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Design of a Liquid Level Detector with a Digital Readout

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ABSTRACT: *The work Liquid Level Detector with Digital Readout serves for the use to eliminate the risk and inaccuracies involved in the usual dipping method used and also avert controversy encountered during supply of liquid products. The device is capable of sensing the level of liquid, accept the binary value and display the digital equivalent. It incorporates a switch sensor which senses the liquid level. A method for determining a liquid level in a vessel includes collecting a charge on an electrode, sensing the collected charge on the electrode with a capacitance sensor through an electrical line, and determining a liquid level in a vessel based on the collected charge sensed by the capacitance sensor.*

***KEYWORDS**: Sensor, transistors, 7 segment display driver, Amplifiers, Resistors, Capacitors.*

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I. INTRODUCTION

Liquid level detector is an instrument which indicates the level or the volume of liquid in a container, or generally in an enclosure [1]. For several years till date liquid level detectors for liquid products have been used largely by distributors in tankers and are also incorporated in motor vehicles, motor cycles, ships and airplanes [2]. In motor vehicles, analogue display meter are used [2-3].This is an introduction of an electronic circuit that will give an accurate form of reading of the level of a liquid and present the result in a form that could be read and understood in a digital readout using 7-segment display[4]. Also, the tank would be calibrated internally in S.I unit for precision reading, using low power consumption.

The choice of the most suitable level sensor for specific application is based on the following requirements range of measurement inside tank, characteristics of the liquid, resolution, accuracy, and Environment inside tank [5]. Since an analogue display meter is involved it would be difficult to obtain an accurate reading. The display meter shows the position of the needle which indicates the level of fuel in the tank [6-7]. In Nigeria today, dipping method is mostly used by petroleum product dealers in Nigeria. Dipping is carried out by inserting a calibrated rule into the tank through an opening created at the top of the tank. This is the only method that was in use in this aspect and is still in use till date.

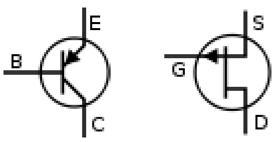
II. AIM

The aim of this work is to design a liquid level detector that will achieve high accuracy in detecting the level of liquid products, and reveal the volume in such a way that it would be understood worldwide. The electronic circuit will measure accurately the level of the liquid and display the result in a digital readout.

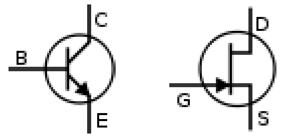
III. COMPONENTS AND SPECIFICATIONS

3.1 Transistor indicator level switch

The essential usefulness of this transistor used comes from its ability to use a small signal applied between one pair of its terminals to control a much larger signal at another pair of terminals [8].



P channel



N channel

Figure 1: BJT and JFET symbols

3.3 4511 BCD 7-segment display drivers

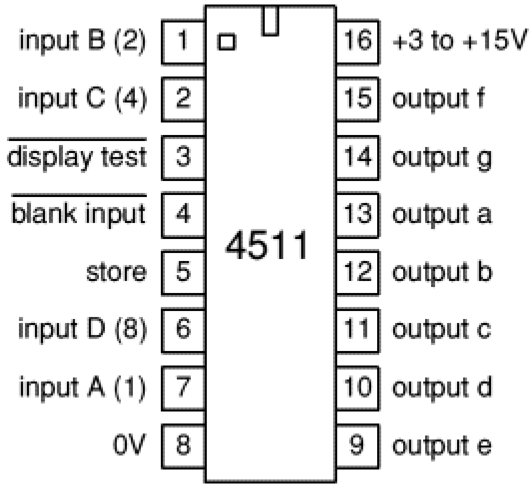


Figure 2: 4511 BCD to 7-segment display driver

The appropriate outputs a-g becomes high to display the binary coded decimal number supplied on inputs A-D. The outputs a-g can source up to 25mA. The 7-segment display segments must be connected between the outputs and 0V with a resistor in series of 330Ω and a 5V supply. A common cathode display was used.

