EE DEPARTMENT, IIT BOMBAY

1ST FEB 2025

EDL - 09/ TUE - 08

MILESTONE - I

STRUCTURAL HEALTH MONITORING SYSTEM USING DSPIC33A

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WHAT IS THE PROBLEM THAT YOU ARE TRYING TO SOLVE?

- We are solving the problem of **detecting structural defects** like mass loading and cracks that weaken metal structures, leading to safety hazards and financial losses.

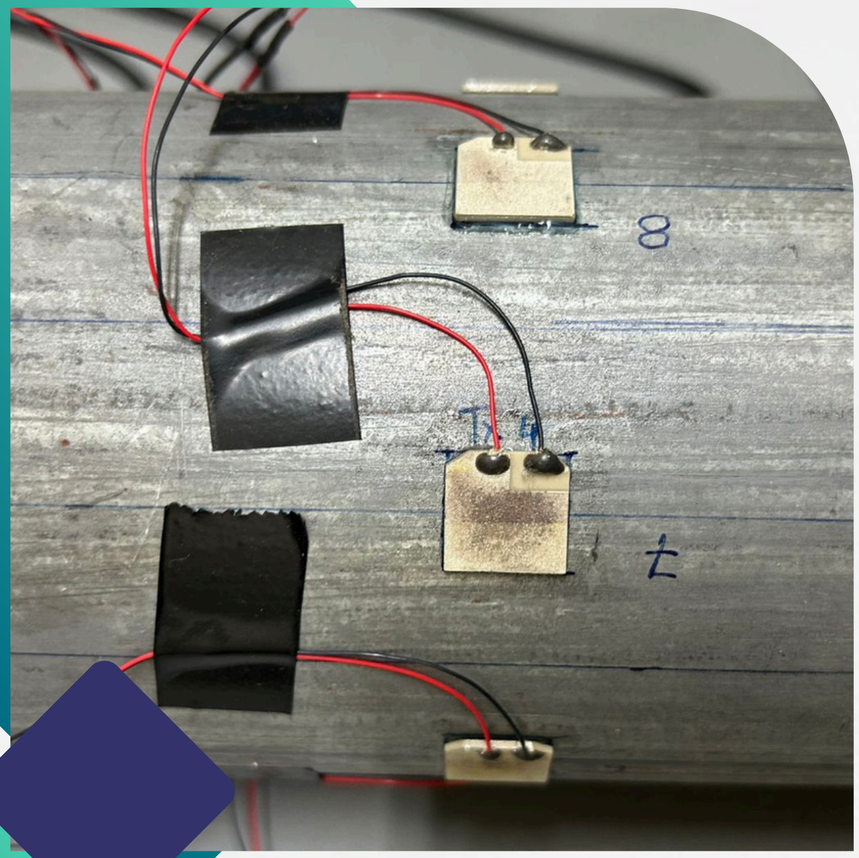
PROPOSED SOLUTION

- We re making a **compact hand held device** that will be used to **identify** the **structural defects** such as mass loading or cracks that can hamper the structures life span.
- By periodic inspection using our product the technicians can take suitable precautionary measures to prevent the deterioration of the metal structures

VALUE PROPOSITION OF OUR SOLUTION

- Our solution offers a **cost-effective** and user-friendly approach to structural health monitoring by **utilizing guided waves** and **PZT transducers**.
- This helps industries reduce maintenance costs, prevent failures, and extend the lifespan of critical infrastructure, ensuring safety and reliability across sectors like oil and gas, transportation, and construction.

HOW WILL YOU ACHIEVE THE SPECIFICATIONS?



WHY DID WE PREFER PZT BASED TRANSDUCERS FOR ACTUATION OF TORSIONAL MODES FOR PIPE INSPECTION

- **PZT-5H transducers** are ideal for **low-power, high-sensitivity guided wave** applications due to their high permittivity, coupling coefficient, and **piezoelectric charge coefficient**.
- Ultrasonic guided wave testing enables long-range pipeline inspection, detecting early-stage defects with minimal signal distortion and attenuation.

