Lab-Volt® Basic Electricity & Electronics

Transistor Feedback Circuits

FACET®

Student Workbook

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Table of Contents

Introduction

This Student Workbook provides a unit-by-unit outline of the Fault Assisted Circuits for Electronics Training (F.A.C.E.T.) curriculum.

The following information is included together with space to take notes as you move through the curriculum.

- The unit objective
- Unit fundamentals
- A list of new terms and words for the unit
- Equipment required for the unit
- The exercise objectives
- Exercise discussion
- Exercise notes

The **Appendix** includes safety information.

UNIT 1 – INTRODUCTION TO THE CIRCUIT BOARD

UNIT OBJECTIVE

At the completion of this unit, you will be able to locate and identify the major circuit blocks on the TRANSISTOR FEEDBACK CIRCUITS circuit board.

UNIT FUNDAMENTALS

The TRANSISTOR FEEDBACK CIRCUITS circuit board consists of 4 circuit blocks:

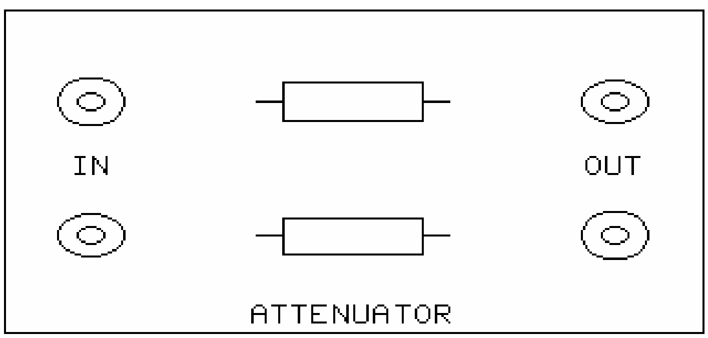
SERIES FEEDBACK/SHUNT FEEDBACK circuit block

MULTISTAGE SHUNT-SERIES FEEDBACK circuit block

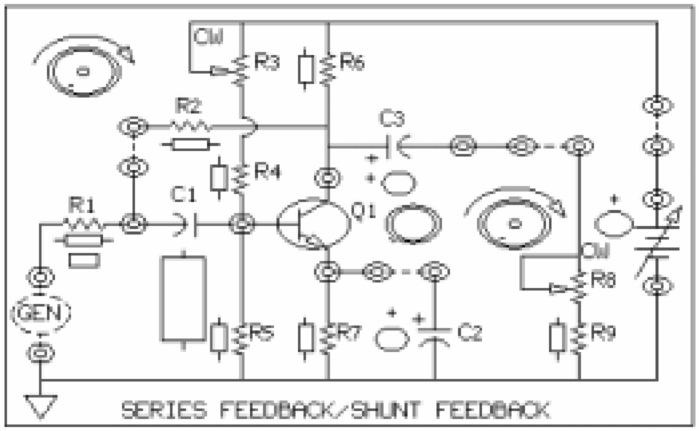
MULTISTAGE SERIES-SHUNT FEEDBACK circuit block

DIFFERENTIAL AMPLIFIER circuit block.

A GENERATOR BUFFER circuit and an ATTENUATOR circuit are also included on the circuit board. Three of the circuit blocks introduce various **feedback** methods. The fourth circuit block is a **differential amplifier**.



The **attenuator** can be used to attenuate or reduce the magnitude of an input signal.



To become familiar with a feedback circuit on the TRANSISTOR FEEDBACK CIRCUITS circuit board, you will set up a typical circuit and use test equipment to look at its operation.

Two-post connectors allow circuit configuration changes and circuit power application.

NEW TERMS AND WORDS

feedback **-** the return of a portion of an amplifier's output to its input.
differential amplifier **-** an amplifier whose output signal is proportional to the algebraic difference between two input signals.
attenuator **-** a passive network that reduces the level of a signal.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
Oscilloscope, dual trace
Generator, sine wave
TRANSISTOR FEEDBACK CIRCUITS circuit board

NOTES

Exercise 1 – Component Location and Identification

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to locate all major circuits on the TRANSISTOR FEEDBACK CIRCUITS circuit board. You will verify your results by correctly identifying circuits and their major components.

