

Practical Session E

Negative Feedback Amplifiers

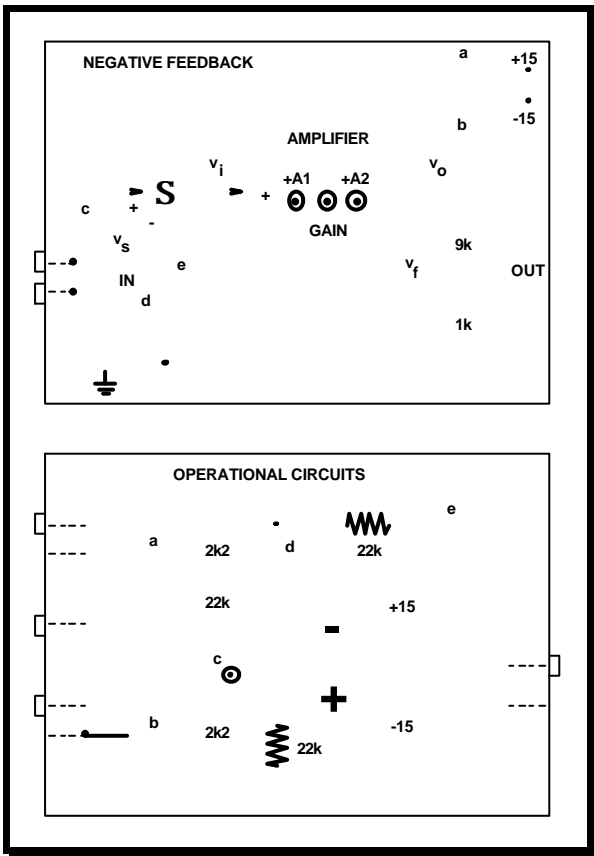
Tutorial F is a prerequisite for this practical session

Introduction

If a fraction of the output of an amplifier is fed back so as to oppose the input, the effective input is reduced, and so is the overall gain. This loss of gain is one of the few disadvantages of "negative feedback", and in this session you will investigate some of the advantages.

A high-gain, often differential, amplifier may be used in a variety of feedback-circuit configurations to accurately perform such common mathematical operations as scaling, addition and subtraction, and integration. During this session you will patch up some such circuits using an inexpensive integrated-circuit amplifier (type 741).

General Circuits



Procedure

A – Advantages of Negative Feedback

(Negative Feedback chassis)

The amplifier and summer used in this part of the experiment have been designed to illustrate well some of the effects of negative feedback. (See Appendix for circuit diagram.) The summer is very close to the ideal over the frequency range of interest; you may check this if you wish.

To power the chassis, a dual power supply is needed, of ± 15 volts. Check these voltages before closing links a, b to connect them to the circuit. (The meters on the supply are accurate enough.) Normally +15 = Supply #2, -15 = Supply #1.

1. Gain Without Feedback

With links c and d closed, the input signal is applied to the amplifier without feedback. Use a link to produce an amplifier gain of +A1. Apply a sinusoidal signal of 1 kHz, and monitor the input and the output with the oscilloscope. Adjust the level of the input until obvious distortion occurs. It is necessary to operate below this level; an output voltage of 7 volts peak to peak is normally suitable. Measure the gain A1.

2. Gain With Feedback

Close link e instead of link d, to apply feedback to the amplifier. What should be the value of the feedback factor β ?

At a frequency of 1 kHz obtain the same output as in section 1.

Measure the applied input voltage v_s , the feedback voltage v_f , the actual input voltage to the amplifier block (= summer output v_i), and the output voltage v_o .

Compare the following quantities, calculated from these four voltages, with predicted or previously measured values:

- i) the measured value of β and the predicted one;
- ii) the measured gain of the amplifier block and A1 as measured in section 1;
- iii) the measured overall gain with feedback and a value calculated using A1 and β .

The reduction of gain given by negative feedback is its main disadvantage; let us now investigate some advantages.

3. Distortion

Return to the same conditions as in section 1. Increase the input voltage until severe clipping of the output occurs. Reduce the input voltage until clipping just ceases, and record the output waveform and the waveform at the input to the amplifier block (= summer output v_i).

Now apply the feedback, and again record the output waveform and the amplifier-block input waveform just before clipping. Comment on these waveforms. (See worked examples 2)ii) and 3)iii) on pages A5b.3 and A5b.5 of these notes.)

B – Operational Amplifiers and Circuits

(Operational Circuits chassis)

Because of the high gain of the amplifier, it is possible to get an appreciable output from small (unwanted) signals developed across wires connecting two points supposedly at the one potential – particularly earth connections. The earth connections in the special chassis have been made as shown in the circuit diagrams, to minimize this effect.

