On The Electrochemical Etching Of Tips For Scanning Tunneling Microscopy

By

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Contents

1.Introduction

The scanning tunneling microscope (STM) is widely known and important surface science instrument, its capacity to perform atomic scale characterization being cause of this importance. The tunneling phenomenon in the microscope occurs when a conductive sample and very sharp metallic tip are placed in near contact separation (<1nm) and voltage difference is applied between them.[1]

From very first experiment with STM it is known that its resolution depends on the sharpness of the tips, with increasing sharpness directly leading to better resolution (up-to atomic resolution). This STM tips are fabricated mostly with Platinum-Iridium or Tungsten wires. Pt - Ir tips are made either by cutting or electrochemical methods, the former being more usual. On the other hand, tungsten tips are fabricated exclusively by electrochemical methods. One of this method is DC drop off method.[2]

In the DC drop off method, the Dc voltage is applied between two electrodes immersed in electrolytic solution, the tungsten wire being the anode. Materials is removed from the tungsten wire, once the voltage is applied between anode and extra electrode. If electrochemical cell is properly constructed, the removal of material will cause formation of neck in tungsten wire which will lead ultimately to its rupture, leaving a sharp tip in zone where fracture occurs.[3]

The name of the method comes from the fact that when the wire breaks, the portion of the wire below fracture zone drops into electrochemical solution, while upper part is used as scanning tip.[1]

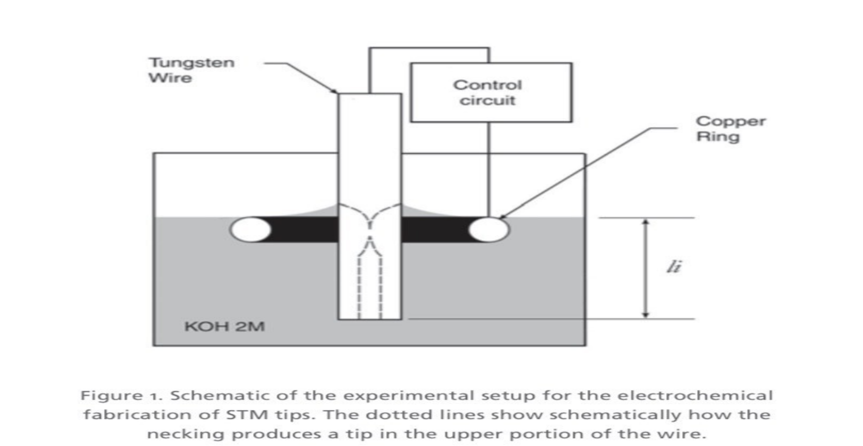


Figure 1: Experimental setup for electrochemical fabrication of STM tips

Relevant parameters for this method have been shown to be voltages in the reaction, which must make process electrochemical one.[4] The length of wire which drops depth of immersion) which mainly defines aspect ratio of the tip 9 tip length over wire diameter) and the time between the drop off and the removal of voltage, called cut-off time, which has an important effect on tip sharpness (tip radius), shorter times lead to sharper tips.[1]

2. Methodology

The experimental set-up (electrochemical cell) used is schematically shown on Figure 1. Polycrystalline tungsten wire (Good fellow 0.5 mm dia. 99.95% pure)
is immersed to a depth in KOH (85% pure) 2M. The depth of immersion is controlled and measured by the turning of a screw. In the surface of the liquid there is a copper wire (23AWG) bend in the form at a circular ring (8 mm dia.). Both ring and wire serve as electrodes in the electrochemical reaction, the wire being anode.[5]

The potential difference is applied by means of a control circuit designed to monitorize the electro polishing current and also to provide appropriate cut- off times in order to obtain sharp tips. It is based on a design by Nakamura. In this circuit the electro polishing current is controlled by means of potentiometer. The emitter-follower Q3 pass a voltage signal to a differentiator. This signal is analogous to the electro polishing current.[6] When there is a sudden fall in this quantity, which indicates tip formation (rupture), the differentiator provides a peak of voltage which in turn changes the state of a flip-flop. The flip-flop turns on transistors Q1 and Q2, Q1 lowers the gate voltage of Q4, thus cutting the voltage provided to the electrochemical reaction. Cut-off times of 160 ns are typical.[5,7]

To measure the effect of depth of immersion in tip morphology and radius, experiments for 2 mm and 3 mm are carried out. The respective voltagram (I-V
curve) of each situation is obtained, and the reaction is performed in the optimum I-V ranges. Tip radius and morphology is observed in a FEI Quanta 200 Scanning Electron Microscope (SEM).[5]

For 2 mm of immersion is consistently 0.68 (evaluated in five tips), with standard deviation 0.01. For 3 mm it is consistently 0.83 (evaluated again in five tips), with standard deviation 0.05. Then, 2 mm of immersion is a better condition, as the aspect ratio is lower, thus making the tip less susceptible to vibrations while operating in the STM. The increasing of aspect ratio by increasing depth of immersion has been observed.[5]