DISCUSSION

- The TRANSISTOR FEEDBACK CIRCUITS circuit board demonstrates four common forms of feedback.
- SERIES FEEDBACK/SHUNT FEEDBACK: Series and shunt feedback in a single transistor amplifier.
- MULTISTAGE SHUNT-SERIES FEEDBACK and MULTISTAGE SERIES-SHUNT FEEDBACK: Multistage circuits that contain two stages of amplification and use a combination of series and shunt feedback.
- DIFFERENTIAL AMPLIFIER: Two transistors in a circuit that amplifies small signals.

NOTES

Exercise 2 – Feedback Amplifier Operation

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to set up and activate a typical circuit block by using two-post connectors and applying power. You will verify your results with an oscilloscope.

DISCUSSION

- The SERIES FEEDBACK/SHUNT FEEDBACK circuit block develops series and shunt feedback in an amplifier circuit.
- The feedback is in parallel with (shunted across) the amplifier input.
- Demonstrate amplifier gain reduction with the use of negative feedback.

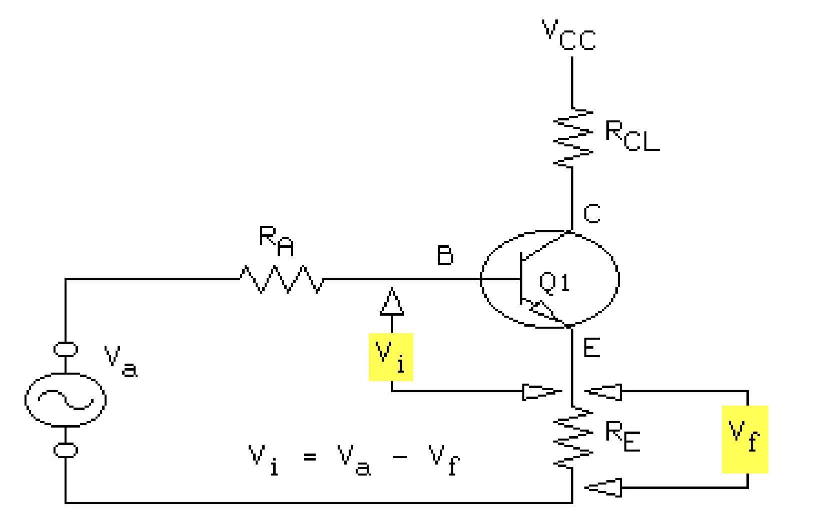
NOTES

UNIT 2 – SERIES FEEDBACK

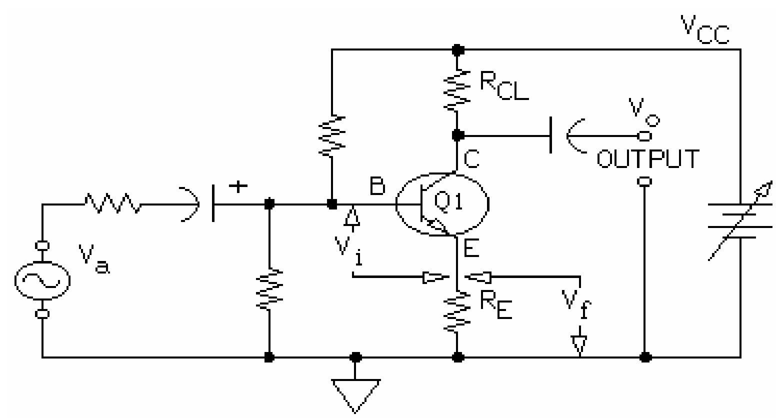
UNIT OBJECTIVE

At the completion this unit, you will be able to describe the effect of a series feedback circuit by using ac and dc measurements.

UNIT FUNDAMENTALS

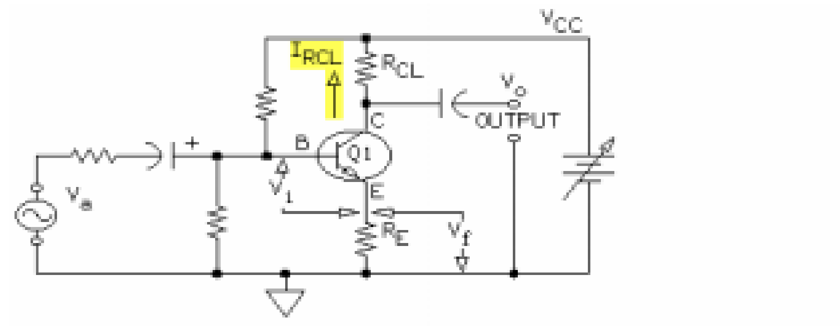


Degenerative feedback also known as inverse feedback or negative feedback, is produced when a portion of an amplifier's output signal is transferred to and opposes the effect of the input.



