DSO

Design Review Report

EE344: Electronic Design Lab

Faculty Mentor: Prof. PC Pandey

Faculty Mentor: Prof. Joseph John

Group: MON-21
TA/RA Guide: Sanskar, Omkar

Group members:
1) Harsh Choudhary (200070023)
2) Harsh Lulla (200070024)
3) Abhinav Ghunawat (200070002)

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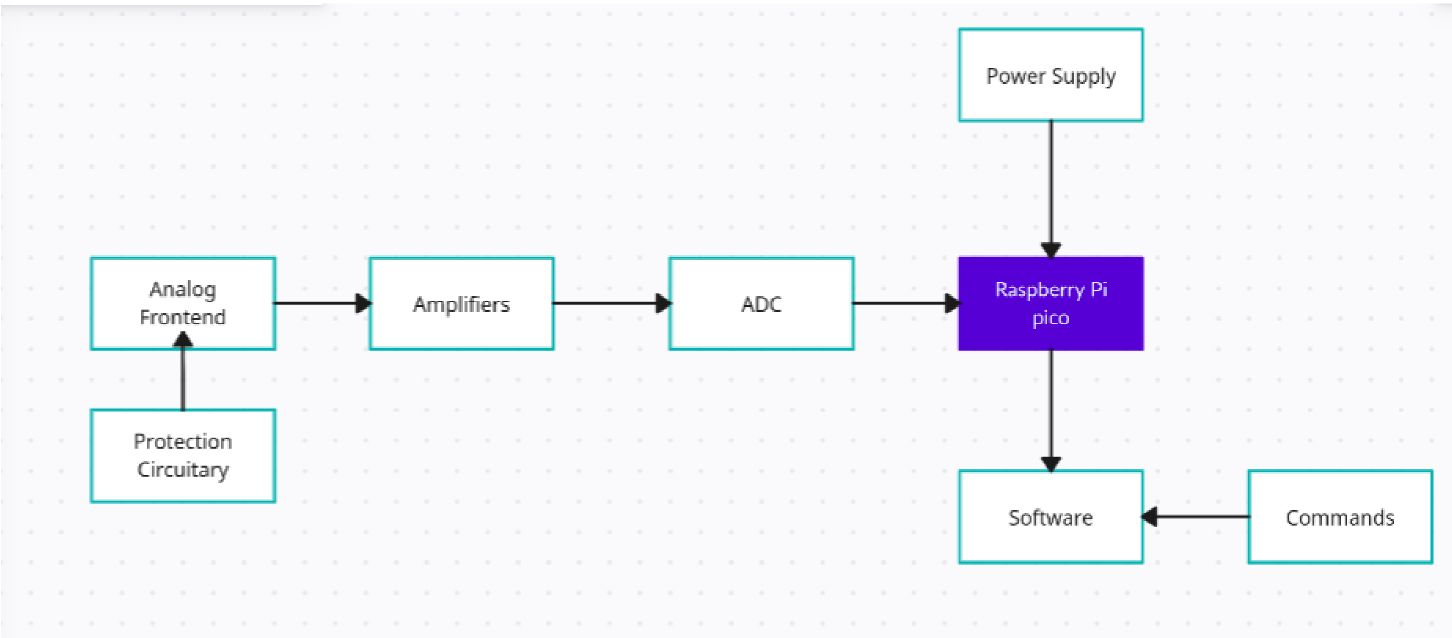
1)Description of Design

1.1 Goal of the project

The purpose of this project is to build a two-channel oscilloscope. This oscilloscope would then be interfaced with an application via Bluetooth/Wi-Fi to see the input waveforms inside the application. The oscilloscope would have protection circuits to prevent voltage and current from going beyond a certain threshold for the safety of the equipment. It would use the ADC of the microcontroller to convert the analog signals to the digital domain. It would also have scaling circuits to appropriately scale up(or down) the signal for display. Finally, it would be connected to a microcontroller and the module to send the samples to the application. The application would display the waveform along with the amplitude and frequency. There would be additional circuitry for triggering as well.

We plan to demonstrate that our oscilloscope can display the supplied signals with proper scaling and triggering on the laptop.

1.2 Block Diagram



2)Project Description

Description of various parts of the project is as follows:

2.1 Input

Measurements shall be taken using a standard BNC connector probe as used for DSOs. Hence, a probe receptacle shall be used to connect to the probe. The standard Input impedance of almost 1MΩ and 120pF in parallel shall be connected.

- For measuring differential voltage we would be using a probe with 3 wires(positive, negative, and ground). Here, the user will have to connect it to the ground separately and there will be two such voltage probes.
- For measuring differential current we would be using probes each with 2 wires (positive and negative)

2.2 Protection circuit

A zener diode with necessary breakdown voltage connected back to back across the input terminals can be used for overvoltage protection. Overcurrent protection can be implemented using elements as simple as a Fuse of appropriate rating once the total current required is calculated for the entire circuit.

- We have selected the 1N4733A Zener diode to protect the circuit from voltages more than 20V
- We will be using Fuse which would protect the circuit from higher currents.

