10

Negative Feedback for Transistor

Chapter 10 Negative Feedback for Transistor

10.1 Study Objective:

(1) Understanding the meaning of each negative feedback circuit.
(2) Understanding the principle of each negative feedback circuit.
(3) Understanding the function of each negative feedback circuit.

10.2 Basic Description:

10.2.1 New Terminology:

(1) Voltage amplifier (Av):
① Output voltage is proportional to input voltage.
② Ideal voltage amplifier: Zi =∞, Zo = 0, Av = Vo/Vs

(2) Current amplifier (Ai):
① Output current is proportional to input current.
② Ideal current amplifier: Zi = 0, Zo = ∞, Ai = Io/Is

(3) Transconductance amplifier (Gm):
① Output current is changed with input voltage.
② Ideal transconductance amplifier: Zi = ∞, Zo = ∞, Gm = Io/Vs

(4) Transresistance amplifier (Rm):
① Output voltage is changed with input current.
② Ideal transconductance amplifier: Zi = 0, Zo = 0, Rm = Vo/Is

10.2.2 Basic Principle:

(1) Feedback for amplifier
1) The circuit topology in which part or all the output signal of an amplifier is re-applied to the input terminal through a feedback network is referred to as feedback. If the phase of feedback signal is same as that of input signals, this feedback is called positive feedback. If the phase of feedback signal is inverse to that of input signals and this feedback signal will be subtracted from the input signal to reduce the gain, this feedback is called negative feedback.

2) The block diagram of the amplifier with feedback is shown in Fig 10.1.

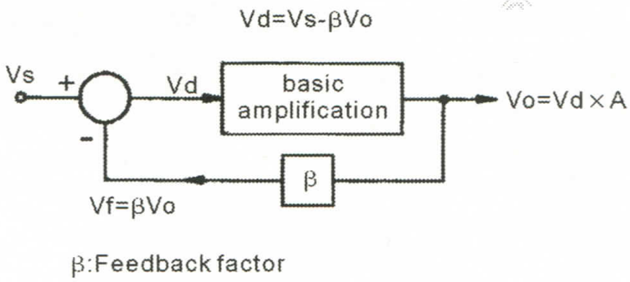


Fig 10-1

Vi: input signal   Vo: output signal

Vf: feedback signal β: feedback factor

and $Vf = \beta Vo$ $Vd = Vs - Vf = Vi$ $Vs = Vi + \beta Vo$

$$A = \frac{Vo}{Vi} \quad Af = \frac{Vo}{Vs} = \frac{Vo}{Vi + \beta Vo} = \frac{\frac{Vo}{Vi}}{\frac{Vi}{Vi} + \beta \frac{Vo}{Vi}} = \frac{A}{1 + \beta A}$$

3) For negative feedback, $-\beta A < 1$ ($\beta A > -1$)
For positive feedback, $-\beta A \geqq 1$ ($\beta A < -1$)

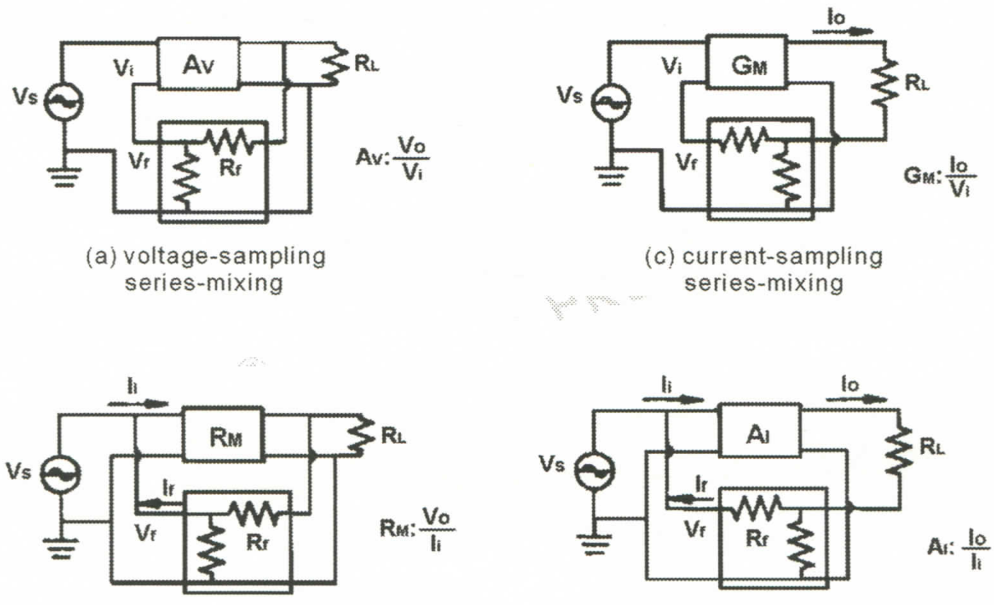
(2) Topologies of negative feedback circuit
Depending on the acquisition of feedback signal and the method of input, the negative feedback circuits can be classified into the following four categories:

