Lab 3: AM Modulator and AM Demodulator

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Aim of the experiment

To study amplitude modulation and demodulation using hardware

- Design of a single-balanced mixer (a multiplier with DC offset)
- Design of an envelope detector to demodulate the signal
- Design of a double-balanced mixer to avoid carrier feed-through (This part of the experiment carries bonus marks)

Pre-lab Work

- Make sure that you have completed implementation of amplitude modulation and demodulation in GNU radio in Lab2.
- Make sure that you have read the supporting material uploaded along with this document.

Components Required

- IC LM3086 / IC CA3086E
- Resistors(quantity) – 470Ω(1), 1kΩ(2), 10kΩ(2), 15kΩ(1),18kΩ(2),68kΩ(1)
- Capacitors(quantity) – 0.33 uF(3)
- Diode – 1N914
- Potentiometer –500Ω
- Arbitrary Function Generator (dual-channel function generator)
- Single channel function generator
- DSO
- Multimeter
- Breadboard for connecting wires

  Note: Ensure that all components are taken(with reference to figure in page no.14 , also extra resistors and capacitors may be required to design envelope detector circuit with reference to page no.19)

How to Use a DSO(Digital storage oscilloscope)

Image courtesy: https://in.tek.com/datasheet/digital-storage-oscilloscope-0

How to Use a DSO

- Many features of DSO are similar to that of a CRO
- The volts/div knob is used to change the y-axis scale and the time/div knob is used to change the x-axis scale
- Math option is used to perform mathematical operations such as FFT, addition, subtraction, multiplication, etc on the signals
- While performing arithmetic operations on the signals make sure that the scales of both channels are the same
- Use Run/Stop button to Run/Freeze the waveforms
- Waveforms can also be made stationary by using proper triggering (Check with the TA if required).

Image courtesy: https://www.tek.com/arbitrary-function-generator/afg1000-arbitrary-function-generator

How to use AFG

- To produce different waveforms choose from the wave function options available (Sine, Square, Ramp etc.)
- Use ‘Mod’ key on the panel to use options to generate - Modulated, Sweep, Burst, Continuous nature of waves. We will be using continuous mode. If we need to use Mod mode then Mod key will glow.
- You can adjust Freq/Period, Start Phase, Offset, Amplitude, etc by using vertical array of keys which are aligned at right side of display

How to use AFG (cntd)

- The number pad is used to enter the required values of frequency, phase or amplitude. The knob can also be used to adjust the selected parameter
- Make sure that the output is in High-Z (i.e. high impedance) mode for each experiment in EE340. (This is because the AFGs will be driving circuits which have an impedance that is much higher than the characteristic impedance of the transmission line.) In low impedance state, the AFG will generate more voltage (than programmed for), which may damage your devices.
- To set High-Z, Use following keys$\rightarrow$ (Utility) $\rightarrow$ (Output Setup)$\rightarrow$(High Z)

Important tips

- To avoid noise pickup and easy debugging:
  - Use shorter wires for supply to avoid external pickup and keep resistor legs short for easy debugging.
  - Short "Ground" terminals of all units/supply to reduce the effect of noise pickup.
  - The alligator clips of the probes (Negative terminal) should be connected to the oscilloscope "Ground"
- If you are not getting a desired output then observe the waveforms at different nodes starting from the signal source to trace the location of the fault

Part 1 Single-Balanced Mixer (Multiplier with DC Offset)

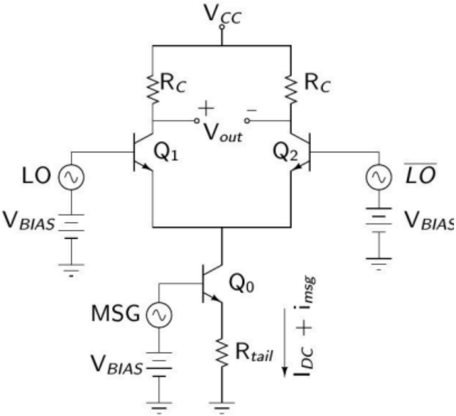


Figure: Single-Balanced Mixer

Part 1 Single-Balanced Mixer (Multiplier with DC Offset)(cnt'd)

- The output of the mixer has frequency components at the carrier frequency (f_{LO}) and at two side bands $f_{LO} + f_{MSG}$ and f_{LO} - f_{MSG}
- We can observe from the circuit that the tail current is $I_{DC} + i_{MSG}$
- Hence, the output (V_{out}) is proportional to $(I_{DC} + i_{MSG})V_{LO}$
- The carrier component at the output is a result of this DC offset

Part 1 Single-Balanced Mixer (Multiplier with DC Offset)(cnt'd)

