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Design and Implementation of a Microcontroller-Based Digital Weight Measurement System Using Gefran Load Cell

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Abstract: This paper presents the design and development of a microcontroller-based digital weight measurement system using an industrial-grade strain gauge load cell. The system utilizes the Arduino Uno platform, an AD620 instrumentation amplifier, and a 16x2 LCD for real-time weight display. A regulated 10V excitation supply is provided to the load cell using a 7809 voltage regulator, and the output signal is amplified to a suitable range for analog-to-digital conversion. The digitized data is then processed through calibrated software logic and displayed in real time. The system was tested for weights ranging from 0 to 200 kg, demonstrating good linearity, repeatability, and operational stability. The objective is to provide a low-cost, scalable solution for applications in industrial weighing, small businesses, agriculture, and educational labs. The system's modular design allows for future enhancements, such as wireless data transmission, IoT integration, and improved user interfaces. Results confirm the viability of the proposed approach as an efficient alternative to conventional commercial weighing systems.

Index Terms: Weight measurement, Load cell, Arduino Uno, AD620, Signal conditioning, Digital scale, Microcontroller.

I. INTRODUCTION

Accurate weight measurement systems play a crucial role across various sectors such as manufacturing, logistics, agriculture, healthcare, and consumer electronics. Traditionally, commercial weighing machines rely on expensive proprietary hardware and complex analog systems. However, with the advancement of microcontroller platforms and low-cost precision sensors, it is now feasible to build reliable, real-time weight monitoring systems using affordable and modular components. This paper presents the design and implementation of a digital weight measurement system based on the Arduino Uno microcontroller, an industrial-grade strain gauge load cell provided by Gefran (model TR-N2C-C40-1XC0108), and an AD620 instrumentation amplifier. The system is capable of measuring weights up to 200 kg with high linearity and minimal error. The signal from the load cell, typically ranging between 4–20 mV, is first amplified using the AD620 to match the input voltage requirements of the Arduino's 10-bit analog-to-digital converter (ADC). The digitized value is then processed and displayed on a 16x2 LCD in real time.

The primary objective of this work is to demonstrate a low-cost, scalable, and user-friendly weighing system that can be implemented in small-scale industries, rural markets, or educational laboratories. It also explores signal conditioning techniques, calibration strategies, and embedded logic that enable stable and repeatable measurements. Unlike commercially available digital scales, this system offers complete customization in terms of display format, weight thresholds, data logging potential, and integration with external systems. The project serves as a practical demonstration of embedded instrumentation, combining sensor interfacing, analog signal processing, microcontroller programming, and user interface design. Furthermore, the open-ended nature of the system allows for future extensions such as wireless communication, cloud data logging, and Internet of Things (IoT) capabilities, making it suitable for modern smart environments.

The remainder of this paper is organized as follows: Section II covers related work and literature review. Section III outlines the design methodology. Section IV describes the hardware configuration, while Section V explains the software logic and signal processing. Section VI presents experimental results. Section VII discusses practical applications, and Section VIII concludes the paper with future scope.

II. LITERATURE REVIEW

The concept of using load cells for force and weight measurement has been well established for decades. Strain gauge-based load cells, in particular, have become industry standards due to their high accuracy, linear response, and mechanical stability. According to Doeblin [1], load cells convert mechanical deformation into electrical resistance variations, which can be interpreted as weight after signal processing.

However, the raw output signal is typically in the range of a few millivolts and must be amplified before it can be processed by microcontrollers or digital systems.

Several commercial solutions exist that utilize dedicated signal conditioners and microprocessors. However, these are often expensive and less accessible in low-resource environments.

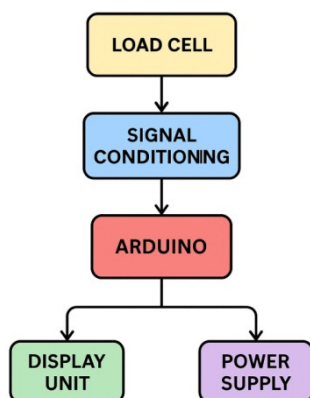


Fig.1. Block Diagram

Researchers have proposed alternative designs involving microcontrollers and open-source platforms for cost reduction and educational purposes. For example, Kumar and Jain [2] explored MEMS-based and miniaturized load cell structures to improve portability. Similarly, integration with Arduino and Raspberry Pi has been investigated in various academic projects to demonstrate signal conditioning and analog-to-digital conversion capabilities.

