EE 340: Communications Laboratory
Autumn 2016

Lab 3: AM Modulator and AM Demodulator

Legends used

Question/Observation: Show it to the TA and explain (carries marks)

Recall / try to reason out / useful information

Caution (be very careful!)

Additional information / weblink

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 had 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
- Resistors –180Ω*, 470Ω, 1 kΩ, 10 kΩ, 15 kΩ,18 kΩ,68 kΩ,1MΩ*
- Capacitors –100 *pF , 0.33μ F*
- Diode – IN914
- Potentiometer –500Ω
- Arbitrary Function Generator (dual-channel function generator)
- Single channel function generator
- DSO
- Multimeter
- Breadboard for connecting wires

How to Use a DSO

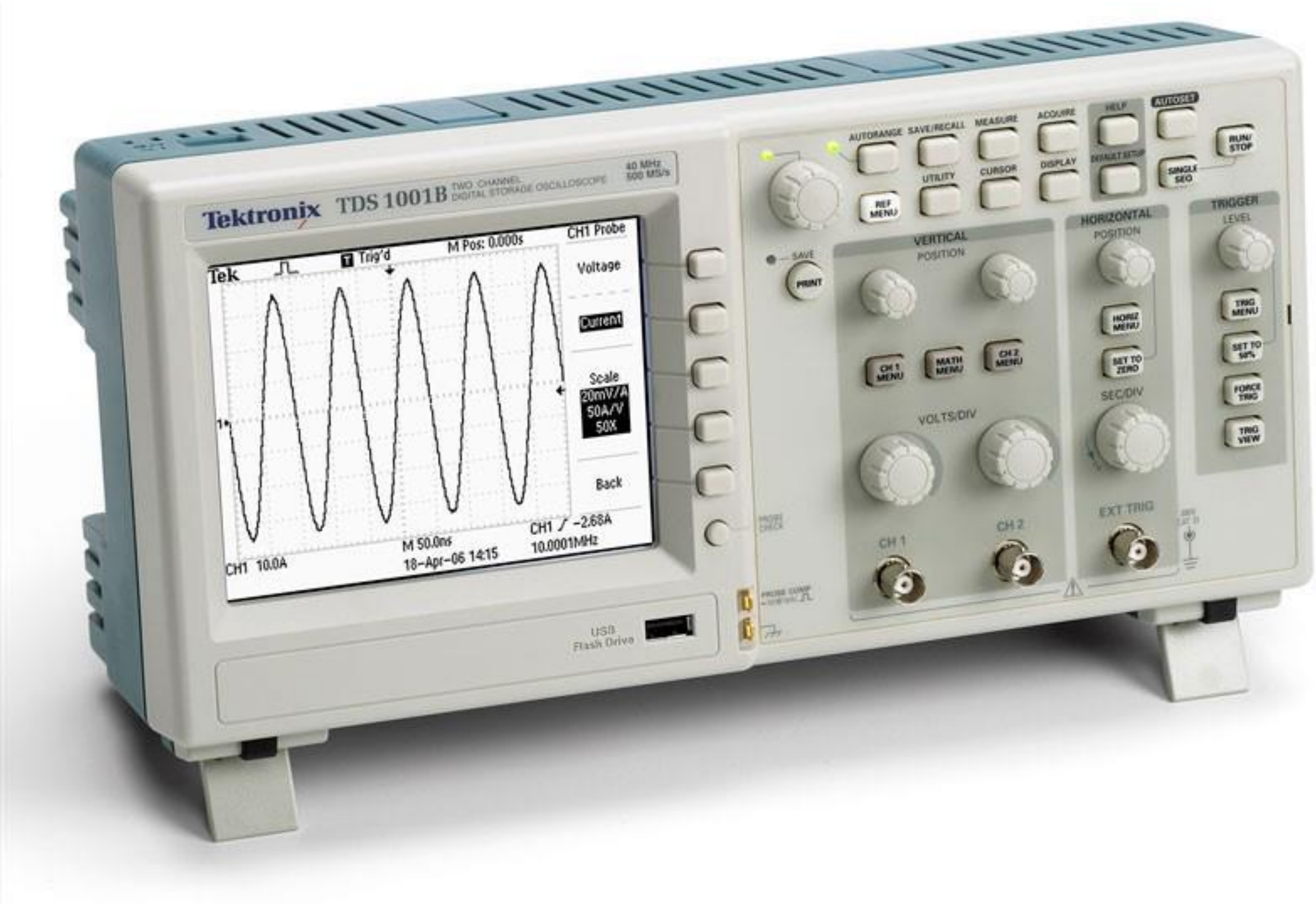


Image courtesy:
http://www.testequity.com/products/1412/

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 freeze/run the waveforms
- Waveforms can also be made stationary by using proper triggering (Check with the TA if required).