1) Voltage-sampling series-mixing negative feedback: Part of voltage is taken from the output terminal and is then applied to the input terminal though series network.

2) Voltage-sampling shunt-mixing negative feedback: Part of voltage is taken from the output terminal and is then applied to the input terminal though shunt network.

3) Current-sampling series-mixing negative feedback: Part of current (alternatively, this current can be converted to voltage) is taken from the output terminal and is then applied to the input terminal though series network.

4) Current-sampling shunt-mixing negative feedback: Part of current is taken from the output terminal and is then applied to the input terminal though shunt network.



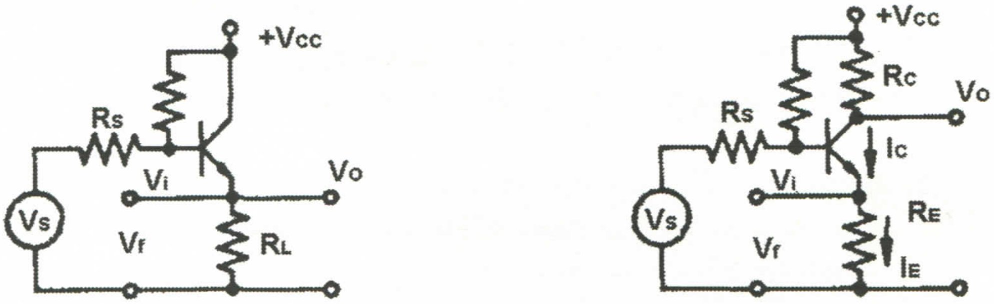
(a) voltage-sampling series-mixing

(c) current-sampling series-mixing

(b)voltage-sampling shunt-mixing

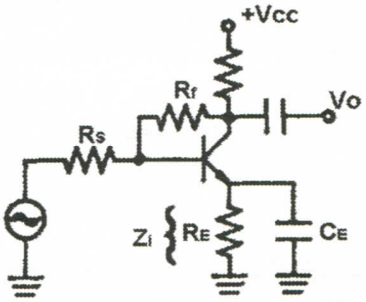
(d)current-sampling shunt-mixing

Circuit diagram:



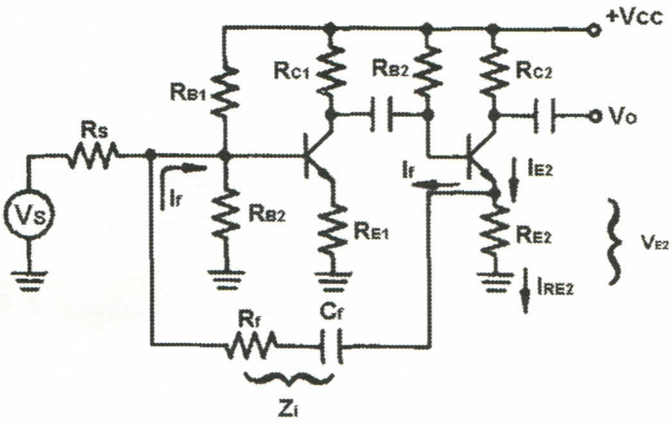
(a) voltage-sampling
series-mixing
Vf=Vo
(100% feedback)

(c) current-sampling
series-mixing
If=Ie
vf=Ie × Re



$$Vf=Vo \times \frac{Zi}{Rf+Zi}$$

(b)voltage-sampling
shunt-mixing



If=Ie2-Ire2

$$Vf=Ve2 \times \frac{Zi}{Zf+Zi}$$

$(Ve2=Ire2 \times Re2)$

(d)current-sampling
shunt-mixing

Comparing these block diagrams and circuit diagrams we can find out:

1) The voltages are taken through shunt arrangement for both voltage-sampling series-mixing negative feedback circuit and voltage-sampling shunt-mixing negative feedback circuit.