HOW WILL YOU ACHIEVE THE SPECIFICATIONS?

MOTIVE BEHIND CHOOSING THE SPECIFIC SMPS AND BUCK CONVERTER BASED POWER MODULE.

- Our earlier ideation involved a **Keithley power source**, which was expensive and difficult to transport.
- We replaced it with a **compact, plug-in power module**, streamlining power management and debugging with **cascaded regulators** for efficiency.

TECHNICAL DETAILS

PRINCIPAL OF OPERATION

- **Hanning pulse generation** using the **dsPIC33A** microcontroller and converting to an analog signal via a DAC.
- This signal is then amplified by a **power amplifier** to approximately **100Vpp** before being transmitted through a **PZT transducer**, propagating **guided waves** through a metal pipe sample.

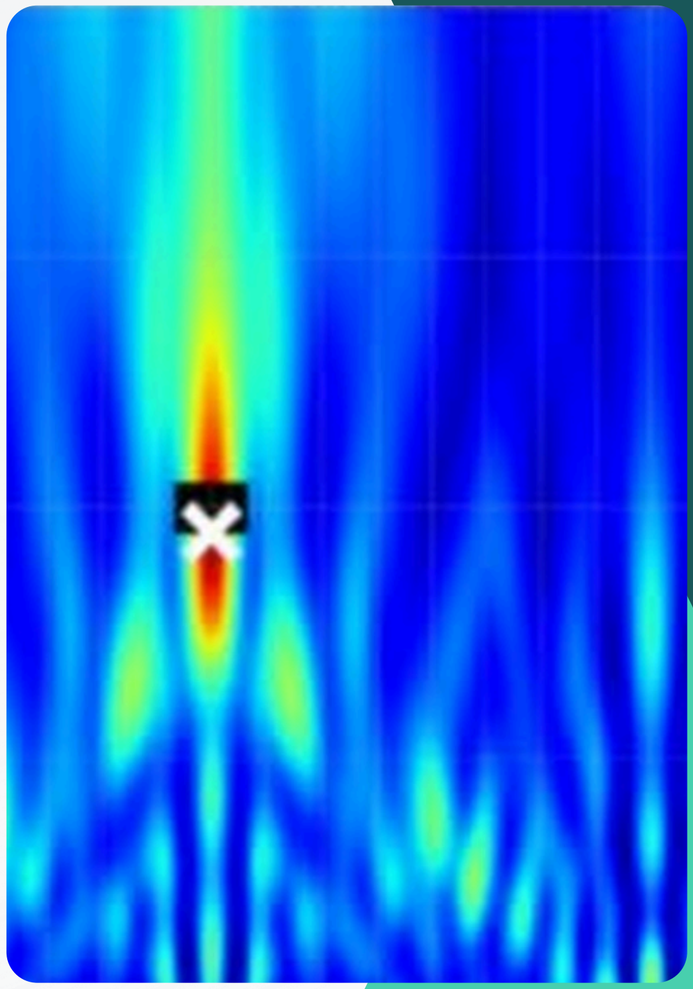
TECHNICAL DETAILS

PRINCIPAL OF OPERATION

- A receiver **PZT transducer** captures these waves, and the signal is amplified using an **INA128** before being digitized by a **10-bit ADC** and stored in memory.
- **Baseline data** is recorded for the pipe without defects, and for analysis, we flatten the pipe's surface and assign a **Cartesian coordinate system**.

PRINCIPAL OF OPERATION

- To calculate the **Damage Index (DI)**, we determine the **time of arrival**, extract the **signal window**, and compute the difference from the baseline.
- This process is repeated for all coordinates to generate a **DI map**, which is transmitted to a PC via an **ESP32 WiFi module**.