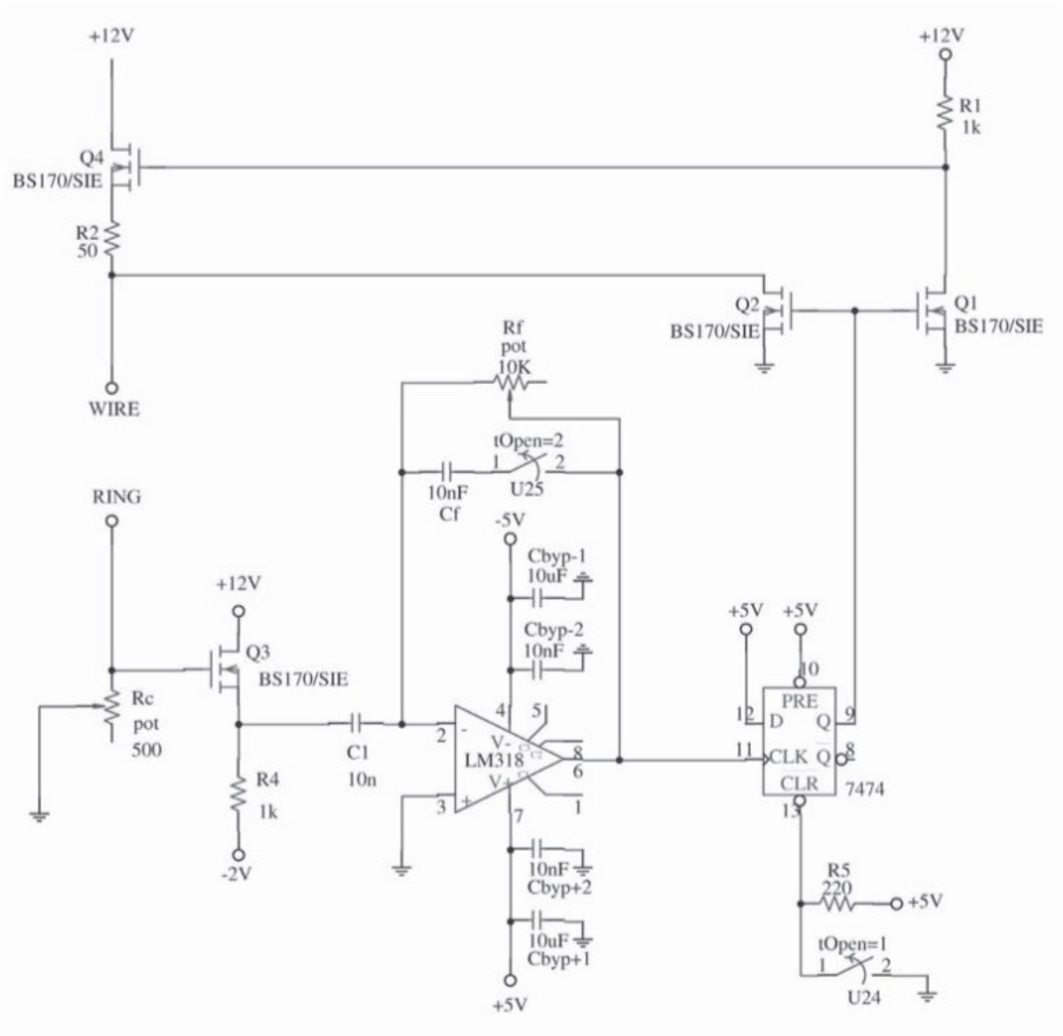


Figure 2. Control circuit used to monitorize the electropolishing current and to provide short cut-off times.

Figure 2: Control circuit used to monitorize the electropolishing current and to provide short cut-off times.

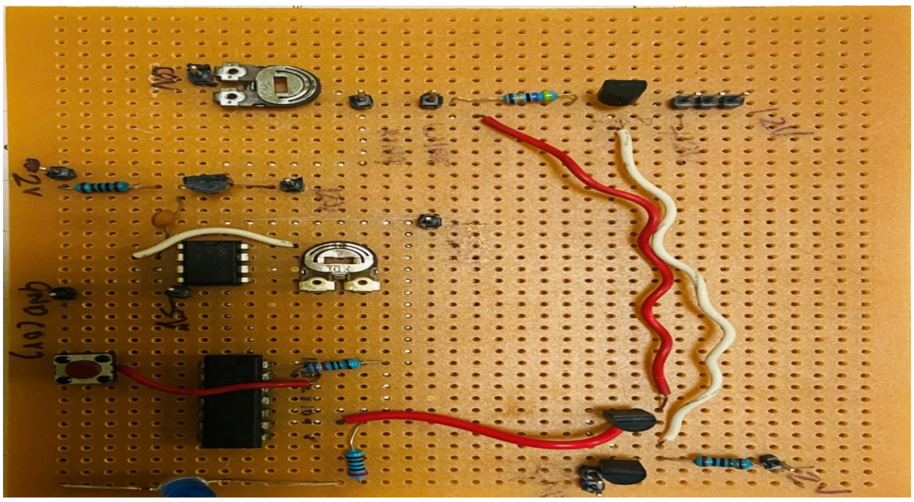


Figure 3: Scanning Tunneling tip circuit.

