Design and Prototype of Specific Gravity based Element Identifier

by

Mohd Azrin Bin Ahmad

A project dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical and Electronics Engineering)

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CERTIFICATION OF APPROVAL

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June 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the originality work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD AZRIN BIN AHMAD

ABSTRACT

All elements have distinct density and this special feature make them can be effectively identified.The concept of buoyouncy and Archimedes' theory is applied in this project to find the volume of the elements. According to Archimedes, The buoyant force on a submerged object is equal to the weight of the fluid displaced. This principle is useful for determining the volume and therefore the density of an irregularly shaped object by measuring its mass in air and its effective mass when submerged in water. This effective mass under water will be its actual mass minus the mass of the fluid displaced. The difference between the real and effective mass therefore gives the mass of water displaced and allows the calculation of the volume of the irregularly shaped object. Then the specific gravity of the elements is calculated and the value is compared to the table to identify the corresponding elements

The element identifier that is design in this project should be able to measure actual specific gravity of all the elements to achieve accurate reading and able to identify the elements correctly. However there are some errors that can not be avoided during the measurement process. The most difficult error to be avoided is vibration error because this element identifier uses water to measure the volume of the elements. The vibration error will occur during the submerging process of the elements into the water. Other errors that are discussed in this report are quantization error that occurs in process of converting the analogue reading to digital.

ACKNOWLEDGEMENT

I would like to thanks my coordinator, Pn Salina Mohamad for giving me an opportunity to take part in the final year project. My involvement in the project has significantly shaped my vision in the real world of electrical and electronic engineering and also gave me confidence to go out and face the world. I would also like to thank my supervisor, AP Dr Herman Agustiawan for giving continuous guidance and great ideas from the beginning to the end of this project. His remarkable contribution in this project is highly appreciated. Thanks to all my friends that support me in the process of completing this project.

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LIST OF ABBREVIATION

ρ = Density (kg/m^3)

m = Mass of the substance, measured in *kg*

V = Volume of the substance, measured in m^3

S = Specific gravity of the substance (*Dimensionless*)

P = Pressure, measure in *atm*

T = Temperature measure in *Kelvin*

ρ_w = Density of the Water (kg/m^3)

ρ_e = Density of the Substance (kg/m^3)

m_o = Mass of the substance in air (kg)

m_s = Apparent mass of the substance when submerged (kg)

PIC = Programmable Intelligent Computer

ROM = Random Access Memory

LCD = Liquid Crystal Display

LED = Light Emitting Diode

I/O = Input and Output

A/D = Analogue to Digital

CHAPTER 1
INTRODUCTION

1.1 Background of Study

1.1.1 Density

In physics, density is mass, *m* per unit volume, *V*. For the common case of a homogeneous substance, it is expressed in equation 1:

$$\rho = \frac{m}{V} \quad \text{.......} \quad (1)$$

where, in SI units:

ρ (rho) is the density of the substance, measured in $kg{\cdot}m^{-3}$

m is the mass of the substance, measured in *kg*

V is the volume of the substance, measured in m^3

For a homogeneous object, the formula mass/volume may be used. The mass is normally measured with an appropriate scale; the volume may be measured directly (from the geometry of the object) or by the displacement of a liquid. A very common instrument for the direct measurement of the density of a liquid is the hydrometer. A less common device for measuring fluid density is a pycnometer; a similar device for measuring the absolute density of a solid is a gas pycnometer [7].

1.1.2 Specific Gravity

The specific gravity of liquids or solids is defined as the ratio of density of the material to the density of distilled water. (S = density of the material/density of water). This implies that if the specific gravity is approximately equal to 1.000, then the density of the material is close to the density of water. If the specific gravity is large this means that the density of the material is much larger than the density of water and if the specific gravity is small this implies that the density of the material is much smaller than the density of water [6].

1.1.3 Buoyancy

In physics, buoyancy is the upward force on an object produced by the surrounding liquid or gas in which it is fully or partially immersed, due to the pressure difference of the fluid between the top and bottom of the object. The net upward buoyancy force is equal to the magnitude of the weight of fluid displaced by the body. This force enables the object to float or at least to seem lighter. Buoyancy is important for many vehicles such as boats, ships, balloons, and airships, and plays a role in diverse natural phenomena such as sedimentation [10].

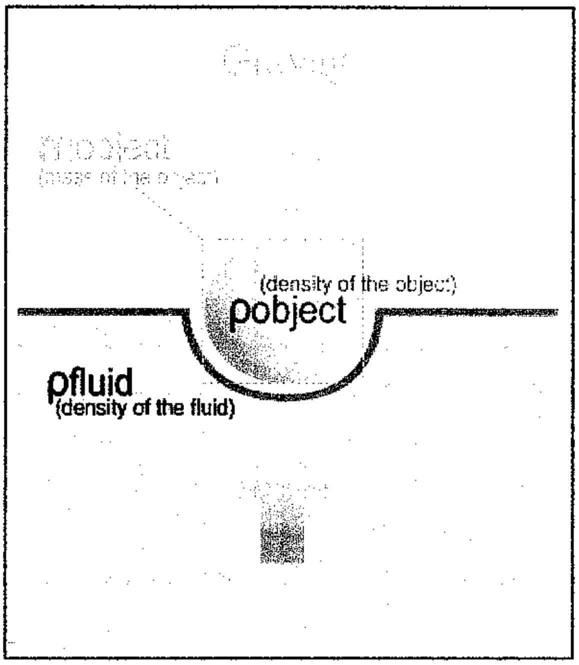


Figure 1: Buoyant Force to an Immersed Object

1.1.4 Archimedes Principal

The buoyant force on a submerged object is equal to the weight of the fluid displaced. This principle is useful for determining the volume and therefore the density of an irregularly shaped object by measuring its mass in air and its effective mass when submerged in water (density = 1 gram per cubic centimetre). This effective mass under water will be its actual mass minus the mass of the fluid displaced. The difference between the real and effective mass therefore gives the mass of water displaced and allows the calculation of the volume of the irregularly shaped object. The mass divided by the volume thus determined gives a measure of the average density of the object. Archimedes found that the density of the king's supposedly gold crown was actually much less than the density of gold and implying that it was either hollow or filled with a less dense substance. Examination of the nature of buoyancy shows that the buoyant force on a volume of water and a submerged object of the same volume is the same. Since it exactly supports the volume of water, it follows that the buoyant force on any submerged object is equal to the weight of the water displaced. This is the essence of Archimedes principle [11].

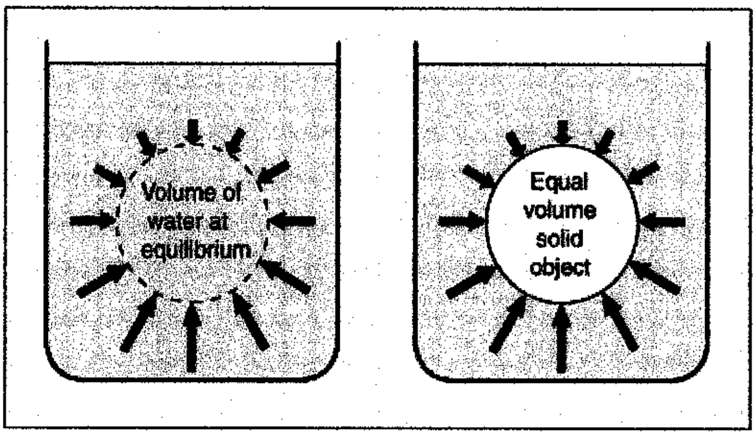


Figure 2: Archimedes' Principal of Submerse Object

1.2 Problem Statement

1. The manual calculation method to identify elements sometimes gave inaccuracy result due to human errors.

2. The available element identifiers are too expensive

1.3 Objective

The objective of the project is to distinguish the elements by its specific gravity.

1.4 Scope of the Study

The scope of the project is to design a working prototype of element identifier that can measure the specific gravity of the elements in solid.

1.5 Assumption

In order to calculate the specific gravity of the elements, the water density is assumed to be 1000 kg/m³ at 1 atm pressure of atmosphere temperature at 298 K (25°C). The formula to calculate the density of the water if the pressure and temperature is change is given by equation 2:

$$\rho_2 = \frac{\rho_1 \; x \; P_2}{P_1} \, x \, \frac{T_1}{T_2} \qquad \text{.................................... (2)}$$

where, in SI units:

ρ_2 is the new density of the water, measured in $kg \cdot m^{-3}$

P_2 is the new atmosphere, measured in *atm*

T_2 is the temperature of the water, measured in *Kelvin*

At ρ_1= 1000 kg/m³ , T_1 = 298 Kelvin and P_1=1 atm

CHAPTER 2
LITERATURE REVIEW

2.1 Archimedes' Principal Application

This project apply Archimedes concept to measure the volume of the element. According to Archimedes, a body immersed in a fluid experiences a force equal to the weight of the displaced fluid. At Archimedes time, a new crown in the shape of a laurel wreath had been made for his king, and Archimedes was asked to determine whether it was of solid gold, or whether silver had been added by a dishonest goldsmith. Archimedes had to solve the problem without damaging the crown, so he could not melt it down in order to measure its density as a cube, which would have been the simplest solution. While taking a bath, he noticed that the level of the water rose as he got in. He realized that this effect could be used to determine the volume of the crown, and therefore its density after weighing it. The density of the crown would be lower if cheaper and less dense metals had been added [6]. Archimedes determines the density of the crown by divide the mass of the crown with the volume of the crown by formula shown in the figure below:

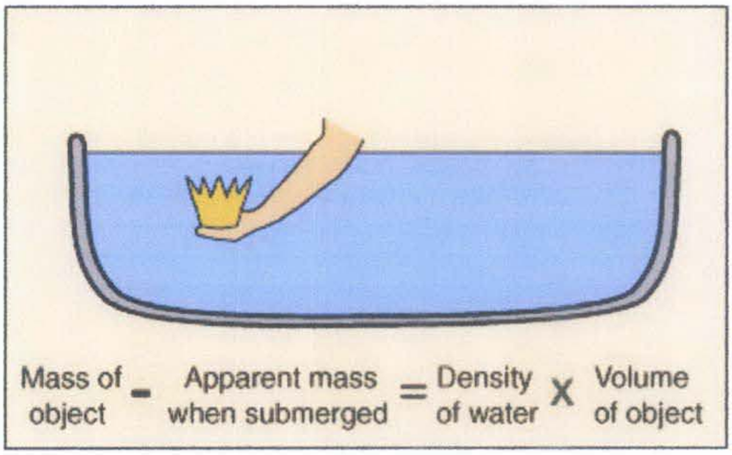


Figure 3: Archimedes' Experiment

2.2 Method to Measure Density Established by Gold Diggers

There are two manual methods to determined specific gravity that is established by gold diggers to check the purity of the gold. The method is as explain below.

