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Electronic Design and Analysis LoadCell Sensor Using STM32 Microcontroller

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Abstract: *Loadcell is an electromechanical device commonly called a Transducer, which is a force that works based on the principle of deformation of a material due to working mechanical stress, then converts the mechanical force into an electrical signal. The strain that occurs in the skin layer of the material is measured using a strain sensor or strain gauge. In this research, the electronic design of the load cell circuit will be carried out using the STM32 microcontroller programmed using the Arduino IDE. The components used in this design are load cell, HX711, RTC DS1307, STM32 microcontroller, SD Card Module, and 16x2 I2C LCD. The use of RTC DS1307 is to find out real-time time. Use of SD Card Module to store data so that it can be processed on a laptop/PC. As well as the use of a 16x2 I2C LCD to display time data and also the load calculated by the loadcell.*

Keywords—Loadcell, Microcontroller STM32, Arduino IDE

1. INTRODUCTION

Nowadays the demand for digital weighing machines increasing day by day in most business enterprises because measuring the weight with digital weighing machine is user-friendly with a variety of various applications [1]. Technical innovation in the industry is regarded by many people as the best way of making the industry more profitable [2]. Along with the development of technology, all applications related to human activities have been designed according to the desired functions and benefits, with more efficient use of time and maximum benefits obtained. With the development of electronics, there are many instruments that use electronic systems, because this system produces instruments that are much better than using analog instruments, as well as the weighing system. The electronic weighing system calculates the analog weighing system.

Digital weighing machine is an electronic device that gives a digital display of every load that is placed on it [3]. Measurement is an activity that aims to get the value of a quantity [2]. Measurement is a process that is carried out systematically to obtain quantitative quantities of a certain object using standard measuring instruments.

Scales are tools that function to determine the weight of an object. Digital scales have a higher level of accuracy and more efficient operation than analog scales. Users only see the numbers listed on the LCD (Liquid Crystal Display) screen. Each scale required for TERA is a maximum of once a year because all scales in the process of being used for a certain period of time will experience mechanical deformation in the scale frame, this will affect the accuracy of the load cell on the scale.

In this report, a loadcell circuit will be designed using an STM32 microcontroller. For this reason, a load data collection will be carried out from the loadcell and also analyze the data obtained and carry out the software design of many instrument circuits.

1.1 Objectives of Practical Work

In general, the purpose of doing practical work is to increase knowledge and knowledge and apply the theories gained during lectures to industrial systems in the field.

Specifically, the objective of the Practical Work is to design and test the hardware and software of a load cell circuit using an STM32 microcontroller to weigh an object in the form of a wrench.

1.2 Problem Limitation

The problem limitations in this Practical many instruments used of load cell weighing circuit using STM32 microcontroller.

2. Software design for load cell weighing circuit using Arduino IDE.

2. LITERATURE REVIEW

2.1 Load Cell

A load cell is a device test electrical devices that may alter a energy into other energy used to change a style into signal electricity [4]. Load Cell is the main component of Digital Scale. The component is a transducer which converting compressive energy into electrical energy [5]. A load cell sensor is an electronic transducer that can convert physical quantities into electrical signals. Loadcell is a sensor designed to detect the pressure or weight of a load, loadcell sensors are generally used as the main component in digital weighing systems and can be applied to bridge scales that function to weigh the weight of trucks carrying raw materials, measurements carried out by loadcells use the pressure principle. The shape of the load cell can be seen in Figure 1.

Figure 1. The physical form of load cell

The Working Principle of the Weight Sensor (load cell), During the weighing process it will cause a reaction to the metal elements in the loadcell which causes an elastic force. The force generated by this strain is converted into an electrical signal by a strain gauge attached to the load cell. The world standard unit of measurement of weight is the kilogram (kg)[6].

The module communicates with the period's use controller via TTL232. Simple structure, easy to use, stable and reliable results, high sensitivity, and able to measure changes quickly.

