LABORATORY REPORT - CHAPTER 1

v7.2

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Date	28.09.2024
Total Grade	/100

Remarks: Record all your measurements and write all your answers in the boxes provided. Do not write anything in the cells labelled as GRADE. Never forget to explain your results and to specify the units of your measurements.

Preliminary Work

1. Multimeter

A multimeter is a combination measuring instrument that can act like as voltmeter, ammeter, ohmmeter and in some cases as capacitance meter.

1. Read the manual of your multimeter. Find the smallest and largest resistance, DC voltage, AC voltage, DC current and AC current your multimeter can measure. Note that the smallest value is determined by the resolution of the multimeter, so it is not the full-scale value at its smallest scale.

R_{low}= 0.1 Ω R_{high}= 40 M Ω

DC: V_{low}= 0.1 mV V_{high}= 1000 V

AC: V_{low}= 0.1 mV V_{high}= 750 V

DC: I_{low}= 0.1 μA I_{high}= 10 A

AC: I_{low}= 0.1 μA I_{high}= 10 A

1.1. GRADE:

2. Many multimeters have a "Sleep mode" to preserve the battery life. If the meter is not used and the input is inactive for a period it will go into Sleep mode. Find how long that period is from the manual of your multimeter. Find out how to wake up the multimeter. Some multimeters also have an ability to disable the sleep mode altogether. Find out if your multimeter has such a feature and explain how.

Inactivity period for sleep mode= 15 min

Explain how to wake up from the sleep mode: Pressing any key

Explain how to disable the sleep mode if exists: Pressing 'SELECT' key before power on it will cancel the function of auto power off.

1.2. GRADE:

3. Many multimeters have a continuity beeper. It is activated by pressing button or selecting a position in its rotary switch. If the resistance between the leads is under about 50 Ω, the beeper will sound continuously, designating a short circuit. Find out if your multimeter has a continuity beeper.

Continuity beeper function present? Yes, it is.

Explain how it works: When connecting the test probes of two points of circuit, if the resistance is approx. 50 Ω the beeper will go off.

1.3. GRADE:

4. Most good multimeters have a RANGE button. If you know the approximate value of the resistance you want to measure, you can set the specific range of measurement by repeatedly pressing the RANGE button. Otherwise, the multimeter is in the slower AUTO mode. Find out if your multimeter has a "RANGE" function. If it does, learn how it functions.

RANGE function present? Yes, it is.

Explain how it works: The default mode of the multimeter is automatic measurement, "AUTO". If we press the RANGE key it goes into manual mode and the range changes between Ω, kΩ, MΩ so that resistance can be ~~measured more precisely.~~

1.4. GRADE:

5. Some multimeters have a "HOLD" function. If you press the HOLD button during a measurement, the reading will be held. Press the HOLD button again to exit the function. Find out if your multimeter has a HOLD function. If it does, learn how it functions.

HOLD function present? Yes, it is.

Explain how it works: With "HOLD" key the present value will be hold on LCD and pressing again will exit the function. Pressing the key for 2 seconds will turn on the backlight.

1.5. GRADE:

6. Some multimeters have capacitance measurement capability. Find out if your multimeter has this capability. If it does, find out the minimum and maximum capacitance values it can measure. The smallest value is not the full-scale value at its smallest scale. You can learn it from the accuracy

specification of the multimeter. Note that the capacitance of the test leads is not excluded from the measurement. To remove the capacitance of the probe and to adjust to zero press the REL button (if it exists) before the measurement. For large valued capacitors you may need to wait up to 15 seconds or more for the reading.

Capacitance measurement function present? Yes, it is.

Minimum capacitance= 10 pF Maximum capacitance= 100 mF

1.6. GRADE:

7. Some multimeters have non-contact AC voltage detection (NCD) capability. Such multimeters can detect the presence of an AC voltage (larger than 50 V) on a conductor when it is brought closer to the conductor. Find out if your multimeter has such a capability. Try it on a power cable plugged in and removed.

NCD capability: My multimeter does not have a NCD capability.

Explain how it works:

1.7. GRADE:

Experimental Work

1. Multimeter

1. 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)= 3.270 M Ω	R(wet fingers)= 1.580 M Ω

1.1. GRADE:

2. Use your multimeter to measure the value of a resistance. Get one more resistance of the same value. Since the resistance of your hands is not infinite, make sure that you do not touch your fingers while you make resistance measurements. If your multimeter has a RANGE button, press the RANGE button to set the appropriate range. Measure the resistances. Record your readings. Are the readings consistent with the color code of the resistors (see the color code Table in p. 32)? Note that the first color is never silver or gold. Silver or gold shows the tolerance of the resistor. They should be treated as the last color and can be used to orient the direction of color code reading.

   Compare the variation in the resistance values with the tolerance of the resistor shown by the color code. The percent tolerance is given by

$$\text{Tolerance} = \frac{(\text{Measured Value}) - (\text{Nominal Value})}{(\text{Nominal value})} \times 100 \quad (1)$$

Colors of resistor= Brown, red, yellow, gold

Color coded nominal value R= 120 k Ω Color coded tolerance= $\pm 5\%$

Measured: R= 119.5 k Ω R= 118.1 k Ω

Measured maximum tolerance = $\pm\%$ 1.5

1.2. GRADE:

120 000

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= 11.06 MΩ   Data: R_V= 10 MΩ

AC Voltmeter, Measured: R_V= 11,07 MΩ   Data: R_V= 10 MΩ

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. Set your multimeter to current reading scale (it becomes an *ammeter*) as shown in Fig. 1. Connect one lead of