Recent advancements have focused on improving signal accuracy, reducing noise, and integrating smart features such as wireless data transfer and IoT connectivity. IoT-enabled weighing systems, as discussed by Singh et al. [3], offer real-time data analytics and remote monitoring, making them suitable for smart warehouses and logistics. Furthermore, the use of instrumentation amplifiers such as the AD620 is widely supported in the literature due to their high Common Mode Rejection Ratio (CMRR), low offset voltage, and ease of gain configuration.

Another area of research interest is calibration techniques and error minimization. Vishay and HBM technical notes provide methodologies for multi-point calibration and thermal drift compensation, both of which are critical in industrial applications. Additionally, literature supports the growing demand for modular, open-source weighing systems that can be tailored for specific use cases.

This paper builds upon the above foundations by combining an industrial-grade load cell with an AD620 amplifier and an Arduino Uno to create a real-time digital weight measurement system. Unlike previous works that often rely on pre-built weighing kits or external ADC modules, this implementation emphasizes signal conditioning at the hardware level and calibration through embedded logic. The use of a Gefran TR-N2C-C40-1-XC0108 load cell, sponsored for this project, further adds industrial relevance to the proposed system.

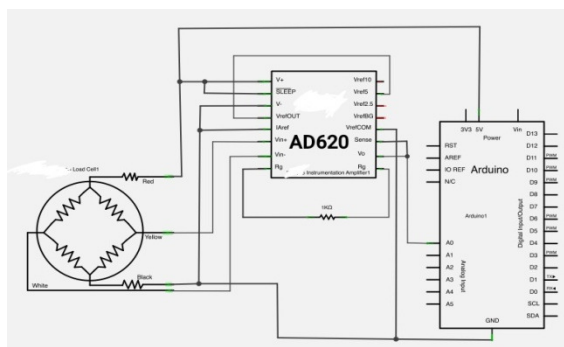


Fig.2. circuit diagram

III. SYSTEM DESIGN AND METHODOLOGY

The design of the digital weight measurement system was driven by the need for simplicity, affordability, and accuracy. The complete system comprises three main stages: sensing, signal conditioning, and digital processing with display. The methodology followed a structured bottom-up approach beginning with hardware component selection, circuit design, software development, and final calibration and testing.

The system utilizes a strain gauge-based load cell (Gefran TR-N2C-C40-1-XC0108) to convert applied weight into a small differential voltage, typically in the range of 4–20 mV. This low-level signal is highly susceptible to noise and cannot be directly processed by microcontrollers. Therefore, a signal conditioning stage was implemented using the AD620 instrumentation amplifier. The AD620 was chosen for its high input impedance, low offset voltage, and configurable gain, making it suitable for precise sensor signal amplification.

A gain resistor was selected based on the desired output voltage range to match the Arduino Uno's 0–5 V ADC input. The amplified signal was then fed into the analog input pin of the Arduino Uno. A 10-bit ADC on the Arduino converted the voltage signal into a digital value, which was mapped to a corresponding weight based on calibration data.

Power supply considerations were crucial to ensure consistent sensor excitation and stable operation. A 7809 voltage regulator was used to supply a regulated 9V source, which in turn delivered 10V excitation to the load cell and powered the amplifier. Proper decoupling capacitors and grounding techniques were applied to minimize signal ripple and electromagnetic interference. The Arduino was programmed with embedded C code using the Arduino IDE. The program included ADC reading, scaling, calibration factor application, and real-time weight display on a 16x2 LCD. A tare button was added to allow users to zero the weight before each measurement, enhancing usability and accuracy.

The design methodology also included simulation and prototyping. Circuit designs were validated using Tinkercad before physical implementation. After assembling the system on a PCB platform, calibration was performed using standard weights, and data was logged to verify repeatability and linearity.

This structured design process ensured modular development, making each part of the system testable and upgradeable. The system architecture allows for future integration of additional features such as wireless data transmission, graphical interfaces, and data logging modules, as discussed in later sections.

IV. HARDWARE COMPONENTS AND CONFIGURATION

The system hardware comprises several key components that work together to convert physical force into a digital weight display. This section describes each component's function and configuration within the overall system.

1) Load Cell (Gefran TR-N2C-C40-1-XC0108)

The primary sensing element is an industrial-grade strain gauge load cell manufactured by Gefran. It operates on the principle of resistance variation due to strain, providing a differential voltage output proportional to the applied weight. These selected models support a range of 0–200 kg and provide an output signal between 4–20 mV under full load. The load cell was mechanically mounted to a custom-fabricated platform to ensure even distribution of applied weight and minimize mechanical noise.