Display test and blank input are active-low so they should be high for normal operation. When display test is low all the display segments should light and when blank input is low the display will be blank. The store input should be low for normal operation. When store is high the displayed number is stored internally to give a constant display regardless of any changes which may occur to the inputs A-D. The 4511 is intended for BCD (binary coded decimal). Inputs values from 10 to 15 (1010 to 1111 in binary) will give a blank display (all segments off).

3.4 7 segments LED display for digital readout

An LED package with a digital readout was used, each LED was connected with one terminal to its own pin, while the other LED terminal connected in common with all other LEDs in the device and brought out to a shared pin. This shared pin will then make up all of the cathodes (negative terminals) OR all of the anodes (positive terminals) of the LEDs in the device; and so will be either a "Common Cathode" or "Common Anode" device depending how it is constructed. Hence a 7 segment plus display package will only require nine pins to be present and connected.

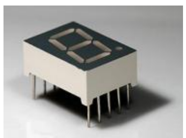


Figure 3: Seven Segment Display

3.5 Low power rectifier circuit for the power supply

The PSU converts the 220V from the Mains voltage to approximately 12V and 5V dealing with digital integrated circuit. Figure 4 shows the circuit diagram of the power supply unit.

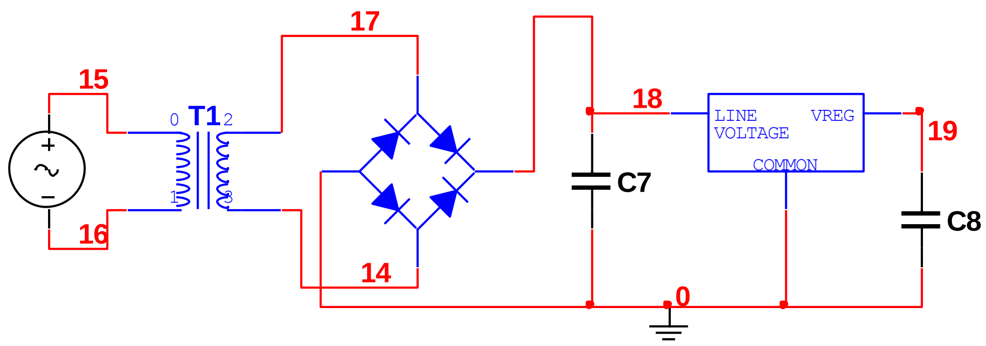


Figure 4: Low power rectifier circuit for the power supply

IV. DESIGN METHODS

The design of the Liquid level detector system is divided into three sections which are the Level Detector Unit, Encoder and the Decoder and Display as shown in figure 5. A darlington pair transistor with an open base is used because of its high gain ability. When the liquid reaches a particular level it would drive the base of the darlington pair into saturation, thereby producing an equivalent output. The liquid whose level is to be measured makes use of its electrical conductivity. The switch sensor comprises probes which are a little spaced apart that are immersed completely into the liquid. As the liquid gets to the 1st level and 2nd level , it saturates the 1st transistor and 2nd transistor respectively. This process repeats itself for the 3rd level and so on.The signals from the Transistor indicator level switches are amplified with an op-amp used as a comparator having only two states namely the Vcc and GROUND. The signals will be at the inverting input while a reference is placed at the non-inverting input. When a signal is received from the transistors due to a detected liquid level, the OP-AMP will be negatively saturated and produce an output equal to –Vcc . Ten of such outputs are possible in this project. These signals are thus fed to a coding circuit. The coding circuit consists of a 74147MCU, this is an integrated circuit designated to produce a binary equivalent to its decimal input. It is called a 3 – 10 bits decimal to binary priority encoder. The outputs from the amplifier circuits are connected directly as the input of the priority encoder. As each amplifier produces the required signal, the 74147MCU produces a binary equivalent corresponding to the signal which OP-AMP is supplying. The input to the encoder is active low, hence it responds to saturated signals from the OP-AMP output. The Modulator circuit reconverts the low output of the 74147 so that it will be meaningful to the decoder circuit. The decoder circuit comprises of a 4511 7 – segment LED display drive. This is an integrated circuit designed to display a decimal readout of its equivalent binary input on the 7 – segment LED. This binary input is got from the modulator circuit. The binary signals by design always correspond to the detected liquid level in the container. Finally, the 7 – segment LED displays the liquid level in liters digitally.