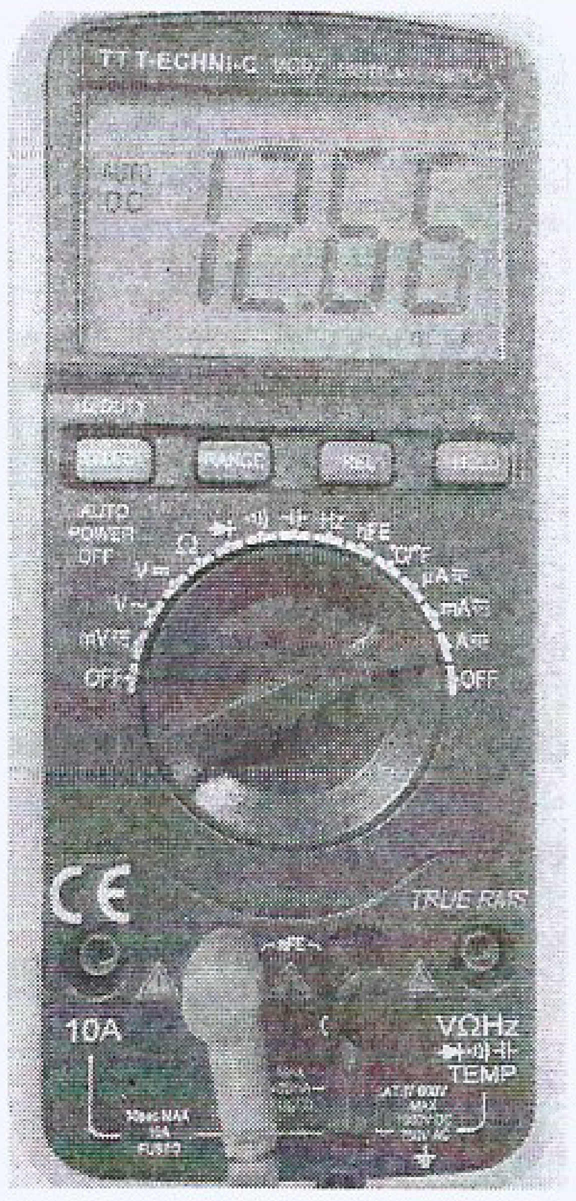


Figure 1: A multimeter set as an ammeter.

the resistance to the positive terminal of the power supply (set at +5.00V) and place the multimeter in *series* with the resistor and the negative terminal to the power supply as shown in Fig. 2 to

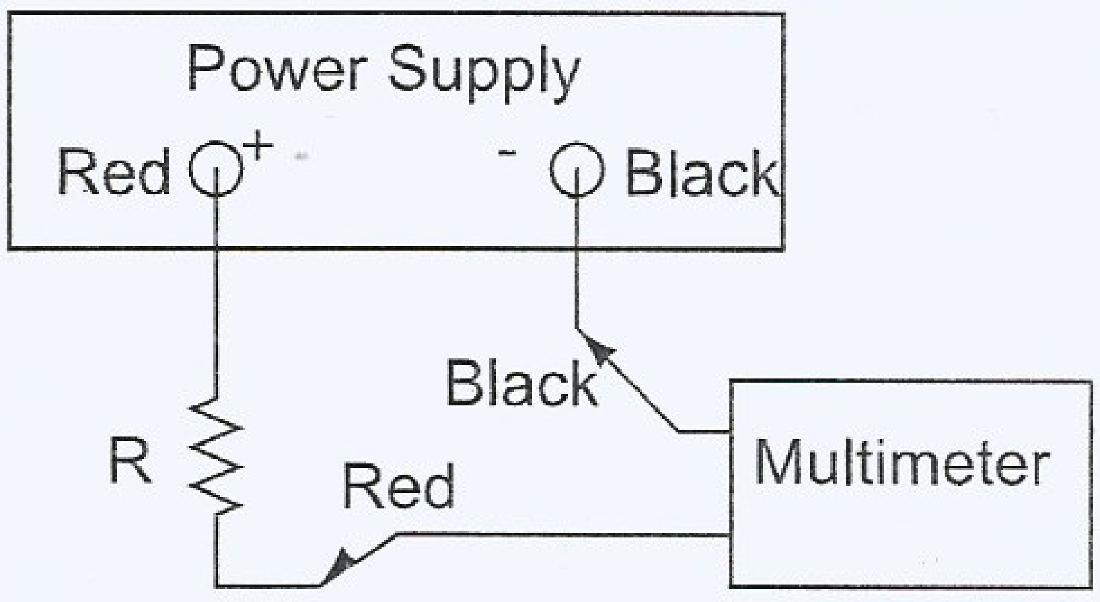


Figure 2: Connection of a multimeter as an ammeter.

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= 177.5 Ω   Measured: V= 4.99 V

Measured: I= 28.33 mA   Calculated: $I = V/R$= 28.11 mA

0,02631

Comments: Because of ammeter's resistance, the total of system resistance increases. From $I=V/R$ because resistance increased the current should have decreased. The error can be because of measurement errors of ammeter. The voltage measured from the resistance also decreases from $V=I.R$ since current decreased.

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: $R_A=$ 1.5 Ω

Comments: From $I=V/R$, since R is now 179 Ω, we find I as 27,93 mA. This is less closer to the measured value we found in item 1.5. That might have happened because of multimeters measurement errors and because of environment. But overall this resistance explains why measured voltage is lower than 5V.