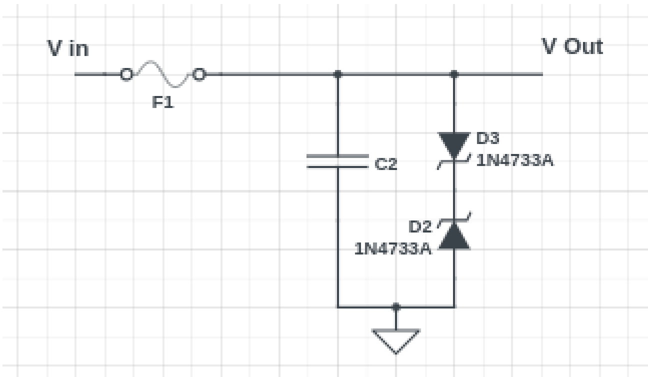


Figure: Protection Circuit

2.3 I-to-V conversion

We will use INA210 for this purpose, it is a bidirectional high-precision current sense amplifier, meaning it can measure both positive and negative currents. They have differential input pins (INA+ and INA-) for the current source and provide a voltage output proportional to the input current. It takes input power supply from 2.7V to 26V.

So, we have decided the following circuitry with Vout = (IR_S)xGain + V_{ref}

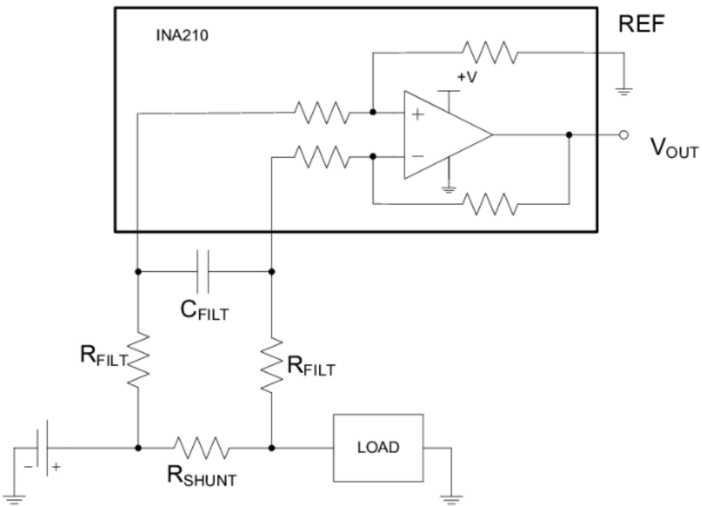


Figure: Bi-directional I to V conversion using INA210

2.4 Scaling

We have planned to use an instrumentation amplifier for amplification and to take the difference of two voltages. INA326 can be used for this purpose. It is a precision instrumentation amplifier and works with a single-sided source voltage of 5V. Its gain is given by **(R3/R2)((2R1+Rgain)/Rgain).**

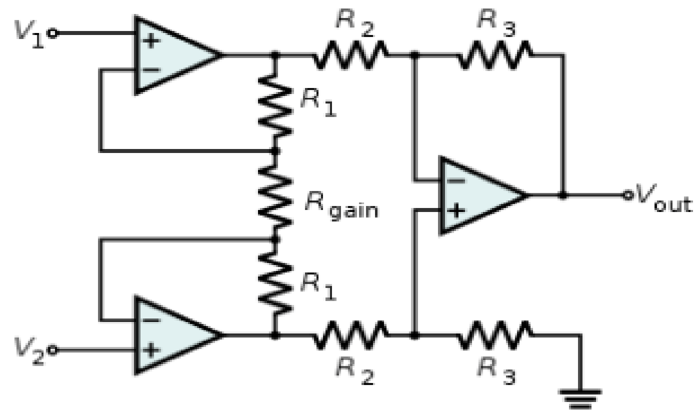


Figure: Instrumentation Amplifier

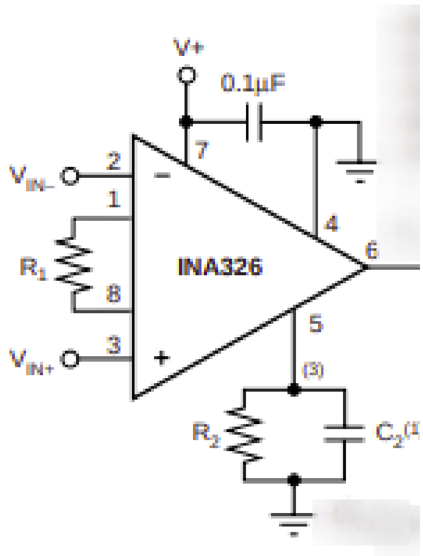


Figure: INA326 Circuit

X, Y Scaling will be done using hardware and not software as software receives values converted using ADC and thus it has quantization error. Further scaling it would scale up the error term also.
The value of gain will be transmitted from the software to the microcontroller and it will vary the scaling factor in the hardware accordingly.

