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Measurement of Force Using Load Cell

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Abstract: This Paper covers the basics of force measuring systems and load cells based on strain gauges. The result from a load cell is generated by the elasticity of a high tensile strength component. Load cells can be easily designed to withstand a wide range of forces while maintaining a high level of reliability. We have created a device that utilizes a load cell with a strain gauge to measure force accurately
Keywords: Design, strain gauge, force, Reliability, Tensile strength Load cell

I. INTRODUCTION

A. Force
Force is a measure of the interaction between objects. Weight is the force of gravity acting on an object, load typically refers to the force acting on a surface or an object, and Mass, on the other hand, is a measure of the amount of substance in an object. A vector with direction and magnitude is called a force. It manifests in several ways, such as gravitational pull, electromagnetic force, and short-range atomic force. The Newton (N) is the SI unit of force.

B. Load Cells
A transducer that transforms force into an electrical output that can be measured is called a load cell. Although there are many different types of load cells, the most widely used kind are strain gage based load cells.
In most laboratories, strain gage load cells are still the standard for precision weighing, with the exception of a few. Hydraulic load cells are taken into consideration in remote places since they do not require a power source, while pneumatic load cells are occasionally employed where inherent safety and hygiene are desired. Strain gage load cells are appropriate for nearly all industrial applications and provide accuracy ranging from 0.03% to 0.25% full scale.

C. Types of Load Cells
1) Hydraulic load cells
2) Pneumatic load cells
3) Strain-gage load cells

In our project, we used multiple strain gauges in different configurations according to the requirement. We connected the output to an amplifier and then forward the signal to the microcontroller for data logging. The data can be then referred to for analysis and validation.

D. Strain Gauge Load Cells
Strain Gauge Load Cells for Strain these load cells are the most widely used and a perfect illustration of elastic devices. Every unit is built on an elastic component that combines many resistance strain gauges. The size of the strain field produced by the force depends on the element's geometry and elastic modulus. The force measurement is dependent on the integration of these discrete strain readings, as each strain gauge reacts to the local strain at its location. Strain gauge load cells have rated capacities ranging from 5 N to over 50 MN.
Strain-gage load cells convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gages are used to obtain maximum sensitivity and temperature compensation.
Two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load. Other load cells are fading into obscurity, as strain gage load cells continue to increase their accuracy and lower their unit costs.

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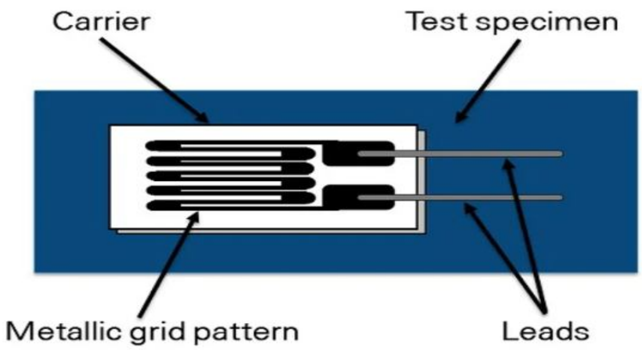
E. What is a Strain Gauge and How Do They Work?

Engineers commonly utilize strain gauges to determine the impact of external forces on an object. Direct strain measurement enables the indirect quantification of stress, torque, pressure, deflection, and various other quantities. Strain is a unit less quantity that represents the proportion of an object's final length to its original length. It is described as the difference in size of a material compared to its original, unaltered size. Consequently, a material undergoes positive strain when stretched, and negative strain when compressed. To calculate stress, divide the applied force by the original cross-sectional area of the object



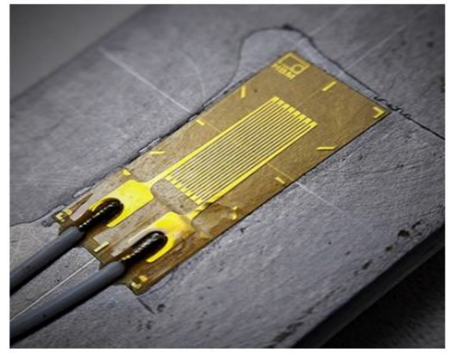


Fig. 1 Composition of a strain gauge   Fig. 1 Example of a strain gauge

Figure 1. Strain is the ratio of the change in length of a material to the original, unaffected length.