Damage Index Map

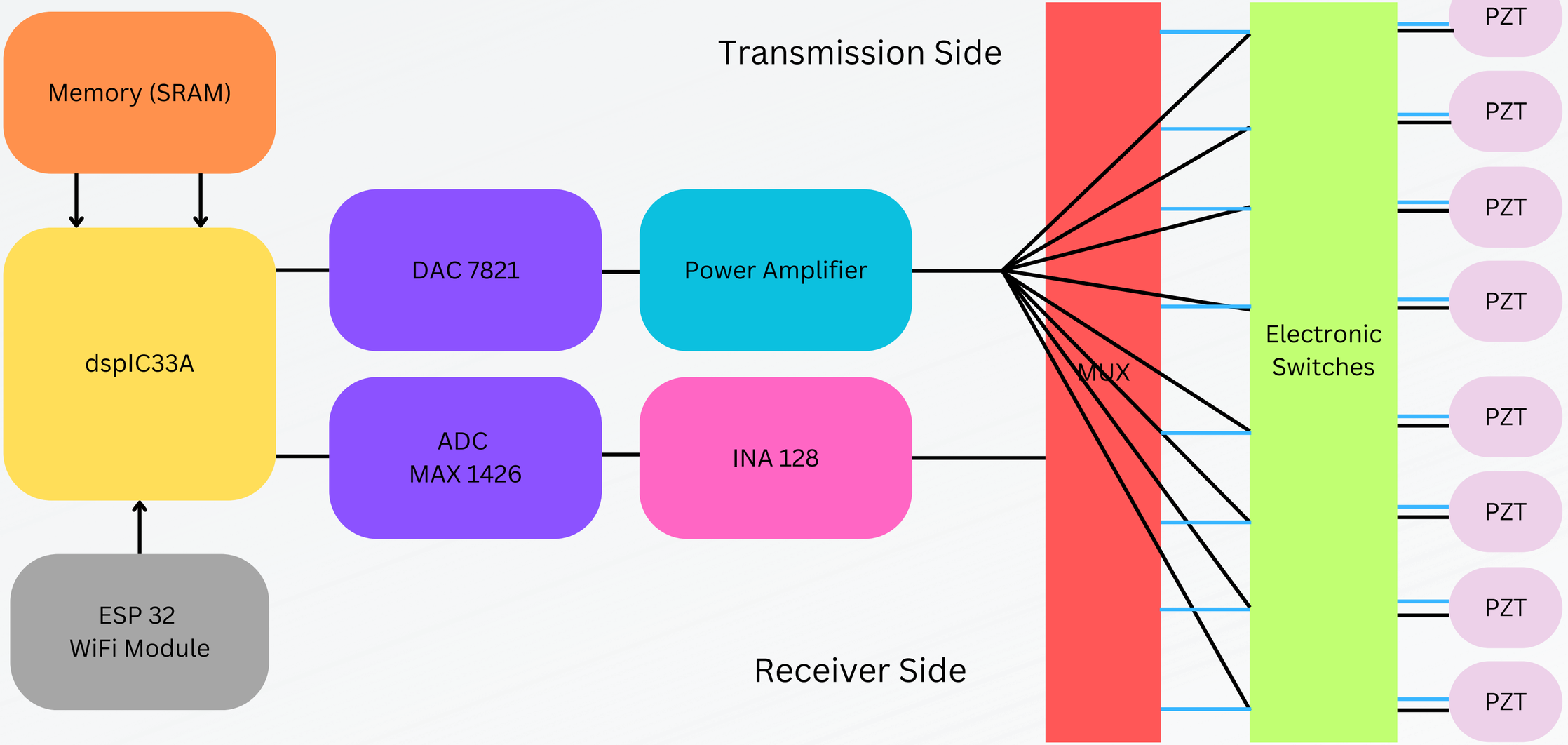
TARGET SPECIFICATIONS

- **Wireless Embedded Platform:** System should enable ultrasonic guided wave-based inspection of structures.
- **Multi-Channel Support:** At least 8 transducer channels with the ability to configure each transducer as a transmitter, receiver, or transceiver.
- **Excitation Signal:** Transmitters should generate a 20Vp-p Hanning windowed 5-cycle sine pulse, with an option to amplify up to 100Vp-p or more using an onboard power amplifier.
- **Receiver Signal Chain:** Must include an instrumentation amplifier and appropriate filters for signal conditioning.