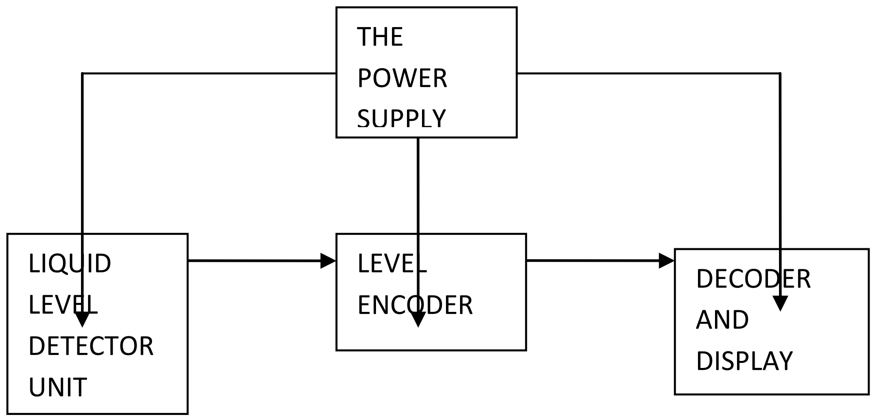


Figure 5: Block diagram of the liquid level detector system.

THE LIQUID LEVEL DETECTOR UNIT

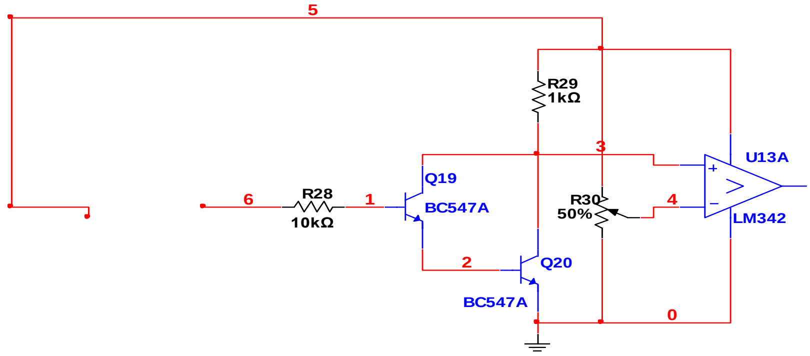


Figure 6: Circuit diagram of the liquid level detector unit

This is the circuit that detects the liquid level. The R2 is the collector resistor, necessary for collector current to flow. Its value is chosen at 1kΩ while R1 is a base resistor necessary for switching.

For effective switching, R1 is given as R1=10 ×R2
R1 = 10 × 1000
R1 = 10,000 or 10kΩ.
R3 sets the reference voltage for the comparator and it is desired that this reference be about 50% of the supply.
Va = 5v,

50% of Va = 0.5 × 5 = 2.5V.
Using Voltage Divider Rule; [8]

$$Vout = \frac{R_2}{R_1 + R} V_{in} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [1]$$

$$\frac{\text{Vout}}{\text{Vin}} = \frac{\text{R2}}{\text{R1} + \text{R}} = \frac{2.5}{5} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [2]$$

Manipulating the above equation, it is found out the setting R2 = R1, the above relationship will be satisfied. R1 R2 = Variable resistor = 10kΩ.The op – amp chosen is the LM 324. For its load Op-amp characteristics and its utilization of a single polarity power supply unit.

