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

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Abstract: Thispaperpresentsthedesignanddevelopment 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 a7809voltageregulator,andtheoutputsignalisamplifiedto a suitable range for analog-to-digital conversion. The digitized data is then processed through calibrated software logic and displayedinrealtime.Thesystemwastestedforweightsranging from 0 to 200 kg, demonstrating good linearity, repeatability,andoperationalstability.Theobjectiveistoprovidealow- 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 datatransmission,IoTintegration,andimproveduserinterfaces. Results confirm the viability of the proposed approach as an efficientalternativetoconventionalcommercialweighingsystems.

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

I. INTRODUCTION

Accurateweightmeasurementsystemsplayacrucialroleacrossvarioussectorssuchasmanufacturing,logistics,agriculture,healthcare,andconsumerelectronics.Traditionally, commercial weighing machines rely on expensive proprietary hardware and complex analog systems.However,withthead- vancementofmicrocontrollerplatformsandlow-costprecision sensors,itisnowfeasibletobuildreliable,real-timeweightmonitoringsystemsusingaffordableandmodularcomponents.ThispaperpresentsthedesignandimplementationofadigitalweightmeasurementsystembasedontheArduinoUnomicrocontroller,anindustrial-gradestraingaugeload cellprovidedbyGefran(modelTR-N2C-C40-1XC0108),andanAD620instrumentationamplifier.Thesystemiscapableofmeasuringweightsupto200kgwithhighlinearityand minimal error. The signal from the load cell, typically ranging between4–20mV,isfirstamplifiedusingtheAD620to matchtheinputvoltagerequirementsoftheArduino's10-bitanalog-to-digital converter (ADC). The digitized value is then processed and displayed on a 16x2 LCD in real time.

Theprimaryobjectiveofthisworkistodemonstratea low-cost, scalable, and user-friendly weighing system that can beimplementedinsmallscaleindustries,ruralmarkets,oreducationallaboratories.Italsoexploressignalconditioningtechniques,calibration strategies,andembeddedlogicthatenablestableandrepeatablemeasurements.Unlikecommerciallyavailabledigitalscales,thissystemoffers complete customizationintermsofdisplayformat,weightthresholds, data logging potential, and integration with external systems. The projectserves as a practical demonstration of embedded instrumentation,combiningsensorinterfacing,analogsignal processing, microcontrollerprogramming,anduserinterfacedesign.Furthermore,theopenendednatureofthesystemallowsfutureextensionssuchaswirelesscommunication,clouddatalogging,andInternetofThings(IoT)capabilities,makingitsuitableformodernsmartenvironments.

Theremainderofthispaperisorganizedasfollows:Section IIcoversrelatedworkandliteraturereview.SectionIIIoutlines the design methodology. Section IV describes the hardware configuration,whileSectionVexplainsthesoftwarelogicand 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 me-chanicalstability.AccordingtoDoebelin[1],loadcellsconvert mechanical deformation into electrical resistance variations, which can be interpreted as weight after signal processing.

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However, the raw output signal is typically in the range of a fewmillivoltsandmustbeamplifiedbeforeitcanbeprocessed by microcontrollers or digital systems.
Severalcommercialsolutionsexistthatutilizededicatedsignalconditionersandmicroprocessors.However,theseareoftenexpensiveandless accessibleinlow-resourceenvironments.

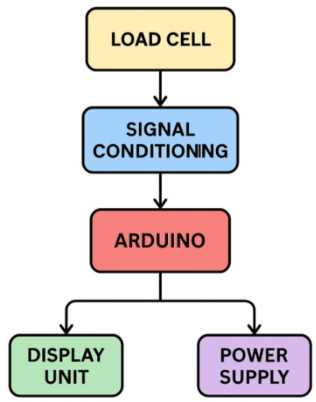

Fig.1.BlockDiagram

Researchers have proposed alternative designs involving mi- crocontrollers and open-source platforms for cost reduction and educational purposes. For example, Kumar and Jain [2] explored MEMS-based and miniaturized load cell structuresto improve portability. Similarly, integration with Arduinoand 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 weighingsystems,asdiscussedbySinghetal.[3],offer real-time data analytics and remote monitoring, making them suitable for smart warehouses and logistics. Furthermore, the useofinstrumentationamplifierssuchastheAD620iswidely 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 de- mand for modular, open-source weighing systems that can be tailored for specific use cases.
Thispaperbuildsupontheabovefoundationsbycombining 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 calibrationthroughembeddedlogic.TheuseofaGefran TR-N2C-C40-1-XC0108 load cell, sponsored for this project, further adds industrial relevance to the proposed system.