2) The currents are taken through series arrangement for both current-sampling series-mixing negative feedback circuit and current-sampling shunt-mixing negative feedback circuit (the current will be converted to voltage through resistor).

3) The feedback signals are applied to the input terminals through shunt arrangement for both voltage-sampling shuntmixing and current-sampling shunt-mixing negative feedback circuit.

4) The feedback signals are applied to the input terminals through series arrangement for both voltage-sampling series-mixing and current-sampling series-mixing negative feedback circuit.

Table (1) shows the variation of input impedance of these feedback circuits.

	voltage-sampling series-mixing	current-sampling series-mixing	voltage-sampling shunt-mixing	current-sampling shunt-mixing
Zif	increase	increase	decrdase	decrdase
Zof	decrdase	increase	decrdase	increase

We can find out from Table (1):

① Zif will be increased if the feedback signal is applied to the input terminal through series arrangement, wherein the input impedance is increased because the feedback network is connected to the input circuit in series. On the contrary, Zif will be decreased for shunt-mixing feedback.

② Zof will be decreased if the feedback signal is taken by shunt arrangement, wherein the output impedance is increased because the feedback network is connected to the output circuit in shunt. On the contrary, Zof will be increased if the feedback signal is taken by series arrangement.

③ Voltage shall be taken by shunt arrangement; current shall be taken by series arrangement.

(3) Properties of negative feedback circuit:

1) Gain will be decreased. $Af = \frac{A}{1+\beta A}$

2) Stability of circuit will be increased.

3) Nonlinear distortion will be reduced. $Df = \frac{D}{1+\beta A}$

4) Noise will be reduced. $Nf = \frac{N}{1+\beta A}$

5) Bandwidth will be extended. $BWf = (1 + \beta A)\ BW$

6) Zi and Zo will be changed with feedback topology,

10.3 Experiment Equipments

(1) KL-200 Linear Circuit Lab.
(2) Experiment Module: KL-23007.
(3) Materials: As indicated in the KL-23007.
(4) Experiment Instrument: 1. Signal generator.
2. Oscilloscope.
3. Multimeter.
(5) Tools: Basic hand tools.

10.4 Experiment Items:

Item one (10-1): Experiment for voltage-sampling series-mixing negative feedback circuit

10-1-1

10-1-1-1 Experiment Procedures:

(1) Firsts fix the module KL-23007 in the KL-200 Linear Circuit Lab, then locates the block marked 23007-block b.

(2) Insert the short-circuit clip by referring to Fig 10-2 and the short-circuit clip arrangement diagram 23007-block b.1. The negative feedback is disconnected (short-circuit clip is not connected to C14 R31 circuit).

(3) Use multimeter (DCV) to measure Vc10 and Vc9(Q9.Q10 collector).

(4) Connect signal generator and oscilloscope in the input terminal (IN3), and connect oscilloscope to the output terminal (OUT). Adjust the output of signal generator to 1KHz sine wave and gradually increase the output voltage so that the oscilloscope can display maximum non-distorted waveform in the output terminal. View and record the waveforms in IN3 and OUT respectively.

(5) Use oscilloscope to measure the waveforms in TP3 and TP7, then make records.

(6) Connect the negative feedback circuit (short-circuit clip is connected to C14 R31 circuit).

(7) Repeat Step (3) (4) (5).