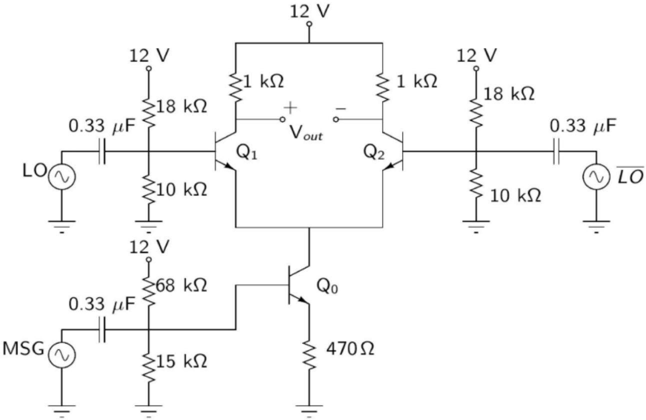


Figure: Single-Balanced Mixer circuit

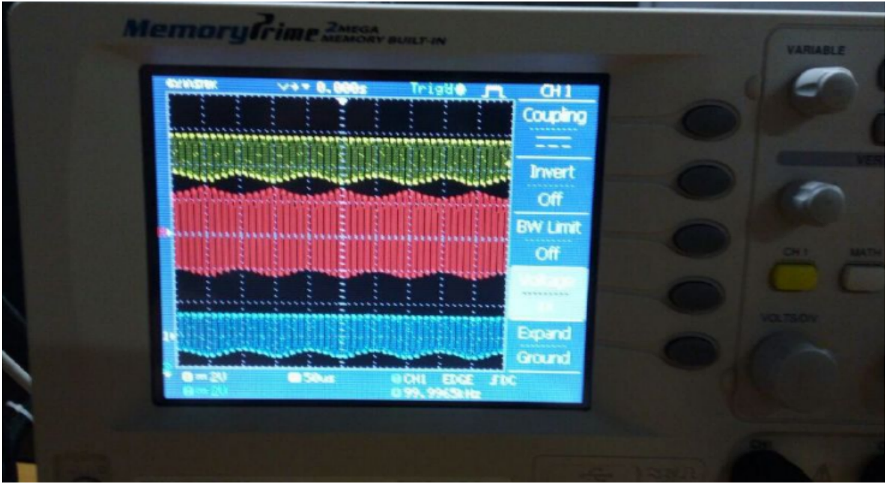
Part 1 Single-Balanced Mixer (Multiplier with DC Offset)(cnt'd)

- Make the breadboard connections as shown in the above circuit diagram. Choose the differential pair in the IC and Q1 and Q2 connections(Why? Recall the differential amplifier experiment from EE 230)
- Apply sinusoidal carrier signals to terminals marked LO and $\bar{LO}$. Use dual channel function generator for the same
- Set the frequency of carrier signal to 100KHz,amplitude of 2Vp-p and phase difference of 180 degrees
- Apply sinusoidal message signal from single channel function generator
- Set the frequency of the message signal to 1KHz and amplitude to 100 mVp-p
- Observe the time domain modulated signal at the output

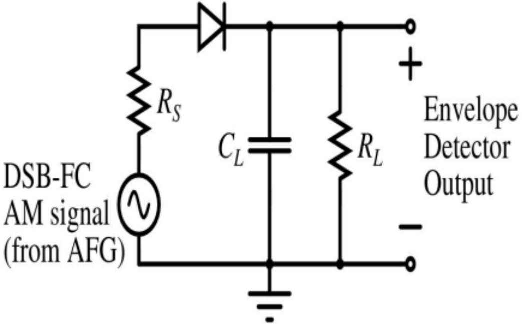
Part 1 Single-Balanced Mixer (Multiplier with DC Offset)(cnt'd)

- For observing single-ended output connect the DSO probes between the positive output terminal and ground(Select AC coupling option)
- To observe the differential output connect the positive output terminal to one channel and negative output terminal to another channel and take the difference using the Math function. Use equal scales while subtracting. (DO NOT CONNECT THE PROBE OF A SINGLE CHANNEL BETWEEN POSITIVE AND NEGATIVE OUTPUT TERMINALS TO OBSERVE DIFFERENTIAL OUTPUT.)
- Trigger the DSO properly (using the message signal as the external signal) so that the modulated waveform appears stationary.
- Trigger the DSO properly (using the message signal as the external signal) so that the modulated waveform appears stationary.
- Vary the amplitude of carrier and message signal and observe the difference. Is there any improvement in the result?

Expected Output



Part 2: Envelope Detector



- In this part of the experiment we build an envelope detector to demodulate the DSB-FC (AM) signal generated by the **AFG**
- Figure out the capacitor and resistor values and make the circuit as shown in the above circuit diagram.