How to use the AFG

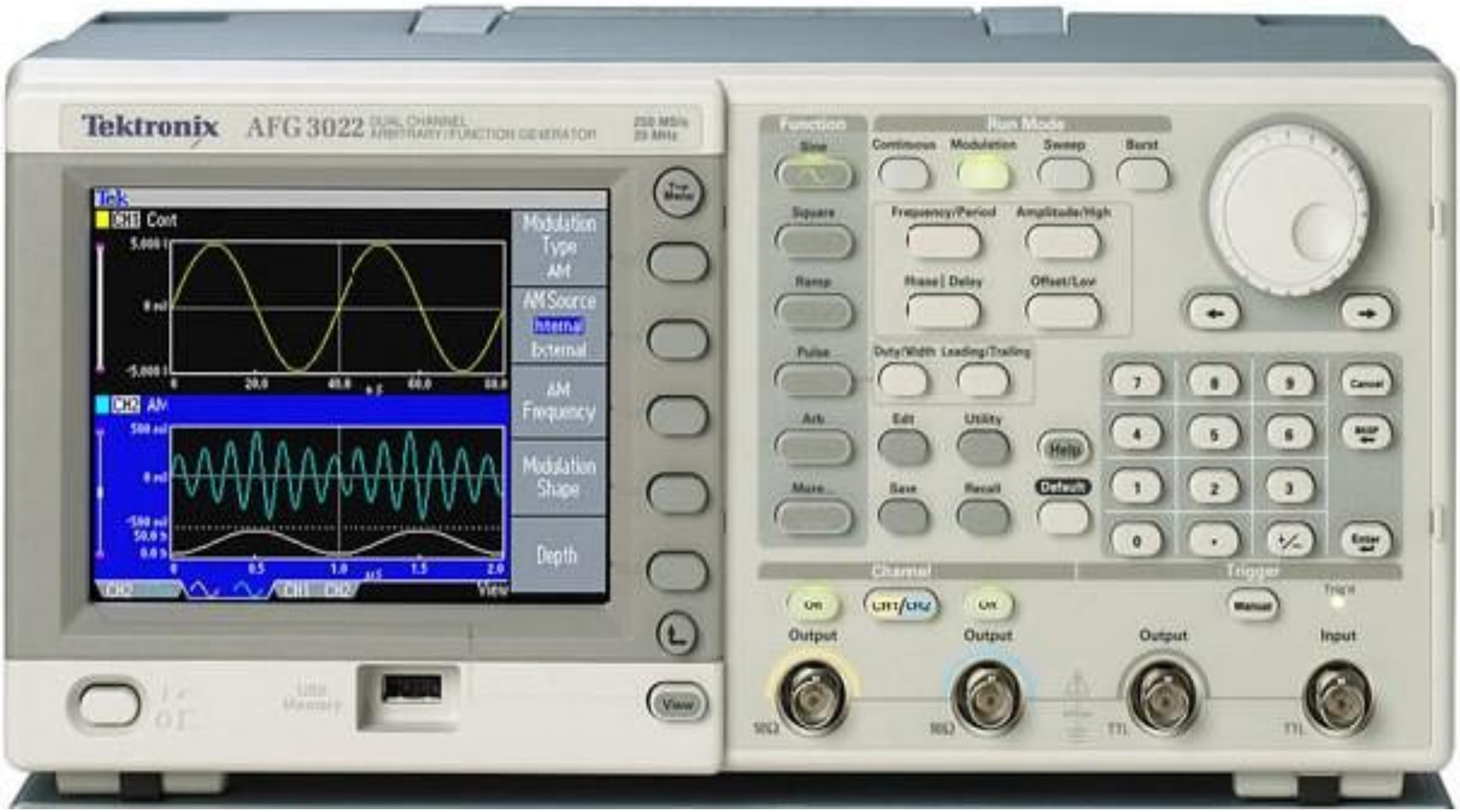


Image courtesy:
http://www.mathworks.com/matlabcentral/fileexchange/45766-tektronix-afg3252-demo

How to use the AFG

- To produce different waveforms choose from the wave function options available (Sine, Square, Ramp etc.)
- Choose the 'Continuous' option to generate standard wave shapes or 'Modulation' option to generate modulated waves (however in this particular experiment 'Modulation' option is not used)