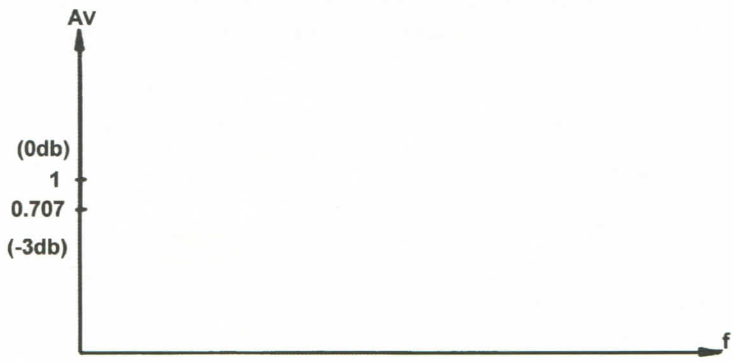
(8) Adjust the output of signal generator to 10Hz~20KHz, then view the waveforms of Vin and Vout for both the circuits with negative feedback and without negative feedback. Make records, and compare the frequency response of these two circuits. The frequency response curves of Av corresponding to f shall be recorded in Table 10-1 (b) (c).

10-1-1-2 Experiment Result:

The experiment results shall be recorded in Table 10-1 (a) (b) (c), then compare the difference between the circuits with and without negative feedback.

measured voltage	without negative feedback	with negative feedback
Vc10 (DCV)		
Vc9 (DCV)		
Vin3 (Vp-p)		
Vr30 (TP7)(Vp-p)		
Vb9 (TP3)(Vp-p)		
Vout (Vp-p)		
Av:Vout/Vin3		

Table 10-1 (a)



(b) Frequency response of the circuit without negative feedback

(c) Frequency response of the circuit with negative feedback

Table 10-1

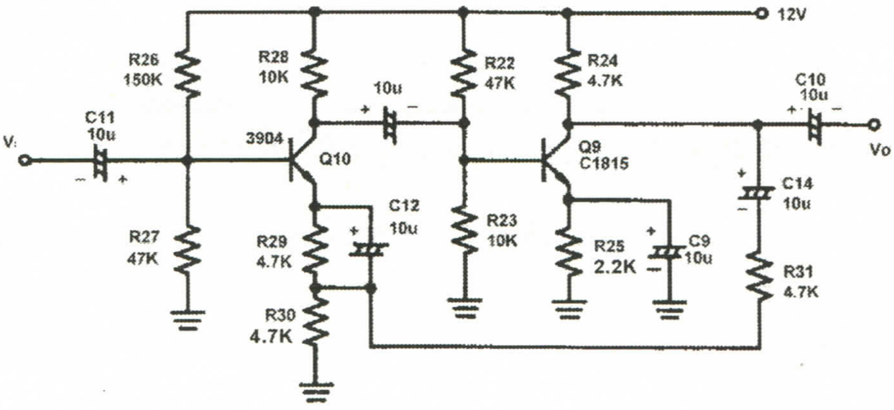


Fig 10-2

current-sampling shunt-mixing

(current-sampling series-mixing)

voltage-sampling series-mixing

disconnection at Step (2)

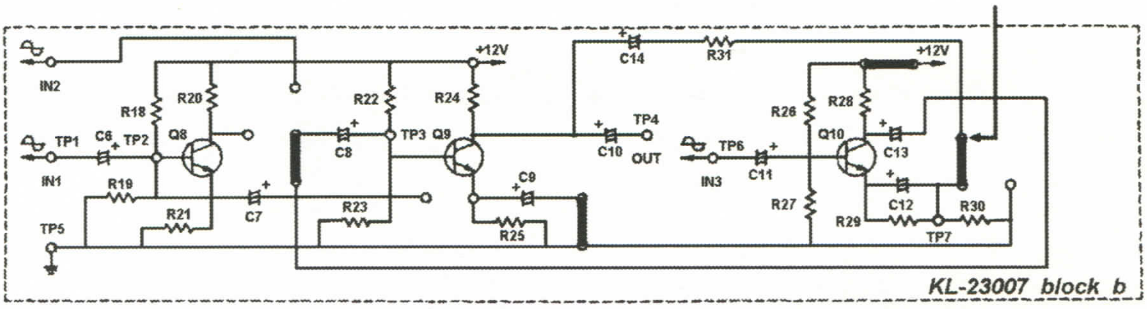


Fig 23007-block b.1

Item two (10-2): Experiment for voltage-sampling shunt-mixing negative feedback circuit

10-2-1

10-2-1-1 Experiment Procedures:

(1) Insert the short-circuit clip by referring to Fig 10-3 and the short-circuit clip arrangement diagram 23007-block c. The negative feedback is disconnected (short-circuit clip is not connected to R34 C16 circuit).

