

7-1 Variations in Current Gain

The current gain β_{dc} of a transistor depends on three factors: the transistor, the collector current, and the temperature. For instance, when you replace a transistor with another of the same type, the current gain usually changes. Likewise, if the collector current or temperature changes, the current gain will change.

Worst and Best Case

As a concrete example, the data sheet of a 2N3904 lists a minimum h_{FE} of 100 and a maximum of 300 when the temperature is 25°C and the collector current is 10 mA. If we build thousands of circuits with 2N3904s, some of the transistors will have a current gain as low as 100 (worst case), and others will have a current gain as high as 300 (best case).

Figure 7-1 shows the graphs of a 2N3904 for the worst case (minimum h_{FE}). Look at the middle curve, the current gain for an ambient temperature of 25°C. When the collector current is 10 mA, the current gain is 100, the worst case for a 2N3904. (In the best case, a few 2N3904s have a current gain of 300 at 10 mA and 25°C.)

Effect of Current and Temperature

When the temperature is 25°C (the middle curve), the current gain is 50 at 0.1 mA. As the current increases from 0.1 mA to 10 mA, h_{FE} increases to a maximum of 100. Then, it decreases to less than 20 at 200 mA.

Also notice the effect of temperature. When the temperature decreases, the current gain is less (the bottom curve). On the other hand, when the temperature increases, h_{FE} increases over most of the current range (the top curve).

Main Idea

As you can see, transistor replacement, collector-current changes, or temperature changes can produce large changes in h_{FE} or β_{dc} . At a given temperature, a 3:1 change is possible when a transistor is replaced. When the temperature varies, an additional 3:1 variation is possible. And when the current varies, more than a 3:1 variation is possible. In summary, the 2N3904 may have a current gain of less than 10 to more than 300. Because of this, any design that depends on a precise value of current gain will fail in mass production.

GOOD TO KNOW

The symbol h_{FE} represents the forward current transfer ratio in the common-emitter configuration. The symbol h_{FE} is a hybrid (h)-parameter symbol. The h -parameter system is the most common system in use today for specifying transistor parameters.

Figure 7-1 Variation of current gain.

