Experimental Work

1. Multimeter

1. Use your multimeter to measure the value of a resistance. Measure the resistance between your two hands using Ω scale of your multimeter (it becomes an *ohmmeter*). Wet your fingers and repeat the measurement. Record the readings.

R(normal)= 7.15 MΩ	R(wet fingers)= 4.17 MΩ

1.1. GRADE:

2. Get one more resistance of the same value. If your multimeter has a RANGE button, press the RANGE button to set the appropriate range. Measure the resistances. Since the resistance of your hands is not infinite, make sure that you do not touch your fingers while you make resistance measurements. Record your readings. Are the readings consistent with the color code of the resistors (see the color code Table in p. 31)? Compare the variation in the resistance values with the tolerance of the resistor shown by the color code.

Colors of resistor= Green – blue – green – brown

Color coded nominal value R= 5.60 MΩ Color coded tolerance= ± 1%

Measured: R= 5.63 MΩ R= 5.55 MΩ

Measured maximum tolerance = ± 0.89%

1.2. GRADE:

3. Use your multimeter to measure the voltage of the power supply: Adjust the power supply to +5.00V. Set your multimeter to DC voltage scale (your multimeter becomes a *DC voltmeter*) and measure the voltage, V_{DC}, across the terminals. Record and compare the readings.

Adjusted: V_{DC}= 5.00 V	Measured: V_{DC}= 5.01 V

1.3. GRADE:

4. An *ideal* voltmeter has infinite resistance not to disturb the voltage it is measuring. But real voltmeters have a finite resistance. Measure the resistance, R_V, of your voltmeter at DC and AC scales using another multimeter and record it. Compare it with the data given in the manual of the multimeter.

DC Voltmeter, Measured: R_V= 11.80 MΩ	Data: R_V= 10 MΩ
AC Voltmeter, Measured: R_V= 11.93 MΩ	Data: R_V= 10 MΩ

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1.4. GRADE:

5. Use your multimeter to measure the current through a resistor: Choose a resistor between 100 Ω and 220 Ω. Measure its value using your multimeter. Set the power supply voltage to +5.00V. Measure it with your multimeter. Connect one lead of the resistance to the positive terminal of the power supply (set at +5.00V). Set your multimeter to current reading scale (it becomes an *ammeter*) and place the multimeter in *series* with the resistor and the negative terminal to the power supply to measure the current through the resistor. DO NOT place the leads of your multimeter directly across the power supply; you may blow the fuse of your ammeter! Record the current reading. Find out if Ohm's law is satisfied. Does the resistance of the ammeter affect the measurement?

Measured: $R=$ 150.7 Ω Measured: $V=$ 5.01 V

Measured: $I=$ 0.033 A Calculated: $I=V/R=$ 0.332 A

Comments: measured and calculated values are slightly different from each other. the reason could be the instability of the power supply and resistance in the ammeter is also relatable with the difference between measured and calculated data.

1.5. GRADE:

6. Measure the resistance, R_A, of your ammeter by using another multimeter in its Ω scale. Does it explain the difference between the calculated and measured values in the item 1.5? Comment on your results.

Measured: $R_A=$ 1.0 Ω

Comments: Ammeter can only be connected in series to circuit, therefore it increases the total resistance. measured value is less than calculated value.

1.6. GRADE:

We note that measuring current is always more difficult than measuring voltage. To measure the current the multimeter must be placed in series with the branch. This usually means the circuit must be modified to be able to measure current. On the other hand, measuring voltage is easier. You can just touch the terminals in parallel with the multimeter leads. There is no need to modify the circuit. That is why *nodal* analysis is preferred instead of *mesh* analysis.

7. If your multimeter has capacitance measurement capability, get two capacitors, one larger than the minimum and the other less than the maximum. Measure the values. Compare with the values written on the capacitors. Note that most capacitors with values less than 1 μF, have numeric codes indicating their values in *picofarads* (pF) similar to the resistor codes. For example, 103 means 10 plus three zeros: 10,000 pF. 221 means 220 pF.