(2) Use multimeter (DCV) to measure Vc17 (the voltage at collector of the transistor).

(3) Connect signal generator and oscilloscope in the input terminal (IN), and connect oscilloscope to the output terminal. Adjust the output of signal generator to 1KHz sine wave and gradually increase the output voltage so that the oscilloscope can display maximum non-distorted waveform in the output terminal. View and record the waveforms in IN and OUT respectively.

(4) Connect the negative feedback circuit (short-circuit clip is connected to R34 C16 circuit).

(5) Repeat Step (2) (3).

(6) Adjust the output of signal generator to 10Hz~20KHz, then view the frequency response for both the circuits with negative feedback and without negative feedback. The frequency response curves of Av corresponding to f shall be plotted in Table 10-2 (b) (c).

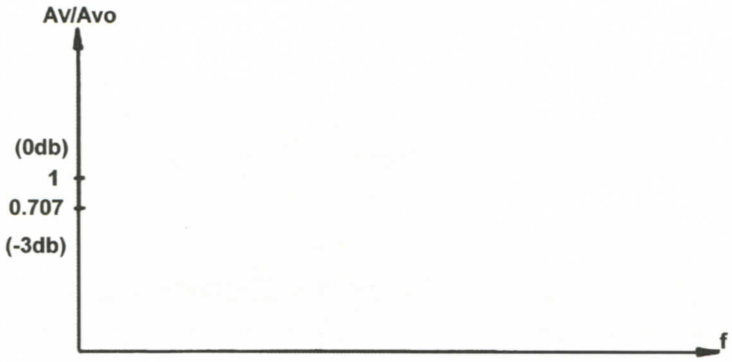
10-2-1-2 Experiment Result:

The experiment results shall be recorded in Table 10-2 (a) (b) (c), then compare the difference between the circuits with and without negative feedback.

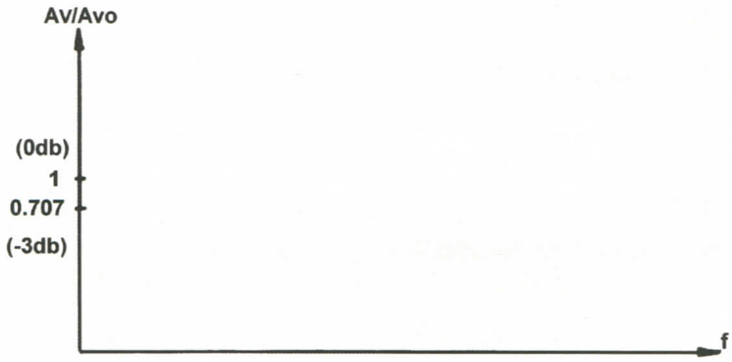
measured voltage	without negative feedback	with netative feedback
Vin (Vp-p)		
Vout (Vp-p)		
Vc11 (DCV)		
Av : Vout/Vin3		

Table 10-2 (a)

Avo: The Av when Vo is maximum.



(b) Frequency feedback



(c) Frequency response of the circuit with negative feedback

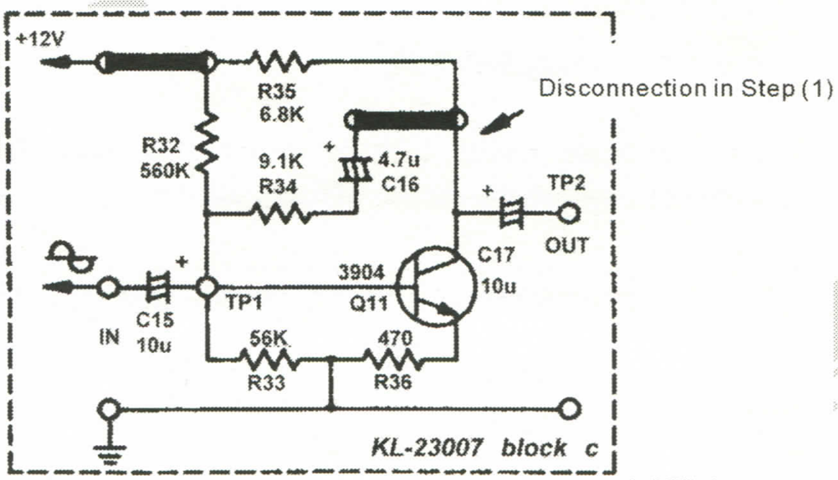


Fig 10-3 (Fig 23007-block c.1)

