Multi-Stage Amplifiers

Consider all the types of transistor amplifiers that we have studied (e.g., differential pair, common emitter, source follower, etc.).

* Each had at least one attractive feature (e.g. high open-circuit voltage gain, low output resistance, differential gain, high input resistance, etc.)

* But each also had at least one sub-optimum feature (e.g., low-open-circuit voltage gain, low input resistance, high output resistance, etc.).

Q: Yikes! Is building the perfect amplifier completely impossible??

A: Well, certainly building a perfect amplifier is not achievable, but we can build amplifiers that are very, very good!

For example, consider the op-amp that you use in lab. It had a high input resistance, and a very high open-circuit (differential) voltage gain, and a low output resistance!
A: Undoubtedly so! However, that is not the main reason why the designer of your op-amp was successful. For you see, the op-amp you used in the lab was a multi-stage amplifier!

A multi-stage amplifier is a complex circuit constructed using several of the basic designs (e.g., common source, emitter follower) that we have studied. Typically, a multi-stage amplifier consists of 3 sections:

1. The Input Stage - This section has one purpose, to provide the multi-stage amplifier with a high input resistance. For differential amplifiers, this stage must also be a differential amplifier (e.g., a differential pair).

2. The Gain Stages - This section consists of one or more amplifiers (stages) with high open-circuit voltage gain (e.g., common emitter, common source). This section thus provides the required voltage gain for the multi-stage amplifier.
3. The Output Stage - The third and final section of the multi-section amplifier likewise has one purpose: to provide the multi-stage amplifier with a low output resistance. As such, this stage is often a common collector (emitter follower), or common drain (source follower).
For example, consider this operational amplifier circuit:

Note the input stage is a differential pair, the gain stage is common-emitter amp, and the output stage is a emitter follower (i.e., common-collector) amp.

Consider now these integrated circuit Multi-Stage Amplifiers:
For this example, Q₈ is a current source, with Q₅ and Q₇ parts of a current mirror!

Transistor Q₅ provides the current source for a PMOS differential pair. PMOS devices Q₁ and Q₂ are the two input transistors for this differential pair, while Q₃ and Q₄ are the active loads of the differential pair—they act as the two drain resistors R_D.

Finally, transistors Q₆ and Q₇ form a common source amplifier (high gain!) where the amplifier “load” is the current source Q₇. Note that the output resistance of this amp is very high!
In this multistage circuit, Q₉ forms a current source, and Q₃ and Q₆ complete the current mirror.

Clearly Q₁ and Q₂ form a BJT differential pair, as does transistors Q₄ and Q₅. The first differential pair is the input stage, where the second differential pair acts as a gain stage (recall the open-circuit voltage gain of a BJT diff. pair is large).

Transistor Q₈ is clearly part of an emitter-follower output stage.
A: The reason for the section including Q7 is “DC shifting”. Note that there are no AC coupling (i.e., DC blocking) capacitors in this circuit, and thus the DC biasing of one stage affects the DC biasing of another.

The circuit associated with Q7 allows the output of the second differential amplifier to be connected to the input of the emitter-follower without messing up the required DC bias levels for the collector of Q5 and the base of Q8.

Q: Wait a second! I see where you have neglected to speak about transistor Q7. It looks to me that it forms an amplifier that is neither a common emitter nor a common collector configuration!?!