4. Inverting Amplifier

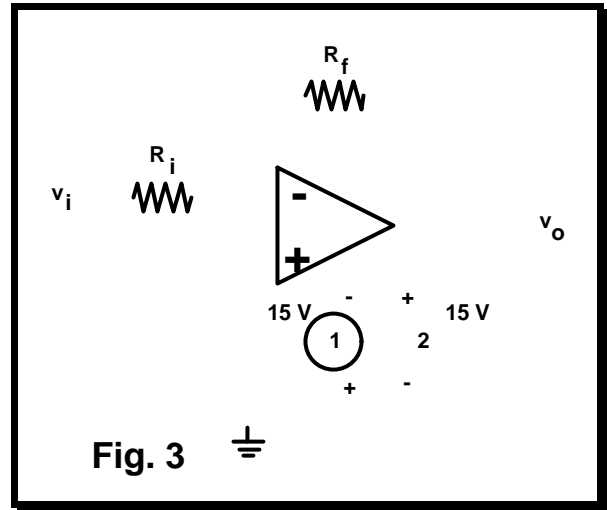
Set both power supplies to 15 V. (The meters on the supply are accurate enough.)

Note concerning circuit diagrams

Following a common convention, in later sections the power supply connections are not shown. The two power supplies are in fact connected (at the 7-pin socket on the chassis) as shown in Fig. 3.

a) Unity gain

- i) Set up the circuit of Fig. 3 below (links b, c, e), with $R_i = R_f = 22 \text{ k}\Omega$.



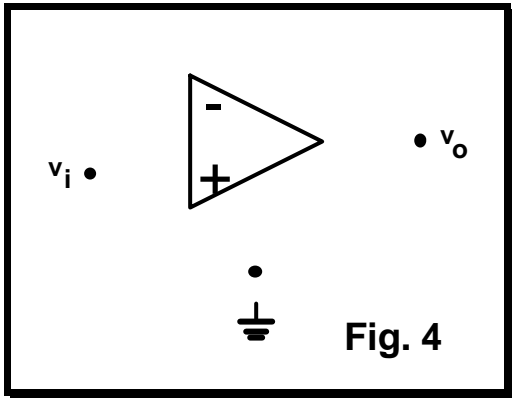
- ii) Apply a sinusoidal input to make v_o a few volts at 100 Hz. Check the gain $|v_o| / |v_i|$, also the phase shift.
 - iii) Increase the input frequency until the output drops 3 dB, to measure the bandwidth. However it is likely that, because circuit limitations impose a maximum value of dv_o/dt ("Slew rate"), the output will be distorted at higher frequencies. In this case make sure that you reduce the input level until the output is sinusoidal, then make the measurement.
- b) Gain of 10**
- i-iii) Repeat 4)a) with $R_i = 2 \cdot 2 \text{ k}\Omega$ $R_f = 22 \text{ k}\Omega$.

- iv) Compare the product, derived from these measurements:
 $(1 + |gain|) \times \text{bandwidth}$
 with the same product derived from measurements in 4)a)iii).
- v) Compare these products with the unity-gain frequency of the amplifier.
 (1 MHz from the data sheet.)

5. Non-inverting Amplifier

a) Unity Gain

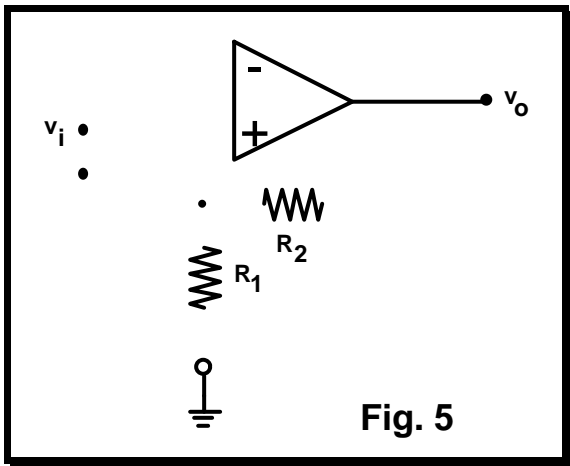
Set up the circuit of Fig. 4 below (links c,d).