Item three (10-3): Experiment for current-sampling series-mixing negative feedback circuit

10-3-1

10-3-1-1 Experiment Procedures:

(1) Insert the short-circuit clip by referring to Fig 10-4 and the short-circuit clip arrangement diagram 23007-block b.2. Connect capacitor C9 to bypass R25 (1KΩ) that acts as the comments device in this current-sampling series-mixing circuit. The AC impedance of the capacitor is very small.

(2) Use multimeter (DCV) to measure Vc9(Q9 collector).

(3) Connect signal generator and oscilloscope in the input terminal (IN2), and connect oscilloscope to the output terminal (OUT). Adjust the output of signal generator to 1KHz sine wave and gradually increase the output voltage so that the oscilloscope can display maximum non-distorted waveform in the output terminal. View and record the waveforms in IN and OUT respectively.

(4) Remove C9 (disconnect the short-circuit clip) so that this circuit will operate as the topology of negative feedback.

(5) Repeat Step (2) (3).

10-3-1-2 Experiment Result:

The experiment results shall be recorded in Table 10-3, then compare the difference between the circuits with and without negative feedback.

measured voltage	without negative feedback	with negative feedback
Vin2 (Vp-p)		
Vout (Vp-p)		
Vc9 (DCV)		
Av : Vout/Vin2		

Table 10-3

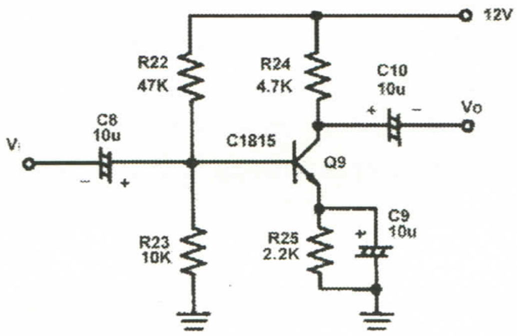


Fig 10-4 Current-sampling series-mixing negative feedback circuit

current-sampling shunt-mixing	(current-sampling series-mixing)	voltage-sampling series-mixing

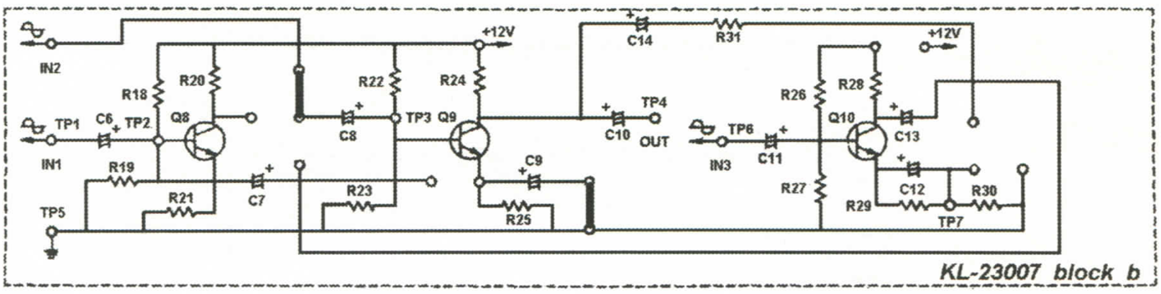


Fig 23007-block b.2

Item four (10-4): Experiment for current-sampling shunt-mixing negative feedback circuit

10-4-1

10-4-1-1 Experiment Procedures:

(1) Insert the short-circuit clip by referring to Fig 10-5 and the short-circuit clip arrangement diagram 23007-block b.3. The capacitor C7 (10 μF) for negative feedback is disconnected.