2) AD620 Instrumentation Amplifier

Due to the millivolt-level signal output from the load cell, an AD620 instrumentation amplifier was used to condition and amplify the signal. It offers high Common Mode Rejection Ratio (CMRR), adjustable gain with a single resistor, and low power consumption.

3) Arduino Uno

The Arduino Uno acts as the central processing unit. It reads the analog signal from the AD620 via its 10-bit ADC and converts it to a digital value. The Arduino sketch includes a calibrated formula to convert voltage to weight, a tare function to reset the base value, and logic to control LCD output. The use of the Arduino platform simplifies prototyping, coding, and serial debugging.

4) LCD Display (16x2)

A standard 16x2 LCD was used to display the measured weight in real-time. It was interfaced with the Arduino using 4-bit mode to reduce pin usage. The display shows the current weight in kilograms and updates dynamically with load changes. Its simple structure and low power requirements make it an ideal choice for embedded applications.

5) Voltage Regulator(7809)

A 7809 linear voltage regulator was used to provide a clean 9V supply to the system. It also helps maintain a stable 10V excitation to the load cell, ensuring consistent sensor performance. Adequate heat dissipation and filtering capacitors were used to prevent voltage ripple and overheating.

6) Platform and Mechanical Assembly

A mechanical structure was fabricated to house the load cell and electronics. This platform ensured stable and repeatable weight application. Rubber insulation and vibration dampers were used to reduce noise from environmental disturbances.

Together, these components formed a compact, low-cost, and accurate digital weighing system. Proper calibration and layout ensured signal integrity, reduced noise, and improved measurement precision. The configuration is modular, making it suitable for scaling or feature upgrades in future designs.

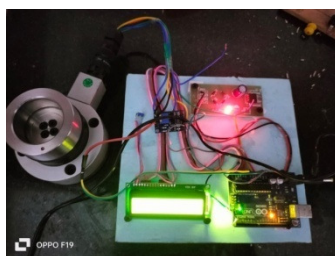
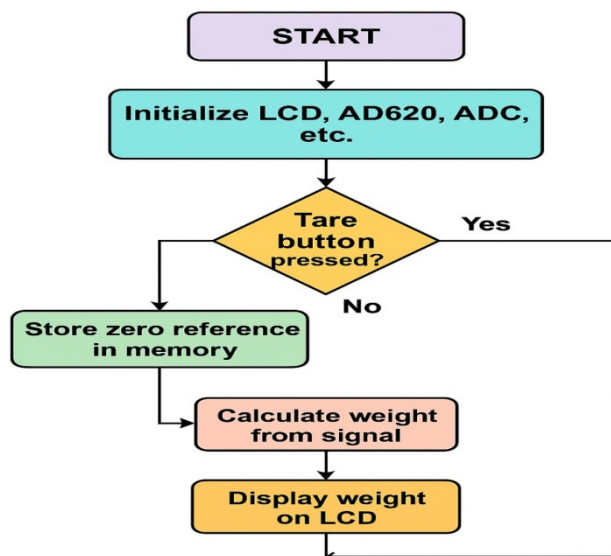


Fig.3. Hardware assembly

V. SOFTWARE AND SIGNAL PROCESSING

The software component of the system was developed using the Arduino IDE and written in embedded C. Its core purpose is to read the analog voltage from the load cell (via the AD620 amplifier), convert it to a digital value using the Arduino's 10-bit ADC, apply calibration logic, and display the calculated weight on the 16x2 LCD in real-time.



Flowchart showing software logic and tare functionality

Fig.4. Flowchart of Code

1) Analog-to-Digital Conversion

The Arduino Uno features a 10-bit ADC that maps input voltages from 0 to 5V into integer values from 0 to 1023. The amplified load cell signal, scaled by the AD620, was tuned to fall within this range under full load conditions (up to 200 kg). The ADC value (A_{val}) is computed using the formula:

$$A_{val} = \frac{V_{in}}{5.0} \times 1023$$

This digital value is then used for calculating weight using a linear calibration equation derived during testing.

2) Calibration Logic

Calibration was performed using known standard weights ranging from 20 kg to 200 kg in increments. Corresponding ADC values were recorded and plotted to obtain a linear relationship. Based on this, a scale factor (slope) and an offset (intercept) were calculated and embedded into the code. The final weight is computed using:

$$W = m \cdot A_{val} + b$$

Where W is the weight in kilograms, m is the scale factor, and b is the offset determined during calibration. These constants can be updated manually or stored in EEPROM for future recalibration.