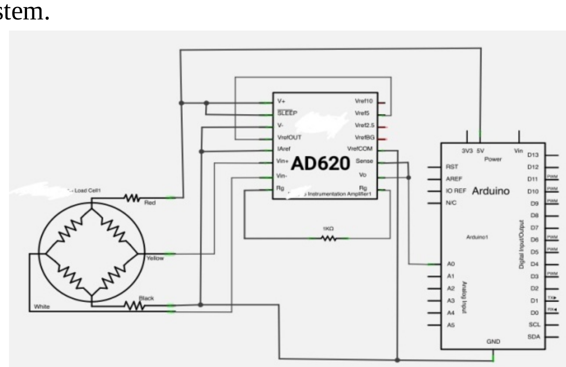

Fig.2.circuitdiagram

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 be- ginning 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 smalldifferentialvoltage,typicallyintherangeof4–20 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. Theamplifiedsignalwasthenfedintotheanaloginputpin of the Arduino Uno. A 10-bit ADC on the Arduino converted thevoltagesignalintoadigitalvalue,whichwasmappedto a corresponding weight based on calibration data.

Power supply considerations were crucial to ensure consis- tent sensor excitation and stable operation. A 7809 voltage regulator was used to supply a regulated 9V source, which in turndelivered10Vexcitationtotheloadcellandpowered the amplifier. Proper decoupling capacitors and grounding techniques were applied to minimize signal ripple and elec- tromagnetic 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 develop- ment,makingeachpartofthesystemtestableandupgradeable. The system architecture allows for future integration of addi- tionalfeaturessuchaswirelessdatatransmission,graphical interfaces,anddataloggingmodules,asdiscussedinlater sections.

IV. HARDWARE COMPONENTS AND CONFIGURATION

The system hardware comprises several key components that work together to convert physical force into a digital weightdisplay.Thissectiondescribeseachcomponent'sfunc- tion and configuration within the overall system.

1) LoadCell(GefranTR-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. Theselectedmodelsupportsarangeof0–200kgandprovides anoutputsignalbetween4–20mVunderfullload.The load cell was mechanically mounted to a custom-fabricated platform to ensure even distribution of applied weight and minimize mechanical noise.

2) AD620InstrumentationAmplifier

Due to the millivolt-level signal output from the load cell, anAD620instrumentationamplifierwasusedtoconditionand amplify the signal. It offers high Common Mode Rejection Ratio (CMRR), adjustable gain with a single resistor, and low power consumption.

3) ArduinoUno

TheArduinoUnoactsasthecentralprocessingunit.Itreads the analog signal from the AD620 via its 10-bit ADC and converts it to a digital value. The Arduino sketch includes a calibratedformulatoconvertvoltagetoweight,atarefunction to reset the base value, and logic to control LCD output. The use of the Arduino platform simplifies prototyping, coding, and serial debugging.

4) LCDDisplay(16x2)

A standard 16x2 LCD was used to display the measured weight in real-time. It was interfaced with the Arduino using 4-bitmodetoreducepinusage.Thedisplayshowsthe current weight in kilograms and updates dynamically withloadchanges.Itssimplestructureandlowpowerrequirements make it an ideal choice for embedded applications.

5) VoltageRegulator(7809)

A 7809 linear voltage regulator was used to provide a clean 9Vsupplytothesystem.Italsohelpsmaintainastable 10V excitation to the load cell, ensuring consistent sensor performance.Adequateheatdissipationandfilteringcapacitors were used to prevent voltage ripple and overheating.

6) PlatformandMechanicalAssembly

Amechanicalstructurewasfabricatedtohousetheloadcell 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 measurementprecision.Theconfigurationismodular,making it suitable for scaling or feature upgrades in future designs.