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 another reason 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. Before connecting the capacitor across the multimeter probes, press REL button to get a zero reading. 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. 100 pf

Capacitance value: 100 pF Measured capacitance value: 117 pF

Capacitance value: 390 nF Measured capacitance value: 396.2 nF

1.7. GRADE:

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= 23.3 Ω	R_2= 12.1 Ω	R_3= 33.2 Ω	R_4= 39.3 Ω

2.3. GRADE:

4. Solder the four resistors as shown in Fig. 3. 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.

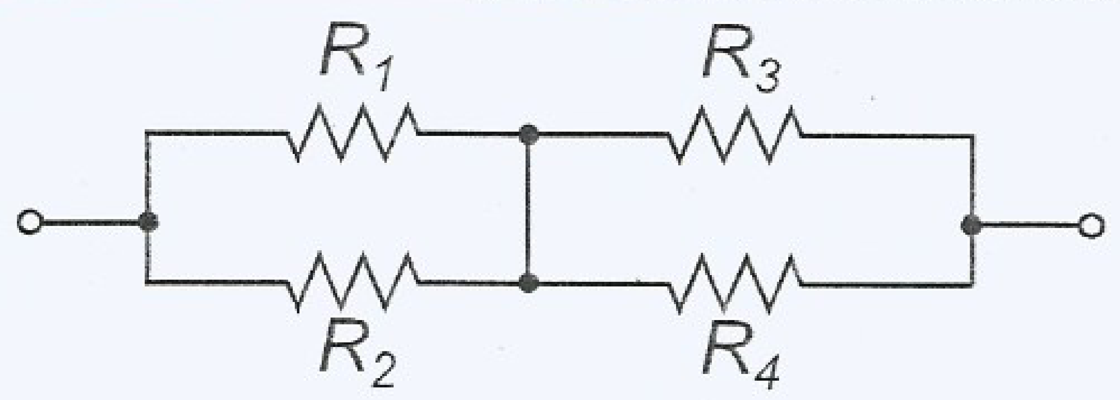


Figure 3: Solder four resistors as shown in the diagram.

$\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{Re}$

Calculated R_T= 25.96 Measured R_T= 25.7

Comments: The numbers are very close, but difference may be because multimeters measurement errors and because of environment,

$\frac{R_2+R_1}{R_1R_2}$

2.4. GRADE:

$\frac{R_1 R_2}{R_1+R_2}$

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. 4. Nevertheless, other brand or model digital oscilloscopes are also very similar.

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.