Negative feedback decreases the gain, increases the bandwidth, and affects the **input impedance** and the **output impedance** of an amplifier. **Series feedback** is applied in series with the input (V_a).

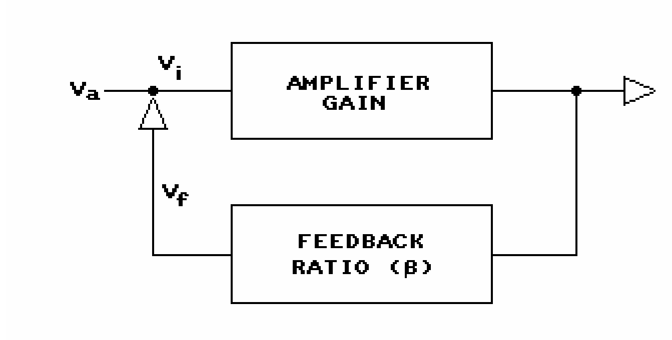
Current feedback is a feedback current that is proportional to output current (I_{RCL}).



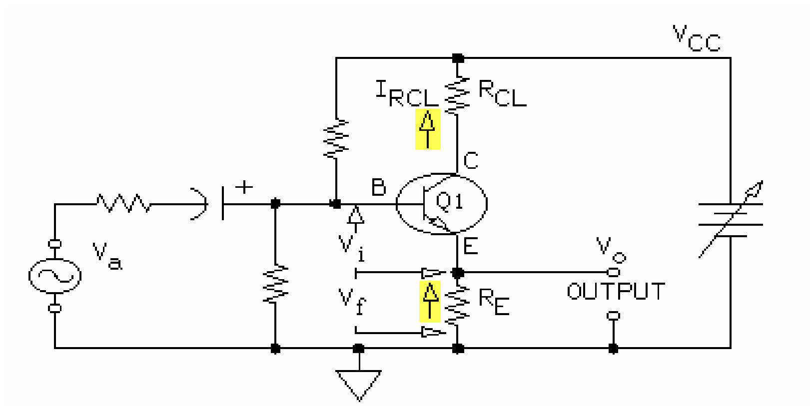
The output current (I_{RCL}) flows through the emitter feedback resistor (R_E).

I_{RCL} through R_E develops a feedback voltage (V_f).

V_f opposes the input voltage (V_a).



The **feedback ratio (β)** is the fractional part of the output voltage that is fed back to the input.



To understand the feedback ratio (β) in a common emitter amplifier such as this one, consider the output taken across the emitter resistor (R_E).

Since all of the output voltage (V_o) is fed back to the input ($V_f = V_o$), the feedback ratio (β) would be 1.

The gain relationship for any type of amplifier with feedback is determined by the following equation, where A_f is the gain with feedback and A is the gain without feedback.

$$A_f = \frac{A}{1 + (A \times B)}$$

In case of negative feedback, β is a negative quantity, and you need to take the minus sign into account when you calculate gain.

NEW TERMS AND WORDS

degenerative feedback - a mode of feedback in which a portion of the output is fed back to and opposes the input; also called inverse feedback or negative feedback.
input impedance - the impedance across the input terminals of an amplifier.
output impedance - the impedance across the output terminals of an amplifier; also called source impedance.
series feedback - a feedback signal applied in series with the input signal.
current feedback - a feedback signal that is proportional to output current.
feedback ratio - the portion of the output voltage that is fed back to the input; also referred to as feedback factor.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
Oscilloscope, dual trace
Generator, sine wave
TRANSISTOR FEEDBACK CIRCUITS circuit board

NOTES

Exercise 1 – Effect of Feedback on AC Gain

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe and measure the effect of series feedback on ac gain by using a typical series feedback circuit. You will verify your results with a multimeter and an oscilloscope.