- To vary the frequency, phase and amplitude use the 'Frequency/Period', 'Phase/Delay' and 'Amplitude/High' options respectively
- 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 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, click on (Top Menu) → (Output Menu) → (Load Impedance)→(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".

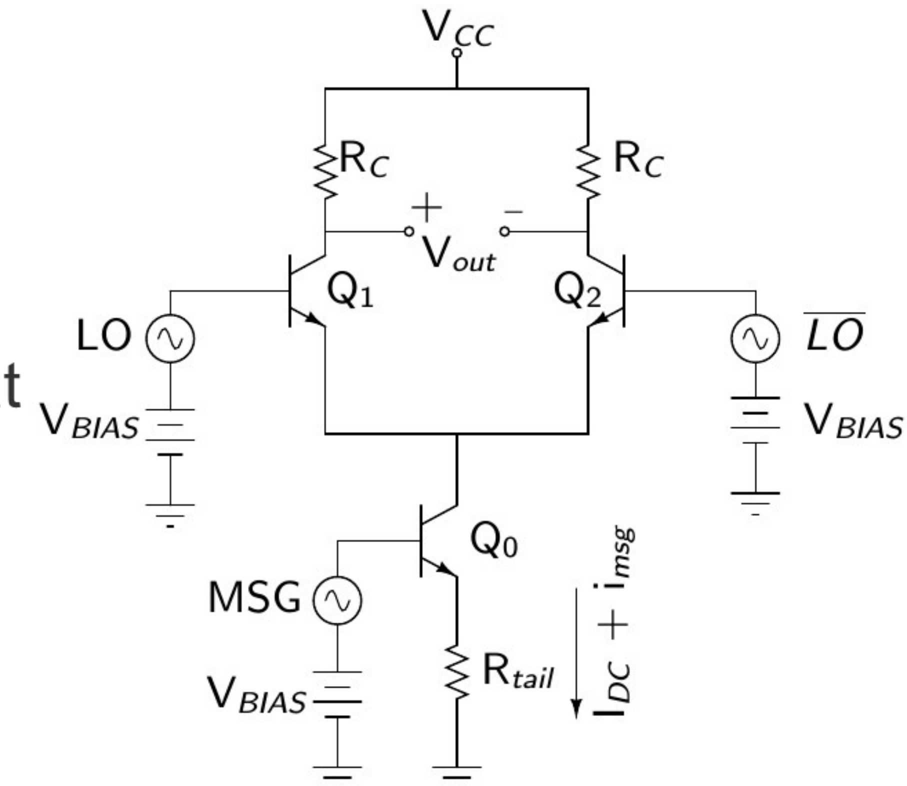
- If you are not getting a desired output then observe the waveforms at different nodes starting from the signal source to trace the location of the fault.