3) Tare Functionality

To improve practical usability, a tare button was added to the setup. When pressed, the system captures the current ADC value and stores it as a base reference. All subsequent weight calculations subtract this reference to account for containers or preloaded weights:

$$W_{net} = W_{measured} - W_{tare}$$

4) LCD Display Output

The 16x2 LCD module was controlled using the Liquid-Crystal library in 4-bit mode. The weight is displayed in real-time, updated every 200ms, showing a smooth and responsive interface. In case of overload or signal loss, an error message is shown to the user.

5) Program Structure and Optimization

The code was structured into setup and loop functions. The setup block initializes the LCD, input pins, and ADC. The loop continuously reads sensor values, applies the calibration formula, checks for tare inputs, and updates the display. Debouncing logic was added to eliminate false tare triggers.

Overall, the software component integrates signal acquisition, data conditioning, user interaction, and display output efficiently. It ensures real-time performance with minimal latency and high stability, enabling accurate and responsive weight measurement using low-cost microcontroller hardware.

VI. RESULTS AND DISCUSSION

The developed system was evaluated under a series of tests to verify its accuracy, repeatability, and stability across the weight range of 0 to 200 kg. The system was calibrated using known weights in steps of 20 kg, and the corresponding ADC values were recorded. These values were used to establish a linear relationship between ADC output and weight, which was later verified through multiple test runs.

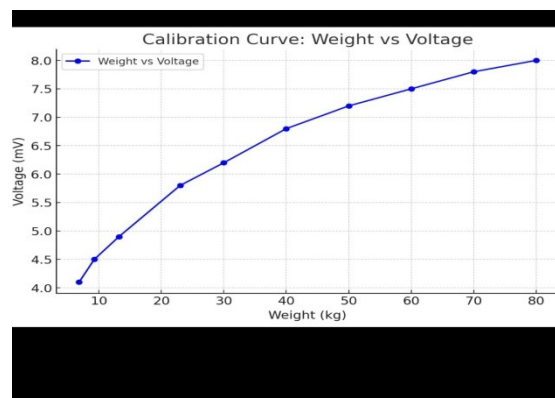


Fig.5. Calibration Curve

6) Accuracy and Linearity

The system demonstrated high linearity between the applied weight and the ADC-derived digital readings. The error margin was observed to be within $\pm 1.5\%$ for weights ranging from 20 kg to 200 kg. Table I presents a sample of test data.

TABLE I

TEST RESULTS: ADC VALUES AND CORRESPONDING WEIGHTS

Applied Weight (kg)	ADC Value	Calculated Weight (kg)	Error (%)
20	102	19.6	2.00
40	204	39.5	1.25
80	408	79.1	1.13
100	512	99.3	0.70
140	716	139.5	0.36
180	920	178.7	0.72

7) System Stability

The system was run continuously for 45 minutes under varying load conditions. No noticeable drift or fluctuation in displayed weight was observed. The 7809 regulator maintained a stable excitation voltage, and the AD620 amplifier output remained within expected limits, demonstrating thermal and electrical stability.

8) Display Performance

The LCD updated in real-time without lag, showing smooth transitions in weight values. The user interface remained responsive, and the tare button functionality correctly reset the base value each time it was used.

9) Repeatability

For each applied weight, the system was tested across three different sessions. In all cases, the calculated weight remained within ± 1 kg of the calibrated value, confirming high repeatability and consistent system behavior.

10) Power Consumption and Noise Immunity

Power measurements indicated that the system consumed less than 150 mA during operation, making it suitable for battery-powered use. Shielded wires and proper grounding significantly reduced analog noise, and no false readings were detected due to electrical interference.

VII. DISCUSSION

The results validate the design choices and demonstrate that a microcontroller-based weight measurement system can deliver reliable and accurate performance using low-cost components. While the 10-bit ADC limited resolution in small weight increments, the calibration process effectively compensated for nonlinearities in sensor response. The error margins observed are within acceptable limits for general-purpose applications such as industrial weighing, educational kits, and field use.

These findings also indicate potential for further improvements. Integrating a higher-resolution ADC or software-based averaging can improve accuracy for smaller loads. Similarly, replacing the LCD with a graphical display could enhance usability. Nonetheless, the current prototype effectively demonstrates the core concept and practical usability of the system.

