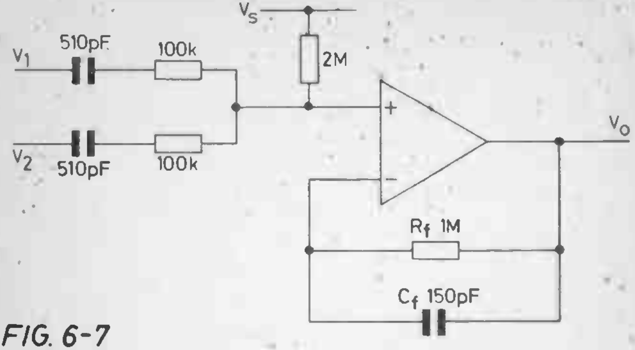


FIG. 6-7

Two signals are applied to the + input. V is larger in amplitude than V_2, and the difference frequency appears at the output. Relatively high frequencies can be applied to the input, but the difference frequency must be within the bandpass of the amplifier and low pass filter.

Tachometer Variations

Two interesting variations on the basic tachometer circuit are easily achieved with the LM 3900. Fig. 6.8 is a frequency differencing circuit, in which the DC output voltage is a function of the difference between the two inputs. Fig. 6.9 is

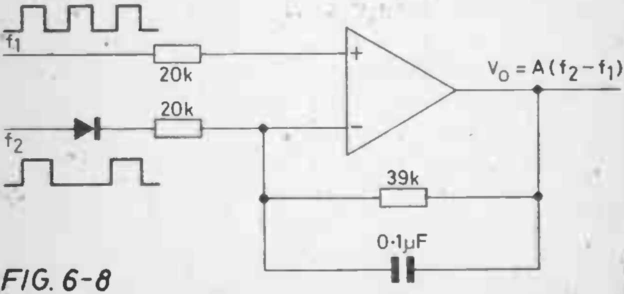


FIG. 6-8

a frequency averaging circuit, in which the DC output is proportional to the sum of the two inputs.

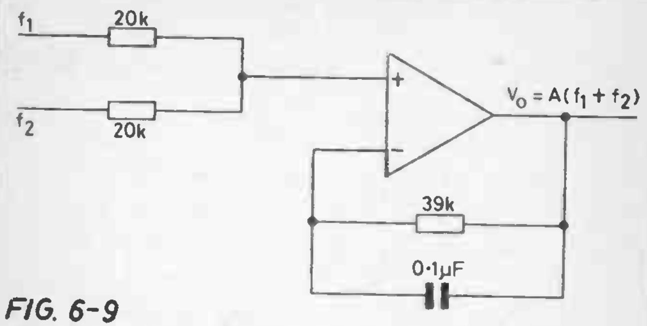


FIG. 6-9

Current Sources

The output current from the LM 3900 is limited and it has already been observed that it is not a power device. But its ability to control an external transistor makes it useful in power circuits. Here are shown some current source and sink circuits which are controlled by the LM 3900.

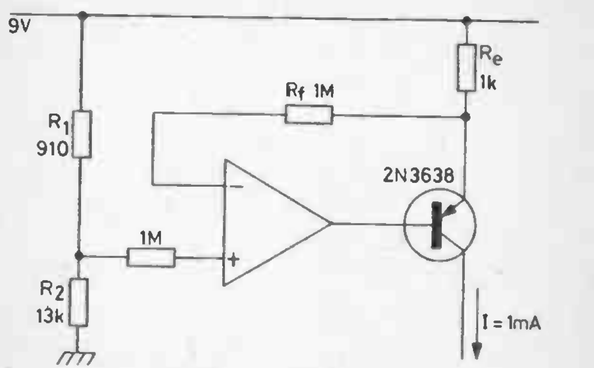


FIG. 6-10

Fig. 6.10 is a simple fixed current source. R_1 and R_2 establish a bias point, and R allows the output voltage to settle at this same point. The voltage drop across R_1 is in effect the same voltage drop across the emitter resistor. With the values shown this is about 1v, and so the current is 1 ma.