DISCUSSION

- A common emitter type amplifier with an unbypassed emitter resistor is used to demonstrate series feedback, a common type of negative feedback.
- Negative feedback results in a reduction in gain of the amplifier to which it is applied.
- Assume an increase in base current from a positive-going input signal: voltage at the emitter will go more positive, effectively reducing the base signal by an equal amount.
- A large capacitor across the emitter resistor effectively bypasses the positive-going input signal to ground so that no reduction of the base signal occurs.
- The feedback factor (β) is determined from the values of the emitter resistor (R_E) and the collector resistor (R_C).
- To achieve negative feedback, the feedback factor (β) must be a negative quantity.

NOTES

Exercise 2 – Effect of Feedback on Bandwidth

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to under-stand the effect of series negative feedback on bandwidth by using a typical series feedback circuit. You will verify your results with an oscilloscope.

DISCUSSION

- Amplifier bandwidth defined
- Lower and upper cutoff frequencies specified as 3 dB down from midrange level
- Approximate bandwidth using square wave input signal and formula $f_x = 0.159/T$.

Negative feedback reduces the gain of an amplifier and increases bandwidth.

NOTES

Exercise 3 – Effect of Feedback on Impedance

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe the effect of series feedback on input impedance by using a typical series feedback circuit. You will verify your results with an oscilloscope.

DISCUSSION

- Simple input impedance is the sum of all series elements and the transistor base input impedance including effects of any bias resistors.
- Adding series negative feedback to a common emitter amplifier increases input impedance.
- $V_{R1} = V_i - V_b$
- $I_i = V_{R1}/R1$
- $Z_i = V_i/I_i$

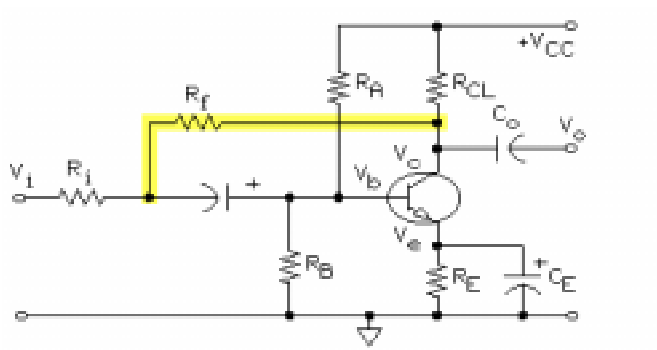
NOTES

UNIT 3 – SHUNT FEEDBACK

UNIT OBJECTIVE

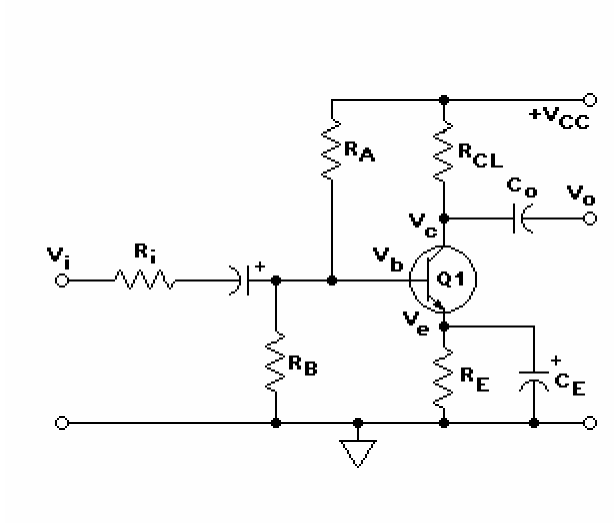
At the completion of this unit, you will be able to describe the effects of shunt feedback on ac gain, bandwidth, input impedance, and output impedance by using a typical shunt feedback circuit.