TARGET SPECIFICATIONS

- **Wireless Data Transmission:** Captured data should be transmitted wirelessly to a laptop for visualization and post-processing.
- **Compact and Portable:** The system should be designed for easy handling and deployment in real-world inspection scenarios.
- **Efficient Power Management:** Integrated power module for stable operation and simplified debugging.

BLOCK DIAGRAM



BLOCK DIAGRAM

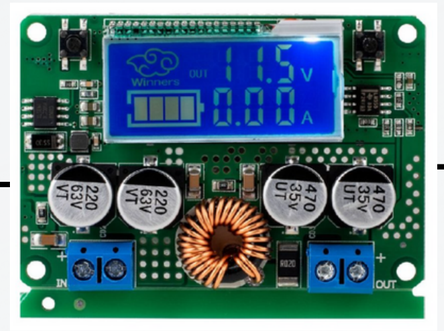
240V AC

SMPS
X2

+48 V DC
7.3 A (max)

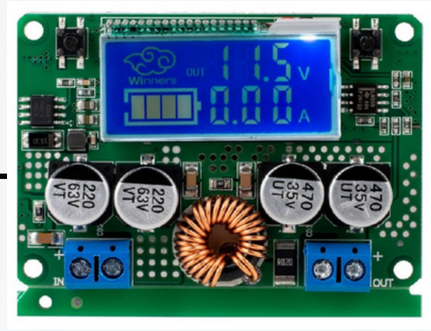
SMPS
X2

-48 V DC
7.3 A (max)

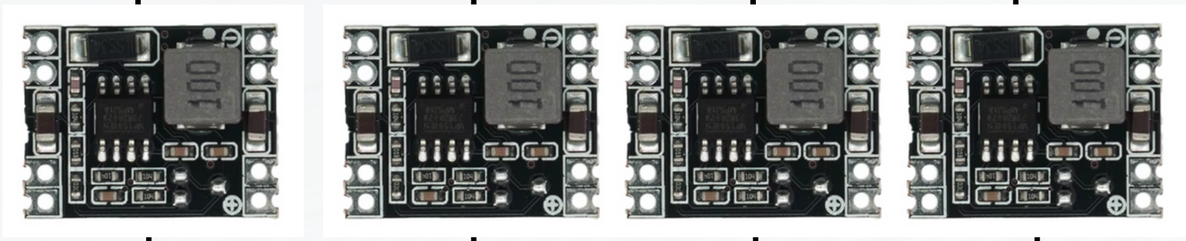


-15V DC

INA 128



+15V DC



3.3 V DC
dspIC33A
ESP32 (WiFi Module)
Digital VDD of ADC
SRAM (Memory)

5V DC
for Analog VDD
of ADC

+10V DC
DAC reference
voltage

-10V DC
DAC reference
voltage

JUSTIFICATION OF CHOICE OF COMPONENTS

- INA in place of OPamp – more CMRR of INA
- ADC/DAC – more resolution and High Sampling rate
- Power Amplifier(OPA454) – sustains high supply input to give high output
- Wifi module(ESP32) – have flash memory, 520kB RAM

BILL OF MATERIALS

Project Title: dsPIC33A Microcontroller based ultrasonic guided wave Structural Health Monitoring System