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

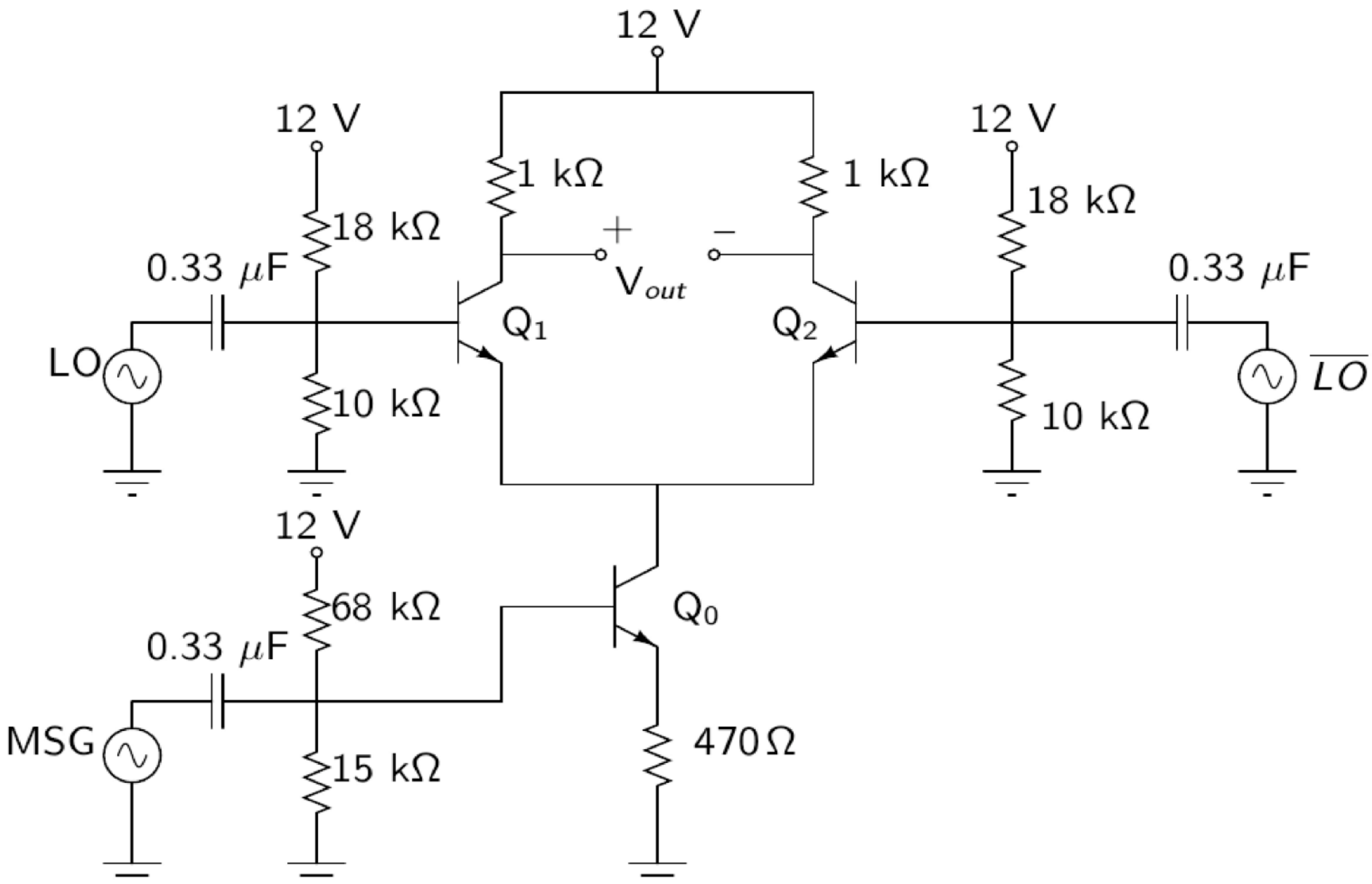
- The output of the mixer has frequency components at carrier frequency (f_{LO}) and at the two side bands $f_{LO}+f_{MSG}$ and $f_{LO}-f_{MSG}$
- We can observe from the circuit that the tail current is $I_{DC}+i_{msg}$
- Hence the output is,

$$V_{out} \propto (I_{DC}+i_{msg})V_{LO}$$

- The carrier component at the output is a result of this DC offset



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



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

Make the breadboard connections as shown in the circuit diagram. Choose the differential pair in the IC for Q1 and Q2 connections (Why? Recall differential amplifier experiment from EE 230)