3. Theoretical Methods

i. Resistor Colour Coding

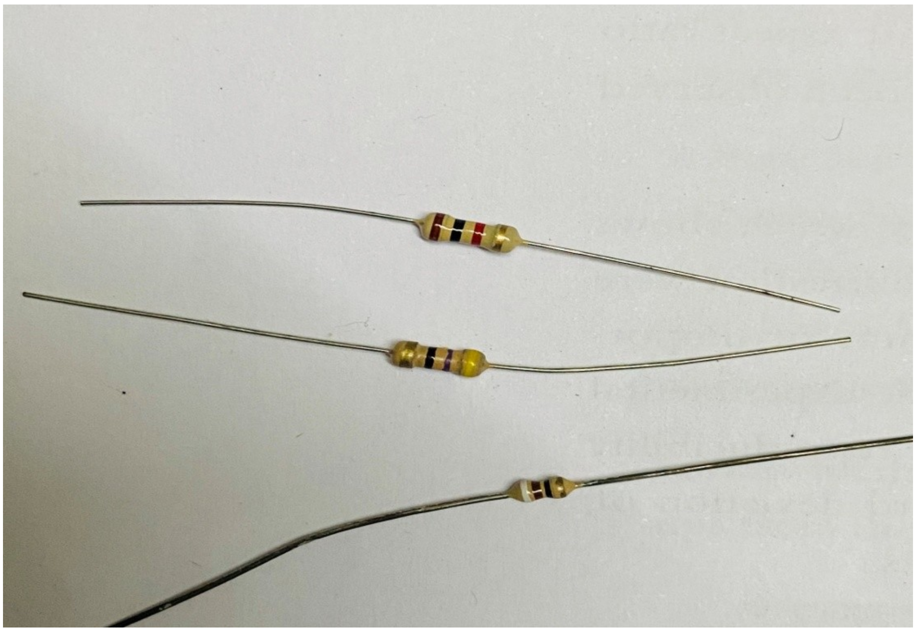


Figure 4: Resistor colour coding

COLOUR	NUMBER	MULTIPLIER	TOLERANCE (%)
Black	0	10 E0	
Brown	1	10 E1	
Red	2	10 E2	
Orange	3	10 E3	
Yellow	4	10 E4	
Green	5	10 E5	
Blue	6	10 E6	
Violet	7	10 E7	