2.2 HX711 Amplifier Module

The HX711 is an integrated component of "AVIA SEMICONDUCTOR", the HX711 24-bit precision analog to digital converter (ADC) designed for digital weighing sensors and industrial control applications connected to bridge sensors. HX711 is a weighing module, which has the working principle of converting the measured changes in resistance changes and converting them into voltage quantities through the existing circuit. The HX711 load cell amplifier is used to get measurable data out from a load cell and strain gauge[7].

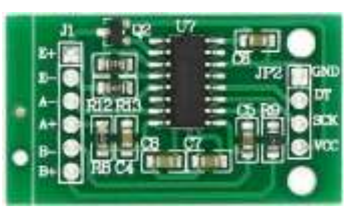

Figure 2. HX 711 Module

In Figure 2. it can be seen that the HX711 module has 1 output pin SCK pin/clock signal and has 1 DT/data input pin.

2.3 RTC DS1307

RTC is the system clock, that is necessary to make the device performs real-time monitoring. RTC has its own supply voltage, so RTC is always on even when the device supply voltage is shut down. In this system[8]. RTC (Real Time Clock) is an electronic clock in the form of a chip that can calculate the time (from seconds to years) accurately and store the time data in real-time. The DS1307 serial real-time clock (RTC) is a low-power, full binary-coded decimal (BCD) clock/calendar plus 56 bytes of NV SRAM[9]. An example of the DS1307 RTC chip can be seen in Figure 3. Configuration to STM32 can be seen in Table 1.

Figure 3. RTC DS1307

Table 1. RTC DS1307 Pin Configuration to STM32

RTC DS1307	STM32
GND Pin	G Pin
VCC Pin	5V Pin
SDA Pin	B7 Pin
SCL Pin	B6 Pin

2.4 Regulator Module XL4005

The XL4005 is a 300KHz fixed frequency PWM buck (step-down) DC/DC converter, capable of driving a 5A load with high efficiency, low ripple and excellent line and load regulation[10]. Regulator Module XL4005 is a series of 300 kHz fixed-voltage fixed-voltage (PWM) DC/DC converter modules using the XL4005 Regulator IC, capable of driving 5A loads with high efficiency, low towing, and excellent line and load regulation. Requiring a minimum number of external components, the regulator is easy to use and includes internal frequency compensation and a fixed-frequency oscillator. The shape of the XL4005 regulator module can be seen in Figure 4.

Figure 4. Regulator Module XL4005

The Regulator Module XL4005 can work with a supply voltage of 5-32V and an operating temperature of -40 - +85 degrees. The XL4005 regulator module uses an SMD (Surface Mount Device) IC and there is a potentio to adjust the input voltage from 0.8 – 24V DC at a working frequency of 300 kHz so that it can be adjusted according to voltage requirements.

2.5 SD Card Module and Micro SD

SD (Secure Digital) is a flash memory card format. This memory card is used in some portable media, such as PDAs, digital cameras, or mobile phones. This card was developed by SanDisk, Toshiba, and Panasonic based on the existing Multi Media Card (MMC). In addition to having a better security system than Multi Media Cards, SD Cards can also be more easily distinguished from MMC because they are thicker in size than standard MMC cards.

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Table 2. SD Card Pin Configuration to STM32

Modul SD *Card*	STM32
CS Pin	A4 Pin
MISO Pin	A7 Pin
MOSI Pin	A6 Pin
SCK Pin	A5 Pin
5V Pin	5V Pin
GND Pin	GND Pin
3.3V Pin	3.3V Pin

Figure 5. SD Card Module and Micro SD

Standard SD cards measure 32mm x 24mm x 2.1mm, but some SD cards are as thin as MMC (1.4mm). In its development, the card is also produced in two smaller size variations, the two variants are known as MiniSD and MicroSD or TransFlash (T-Flash). In general, SD cards are distinguished by the available data transfer rates, namely regular speed (150 KB/s) and high speed. Table 2.2 shows the SD Card pin configuration to STM32 and Figure 5. is a form of SD Card and Micro SD used.

2.6 LCD (Liquid Crystal Display)

The features presented in this LCD are:

- Consists of 16 characters and 2 lines which have 192 characters stored.
- There is a programmable character generator.
- Addressable with 4-bit and 8-bit modes.
- Equipped with back light.