2.2.1 Method 1

For the first method, place the container with water on a scale and note the weight or zero the scale for a direct measurement. Suspend the sample in the container of water by a very thin thread or thin fishing line or similar line so that the volume of the line is negligible compared to the volume of the sample. Hold the string or tie it to a brace such as a simple banana holder. The sample must be completely submerged but not touch the bottom or sides of the container. Then measure the weight of the container with the sample suspended in the water. The increased weight of the water should be noted. Call this as weight of the displaced water. See Figure 4 The advantage of this method is that a variety of scales can be used such as the triple beam balance that is shown.

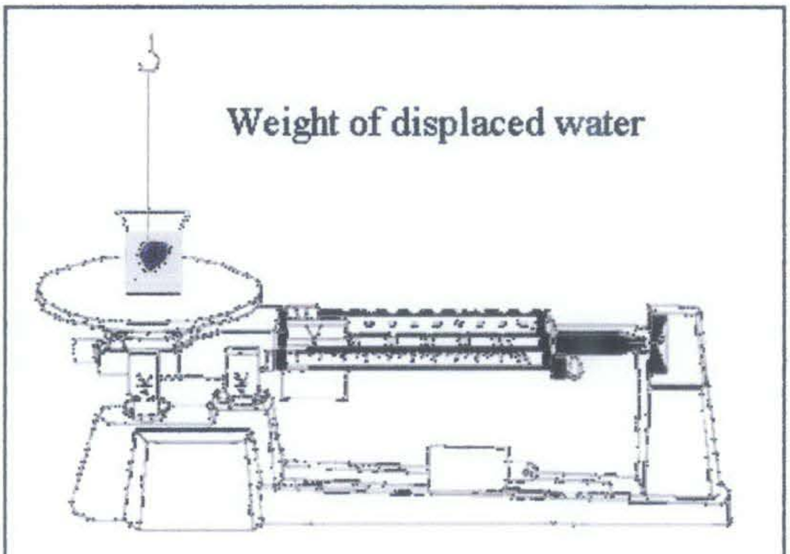


Figure 4 :Measure the Weight of Displaced Water

2.2.2 Method 2

The second method requires a balance or similar type scale as the weight of the sample itself must be measured while it is completely suspended in water. Again the sample must be completely submerged but not touch the bottom or sides of the container. Note the weight, which we will call weight of the sample in water. See Figure 5.

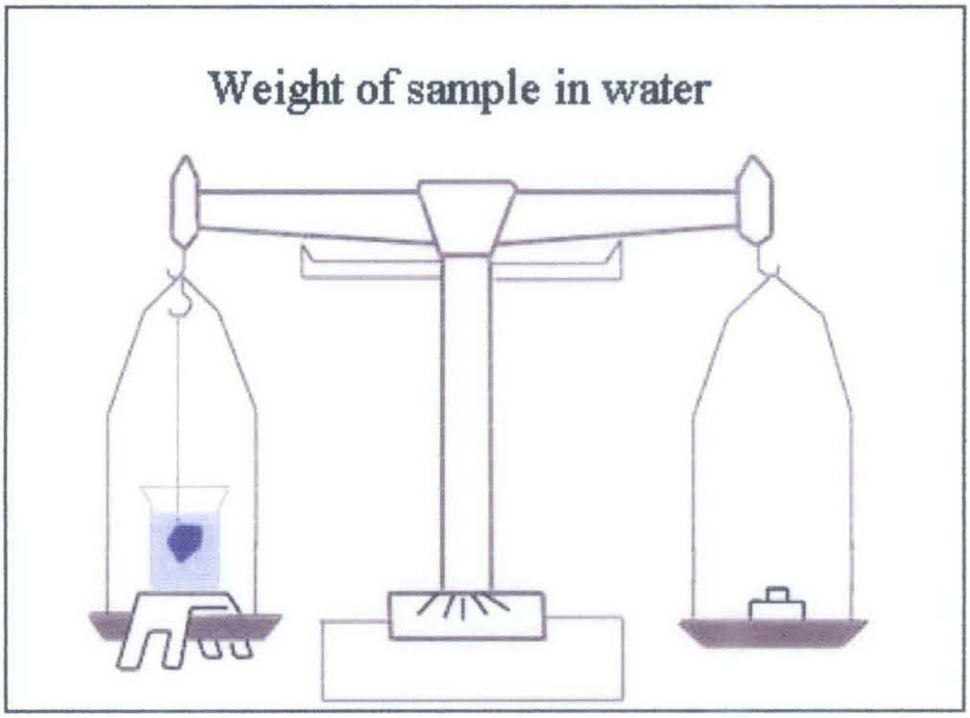


Figure 5: Measure the Weight Of Displaced Water By Comparison

2.3 The Available Element Identifier in Market

There are several specific gravity meter that is available in market as shown in Appendix G. The prices are between 2000 and 3000 USD.

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

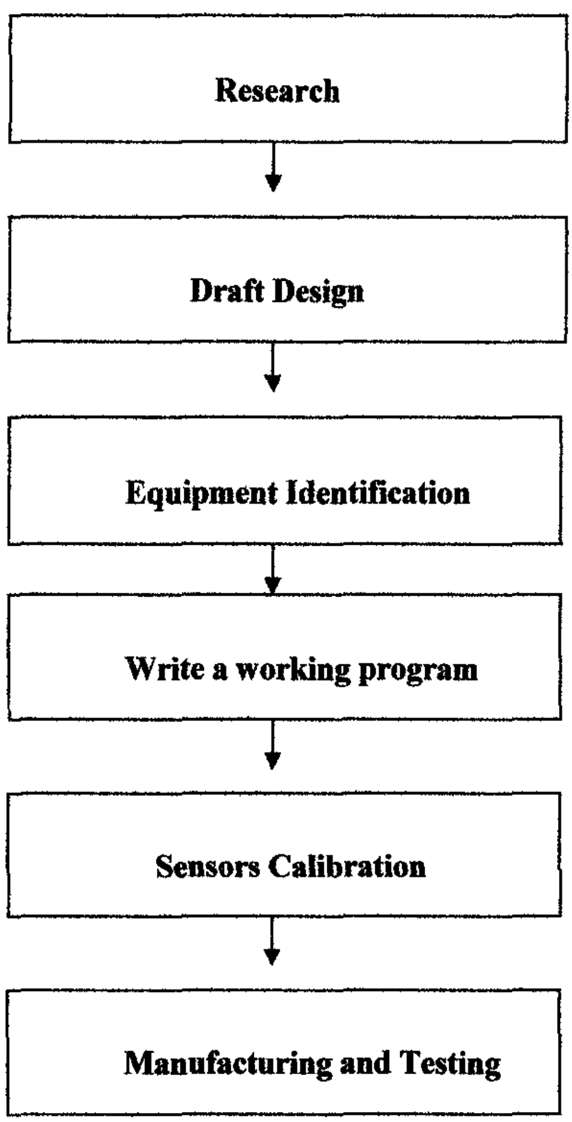


Figure 6: Flow Chart of Procedure Identification

Block 1: Research on the theory of density, specific gravity, buoyancy, Archimedes' principal and all related information on density and specific gravity measurement. Gather all the data of element identifiers use the concept of density or specific gravity that available in market and do market survey of the components that needs to be use in prototyping the element identifier for this project.

Block 2: Do drafts design, plan the flow and consider all the calculations involved in this element identifier. All the constant values are determined.

Block 3: Identify the equipments and tools that are required in order to complete the working prototype of this project.

Block 4: Write a working coding for the microcontroller and test its functionality. The code is uploaded to the PIC with help of Warp 13 and PIC C Compiler.

Block 5: Calibrate the mass sensor of this element identifier to give accurate reading in order to identify the elements correctly.

Block 6: Do a manufacturing and testing of this element identifier and record all the testing result. The full report for this project is prepared.

3.2 Tools / Equipment Required

3.2.1 Software

1. **Borland C++**

The software is uses as a platform to write the program in C language for the testing purpose before upload to the PIC in the main circuit.

2. PIC C Compiler

This software converts the .c file to Intel hex file before the code is uploaded to the PIC. The steps are show in the figures below:

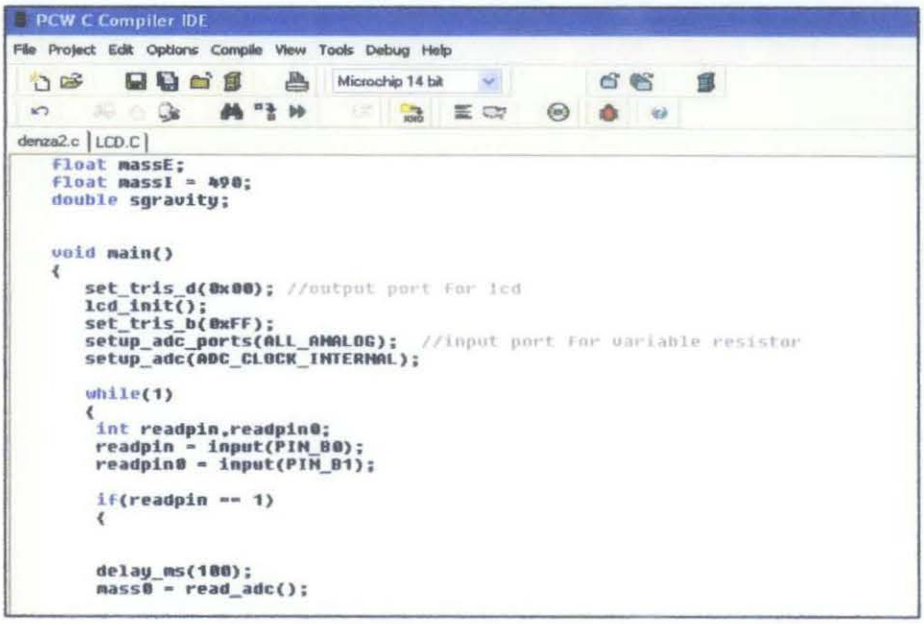


Figure 7: Complete Program in PIC C Compiler

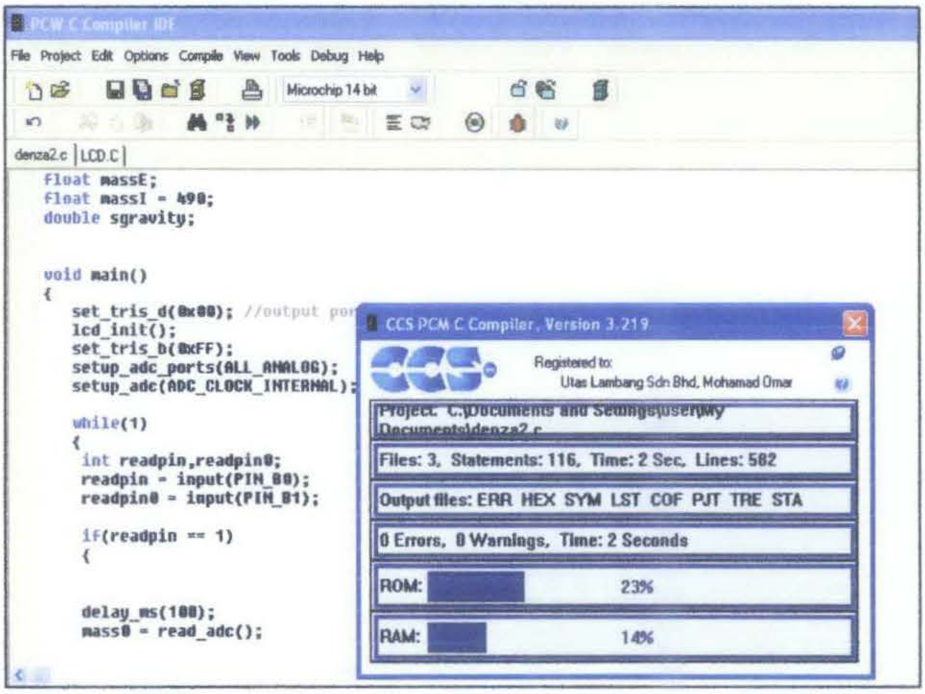


Figure 8: Compile and Convert the to Intel Hex file

3. Warp 13 Programmer Software

The software program the PIC random access memory (ROM) and copy instruction from Intel hex file to the PIC through the Warp 13 Programmer Hardware. The steps are as shown below:

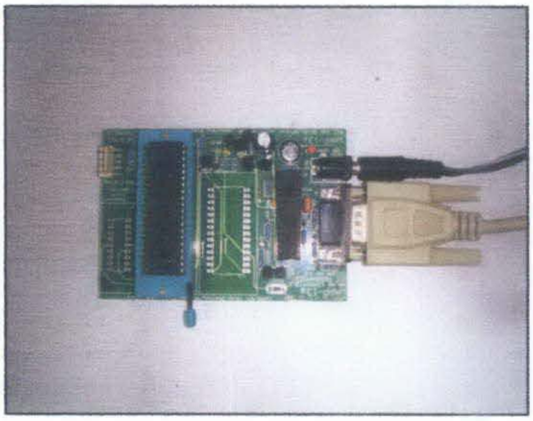


Figure 9 : Connect the PIC to the Warp 13 Hardware

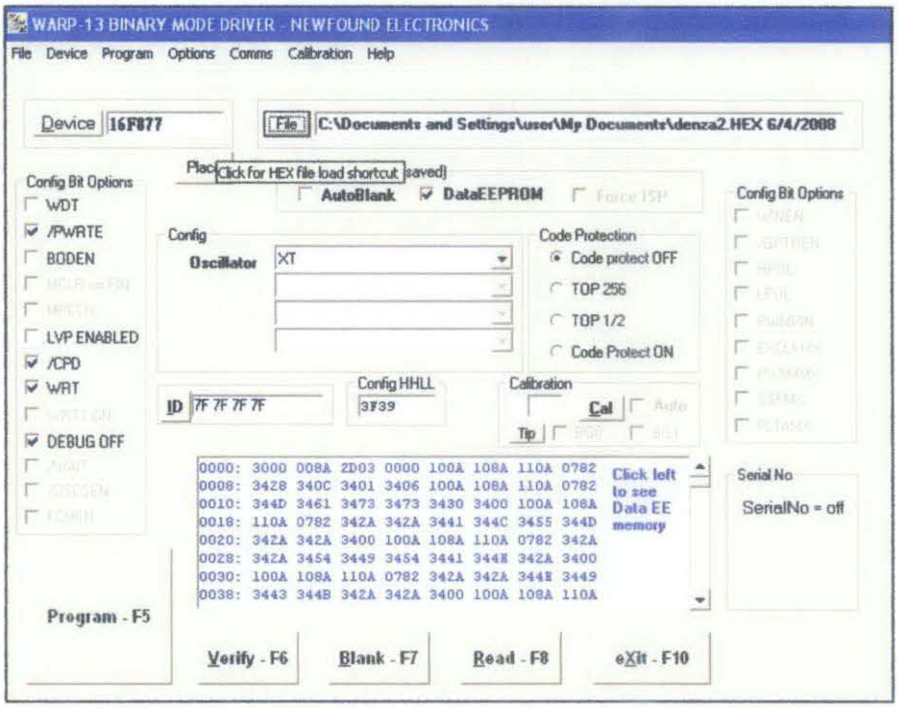


Figure 10 : Load the Intel Hex file to the Warp 13 Software

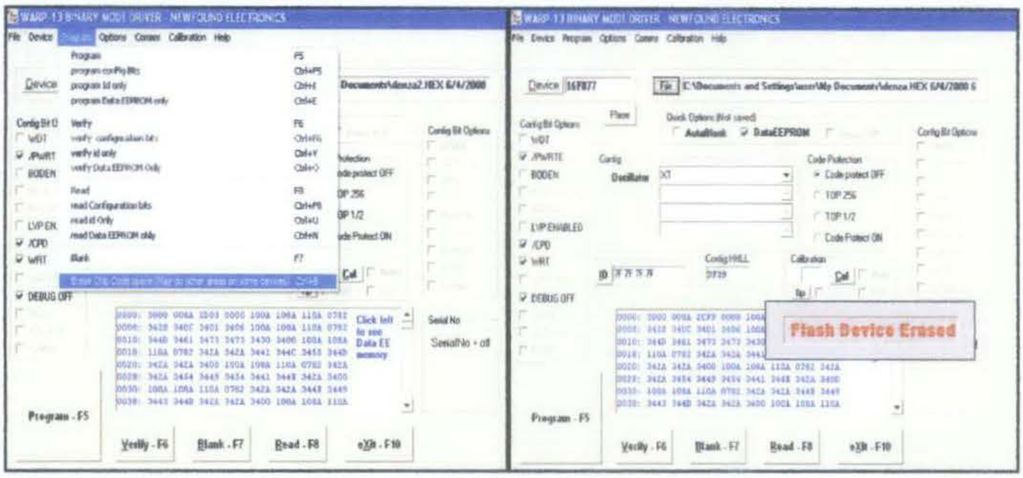


Figure 11: Erase the Data in PIC

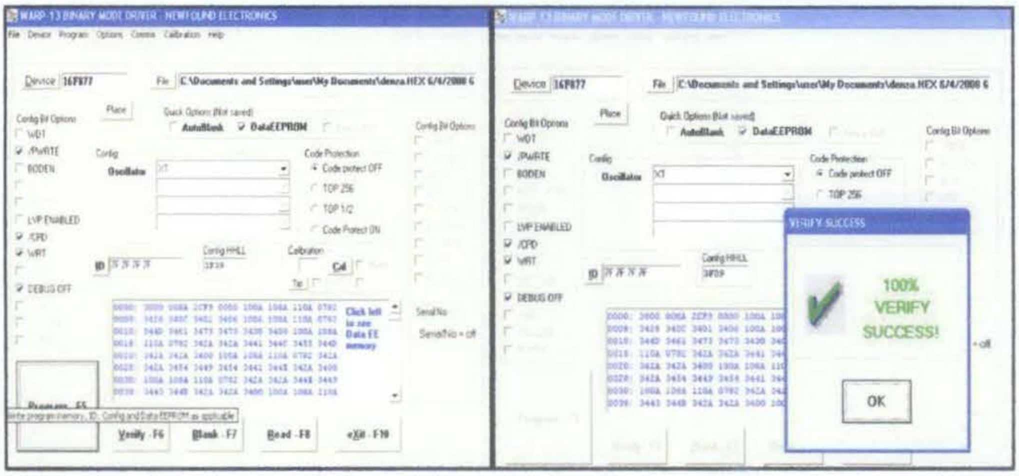


Figure 12: Upload the Program to the PIC

3.2.2 Hardware

3.2.2.1 The Component

Table below show the entire components needed in order to accomplish this project.

Table 1: Component List

Part Name & Number	Amount Needed	Module
PIC16F877A	1	Microcontroller
Clock (FOX F1100E)	1	Microcontroller
Voltage Regulator (7805)	1	Power Supply
9V Battery	1	Power Supply
Switch	1	Push-Button Switch
Kitchen Scale	1	Mass sensor
LCD (8x2 module)	1	LCD
Potentiometer	1	Mass Sensor
Resistors	3	Switch
Beaker	1	Interface

1. Liquid Crystal Display (LCD)

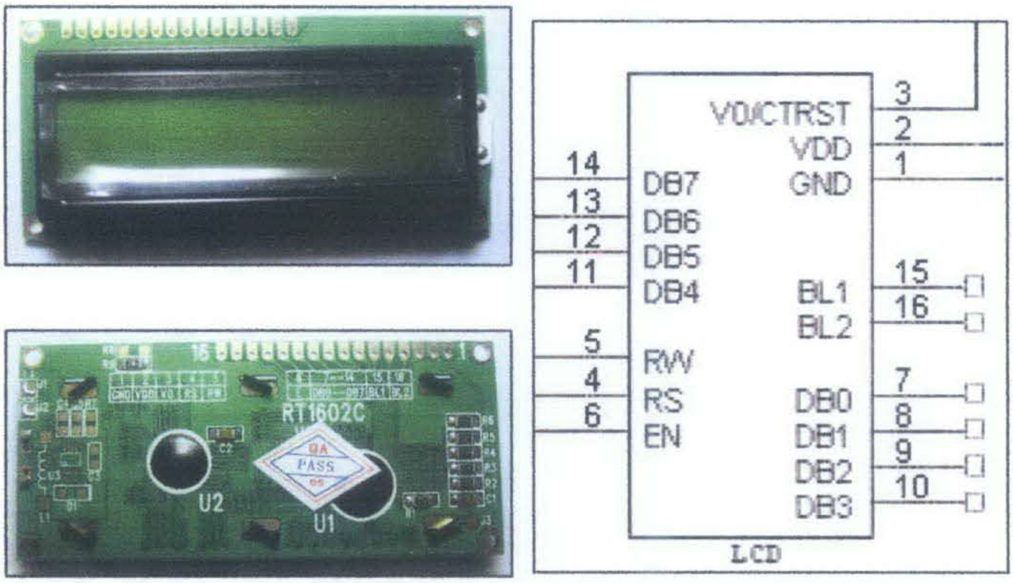


Figure 13 : RT1602C LCD

The RT1602C LCD is used for the display needs. It is a 16x2 backlit display that consumes relatively low power (6.5mW) if the LED backlights are not activated. Only four of the eight data bus line pins are use as it satisfies all of the requirements. The LED backlights in not plan to put in the design because of the LED's high power consumption and the fact that the device will most likely be used in the daytime under good lighting conditions. The V0 pin is grounded for maximum contrast.