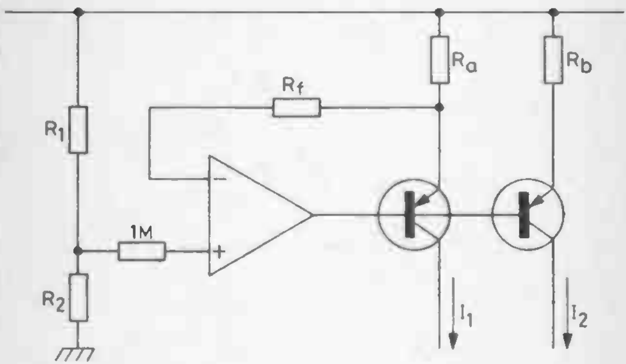


FIG. 6-11

Fig. 6.11 is an extension of the above circuit. The second transistor acts as another current source, and the choice of its emitter resistor will govern the current level. The relationship between the two currents is given by:–

$$I_2 = I_1 \cdot \frac{R_a}{R_b}$$

A slight variation in the circuit produces Fig. 6.12. Now the amount of current is controlled by the input voltage.

By using an NPN transistor a current sink can be made. Fig. 6.13 shows this.

Current sources and sinks find applications in areas where high gain may be required from a transducer which has a low output voltage. By loading the transducer with a constant current device a larger output voltage swing can be obtained.

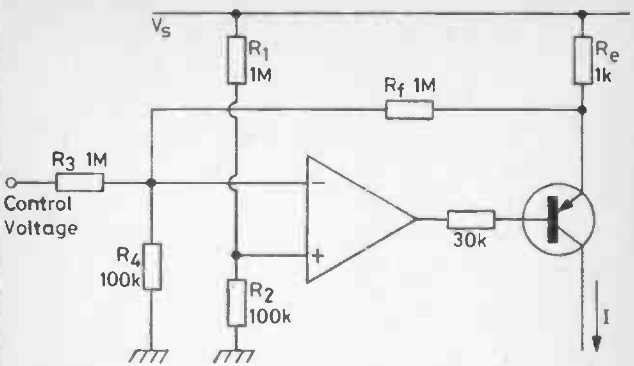


FIG. 6-12

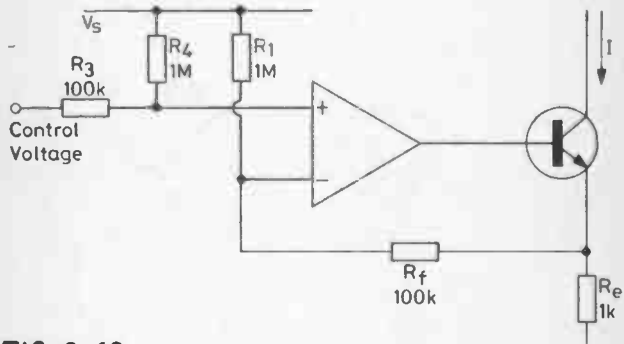


FIG. 6-13

APPENDIX : THE LM 3900 CIRCUIT

The basic circuit of the LM 3900 is shown in Fig. A.1. Q1 is the basic amplifier, and Q2 is a constant current load which enables gains in excess of 60 db to be achieved. Q3 is an emitter follower output, with a constant current load provided by Q4. Q3 can operate from cut off to almost saturation, hence the output voltage can range from very near 0v to almost V_S.

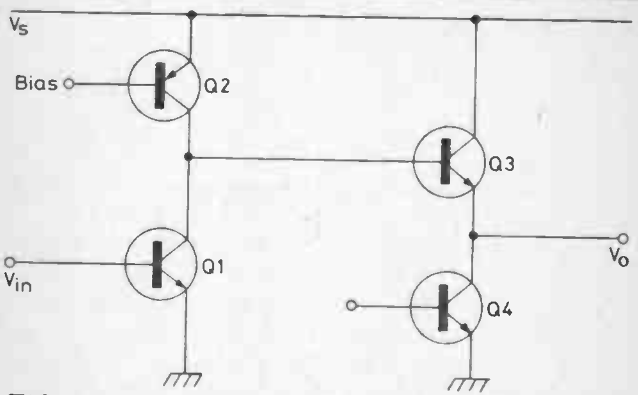


FIG. A-1

Hence the best DC output point is half way between these two extremes – at $V_S/2$.