UNIT FUNDAMENTALS



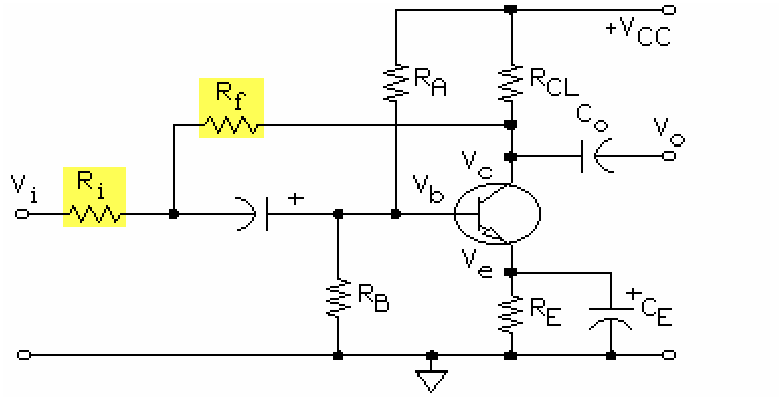
Shunt negative feedback places a portion of an amplifier's output voltage in shunt (parallel) with the input voltage.

Shunt feedback effectively shunts the input and the output of an amplifier.



For a transistor amplifier without feedback, the gain (A) depends on the transistor ac gain (β). For the transistor used in this circuit, β can vary from 50 to 300.

$$Av = \beta$$



The gain (A_f) of a shunt feedback amplifier equals the ratio of the feedback resistor (R_f) to the series input resistor (R_i).

$$A_f = R_f / R_i$$

For shunt feedback, the feedback ratio (β) is the reciprocal of A_f.

$$\beta = R_i / R_f$$

Therefore, this equation applies.

$$\beta = 1/A_f$$

Negative shunt feedback decreases gain but increases the bandwidth.

NEW TERMS AND WORDS

***Shunt feedback* -** feedback voltage that is effectively applied in parallel with the input signal.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
Oscilloscope, dual trace
Generator, sine/square wave
TRANSISTOR FEEDBACK CIRCUITS circuit board

NOTES

Exercise 1 – Effect of Shunt Feedback on AC Gain

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to understand the effect of shunt negative feedback on ac gain by using a typical shunt feedback circuit. You will verify your results with an oscilloscope.

EXERCISE DISCUSSION

- A small positive change in V_i of a transistor increases base current which, in turn, decreases collector voltage V_c.
- A portion of this decreasing collector voltage is sent back to, and summed with, the rising input signal.
- The positive-going voltage V_i and the opposite-in-phase V_c oppose each other.
- The gain with feedback (A_f) of a shunt feedback amplifier is approximately equal to the ratio of feedback resistor R_f to series input resistor R_i: $A_f = R_f/R_i$.
- For shunt feedback, the feedback ratio (β) is the reciprocal of Af: $\beta = R_i/R_f$.

NOTES

Exercise 2 – Effect of Feedback on Bandwidth

EXERCISE OBJECTIVE

When you have completed this exercise, you will understand the effect of shunt negative feedback on bandwidth by using a typical shunt feed-back circuit. You will verify your results with an oscilloscope.

DISCUSSION

- Bandwidth defines the breadth of input frequency for which the output amplitude remains constant, within prescribed limits
- Limits are usually defined as upper and lower cutoff frequency
- Cutoff frequency is where the gain of an amplifier falls to 3 dB of its average gain
- Average gain means the midrange gain: the gain at the center of its bandwidth
- A square wave can be used to measure bandwidth of an amplifier by checking certain characteristics of the square wave at the output of the amplifier
- As viewed on an oscilloscope, the lower cutoff frequency is the time (T) it takes the square-wave leading edge to reach 63 percent of its final level
- As viewed on an oscilloscope, the upper cutoff frequency is the time it takes the output to fall 63 percent
- Simplified equation for lower (or upper) cutoff frequency is: f1 (or f2) = 0.159/T

NOTES

Exercise 3 – Effect of Feedback on Impedance

EXERCISE OBJECTIVE

When you have completed this exercise, you will understand the effect of shunt negative feedback on input and output impedance by using a typical shunt feedback circuit. You will verify your results with an oscilloscope.