As seen in the above illustration, each strain gauge is made up of a metal foil that is insulated by a flexible substrate. The gauge receives a current from the two leads, and the gauge measures the change in resistance when the surface of the object being measured stretches or shrinks. How this change in resistance relates to the change in length on the surface of the object being tested. The change in electrical resistance across a tiny piece of conductive foil is how strain gauges measure strain. The strain gauge's sensitivity is known as the gauge factor. It transforms the resistance change into a length change.

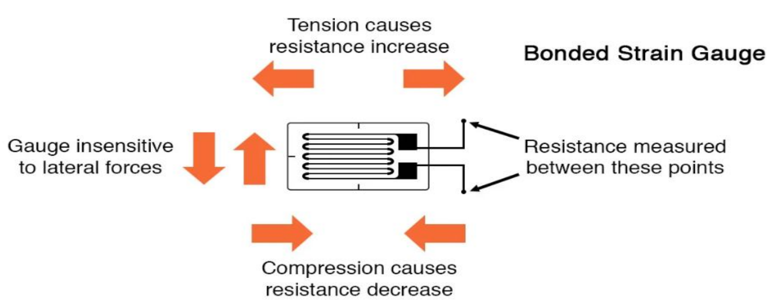


Fig. 3 Bonded strain gauge

As a strain gauge experiences bending, stretching, or twisting, the change in resistance across the metal foil is measured by a Wheatstone bridge. The change in resistance that is measured is proportional to the strain experienced by the object.

The sensor Gauge Factor GF of a strain gauge is a characteristic transfer coefficient that relates the gauge element sensitivity to strain ε relative to its change in resistance ΔR. More specifically, GF is the ratio of the fractional change in resistance to the strain

$(GF = (\Delta R / R) / (\Delta L / L) = (\Delta R / R) / \varepsilon$

II. LITERATURE SURVEY

Abhishek Mehendale, Siddhesh Mehta. Has explained about Physics and mathematics can only take Engineering designs so far in real life. Experimentation of the design is a key factor when we talk about design reliability, quality and performance. To ensure that the testing and validation of our engineer’s design does justice to the hard work and effort that is put into it, our team has come up with a reliable method to test the physical resilience to forces that a part can expect to experience in it’s life. We propose to use strain gauges in specific formations on the designed prototype to understand it’s behavior under stress.

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In this paper we are proposed measure the forces under staring gauge based load cells and basic information about force,load cell,strain gauges.

III. EXPERIMENTAL SETUP

A. Strain Gauge

A Strain gauge is a devices that measures change in electrical resistance when a forces is applied. Atypical strain gauge is made up of very fine wire set up in grid pattern in a way that produces a linear change in resistance when strain is applied along on axis this change is converted into corresponding change in voltage. This voltage is the fed to the HX711 voltage amplifier.

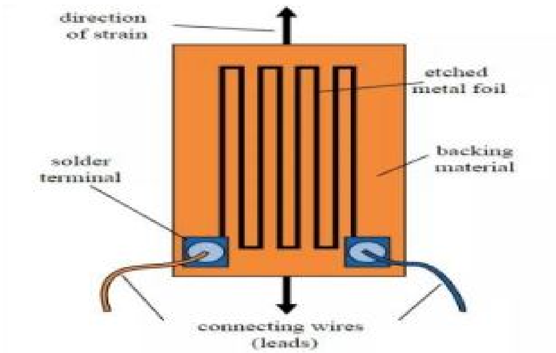


Fig. 4 Strain gauge

B. Load Cell

Single-point load cell is one of the major categories or types of load cell commonly found within the weighing industry. Other types include, for example; compression, tension and beam. The defining characteristic of a single-point is its ability to accommodate off-center loading. Typically, the load needs to be aligned with the cell to maintain accurate readings. If the weight moves off-axis, it introduces error. Single-points, due to their geometric design, allow for some flexibility, and can thus maintain accurate readings even if the weight is unevenly distributed.

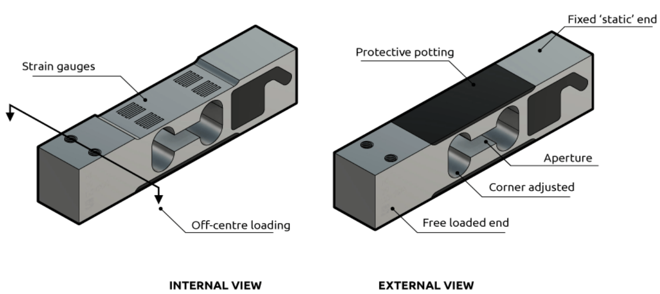
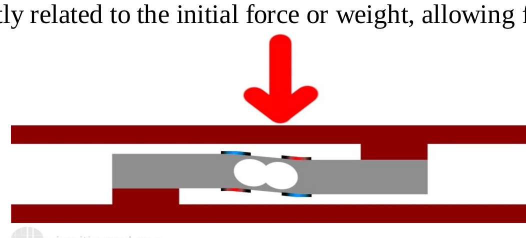