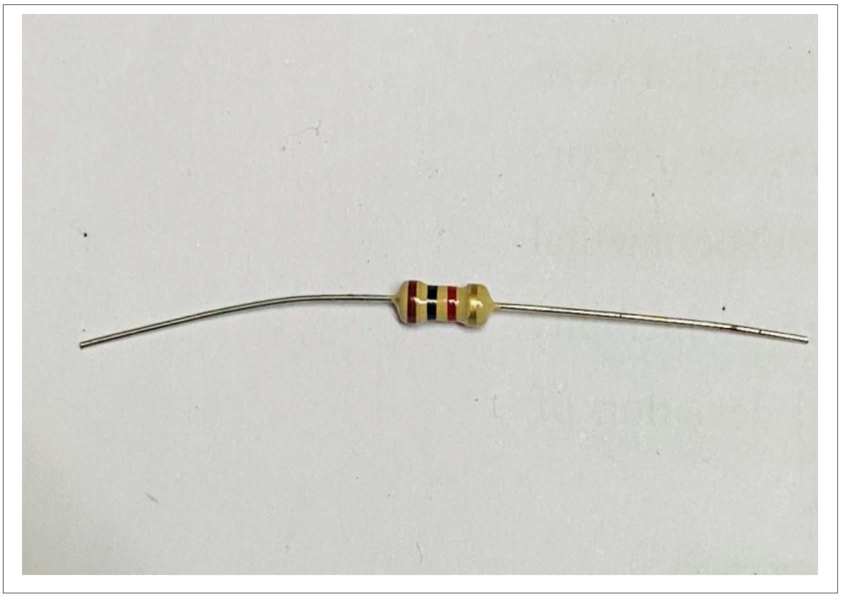
Grey

White

Gold

Silver

No Colour

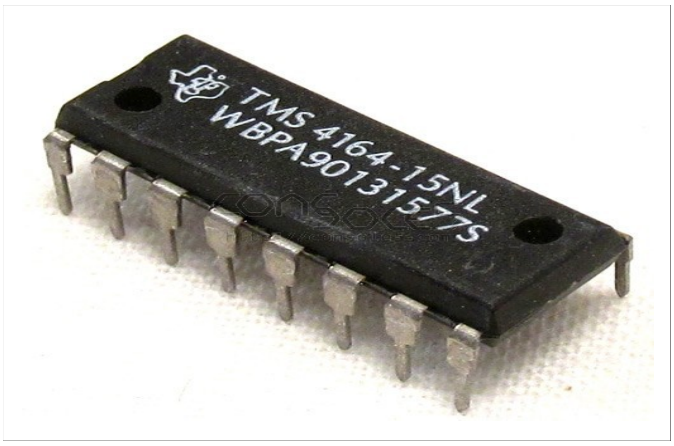


The name for the above resistor is $16*10^2 \pm 5\%$

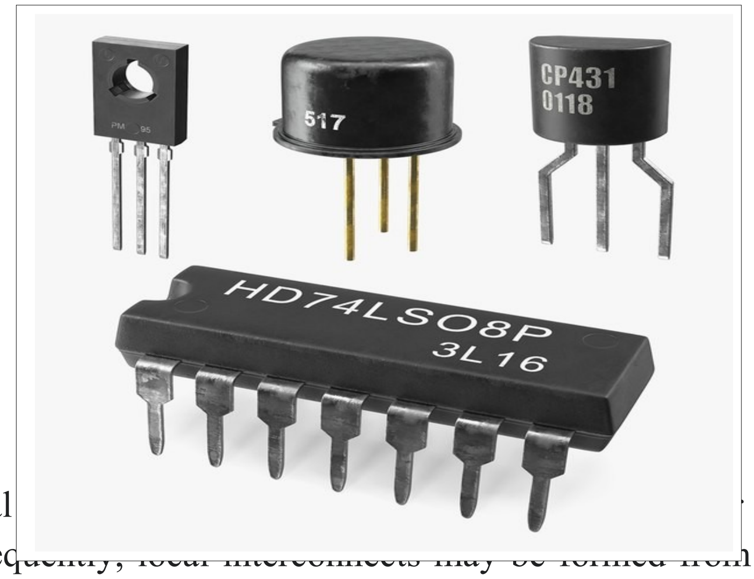
The name of the below resistor is $46*10^6 \pm 5\%$

ii. Interconnect in IC (Integrated Circuits)

Interconnects are structures that connect two or more circuit elements (such as transistors) together electrically. The design and layout of interconnects on an IC is vital to its proper function, performance, power efficiency, reliability, and fabrication yield. The material interconnects are made from depends on many factors. Chemical and mechanical compatibility with the semiconductor substrate and the dielectric between the levels of interconnect is necessary, otherwise barrier layers are needed. Suitability for fabrication is also required; some chemistries and processes prevent the integration of materials and unit processes into a larger technology (recipe) for IC fabrication. In fabrication, interconnects are formed during the back end of line after the fabrication of the transistors on the substrate.

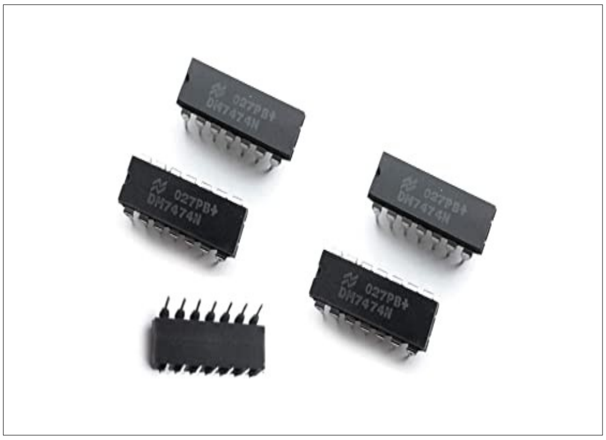


Interconnects are classified as *local* or *global* interconnects depending on the signal propagation distance it is able to support. The width and thickness of the interconnect, as well as the material from which it is made, are some of the significant factors that determine the distance a signal may propagate. Local interconnects connect circuit elements that are very close together, such as transistors separated by ten or so other contiguously laid out transistors.

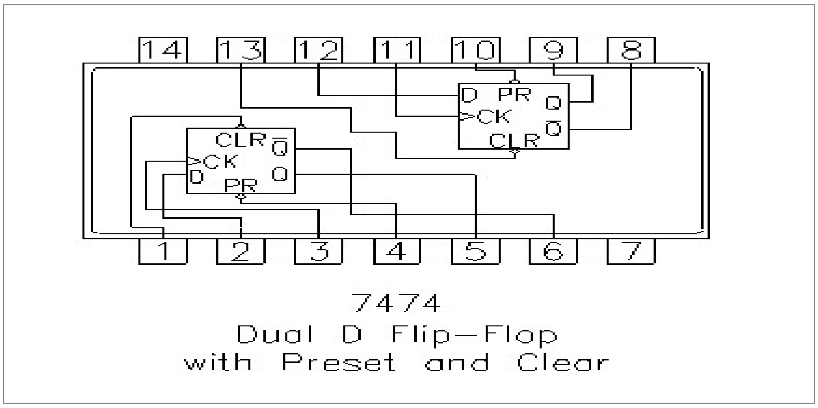


Global large-area sub-circuits. Consequently, local interconnects may be formed from materials with relatively high electrical resistivity such as polycrystalline silicon (sometimes silicided to extend its range) or tungsten. To extend the distance an interconnect may reach, various circuits such as buffers or restorers may be inserted at various points.

