WEIGHT SENSOR

Course: EC153

Joy of Electronics

Mid Lab Project

Lecturer: Dr J. Ravi Kumar

Members involved in the Project:

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Abstract:

This project uses basic concepts and components of Electronics by simply using Force-Sensing Resistor and Bipolar Junction Transistors. The Biasing used in the circuit is Voltage Divider Bias and using this concept, LEDs are used to display the force applied to the FSR qualitatively. This circuit is constructed on a Zero Printed Circuit Board and the components are soldered together. The goal in our minds while constructing this Weight Sensor is to build and finish the circuit without using any advanced Integrated Circuits or Microcontrollers. The main component is a Force-Sensing resistor which is a material whose resistance changes when force, pressure or mechanical stress is applied. They are sometimes referred to by the initialism FSR. This is brief summary of the Project.

Aim:

To build a qualitative weight sensor using transistors and force sensing resistors without any ICs. The number of LEDs glowing show the force applied to it. The DC Voltage is given to the circuit using a Power Supply Circuit using 220V – 12V Step Down Transformer.

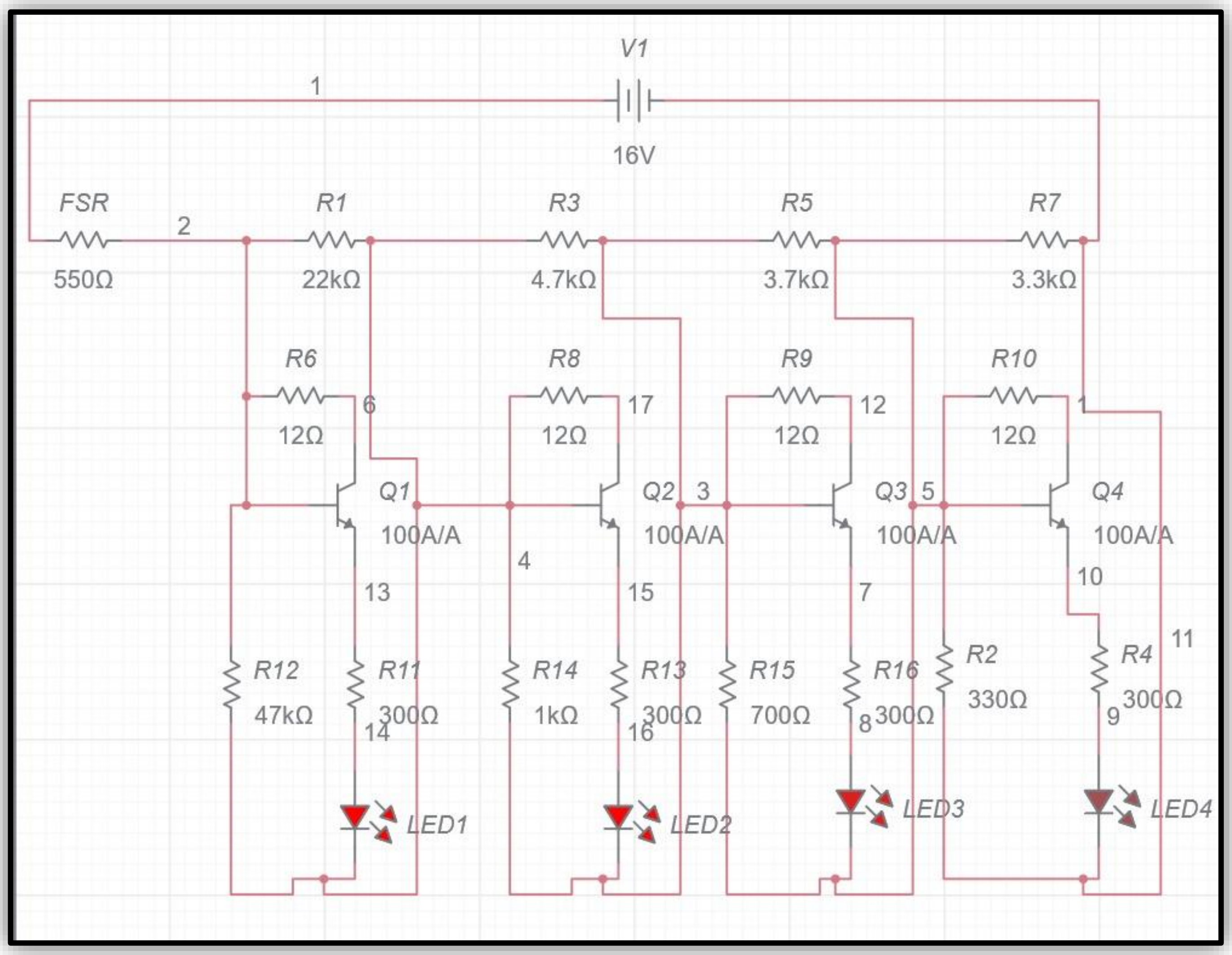
Apparatus Required:

1. **FSR of Model FS406 (1) --- Rs.450/-**
2. **BJT of Model BC547 (4) --- Rs.50/-**
3. **LEDs of Red Colour (4) --- Rs.20/-**
4. **Resistors of Various Values: --- Rs.20/-**
   i. **22 kΩ (1)**
   ii. **6.9 kΩ (2)**
   iii. **3.7 kΩ (1)**
   iv. **3.3 kΩ (1)**
   v. **12 Ω (4)**
   vi. **330 Ω (4)**
   vii. **39 kΩ (1)**
   viii. **4.8 kΩ (1)**
   ix. **1.5 kΩ (2)**
5. **Power Supply Circuit: --- Rs.300/-**

i. **Transformer 220V – 12V Step Down Transformer**
ii. **Diodes of Model IN4007 (4)**
iii. **Capacitors -- 1000 μF and 1 μF**
iv. **Voltage Regulator – LM781 (1)**
v. **LED of Red Colour (1)**

6. **Connecting Wires, Breadboard, Soldering Equipment**

Schematic Diagram:



Theory:

Principle of FSR:

FSRs are two terminal devices with a resistance that depends on applied force. FSR consist of a conductive polymer, which changes resistance in a predictable manner following application of force to its surface. They are normally supplied as a polymer sheet. The sensing film consists of both electrically conducting and non-conducting particles suspended in matrix. The particles are sub-micrometre sizes, and are formulated to reduce the temperature dependence, improve mechanical properties and increase surface

durability. Applying a force to the surface of the sensing film causes particles to touch the conducting electrodes, changing the resistance of the film. There are two major operating principles in force-sensing resistors: percolation and quantum tunnelling. Although both phenomena actually occur simultaneously in the conductive polymer, one phenomenon dominates over the other depending on particle concentration.