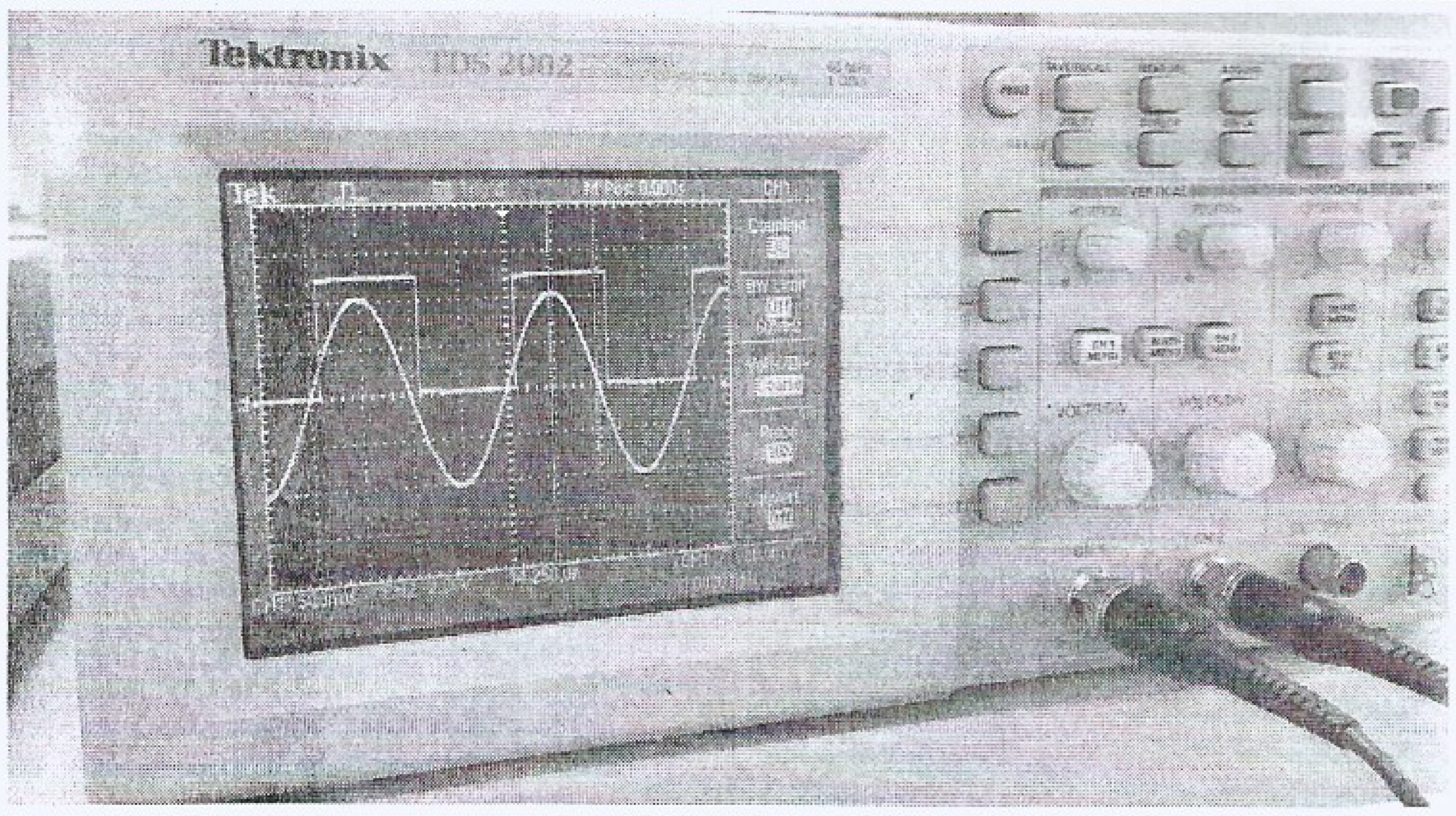


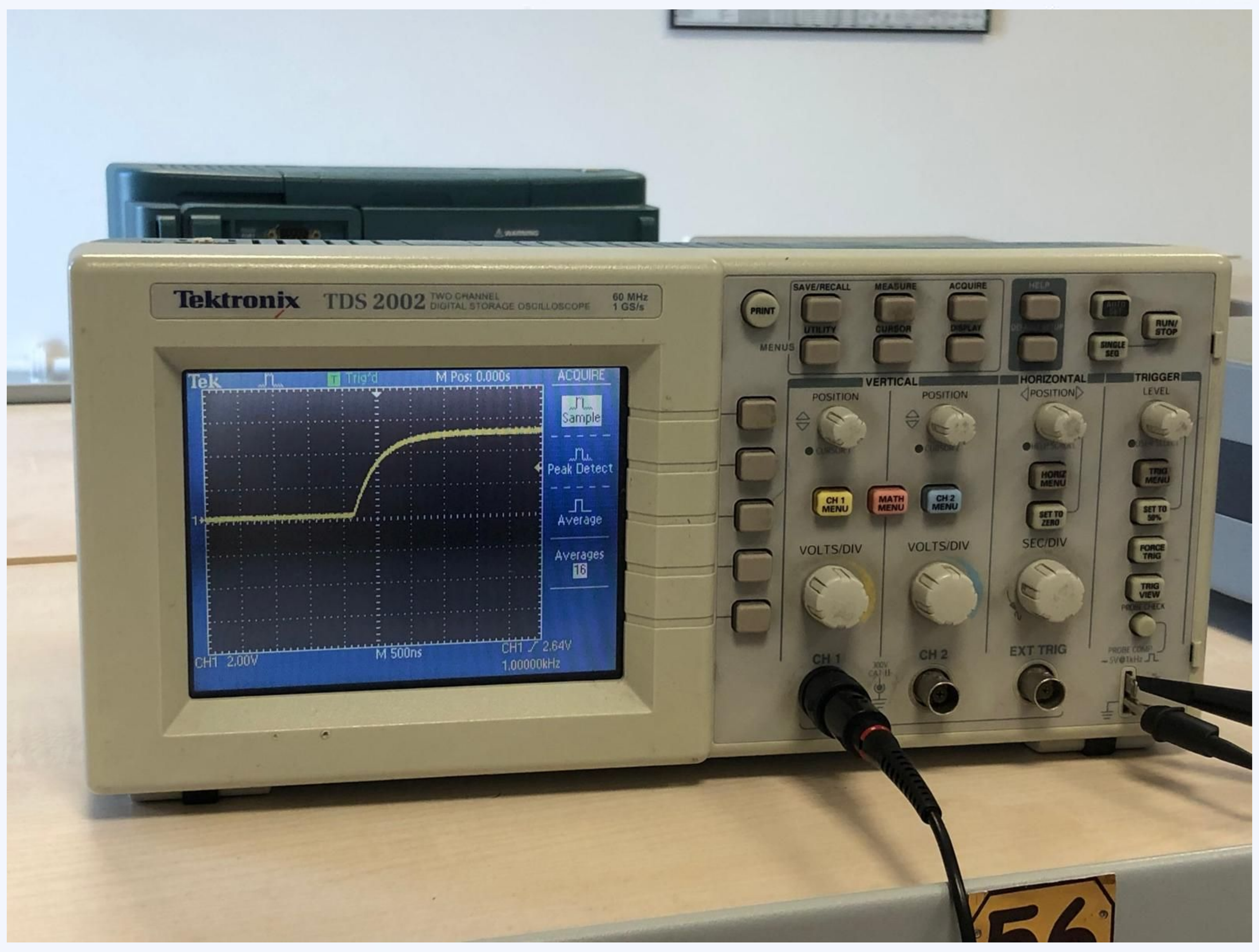
Figure 4: Tektronix TDS2002 two-channel digital oscilloscope showing sinusoidal and square waveforms

Comments: With DC coupling both AC and DC signals show on the screen, that is why the wave usually appears higher on the screen. AC coupling blocks DC and only shows AC signals, and the wave is usually centered around the baseline. Ground coupling makes the input signal disconnected and only shows 0 V.

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 photo:



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: When we change the trigger slope to falling, the oscilloscope will start capturing the waves when it transitions from high voltage to low voltage.

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.

Δt= 1 ms f= 1 kHz ΔV= 5.2 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.