Fig. 5 single point load cell

Single-points, similar to all contemporary load cells, are transducers that essentially change force or weight into an electrical signal. This is achieved through the use of strain gauges that are connected to the body of the load cell. When the load cell is in use, it experiences slight deformation in its shape. The strain gauges detect this alteration, deforming along with the body and causing a voltage shift. This voltage signal is directly related to the initial force or weight, allowing for its calculation after applying the load



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C. HX711 Amplifier

The HX711 load cell amplifier module enables retrieving data from a load cell and forwarding it to Arduino for weight value computation. This module comes with an integrated HX711 chip which has a high precision analog to digital converter of 24 bits. It relies on a two-wire interface to communicate with microcontrollers. It is a top amplifier for constructing a cost-effective weighing scale while also enhancing its reliability and performance. It is simple to connect a load cell to an HX711 amplifier using just 4 wires, without needing an external power source, in order to calculate weight. It functions with a voltage of 2.7v to 5v DC. This allows it to work with various microcontrollers that are currently on the market.

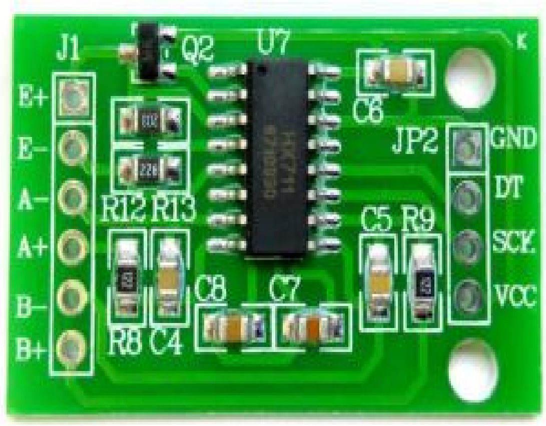

Fig. 6 HX711 Amplifier Module

D. Arduino UNO

The Arduino UNO is a standard board of Arduino. Here UNO means 'one' in Italian. It was named as UNO to label the first release of Arduino Software. It was also the first USB board released by Arduino. It is considered as the powerful board used in various projects. Arduino.cc developed the Arduino UNO board

Arduino UNO is based on an ATmega328P microcontroller. It is easy to use compared to other boards, such as the Arduino Mega board, etc. The board consists of digital and analog Input/output pins (I/O), shields, and other circuits.

The Arduino UNO includes 6 analog pin inputs, 14 digital pins, a USB connector, a power jack, and an ICSP (In-Circuit Serial Programming) header. It is programmed based on IDE, which stands for Integrated Development Environment. It can run on both online and offline platforms.