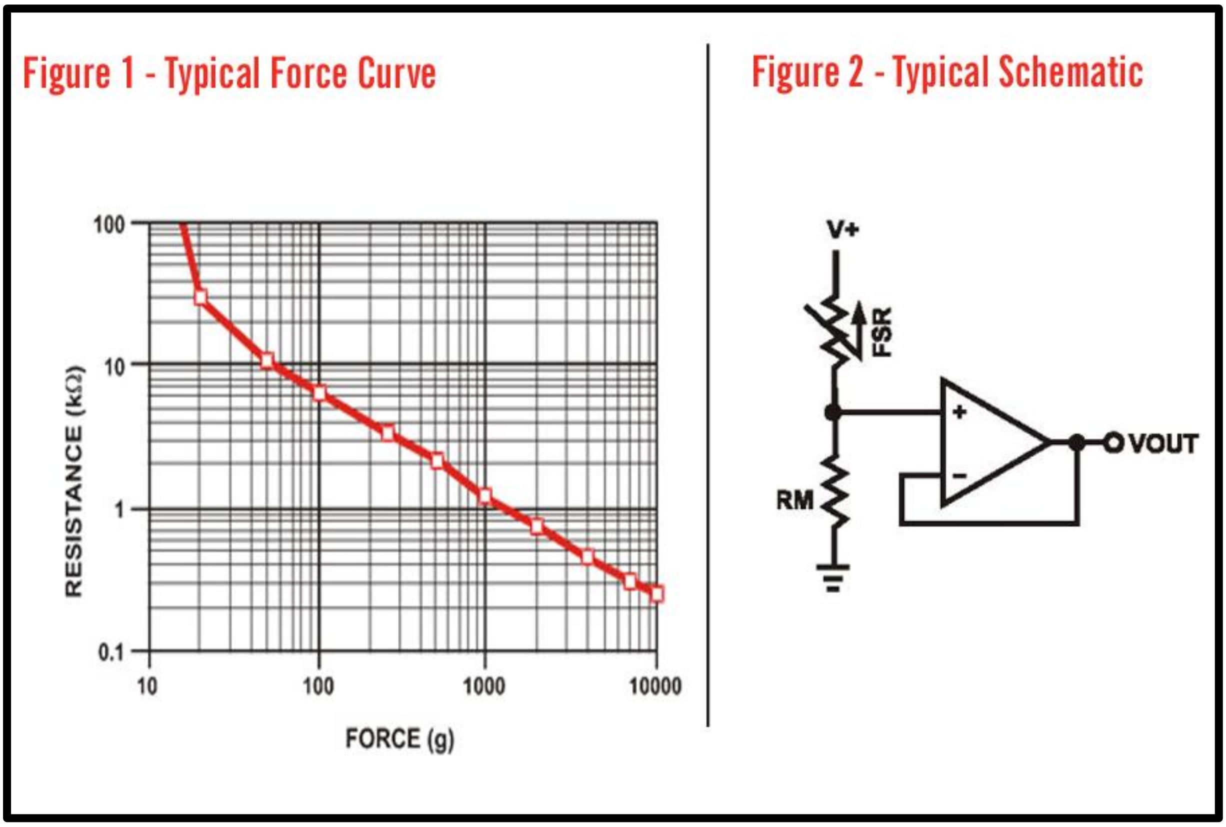
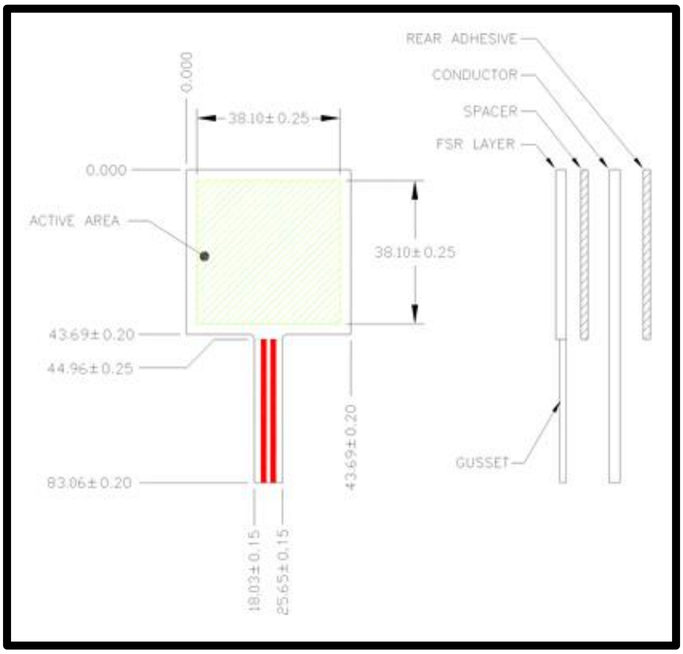