2. Microcontroller

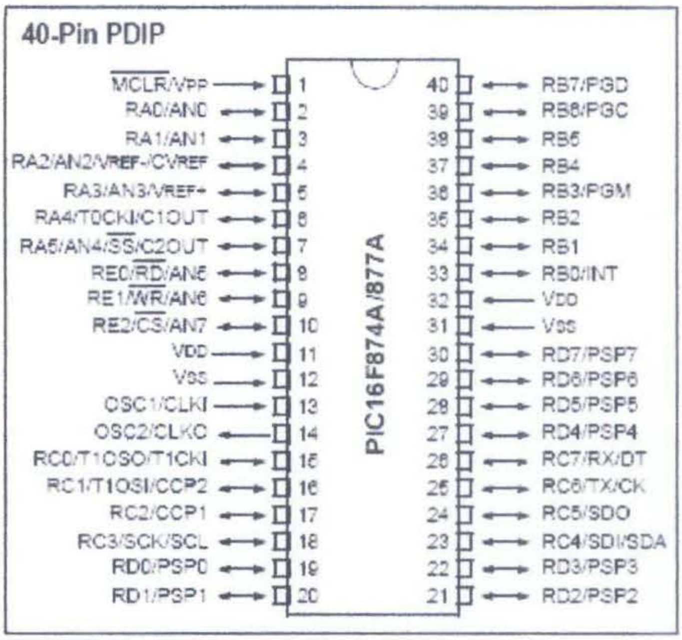


Figure 14 : PIC 168F77A Microcontroller

The PIC168F77A is use as a microcontroller. It is capable of performing analogue to digital conversions, and is well suited for controlling LCD's and executing on-board calculations. The seven of the I/O ports in PORTB is use for the LCD and three of the A/D converter ports on PORTA for mass sensor. The PIC will be driven by a 4MHz external crystal oscillator, and powered by a 3V battery through a step-up switch regulator. The 47kOhm resistor on the master clear pin (pin 1) is to help limit current in case of transient voltage spikes. For purposes of the project, the 28-pin PIC16F873A would suffice, but because of its availability and the accessible support, the PIC16F877A is elected to be use in the prototype design.

3. Mass Sensor

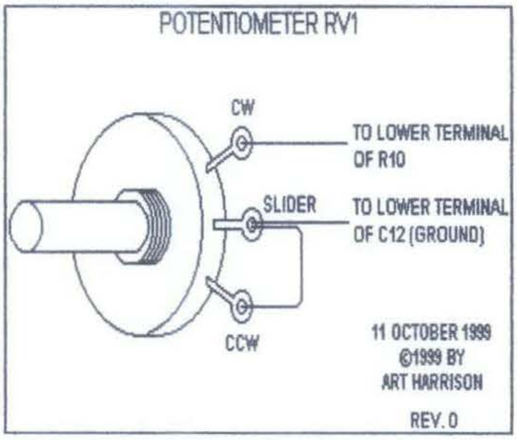


Figure 15 : Potentiometer

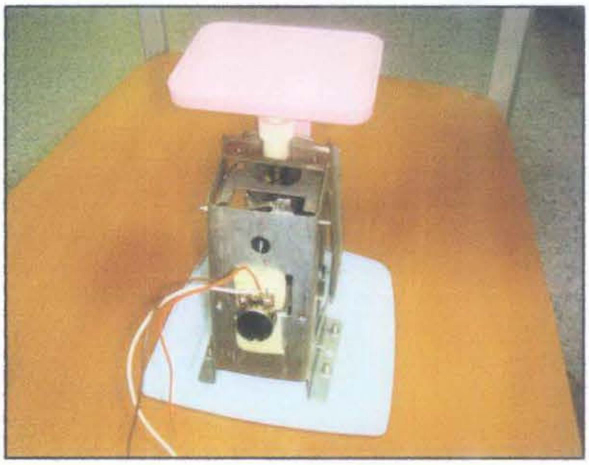


Figure 16: Potentiometer Attached to the Kitchen Scale

The gear to turn the indicator of kitchen scale is attached to the potentiometer turner. The force from the weight of the sample will turn the turner and vary the resistance. Using the voltage divider concept, the voltage will be varied proportionally with the resistance under constasnt current flow because voltage is equal to current multiply by resistor (V=IR).

3.3 The Design of the Element Identifier

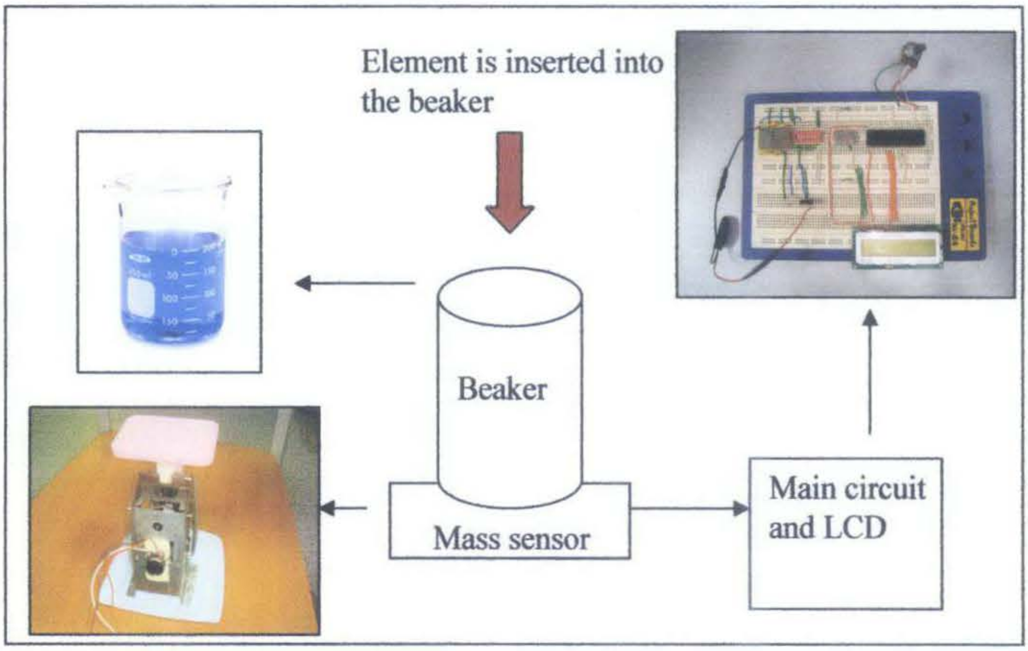


Figure 17: The Design of Element Identifier

1. The mass of the element in air, m_o, is measured by the mass sensor and the value is send to the microcontroller.

2. The apparent mass of the element, m_s, when submerged is calculated from the different between the mass of the beaker with water before and after the element is inserted.

3. The volume of the element, V, be calculated by the equation 3:

$$V = \frac{m_o - m_s}{\rho_w} \quad \text{...} \quad (3)$$

4. Then the density of the element, ρ_e, is determined by dividing the m_o, over the *V*.

$$\rho_e = \frac{m_o}{V} \quad \text{...} (4)$$

5. Substitute equation 3 into equation 4 give:

$$\rho_e = \frac{m_o \rho_w}{m_o - m_s} \quad \text{..} (5)$$

6. The specific gravity, *S*, is calculated by divide the ρ_e with the ρ_w.

$$S = \frac{\rho_e}{\rho_w} \quad \text{..} (6)$$

7. The equation is simplified by substitute equation 5 into equation 6 so that the element identifier only needs to determine the value of m_o and m_s to find the specific gravity.

$$S = \frac{m_o \rho_w}{m_o - m_s} X \frac{1}{\rho_w}$$

$$S = \frac{m_o}{m_o - m_s} \quad \text{..} (7)$$

8. The value is compared to the database inside the microcontroller and the name of the element is displayed on the LCD.

For all the equation above, where, in SI units:

V is volume of the element, measure in m^3

m_o is mass of the element, measured in kg

m_s is apparent mass of the element when submerged, measured in kg

ρ_w is density of the water, measured in $kg \cdot m^{-3}$

ρ_e is density of the element, measured in $kg \cdot m^{-3}$

S is specific gravity of the element (dimensionless)

3.4 The Flow of the Design

3.4.1 Block Diagram

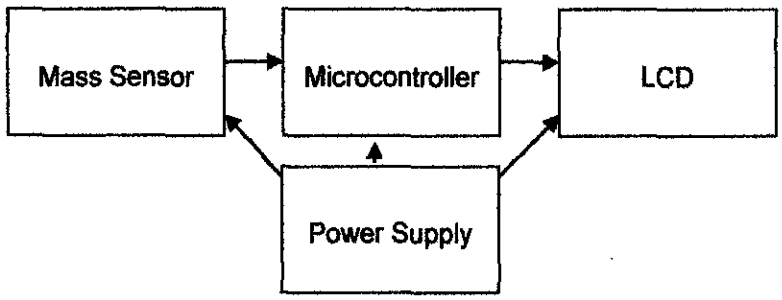


Figure 18: Block Diagram

3.4.2 Block Descriptions

LCD (Liquid Crystal Display): The LCD will display the name of the element after the mass of the element both in the air and when submerged is measured.

Microcontroller: The microcontroller, the brains of the device, performs all of the mathematical computations and control functions. It receives analogue inputs from the mass sensor, digitizes the analogue signals, processes the information to calculate the specific gravity of the elements, and then transmits the results to the LCD for display. The PIC microcontroller will be driven by a 4MHz external clock oscillator (FOX F1100E).

Power Supply: The power supply circuit is responsible for driving all the device components (LCD, PIC, sensors.). It will consist of a 9V battery, switch to control when the device is on and off, and a DC-DC step-up switch regulator, which will step the incoming 9V up to the 5V requirement of the sensors, microcontroller and LCD.

Mass Sensor: The mass sensor will determine the mass of the element in air, m_o, and the apparent mass of the elements when submerged into the water, m_s, and send all the values to the microcontroller for calculation of specific gravity.

CHAPTER 4

RESULT AND DISCUSSION

4.1 The Elements

In this project, the element identifier is expected to be able to measure the specific gravity and identify more than 100 elements. The elements and their specific gravity tables are shown in Appendix F. In this report, there are only 5 elements tested and they are tar, nickel, aluminium, titanium and diamond which are their specific gravity 1.2, 7.9, 2.64, 4.54 and 3.51 respectively. The uncertainty is +/- 0.5.

4.2 The Errors Involves

4.2.1 Analogue-To-Digital Converter

An **analogue-to-digital converter** (abbreviated **ADC**, **A/D** or **A to D**) is an electronic integrated circuit, which converts continuous signals to discrete digital numbers. The reverse operation is performed by a digital-to-analogue converter (**DAC**) [5].

Typically, an ADC is an electronic device that converts an input analogue voltage (or current) to a digital number. The digital output may be using different coding schemes, such as binary and two's complement binary. However, some non-electronic or only partially electronic devices, such as rotary encoders, can also be considered ADCs [5].

4.2.2 Quantization Error

When converting from an analogue signal a digital signal, error is unavoidable. An analogue signal is continuous, with ideally infinite accuracy, while the digital signal's accuracy is dependent on the quantization resolution, or number of bits of the analogue to digital converter. The difference between the actual analogue value and approximated digital value due to the "rounding" that occurs while converting is called **quantization error** [4].