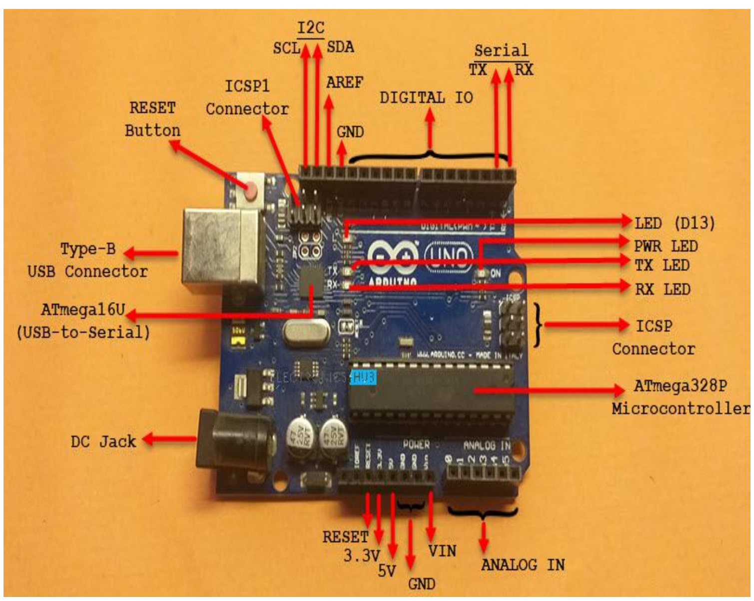

Fig. 7 Interfacing load cell, HX711 load cell amplifier module with Arduino

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E. Measuring Setup

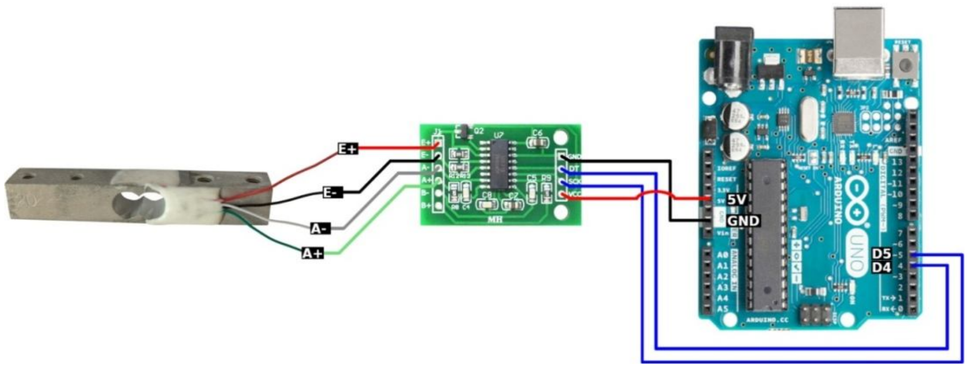

Fig. 8 Measurement of load cell setup

IV. METHODOLOGY

Following are steps to connect all the required components according to the circuit diagram

1) *Connect the red wire to the E+ and the black wire to the E- output of the HX711 Module:* We chose the red and black wire pair to be the power wires of the load cell. E+ and E- are the sensor power outputs of the HX711 module.
2) *Connect the green wire to the A+ and the white one to the A- inputs of the HX711 module:* A+ and A- are the measurement inputs of the HX711 module. Like with the power wires, the polarity is not important. You just need to recalibrate in the software if you switch them up.
3) *Connect the GND of the HX711 module to the Arduino GND and VCC to the Arduino 5V pin:* HX711 also works with 3.3V. If you have some other microcontroller that runs on 3.3V, you can use 3.3V instead of 5V.
4) *Connect the DT and SCK of the HX711 module to any of the Arduino digital IO pins:* In the schematic, I used pins 4 and 5, since those are the default pins for the examples of the "HX711_ADC" library.

If you want to use interrupts to update scale data, then you should connect the DT output to an interrupt enabled pin of the Arduino. For Uno/Nano, those are pins 2 and 3.

A. Calibrating Load cell with HX711 amplifier

After connecting all the required components it's time to upload the code, but here in this project calibrating the device is the most important factor and we need to **know the calibration value** for main code to measure the weight with high accuracy.

B. Applications of Load Cells

1) *Weighing Scales:* Load cells can be used to build digital weighing scales for a variety of applications, such as kitchen scales, luggage scales, or shipping scales.
2) *Industrial Automation:* Load cells can be used to measure forces in industrial automation systems, such as conveyor belts, hoists, or other machinery.
3) *Load Testing:* Load cells can be used to test the strength and capacity of materials, structures, or equipment, such as bridges, cranes, or aircraft components.
4) *Force Feedback Devices:* Load cells can be used in devices that provide haptic feedback, such as joystick handles or game controllers.
5) *Medical Devices:* Load cells can be used in medical devices, such as rehabilitation equipment or prosthetics, to measure forces applied by the user
6) *Quality Control:* Load cells can be used to measure forces in quality control applications, such as testing the strength of welds or adhesives.
7) *Force Measurement:* Load cells can be used to measure forces in a variety of settings, such as testing the grip strength of athletes or measuring the forces applied by a machine tool.
8) *Agricultural Applications:* Load cells can be used in agricultural settings, such as measuring the weight of crops or livestock.
9) *Robotics:* Load cells can be used in robotic systems to measure forces applied by the robot, such as when grasping or manipulating objects.

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C. Advantages

1) Metallic foil Strain gauge Load cell sensor are the most common technology
2) Its high accuracy
3) Long term reliability
4) There is no moving part & hence no wear
5) Strain gauges are very precise
6) It has a high frequency bandwidth

D. Disadvantages

1) It is non linear
2) It is needs regular calibration to use perfectly takes the reading

V. RESULTS AND CONCLUSIONS

1) It can be inferred that applying stress to the load cell leads to a reduction in output voltage.
2) A load cell has the ability to measure various types of load. The strain gauge is placed in the load cell to measure resistance changes when the cell is under load. Sensitive circuitry is necessary to accurately measure the very small changes in resistance per unit of strain.
3) The voltage output does not change in a linear manner as the resistances vary.

