Mixer

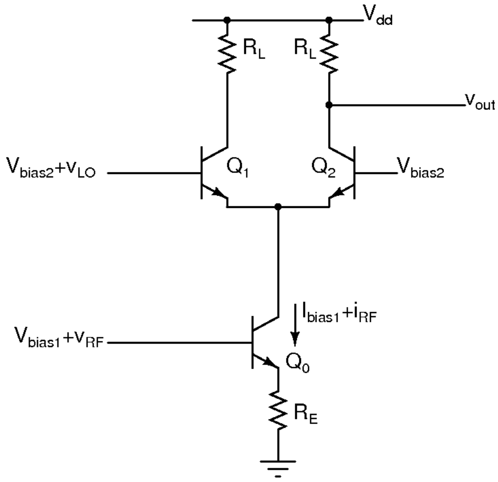
Goals

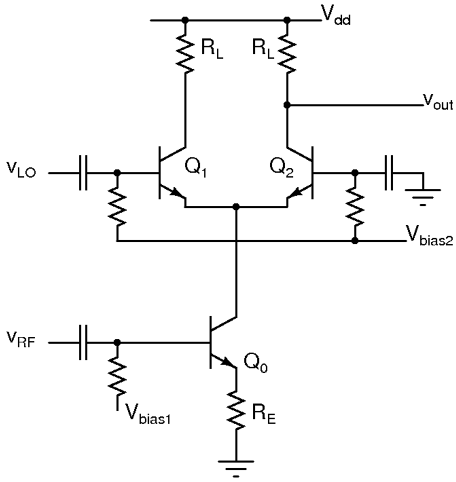
- Understand the operation of a mixer used for frequency conversion
- Design and build a single balanced mixer

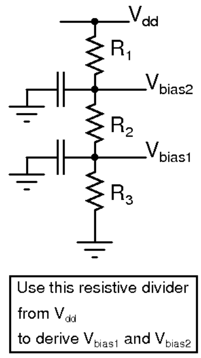
Principle

- A mixer is used for frequency conversion. For example, it is used in radio receivers to convert incoming signals at a high frequency to a lower intermediate frequency. And, in transmitters, it is used to convert low frequencies such as voice to high carrier frequencies.
- A linear time invariant network cannot generate new frequencies. For frequency conversion, one needs nonlinearity or time variance. The mixer you'll build here is of the latter variety-i.e. its input signal will experience a time varying gain(controlled by another signal). In this respect, it'll be different from circuits you have studied so far, most of which have been linear and time invariant. Be sure to go through the description and this lecture before the experiment.
- A message signal $v_{RF}(t)$ has to be shifted in frequency by an amount f_{LO} while retaining its spectral shape. i.e. $V_{RF}(f)$ has to be turned into $V_{RF}(f \pm f_{LO})$. Frequency conversion is accomplished by the mathematical operation $v_{out} = k*v_{RF}*v_{LO}$ where v_{LO} is a sinusoid of frequency f_{LO}. Of the two components at $f \pm f_{LO}$, one of them can be selected using a filter to attenuate the other. (The terms v_{RF} and v_{LO} are carried over from radios where they stand for radio frequency input and local oscillator signal respectively)
- For practical reasons, switching mixers are used instead of multipliers. i.e. v_{LO} is a square wave of frequency f_{LO} instead of a sinusoid. These are described by $v_{out} = k*v_{RF}*sgn(v_{LO})$ where sgn() denotes the signum function. $sgn(v_{LO})$ where v_{LO} is a sinusoid at f_{LO} contains odd harmonics $n*f_{LO}$, n=1,3,5,… In this case, $V_{RF}(f)$ is turned into $V_{RF}(f \pm n*f_{LO})$, n=1,3,5,… As before, the desired component can be selected using a filter to attenuate all but one of them.
- The figure below shows a mixer. The combination of Q_0 and R_E converts the input signal v_{RF} to a signal current i_{RF} riding on a bias current I_{bias}. The differential pair $Q_{1,2}$ is driven by v_{LO} which is a square wave or a sufficiently high amplitude sinusoid such that only one of $Q_{1,2}$ is completely on at a given time and the other is switched off. The current $I_{bias}+i_{RF}$ is steered to the two load resistors alternately. Consequently, the voltage at the collector will be a certain bias voltage plus $k*(I_{bias}+i_{RF})*sgn(v_{LO})$.

- One deviation of this circuit from the description in the previous paragraphs is the presence of I_{bias} in addition to i_{RF}. Therefore, if v_{RF}=0(i.e. i_{RF}=0), the output will contain a component proportional to sgn(v_{LO}). This also needs to be filtered out if only the sum or difference frequency component is to be extracted. This is known as local oscillator(LO) feedthrough and is a characteristic of this type of mixers which are known as single balanced mixers.







To be done before the lab session

- Go through the lecture on mixers [http://www.ee.iitm.ac.in/~nagendra/EC330/200901/lectures/ec330-mixer1/ec330-mixer1.swf].
- Design a single balanced mixer using BC107 transistors(you can of course use BC177 transistors and turn the whole circuit upside down). Use a 12V supply and about 1mA bias current. Use a voltage divider to generate V_{bias1} and V_{bias2}. Remember to bypass the bias nodes to ground. The mixer should be able to take in an input peak of 1V and have a conversion gain(ratio of the *sinusoidal component* at f_{RF}+f_{LO} OR f_{RF}-f_{LO} at the output to the amplitude of the *input sinusoid*) of 1.
- Wire up the circuit. Circuits with many transistors tend to be more messy to wire up than circuits with ICs. Make sure you give yourselves enough time to do this.
- You'll need the oscillator from the previous experiment to provide the LO input. The fixed frequency oscillator will be adequate.

Experiment

- Drive the input with a low frequency v_{RF}(~ 1kHz) and a high frequency v_{LO}(~10kHz) and observe the output. You can use the oscillator designed in the previous experiment as the 10kHz source.
- Drive the mixer with a v_{RF} and v_{LO} at close by, but not identical frequencies and observe the low frequency(f_{RF}-f_{LO}) output. For filtering out the high frequency component, use a capacitor of appropriate value across R_L which will short it out at high frequencies. Filtering will be a lot easier if you choose a higher f_{LO}, say 25kHz or 50kHz, and a difference frequency around 1kHz.
- Remove the RF input and observe the LO feedthrough

- **Questions**:
  - How will you get rid of the LO feedthrough?
  - What happens in this experiment if you do not bypass the bias nodes V_{bias1} and V_{bias2} generated using a resistive divider?

Applications

- This(modified to get rid of the LO feedthrough) is probably the most widely used topology for mixers. [An alternative is to use switches(MOS transistors or diodes) to direct the signal to the output and away from it.] It is used in both transmitters and receivers. Typically, in a receiver, a high frequency v_{RF} is mixed with a comparably high frequency v_{LO} to convert the signal to a relatively low intermediate frequency $f_{IF}=f_{LO}-f_{RF}$. In a transmitter, a low frequency “message signal” v_{mod} around zero frequency is mixed with a high frequency v_{LO} to convert the signal to the carrier frequency f_{LO}. Although in its native form it does amplitude modulation, combinations of mixers are used for other types of signalling that involve both amplitude and phase modulation. You will see this in your courses on communication systems.

Something to try on your own

- Drive the lower input with audio, say from your computer or digital player. Drive the LO input with a sinusoid in the AM band(0.5-1.5MHz). You should be able to use an AM radio placed close by to receive the transmitted audio. You can use a short wire connected to the output node as an antenna.