Figure 6. Liquid Crystal Display

Figure 6. is a form of I2C LCD. I2C to STM32 LCD pin configuration can be seen in Table.3.

Table 2. LCD I2C Pin Configuration to STM32

LCD I2C	**STM32**
GND Pin	G Pin
VCC Pin	5V Pin
SDA Pin	B7 Pin
SCL Pin	B6 Pin

2.7 Microcontroller STM32F103C8T6 (bluepill)

This module uses STM32F103C8T6 (ARM 32 Cortex-M3 CPU) of the STM32 series with a working voltage of 3.3V, has 64K flash memory, 20K SRAM, and a clock frequency of 8 to 72 MHz. STM32F103C8 specifications can be seen in Figure 7. Board STM32F103C8T6 (BluePill).

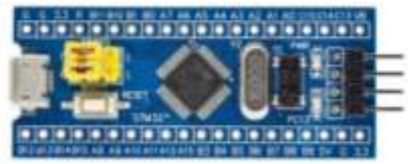

Figure 7. STM32F103C8T6 Microcontroller

The specifications on the STM32F103C8T6 microcontroller are following what the designer expected, especially since this microcontroller is among the fastest compared to the Arduino type. In addition, there is also a built-in LED (already attached to the board) which is connected to the PC13 pin, usually used to try programs. The detailed description of the STM32 system minimum pin configuration is shown in Figure 8. below.

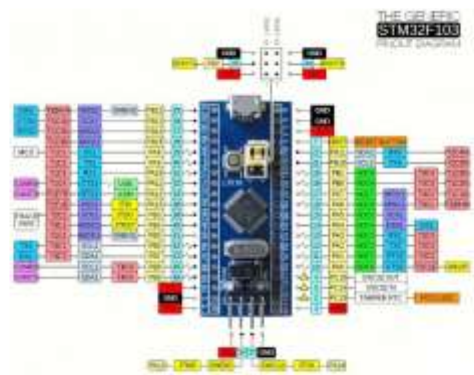

Figure 8. STM32F103C8T6 Microcontroller Configuration

3. Load Cell Scales Design and Testing

3.1 Components in the Circuit

In designing a series of load cell scales, several components are needed. The main components in this design are the STM32 microcontroller and also a load cell with a capacity of 350 kg. A load cell with a large capacity is used because in addition to designing it as a load cell scale in the future it will also be used as a tensile test tool. The following components used in the design can be seen in Table 4.

Table 3. Components in the Circuit

No.	**Component**	**Quantity**
1	STM32F103C8T6 Microcontroller	1
2	Load Cell 350kg	1
3	HX711 Module	1
4	SD Card Module	1
5	16x2. LCD I2C	1
6	RTC DS1307	1

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7	XL4015 DC Step Down	1
8	20cm x 15cm. PCB dot	1
9	0.15mm. Mini Cable	2m

3.2 Block Diagram

This circuit block diagram is divided into 3 segments, namely the input segment, the main process segment, and the output segment. In the input segment, there is a load cell for weighing samples and the signal issued by the load cell is amplified by the HX711 module. Then there is also the RTC DS1307 to retrieve real-time date and time data.

In the main process segment, there is an STM32 microcontroller as the data processing brain which is supplied with a voltage of 5V by a DC power supply. Furthermore, in the output segment, there is a 16x2 I2C LCD to display measurement data, and there is also an SD card module for real-time storage of measurement data. More details can be seen in Figure 9.

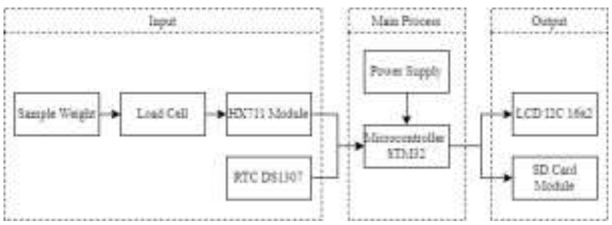

Figure 9. Load Cell Circuit Block Diagram

3.3 Block Diagram Component Functions

The following is a function of each component in the block diagram.