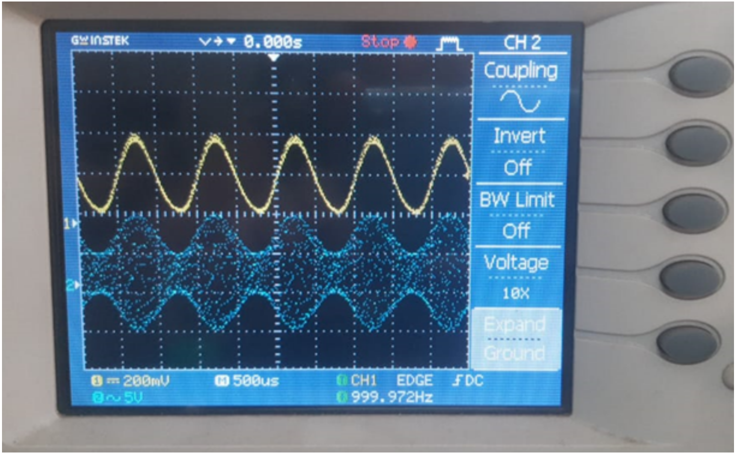
Part 2: Generating DSB-FC AM Signal on the AFG

- To generate a DSB-FC AM signal using the AFG, select the following parameters on the AFG:
  - Frequency(carrier) = 100 KHz
  - Amplitude(carrier) = 2 V
  - Function = “Sine“
  - Run mode = “Modulation“
  - Modulation Type = “AM“
  - AM Source = “Internal“
  - AM Frequency = 1 KHz
  - Modulation Shape = “Sine“
  - Depth = 50% (i.e,Amplitude of message = 1 V)
- Observe the generated DSB-FC AM signal on DSO in time as well as frequency domain

Part 2: Envelope Detector

- Connect Rs (preferably less than 100Ω) as a resistor externally even though Rs represents the output resistor for the source
- Give the output of the AFG (DSB-FC signal) as input to the envelope detector
- Observe the time domain demodulated sinusoidal signal at the output
- Select the FFT option on the DSO and observe the frequency domain spectrum (Use the FFT Zoom option to view Spectrum)
- The time constant of the envelope detector should satisfy the following condition $1/w_c << RC << 1/w_m$

Expected Demodulated Output



Part 3: Double-Balanced Mixer (Multiplier without DC Offset)

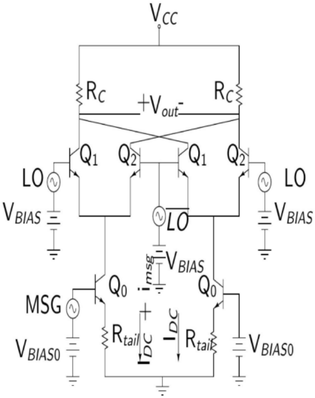


Figure: Double-Balanced Mixer

Part 3: Double-Balanced Mixer (Multiplier without DC Offset)(cnt'd)

- The output of the mixer has frequency components at $f_{LO} + f_{MSG}$ and $f_{LO} - f_{MSG}$
- We can observe from the circuit that the tail current is $I_{DC} + i_{msg}$ in one branch and I_{DC} for the other
- Hence the output (V_{out}) is proportional to $(I_{DC} + i_{MSG})V_{LO} + I_{DC} * (-V_{LO})$
- Hence the carrier component gets canceled resulting in DSB-SC modulated signal.

Part 3: Double-Balanced Mixer (Multiplier without DC Offset)(cnt'd)

- This part of the experiment carries bonus marks
- Make the connections as shown in the circuit diagram. The circuit is more or less just a replication of the single-balanced mixer
- Again choose differential pairs for Q1-Q2 and Q4-Q5
- Choose transistors from the same chip for tail sources (Why?)
- Observe the time domain modulated waveform and frequency domain spectrum
- Vary the potentiometer present at the tail and observe the difference in the frequency domain

Part 3: Double-Balanced Mixer (Multiplier without DC Offset)(cnt'd)

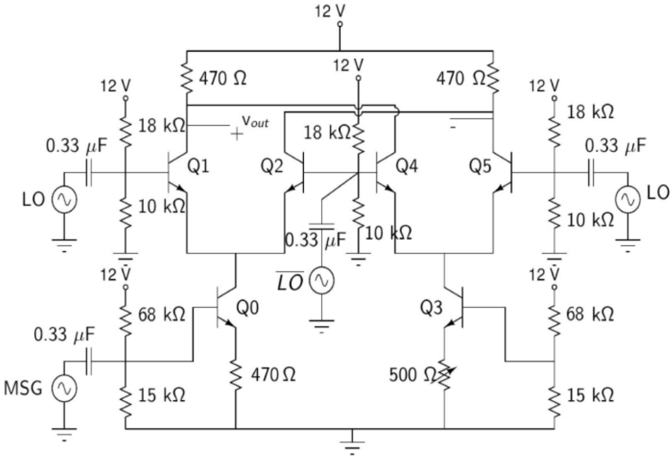


Figure: Double-Balanced Mixer circuit