Group ID: TUE-08 / EDL - 09

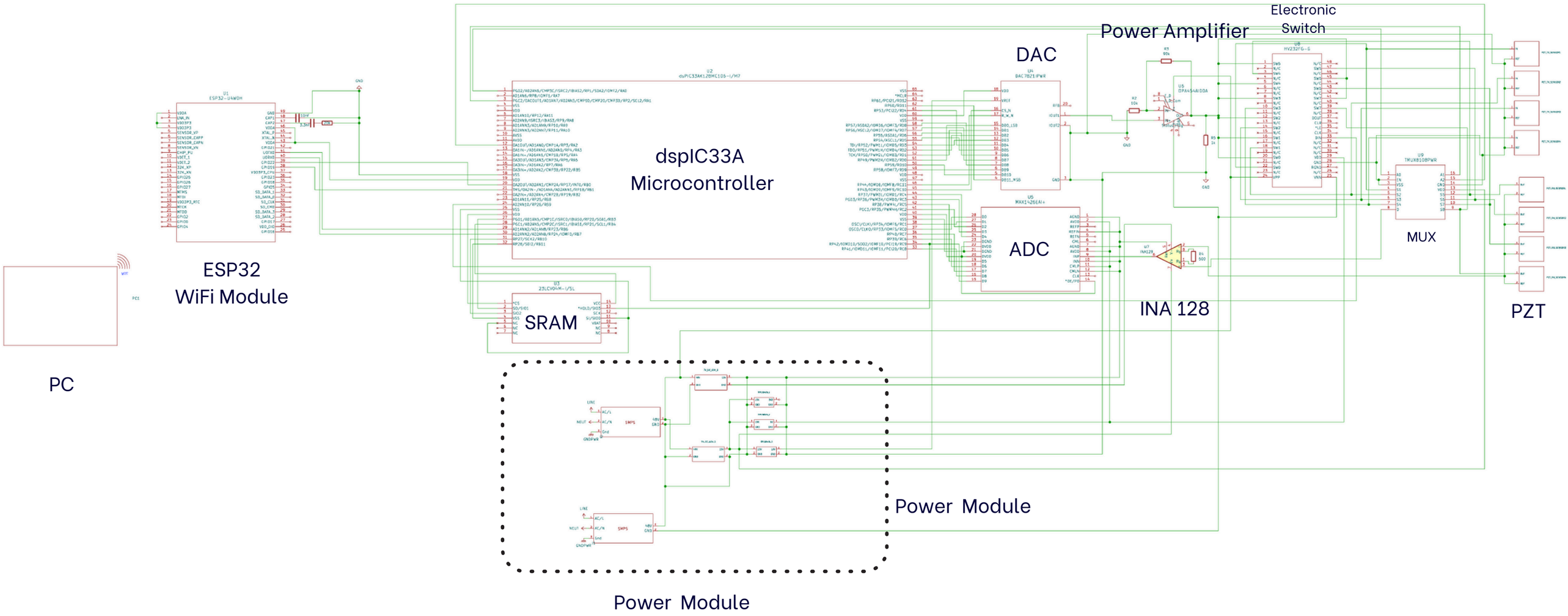
Name of the Group Members: Angad Singh, Amol Pagare, Subhanshu Choudhary, Anuj Yadav, Anuj Gautam

Contact details of the Group Member responsible for BOM: 22b3971@iitb.ac.in, 9834448080