2.5 Microcontroller

Microcontroller will be used for transmitting the signal from hardware to software using a wireless medium (Bluetooth/Wi-Fi) or using wire. First, it will convert analog input from the hardware to digital. Also, the Computer will communicate values of X-scale, Y-scale, and channel settings to the microcontroller, based on them, it will set the gain of the amplifier and control the multiplexer to give values of the required channels to ADC.

We have decided to use Raspberry Pi Pico for this purpose

- We will be providing power to the microcontroller using a mobile phone charger
- It has an in-built 12-bit SAR type ADC. Hence, the digital value between 0-4095 will be mapped to analog values.
- Communication will be bi-directional (in duplex mode), we will use Bluetooth/Wi-Fi/Type-C cable for connecting the devices.
- It is a dual-core Arm Cortex-M0+ processor and provides flexible clock and power management.
- The board features 26 GPIO pins, including 2 analog inputs, 2 pulse width modulation (PWM) outputs, and 2 serial peripheral interface (SPI) interfaces
- It supports microPython, which is python library made for microcontrollers

2.6 Triggering and Frequency Detection

We will initially do edge triggering and later as per the availability of time we can implement more triggers and also can use algorithms like peak detector or level crossing for frequency detection in sinusoidal and square waves as an additional feature.

2.7 Power Management

- We will supply power to the microcontroller using an adapter.
- To save power, we will transmit a signal from the multiplexer to the ADC only when it is turned from the

software.

2.8 Interfacing Application

We are planning to use an application based on python. Data will be received from Bluetooth/Wi-fi and would be processed to reconstruct the given signal. The triggering mechanism will be applied from the software itself and other features which will be implemented are:

1. Voltage-scaling (Sending gain value from GUI to the microcontroller)
2. Time Scaling
3. Trigger-Mode
4. X and Y Shift
5. Voltage/Current mode Selector

3. Weekly Targets and work distribution

The work distribution according to past experience and interest will be Harsh Choudhary for analog and software, Harsh Lulla for microcontroller and analog, and Abhinav for PCB and packaging. Power Management will be handled by all three of us.

A tentative schedule for throughout the semester is as follows:

1. Week 1: February 1 - February 7

We will have submitted the bill of materials and the components will be procured this week. Meanwhile, we will start with the schematic circuit diagrams for the ADC data transfer and the USB+Bluetooth interfacing with the microcontroller. We will also design the protection circuitry

2. Week 2: February 8 - February 14

After sourcing the components, we will start building the basic analog protection circuit, and we will work on the circuit that amplifies and attenuates the input signal. We will build the I-V conversion circuit on the breadboard. Harsh L will work on USB and Bluetooth interfacing with the microcontroller.

- **Milestone: February 15 - Schematics and preliminary analysis(breadboard) review**

3. Week 3: February 28 – March 6

Harsh L will start interfacing the Pico with the laptop and the ADC conversion of the signals. We will primarily work on wireless communication through Bluetooth and wired communication using USB. Harsh C will start creating the translation and scaling features on the oscilloscope display. Abhinav will initialize the work on the PCB design. We will all work on studying the different conditions the DSO will be subject to in various current and voltage applications.

4. Week 4: March 7 – March 13

Harsh L will work on the anti-aliasing filter circuit which will incorporate the sampling rate set by the user to remove higher frequency noise on the display. Harsh C will work on interpreting the signal data on the display. Abhinav will work on estimating the power consumption of the circuit and finalize the PCB design.

- Milestone: March 15 - Schematics and preliminary analysis(breadboard) review

5. Week 5: March 16 – March 22

We will collectively design packaging for the PCB design and start wrapping up the documentation of the final product. We will test the product under different conditions and make sure each subsystem is working nominally.

- Milestone: March 24 – Initial subsystem testing review – 1
- Milestone: April 5 – Individual subsystem testing review - 2

4. Common and different between groups

The additional feature which our group is implementing is an anti-aliasing filter which uses the Nyquist criteria to filter out higher frequency components of the differential signal. This is a challenging task as this requires us to set the cut-off frequency of the bandpass filter to be variable as the sample rate itself is variable. We will need to build an active low-pass filter circuit with variable cut-off frequency for this task.

There are two other groups doing the same project. We will collectively discuss and build upon each other's shortcomings. Our basic hardware circuit should be similar to the ones developed by the other groups.

One group is implementing the auto-set feature. This automatically adjusts the x-scale and y-scale based on the input signals applied, and the other group is implementing reverse Nyquist criteria where a lower bound of the frequency spectrum is applied. This, however, introduces a challenge as the signal must be sampled in a fixed time called the aperture time.

5. Bill of materials (BOM)

Initial sketch of our Bill of material is as follows:

Item	**Quantity**	**Unit Price**
Microcontroller (Raspberry pi pico)	1	Rs 590
Instrumentation Amplifier (INA 326)	2	Rs 285
4:1 Analog Multiplexer(MC14066BDG)	6	Rs 57
Op Amp(LM358)	4	Rs. 225
I- to-V Converter (INA 210)	2	Rs 130
Diode (1N4747A)	8	Rs 6