2. Literature Review

2.1 previous works

The first real effort was made by Liberson in 1961to supply electronic stimulation as an aid to recover function in disabled persons. Liberson designed portable FES device to treated foot drop by stimulating the personal nerve of patients suffering from drop foot during gait, which is basically an electronic devices that can generate pulses with the correct amplitude,frequency and duration in order to stimulate the damaged nerves externally .use Liberson a heel switch located under the feet of a patient's shoe, would activate a FES system worn by the patient [2].

Drop foot correction device can be applied using external, percutaneous a comparison of percutaneous and external stimulators during gait in a case report of a child with hemiplegic cerebral palsy . The risen dorsiflexion was greater with percutaneous stimulators [3].

FES can be applied in three way using external, percutaneous, or implanted electrodes. In external application, a pair of self-adhesive electrodes is placed on and near the personal nerve in the leg. The actual points of placement are important as it affects the strength and efficiency of the stimulation and the patient comfort level. In the case of percutaneous FES, an electrode is placed under the skin and close to the personal nerve with the aid of needle.

Percutaneous FES is more effective than the external FES but its placement may require medically qualified staff. Percutaneous FES is also prone to infection and it is difficult to keep it in place for long times. Implanted FES is based on placing the electrodes under the skin permanently by a small surgery. In some applications, the actual stimulation device may also be implanted under the skin. Although this is suitable for long term use, it has the disadvantages that as with the percutaneous FES, qualified medical staff is required to implant the device and as with any type of surgery there is always the risk of infection [4].

In a typical application, external electrodes, energized by an electronic device are placed above the personal nerve. During walking the heel switch triggered stimulation then the pulses generated at the correct times because the tibia is anterior muscle to be contracted (dorsiflexion of the foot) during swing phase of the gait cycle and hence help the patient prevent it from dragging on the ground and lift the foot [4].

In a systematic study of investigators the improvement of gait cycle in stroke patients with foot drop during the personal nerve stimulation. As a result of the studies investigators suggested that there is positive orthotic impact of FES on walking speed [5].

The orthotic versus therapeutic impacts of Functional Electronic Stimulation devices was compared by the Van der Linden, in this study FES supplied to the ankle dorsiflexors and quadriceps in fourteen children with cerebral palsy. For the orthotic impact of FES, statistically significant effect was found for the measurement of the deviation of overall gaitcycle pattern from the normal. FES to the dorsiflexors ensued in a statistically significant orthotic effect on peak dorsiflexion in swing phase and the foot-floor angle at first contact. This study showed that FES implemented to the dorsiflexors ensued insignificant improvements in the gait cycle of patients with CP. On the other hand no long term treatment effect of using FES was found [6].

The therapeutic and orthotic impacts of a drop foot electronic stimulator on gait performance of subjects with chronic non-progressive (stroke) and progressive (MS) disorders were compared. As a result shown that, both groups had an orthotic benefit from FES however the therapeutic impact ended for a shorter time in progressive disorders [7].

In another research the FES systems, sensors are placed inside the shoe which are connected to a stimulator device using lead wires or cables. One of the biggest disadvantages of the cabled systems is the cable complexity, and also device giving discomfort to the patient during the walking, because of the cables around the shoe and the foot. The system designed by the author is wireless and was developed by removing this cables from the device and by using Radio Frequency (RF) transmitter /receiver pair to connect the sensors to the stimulator device.[8].

2.2 The Gait Cycle

Human gait cycle consist of one full step that begins with, when the heel of one foot lifts from the ground and ends with , when heel of the same foot touches to ground again. It consist of two phases swing phase and stance phase. In other words Locomotion is a complex function. The movements of the lower limb during walking on a level surface may be divided into alternating swing & stance phases. The stance phase begins with heel strike, when the heel strikes the ground and begins to assume the body's full weight, and ends with push-off from the fore foot. The swing phase begins after push-off, when the toes leave the ground, and ends when the heel strikes the ground. Walking is a remarkably efficient activity, taking advantage of gravity and momentum so that a minimal of physical exertion is requisite .During the gait swing phase contains nearly 40% of the walking cycle and the stance phase, 60% of the walking cycle. In running, the time and percentage of the gait cycle represented by the decrease in stance phase[9], Figure(2.1) show Typical Phases of the Gait Cycle.

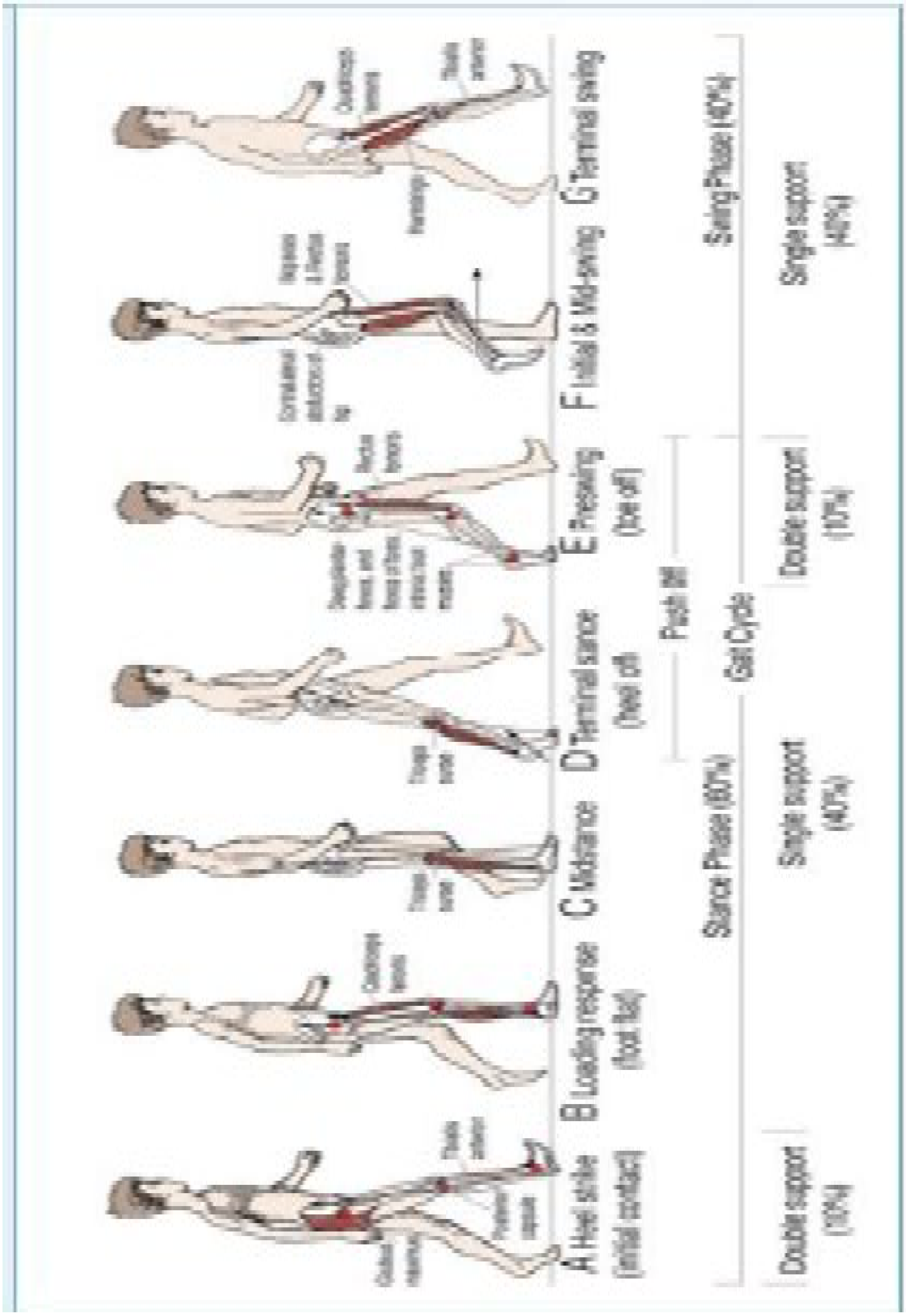

Figure (2.1) Typical Phases of the Gait Cycle.

2.2.1 The Normal Gait Cycle

The natural gait cycle is as shown below in sequence:

Swing Phase During the movement it defined as the period of time when the foot is not in contact with the ground. In those cases while the foot never leaves the ground (foot strike), it can be defined as the phase when all portions of the foot are in forward motion.

Initial Contact The point in the gait cycle where the foot initially makes contact with the ground; this specifies the beginning of the stance phase, It is suggested that heel strike not be a term used in clinical gait analysis as in many circumstances initial contact is not made with the heel. Suggestion: Should use foot strike.

Terminal Contact The point in the gait cycle while the foot leaves (foot-rise) the ground: this specifies the beginning of the swing phase or end of the stance phase.

Additionally referred to as foot rises or foot off, Toe off should not be used in situations where the toe is not the last part of the foot to leave the ground.

2.2.2 Gait Cycle of Dropped Foot Patients

Drop foot gait cycle requires more exaggerated phases as explained below in sequence.

Dropped Foot Swing Phase During the walking cycle if the foot happens to be the affected foot, there will be greater flexion at the knee to accommodate the disability to dorsiflex. This increase in knee extension will cause a stair climbing movement.

Dropped Foot Initial Contact First contact of the foot that is in movement will not have natural heel toe foot strike. Instead of the foot may either slap the ground or the overall foot may be located on the ground all at once.

Dropped foot Terminal Contact Terminal contact that is observed in patients that have dropped foot is quite different. Since patients tend to have weakness in the affected foot, they may have the disability to support weight of body. Frequently, a cane or walker will be used to assist in this aspect.

The part of the dropped foot gait cycle that introduces most dorsiflexion of the muscle would be Heel Contact of the foot at ten percent of Gait Cycle, and the overall swing phase, or between sixty-hundred percent of the Gait Cycle. This is determined as a Gait Abnormalities [10].

2.3 Sensors

Sensors are the basic requirements of the FES devices to determine the patient's activities. All FES systems consist of various sensors to detect activities when the stimulus should be applied to the paralyzed muscles .Some commonly used sensor types are shown below:

- Force Sensitive Sensors or Force Sensitive Resistor (FSR)
- Push Button Switches
- Tilt Sensors
- Goniometers
- (EMG) Electromyography Sensors
- Accelerometers
- Gyroscopes

Force sensitive sensor are also known as force sensitive resistor these sensors consist of a conductive polymers, which changes resistance in a presumable manner following application of force on its surface. FSR sensors are in-shoe sensors and are fitted to an insole to detect movements of the foot . The controller assembly is usually kept in the pocket or is attached to a belt around the body and these sensors are normally connected to the microcontroller with a pair of wires or connection can be established via wireless system. When the heel rise is detected with a wired or wireless system , the status of the input pin changes at the microcontroller input and this applies stimulation to the personal nerve of the limb Figure(2.2) illustrate Force Sensitive Resistors.

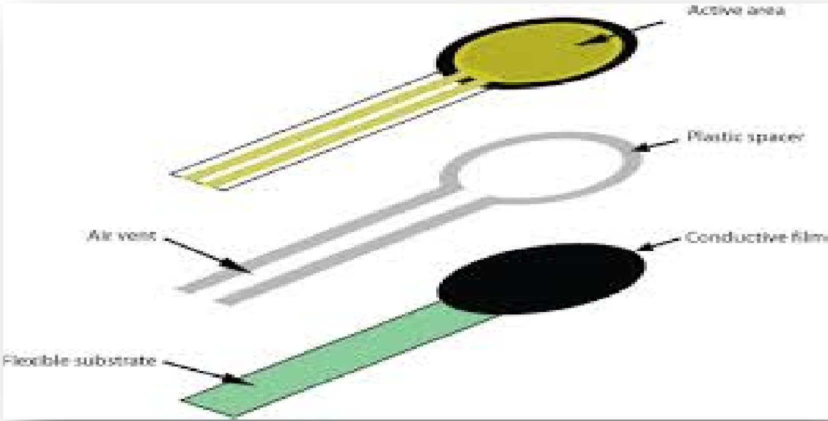

Figure (2.2) Force Sensitive Resistors.

FSR sensors are rectangular or round shaped flexible resistance devices whose resistance changes with the applied pressure on its surface. These resistive sensors are generally used with a potential divider resistor networks such that the output voltage is either low or high depending upon whether or not pressure is applied on the sensor [11].

Features

- **Size** 1/2" (12.5mm) diameter active area by 0.02" thick (Interlink does have some that are as large as 1.5"x1.5")
- **Resistance range:** Infinite/open circuit (no pressure), 100KΩ (light pressure) to 200Ω (max. pressure)
- **Low cost.**

- **Force range**: 0 to 20 lb. (0 to 100 New tons) applied evenly over the 0.125 sq in surface area
- **Power supply:** Any! Uses less than 1mA of current (depends on any pull up/down resistors used and supply voltage)

2.4 Microcontroller

A microcontroller (sometimes abbreviated **μC**, **uC** or **MCU**) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

The ATmega16 is a low power CMOS 8bitmicrocontroller based on the AVR enhanced RISC architecture .by executing powerful instructions in a single clock cycle ,the ATmega16achieves throughputs approaching 1MIPS per MHz allowing the system designed to optimize power consumption versus processing speed .

2.4.1 important feature

• High-performance, Low-power Atmel® AVR® 8-bit Microcontroller

• Advanced RISC Architecture

– 131 Powerful Instructions – Most Single-clock Cycle Execution

– 32 x 8 General Purpose Working Registers

– Fully Static Operation

• I/O and Packages

– 32 Programmable I/O Lines

• Operating Voltages

– 4.5V - 5.5V for ATmega16

• Speed Grades

– 0 - 16 MHz for ATmega16

• Power Consumption @ 1 MHz, 3V, and 25°C for ATmega16L

– Active: 1.1 mA

2.4.2 Pin description.

VCC Digital supply voltage

GND Ground

Port X(X=A,B,C,D)

Port X (PX7..PX0)

Port X serves as the analog inputs to the A/D Converter. Port X also serves as an 8-bit bi-directional I/O port if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

RESET Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset.

XTAL1 Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

XTAL2 Output from the inverting Oscillator amplifier

AVCC is the supply voltage pin for Port A and the A/D Converter

AREF is the analog reference pin for the A/D Converter.[12]**,** Figure(2.3) ATMEGA16 pins configuration**.**

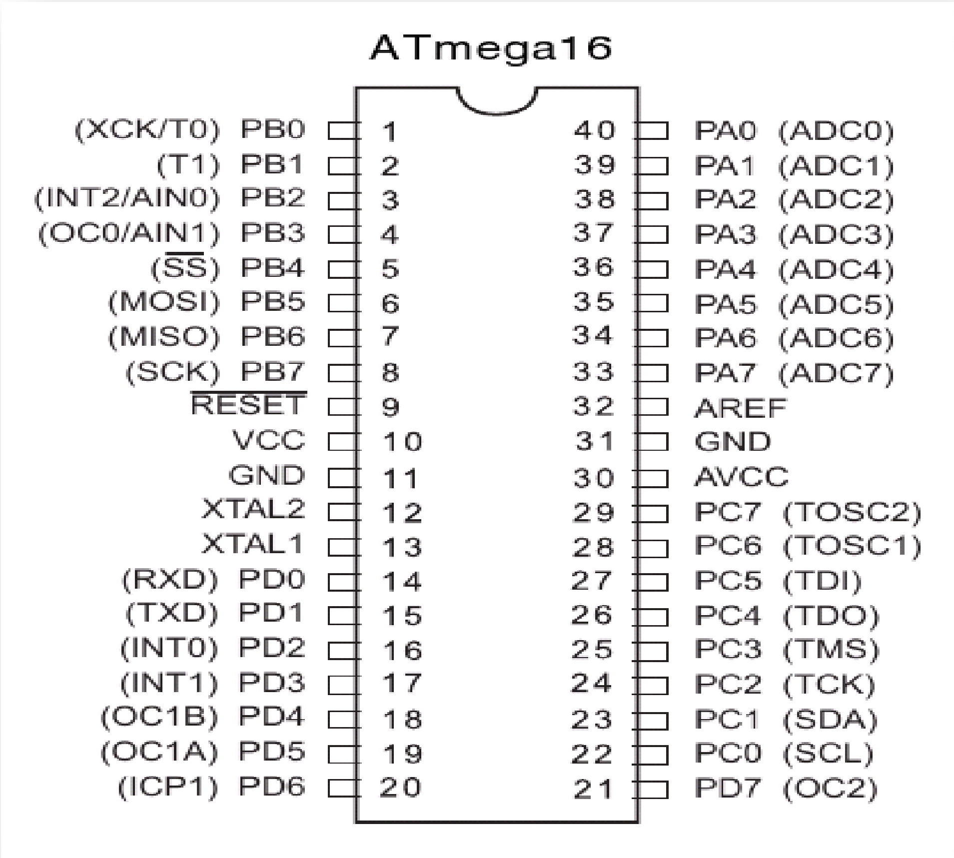

Figure (2.3) ATMEGA16 pins configuration**.**

2.5 Zigbee transceiver module:

Zigbee is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. Zigbee is based on an IEEE 802.15.4 standard. Though its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics,[1].

ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128 bit symmetric encryption keys.) ZigBee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range low-rate wireless data transfer. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi

The CC2520 is TI's second generation ZigBee IEEE 802.15.4 RF transceiver for the 2.4 GHz unlicensed ISM band. This chip enables industrial grade applications by offering state-of-the-arts electivity/co-existence, excellent link budget ,operation up to 125°C and low voltage operation. In addition, the CC2520 provides extensive hardware support for frame handling, data buffering, burst transmissions, data encryption ,data authentication, clear channel assessment, link quality indication and frame timing information. These features reduce the load on the host controller .In a typical system, the CC2520 will be used together with a microcontroller and a few additional passive components.[13]

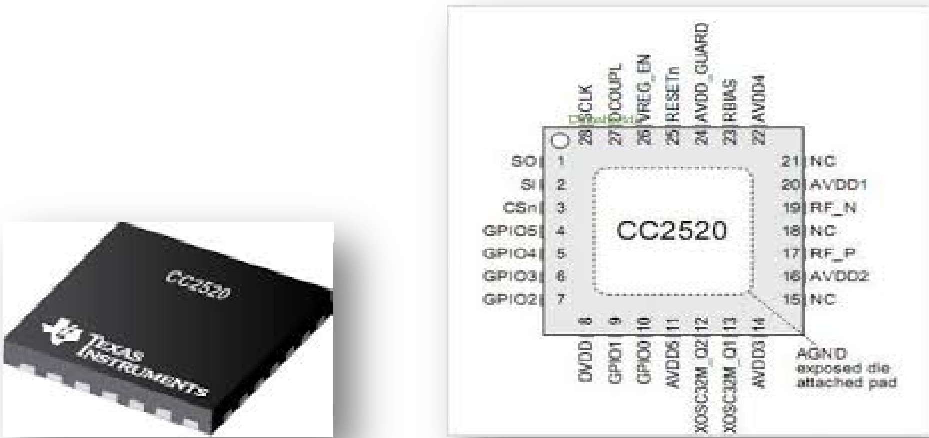

Figure (2.4) second generation zigbee **(CC2520)**

2.5.1 Pin out

The pin description generation zigbee (CC2025), the pins are grouped into three type serial peripheral interface (SPI) and general propose and Minimum Instruction Set Computer (MISC) as shown in table (2.1).

Table 2.1: pin out of second generation zigbee cc2025**:**

Signal	**Pin #**	**Type**	**Description**
SPI			
SCLK	28	I	SPI interface: Serial Clock. Maximum 8 MHz
SO	1	O	SPI interface: Serial Out
SI	2	I	SPI interface: Serial In
CSn	3	I	SPI interface: Chip Select, active low
General Purpose digital I/O			
GPIO0..GPIO5	10,9,7,	IO	General purpose digital I/O
Misc			
RESETn	25	I	External reset pin, active low
VREG_EN	26	I	When high, digital voltage regulator is active.
NC	1518,21		Not Connected.
AGND	Die Pad	Ground (Analog	

2.5.2 Feature

- DSSS transceiver
- 250kbps data rate, 2 MChip/s chip rate
- Very low current consumption

- RX (receiving frame, -50 dBm): 18.5 mA
- RX (waiting for frame): 22.3 mA
- TX (+5 dBm output power): 33.6 mA
- TX (0 dBm output power): 25.8 mA

- Low power fully static CMOS design
- Very good sensitivity (-98dBm)
- Low supply voltage (1.8 - 3.8 V)
- I/Q direct conversion transceiver

2.6 High Voltage & Switching circuit

In response to signals which is detected from the sensors, the microcontroller provides the required stimulus current (output waveforms) at the correct times as low level output voltages for stimulation. The High Voltage & Switching circuit is then controlled to increase this stimulus current or voltage to the required level. Switching circuit generally consists of a DC to DC converter and transformers to convert low voltage level to the high voltage level, for example; + 9 V to + 80 V. The output of FES devices can be either constant voltage or constant current. In a constant voltage device, the pulse amplitude is around 80 V and the skin resistance increases if the current is lowered.

Constant current devices supply around 120 mA current and they are less affected from changing of skin resistance . The output waveform from the FES devices is a pulse with a changeable pulse duration and frequency. The pulse shape can be monophasic, take shape from positive pulses only, symmetric or asymmetric biphasic, where the pulses are both positive and negative with no gap in between them, and symmetric biphasic with inter pulse intervals .The pulse duration between 50 μs − 1 ms, and the pulse frequency in most devices change between 1 − 100 Hz [14].

Figure (2.5): MC34063 8 Pins DC to DC Converter 3.0-40V Output Current 1.5A**.**

2.7 Liquid Crystal Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. [15]. Figure (2.6): show 16x2 LCD.

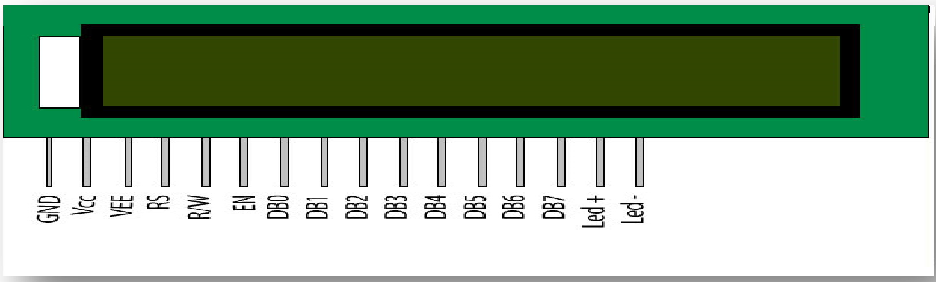

Figure (2.6):16x2 LCD

A 16x2 LCD display content of 16 pins, Table (2.2) show the function of each pin.

Table 2.2: Pin description**.**

Pin	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7…14	8-bit data pins	DB0..DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

2.8 Electrodes

The generated electrical pulses from FES device is transmitted on the paralyzed muscle by conductors. The electrode cable is rubber or plastic insulated flexible silver or copper wire. The thick-ness of the wire depended on the amount of current to be carried by the conductors, the thicker the conductor means conductor can carry a larger value of current so conductivity and current-carrying amount is directly proportional to each other. Electrode wires may be a uniform color-coded or color according to the function of electrodes.

Generally color coding of the cables are as follows, the wire to the positive electrode is anode, and to negative electrode is conventionally black colored which is cathode Figure(2.7) illustrate that.

Figure (2.7) .Color coding of the Electrode Cables

An electrode pad's medium that get into touch between the cable from the FES device and the patient's body . It usually introduces good conductor materials that form and shape can be adapted to conform to shape of the body. Also mediums include metal foil (electrode conductors are generally made by an zinc alloy, tin & lead), water, moist pad, or flexible silicone or carbon pad, figure (2.8) shown that.

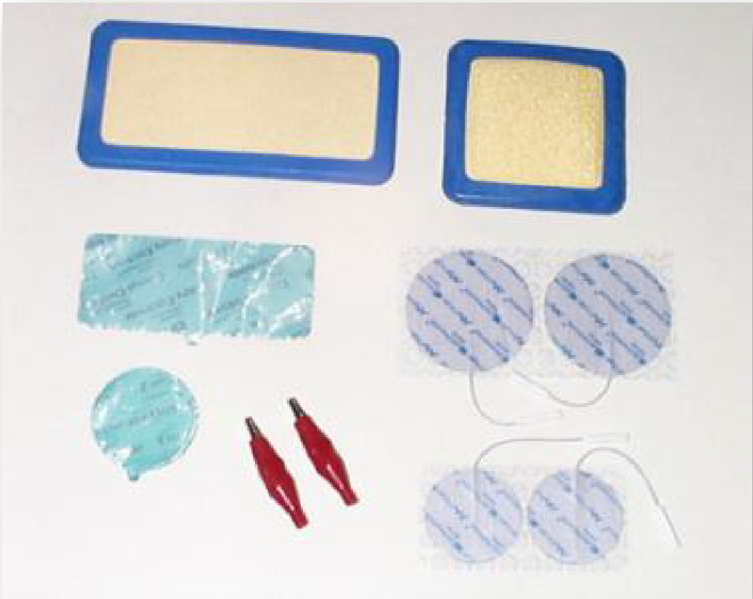

Figure (2.8): Flexible Electrode Pads

Electrode pads are generally produced in pairs, of equal size. The current densities of the two equal sizes of electrodes are distributed equally between them during the electrical stimulation. If one pad is twice as large as the other is, the current density under the smaller one will be twice as great as that under the larger. As the current spreads between two electrodes pads, across the body, its density must progressively decrease so that midway between them the density is the least.

The closer the electrodes are to one another, the greater the density of the current that passes between two electrode pads. The higher the current density means that the greater effect on the tissues stimulated .The electric current transmitted throughout the cable length after all cause to breaks in the cable at the sites and to some crystallization of the conductor (conducting wire) while the most bending or movement of the wires occurs, at both ends of the connections which is generally close to the electrode connection.