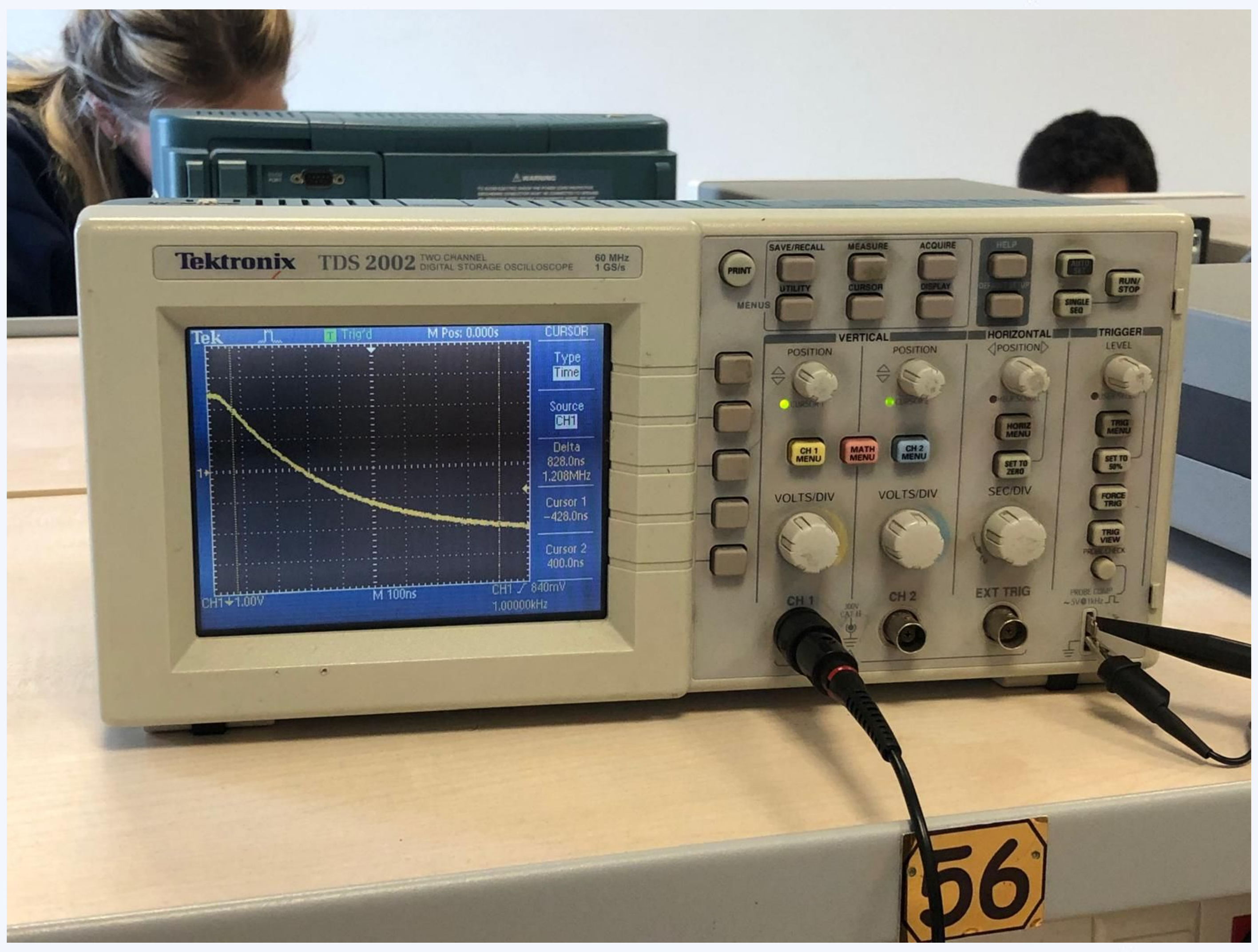
Observations: When we change the trigger level we change when the oscilloscope starts capturing the wave. So when we turn the trigger level knob to a higher voltage, it makes oscilloscope to trigger at the beginning of the falling edge. When we decrease the trigger level, the oscilloscope triggers at the end of the falling edge.

3.7. GRADE:

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. Set the horizontal time scale to 100 ns/DIV. Find the 90% (4.5 V) and 10% (0.5 V) voltage points on the vertical scale and set the time cursors to those points to determine the fall time. Take a photo of the screen for your report.

t_f= 828 ns

Screen photo:

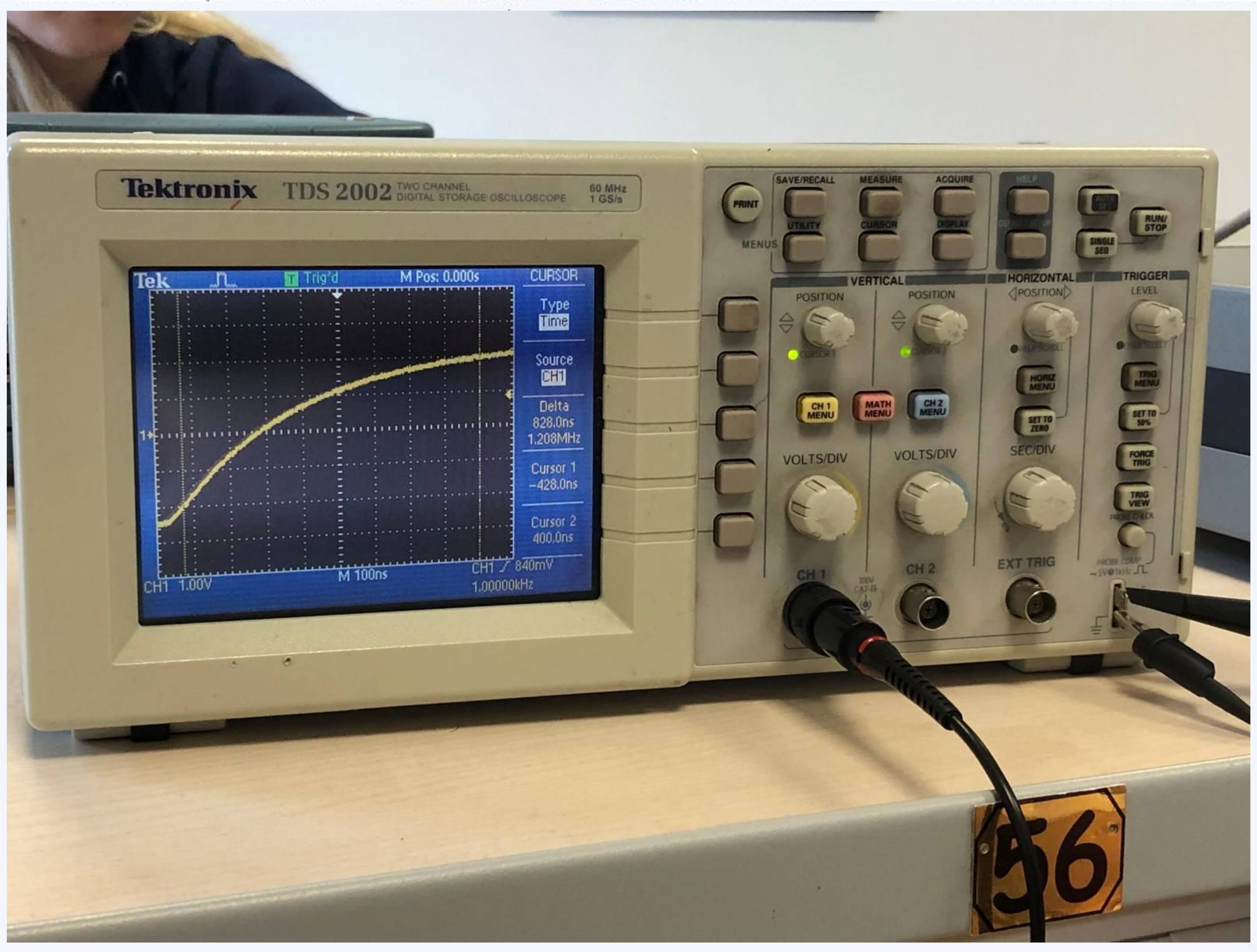


3.8. GRADE:

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= 828 ns

Screen photo:



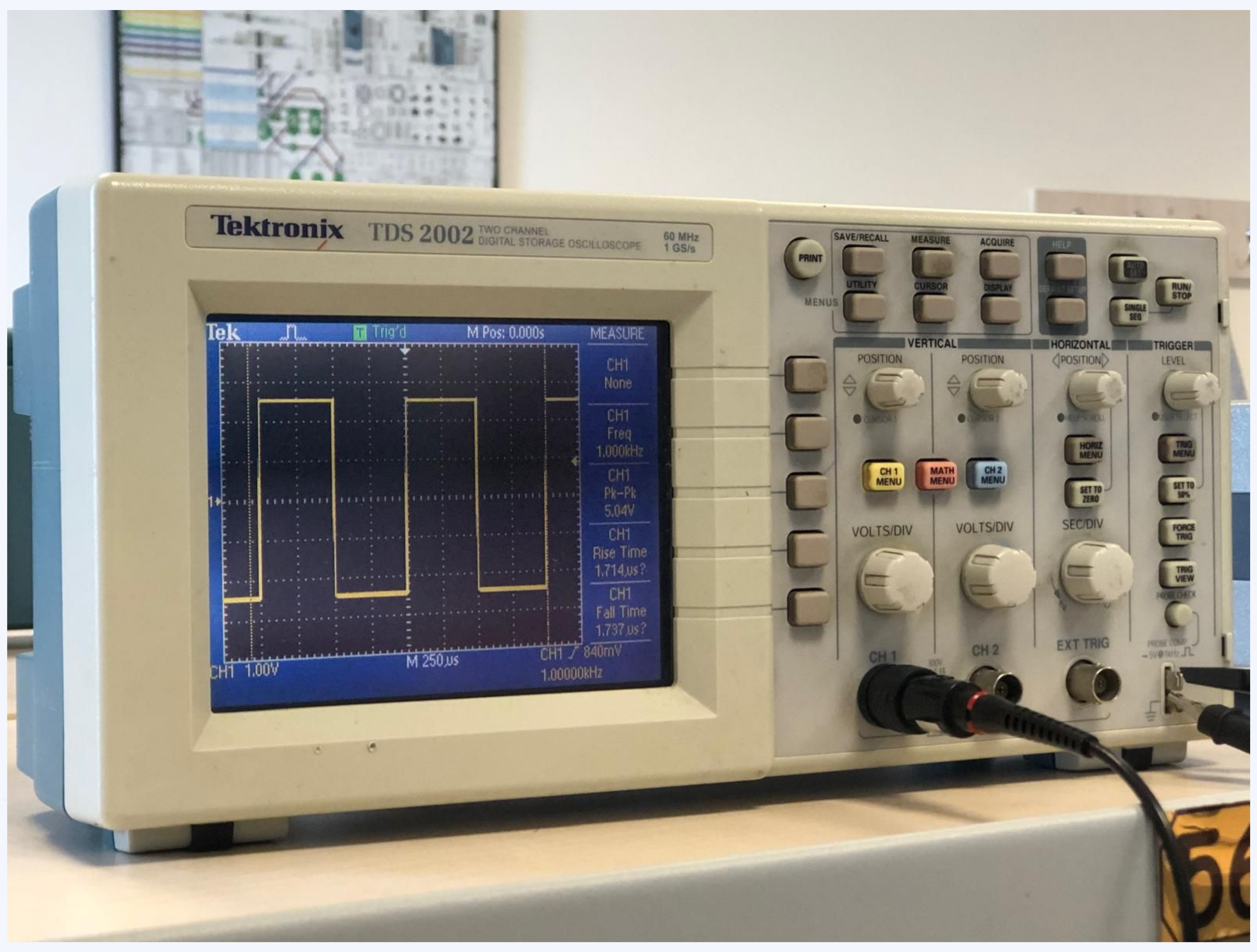
3.9. GRADE:

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 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.