4.3 The Schematic Diagram

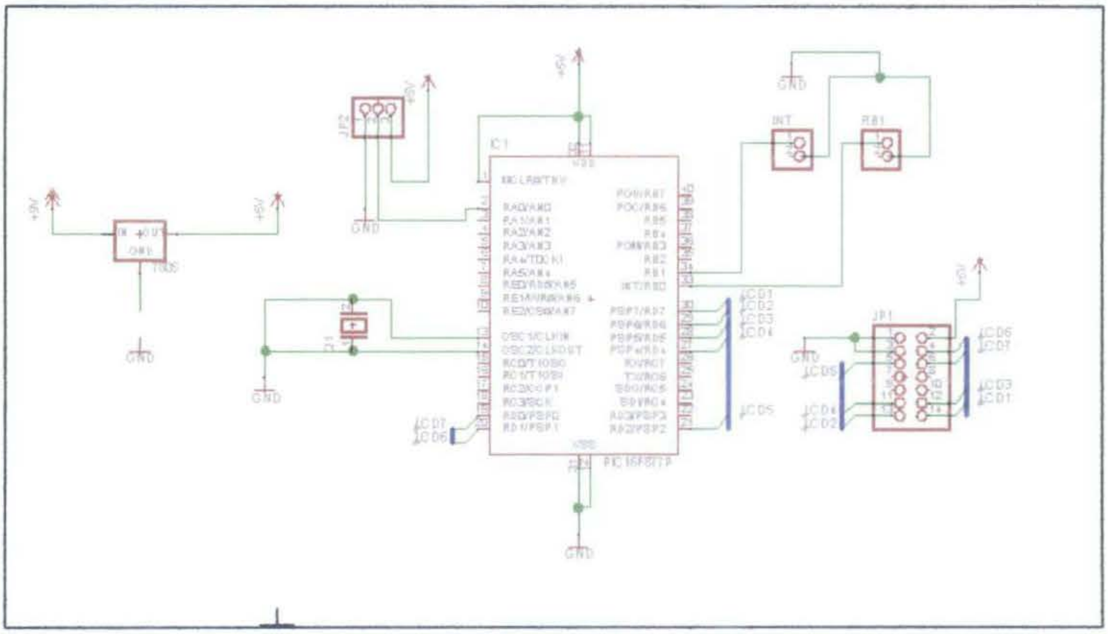


Figure 19: Schematic Diagram of Main Circuit

Figure above show the schematic diagram of the main circuit for this prototype element identifier. The schematic shows the connection of voltage regulator (7805), the supply unit, the clock and the LCD to the PIC.

4.4 The Working Program

The main program for calculation and identification is generated using software Borland C++ in C code. This code is tested to show the right elements given the mass value in the air and apparent submerged mass value.

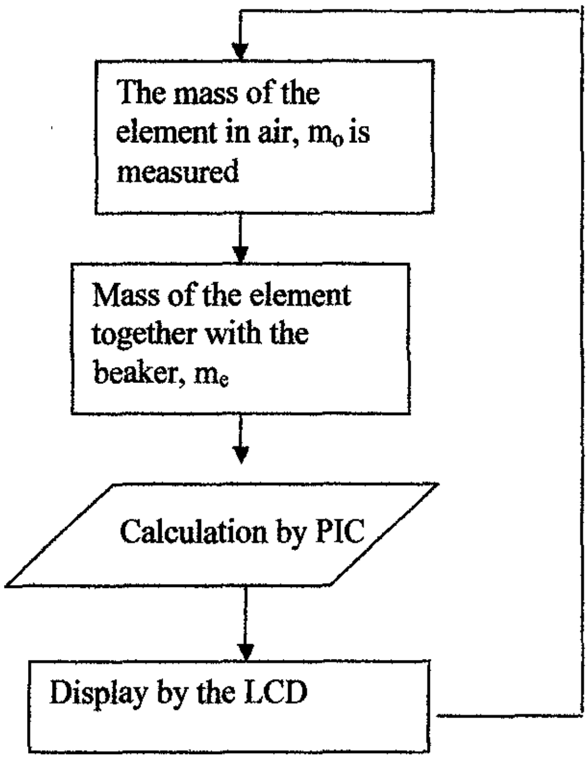


Figure 20: Flow Chart of Working Program

4.4.1 The C Code

```
#include <16F877A.h>
#device ADC=10
#fuses XT, NOWDT, NOPROTECT, NOPUT, NOBROWNOUT, NOLVP
#use delay(clock = 4000000)
#include <LCD.C>


float mass0;
float massE;
float massI = 490;
double sgravity;


void main()
{
  set_tris_d(0x00);  //output port for lcd
  lcd_init();
  set_tris_b(0xFF);
  setup_adc_ports(ALL_ANALOG);  //input port for variable resistor
  setup_adc(ADC_CLOCK_INTERNAL);

  while(1)
  {
   int readpin,readpin0;
   readpin = input(PIN_B0);
   readpin0 = input(PIN_B1);

   if(readpin == 1)
   {


   delay_ms(100);
   mass0 = read_adc();



   lcd_gotoxy(1,1);
   printf(lcd_putc,"Mass0");
   lcd_gotoxy(1,2);
   printf(lcd_putc,"%5.0fg",mass0);
   delay_ms(100);
  }else{


   delay_ms(100);
   massE = read_adc();
   sgravity = mass0/(mass0-massE+massI);

   if(readpin0==0){

   lcd_gotoxy(1,1);
   printf(lcd_putc,"%3.0f %3.0f",mass0,massE);
   }else if(readpin0==1){
   lcd_gotoxy(1,1);
   printf(lcd_putc,"SG %1.2f",sgravity);
   }
```

```
//lcd_gotoxy(1,2);
//printf(lcd_putc,"material");

if(sgravity<3.14 && sgravity>2.14){

lcd_gotoxy(1,2);
printf(lcd_putc,"**ALUM**");

}else if(sgravity >4.04 && sgravity <5.04){

lcd_gotoxy(1,2);
printf(lcd_putc,"**TITAN*");

}else if(sgravity >8.4 && sgravity <9.4){

lcd_gotoxy(1,2);
printf(lcd_putc,"**NICK**");

}else if(sgravity >0.7 && sgravity <1.7){

lcd_gotoxy(1,2);
printf(lcd_putc,"**TAR***");

}else if(sgravity <4.01 && sgravity >3.01){

lcd_gotoxy(1,2);
printf(lcd_putc,"*DIAMOND");
}else{

lcd_gotoxy(1,2);
printf(lcd_putc,"*NOMATCH");
}


}

}
}
```

4.5 Hardware Testing

The functionality of the hardware is tested as shown below:

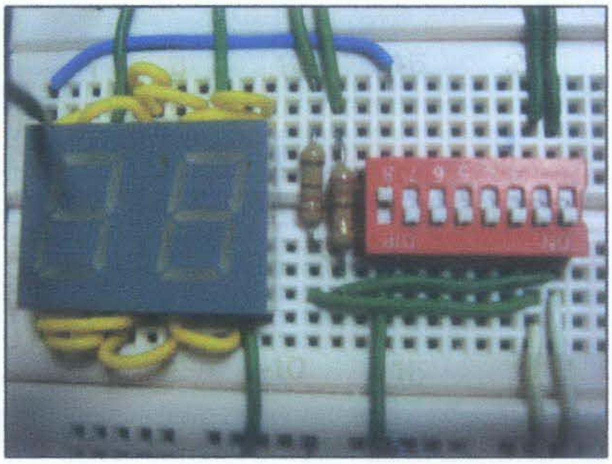


Figure 21: The Initial Condition of the Hardware

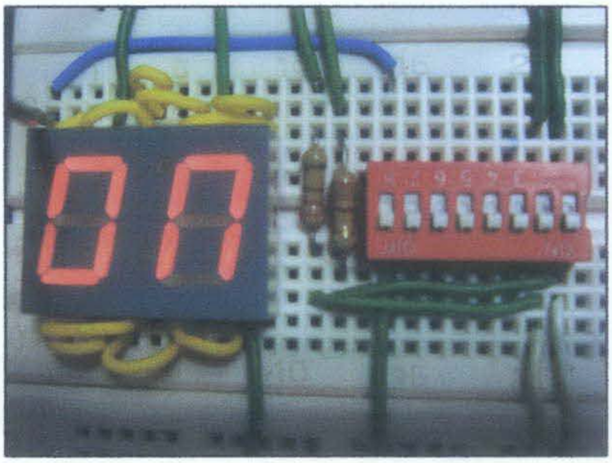


Figure 22: The Hardware in Switch On Mode

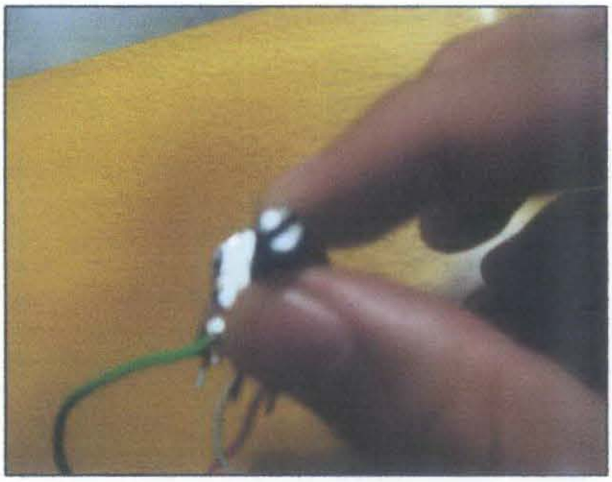


Figure 23: Vary the Mass Using the Potentiometer

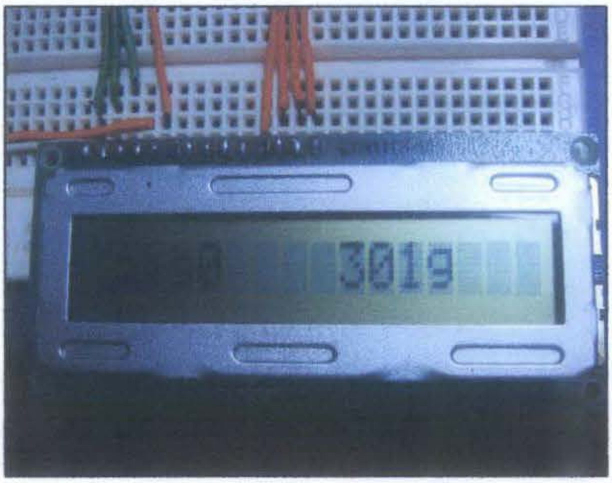


Figure 24: The LCD shows a value of 301 grams

Figure 23 and 24 above shows the example an element with a mass of 301 grams on air.