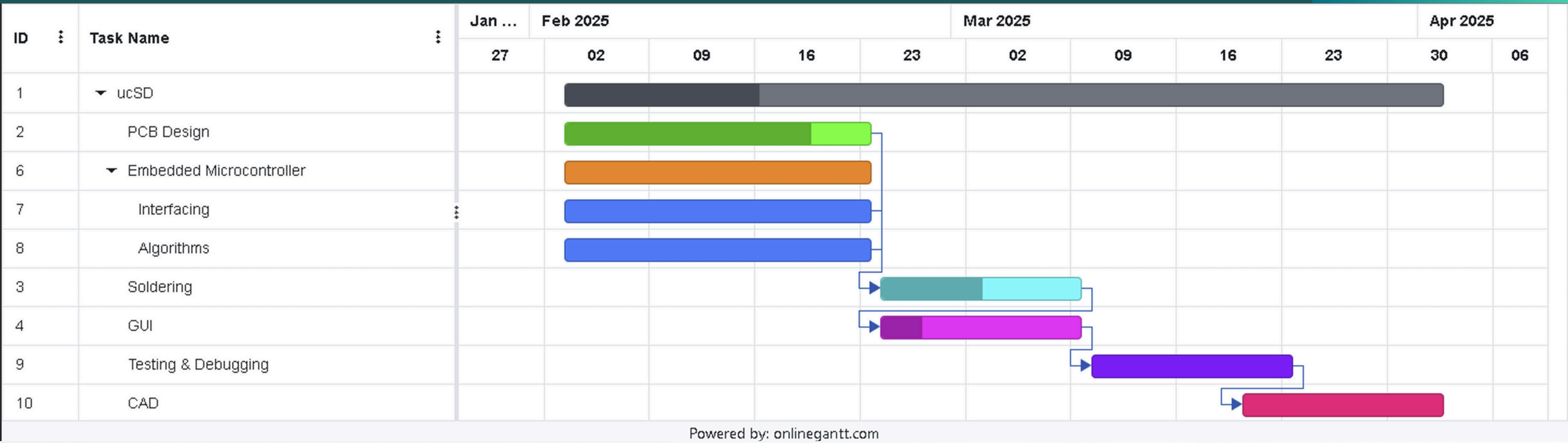
BOM

Sr.No	Usage (Name of the "Circuit block/Functional block" in which components is used)	Part description (OpAMP,ADC,DAC etc)	Manufacturing Part Number	Package type/Footprint	Required Qty + Spare	Cost per each item	Total Cost
1	Wifi Module	ESP32 wifi module	ESP32 U4WDH	QFN 5*5 Package	1+1	₹ 240.00	₹ 480.00
2	Power Operational Amplifier	OpAMP	OPA454AIDDA	8-Pin SO Package	1+1	₹ 551.00	₹ 1,102.00
3	Microcontroller	Microcontroller	dsPIC33AK128MC106-E/PT	VQFN-64	1+1	₹ 211.84	₹ 423.68
4	Digital to Analog Converter	DAC	DAC7821IPWR	20-Lead TSSOP	1+1	₹ 653.02	₹ 1,306.04
5	Analog to Digital Converter	ADC	MAX1426EAI+	28-pin SSOP package	1+1	₹ 978.30	₹ 1,956.60
6	Switch Mode Power Supply	SMPS	Mean Well LRS-350-48	Metal Cased	2+1	₹ 2,600.00	₹ 7,800.00
7	Memory	SRAM	23LCV04M-I/ST	TSSOP-14	1+1	₹ 398.00	₹ 796.00
8	Instrumentation Amplifier	INA	INA128	SMD Package	1+1	₹ 279.00	₹ 558.00
9	PZT Sensor (SP-5H)	PZT Sensor	SP-5H	Sensor	8	₹ 5,000.00	₹ 40,000.00
10	Step down regulator Power supply	Buck Converter	Buck converter power supply	PCB Module	2+1	₹ 1,004.00	₹ 3,012.00
11	Mux Switch IC	Multiplexer	TMUX8108PWR	TSSOP-16	1+1	₹ 737.26	₹ 1,474.52
12	Electronic Switch	MOSFET based switch	HV232FG-G	48-LQFP	1+1	₹ 1,922.10	₹ 3,844.20
13	Step-down Power Supply Module	Buck Converter	MP1584EN	PCB Module	3+3	₹ 49.00	₹ 294.00
						TOTAL	₹ 63,047.04

CIRCUIT DIAGRAMS



GANTT CHART FOR WORK DELEGATION



KEY RISKS AND MITIGATION STRATEGIES

MEMORY MANAGEMENT

- Risk: The dsPIC33A has limited onboard memory, which may prevent complete data storage.
- Mitigation: Integrate a separate SRAM module to expand memory capacity.

POWER MANAGEMENT

- Risk: The inherent signal from the transducer is too weak for effective transmission.
- Mitigation: Use a power amplifier to boost the output voltage to 100Vp-p.

THERMAL MANAGEMENT

- Risk: High power operation may lead to excessive heat generation, affecting performance.
- Mitigation: Implement a heat sink or an active cooling solution to dissipate heat efficiently.

DELIVERABLES

01. Wireless Embedded Platform

Wireless Embedded Platform for ultrasonic guided wave-based inspection with 8 transducer channels.

02. Damage Index Map Implementation

To create a DI map on board the dspIC33A which will convey the exact deviations form the baseline model.

03. Compact Device

We need to create a compact device to aid convenience.