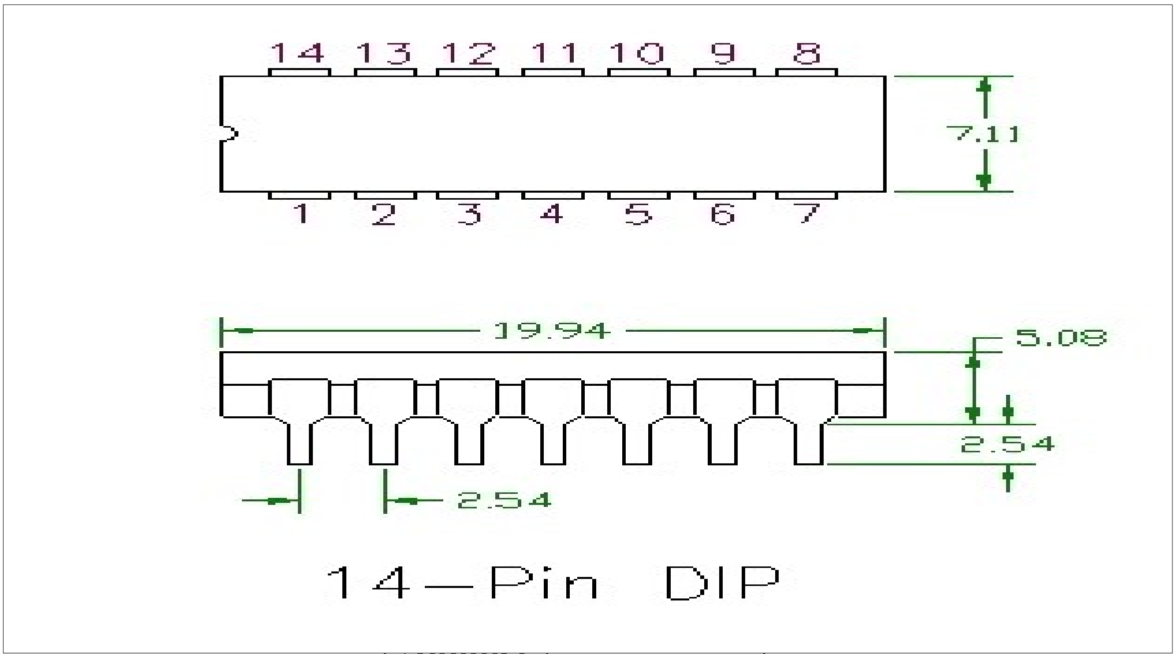
iii. 7474 Dual Flip-Flop Datasheet



Pin Layout



Dimensional Drawing



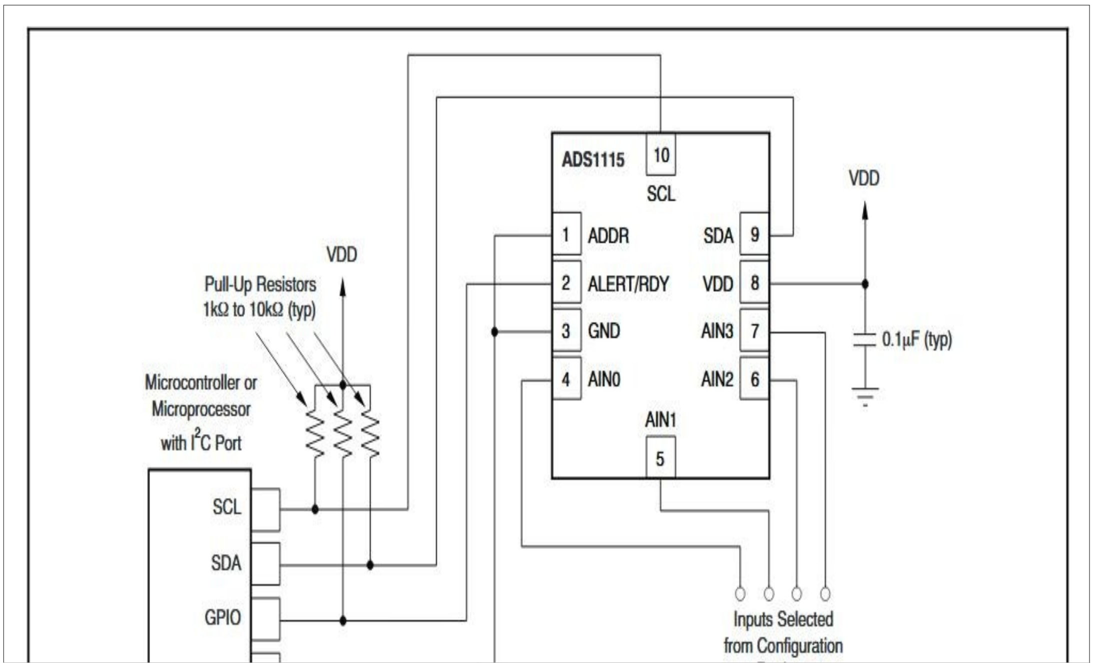
Number	
1	Clear 1 Input
2	D1 Input
3	Clock 1 Input
4	Preset 1 Input
5	Q1 Output
6	Complement Q1 Output
7	Ground
8	Complement Q2 Output
9	Q2 Output
10	Preset 2 Input
11	Clock 2