Capacitance value: 4.7 μF Measured capacitance value: 4.5 μF

Capacitance value: 180 nF Measured capacitance value: 176.2 nF

1.7. GRADE:

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Soldering

1. You will learn good soldering in this exercise. Soldering is a chemical process to form an alloy of solder and the soldered metal pieces. Soldering iron must be hot and its tip must be shiny in order to make good solder joint. Put some water on the soldering sponge and keep it wet through out the soldering session. Turn the soldering iron on and wait until it is hot. Solder must immediately melt on the tip when it is hot enough. Put some solder on the tip and wipe the tip with wet sponge. The tip will shine. This process is called tinning. Now the iron is ready to make a solder joint. If the tip is not shiny, the heat transfer from the tip to the component is poor. You may end up with a *cold* solder. Cold solders are very problematic, they may conduct intermittently. It is very difficult to find where the cold solder is. So it is best to make a good solder to begin with.

   The joint to be soldered must be mechanically sturdy enough before solder is applied, so that when the solder is hot and in fluid form, the joint must not move. Place the tip in contact with the joint, touching all parts to be soldered. Place the solder in contact with the parts (not the tip) opposite to the tip. Solder must melt within a second. Remove the tip and the solder.

2. Solder wire contains a flux that assists the solder in making a wetted joint. When heated, the flux gives off a potentially irritant vapor. Avoid inhaling this smoke.

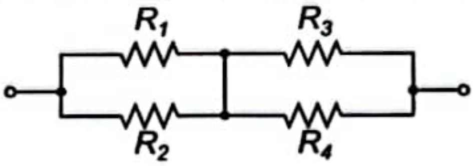
3. Choose four different resistors in the range 10 Ω to 47 Ω. Measure the value of each accurately using your multimeter.

R_1= 12.5	R_2= 15.6	R_3= 27.1	R_4= 33.2

2.3. GRADE:

4. Solder the four resistors as shown in Fig. 1. Calculate the total resistance of the combination using the measured values of resistors. Measure the total resistance of the combination, R_T, using your multimeter. Comment on any difference.

$\frac{1}{Req} = \frac{1}{12.5} + \frac{1}{15.6} = 6,94$



$\frac{1}{Req} = \frac{1}{27.1} + \frac{1}{33.2} = 14,92$

Figure 1: Solder four resistors as shown in the diagram.

Calculated R_T= 21.56 Ω   Measured R_T= 21.7 Ω

Comments: Calculated value is slightly less than measured value, due to the uncertainty of the multimeter.

2.4. GRADE:

Oscilloscope

Oscilloscopes are very important and commonly used instruments in Electrical Engineering. Their screens show the voltage as a function of time waveform. They may show more than one waveform simultaneously. Oscilloscopes have many knobs and buttons. To make full use of an oscilloscope, it is mandatory to learn the functions of them. The following steps apply to Tektronix TDS20XX series digital oscilloscopes, shown in Fig. 2. Nevertheless, other brand or model digital oscilloscopes are also very similar.

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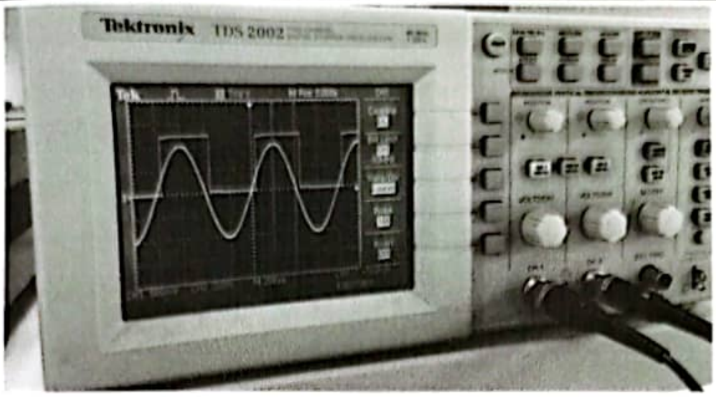


Figure 2: Tektronix TDS2002 two-channel digital oscilloscope.

1. Connect the oscilloscope probe to CH 1. Set the switch on the probe to 10×. Connect the probe tip to PROBE COMP using the probe hook. Press CH 1 MENU button. New options will appear on the screen. Press the Coupling button until it indicates DC (DC coupling means the signal appears on the screen with its DC part.) Now, press AUTOSET button. (Expert engineers do NOT use AUTOSET button! It is there to be used by rookies. Avoid using the AUTOSET button to become an expert :) You should now see a stable square waveform on the screen. Observe that green Trig'd is being displayed indicating that the oscilloscope is *triggered*.