$\Delta t=$ 1 ms $f=$ 1 kHz $\Delta V=$ 5.04 V

$t_f=$ 1.737 μs $t_r=$ 1.714 μs

Screen photo:



3.10. GRADE:

11. Set the trigger mode to NORM. Vary the TRIG LEVEL until the oscilloscope is no longer triggered. Note that the last triggered waveform remains frozen on the oscilloscope screen. Set the trigger mode to AUTO. In this mode, the oscilloscope will show new waveforms even though it is not triggered. NORM trigger mode can be used if you want to capture a rare event. For example, if a waveform has a voltage spike occurring once in a while, you can set the trigger level to the level of expected spike and set the trigger mode to NORM to capture that rare event. Explain the difference between Trigger mode AUTO and NORM.

Difference between AUTO and NORM: In AUTO mode, the screen always show a wave form even if it is not triggered by refreshing the data in time periods. In NORM mode, we must adjust the trigger level if we want to see the wave form. So the difference is we do not have to adjust the trigger level to see a waveform in AUTO mode, but we need manual triggering in NORM mode.

3.11. GRADE:

12. 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. If there is no signal input on CH 2, there can be no trigger. Change the Source button to change the source to CH 1. Explain the meaning of source button.

Meaning of source button: The source button chooses which channel to use for triggering. Since we only have a signal on channel 1, the oscilloscope cannot trigger the signal if we choose CH 2 as the source.

3.12. GRADE:

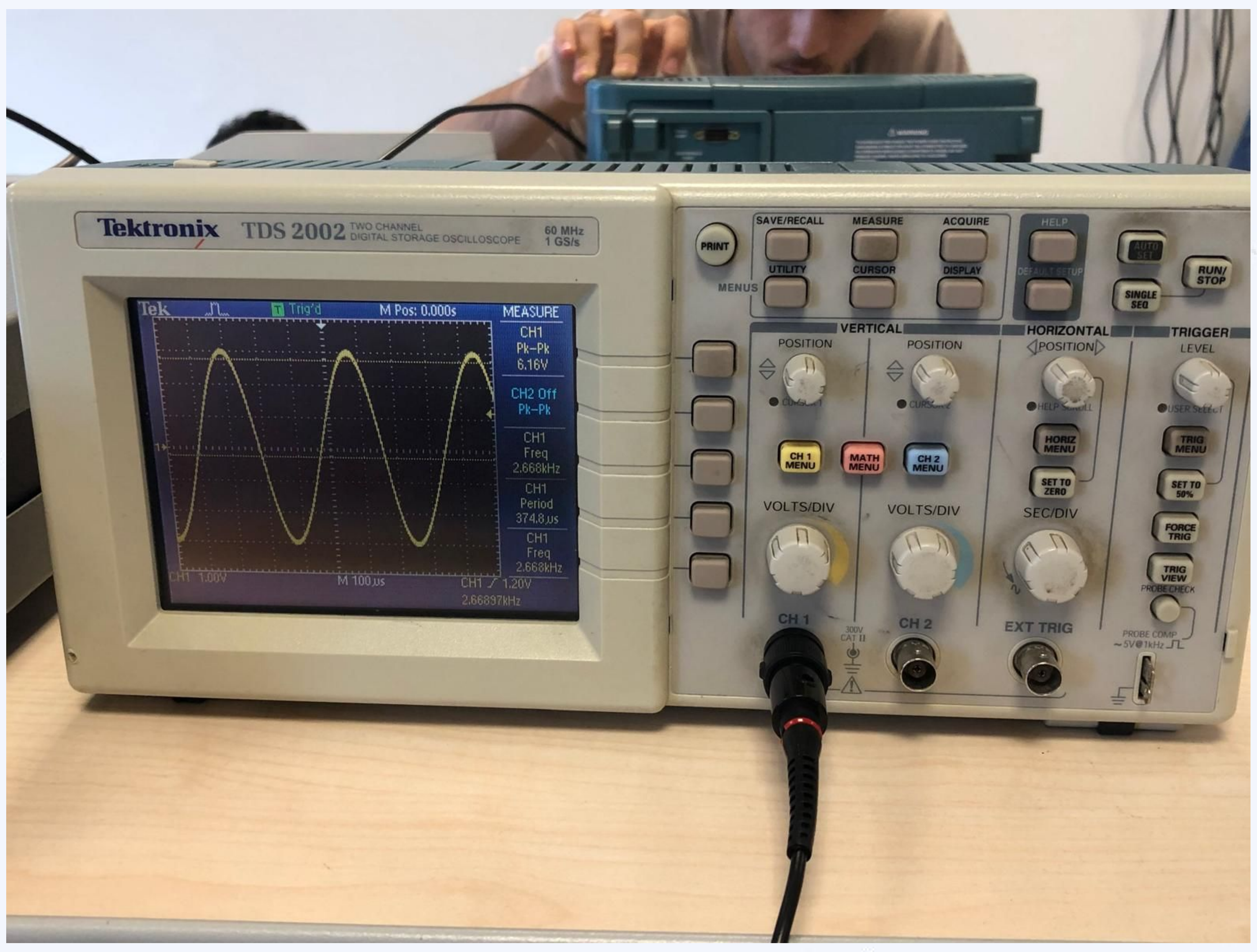
13. Press the Trigger Source button repeatedly until AC Line is the trigger source. AC Line means the trigger source is AC 50 Hz power line of the oscilloscope. Press the TRIG VIEW button to see the trigger signal and the automatic trigger level set by the oscilloscope. If a signal related to 50 Hz line 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 AC Line. Explain.

