Multi-Stage Tuned Amplifier

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1 Objective

To compare the operation of common-emitter and common-base tuned amplifier stages, and to design and characterize a multi-stage, high-gain IF amplifier for 10 MHz operation with 50Ω input and output impedances.

2 Principles of Operation

Tuned amplifiers are critical for electronic communications because they increase the power of desired signal but reject other frequencies as noise. At 10 MHz, a tuned amplifier could be used with an antenna to recieve HF amateur radio from the other side of the world [1], or could be used in a computer to recieve 10Base-T ethernet.

There are three possible circuit configurations for bipolar junction transistors (BJT) biased in forward-active mode, based on which terminals are used for input, output, and common reference.

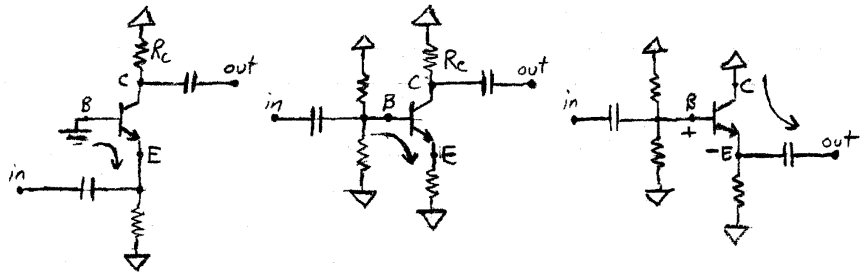

Figure 1: Common-base (left), common-emitter (middle), and common-collector (right) configurations for BJT amplifiers.

Each configuration has its tradeoffs. The common-base (CB) configuration is a good current buffer, with $A_i \approx 1$ and low input impedance. The common-emitter (CE) configuration offers the best overall power gain, but A_v and A_i may vary with loadings. The common-collector configuration, or emitter-follower, is a good voltage buffer ($A_v \approx 1$) with low output impedance.

The three configurations can be cascaded together to gain the benefits of each and mask their deficiencies. If cascaded in the order shown in figure 1, from left-to-right, the resulting 3-stage broadband amplifier would have low input impedance, good power gain, and minimal output impedance.

A slight modification to the CE and CB configurations in figure 1 can apply a filter to the broadband amplifier; tuning the gain to a narrow frequency set by a tank circuit.

Because BJTs are minority carrier devices, they act as current amplifiers without being strongly affected by voltage. For the two configurations where the output is at the collector (CB and CE), the BJT acts like a dependent current source feeding the output load and the biasing resistance R_C. As a result, the voltage gain for these configurations is determined primarily by how difficult it is for the collector current to reach ground; $A_v \propto R_C||R_L$.

The designer can take advantage of the collector current's obstinance by replacing R_C with an impedance that varies with frequency. Using an inductor and a capacitor in parallel would provide shorts to ground for DC currents and very high frequency currents. Parallel LC circuits also have a resonance frequency at which their net impedance approaches infinity because power simply oscillates between the two. [2] The result is that the amplifier gain will be very high at resonance, when impedance is high, but will drop quickly for other frequencies.

[1] 10 MHz waves can traverse the curve of the earth because they get reflected by charged particles in the ionosphere, called ionospheric skip propagation.

[2] For this reason, an $L||C$ circuit is called a tank circuit.