- Apply sinusoidal carrier signals to terminals marked LO and $\overline{LO}$. Use dual channel function generator for the same.
- Set the frequency of the carrier to 100 kHz, amplitude to 200 mVp-p and phase difference to 180 degrees.
- Apply sinusiodal message signal from single channel function generator
- Set the frequency of message signal to 10 kHz and amplitude to 100mVpp.

Observe the time domain modulated signal at the output

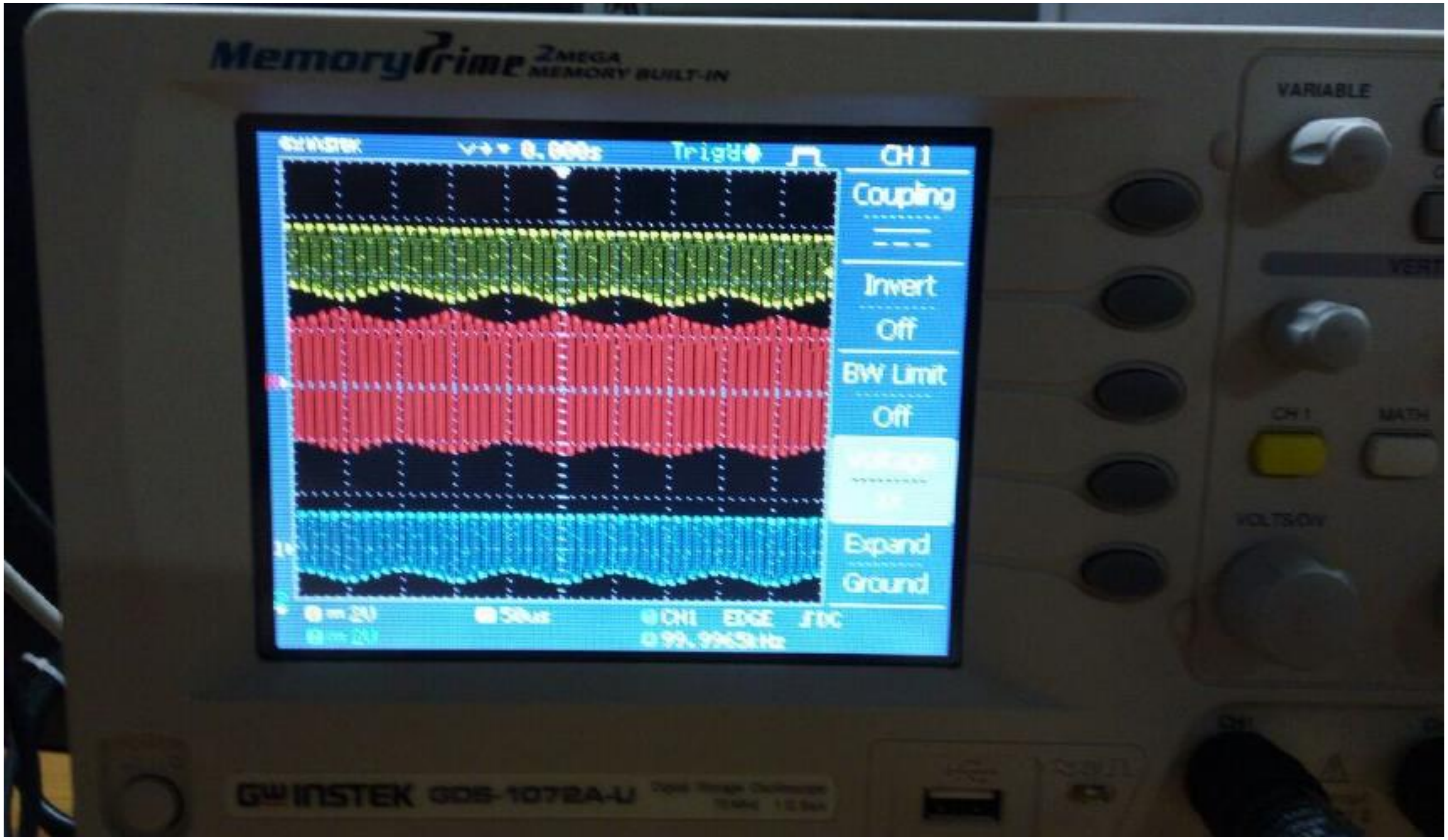
Part 1 : Single-Balanced Mixer (Multiplier with DC Offset)