1. Weight sample serves as the object to be measured or weighed
2. Loadcell functions to change the mechanical force due to the load from the object into an electrical signal
3. The HX711 module converts the measured changes in resistance changes and converts them into voltage quantities
4. RTC DS1307 functions to retrieve real-time date and time data
5. DC Power Supply serves to supply the needs of the STM32 microcontroller working voltage of 5V
6. The STM32 microcontroller functions as the brain of the circuit to control components and process input into the desired output.
7. LCD I2C 16x2 functions to display measurement data
8. SD Card Module functions to store measurement data so that it can be processed on various devices.

3.4 Program Flowchart

To run the program, the first step is to turn on the power supply. Then the program on the STM32 microcontroller will initialize the port. After the initialization is complete, the load cell calibration process is carried out, then the load cell will measure the object sample in the form of a wrench. Then HX711 will convert the change in resistance into voltage by HX711. The RTC DS1307 also keeps time data in real-time. The measurement results by the converted load cell are stored by the SD card module in real-time and also displayed on the 16x2 I2C LCD. The following program flowchart can be seen in Figure 10.

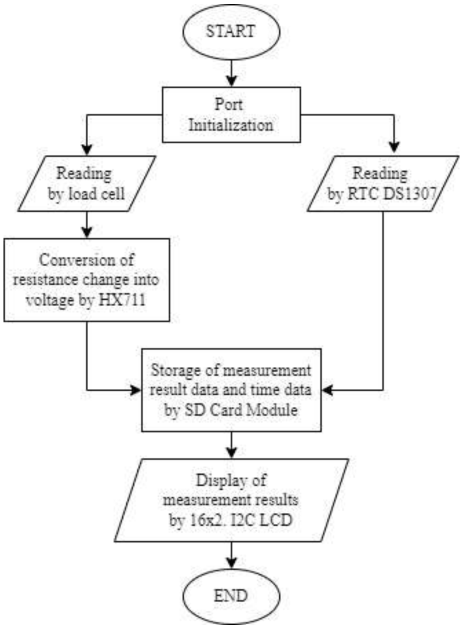

Figure 10. *Flowchart* Program

3.5 Program Design

The library used to process load cell data is <HX711_ADC.h>, while the SD card module uses the <SD.h> <EEPROM.h> library. Then RTC DS1307 uses the library "RTClib.h". The 16x2 I2C LCD uses the <LiquidCrystal_I2C.h> library. For more details, the following program script:

```
#include <HX711_ADC.h>
#include <EEPROM.h>
#include <SD.h>
#include <SPI.h>
#include <Wire.h>
#include "RTClib.h"
#include <LiquidCrystal_I2C.h>
```

Next is the function to set the initial time to match real-time. To run the timing function, it is necessary to uncomment the function, the purpose of making a function in the form of a comment is to keep real-time unchanged when running the program. The way to set it is by uncommenting the program, then filling in the details of the year, month, date, hour, minute, and second. Details of the script can be seen below:

```
void setup() {
  float calibrationValue; // calibration value
  calibrationValue = 10.19; // uncomment this if
you want to set this value in the sketch

  LoadCell.begin();
  long stabilizingtime = 2000; // tare preciscion
can be improved by adding a few seconds of
stabilizing time
```

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```
  boolean _tare = true; //set this to false if you
don't want tare to be performed in the next step
  LoadCell.start(stabilizingtime, _tare);
  if (LoadCell.getTareTimeoutFlag()) {
Serial.println("Timeout, check MCU>HX711 wiring and
pin designations");
  }
  else {
    LoadCell.setCalFactor(calibrationValue); // set
calibration factor (float)
    Serial.println("Startup is complete");
  }
delay(3000);
```

Next is the function to set the initial time to match real-time. To run the timing function, it is necessary to uncomment the function, the purpose of making a function in the form of a comment is to keep real-time unchanged when running the program. The way to set it is by uncommenting the program, then filling in the details of the year, month, date, hour, minute, and second. Details of the script can be seen below:

```
//Set time for the first time
//rtc.adjust(DateTime(F(_DATE), F(TIME_)));
//rtc.adjust(DateTime(2022, 02, 18, 17, 29, 0));
SDCard_init();
}
```

Furthermore, the void loop () is used to display data on the Arduino IDE serial monitor and 16x2 I2C LCD. The weight data of the load cell is obtained from the LoadCell.getData() function. Save the data to the micro SD with the function Serial.println(" --Saved to "+String(fileName)+".txt!") . Details of the script can be seen below:

```
void loop() {
  Loadcell();
  DS3231_read();
  DS3231_display();
   LoadCell.update(); // retrieves data from the
   load cell
  float i = LoadCell.getData(); // get output value
  lcd.setCursor(0,0);
  lcd.print(i);
  lcd.setCursor(7,0);
  lcd.print("g");
  float kg = i/1000;
  lcd.setCursor(0,1);
  lcd.print(kg);
  lcd.setCursor(6,1);
  lcd.print("kg");

Serial.println(String(Calendar)+","+String(Time)+",
"+String(i));
         myFile = SD.open(String(fileName)+".txt",
         FILE_WRITE);
    if (myFile) {
       // Write to file
       myFile.println(String(Calendar)+","+String(
       Time)+","+String(i));
      myFile.close(); // close the file
       Serial.println(" --Saved to
       "+String(fileName)+".txt!");
    }
    else {
               Serial.println(" error opening
         "+String(fileName)+".txt");
    }
  delay(1000);
}
```

Furthermore, in the void Load Cell () there is a process of converting the signal obtained from the HX711 to be converted into weight data in grams. Details of the script can be seen below:

```
void Loadcell(){
  static boolean newDataReady = 0;
  const int serialPrintInterval = 100; //increase
value to slow down serial print activity

  // check for new data/start next conversion:
  if (LoadCell.update()) newDataReady = true;