Gain and bias are provided and controlled by R_f as in Fig. A.2. But here the LM 3900 is different from the conventional op-amp as DC current flows through R_f from the output to the input transistor Q1. This current I_f is given by:–

$$I_f = \frac{V_o - V_{be}}{R_f}$$

Now if the output voltage is half the supply voltage, and it is much greater than V_{be}, this expression simplifies to:–

$$I_f = \frac{V_s}{2R_f} \qquad \text{as } V_o = V_s/2$$

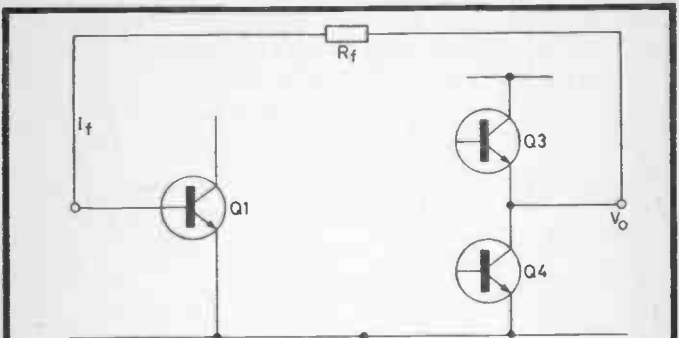


FIG. A-2

This current is far too large a base current to be used for biasing Q1, and most of it must be diverted. This is the function of Q5 in Fig. A.3. The collector current of Q5, I_c is almost all of I_f, and this is controlled by the base current of Q5. This base current is provided by R_2, and it again is far too much, and so most of it is diverted through the diode D. So the current through the diode is made equal to I_c – in other words it 'mirrors' it.

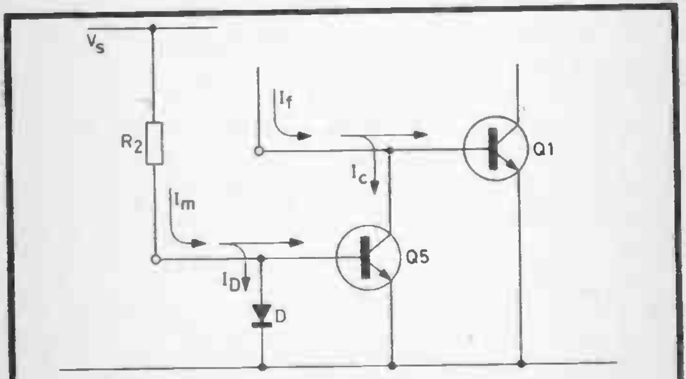


FIG. A-3

If R_2 is connected to the supply voltage, then:–

$$I_d = \frac{V_s}{R_2}$$

Now, as I_d is the same as I_c, it is effectively the same as I_f. So I_d is a 'mirror' current of I_f – which is why it is usually labelled I_m.

So, $$I_m = \frac{V_s}{R_2}$$

and $$I_f = \frac{V_s}{2R_f}$$

so $$\frac{V_s}{R_2} = \frac{V_s}{2R_f}$$

which gives
$$R_2 = 2R_f$$

As this was all based on $V_o = V_s/2$, then this relationship between these two resistors will provided this output voltage.

By following the signal path it can be seen that R_f is connected to the inverting input, and a signal at the other input, Q5, will be non inverted at the output.

IC manufacturing techniques make it very easy to put many transistors in a small space, and allow several unique circuits to be used. As with all ICs the LM 3900 takes advantage of this, especially in the constant current circuits and their biasing to produce the complex looking final circuit. But the basis of its operation as a high gain amplifier, biased to $V_s/2$, is as simple as the above description.

Notes

Notes

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A must for any electronic enthusiast's library.

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IC LM3900 Projects

- The purpose of this book is to introduce the LM3900 to the Technician, Experimenter and Hobbyist. It provides the groundwork for both simple and more advanced uses and is considerably more than just a collection of simple circuits or projects.

- The LM3900 is different from conventional 'Op-Amps'; it can be used for many of the usual applications as well as many new ones. It is one of the most versatile, inexpensive and freely available devices on the market today.

- The book is divided into six basic sections:—

  Introduction
  Audio Applications
  Simple Linear Applications
  Simple Digital Applications
  Signal Generator Circuits
  Special Applications

- The LM3900 can do much more than is shown here — this is just an introduction. Imagination is the only limitation with this useful device, but first the reader must know the basics and that is what this book is all about.

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