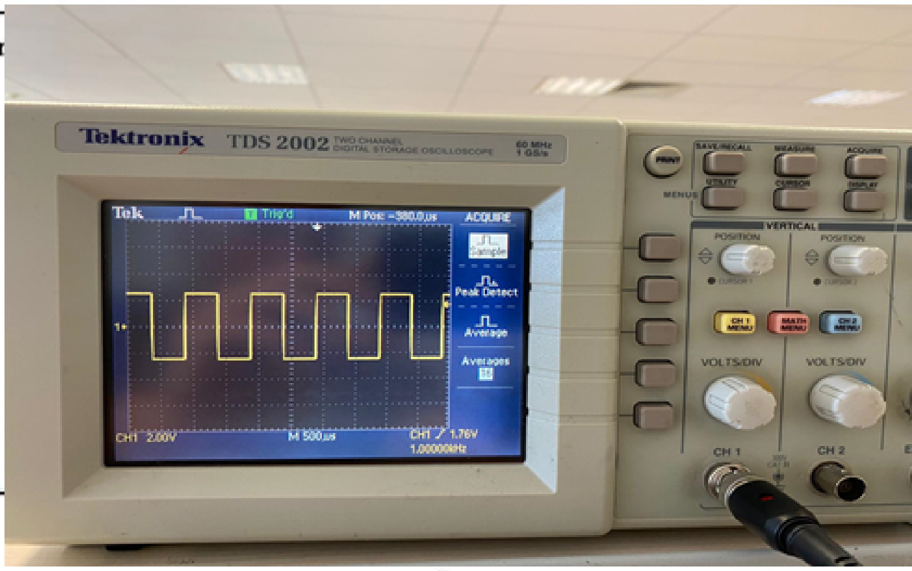
2. Set Coupling: AC using CH1 MENU. Comment on the results. Set Coupling: Ground. Write down the results.

Comments: in DC couplint mode, the bottom of the square waves indicate 0V and top of the waves indicate 5V, in AC coupling mode, the lowest point indicates -2.5V and top of the wave indicates 2.5V. so, the waveform transferred to bottom in AC coupling mode. In ground coupling, no waveform is present, there is only a straight line.

3.2. GRADE:

3. Rotate SEC/DIV knob to change the time scale to 500nsec. Use the Horizontal Position knob to move the waveform left or right to observe the waveform in detail. Press ACQUIRE and set Average 16 to get a waveform with less noise. Take a photo of the screen for your report.

Screen



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3.3. GRADE:

4. Triggering: The trigger determines when the oscilloscope starts to capture data and display a waveform. If the trigger is not set up properly, the display will be unstable or blank. If oscilloscope is triggered, you will see a green colored "Trig'd" display on the top of the screen. It is very important to understand what triggering means.

   Press TRIG VIEW button while turning the TRIGGER LEVEL knob. A dashed line is displayed showing where the trigger level is. Actual triggering occurs at the time point the dashed line intersects the waveform. Rotate the knob until the dashed line is above the square wave so that it does not intersect the waveform. Release the TRIG VIEW button. Trigger is lost. Now you should see an unstable waveform on the screen and green Trig'd readout is gone. Rotate the TRIGGER LEVEL button until the trigger arrow on the right is in the middle of the square wave. Observe that the square wave is triggered again.

   Change the Trigger Slope to Falling. Explain.

Explain: After switching the trigger slope from rising to falling, a new waveform is created, which is the symmetric version with respect to the x-axis of the old waveform

3.4. GRADE:

5. Read and record the Trigger Frequency at the lower right corner of the screen.

Trigger frequency: 1 KHz

3.5. GRADE:

6. Press CURSOR button. Set Type: Time and Source: CH1. Adjust Cursor1 and Cursor2 to determine the period (Δt) and frequency ($1/\Delta t$). Find also the peak-to-peak voltage of the square wave from ΔV readout.

$\Delta t=$ 1 ms $\quad f=$ 1 KHz $\quad \Delta V=$ 5,04 V

3.6. GRADE:

7. Rotate DIV/SEC knob until the time scale becomes 500ns per division. Now you should be able to see the falling edge of the square wave in detail. Rotate the TRIGGER LEVEL knob to change the point where the trigger occurs. Write down your observations.