THE ENCODER UNIT

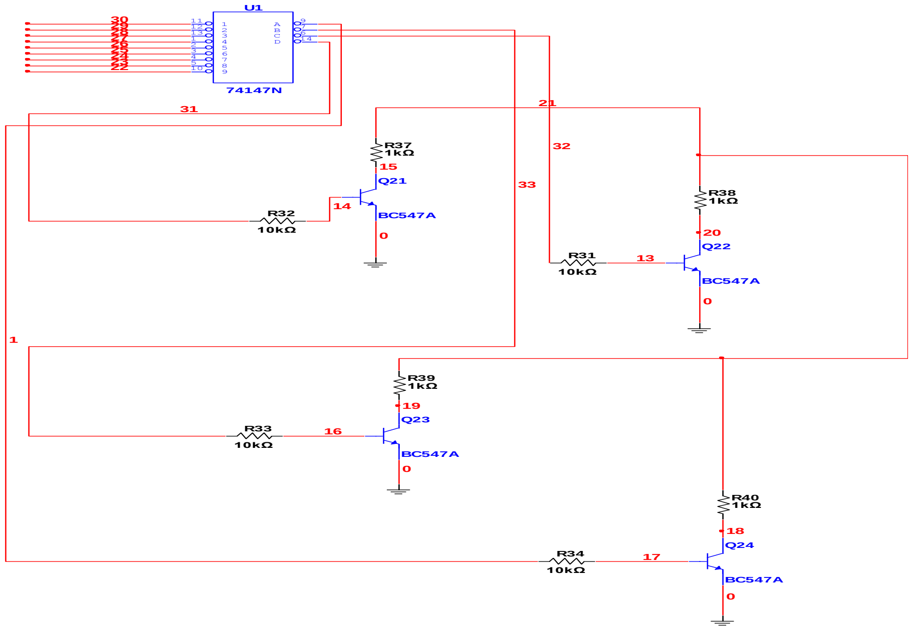


Figure 6: The circuit diagram of the Encoder Unit

This is the 10 to 4 bit priority encoder. The transistors are to be used as inverters. So any transistor with a high gain could be used. The base resistor and collector resistor of the transistor are given by the relationship.

$R_b = 10 \times R_c$ … … … … … … … … … … … … [3]