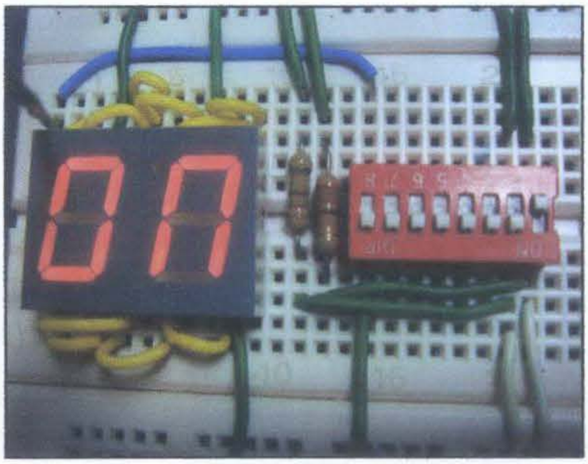


Figure 25: The Second Switch is Switched On

Figure 26: Test for Aluminium Specific Gravity

Figure 26: Test for Titanium Specific Gravity

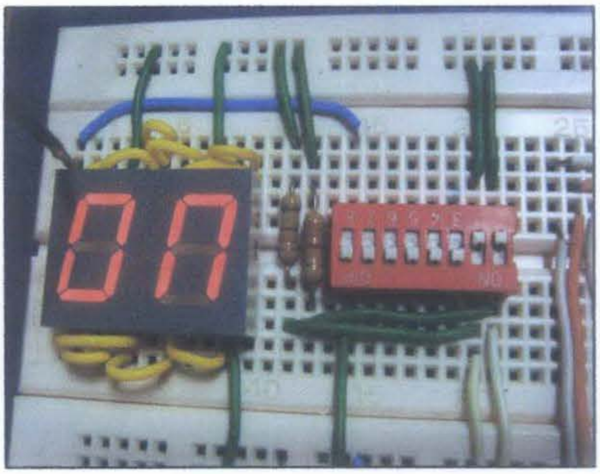


Figure 27: Third Switch is Switched On

The third switch is used to show the measured value in grams. The value indicated the value of the elements together with the beaker and water.

Figure 28: Test Mass Value for Aluminium

Figure 29: Test Mass Value for Titanium

Figure 30: Test Mass Value for Not Match

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this project, the element density can be determined indirectly from its specific gravity assuming in constant temperature and pressure. To identify the elements correctly and achieved high sensitivity of this element identifier, all the errors that effect the measurement of specific gravity need to be eliminated. There are several errors involved in measurement of the specific gravity in this project such as vibration and quantization. The sensor need to be well-calibrated and a few modification need to be added to the sensor in order to achieve high accuracy of reading. The kitchen scale used in this project can be replaced by hydraulic or electronic mass sensor. There are certain elements that have same specific gravity value and the use of fuzzy logic application can be use to effectively differentiate them. Due to the very small difference of specific gravity of certain elements, the database of this element identifier needs to be expanded to identify correctly the element and improve its performance.

REFERENCES

[1] http://www.me.utexas.edu/~dsclab/labs/elecmeas/level_sensor.html

[2] http://www.reade.com/br/Reference-%10-Educational/Particle-Property-Briefings/Specific- Gravity-Table-for-Metals,-Minerals-&-Ceramics.html

[3] http://www.reade.com/Particle_Briefings/spec_gra2.html

[4] http://en.wikipedia.org/Quantization

[5] http://en.wikipedia.org/ADC

[6] http://en.wikipedia.org/specific gravity

[7] http://en.wikipedia.org/density

[8] http://www.migatron.com/

[9] http://en.wikipedia.org/wiki/Archimedes

[10] http://en.wikipedia.org/wiki/Buoyancy

[11] http://hyperphysics.phy-astr.gsu.edu/Hbase/pbuoy.html#arch2

APPENDICES

APPENDIX A

Datasheet for PIC16F877A

MICROCHIP PIC16F874A/877A

40-Pin Enhanced FLASH Microcontroller Product Brief

High Performance RISC CPU:

- Only 35 single word instructions to learn
- All single cycle instructions except for program branches, which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to other 40-pin PIC16CXXX and PIC16FXXX microcontrollers

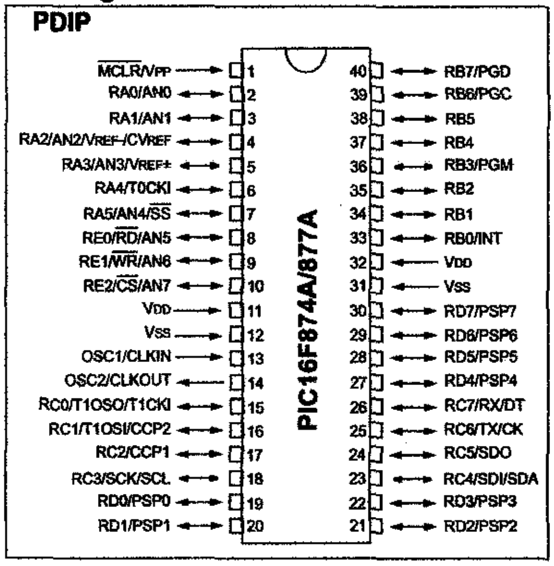
Peripheral Features:

- Timer0 module: 8-bit timer/counter with 8-bit prescaler
- Timer1 module: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2 module: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
- Master Synchronous Serial Port (MSSP) module. Two modes of operation:
  - 3-wire SPI™ (supports all 4 SPI modes)
  - I^2C™ Master and Slave mode
- Addressable USART module:
  - Supports interrupt on Address bit
- Parallel Slave Port (PSP) module 8-bits wide, external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls
- High Sink/Source Current: 25 mA

Analog Features:

- 10-bit 8-ch Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (VREF) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Pin Diagram:



CMOS Technology:

- Low power, high speed FLASH/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low power consumption

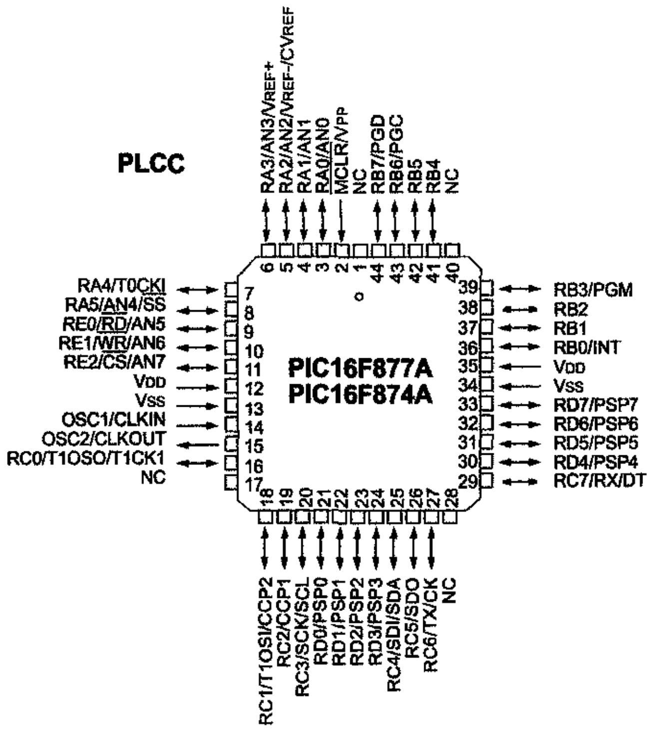
Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced FLASH program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

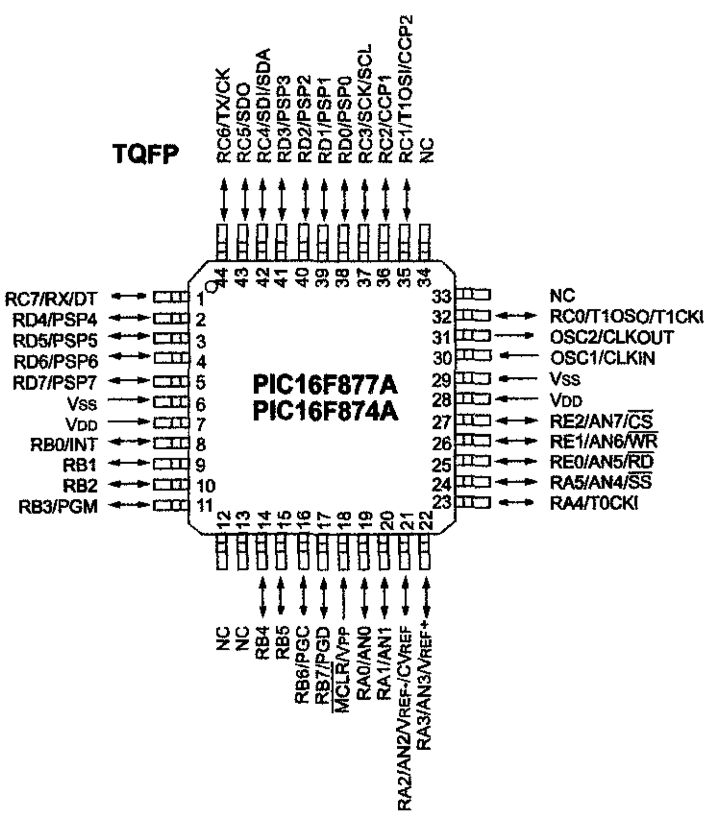
Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I^2C			
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2 / 1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2 / 1	2

Pin Diagrams:

PLCC



TQFP



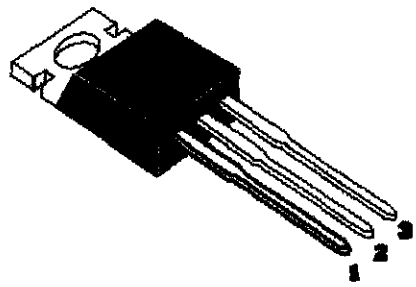
 Advance Information

APPENDIX B

Datasheet for Voltage Regulator 7805

3-TERMINAL POSITIVE VOLTAGE REGULATOR

Package: TO-220



PIN / STYLE	1	2	3
NO.1	I	G	O

FEATURES

*Output current In Excess Of 1A
*Fixed output voltage of 5V available
*Thermal overload shutdown protection
*Short circuit current limiting
*Output transistor SOA protection

ABSOLUTE MAXIMUM RATINGS

(Operating temperature range applies unless otherwise specified)

Characteristic	Symbol	Rating	Unit
Input voltage	V_I	35	V
Output Current	I_O	1.5	A
Power Dissipation	P_D	Internally Limited	mW
Operating Junction Temperature Range	T_{OPR}	-20~150	^0C
Storage Temperature Range	T_{STG}	-55~150	^0C

ELECTRICAL CHARACTERISTICS at Tamb=25°C

(V_I=10V, I_O=0.5A, 0°C<T_J<125°C, C_I=0.33uF, C_O=0.1uF, unless otherwise specified)(Note 1)

Characteristic	Symbol	Min	Typ	Max	Unit	Test Conditions
Output Voltage	V_O	4.8	5	5.2	V	T_J=25°C
Output Voltage	V_O	4.75		5.25	V	8V≤ V_I≤ 20V, I_O=5mA-1.0A PD<15W
Load Regulation	ΔV_O		1.3	100	mV	T_J=25°C, I_O=5mA-1.5A
Load Regulation	ΔV_O		0.15	50	mV	T_J=25°C, I_O=0.25A-0.75A
Line Regulation	ΔV_O		5	100	mV	7V≤ V_I≤ 25V, T_J=25°C
Line Regulation	ΔV_O		1.3	50	mV	8V≤ V_I ≤12V, T_J=25°C
Quiescent Current	Iq		3.2	8	mA	T_J=25°C
Quiescent Current Change	Δ Iq			1.3	mA	8V≤ V_I≤ 25V
Quiescent Current Change	Δ Iq			0.5	mA	5mA≤ I_O≤ 1.0A
Output Noise Voltage	V_N		10		uV	10Hz≤ f≤100kHz
Temperature coefficient of V_O	$\Delta V_O/\Delta T$		-0.30		mV/°C	
Ripple Rejection	RR		68		dB	8V≤ V_I≤ 18V, f=120Hz, T_J=25°C
Peak Output Current	Ipk		2.2		A	Tj=25°C
Short-Circuit Current	Isc		200		mA	Vi=35V, Tj=25°C
Dropout Voltage	V_D		2.0		V	T_J=25°C Io=1A