Observations: Rotating the DIV/SEC knob is changing the waveform from a square wave to a falling edge of the squarewave, which means, the function of the DIV/sec knob is to zoom in and out. If the trigger level is between the top and bottom of the squarewave, the wave is stable, otherwise unstable

3.7. GRADE:

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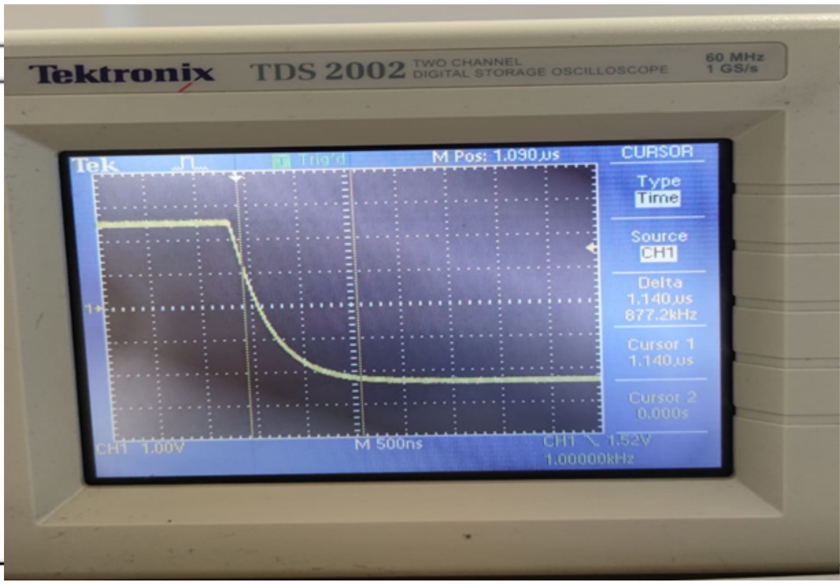
8. Find the Fall Time, t_f, of the signal (from 90% to 10% voltage points) using cursors. To get a more accurate measurement, you can increase the vertical scale sensitivity to 1V per division using the lower CH1 knob. You can move the signal up and down using the upper CH1 knob. Take a photo of the screen for your report.

t_f= 1,140 μs

Screen photo:

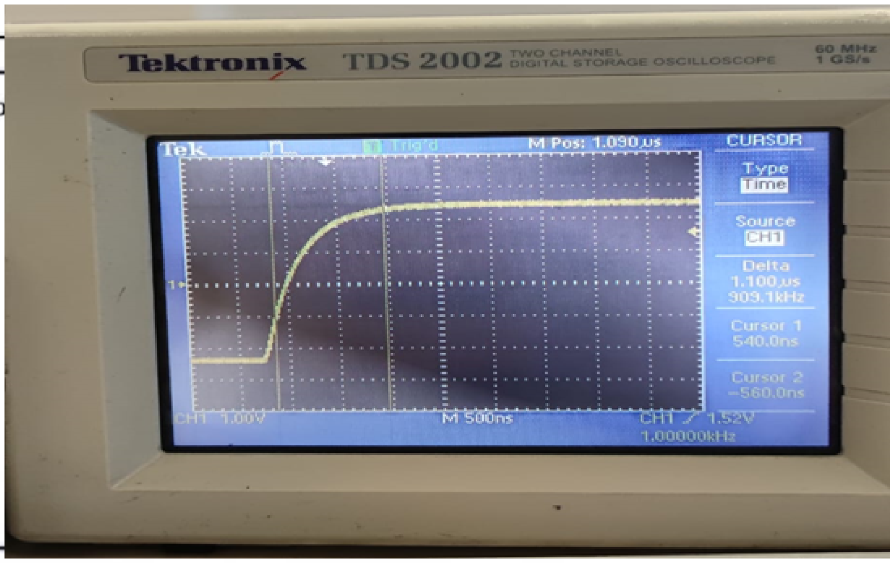


3.8. GRADE:

9. Change the Trigger Slope to Rising. Find the Rise Time, t_r, of the signal (from 10% to 90%). Take a photo of the screen for your report.

t_r= 1,100 μs

Screen pho



3.9. GRADE:

10. Press MEASURE button and set the appropriate buttons to display Period, Freq, Pk-Pk, Rise Time and Fall Time of the signal automatically. You need to see one full period on the screen to

