ENGR3200 Laboratory 3

Building Electronic Instrumentation Systems

1 Aim

Electronic instrumentation systems are widely used in several industries, namely, industrial control and automation, biomedical instruments, electrical power transmission and distribution, avionics, robotics and general electronic troubleshooting and design. This laboratory exercise aims to allow students to use their knowledge of electronics to develop practical instrumentation systems that have applications in various industries.

2 Objectives

The objective is for students to develop an electronic instrumentation system that can accurately measure the circuit parameters shown below. This should be implemented using AVR C-program and the ATMega16/32 circuit shown in Appendix B.

All students should implement these measurements

1. Voltage in a DC circuit
2. Capacitance
3. Resistance

EE and BME Students should implement the following

1. Temperature
2. Frequency of a square wave (DC signal).
3. Inductance
4. Distance Measurement

EPE Students should implement the following

Measure the following parameters of a single-phase 120VAC source supplying power to a load.

1. Voltage (Use Potential Transformer – A transformer from an old radio or other devices can be used.)
2. Current (Use CT)
3. Frequency
4. Phase
5. True and Apparent power

NB: 20% Bonus mark for students who implement all the measurements.

Students should use the circuit provided in Appendix A as the foundation for building the electronic instrumentation system. Modification of the circuit can be done as needed.

The main tasks for the students are:

1. Build the electronic instrumentation circuit on a breadboard. For
2. Write the program to implement the instrumentation system.
3. Demonstrate the performance of the system to the Lecturer or a TA.
4. Document and present the results.

Students should document the software and hardware design for the meters, including the concept used to arrive at the solution. <u>Take pictures during measurement and include them in your report. The tolerance of the meters must also be stated in your report</u>.

3 System Specifications

When the circuit is powered, it should start in “Voltmeter Mode”. All measurements with the specified units should be displayed on the LCD. The push button on pin PD2 should be used to switch between the different measurements mode, for example: “Voltmeter”, “Capacitance Meter”, “Inductance Meter”, “Temperature Meter”, “Frequency Meter”, etc.

The design of each meter should be done as follows.

3.1 DC Volt Meter

The voltmeter is designed using a voltage divider created with the R9 (10kΩ) and R8 (100kΩ) resistors and connected to the A/D pin (PA2) of the microcontroller (see the figure in Appendix A). Students need to determine the maximum input voltage to the system since the maximum voltage to the A/D port is 5V. The software should be written to minimise the errors introduced by the actual values of the resistors.

Students should use a multimeter to verify the accuracy of the implemented voltmeter. Include pictures of both instruments measuring different voltages in your Lab report.

3.2 Temperature Meter

The temperature is measured using an LM35 integrated circuit temperature sensor. The output from the sensor is connected to A/D pin PA1 on the microcontroller. Students should download the datasheet for the LM35 and carefully observer its pinout before inserting the device into the circuit.

3.3 Frequency Meter

The input capture feature of the microcontroller is used to measure the frequency of the input signal. The signal is connected to the ICP1 pin of the microcontroller via a 1kΩ resistor. Students should revisit the input capture lecture in course ECSE2104 or ELET 2450 or in the text “AVR Microcontroller and Embedded Systems: Using Assembly and C”.

The same method is used to measure the frequency of an AC and DC signal. However, the AC signal should be properly conditioned before it is sent to the microcontroller.

3.4 Capacitance Meter

The circuit is designed to measure standard value capacitors. The measurement of an unknown capacitance is done using the knowledge of charging a capacitor in an RC network. If it takes time, *t*, to charge a capacitor to a particular voltage, V_C; and the input voltage V_{in} and resistance *R* are known, then the unknown capacitance, *C* can be found using the following formula:

$$V_C = V_{in}(1 - e^{-t/RC})$$

In the circuit, V_C = 2.5V which is determined by R3 and R4 voltage divider circuit. This 2.5 V is connected to inverting input (AIN1) of the voltage comparator in the microcontroller.

The time to charge the capacitor to V_C is measured using a counter in the microcontroller. The counter should be incremented every clock cycle. Since an 8 MHz crystal is used in the circuit:

Fosc = 8 MHz; => 1 clock cycle = 1/Fosc = 0.000000125 = $0.125*10^{(-6)}$

Therefore elapsed time, t = Counter X $0.125*10^{(-6)}$

Now, to find the capacitance, C

$$V_c = V_{in}\left(1 - e^{-t/RC}\right)$$

NB: You should insert the actual circuit values of V_c and V_{in} in the formula.

$$2.5 = 5\left(1 - e^{-t/RC}\right)$$

$$0.5 = 1 - e^{-t/RC}$$

$$e^{-t/RC} = 0.5$$

$$ln\left(e^{-t/RC}\right) = \ln(0.5)$$

$$t/RC = 0.693$$

$$t = 0.693 \times RC$$

$$C = t/(0.693 \times R)$$

$$C = Counter \times 0.125 \times 10^{-6}/(0.693 \times 10 \times 10^3)$$

$$C = Counter \times 1.80375 \times 10^{-11}$$

The procedure that the software will use to measure the capacitance according to the circuit in Appendix B is as follows:

1. The capacitor is first discharged through R6 by setting PB2 (AIN0) as output, bringing it low, and setting charging pin PB0 low.
2. The capacitor voltage is monitored via R7 using A/D pin PA0 until the voltage is zero before moving to the next step.
3. PB2 (AIN0) is set to input, and analogue comparator interrupt is enabled. The capacitor voltage is connected to the non-inverting input (AIN0) of the analogue comparator in the microcontroller via resistor R6. An analogue comparator interrupt will be triggered when the capacitor is charged just above 2.5 V.