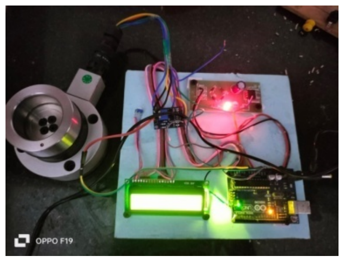

Fig.3.Hardwareassembly

V. SOFTWARE AND SIGNAL PROCESSING

Thesoftwarecomponentofthesystemwasdevelopedusing the Arduino IDE and written in embedded C. Its core purpose istoreadtheanalogvoltagefromtheloadcell(viatheAD620 amplifier),convertittoadigitalvalueusingtheArduino's10- bit ADC, apply calibration logic, and display the calculated weight on the 16x2 LCD in real-time.

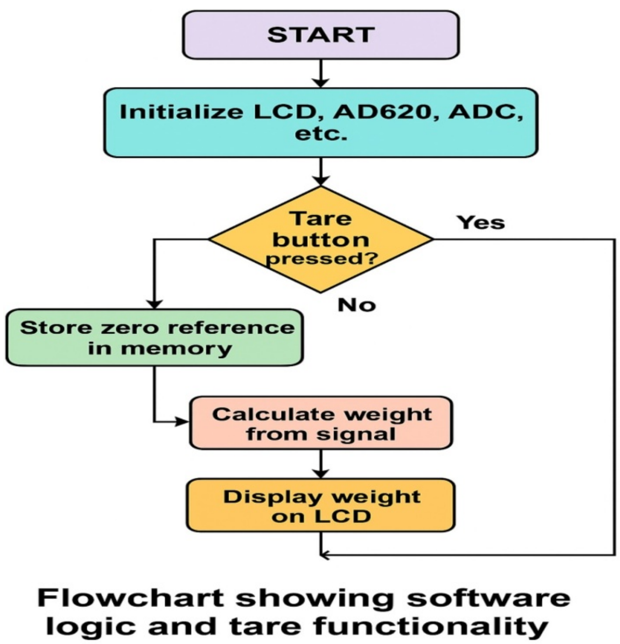

Fig.4.FlowchartofCode

1) Analog-to-DigitalConversion

The Arduino Uno features a 10-bit ADC that maps input voltages from 0 to 5V into integer values from 0 to 1023. The amplifiedloadcellsignal,scaledbytheAD620,wastuned to fall within this range under full load conditions (up to 200 kg).TheADCvalue(A_{val})*iscomputedusingtheformula*:

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

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

2) CalibrationLogic

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:

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

WhereWistheweightinkilograms,misthescale factor,andbistheoffsetdetermineddduringcalibration.These constants can be updated manually or stored in EEPROM for future recalibration.

3) TareFunctionality

To improve practical usability, a tare button was added to thesetup.Whenpressed,thesystemcapturesthecurrentADC value and stores it as a base reference. All subsequent weight calculations subtract this reference to account for containersor preloaded weights:

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

4) LCDDisplayOutput

The 16x2 LCD module was controlled using the Liquid- Crystal library in 4-bit mode. The weight is displayed in real-time,updatedevery200ms,showingasmoothandresponsive interface. In case of overload or signal loss, an error message is shown to the user.

5) ProgramStructureandOptimization

The code was structured into setup and loop functions. The setup block initializes the LCD, input pins, and ADC. Theloop 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 acquisi- tion, data conditioning, user interaction, and display output efficiently. It ensures real-time performance with minimal latency and high stability, enabling accurate and responsive weightmeasurementusinglow-costmicrocontrollerhardware.

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.