This article explores fundamental information about force and load cell. Strain gauges, highly adaptable geotechnical instruments, have a wide range of uses to enhance safety and productivity. In this project, our goal was to create a project that was simple, efficient, and easy to replicate for individuals and students with no experience in electronics. We successfully streamlined the system into a few components without sacrificing its functionality. The system can be used for designing various types, sizes, materials, and mechanisms. It has great potential for various applications on a large scale, for example in aerospace, cable bridges, rail monitoring, and for measuring torque and power in various types of rotating equipment like fans, generators, wheels, and propellers

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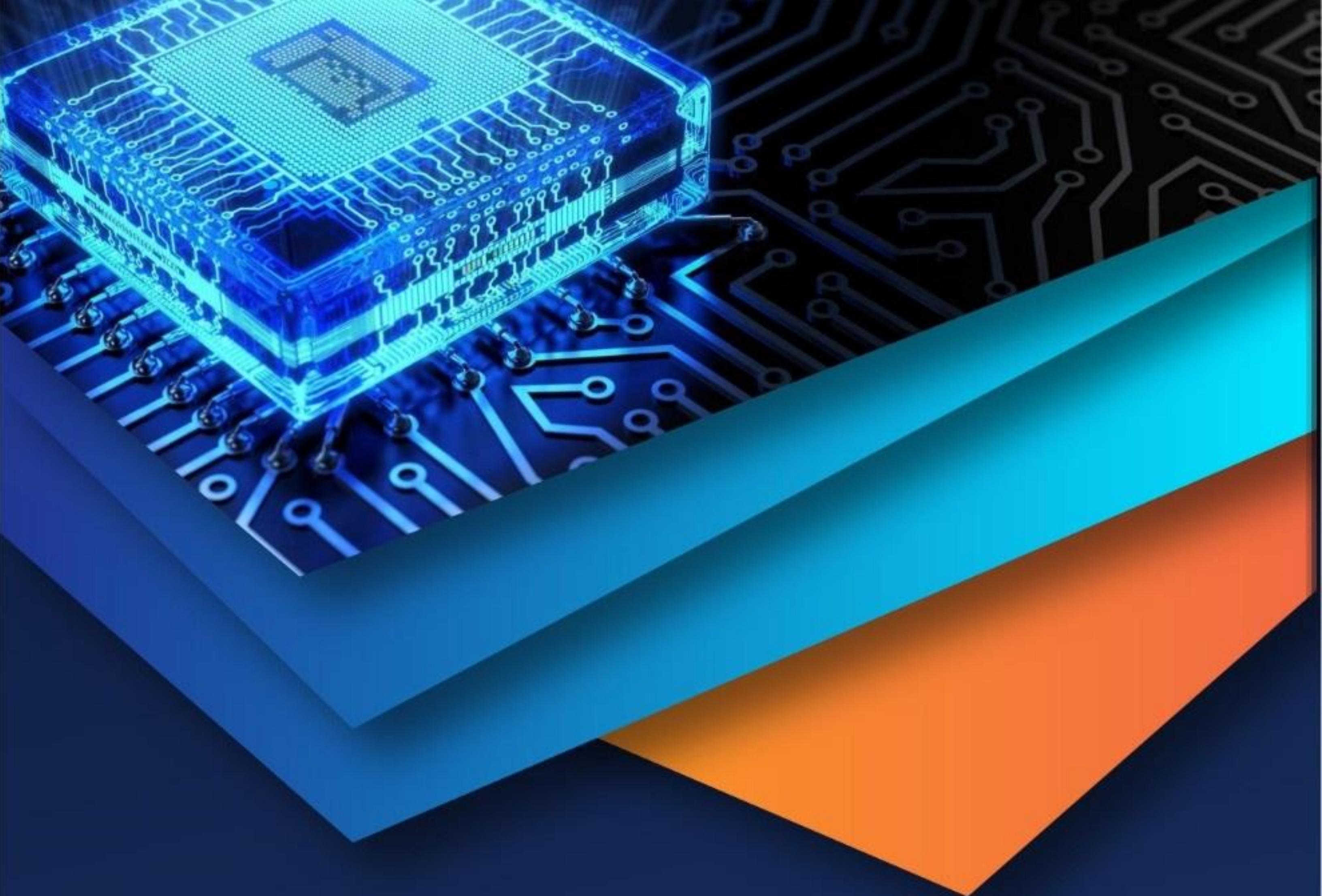

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