Equation 3, must be satisfied for effective switching. Choosing

Rb = 1000Ω

Rb = 10000/10

Rc = 100Ω

Rb = 10kΩ, Rc = 1kΩ

THE DECODER AND DISPLAY

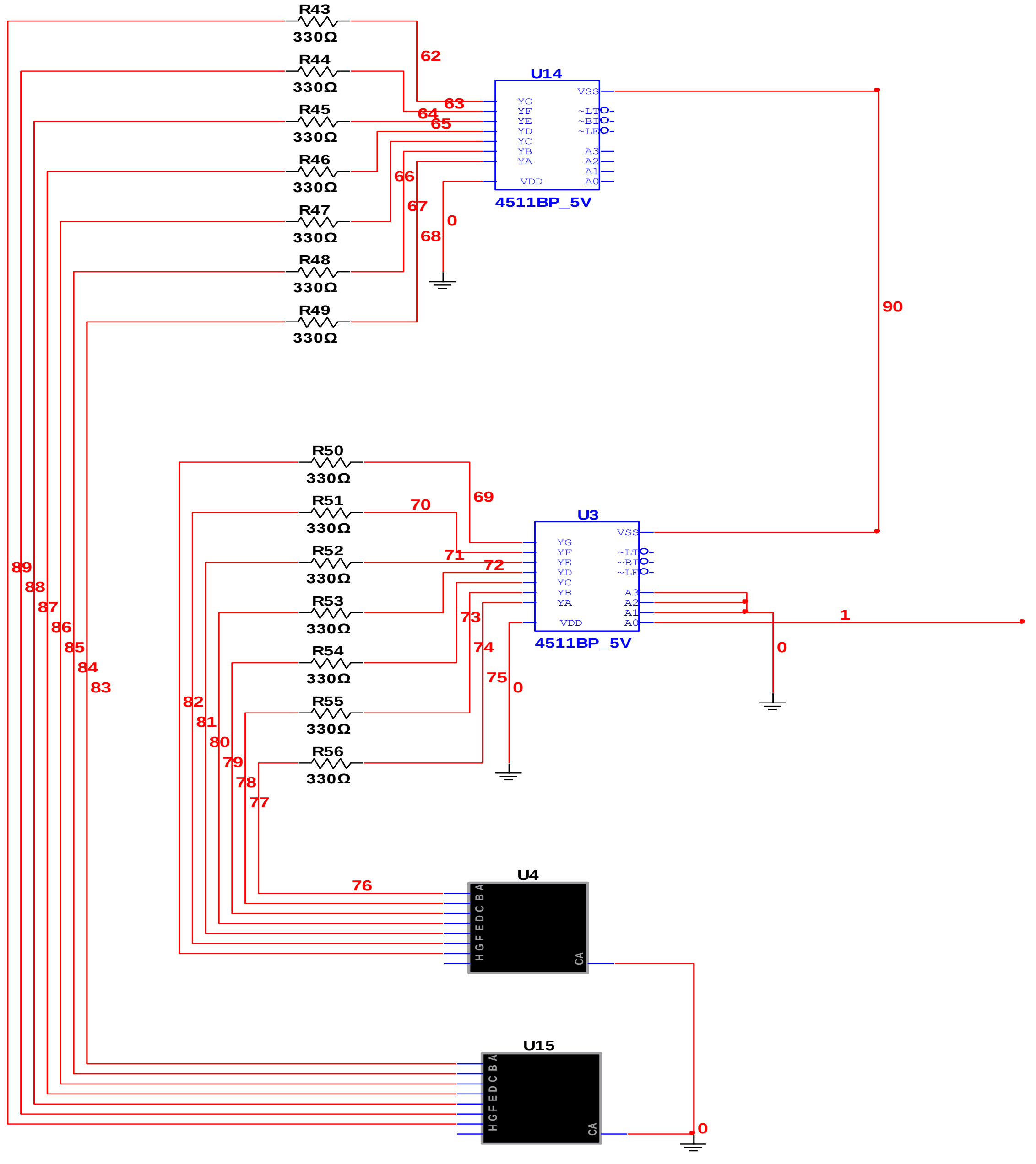


Figure 7: The circuit diagram of the Decoder and display Unit

THE CIRCUIT DIAGRAM

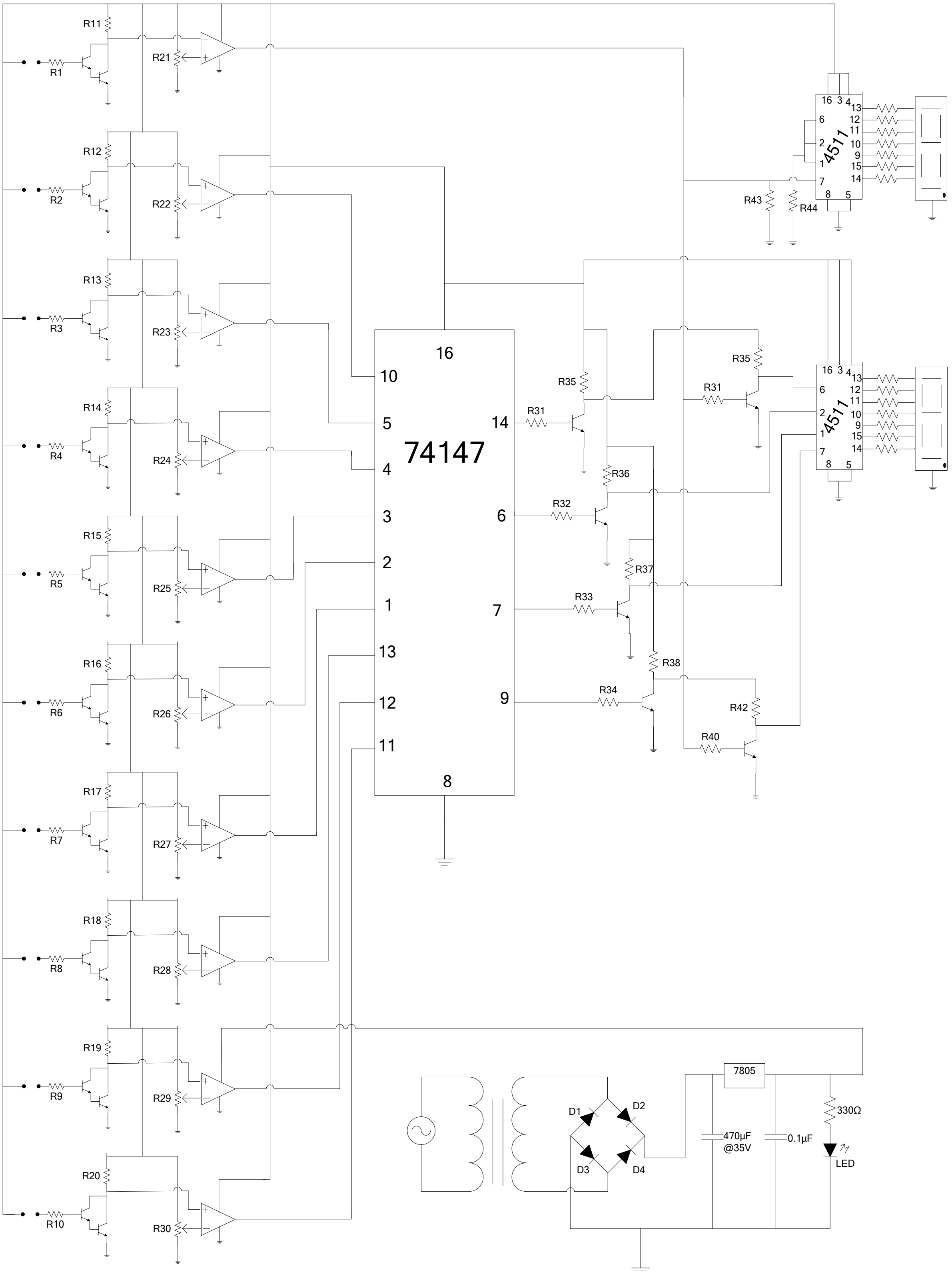


Figure 8: Complete circuit diagram of the liquid level detector unit with a digital read out.

V. MODE OF OPERATION

The liquid container is segmented into ten parts, as the liquid level gets to a set reference, it closes the switch while other switches remain open. Thus current flows into the base of the darlington pair transistor. At each level of liquid is indicated, the darlington pair transistor sends out current to the Lm 324 Operational Amplifier .The operational amplifier sends this current to a 3 – 10 bits decimal to binary priority encoder. This phenomenon repeats itself as the liquid rises to higher levels. This means that the second darlington pair transistor would produce an output when the liquid level gets to two litres, the third darlington pair transistor would produce an output when the liquid gets to three litres. This continues until it gets to the tenth litre. Although, hundreds of thousand litres can be obtained but for the sake of this project only ten litres are to be calibrated for. Each output from the darlington pair transistor is in turn amplified by the LM 324 Operational amplifier, the output from the amplifier are fed into the 3 – 10 bits priority encoder. This integrated circuit is an active low device, therefore it needs a negative collector current (-Vcc) for its trigger. The outputs from the encoder are the binary equivalents of the corresponding decimal input. However, since the output is an active low output, it is inverted. This means that a binary 2 (0010) would be displayed as 1101 while a binary 6 (0101) would be displayed as 1010. The final output is then fed into the 7 – segment LED display Driver 4511 . This integrated circuit would display a decimal digital readout on the 7 – segment LED, a decimal number corresponding to its binary input. Thus, for every binary output, it is displayed as a readable decimal digit at each level. Liquid level can be read off directly from the 7 – segment LED. Hence, we have the digital display.

VI. CONCLUSION

This project design is capable of producing the digital display of the value of liquid in a container. It helped increase accuracy in measurement and as well ease the stress of gauging the level of liquid products especially in tankers in Nigeria where dipping method is used. A test carried out on the design ensured that the liquid level detector functioned according to specification. This test helped to ascertain that its behavior did not deviate from what was expected. Thus the design was good**.** The liquid level detector is generally useful to all liquid product dealers such as petroleum product dealers, water suppliers and so on. It is convenient, efficient, and easy to operate.

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