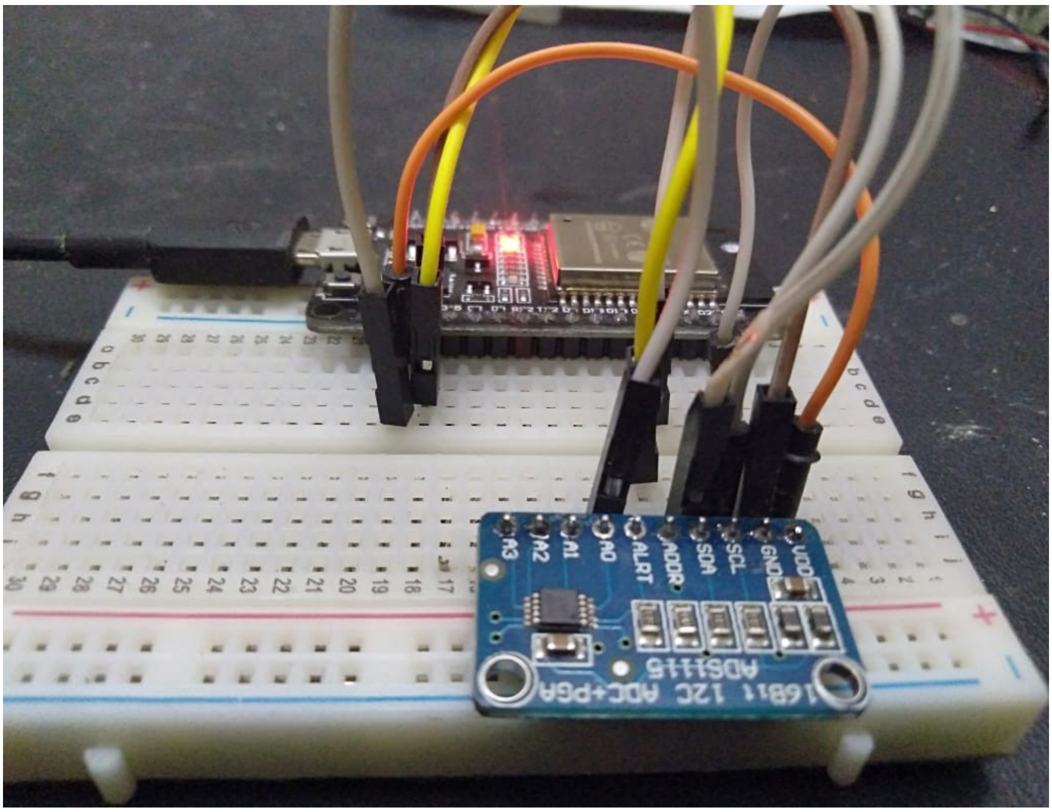
	Input
12	D2 Input
13	Clear 2 Input
14	Positive Supply

iv. LM318 Datasheet

LM318 is basically an Operational Amplifier (Op-amp). It has high processing speed. Its processing speed is almost ten (10) times higher than the processing speed of general normally available operational amplifier. LM318 provides higher slew rates. In inverting applications, it is able to double the frequency and increase the slew rates too up to certain level. LM318 can be used in fast integrator, wide band amplifier and digit to analog converter.

v. ADS115 Datasheet

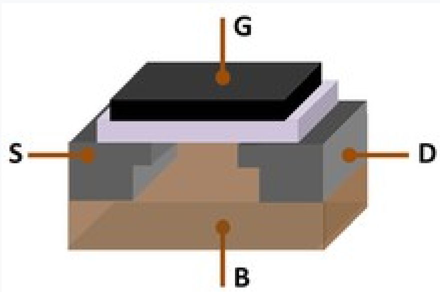




vi. MOSFET

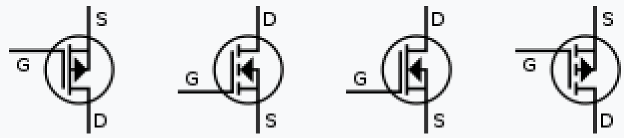
The **metal–oxide–semiconductor field-effect transistor** (**MOSFET**, **MOS-FET**, or **MOS FET**), also known as the **metal–oxide–silicon transistor** (**MOS transistor**, or **MOS**), is a type of insulated-gate field effect transistor that is fabricated by the controlled oxidation of a semiconductor, typically silicon. The voltage of the gate terminal determines the electrical conductivity of the device; this ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electrical signals.

MOSFET



MOSFET, showing gate (G), body (B), source (S) and drain (D) terminals. The gate is separated from the body by an insulating .

Working principle	Semiconductor
Invented	1959
First production	1960

Pin configuration	gate (G), body (B), source (S) and drain (D)
Electronic symbol	
	

*A. **Types of** MOSFET*

a) Floating- gate MOSFET (FGMOS)

The floating-gate MOSFET (FGMOS) is a type of MOSFET where the gate is electrically isolated, creating a floating node in DC and a number of secondary gates or inputs are deposited above the floating gate (FG) and are electrically isolated from it. The first report of a floating-gate MOSFET (FGMOS) was made by Dawon Kahng (co-inventor of the original MOSFET) and Simon Min Sze in 1967

The FGMOS is commonly used as a floating-gate memory cell, the digital storage element in EPROM, EEPROM and flash memories. Other uses of the FGMOS include a neuronal computational element in neural networks, analog storage element, digital potentiometers and single-transistor DACs.

b) Power MOSFET

Power MOSFET have a different structure as with most power devices, the structure is vertical and not planar. Using a vertical structure, it is possible for the transistor to sustain both high blocking voltage and high current. The voltage rating of the transistor is a function of the doping and thickness of the N-epitaxial layer (see cross section), while the current rating is a function of the channel width (the wider the channel, the higher the current). In a planar structure, the current and breakdown voltage ratings are both a function of the channel dimensions (respectively width and length of the channel), resulting in inefficient use of the "silicon estate". With the vertical structure, the component area is roughly proportional to the current it can sustain, and the component thickness (actually the N-epitaxial layer thickness) is proportional to the breakdown voltage.