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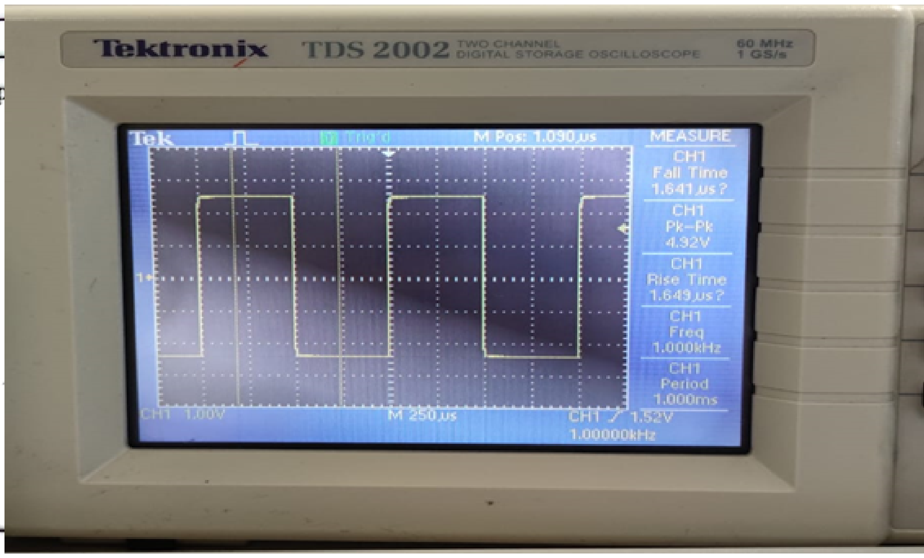
be able to measure period and frequency. Take a photo of the screen for your report. Compare automatic measurement results with those obtained by cursors.

Δt= 1,000 ms f= 1 kHz ΔV= 4,32V

t_f= 1,636 μs t_r= 1,636 μs

Screen p



3.10. GRADE:

11. Trigger Source: Use the Trigger Source button to choose the signal to be used as a trigger. Press the Source button to change the trigger source to CH 2. Explain the consequences.

Consequences: Square waveforms can be seen on the screen in CH2. However, they couldn't be triggered because nothing is connected to CH2.

3.11. GRADE:

12. Press the Trigger Source button repeatedly until Line is the trigger source. Line means the trigger source is 50 Hz power line of the oscilloscope. If a signal related to 50 Hz line is being investigated, it is very convenient: Use the probe of CH 1 to touch your finger. Your body acts like an antenna to pick the 50 Hz line signal in the environment. Observe the oscilloscope while the trigger source is Line. Explain.

Explain: A distorted sinusoidal waveform is created after touching the probe in CH1. After the source is set to "Line", waveform became more steady and readable.

3.12. GRADE:

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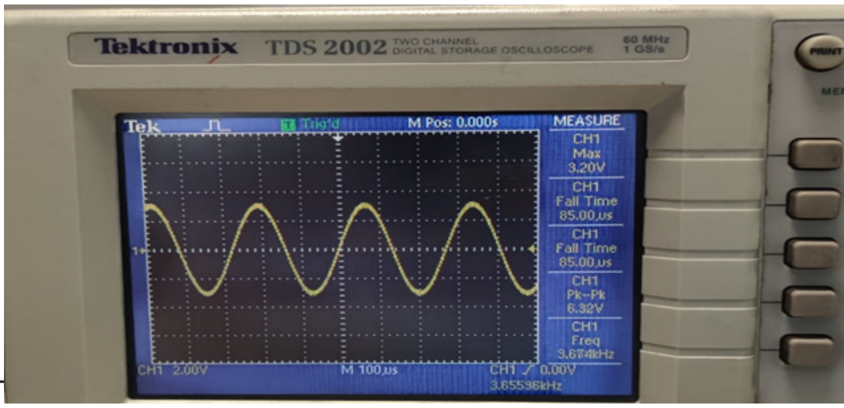
13. Adjust the signal generator so that it generates a sine wave with a frequency equal to the last four digits of your student ID number. Set the amplitude to 3 V peak-to-peak. Set the oscilloscope to observe one full-cycle of the sinusoidal waveform filling the screen. Do not use AUTOSET! Display the frequency, period and peak-to-peak voltage values. Take a photo of the screen for your report. Comment on the agreement between the signal generator settings and oscilloscope measurements.

Screen photo: Frequency values are same with each other. 3656MHz. However, I inputted 3 V pk-pk voltage, in oscilloscope screen, it can be seen that 2 V pk-pk value is present. Period values are also same with each other.



3.13. GRADE:

14. Set the signal generator amplitude to 20 mV peak-to-peak. Notice that the signal is more noisy. Press ACQUIRE button. Change the mode to Average and 16 Averages. The oscilloscope will take the average of 16 (or 64) samples to reduce the noise and to generate a better quality display. Use Average mode when the signal is small and noisy.