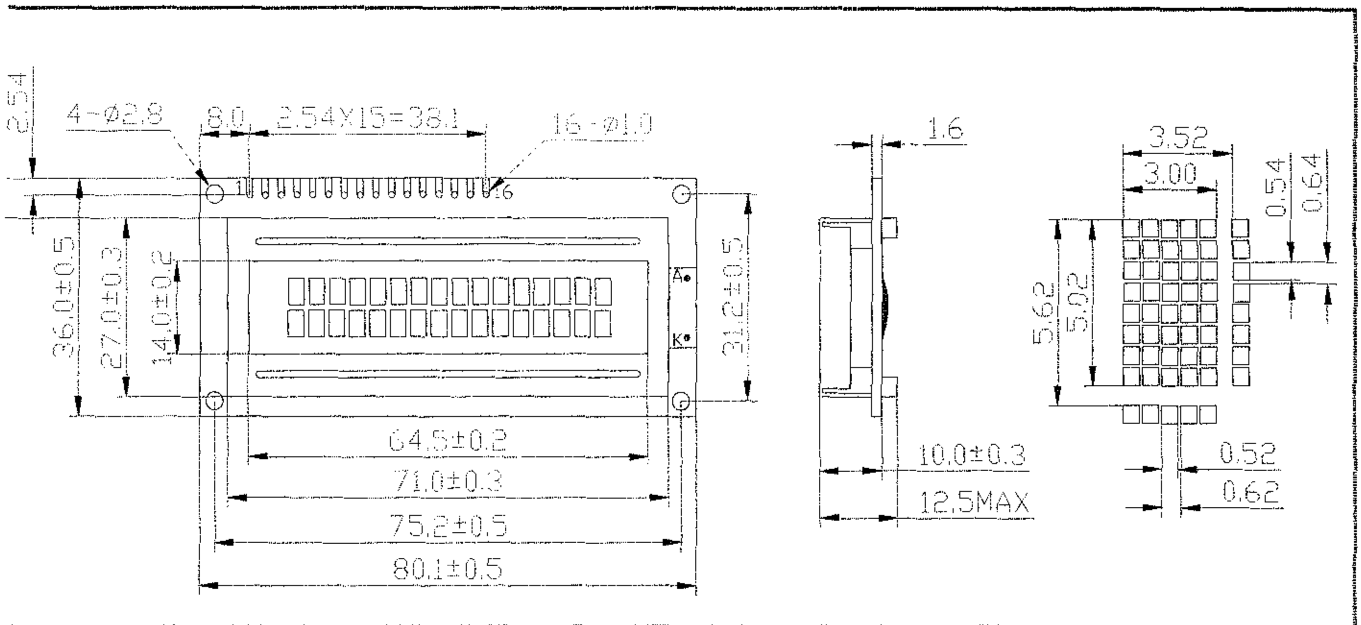
Note1: The maximum steady state usable output current is dependent on input voltage, heat sinking, lead length of the package and copper patten of PCB. The data above represent pulse test conditions with junction temperatures specified at the initiation of test.

APPENDIX C

Datasheet for RT1602C LCD

RT1602C

Tel:86-755-27931867, 27931884, 27931806, 27931875
FAX:86-755-27931864 Postcode:518102
E-Mail:ruite168@21cn.com Http://www.ruitelcd.com



...ANICAL DATA

	Nominal Dimensions	Unit
...e Size(W×H×T)	••••• ••••• ••••••••	mm
...g Area(W×H)	••••• ••••••••••••	mm
...ter Size(W×H)	••••• ••••••••••••	mm
...ze(W×H)	••••• ••••••••••••	mm

...LUTE MAXIMUM RATINGS

	Symbol	Min	Type	Max	Unit
...ing Voltage	VDD	•••	•••	••••	V
...ing Current	IDD	•••	•••	••••	mA
...Voltage	V_{LED}	•••	•••	••••	V
...Current	I_{LED}	••	•••	••••	mA
...ing Temp.	Topr	•••	•	•••	•
...e Temp.	Tsto	•••	•	•••	•

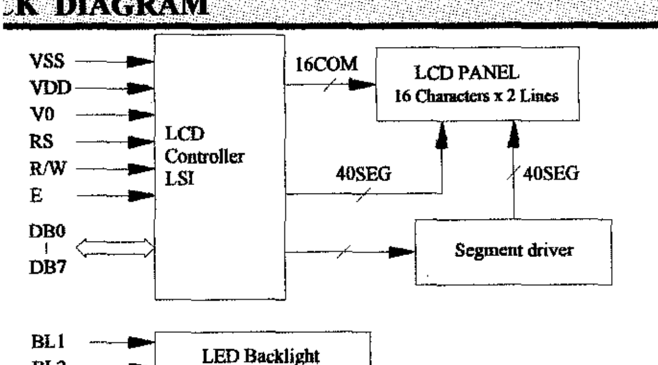
...TRICAL CHARACTERISTICS

	Symbol	Min	Type	Max	Unit
...Hight Voltage	V_{IH}	•••	•	••••	V
...Low Voltage	V_{IL}	•	•	••••	V
...t Hight Voltage	V_{OH}	•••	•	••••	V
...t Low Voltage	V_{OL}	•	•	••••	V

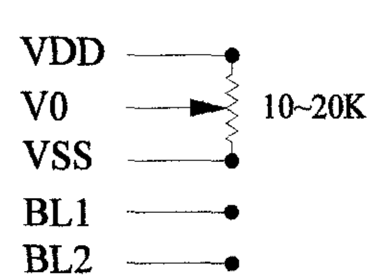
PIN CONNECTIONS

PIN	Symbol	Level	Function
•	GND	• •	GND(0V)
••	VDD	• •	Supply Voltage for Logic(+5V)
••	V0	• •	Power supply for LCD
••	RS	H/L	H: Data• •L: Instruction Code
••	R/W	H/L	H: Read• •L: Write
••	E	H/L	Enable Signal
••	DB0	H/L	Data Bus Line
•••	DB1	H/L	
•••	DB2	H/L	
••••	DB3	H/L	
••••	DB4	H/L	
••••	DB5	H/L	
••••	DB6	H/L	
••••	DB7	H/L	
••••	BL1	• •	Backlight Power(+5V)
••••	BL2	• •	Backlight Power(0V)

...K DIAGRAM



POWER SUPPLY



APPENDIX D

Datasheet for Oscillator FOX F1100E

TTL CLOCK OSCILLATOR
F1100E

The F1100E Clock Oscillator is TTL compatible and features fast rise/fall times with high reliability at low cost. The package is all metal with pin 7 as case ground which provides shielding to help minimize EMI radiation.

Actual Size

FASTFOX

FEATURES

- Industry Standard
- Low Cost
- Drives Full 10 TTL Load
- Wide Frequency Range
- Rugged Resistance Weld

• PART NUMBER SELECTION

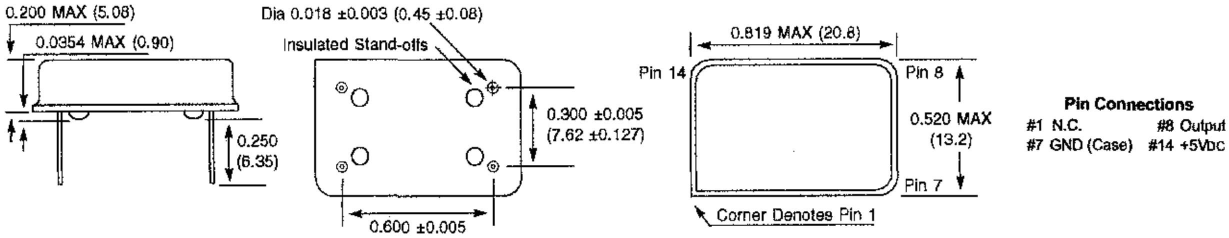
Frequency Stability	Part Number
±100PPM (STD)	F1100E
±50PPM	F1145E
±25PPM	F1144E

Note: -40°C ~ +85°C "R" version available (ex: F1100ER) to 70 MHz

• ELECTRICAL CHARACTERISTICS (Ta = 25°C, VDD = 5.0V, RL = 400Ω, CL = 15pF)

PARAMETERS		FREQUENCY RANGE	CONDITIONS	MIN	MAX	UNITS
Frequency Range	(Fo)			1.000	100.000	MHz
Frequency Stability		1.000 ~ 100.000	All Conditions*	-100	+100	PPM
Temperature Range		1.000 ~ 100.000				
Operating	(TOPR)			0	+70	°C
Storage	(TSTG)			-55	+125	
Supply Voltage	(VDD)	1.000 ~ 100.000		+4.5	+5.5	V
Input Current	(IDD)	1.000 ~ 8.000			15	mA
		8.000+ ~ 24.000			30	
		24.000+ ~ 70.000			70	
		70.000+ ~ 100.000			80	
Output Symmetry		1.000 ~ 8.000	1.4V Level	45	55	%
		8.000+ ~ 100.000		40	60	
Rise Time	(TR)	1.000 ~ 25.000	0.4V to 2.4V		10	nS
		25.000+ ~ 70.000	0.5V to 2.4V		5	
		70.000+ ~ 100.000	0.5V to 2.4V		4	
Fall Time	(TF)	1.000 ~ 25.000	2.4V to 0.4V		10	
		25.000+ ~ 70.000	2.4V to 0.5V		5	
		70.000+ ~ 100.000	2.4V to 0.5V		4	
Output Voltage	(VOL)	1.000 ~ 25.000	IOL = 20 mA		0.4	V
		25.000+ ~ 100.000			0.5	
	(VOH)	1.000 ~ 100.000	IOH = -1 mA	2.4		
Output Current	(IOL)	1.000 ~ 100.000	VOL = 0.5 V		20	mA
	(IOH)		VOH = 2.4 V		-1.0	
Output Load		1.000 ~ 100.000			10	TTL
Start-up Time	(TS)	1.000 ~ 3.500			20	mS
		3.500+ ~ 4.000			35	
		4.000+ ~ 6.000			30	
		6.000+ ~ 20.000			20	
		20.000+ ~ 100.000			15	

* Inclusive of 25°C tolerance, operating temperature range, input voltage change, load change, aging, shock, and vibration.
See page 35 for mechanical specifications, test circuits, and output waveform.
All specifications subject to change without notice. Rev. 7/8/98



Inch dimensions shall govern.
All dimensions are in inches & parenthetically in millimeters.