DISCUSSION

- Bandwidth defines the breadth of input frequency for which the output amplitude remains constant, within prescribed limits
- Limits are usually defined as upper and lower cutoff frequency
- Cutoff frequency is where the gain of an amplifier falls to 3 dB of its average gain
- Average gain means the midrange gain: the gain at the center of its bandwidth
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- As viewed on an oscilloscope, the lower cutoff frequency is the time (T) it takes the square-wave leading edge to reach 63 percent of its final level
- As viewed on an oscilloscope, the upper cutoff frequency is the time it takes the output to fall 63 percent
- Simplified equation for lower (or upper) cutoff frequency is: f1 (or f2) = 0.159/T

NOTES

UNIT 4 – MULTISTAGE AMPLIFIER FEEDBACK

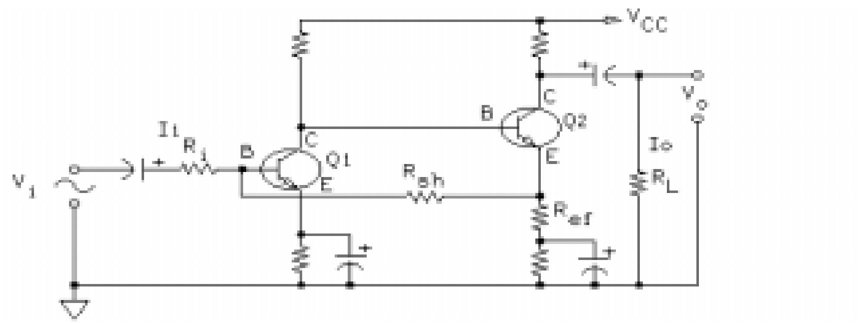
UNIT OBJECTIVE

At the completion of this unit, you will be able to describe the operation and characteristics of two types of multistage feedback amplifiers by using ac and dc measurements.

UNIT FUNDAMENTALS

Multistage feedback is in an amplifier circuit that has more than one stage. This feedback is across the entire amplifier circuit.

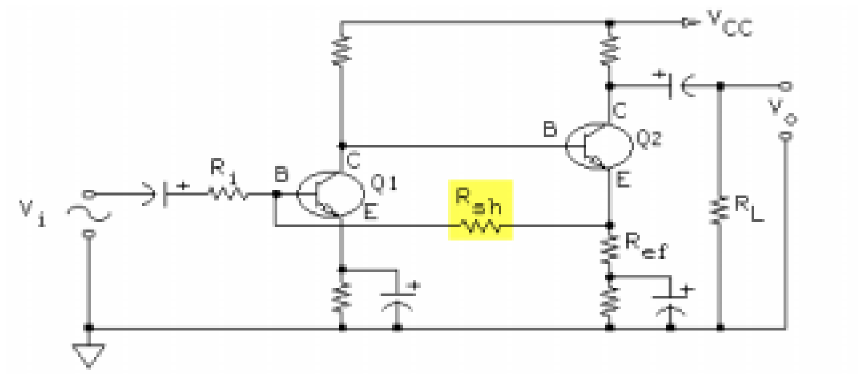
There are two basic types of multistage amplifier feedback: **shunt-series** and **series-shunt**.



Shown is a shunt-series feedback circuit. Resistor R_{sh} provides shunt feedback to the input stage.

Resistor R_{ef} provides series feedback to the output stage.

In a multistage amplifier with shunt-series feedback, the feedback ratio of R_{sh}/R_{ef} determines the ac current gain ($Ai = R_{sh}/R_{ef}$).



Shown is a series-shunt feedback circuit.

Resistor R_{ef} provides series feedback to the input stage.

Resistor R_{sh} provides shunt feedback to the output stage.

In a series-shunt multistage amplifier, the feedback ratio of R_{sh}/R_{ef} determines the voltage gain ($Av = R_{sh}/R_{ef}$).

NEW TERMS AND WORDS

***shunt-series* -** a multistage amplifier in which the input stage has shunt feedback.
***series-shunt* -** a multistage amplifier in which the input stage has series feedback.
***constant current source* -** a high impedance source that delivers the same load current

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
Oscilloscope, dual trace
Generator, sine wave
TRANSISTOR FEEDBACK CIRCUITS circuit board

NOTES

Exercise 1 – Shunt-Series Current Gain

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to calculate and measure shunt-series current gain by using a typical shunt-series multistage amplifier circuit. You will verify your results with an oscilloscope.

DISCUSSION

- Known as a current amplifier, current gain (Ai) equals the shunt resistance (R_{sh}) divided by the series resistance (R_{ef}).