  // get smoothed value from the dataset:
  if (newDataReady) {
    if (millis() > t + serialPrintInterval) {
      float i = LoadCell.getData();
      Serial.print("Load_cell output val: ");
      Serial.println(i);
      newDataReady = 0;
      t = millis();
    }}}
```

3.6 Load Cell Circuit Design

In this loadcell circuit hardware design, all components are put together in a dot PCB, to make it easier in the checking process, experiments are carried out on each part using jumpers. This design will eventually remove the jumpers and replace them with small rainbow wires to make them more compact and tidy. In addition, it also uses a female pin header so that each part can be easily disassembled if you want to check or replace components. The following is a circuit wiring that has been designed using the fritzing application in Figure 11.

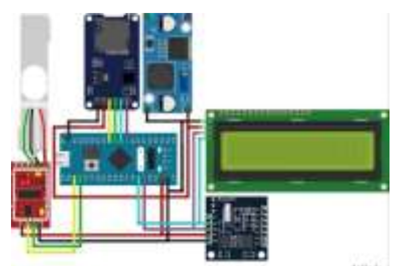

Figure 11. Load cell circuit wiring using STM32

3.7 Design on PCB dot

The circuit design is carried out on the PCB (Printed Circuit Board) dot because it is more flexible and easy to repair the circuit

The following Figure 12. and Figure 13. are the PCB dot display after being assembled using a mini cable and a female pin header from above and below. And the PCB dot display after the components are installed can be seen in Figure 14.

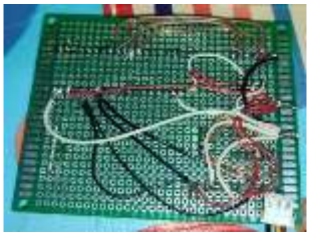

Figure 12. Bottom View of Cable Paths on PCB dot

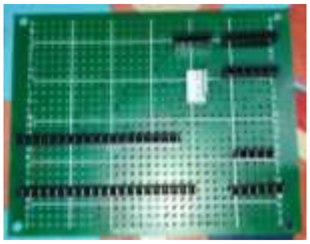

Figure 13. View from the top of the dot PCB after the pin header is installed

Figure 14. Display After All Components Are Installed

This process is carried out so that the circuit that originally used jumpers during the experiment was tidied up and simplified to save space and also maintain the aesthetic value and neatness.

3.8 Soldering Components

Soldering is the process of making metallic connections electrically and mechanically using a certain metal (tin) by combining it with a special tool (solder). The things that need to be considered in soldering components are as follows:

a. The soldering time and temperature should not damage the components to be soldered.

b. The tin maturity at the connection point is attempted as well as possible so that it does not affect the work of the circuit.

c. The distance between solders needs to be considered, not to be too tight because a short can occur which results in component damage.

3.9 Loadcell Test

The testing on this loadcell sensor system is done by comparing the digital scale with the designed loadcell circuit, the test was also carried out by taking data on several wrench weights. This test uses 13 test samples which can be seen in Table 5.

Table 4. Comparison of Object Weight Measurements between Loadcell Scales and Digital Scales

No.	Object	Digital Scale (gram)	Load Cell Scale (gram)	Accuracy (%)	Error (%)
1	Wrench 8mm	30.60	39.35	77.76	22.24
2	Wrench 10mm	43.00	48.69	88.32	11.68
3	Wrench 11mm	56.10	62.03	90.44	9.56
4	Wrench 12mm	61.10	68.41	89.32	10.68
5	Wrench 13mm	67.50	79.30	85.12	14.88
6	Wrench 14mm	84.50	96.28	87.77	12.23
7	Wrench 17mm	136.80	153.39	89.18	10.82
8	Wrench 19mm	163.20	178.90	91.22	8.78
9	Wrenches 8,10,11mm	129.70	140.53	92.29	7.71
10	Wrenches 12,13,14mm	213.10	231.89	91.90	8.10
11	Wrenches 17,19mm	300.00	324.53	92.44	7.56
12	Wrenches 8,10,11,12 mm	190.80	212.37	89.84	10.16
13	Wrenches 13,14,17,19 mm	452.00	488.13	92.60	7.40
Average (%)				89.09	10.91

The results of testing loadcell scales and digital scales can be seen in Table 5. above where the accuracy and accuracy in measuring objects in the form of a wrench with a load cell is about 89.09% on average while the loadcell error is 10.91%.

The factors that cause a fairly large error are:

1. The position of the loadcell is unstable due to the stable position of the loadcell not for weighing but for testing the tensile force of the specimen being tested.

2. In the calibration process, which recommends using a benchmark load of 1000 grams, it is considered less accurate in producing accurate calibration results because the type of loadcell used has a capacity of 350 kg, where there is a ratio of 1:350.

4. Closing

4.1 Conclusion

In practical work with the title "Electronic Design and Analysis of Load Cell Sensors Using STM32 Microcontroller" in CV. Manufacturing Design Engineering (REDESMA) obtained the following conclusions:

1. The load cell circuit has been successfully designed as a weight gauge with an error of 10.91%.
2. The large error in the measurement results using load cell scales is caused by the calibration process which recommends using a benchmark load of 1000 grams, this is considered less accurate in producing calibration because the type of load cell used has a capacity of 350 kg, where there is a comparison of 1:350.

4.2 Suggestion

This suggestion is intended for writers, universities, and companies so that in the future better and more useful research results can be obtained.

1. It is necessary to evaluate the load cell calibration process so that large errors do not occur, as well as to test the exact and stable location of the load cell so that the calibration results are more precise.
2. It is necessary to optimize the specifications of the load cell circuit components so that the design results can be carried out efficiently and maximally, and do not cause overbudget and use of space to a minimum.

5. Acknowledgment

In this report we realize that there are still shortcomings and imperfections, therefore criticism and suggestions are highly expected to improve research on "Design and Analysis of Load Cell Sensors Using the STM32 Microcontroller" to be published. We also hope that this report can be useful for authors and readers.

This research was able to run well thanks to the assistance provided by various parties. On this occasion, the author would like to express his gratitude to the supervisor who has given encouragement and guidance, and the author's parents who have given moral and economic support. CEO CV. Manufacturing Design Engineering (REDESMA) which has allowed the author to carry out research at CV. Manufacture Design Engineering (REDESMA), friends who have accompanied and encouraged, and all parties who cannot be mentioned by the author who has helped so that this research can be completed.

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