Module

3

Amplifiers

Negative Feedback

Introduction to Negative Feedback

What you'll learn in Module 3.

Section 3.0 Introduction to NFB.

• The use of negative feedback in amplifiers.

Section 3.1 NFB and Gain.

• Controlling amplifier gain using NFB.

Section 3.2 NFB and Impedance.

• Using NFB to control Input and Output Impedance.

Section 3.3 NFB, and Noise.

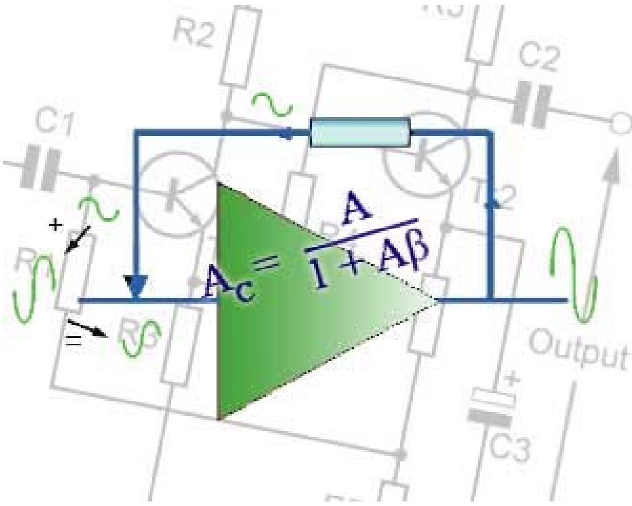
• Using NFB to Reduce Noise in amplifiers.

Section 3.4 NFB, and Distortion.

• Using NFB to Reduce Distortion in amplifiers.

Section 3.5 NFB Quiz.

• Test your knowledge & understanding of negative feedback.



Negative Feedback

Negative feedback is the technique of sampling some of the output of a device or system and applying it back to the input. This makes the input partly dependent on the output, and in doing so makes it possible to exert very fine control over whatever process is being carried out by the system.

NFB With Everything!

Negative feedback is almost as old as machines, and is used in just about every possible process where some control over the output is necessary. Cans of beans may be weighed as they come off a production line and if there is any difference between the weight measured and the ideal weight, the number of beans per can will be automatically adjusted further back in the process to maintain a constant weight.

Manufacturers launching a new product will test public reaction to a small sample of their product by asking prospective buyers for their opinions, and adjust the product design as a result of the feedback. Anything from a builder repeatedly checking that the layers of bricks are level as he builds the wall, to an aircraft landing safely at the correct point on the airport runway is an example of feedback in action.

Positive and Negative Feedback

There are two types of feedback commonly used in electronic circuits, positive (regenerative) feedback and negative (degenerative) feedback. Positive feedback is primarily used in electronic oscillators, it increases gain (and distortion if not properly controlled) and narrows bandwidth to such a degree that it can be the primary reason for oscillators to work at a single frequency, rather than a band of frequencies.

This module describes the application of negative feedback in amplifiers, where its use provides a number of very useful attributes that improve the performance of the amplifier.

Module 3.1

Negative Feedback and Gain

What you'll learn in Module 3.1.

After studying this section, you should be able to:

Understand the basic principles of NFB as applied to amplifiers.

- Open loop gain.
- Closed loop gain.
- The relationship between β and gain.
- Reasons for using Negative Feedback.

Why NFB is needed in amplifiers

Transistors cannot be manufactured to have a closely controlled value of current gain h_{fe} therefore it should not be possible to build a number of examples of the same amplifier circuit, all having the same gain. In addition the gain of a transistor varies with temperature, and even has different gain at different frequencies. All of these factors would make transistor amplifiers totally unreliable and impossible to make in large numbers. The main reason that this situation does not exist, and transistor amplifiers have become the mainstay of the electronics industry is the introduction, very early in the transistor's history, of negative feedback.

Principle of NFB

The principle of negative feedback is that a portion of the output signal is fed back to the input and combined with the input signal in such a way as to reduce it. This reduces the overall gain of the amplifier but also introduces a number of benefits, such as reducing distortion and noise, and widening the amplifier's bandwidth.

Problems with NFB

Introducing feedback within a system can also introduce the possibility of instability; in amplifiers the signal will normally undergo a phase reversal of 180 degrees between input and output but reactive components such as capacitors and inductors, whether actual components or 'stray' capacitance and inductance, can introduce unwanted phase changes at particular (usually high) frequencies. If these additional changes add up to a further 180 degrees at any frequency where the transistor has a gain of more than 1, the application of negative feedback may become positive feedback. Instead of reducing gain this will increase it to the point where the amplifier will become an oscillator and produce unwanted signals. Negative feedback must therefore be designed to maximise the benefits mentioned above, without creating unwanted problems.

The Amplifier in Open Loop Mode

Fig. 3.1.1 shows a phase reversing volta; feedback, which can be called A_o (Ampl 1mV is applied, then the output will be a $A_o = A_o$(mV).