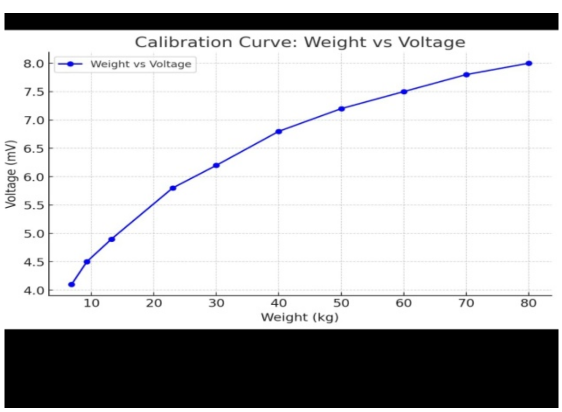

Fig.5.CalibarationCurve

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6) AccuracyandLinearity

Thesystemdemonstratedhighlinearitybetweentheapplied weightandtheADC-deriveddigitalreadings.Theerrormargin was observed to be within ±1.5% for weights ranging from 20 kg to 200 kg. Table I presents a sample of test data.

TABLEI
TESTRESULTS:ADCVALUESANDCORRESPONDINGWEIGHTS

AppliedWeight(kg)	ADCValue	CalculatedWeight(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) SystemStability

The system was run continuously for 45 minutes under varying load conditions. No noticeable drift or fluctuation in displayedweightwasobserved.The7809regulatormaintained a stable excitation voltage, and the AD620 amplifier output remained within expected limits, demonstrating thermal and electrical stability.

8) DisplayPerformance

TheLCDupdatedinreal-timewithoutlag,showingsmooth transitions in weight values. The user interface remained responsive, and the tare button functionality correctly resetthe base value each time it was used.

9) Repeatability

Foreachappliedweight,thesystemwastestedacross three different sessions. In all cases, the calculated weight remainedwithin±1kgofthecalibratedvalue,confirminghigh repeatability and consistent system behavior.

10) PowerConsumptionandNoiseImmunity

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

Theresultsvalidatethedesignchoicesanddemonstratethat a microcontroller-based weight measurement system can de-liverreliableandaccurateperformanceusinglowcostcomponents.Whilethe10bitADClimitedresolutioninsmallweightincrements,thecali brationprocesseffectivelycompensatedfor 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 improve- ments. 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 us- ability. Nonetheless, the current prototype effectively demon- stratesthecoreconceptandpracticalusabilityofthesystem.

VIII. APPLICATIONS

The developed weight measurement system is versatile and applicableacrossvarioussectorsthatrequireaccurateandreal-timeweightmonitoring.Itsmodularity,affordability,andease of customization make it suitable for both commercial and educational environments.

1) IndustrialWeighing

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

2) RetailandCommercialUse

The system is well-suited for digital weighing in retail settingssuchasgrocerystores,grainmarkets,andlocal tradecenters.Itsuser-friendlyinterfaceandcustomizablelogic allow the addition of pricing, labeling, or printing modules, enabling integration into point-of-sale (POS) terminals.

3) LogisticsandWarehousing

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

1) AgricultureandRuralApplications

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) EducationalandLaboratoryEnvironments

The system provides a practical example of sensor interfac- ing, 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) SmartDevicesandIoTApplications

The system's architecture can be extended to include wire- less communication modules (Wi-Fi, Bluetooth), cloud data logging,orsmartphoneintegration.Thiswouldallowreal-time remote monitoring and data analytics, aligning it with IoT- based smart measurement systems for homes and industries.

Insummary,theproposeddesignaddressesawiderange 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 FUTUREWORK

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 accept- able 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 digitaloutput.Theinclusionofatarefunction,astablevoltage regulator,andareal-timeLCDinterfacefurtherenhanced the system's practicality and usability. Continuous testing confirmedthesystem'sthermalandelectricalstability,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 andembeddedprocessing.Theuseofaregulatedpowersupply ensured consistent excitation voltage for the load cell, whichiscriticalforaccuratemeasurement.Mechanically,thesystem 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 ob- jectives, several improvements can be made to increase the system's performance and features:

1) Incorporatingahigher-resolutionADCmodule(16-bitor 24-bit) to improve measurement sensitivity.

2) AddingBluetoothorWi-Fimodulesforwirelessdata transmission to cloud or mobile platforms.
3) DevelopingamobileapporGUIdashboardforremote weight monitoring and data logging.
4) Integratingmultipleloadcellsfordistributedloadsensing in platforms or conveyor systems.
5) ReplacingtheLCDwithatouchscreenorgraphicaldisplay for enhanced user interaction.
6) Poweringthesystemwithrechargeablebatteriesand 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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