FOX Electronics 5570 Enterprise Parkway Fort Myers, Florida 33905 941-693-0099 FAX 941-693-1554 http://www.foxonline.com

APPENDIX E

Elements Name and Their Density

Table 2: the specific gravity of the elements

Elements Name	Specific Gravity
ABS	1.05
Acrylic	1.19
Aluminum min.	2.55
Aluminum max.	2.8
Aluminum Bronze	7.8
Antimony	6.69
Asbestos, cement board	1.4
Asbestos, mill board	1.0
Asbestos, rock	1.6
Asphalt	1.1
Bakelite, solid	1.4
Bark	0.25
Barite	4.5
Basalt rock min.	3.5
Basalt rock max.	3.2
Beeswax	0.95
Beryllium	1.85
Bismuth	9.75
Borax min.	1.7
Boron	2.32
Brick, common red	1.75
Brick, fire clay (firebrick)	2.4
Brick, hard	2.0
Brickwood, in cement	1.8
Brickwood, in mortar	1.6
Bronze aluminum	7.7
Bronze phosphor	8.88

Table 2: the specific gravity of the elements (cont)

Elements Name	Specific Gravity
Cadmium.	8.65
Calcium	4.58
Carbon min.	1.8
Carbon max.	2.1
Chalk	2.0
Charcoal, wood	0.4
Chromium	7.2
Clay min	1.8
Clay max.	2.6
Coal, anthracite	1.5
Coal, bitumious	1.2
Cobalt	8.9
Concrete, ligth	1.4
Concrete, stone	2.2
Corkboard	0.2
Copper .	8.96
CPVC	1.55
Diamond	3.51
Dolomite rock	2.9
Earth, dry	1.4
Emery	4.0
Epoxy	1.8
Fiberboard, ligth	0.24
Fiber hardboard	1.1
Glass min.	2.4
Glass max.	2.8
Glass crystal min.	2.9
Glass crystal max.	3
Glass plate min.	2.45
Glass plate max.	2.72
Gold, 22 carat fine	17.5
Gold, pure	19.32
Granite min.	2.4
Gypsum, solid	2.8
Gypsum, board	0.8
Hairfelt	0.1
Hematite	5.2
Hornblende	3
Ice (0°C, 32°F)	0.92
Iridium min.	21.78
Iridium max.	22.42
Iron cast min.	7.03
Iron cast max.	7.13
Iron slag	2.7
Iron wrought min.	7.6
Iron wrought max	7.9
Leather, dry	0.9
Limestone min.	2.1
Limestone max.	2.86
Lead	11.35
Leather	0.95

Table 2: the specific gravity of the elements (cont)

Elements Name	Specific Gravity
Limestone	2.6
Magnesite	3
Magnetite	3.2
Magnesium	1.74
Marble min.	2.6
Marble max.	2.86
Masonry	2.4
Mercury	13.546
Mica	2.7
Mineral wool blanket	0.1
Molybdenum	10.22
Mortar	1.5
Nickel	8.90
Niobium (Columbium)	8.57
Nylon 6 Cast	1.16
Oak, red	0.7
Osmium	22.57
Paper	0.9
Phosphorus	1.8
Plaster, light	0.7
Plastics, foamed	0.2
Plastics, solid	1.2
Platinum	21.45
Plutonium	19.84
Polycarbonate	1.19
Polyethylene	0.97
Polypropylene	0.91
Porcelain	2.5
Potassium	0.86
PTFE	2.19
Quarts min.	2.5
Quarts max.	2.8
Rhodium	12.41
Sandstone min.	2
Sandstone max.	2.6
Sawdust	0.15
Serpentine min.	2.7
Selenium	4.8
Serpentine max.	2.8
Silica aerogel	0.11
Silicon	2.33
Silver	10.50
Silver. German	8.58
Slate	2.8
Soapstone	2.7
Sodium	0.97
Steel	7.8

Table 2: the specific gravity of the elements (cont)

Elements Name	Specific Gravity
Sulfur	2.0
Talc min	2.6
Talc max.	2.8
Tantalium	16.6
Tar, bituminous	1.2
Tellurium min.	6
Tellurium max.	6.24
Thorium	11.7
Tile	1.8
Tin	7.31
Titanium	. 4.54
Trap rock	3.0
Tungsten	19.22
Uranium	18.8
Vanadium	5.96
Vermiculite	0.13
Vinyl ester	1.8
White metal	7.3
Wood, balsa	0.16
Wood, oak	0.7
Wood, white pine	0.5
Wood, felt	0.3
Wood, loose	0.1
Wool	1.32
Zinc blend min	3.9
Zinc blend max	4.2
Zinc min.	6.9
Zinc max.	7.2

APPENDIX F

Specific Gravity in Market-Densimeter

lectronic Densimeter SD-200L

r measuring solid and liquid specific gravity; Density resolution: 0.0001g/cm^3
apable of measuring solid specific gravity and volume, and its variations down to
e fourth decimal place.

FEATURES

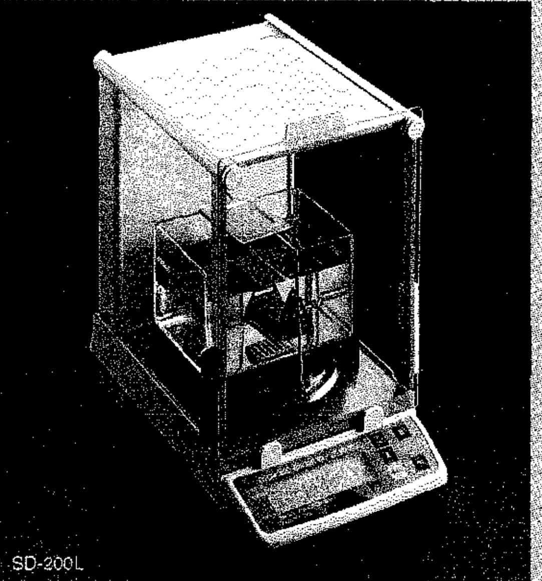
Densimeter with super-accuracy of density resolution of 0.0001g/cm^3.

Very simple measuring procedure allows anyone to use easily.

Solid volume and specific gravity of solid and liquid can be measured with one unit.

SOLID MODE

Capable of measuring volume variation factor.
Capable of indicating errors for the measured value.
Capable of setting measurement time at will.
Capable of compensating water temperature at will; capable of compensating water temperature, which is required for the measurement of the specific gravity.
Capable of measuring plastic pellets.
Capable of measuring readily floating samples, such as urethane rubber, plastics, sponge, and wood.



SD-200L

LIQUID MODE

Measurement time needed is about 20 seconds.
Volume of sample needed for measurement is about 50cc.
To measure different samples successively, just simply replace the beaker.
A measurement result represents only value obtained through measurement at room temperature.

Indication: Weight in the air; Weight in the water; Value of specific gravity; Volume

Sales volume: about 1,000 units

OPTIONAL PARTS

Printer AD-8121B: Dot impact type

Liquid gravity kit, which is need for measurement of liquid.

RS-232C Interface, which is indispensable in case of connection with a printer or a PC.

ISO-related documents: Traceability; Calibration Certificate; Report on of Inspection Results.

SPECIFICATIONS

roduct Name	Electronic Densimeter SD-200L
ensity resolution	0.0001g/cm^3
cale capacity	0.01～200g
leasuring Method	Conform to Pycnometer and Hydrostatic Method
tandards	JIS K6268A, former JIS K6350 (Rubber), JIS K7112 (Plastic) etc ASTM D297-93-16 (Rubber), ASTM D792-00 (Plastic) etc
ower source	AC115～240V
imensions	213 (W) × 319 (D) × 301 (H); Weight: 5.8kg

·LECTRONIC DENSIMETER MD-300S

or measuring solid and liquid specific gravity; Density resolution: 0.001g/cm³
general – purpose new model with high accuracy debuts with additional functions equipped.

FEATURES


MD-300S

Highly precise general-purpose model with density resolution of 0.001g/cm³, *measurable weight 0.01∼300g.*

Capable of measuring specific gravity of liquid (other than those with high viscosity, which need optional parts).

Capable of setting the actual water temperature and specific gravity of the solution with front keys and automatically compensating the measured specific gravity.

Capable of measuring plastic pellets.

Capable of measuring readily floating samples, such as urethane rubber, plastics, sponge, and wood.

Result judgments with Comparator Mode is available.

Optional Setting Mode is available for distinction of uncertain sample or development of new material.

Easy connection to PC with standard equipped interface (RS232C: 9 pins, male connector).

Capable to measure the compensated liquid density by setting *compensated liquid temperature and compensating temperature rate.*

Indication: Weight in the air; Weight in the water; Value of specific gravity; Volume

OPTIONAL PARTS

Printer AD-8121B: Dot impact type

Liquid gravity kit, which is need for measurement of liquid.

ISO-related documents: Traceability; Calibration Certificate; Report on of Inspection Results.

SPECIFICATIONS

roduct Name	Electronic Densimeter MD-300S
ensity resolution	0.001g/cm³
cale capacity	0.01∼300g
leasuring Method	Conform to Pycnometer and Hydrostatic Method
tandards	JIS K6268A, former JIS K6350 (Rubber), JIS K7112 (Plastic) etc ASTM D297 – 93 – 16 (Rubber), ASTM D792 – 00 (Plastic) etc
ower source	AC115∼240V
imensions	(D)218 × (W)190 × (H)170mm / 1.54kg
ccessories	Airtight windshield

ELECTRONIC DENSIMETER EW-300SG

or measuring solid density; Density resolution: 0.01g/cm³
t takes only 10 seconds to measure.
he most suitable instrument to use for specific gravity inspection on the production line.

FEATURES

General – purpose type with density resolution of 0.01g/cm³, measurable weight 0.01～300g.

Very simple measuring procedure allows anyone to use easily.

Capable of measuring instantaneously (measurement time: about 10 seconds), this is the most suitable for the users, who have a number of samples to be measured, to use.

Capable of measuring specific gravity of floating samples, such as urethane rubber, plastics, sponge, and wood, in the water.

Result judgments with Comparator Mode is available.

Easy connection to PC with standard equipped Interface (RS232C: 9 pins, male connector).

Ethanol can be used as a liquid medium with improved Styrol Water Tank.

Measuring the change rate of density.

Indication: Weight in the air; Value of specific gravity; Volume.

EW-300SG

OPTIONAL PARTS

Printer AD-8121B: Dot impact type .

Airtight windshield: EW-300SG is not equipped with an airtight windshield, which is necessary, in case measurement may be difficult due to effect of wind.

ISO-related documents: Traceability; Calibration Certificate; Report on of Inspection Results.

SPECIFICATIONS

Product Name	Electronic Densimeter EW-300SG
Density resolution	0.01g/cm³
Scale capacity	0.01～300g
Measuring Method	Conform to Pycnometer and Hydrostatic Method
Standards	JIS K6268A, former JIS K6350 (Rubber), JIS K7112 (Plastic) etc ASTM D297－93－16 (Rubber), ASTM D792－00 (Plastic) etc
Power source	AC115～240V
Dimensions	(D)218 × (W)190 × (H)170mm / 1.54kg