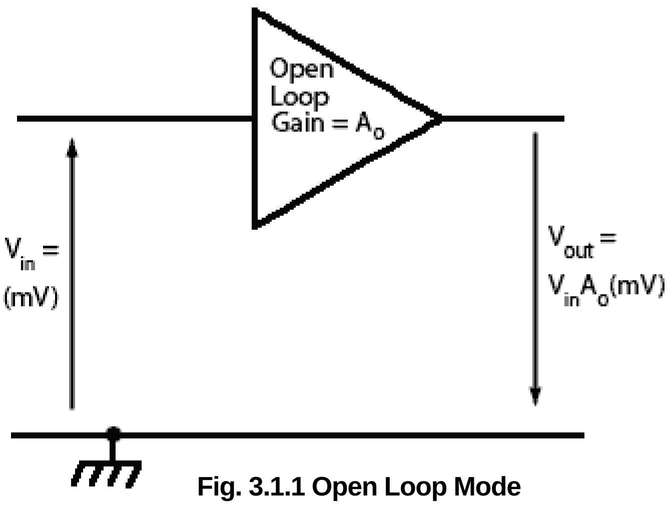


Fig. 3.1.1 Open Loop Mode

The Negative Feedback Amplifier in Closed Loop Mode

A basic negative feedback arrangement is shown in Fig. 3.1.2 where the phase reversing amplifier has a fraction of its output (V_{out}) fed back and added to the input (V_{in}) so as to reduce the amplitude of the input signal. The arrows show the relative polarity of the signals and it can be seen that the output and the feedback signals are in anti-phase to the input signal. The fraction of the output signal to be fed back is controlled by the potential divider (β) and this fraction is added to the input signal in anti-phase so that it is, in effect, subtracted from the input signal (V_{in}) to give a combined signal (V_c) that is reduced in amplitude before being fed to the actual input of the amplifier.

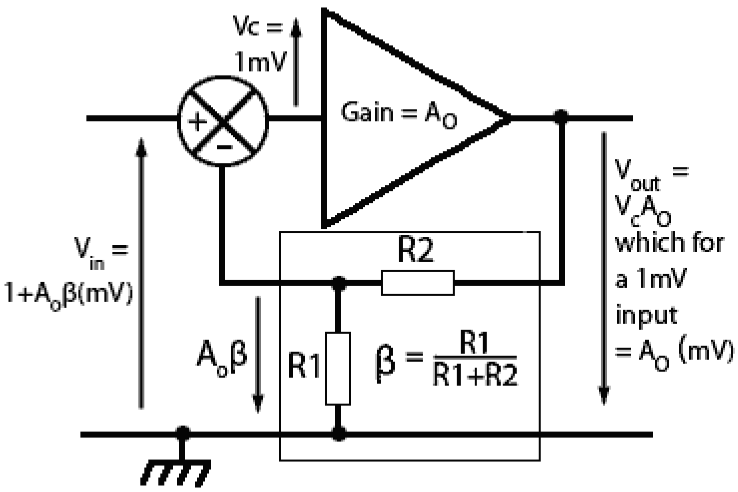


Fig. 3.1.2 Closed Loop Mode

The gain of the amplifier, excluding any feedback, is A_o so that, for example, every 1mV applied across the circuit's input terminals, the amplifier will produce a phase-reversed signal of A_o x 1mV across the output terminals.

The feedback circuit comprising R1 and R2 will feed back a fraction (β) of output V_{out} which = A_o, so that A_o x βmV (Aβ) will be added in anti-phase to the 1mV signal to produce a reduced input signal of V_c.

The signal source V_{in} driving the amplifier must therefore deliver not 1mV but **1+AβmV** to produce the same amplitude of output. Therefore the overall gain of the amplifier with negative feedback is reduced now called the closed loop gain (A_c).

Negative Feedback Formula

The voltage gain of any amplifier can be described by the formula:

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

Because, in the closed loop negative feedback amplifier (Fig. 3.1.2):

$$\mathbf{V_{out} = A_o}$$

and

$$\mathbf{V_{in} = 1 + A_o\beta}$$

the closed loop gain (A_c) can also be described by the standard NFB formula:

$$\text{Closed Loop Gain } A_C = \frac{A_o}{1 + A_o\beta}$$

Negative feedback amplifiers are designed so that the open loop gain A_o (without feedback applied) of the amplifier is much greater than 1, and so the 1 in the formula becomes insignificant. The closed loop gain (A_c) can therefore be approximated to:

$$\frac{A_o}{A_o\beta} \quad \text{or} \quad \frac{1}{\beta}$$

The effect of NFB on amplifier Gain

This is of great significance because it means that, once negative feedback is applied, the closed loop gain A_c depends almost exclusively on β, which in turn depends on the ratio of the potential divider R1, R2.

Example:

The amplifier in Fig 3.1.2 uses the following feedback resistors:

R1 = 1kΩ

R2 = 10kΩ

Therefore:

$$\beta = R1 / (R1+R2) = 0.0909 = 1 / 11$$

and as the closed loop gain $A_c = 1/\beta$ then,

$$\mathbf{A_c\ 1 / 0.0909 = 11}$$

Testing this approximate result against the full formula for the closed loop gain:

Assuming an open loop gain of 1000 and β = 1 / 11 The closed loop gain A_c should be 11

Compare this result with the full formula for closed loop gain by entering the following data into your calculator:

$$\mathbf{1000 / (1+ 1000 * 11^{-1}) = 10.88}$$

So the closed loop gain of the amplifier is actually 10.88, but a gain of 11 is close enough to this figure for any practical purposes.