(2) Use multimeter (DCV) to measure Vc8 and Vc9(Q8 Q9 collector).

(3) Connect signal generator and oscilloscope in the input terminal (IN1), and connect oscilloscope to the output terminal (OUT). Adjust the output of signal generator to 1KHz sine wave and gradually increase the output voltage so that the oscilloscope can display maximum non-distorted waveform in the output terminal. View and record the waveforms in IN and OUT respectively.

(4) Use oscilloscope to measure Vc8 and Vc9(Q8 Q9 collector).

(5) Connect C7 (10μF) so that this circuit will operate as the topology of current-sampling shunt-mixing negative feedback.

(6) Repeat Step (2) (3) (4).

10-4-1-2 Experiment Result:

The experiment results shall be recorded in Table 10-4, then compare the difference between the circuits with and without negative feedback.

measured voltage	without negative feedback	with negative feedback
Vc8 (DCV)		
Vc9 (DCV)		
Vin1 (Vp-p)		
Vc8 (Vp-p)		
Vout (Vp-p)		
Av:Vout/Vin1		

Table 10-4

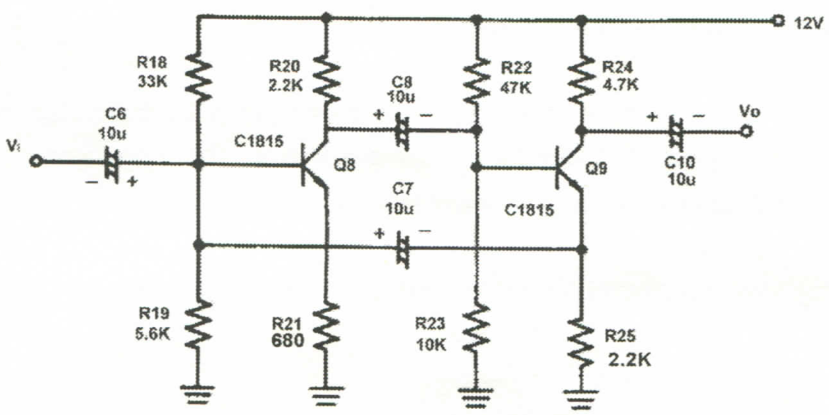


Fig 10-5 Current-sampling shunt-mixing negative feedback circuit

current-sampling shunt-mixing　　(current-sampling series-mixing)　　voltage-sampling series-mixing

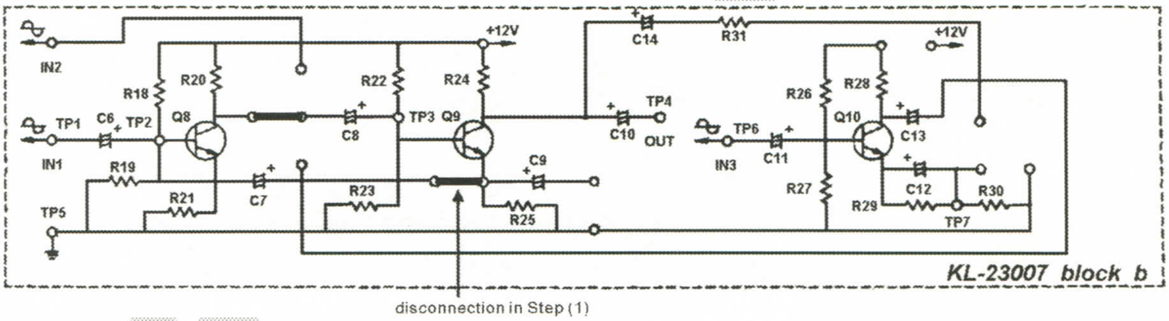


Fig 23007-block b.3

10.5 Experiment Discussion:

This unit has discussed the experiment for negative feedback circuit, the concept of which has already been used in the amplifier circuits of Chapter 6 and Chapter 9. For example, One typical application of voltage-sampling negative feedback is the emitter follower in which an emitter circuit is incorporated. The experiments of this unit can therefore be carried out by referring to the circuits and principles described in Chapter 6 and 9. The practice of Chapter 9, the tone control circuit, is an application of voltage-sampling shunt-mixing negative feedback circuit.