4. The capacitor charging via R5 (10kΩ) is started by setting PB0 (charging pin) high. A timer should begin immediately with the charging.
5. The LED on pin PD7 should be enabled to indicate charging is in progress.
6. When the analogue comparator interrupt is triggered, the elapsed time is determined, and the capacitance value calculated and displayed on the LCD. The LED on pin PD7 should be disabled.
7. Repeat steps one to seven every five seconds or a suitable time for the smooth operation of the instrument.

3.5 Resistance Meter

Method to be determined by the students

3.6 Inductance Meter

Method to be determined by the students.

3.7 AC Voltage Meter

Method to be determined by the students.

3.8 AC Current Meter

Method to be determined by the students.

3.9 AC Phase

Method to be determined by the students.

4 Appendix A: Additional Information

Inductance Measurement

1. https://www.instructables.com/Inductance-Meter-Using-Arduino/

Power Factor Measurement

1. https://www.instructables.com/How-Measure-AC-Power-Factor/
2. https://solarduino.com/how-to-measure-power-factor-and-phase-angle-with-arduino/

Calculating Power Factor

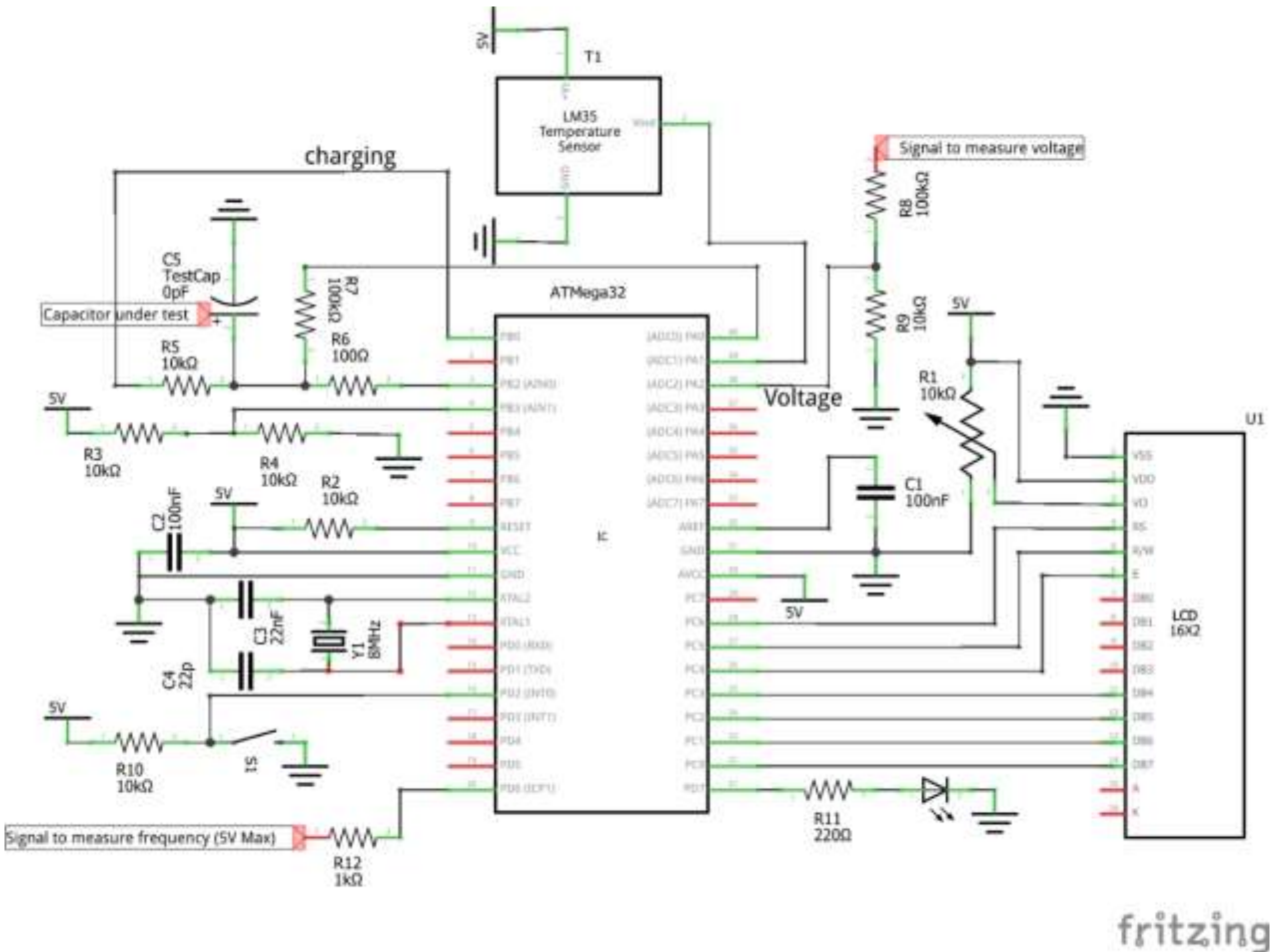
1. https://www.allaboutcircuits.com/textbook/alternating-current/chpt-11/calculating-power-factor/

True, Reactive and Apparent Power

1. https://www.allaboutcircuits.com/textbook/alternating-current/chpt-11/true-reactive-and-apparent-power/

5 Appendix B: Circuit

The microcontroller is an ATMega32/ATMega16



Schematics of Electronics Instrumentation Circuit