NOTES

Exercise 2 – Shunt-Series Output Impedance

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to measure shunt-series output impedance by using a typical shunt-series multi-stage amplifier circuit. You will verify your results with an oscilloscope and a multimeter.

DISCUSSION

- Circuit output impedance (Zo) equals the transistor collector impedance in parallel with the collector resistor.
- Zo = (Rco x Rc)/(Rco + Rc)
- Because of the high output impedance of the circuit, it acts as a constant current source for small loads.

NOTES

Exercise 3 – Series-Shunt Voltage Gain

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to calculate and measure series-shunt voltage gain by using a typical series-shunt multistage amplifier circuit. You will verify your results with an oscilloscope.

DISCUSSION

- In a multistage amplifier with series-shunt feedback, resistor R_{ef} provides series feedback and R_{sh} provides shunt feedback to the input stage
- Circuit voltage gain is directly related to and R_{sh}
- $Av = R_{sh}/R_{ef}$
- A series-shunt feedback amplifier has high voltage gain

NOTES

Exercise 4 – Series-Shunt Output Impedance

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to measure the output impedance of a series-shunt feedback amplifier by using a variable load connected to the circuit output. You will verify your results with an oscilloscope and a multimeter.

DISCUSSION

- Output impedance of a series-shunt amplifier equals the shunt resistor divided by the transistor beta in parallel with the collector resistor
- $Zo = R_{sh}/\beta \parallel Rc$

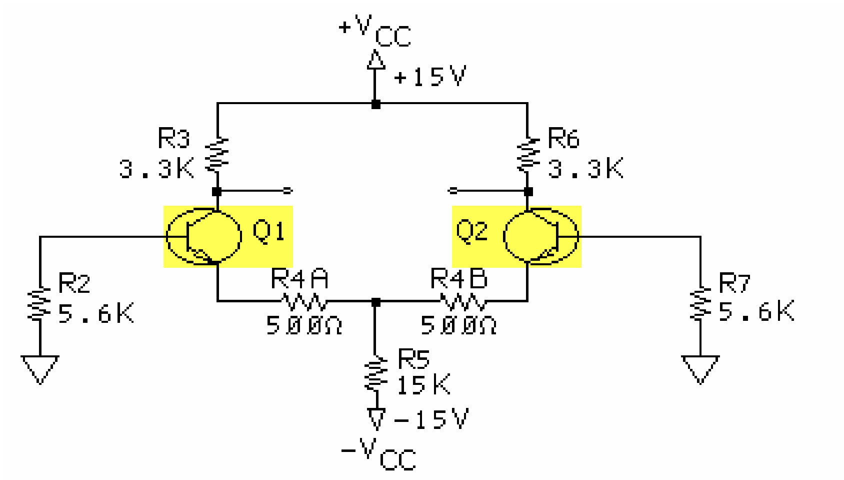
NOTES

UNIT 5 – DIFFERENTIAL AMPLIFIERS

UNIT OBJECTIVE

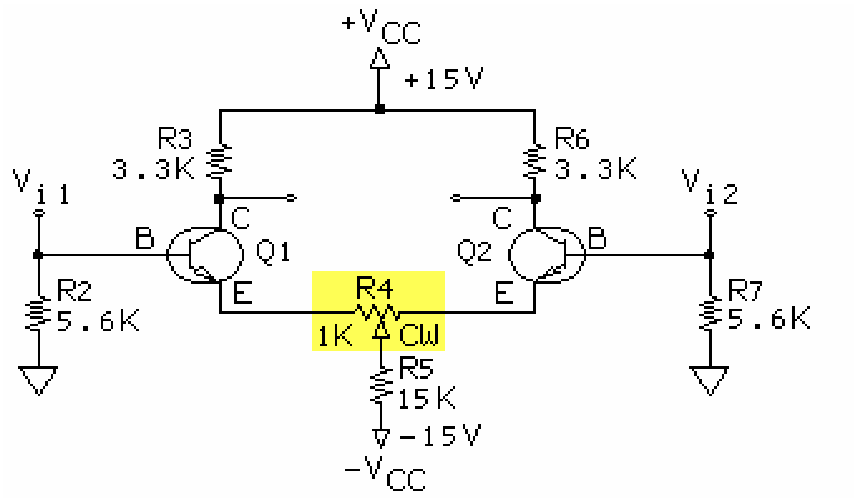
At the completion of this unit, you will be able to describe the operation of a differential amplifier by using ac and dc measurements.