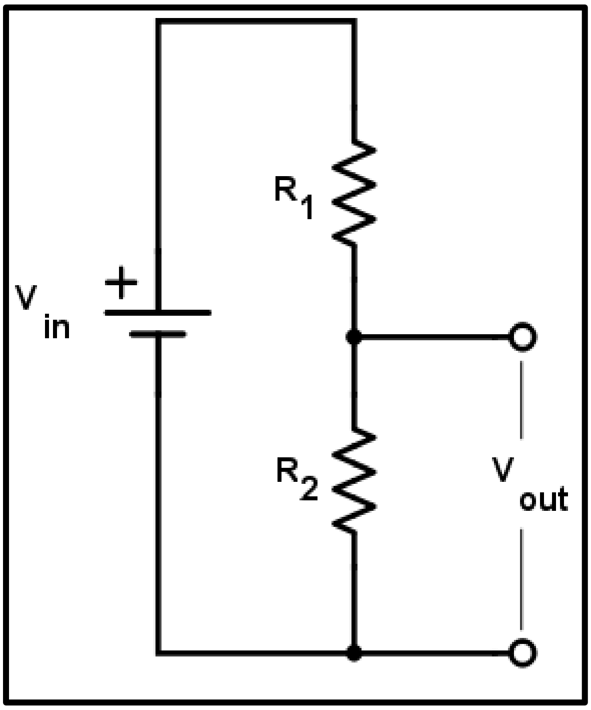
Figure 1 - Typical Force Curve

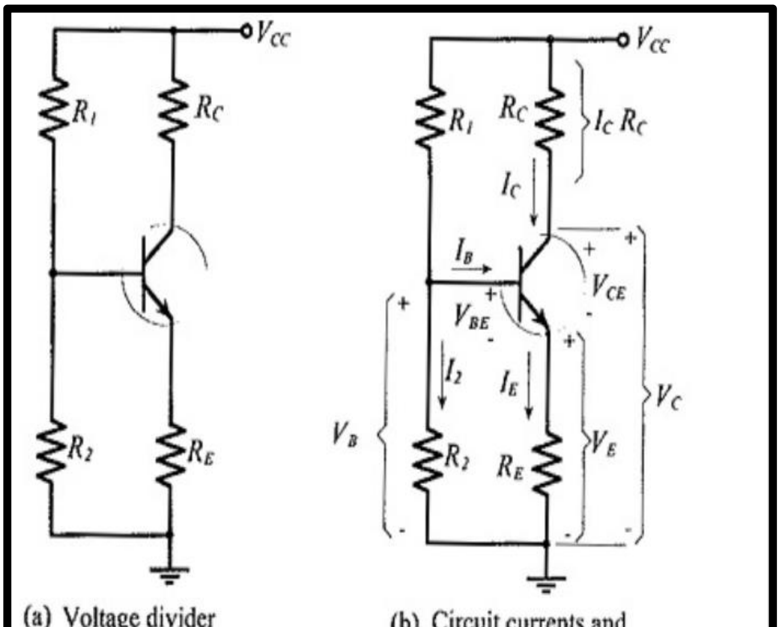
Figure 2 - Typical Schematic



Basic Principle of the Circuit:

The principle behind the circuit is method of turning on the Transistor by changing the bias voltage across R2 (>0.65V) by Voltage Divider Bias. The voltage which is given into the circuit is divided according to the resistances of resistors R1 from voltage divider bias circuit and this voltage is applied to the LED circuit. As shown in the schematic diagrams above, voltage across the R1 changes after applying pressure to the FSR as initially the resistance of FSR is very high and the voltage given to it isn't enough to make the LED glow and as pressure is applied the value of resistance decreases. The lowering in resistance increases voltage being divided and hence the voltage across the LEDs circuit increases and it is sufficient enough to make the LED glow. As there is a further decrease in resistance the voltage across the remaining LED circuits increases and this voltage is sufficient to turn LEDs on.





(a) Voltage divider bias circuit

(b) Circuit currents and voltage drops

Transistor BC457:

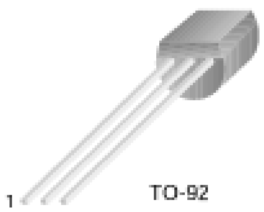
BC546/547/548/549/550

FAIRCHILD SEMICONDUCTOR®

BC546/547/548/549/550

Switching and Applications

- High Voltage: BC546, V_{CEO}=65V
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560



1. Collector 2. Base 3. Emitter

NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings T_a=25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CBO}	Collector-Base Voltage : BC546 : BC547/550 : BC548/549	80 50 30	V V V
V_{CEO}	Collector-Emitter Voltage : BC546 : BC547/550 : BC548/549	65 45 30	V V V
V_{EBO}	Emitter-Base Voltage : BC546/547 : BC548/549/550	6 5	V V
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	°C
T_{STG}	Storage Temperature	-65 ~ 150	°C

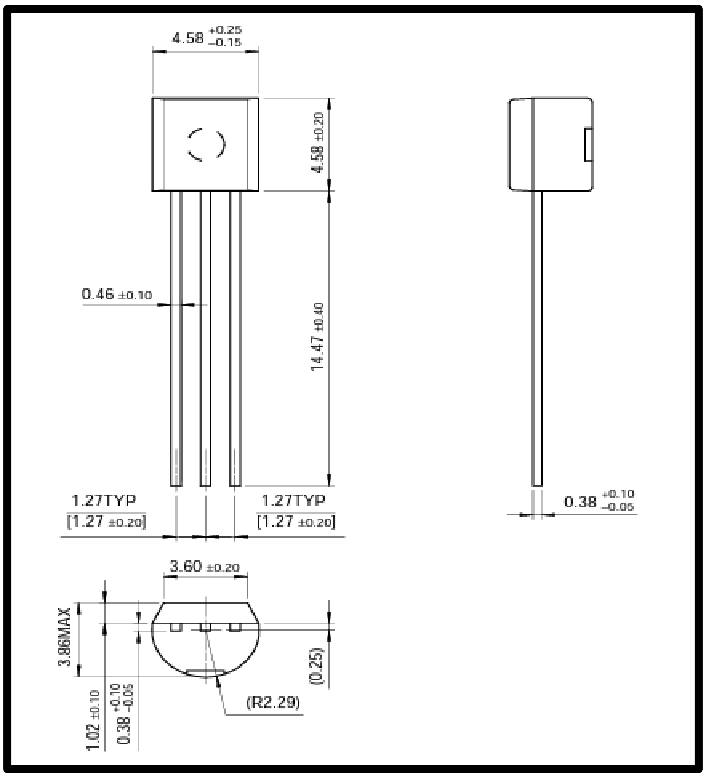
Electrical Characteristics T_a=25°C unless otherwise noted

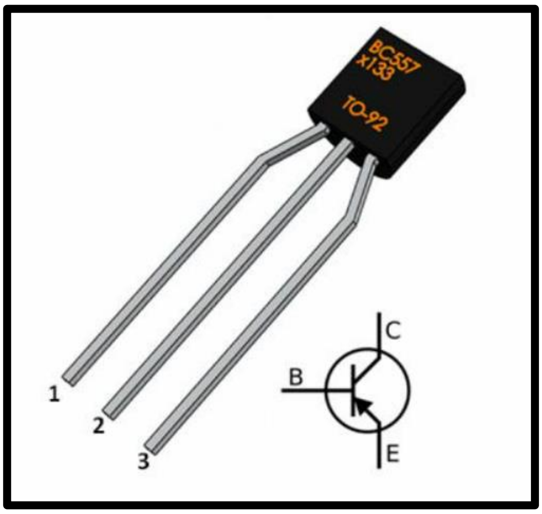
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	V_{CB}=30V, I_E=0			15	nA
h_{FE}	DC Current Gain	V_{CE}=5V, I_C=2mA	110		800	
V_{CE} (sat)	Collector-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA I_C=100mA, I_B=5mA		90 200	250 600	mV mV
V_{BE} (sat)	Base-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA I_C=100mA, I_B=5mA		700 900		mV mV
V_{BE} (on)	Base-Emitter On Voltage	V_{CE}=5V, I_C=2mA V_{CE}=5V, I_C=10mA	580	660	700 720	mV mV
f_T	Current Gain Bandwidth Product	V_{CE}=5V, I_C=10mA, f=100MHz		300		MHz
C_{ob}	Output Capacitance	V_{CB}=10V, I_E=0, f=1MHz		3.5	6	pF
C_{ib}	Input Capacitance	V_{EB}=0.5V, I_C=0, f=1MHz		9		pF
NF	Noise Figure : BC546/547/548 : BC549/550 : BC549 : BC550	V_{CE}=5V, I_C=200μA f=1KHz, R_G=2KΩ V_{CE}=5V, I_C=200μA R_G=2KΩ, f=30~15000MHz		2 1.2 1.4 1.4	10 4 4 3	dB dB dB dB

h_{FE} Classification

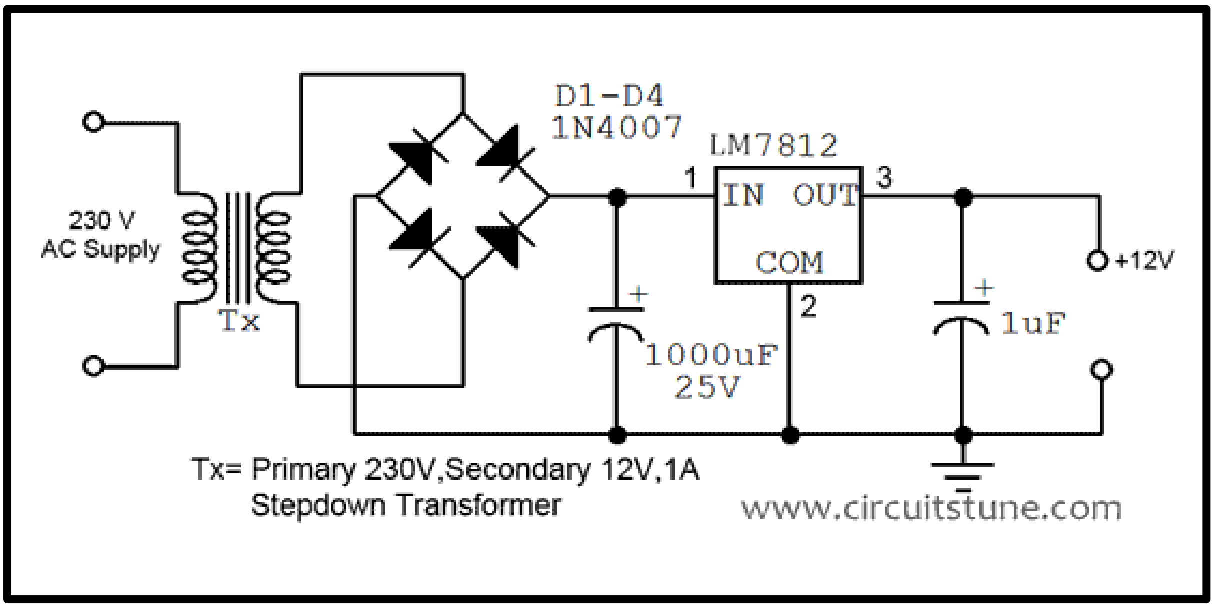
Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

Rev. A2, August 2002





Power Supply Circuit:



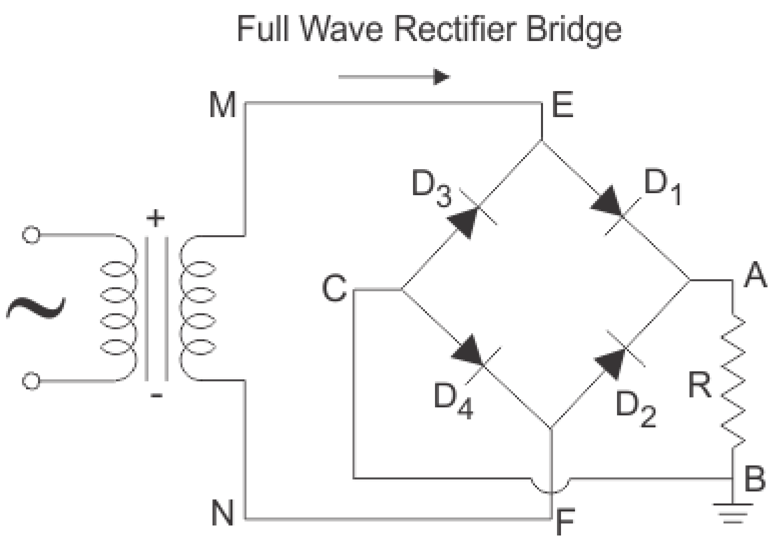
Operation of Regulated Power Supply

Step Down Transformer

A step down transformer will step down the voltage from the ac mains to the required voltage level. The turn's ratio of the transformer is so adjusted such as to obtain the required voltage value. The output of the transformer is given as an input to the rectifier circuit.

Rectification

Rectifier is an electronic circuit consisting of diodes which carries out the rectification process. Rectification is the process of converting an alternating voltage or current into corresponding direct (DC) quantity. The input to a rectifier is AC whereas its output is unidirectional pulsating DC.



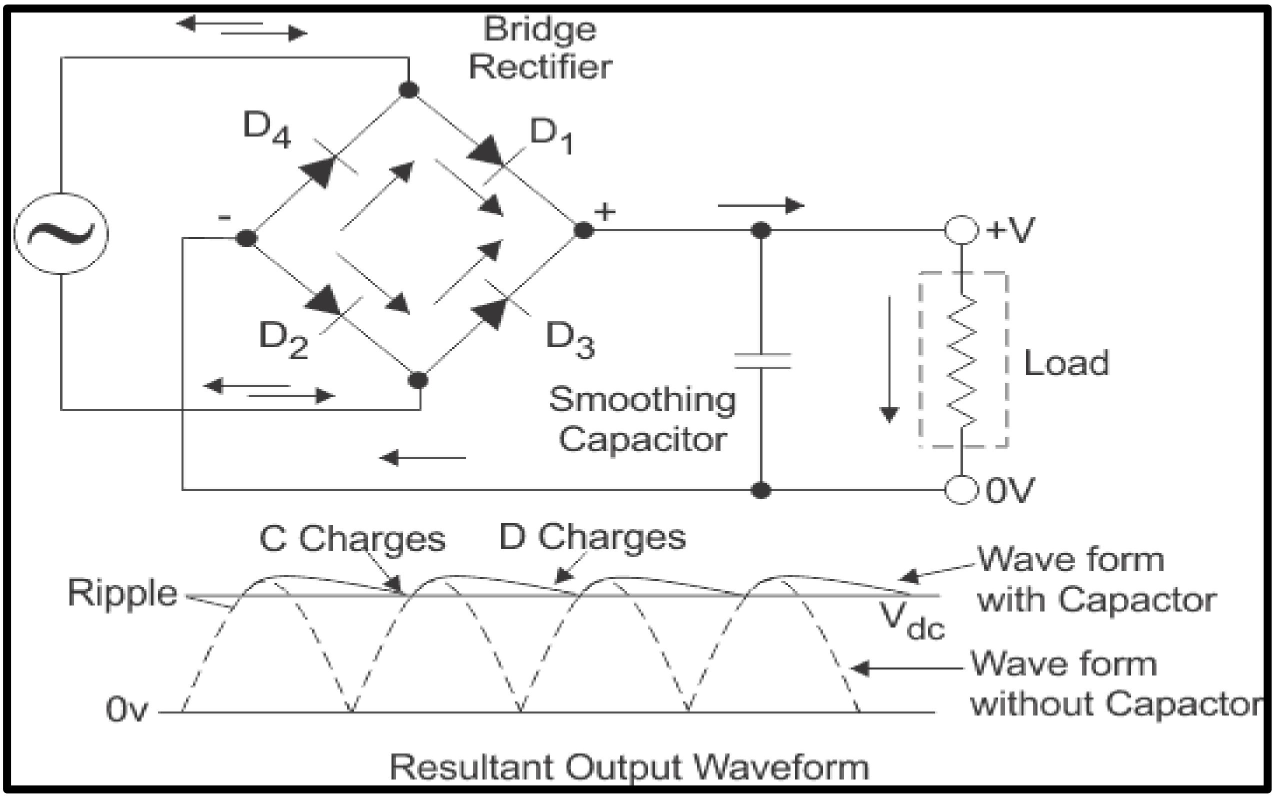
Although a half wave rectifier could technically be used, its power losses are significant compared to a full wave rectifier. As such, a full wave rectifier or a bridge rectifier is used to rectify both the half

cycles of the ac supply (full wave rectification). The figure below shows a full wave bridge rectifier.

A bridge rectifier consists of four p-n junction diodes connected in the manner shown above. In the positive half cycle of the supply, the voltage induced across the secondary of the electrical transformer i.e., VMN is positive. Therefore, point E is positive with respect to F. Hence, diodes D_3 and D_2 are reversed biased and diodes D_1 and D_4 are forward biased. The diode D_3 and D_2 will act as open switches (practically there is some voltage drop) and diodes D_1 andD_4 will act as closed switches and will start conducting. Hence a rectified waveform appears at the output of the rectifier as shown in the first figure. When voltage induced in secondary i.e. VMN is negative than D_3 and D_2 are forward biased with the other two reversed biased and a positive voltage appears at the input of the filter.

DC Filtration

The rectified voltage from the rectifier is a pulsating DC voltage having very high ripple content. But this is not we need we want a pure ripple free DC waveform. Hence a filter is used. Different types of filters are used such as capacitor filter, LC filter, Choke input filter, π type filter. The figure below shows a capacitor filter connected along the output of the rectifier and the resultant output waveform.



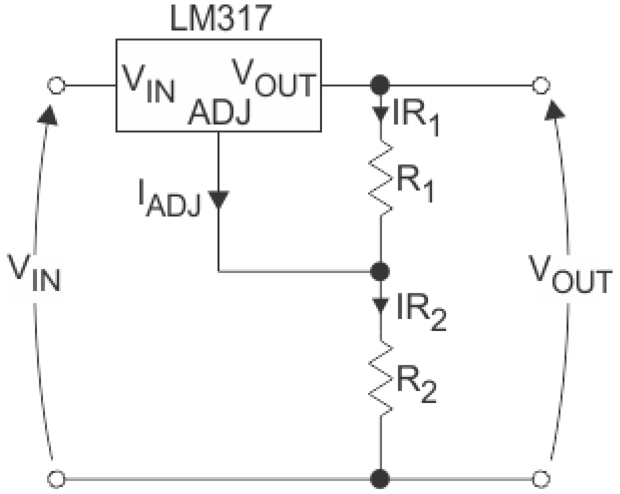
As the instantaneous voltage starts increasing the capacitor charges, it charges until the waveform reaches its peak value. When the instantaneous value starts reducing the capacitor starts discharging exponentially and slowly through the load (input of the regulator in this case). Hence, an almost constant DC value having very less ripple content is obtained.

Regulation

This is the last block in a regulated DC power supply. The output voltage or current will change or fluctuate when there is a change in the input from ac mains or due to change in load current at the output of the regulated power supply or due to other factors like temperature changes. This problem can be eliminated by using a regulator. A regulator will maintain the output constant even when changes at the input or any other changes occur. Transistor series regulator, Fixed and variable IC regulators or a Zener diode operated in the Zener region can be used depending on their applications. IC's

like 78XX and 79XX (such as the IC 7805) are used to obtained fixed values of voltages at the output.
With ICs like LM 317 and 723, we can adjust the output voltage to a required constant value. The figure below shows the LM317 voltage regulator. The output voltage can be adjusted by adjusting the values of resistances R_1 and R_2. Usually, coupling capacitors of values about 0.01μF to 10μF need to be connected at the output and input to address input noise and output transients. Ideally, the output voltage is given by

$$V_{OUT} = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$



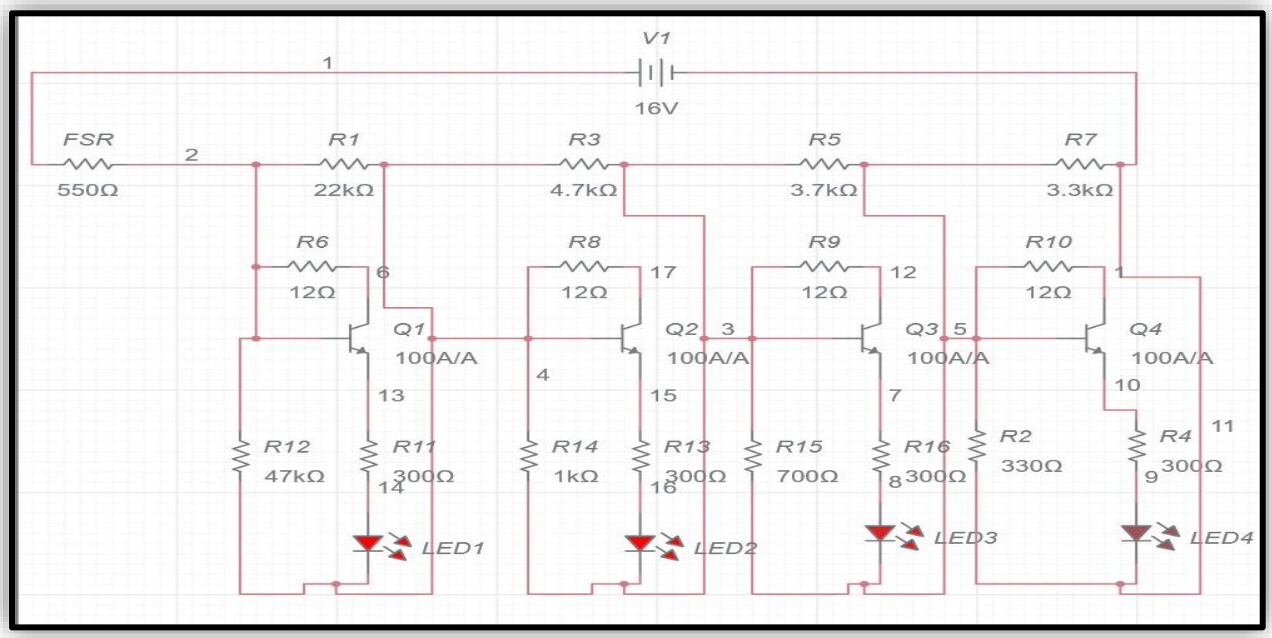
The figure above shows the complete circuit of a regulated +5V DC power supply.

Procedure:

1. **Take a Breadboard and connect the circuit on this breadboard.**
2. **After connecting the circuit together while taking precautions, apply pressure to the FSR and observe the number of LEDs glowing.**
3. **Now, observe the range of resistances required and figure out the value of R2 to be used in for the circuit.**

4. After figuring out the required values of resistors, make sure the input voltage is divided accordingly to all the four LED circuits.
5. From the observed values, we can collect the components and then insert them into the 0-PCB.
6. Now solder all the components together and build the circuit.
7. By using power supply circuit give DC voltage as input.
   The voltage steps down from 220V to 12V after passing through power supply circuit and makes it safe to utilize for experiment.
8. After the required voltage level is attained, we connect the Weight sensor circuit and power supply circuit safely and give DC Voltage as input to it.

Results:



So, from the diagram above you can see that three LEDs are glowing when the value of FSR Resistance is 550Ω and eventually all four LEDs will glow as the FSR's resistance decreases while pressure on it increases. From the typical force curve graph of FSR you can see that when very little force is applied its resistance value is around 100kΩ.

Hence by applying pressure on the FSR, the resistance of it decreases and the amount of voltage which will be available for the LED circuit increases.

Failed Attempts:

1. **Initially the logic used in the circuit wasn't accurate, making all of the LED(s) glow at once.**
2. **Secondly the process of finding appropriate R2 values was a tedious job because of the approximations used as we ignored the input impedance of the transistor circuit.**
3. **Finally, there were a few wrong solders, but were debugged easily on first glance.**

Precautions:

1. **While soldering the circuit together make sure you don't heat a component up by putting solder iron to it too long.**
2. **Always use proper soldering equipment as the temperatures of the tip of solder iron can reach up to 400 ^{0}C.**
3. **Do not burn the LEDs or Transistors by giving them more input voltage than the required value.**
4. **Do not spill solder anywhere on the PCB and make sure to de-solder the connection properly.**