- For observing single-ended output connect the DSO probes between positive output terminal and ground. Select AC coupling option on DSO

To observe the differential output connect positive output terminal to one channel and negative output terminal to another channel and take the difference using 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.
- Select the FFT option on the DSO and observe the frequency domain spectrum of the modulated signal. Use hanning window to remove spurious spectrum due to edge effects
- Vary the amplitude of carrier and message signal and observe the difference. Is there any improvement in the result?
- Take note of the power levels of the carrier and the side-bands

Expected Output



Generating DSB-FC AM Signal on the AFG

- To generate DSB-FC AM signal on the AFG, select the following parameters on the AFG:

– Frequency = 100 KHz

– Amplitude = 2 V

– Function = “Sine“

– Run mode = “Modulation“

– Modulation Type = “AM“

– AM Source = “Internal“

– AM Frequency = 1 KHz

– Modulation Shape = “Sine“

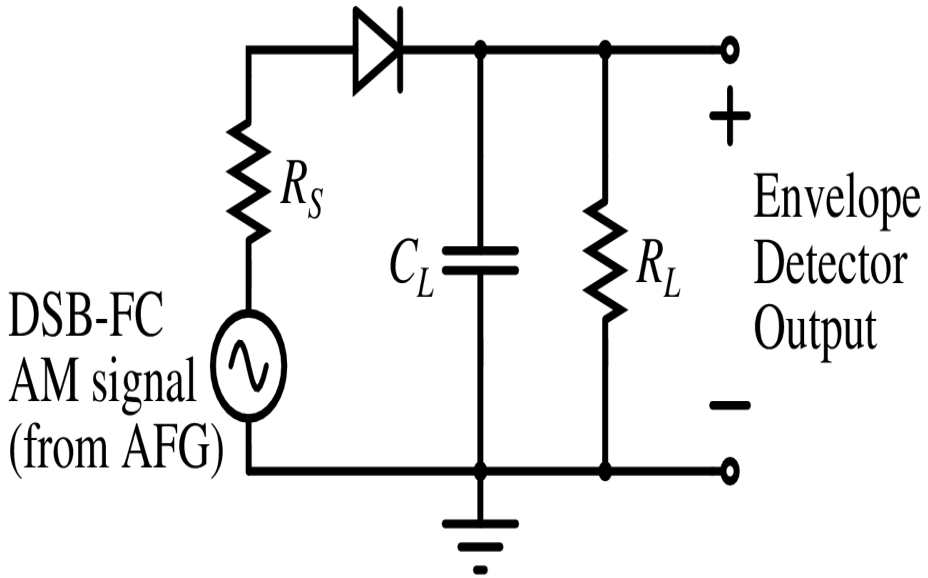
– Depth = 50

- Observe the generated DSB-FC AM signal on DSO in time as well as frequency domain

Part 2 : Envelope Detector

In this part of the experiment
we build an envelope detector to demodulate the signal generated by the AFG

- **Make the connections as shown in the circuit diagram**
- **Connect Rs as resistor externally even though Rs represents the output resistor for the source**