15. Set the frequency of the signal generator to 50.1Hz. Set the Trigger source as Line. Change the frequency of the signal generator until the waveform on the screen no longer drifts. Record the frequency value. This value is equal to the frequency of the Line signal at the time of measurement.

$f = 49.9915 Hz$

3.15. GRADE:

16. Vary the TRIG LEVEL until the oscilloscope is not triggered. Now, set the trigger mode to NORM. What happens? Set the trigger mode to AUTO. By experimenting, find the difference between Trigger mode AUTO and NORM.

Difference between AUTO and NORM: in Auto mode, if the trigger level is above or below the limits of the waveform, the wave became unstable, however, in the norm mode, even if the trigger level is outside the boundaries, a steady wave can be seen.

3.16. GRADE:

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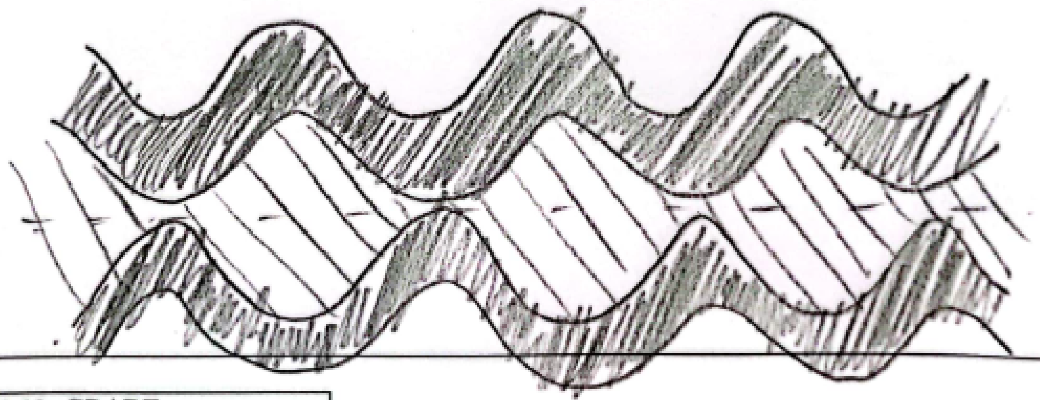
17. Connect the signal generator SYNC output to EXT input of the oscilloscope using a BNC cable. Set the Trigger Source to Ext. Since SYNC output generates a square wave signal, the oscilloscope will have no difficulty with the triggering. Change the amplitude of the input signal to very small values. Observe that you do not have to readjust the trigger level and that triggering is always achieved. This configuration is very robust and it should be preferred whenever possible. Explain the benefits of external triggering.

Benefits of External Triggering: The optimum triggered waveform is obtained with external triggering. The benefits of external triggering is removing the noises and distortions on the waveform.

3.17. GRADE:

18. Set to signal generator to amplitude modulation by pressing the MOD/SWP button and setting it to AM(INT) mode using arrow buttons. Set the signal amplitude to 5 V_{pp}. Set the frequency to 27 MHz. Press [RATE] to adjust the modulation frequency, f_m, to 1 KHz. Press [DEPTH] to adjust the modulation index to 50%. Connect the oscilloscope probe to the output of the generator. On the oscilloscope, set ACQUIRE to PEAK DETECT. This setting allows good visualization of an amplitude modulated (AM) signal. The PEAK DETECT setting should be used when the sampling rate of the oscilloscope is too low compared to the carrier signal. Set the time setting to 5 ms/div. Connect the "Modulation" output of the signal generator (on the back of the signal generator) to EXT trigger input of the oscilloscope using a coaxial BNC cable. Set the Trigger source of the oscilloscope to Ext, coupling AC. Make sure that the oscilloscope is triggered. Observe the AM waveform. Plot the waveform below. Note that when the construction is finished, TRC-11 transmitter is supposed to generate a similar AM signal. Observe the signal's envelope as you change modulating function to Square, Triangle, and Ramp.

AM Waveform for sinusoidal modulation



3.18. GRADE:

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19. Set the modulating function to Sine. Set ACQUIRE button of the oscilloscope to the usual setting of SAMPLE. To be able to freeze the screen. Press RUN/STOP button of the oscilloscope. What do you observe? The high-frequency signal is *aliased* because the sampling rate is not sufficient to capture it.

Explain what you see: Because the wave is in (AM) mode, first, there is not any oscillation seen at the top and bottom of the wave, however, after using the run/stop button, the gaps between the waves become visible and also, the oscillations become more visible

3.19. GRADE:

CHECK POINT:

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