Apply a sinusoidal input to make v_o a few volts at 100 Hz.
 Check the gain $|v_o| / |v_i|$, also the phase shift.

b) Gain of 11

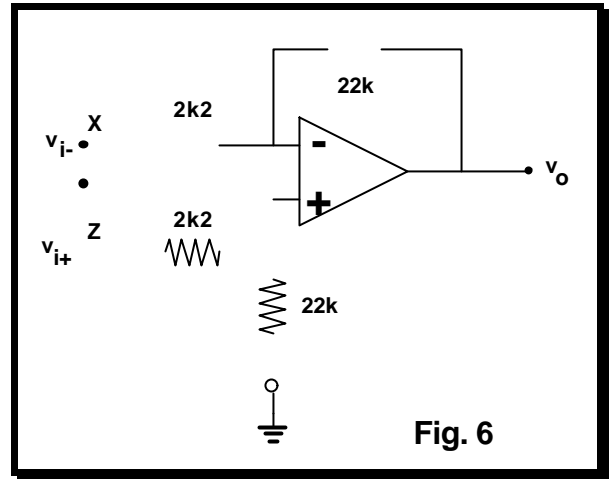
Set up the circuit of Fig. 5 below (links a, c, e) with $R_1 = 2.2 \text{ k}\Omega$, $R_2 = 22 \text{ k}\Omega$.



Proceed as in 5)a).

6. Difference Amplifier (Subtractor)

Set up the circuit of Fig. 6 below (link e).

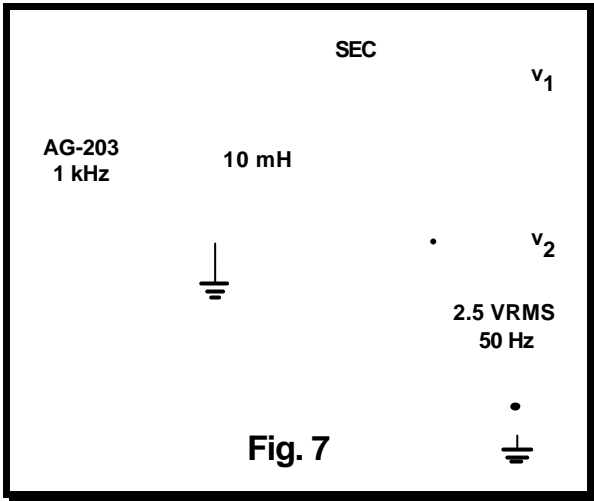


- i) With terminals v_{i+} earthed (link b), check the gain from input v_{i-} .
 (say using a sinusoidal input of 100 mV p-p at 100 Hz).

WARNING: Remove link b before proceeding to the next sections.

- ii) With terminals v_{i-} earthed (link a), check that the gain from input v_{i+} is almost exactly the opposite of that measured in i).
- iii) Now check the common-mode gain by connecting an input signal to both v_{i-} and v_{i+} , using a sinusoidal input of 10 V p-p at 100 Hz from the signal generator. Comment.

- iv) You may derive signals v_1 , v_2 which have a large common-mode component and a small differential-mode component using the circuit of Fig. 7 below.



- a) Wire up the circuit of Fig. 7, initially with the signal generator's amplitude turned right down and the 50 Hz turned off.

WARNING: Check your circuit carefully, as errors could cause blown fuses. Any one of the three black earth sockets on the left wall of the amplifier chassis may be used for the earth connection.

- b) Being careful to use the black earth sockets on the chassis for the earth connections, monitor v_1 on channel 1 of your CRO and v_2 on channel 2. Turn the amplitude of the 1kHz signal fully up and note the size of v_1 and v_2 ; then use the CRO to observe $v_1 - v_2$ (ADD; invert CH2).
- c) Repeat b), but with the 1kHz signal's amplitude turned down and the 50 Hz turned on.
- d) Now apply the full 1kHz signal as well as the 50 Hz. Can you see the 1kHz component of v_1 ?

Use the CRO to observe $v_1 - v_2$, and comment on what you see.

- e) Finally, apply v_1 and v_2 to the circuit of Fig. 6, making

$$v_{i+} = v_1, \quad v_{i-} = v_2$$

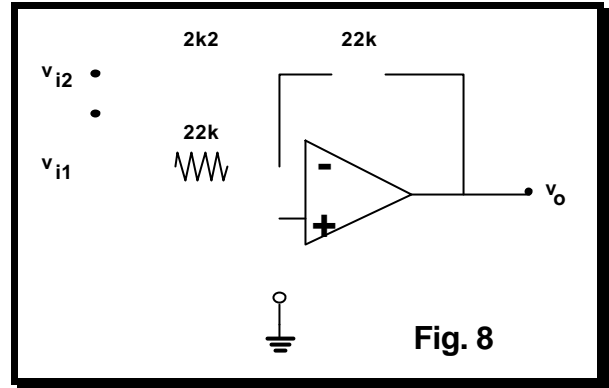
Observe the output of the amplifier, first with only the 1kHz signal applied, then with only the 50Hz signal applied, then with both signals present.

Comment on your results, particularly on how the amplifier responds to common-mode and differential-mode inputs.

7. Operational Adder

(This section is optional)

Set up the circuit of Fig. 8 below (link e).