UNIT FUNDAMENTALS



This circuit is a **differential amplifier**. It has two transistors (Q1 and Q2) with equal gains.

The two emitter resistors (R4A and R4B) are tied together and connect to a common emitter resistor (R5). R5 sets the circuit operating current, which divides equally between the two transistors.



A differential amplifier has several modes of opera-tion. You can take the output between the two collectors or from either transistor collector to ground.

The output taken from one collector with respect to ground is called a **single-ended output**. The output taken between the two collectors is called a **double-ended output**, or more commonly, a **differential output**.

A differential amplifier can also have a **single-ended input** signal at either input or a **differential input**, which is applied between he two inputs and is not referenced to ground.

NEW TERMS AND WORDS

differential amplifier - an amplifier whose output signal is proportional to the algebraic difference between two input signals.
single-ended output - an output that is referenced to ground or circuit common.
differential output - an output circuit in which the signal is taken between two levels which are floating; there is no ground (common) reference.
single-ended input - an input that is referenced to ground or circuit common.
differential input - an input circuit that amplifies the difference between two input terminals.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
Oscilloscope, dual trace
Generator, sine wave
TRANSISTOR FEEDBACK CIRCUITS circuit board

NOTES

Exercise 1 – Operation

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe some characteristics of a differential amplifier by using a typical differential circuit. You will verify your results with an oscilloscope and a multimeter.

DISCUSSION

- Differential amplifier is balanced to equalize collector voltage to zero.
- This circuit is a single-ended input with ground reference
- A single-ended in-phase output is taken from Q2
- A single-ended out-of-phase is taken from Q1
- A nonground-referenced differential output is taken from Q1/Q2 collectors.

NOTES

Exercise 2 – Differential Gain

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to measure single-ended and differential gain by using a typical differential amplifier circuit. You will verify your results with an oscilloscope and a multimeter.

DISCUSSION

- Collector-to-emitter resistor-ratio determines the gain of each half of the differential amplifier
- $A = R_C/(2 \times R_E)$

NOTES

Exercise 3 – Gain

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to measure common mode gain by using a typical differential amplifier circuit. You will verify your results with an oscilloscope, a signal generator, and a multimeter.

EXERCISE DISCUSSION

- A signal applied to both inputs (V_{i1} and V_{i2}) at the same time is called a common mode signal.
- A characteristic of the differential amplifier is its ability to reject common mode signals.
- Common mode signals are rejected only at the differential output; the single-ended outputs contain the common mode signals.

NOTES

APPENDIX A – SAFETY

Safety is everyone's responsibility. All must cooperate to create the safest possible working environment. Students must be reminded of the potential for harm, given common sense safety rules, and instructed to follow the electrical safety rules.

Any environment can be hazardous when it is unfamiliar. The F.A.C.E.T. computer-based laboratory may be a new environment to some students. Instruct students in the proper use of the F.A.C.E.T. equipment and explain what behavior is expected of them in this laboratory. It is up to the instructor to provide the necessary introduction to the learning environment and the equipment. This task will prevent injury to both student and equipment.

The voltage and current used in the F.A.C.E.T. Computer-Based Laboratory are, in themselves, harmless to the normal, healthy person. However, an electrical shock coming as a surprise will be uncomfortable and may cause a reaction that could create injury. The students should be made aware of the following electrical safety rules.

1. Turn off the power before working on a circuit.
2. Always confirm that the circuit is wired correctly before turning on the power. If required, have your instructor check your circuit wiring.
3. Perform the experiments as you are instructed: do not deviate from the documentation.
4. Never touch "live" wires with your bare hands or with tools.
5. Always hold test leads by their insulated areas.
6. Be aware that some components can become very hot during operation. (However, this is not a normal condition for your F.A.C.E.T. course equipment.) Always allow time for the components to cool before proceeding to touch or remove them from the circuit.
7. Do not work without supervision. Be sure someone is nearby to shut off the power and provide first aid in case of an accident.
8. Remove power cords by the plug, not by pulling on the cord. Check for cracked or broken insulation on the cord.