How would a change in the **open loop gain** of the amplifier affect the **closed loop gain** with the same negative feedback applied?

To see the effect of large changes in open loop gain, try the same calculation but this time make the open loop gain $A_o = 5000$

Enter this data into your calculator: $\mathbf{5000 / (1+ 5000 * 11^{-1}) = 10.97}$

So for a 400% increase in the open loop gain, the closed loop gain has changed by only 0.8%

This means that the gain no longer relies on the variable, temperature dependent and non-linear gain characteristics of the transistor, but on a minimal two resistor network that has a linear temperature coefficient and an easily predicted β value.

Negative Feedback Module 3.5

Negative Feedback Quiz 3

Try our quiz, based on the information you can find in Negative Feedback Module 3. You can check your answers by going to:

http://www.learnabout-electronics.org/Amplifiers/amplifiers35.php

1.

Which of the following correctly lists the benefits of using NFB in an amplifier system?

a) More gain, wider bandwidth and reduced noise.

b) Wider bandwidth, better stability and less distortion.

c) Less noise, less distortion and predictable gain.

d) Predictable gain, better reliability and wider bandwidth.

2.

If a voltage amplifier has an open loop gain (A_O) of 150 and a feedback factor (β) of 1/20, what will be the approximate gain with negative feedback applied?

a) 18 b) 55 c) 36 d) 70

3.

What is the NFB method being used in Fig. 3.5.1?

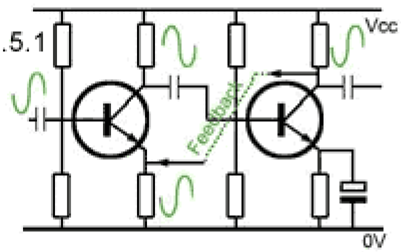
a) Voltage derived, parallel fed.

b) Voltage derived, series fed.

c) Current derived, parallel fed.

d) Current derived, series fed.

Fig. 3.5.1



4.

What is the main advantage of using direct coupling in multi stage NFB amplifiers?

a) It is more efficient than indirect coupling.

b) It increases the input impedance of the amplifier.

c) It reduces phase shifts.

d) It allows more stages to be used.

5.

Refer to Fig. 3.5.2: Which of the following statements most accurately describes the type of inter stage coupling and method of feedback used?

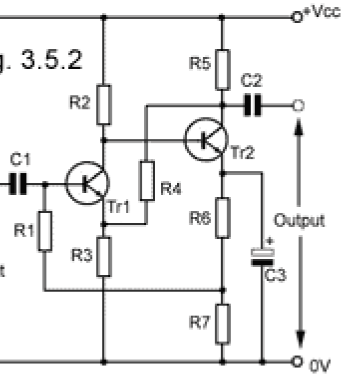
a) Direct coupling with DC negative feedback.

b) Resistive coupling with AC negative feedback.

c) Capacitive coupling with AC and DC negative feedback.

d) DC coupling with AC and DC negative feedback.

Fig. 3.5.2



6.

Refer to Fig. 3.5.2: Assuming that the input signal is normal, what would be the probable effect on the circuit if R4 became open circuit?

a) No output signal.

b) Normal output signal.

c) Large and distorted output signal.

d) Small and distorted output signal.

7.

To increase the input impedance, and reduce the output impedance of a multi stage amplifier, which of the following NFB methods should be used?

a) Voltage derived, parallel fed.

b) Current derived, parallel fed.

c) Voltage derived, series fed.

d) Current derived, series fed.

8.

In an audio amplifier using NFB which of the following methods would be most effective in reducing electro-magnetically induced noise from the power supply?

a) Using a low pass filter in the negative feedback system.

b) Decoupling the DC power lines using both electrolytic and polyester capacitors.

c) Using a high pass filter in the negative feedback system.

d) Using electromagnetic screening on the power supply components.

9.

Negative feedback loops avoid the use of reactive components where possible to minimise which of the following effects?

a) Amplitude distortion.

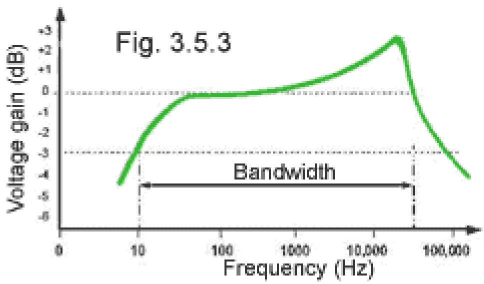
b) Phase distortion.

c) Frequency distortion.

d) External noise.

10.

The audio amplifier response curve illustrated in Fig. 3.5.3 shows which of the following problems?



a) Frequency distortion.

b) Phase distortion.

c) Bandwidth distortion.

d) Amplitude Distortion.

