BJT General Design

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Introduction

The process of performing AC amplifier design using bipolar junction transistor involves

1. Determining the appropriate type of amplifier to use
2. Choosing certain resistor values based on the load resistance
3. Determining appropriate bias conditions for the type of amplifier being designed
4. Performing DC bias design to achieve those conditions
5. Calculating the necessary value of RE1 to achieve a specific gain for common-emitter amplifiers
6. Determining the value of AC coupling capacitors to achieve a specified low frequency response

Step 6 will not be discussed here as the details will be in another note. This paper is concerned with determining resistor values only.

It is possible that a desired gain may not be achievable. This will not be known until some calculation in the design process produces a negative resistor value. The solution is to add one or more stages of gain as needed.

Each type of amplifier will have different issues to consider.

The choice of amplifier type

The three different types of amplifiers; common-emitter, common-base, and common-collector have very different characteristics. For any given amplifier requirement, one of these types will be the best choice although a different type may also perform well. In general, the best amplifier to use is the one whose input resistance is comparable to the source resistance and whose output resistance is comparable to the load resistance. It is usually not possible to satisfy both input and output resistance characteristics simultaneously. Sometimes it is necessary to perform the design for two of the three possible types to see which one ends up providing the best overall characteristics. The following table provides some rough guidelines when the goal is to achieve high power gain. The key parameter that drives the decision is the ratio of the source to the load resistance.

BJT General Design

Source resistance / load resistance	Good choices to consider
greater than 10	Common-collector
2 to 10	Common-emitter or Common-collector
0.5 to 2	Common-emitter
0.1 to 0.5	Common-emitter or Common-base
less than 0.1	Common-base

It can be shown that the common-emitter amplifier is capable of achieving the highest possible power gain although that is not useful if the amplifier is not the best for the given situation – one of the other types will provide higher power gain in those situations. Overall, the common-emitter amplifier is the most flexible in terms of input and output resistance while also achieving reasonable power gain.

The common-base amplifier is generally useful only when the source resistance is much smaller than the load resistance or very high frequency amplification is needed. The common-base amplifier is capable of the highest amplifier bandwidth.

The common-collector amplifier is generally only useful when the source resistance is much higher than the load resistance. The two primary applications for common-collector amplifiers are in input stages to increase the input impedance of the amplifier or in output stages to decrease the output impedance of the amplifier.

Stability of design issues

Stability as used here refers to the desirable characteristic that bias voltages and currents are little affected by changes in temperature or variations in beta of the transistor. Stability and power gain can be in opposition to each other thus requiring compromise or engineering judgment to resolve.

The following are brief summaries of the design steps for each type of amplifier. The details are described in other notes.

Common-emitter design

The basic sequence of steps is

1. Choose an appropriate value for RC based on the load resistance
2. Calculate a value for VBB based on temperature stability requirements
3. Determine a value for VCQ (very complicated – see other notes)
4. Complete the bias design
5. Calculate the value of RE1 to achieve a specific AC gain.

BJT General Design

Common-base design

The design of common-base amplifiers is very similar to the design of common emitter amplifiers

1. Choose an appropriate value for RC based on the load resistance
2. Calculate a value for VBB based on temperature stability requirements
3. Determine a value for VCQ (complicated – see other notes)
4. Complete the bias design
5. Calculate the value of RE1 to achieve either a specific input impedance or a specific AC gain

Common-collector design

The designer does not have control over the gain of a common-collector design. The gain will always be less than one. Typical gains vary from about 0.99 down to 0.7 or below. The designer does have some control of the output impedance by adding a resistor, RE1, in series with the output. This resistor increases the output impedance and also increases the input impedance. However, in all cases, the net gain decreases as a result of the additional voltage division – but some impedance match may be more important than gain.

1. Choose an appropriate value for RE based on the load resistance
2. Calculate the value for VEQ that maximizes signal swing
3. Determine the value for VBB
4. Complete the bias design
5. Calculate the value of RE1 to achieve a specific output impedance