Power MOSFETs with lateral structure is mainly used in high-end audio amplifiers and high-power PA systems. Their advantage is a better behaviour in the saturated region (corresponding to the linear region of a bipolar transistor) than the vertical MOSFETs. Vertical MOSFETs are designed for switching applications

The power MOSFET, which is commonly used in power electronics, was developed in the early 1970s. The power MOSFET enables low gate drive power, fast switching speed, and advanced paralleling capability.[8]

B) Applications of MOSFET

The MOSFET generally forms the basis of modern electronics as the dominant transistor in digital circuits as well as analog integrated circuits It is the basis for numerous modern technologies and is commonly used for a wide range of applications According to Jean-Pierre Colinge, numerous modern

technologies would not exist without the MOSFET, such as the modern computer industry, digital telecommunication systems, video games, pocket calculators, and digital wristwatches,

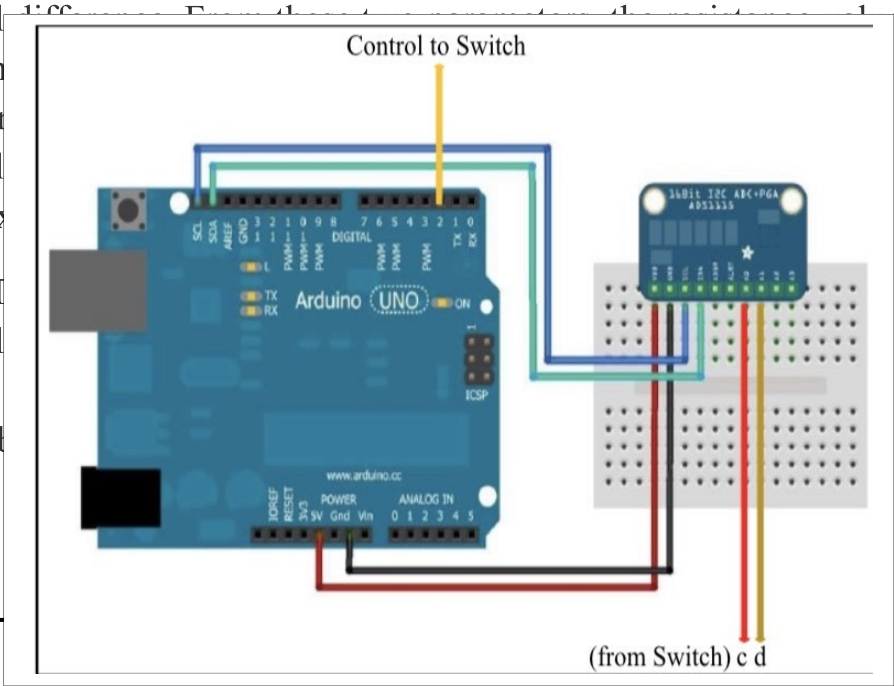
For example, Discrete MOSFET devices are widely used in applications such as switch mode power supplies, variable-frequency drives and other power electronics applications where each device may be switching thousands of watts. Radio-frequency amplifiers up to the UHF spectrum use MOSFET transistors as analog signal and power amplifiers. Radio systems also use MOSFETs as oscillators, or mixers to convert frequencies. MOSFET devices are also applied in audio-frequency power amplifiers for public address systems, sound reinforcement and home and automobile sound systems.

MOSFETs in integrated circuits are the primary elements of computer processors, semiconductor memory, image sensors, and most other types of integrated circuits.[9]

vii. Voltmeter using ADS115

One part of the geo electric method is DC (Direct Current) resistivity measurement. Physical parameters measured by the system are the current and potential ... e is obtained based on ... figuration in the DC ... between the potential ... ectrodes that can be ex...

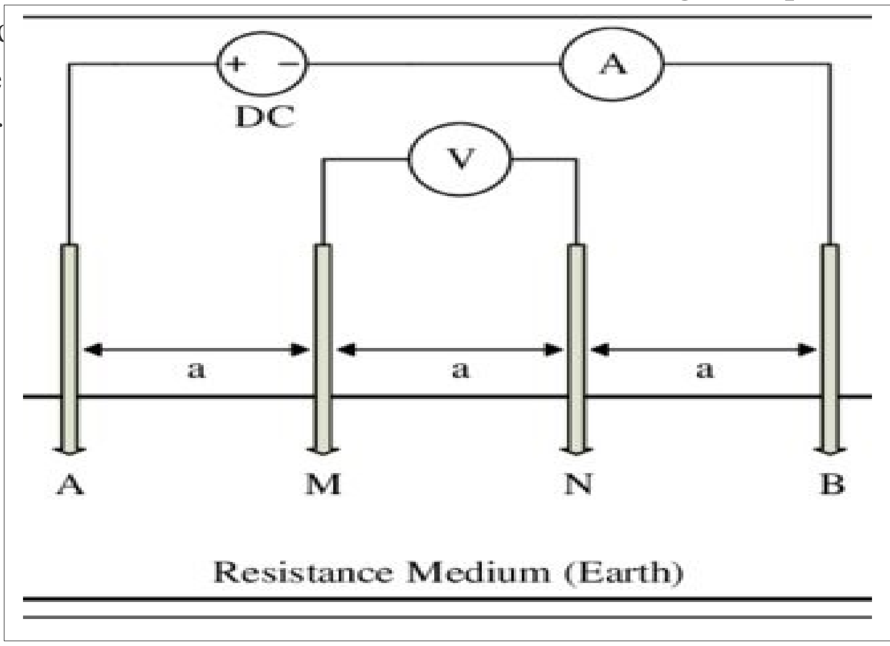
T... measure the potential ... lts and can measure ... his research aims to ... with 16-bit



resolution) and Arduino Uno, which can be applied in DC resistivity measurement.