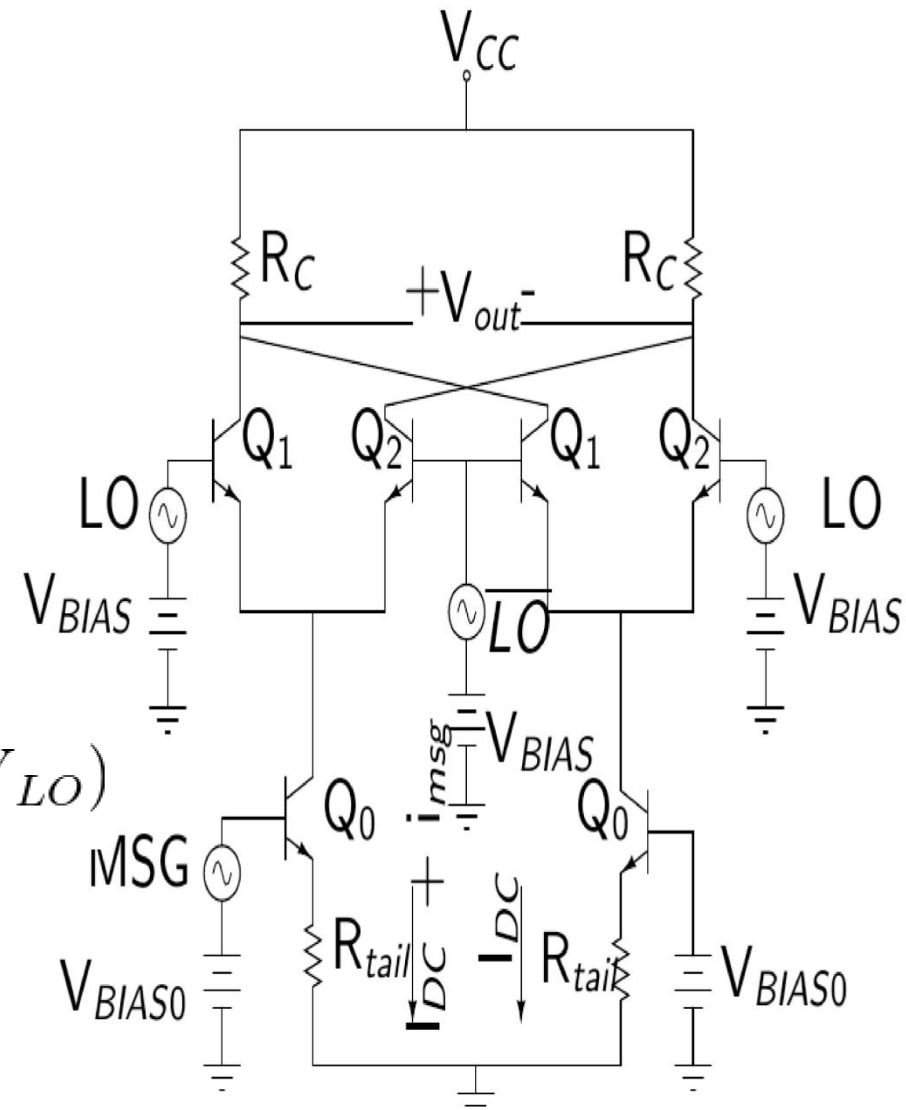
- Give the output of the AFG as input to the envelope detector
- ✓ Observe the time domain demodulated sinusoidal signal at the output
- ✓ Select the FFT option on the DSO and observe the frequency domain spectrum

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

- The output of the mixer has frequency components at fLO + fMSG and fLO - fMSG
- We can observe from the circuit that the tail current is IDC + imsg in one branch and IDC for the other
- Hence the output is

$$V_{out} \propto (I_{DC} + i_{msg}) \times V_{LO} + I_{DC} \times (-V_{LO})$$

- Hence the carrier component gets cancelled resulting in DSB-SC modulated signal



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

- 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)