- i) Using a signal of 2.5 VRMS at 50 Hz (from a transformer) for input v_{i1} , with v_{i2} disconnected, check the gain.
- ii) Using a square-wave signal of 500 mV pp at 1 kHz (from the signal generator) for input v_{i2} , with v_{i1} disconnected, check the gain.
- iii) Sketch the output waveform when v_{i1} and v_{i2} (as in i), ii) are applied simultaneously. Comment.

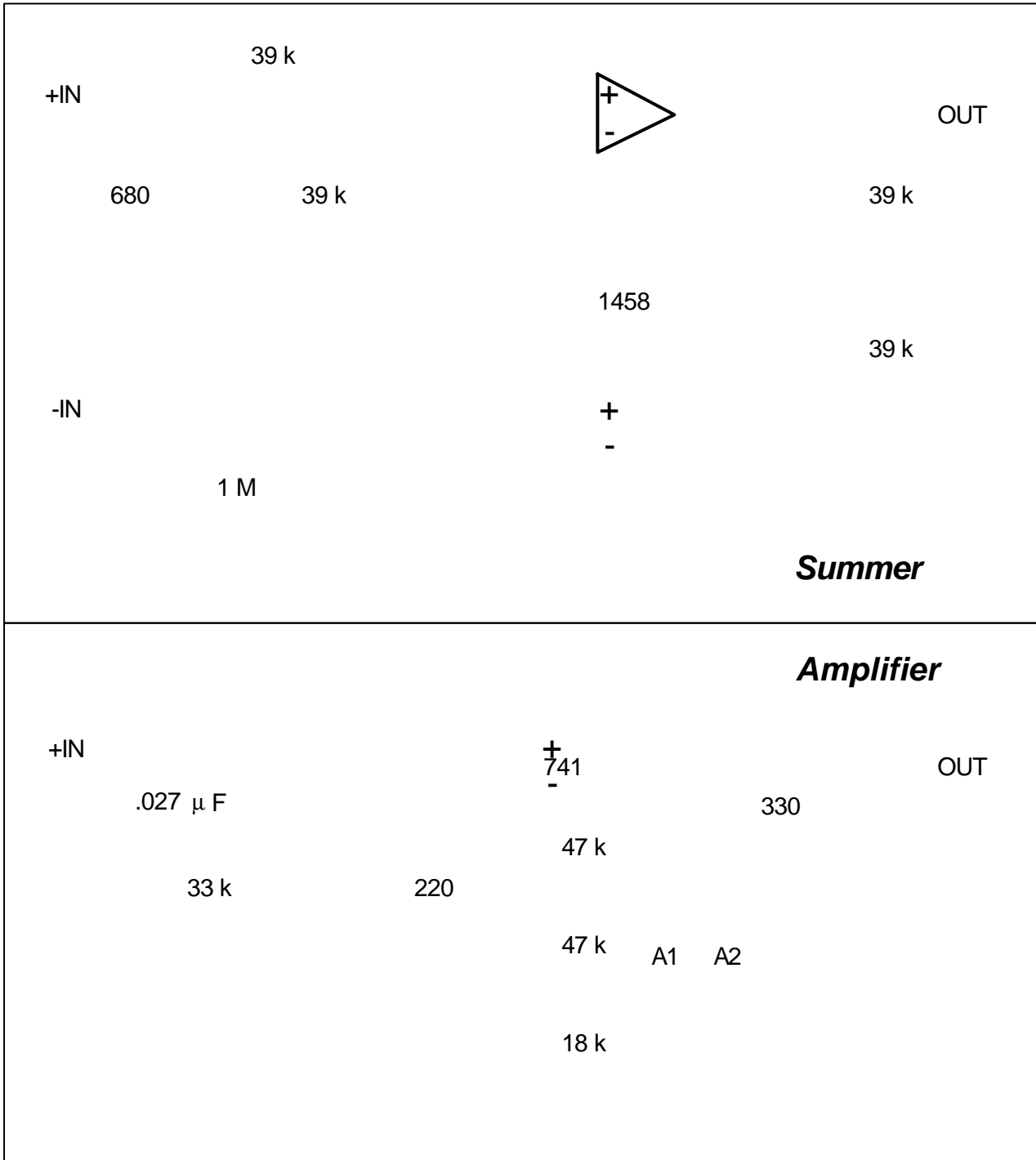
APPENDIX

The circuit of the first part of this experiment uses three operational amplifiers, with values of gain, frequency response, input and output resistance, and distortion tailored to meet the needs of the experiment.

The actual circuit is shown opposite.

Appendix

Circuit for Negative Feedback Chassis



For the purposes of Tutorial Session F,
starred components may be replaced by open circuits.