In this system, there is internal resistance and switch. The internal resistance is around 2.4 MΩ, arranged into a voltage divider circuit to be able to measure the maximum potential input around 1,600 V.

The switch function is to set the measurement mode (as auto-range), which is set by Arduino Uno. Furthermore, ADS1115 uses a differential measurement method to be able to measure a negative potential difference. Based o … an adjustable voltage … difference in resistor … %.[10]



Viii. Raspberry Pi Pinout

- 5v Power

The 5v power pins are connected directly to the Pi's power input and will capably provide the full supply current of mains adaptor, minus that used by the Pi itself.

- 3v3 Power

The 3v3 supply pin on the early raspberry Pi had a maximum available current of only 50Ma. The 5v supply coupled with a 3v3 regulator is recommended for powering 3.3v projects.

- GPIO 2
  GPIO/BCM pin 0 on Rev 1(very early) Pi SDA is one of the i2c pins on the Pi.
- GPIO 14(UART Transmit)
  This pin doubles the UART transmit pin, it is also commonly known as "Serial" and by default will output a console from Pi with a suitable serial cable.
- GPIO 15(UART Receive)
  This pin doubles up as a UART receive pin, RX.
- GPIO 18 (PCM Clock)
  It is used by PCM to provide a clock signal to external audio device such as DAC chip.
- GPIO 4
  Physical/Board pin7
  Wiring Pi pin 7
- GPIO 27
  Physical/Board pin 13
  Wiring Pi pin 2
- GPIO 22
  Physical/Board pin 15
  Wiring Pi pin 3
- GPIO 24
  Physical/Board pin 18
  Wiring pin Pi 5
- GPIO 23
  Physical/Board pin 16
  Wiring pin Pi 4
- GPIO 10
  Physical/Board pin 19
  Wiring pin Pi 12
- GPIO 9
  Physical /Board pin 21

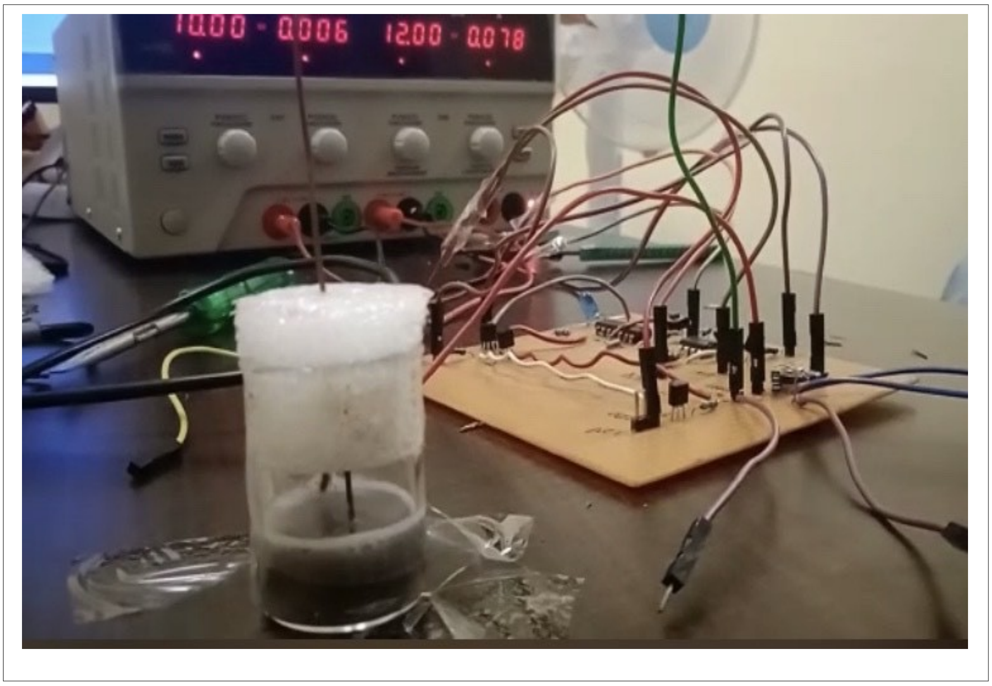
Wiring pin Pi 13

- GPIO 25
  Physical/Board pin 22
  Wiring Pi pin 6
- GPIO 11
  Physical/Board pin 23
  Wiring Pi pin 14
- GPIO 8(SPI chip select 0)
  Physical /Board pin 24
  Wiring pin Pi 10
- GPIO 0 (Hat Eeprom i2c data)
  These pins are generally reserved for i2c communication with the Eeprom.
- GPIO 1 (Hat Eeprom i2c clock)
  These pins are generally reserved for i2c communication with an Eepron.
- GPIO 19(PCM frame Sync)
  It provides a frame sync signal to an external audio device such as DAC chip.
- GPIO 20(PCM data In)
  It is used as data input from an audio device such as an i2c microphone.

- GPIO 21(PCM data Out)
  It is used to provide a data output signal to an external audio device such as DAC chip.
- Ground
  The ground pins on the Raspberry Pi are all electrically connected, so it doesn't matter which one uses if one wiring up a voltage supply.

4. Results and Discussion

The experiment was carried out as shown below:



And the tip which was obtained by the use of the above circuit (Scanning Tunneling M

5. Acknowledgement

The success and final outcome required a lot of guidance, patience, kindness, immense love, hope, peace and grace which got me moving ahead due to My guide

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