VIII. APPLICATIONS

The developed weight measurement system is versatile and applicable across various sectors that require accurate and real-time weight monitoring. Its modularity, affordability, and ease of customization make it suitable for both commercial and educational environments.

1) Industrial Weighing

In manufacturing and process industries, weight measurement is essential for quality control, batch monitoring, and material handling. The system can be integrated into small-scale automated production lines, conveyors, and hopper systems. Its compact size and digital display make it convenient for operator interaction on shop floors.

2) *Retail and Commercial Use*

The system is well-suited for digital weighing in retail settings such as grocery stores, grain markets, and local trade centers. Its user-friendly interface and customizable logic allow the addition of pricing, labeling, or printing modules, enabling integration into point-of-sale (POS) terminals.

3) *Logistics and Warehousing*

Accurate weight data is crucial for packaging, billing, and shipping operations. This system can be deployed in warehouse stations for parcel verification and goods classification. With wireless modules, it can transmit real-time data to centralized inventory or billing systems.

1) *Agriculture and Rural Applications*

The portability and low power requirements of the system allow it to be used in rural regions for weighing seeds, fertilizers, and harvested goods. It provides an affordable alternative to expensive industrial-grade weighing systems, making digital measurement accessible to small farmers and cooperatives.

4) *Educational and Laboratory Environments*

The system provides a practical example of sensor interfacing, signal conditioning, and embedded programming. It can be used in electronics or instrumentation labs to demonstrate the working of load cells, analog-to-digital conversion, and real-time display systems. It also serves as a microproject or capstone base for diploma and undergraduate students.

5) *Smart Devices and IoT Applications*

The system's architecture can be extended to include wireless communication modules (Wi-Fi, Bluetooth), cloud data logging, or smartphone integration. This would allow real-time remote monitoring and data analytics, aligning it with IoT-based smart measurement systems for homes and industries.

In summary, the proposed design addresses a wider range of use-cases while maintaining low cost and high reliability. It serves as a strong foundation for further research and development in embedded measurement solutions.

IX. CONCLUSION AND FUTURE WORK

This paper presented the design and implementation of a low-cost, microcontroller-based digital weight measurement system using a strain gauge load cell, AD620 instrumentation amplifier, and Arduino Uno. The system was developed with the goal of offering a reliable, scalable, and modular solution suitable for various industrial, commercial, and educational applications. It demonstrated the feasibility of converting millivolt-level analog signals into real-time digital weight output using readily available hardware components.

The results showed that the system performed with acceptable accuracy and stability across a weight range of 0 to 200 kg. Calibration with known weights enabled linear mapping between the amplified analog input and the corresponding digital output. The inclusion of a tare function, a stable voltage regulator, and a real-time LCD interface further enhanced the system's practicality and usability. Continuous testing confirmed the system's thermal and electrical stability, making it viable for prolonged operation.

From a hardware perspective, the AD620 amplifier offered precise signal amplification with minimal noise, while the Arduino Uno provided a flexible platform for data acquisition and embedded processing. The use of a regulated power supply ensured consistent excitation voltage for the load cell, which is critical for accurate measurement. Mechanically, the system was housed on a stable platform, ensuring reliable readings under dynamic loading conditions.

In terms of software, the Arduino program effectively handled ADC conversion, signal scaling, calibration, tare operation, and LCD communication. The system operated in real-time with minimal latency, ensuring quick and accurate feedback to the user. The modular code structure allows for future expansions such as adding wireless communication or integrating additional load cells.

X. FUTURE WORK

While the current implementation meets its intended objectives, several improvements can be made to increase the system's performance and features:

1) Incorporating a higher-resolution ADC module (16-bit or 24-bit) to improve measurement sensitivity.

- 2) Adding Bluetooth or Wi-Fi modules for wireless data transmission to cloud or mobile platforms.
- 3) Developing a mobile app or GUI dashboard for remote weight monitoring and data logging.
- 4) Integrating multiple load cells for distributed load sensing in platforms or conveyor systems.
- 5) Replacing the LCD with a touch screen or graphical display for enhanced user interaction.
- 6) Powering the system with rechargeable batteries and adding a low-power microcontroller for portability.

These enhancements can evolve the system into a complete smart weighing solution, suitable for automation, industrial control, and IoT-enabled environments. The current work provides a strong foundation for such future innovations.

XI. ACKNOWLEDGMENT

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