10.6 Repairs for Simulated Faults

Carry out the following repairs by referring to the test results of instruments along with the operating principle, but the electric iron is not allowed to be used. List the faulty parts, and briefly describe your steps for repairs.

10-4: Current-sampling shunt-mixing circuit as shown in Fig 10-5.

1. Fault phenomenon: ① DC bias of Q8 is abnormal.
   ② DC bias of Q8 is abnormal.
   ③ There is no amplification for Q9.
2. Fault parts:
3. Steps for repairs:

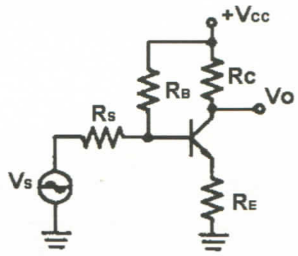
10.7 Problems:

(1) Selection:

( ) 1. Emitter follower is the application of:

1. voltage-sampling series-mixing negative feedback.
2. current-sampling series-mixing negative feedback.
3. current-sampling shunt-mixing negative feedback.

( ) 2.



Re of left Figure operates as:

1. voltage-sampling series-mixing negative feedback.
2. current-sampling series-mixing negative feedback.
3. current-sampling shunt-mixing negative feedback.

( ) 3. When the negative feedback is applied to the amplifier, the amplification factor will:

1. remain unchanged.
2. increase.
3. decrease.

( ) 4. Voltage-sampling series-mixing negative feedback will make Zi:

1. increased.
2. decreased.
3. unchanged .

( ) 5. The amplifier in which output current is proportional to input voltage is called:

1. voltage amplifier.
2. transconductance amplifier.
3. current amplifier.

( ) 6. For a negative feedback amplifier with basic gain A and feedback factor β, the overall gain Avf of this circuit is:

1. $\frac{A}{1+\beta}$
2. $\frac{A}{1+\beta A}$
3. $\frac{A}{1-\beta A}$

( ) 7. After the negative feedback is applied, the bandwidth of an amplifier will be:

1. extended.
2. narrowed.
3. unchanged.

(2) Practice:

1. RC-attenuation tone control circuit

   Carry out the experiment of the circuit shown in Fig (a), then describe Fig (a) is the application of which negative feedback circuit.

   Experiment procedures:

   1) Assemble the circuit according to Fig (a), then apply 18V to Vcc.
   2) Adjust VR1M so that Vce of Q1 is equal to 1/2 Vz.
   3) Adjust VR10K so that Vce of Q2 is approximate 1/2 Vz and Vce of Q3 is approximate 1/2 Vcc.
   4) Feed 1KHz signal to Vi, then adjust the output amplitude of the signal generator so that the maximum non-distorted waveform will be displayed for Vo of this circuit.
   5) Remove R2 and repeat Step (4), then view if the waveform of Vo will be changed.
   6) Describe what types of negative feedback are utilized in this circuit, and which devices constitute these negative feedback circuits.

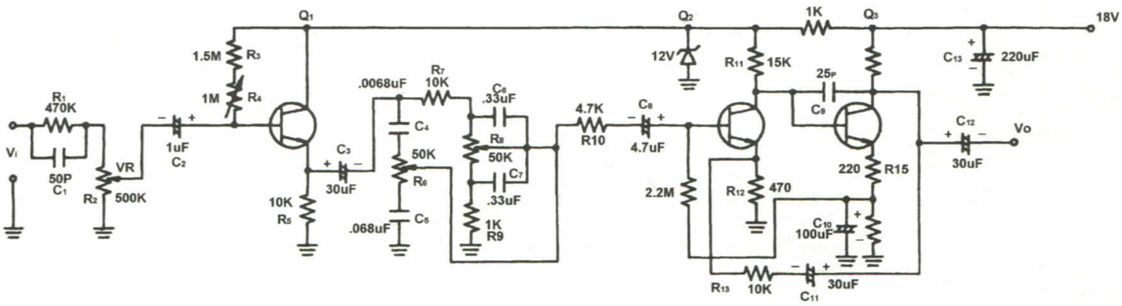


Fig (a) RC-attenuation tone control circuit