Explain: When AC Line is set as the trigger source, it detects the AC signals with 50 Hz power line. When we touch our finger to CH 1, our body acts as an antenna and gets the signals from the environment. So the oscilloscope shows a sine wave of 50 Hz AC line and also the additional noise or signals our body picked up.

3.13. GRADE:

14. Adjust the signal generator so that it generates a sine wave with a frequency (in Hz) 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. Note that the oscilloscope peak-to-peak value is about 6 V peak-to-peak, twice the set value in the signal generator. This is normal, since the signal generator assumes that it has a load of 50 Ω. Since the input resistance of the oscilloscope is much larger than 50Ω, the signal amplitude will be doubled. Take a photo of the screen for your report. Comment on the agreement between the signal generator settings and oscilloscope measurements.

Screen photo:



3.14. GRADE:

15. With frequency set as in the previous step, 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.

16. Set the frequency of the signal generator to 50.1 Hz. Set the amplitude to 5 V. Set the Trigger source as AC 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 AC Line frequency at the time of measurement. Note that the AC line frequency may shift slightly back and forth as a function of time.

$f = 49.968$ Hz

3.16. GRADE:

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 large amplitude 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.

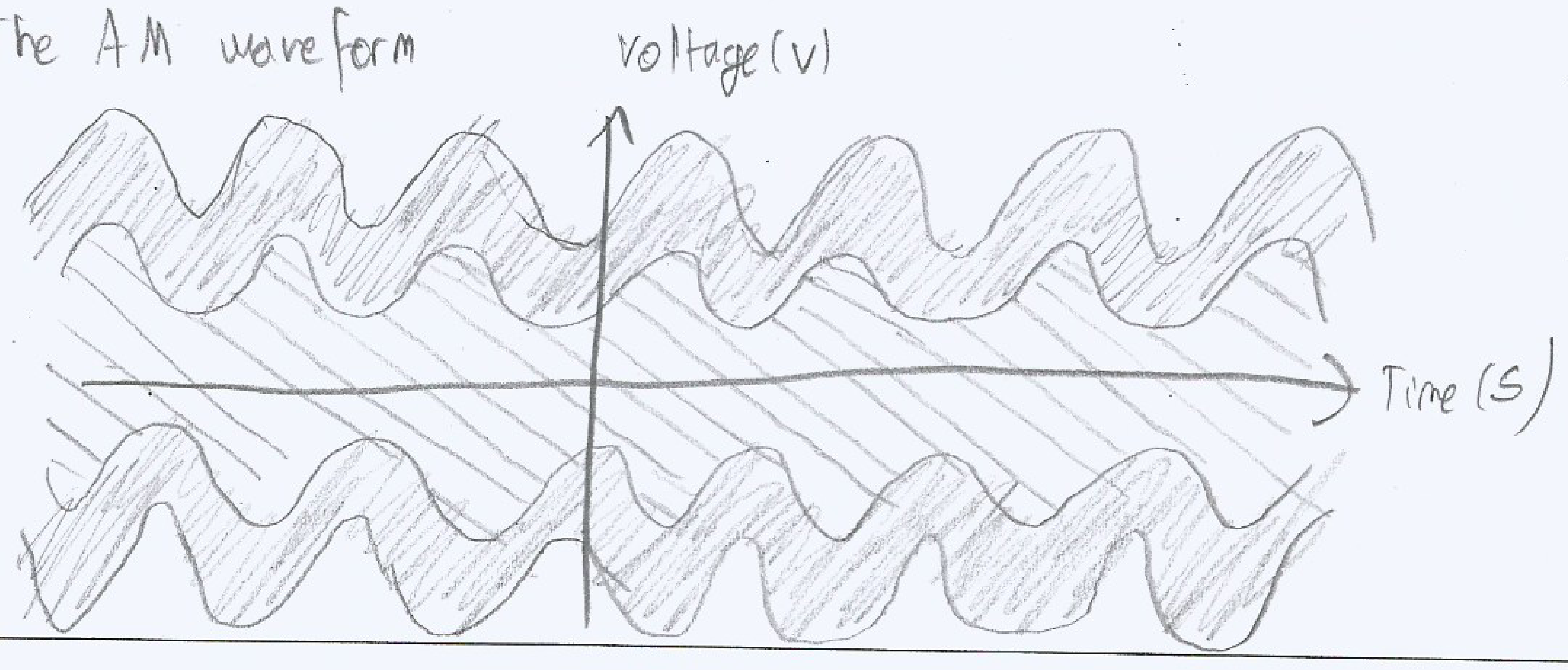
Benefits of External Triggering: With external triggering the oscilloscope can automatically trigger signals. This is especially helpful for complex signals and signals that have low voltage that are hard to adjust triggering manually. It is also very precise and decreases noise as well.

3.17. GRADE:

18. In this item, the signal generator will be set to generate an amplitude modulated (AM) signal similar to the output of TRC-11. 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. 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. Press the TRIG VIEW button to see the trigger signal and the trig level. Make sure that the oscilloscope is triggered. 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 500 μs/div. Observe the AM waveform. Plot the waveform below. Observe the signal's envelope as you change modulating function to Square, Triangle, and Ramp.

AM Waveform for sinusoidal modulation

Plot: The AM waveform



3.18. GRADE:

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 frequency of the signal is too high, oscilloscope cannot capture the signal precisely. That is why we see a distorted version of the waveform.

3.19. GRADE:

CHECK POINT: