

3. System design

3.1 Over view

The stimulator has been designed to correct the drop foot problems in the patient which is programmable and microcontroller based wireless FES system. During the design Of wireless FES device the following parameters were considered, device must be low cost, Operate with low power, battery operated, easily portable, can communicate Wirelessly, stand alone with no external support the figure (3.1) below show the block diagram.

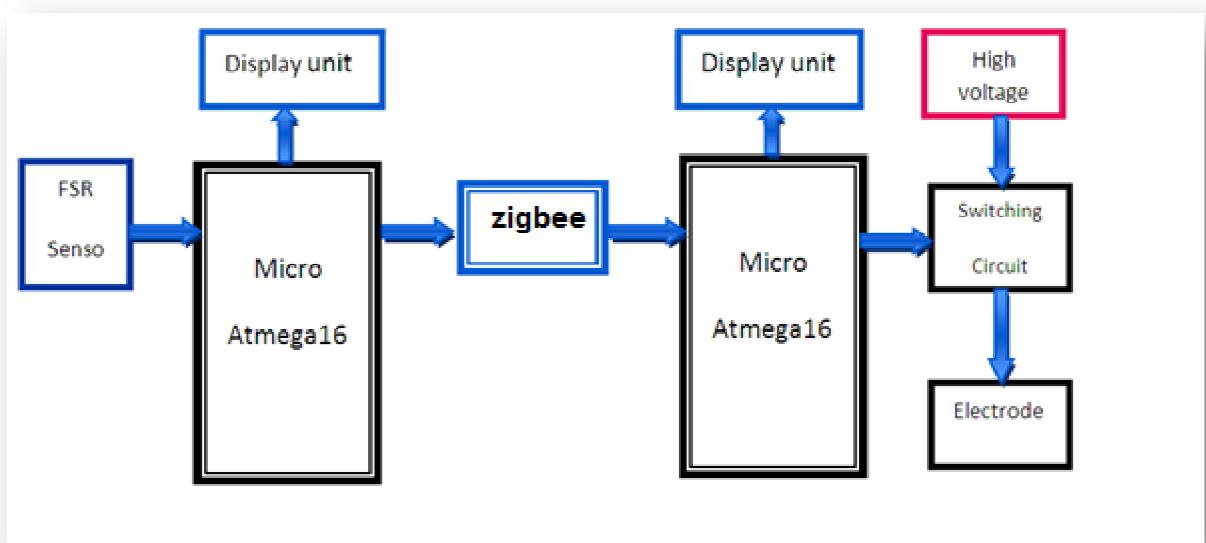


Figure (3.1) block diagram of Wireless Microcontroller Based FES Device.

The FES design consist of force sensing sensors, tow microcontrollers (Atmega16), zigbee module (CC2520), high voltage (MC43063) switching circuit and electrodes. This chapter gives detailed information about the design of the wireless FES device. The algorithm, hardware,

software and also circuit diagram of the wireless FES device has been described in details in the following sections.

This design has been divided into two parts Department transmitter and sensor, Department of the receiver section and control.

3.2 Sensor and transmitter part

This section consists of three basic parts FSR sensor, micro and display unit, show Figure (3.2) below.

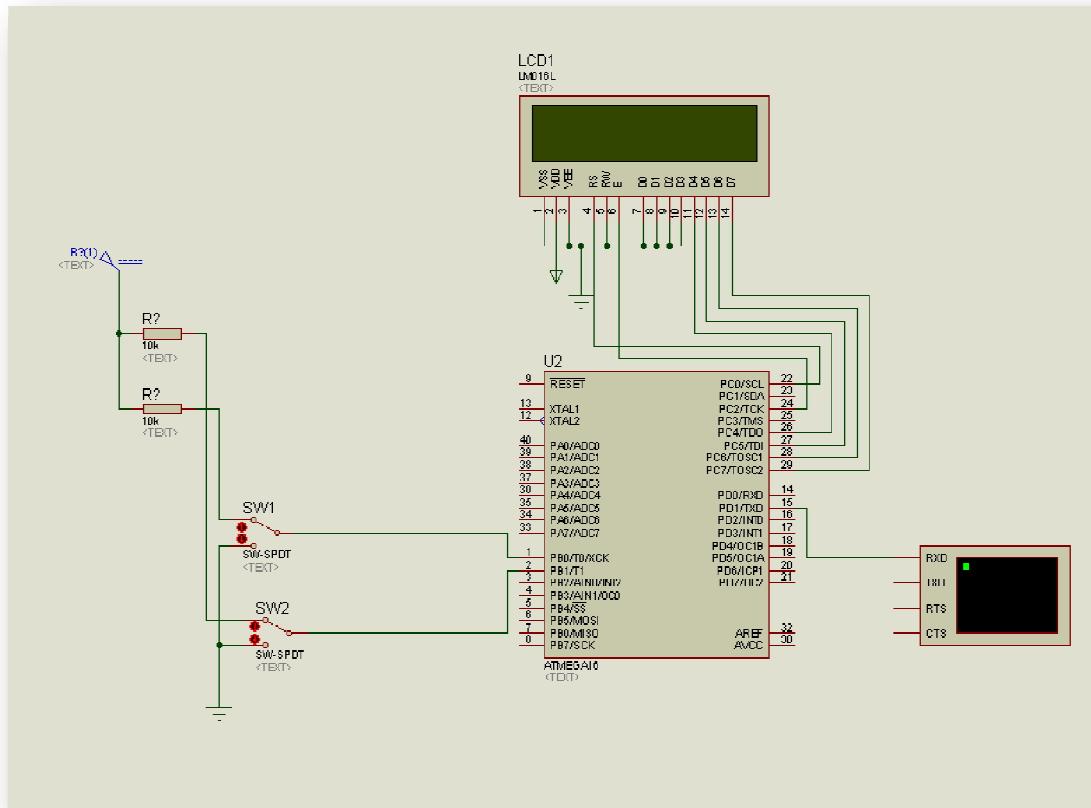


Figure (3.2): Circuit diagram of sensors and transmitter.

3.2.1 Movement detection by FSR sensor

The force sensitive resistors are placed inside the patient's shoe (insole) which is transmitter side of the wireless communication unit. When patient try to walk and lifts foot from the ground, transmitter detects this

movement. Sensor senses the patient's condition, which include the following:

Stand: The two force sensitive resistors are placed inside the patient's shoe which is Transmitter part. In the stand state if any force is applied on any of two force Sensitive resistor , receiver sends signal to the microcontroller so that stimulator Turns to OFF position.

Walk: In this state if patient lift his/her foot from the ground or foot- rise is detected by the device, system is activated so stimulator becomes in ON position.

In other words while patients tries to walk and lifts his/her foot, the transmitter sends (RF) signals to the receiver part. In foot-rise position receiver generate 5 volts otherwise 0 volts, then this generated signal is sent to the microcontroller based controller therefore controller sends a stimulus signal to the patients personal nerve at the feet so that patient can walk. After the foot strike is detected, device Automatically turns to the stand state and the stimulation is stopped by the Microcontroller.

Sleep: While in the Stand state activity of FSR or pre-specified duration has Occurred system reached to sleep state after two second. In this state system gets self-protection to minimize energy expenditure so that the microcontroller is virtually shut down and system operates with a low current (the current consumption is only 30 NA in sleep mode). After the foot-rise is detected FES device automatically returns to the Walk state.

Also in the case **hold foot:** when the foot is raised or deposed shoe for more than two seconds in those cases called hold foot and that the stimulation is stopped by the Microcontroller.

3.2.2 Transmit unit

By using Microcontroller (Atmega16) and senses the two digital signals of tow (FSR) sensor and this means that I have four possibilities for the patient and that has already been summarized and Depending on the values that are read from the sensor the micro send certain values by (zigbee transmitter) also offers cases on screen display (on-off) as shown on following table (3.1):

Table (3.1): states of patient in TX.

Signals detected from sensor	State	Signal transmit by microcontroller
0 0	Stand-sleep	1
0 1	Walk (Foot rise)	2
1 0	Walk (Foot strike)	4
1 1	Walk-sleep (foot hold)	3

3.3 Receiver and Control part

This part consist of zigbee receiver, microcontroller (atmega16), high voltage, switching circuit and electrode, the figure (3.3) below show that.

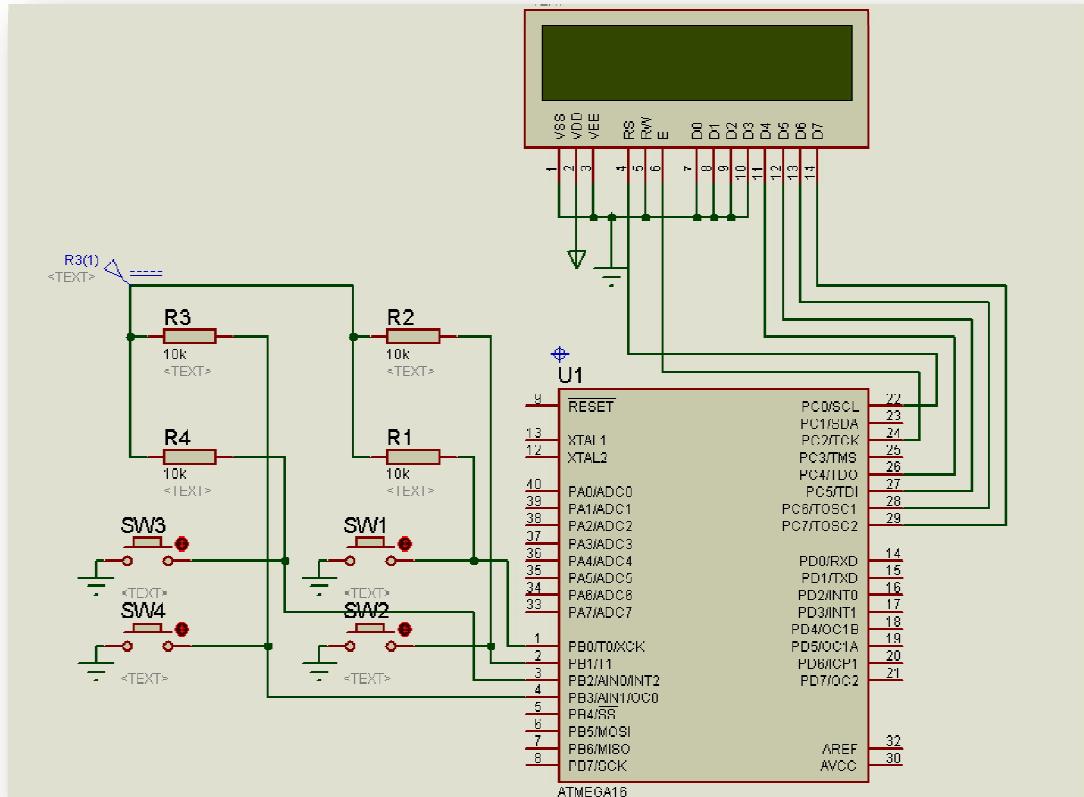


Figure (3.3): Circuit Diagram Receiver and Control.

3.3.1 Control unit

First, micro receive the signal through the (zigbee module) and analysis this signal and determine the condition of the patient (walk, stand and sleep), and also is set to the frequency and pulse width. There are two keys to select a frequency one to navigate through the frequency and the other for frequency selection, and also there are two keys to control the pulse width increases and decreases all this to select the most appropriate frequency and width of the patient depending on the speed of movement and sensation. Frequency values are displayed on the screen when the check as well as pulse width. The following table (3.2) illustrates the values depending on the type of the received signal is controlled in a switch circuit (off and on).

Table 3.2: State patent in RX.

Received Signal	State	switching circuit
1	Stand-sleep	Off-Off
2	Walk (Foot rise)	On
4	Walk (Foot strike)	On
3	Walk-sleep (foot hold)	On-Off

3.3.2 Switches:

Switch (1): for transfer between frequency and display.

Switch (2): select the desired frequency (set).

Switch (3): for increment pulse width modulation (PWM).

Switch (4): for decrement pulse width modulation (PWM).

A liquid-crystal display (LCD):

View the frequency, (PWM) and also the state of patient (walk-stand-sleep).

3.3.4 High voltage and 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, 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 monophonic, 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 figure (3.4) below show that. The transformer converts from 5 voltages into around 80 voltages and the transistor switch the stimulated signal.

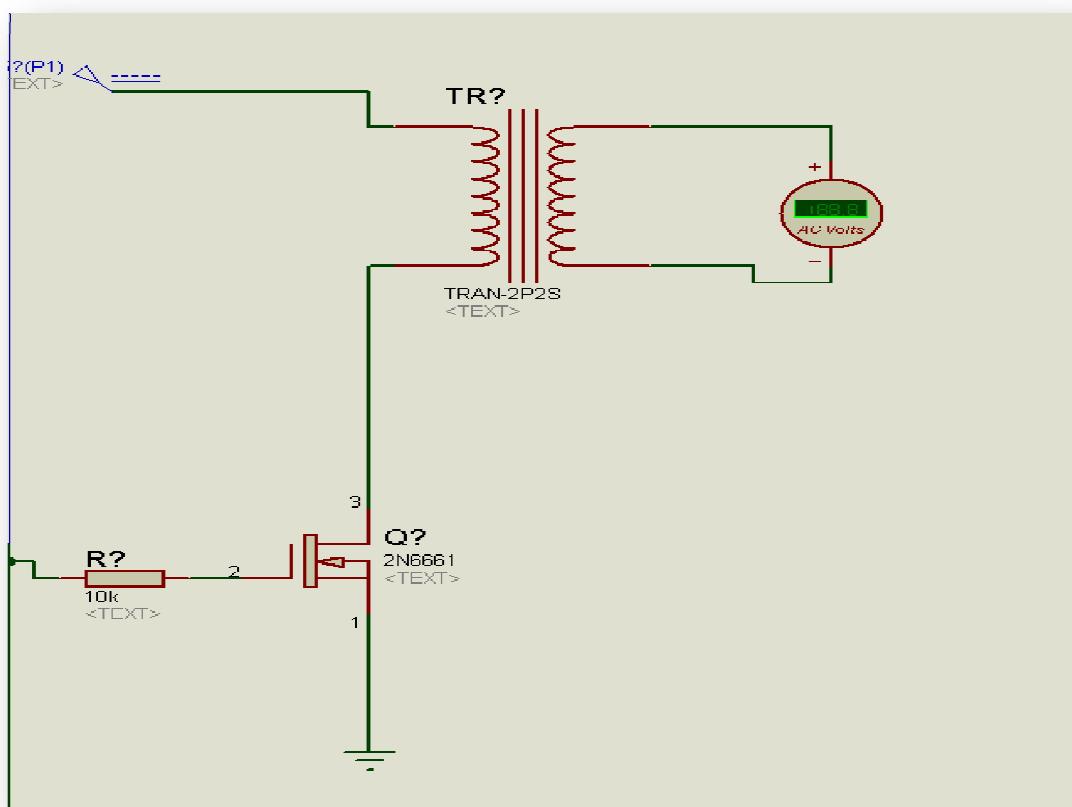


Figure (3.4): High voltage and switching circuit.

3.4 Flow chart

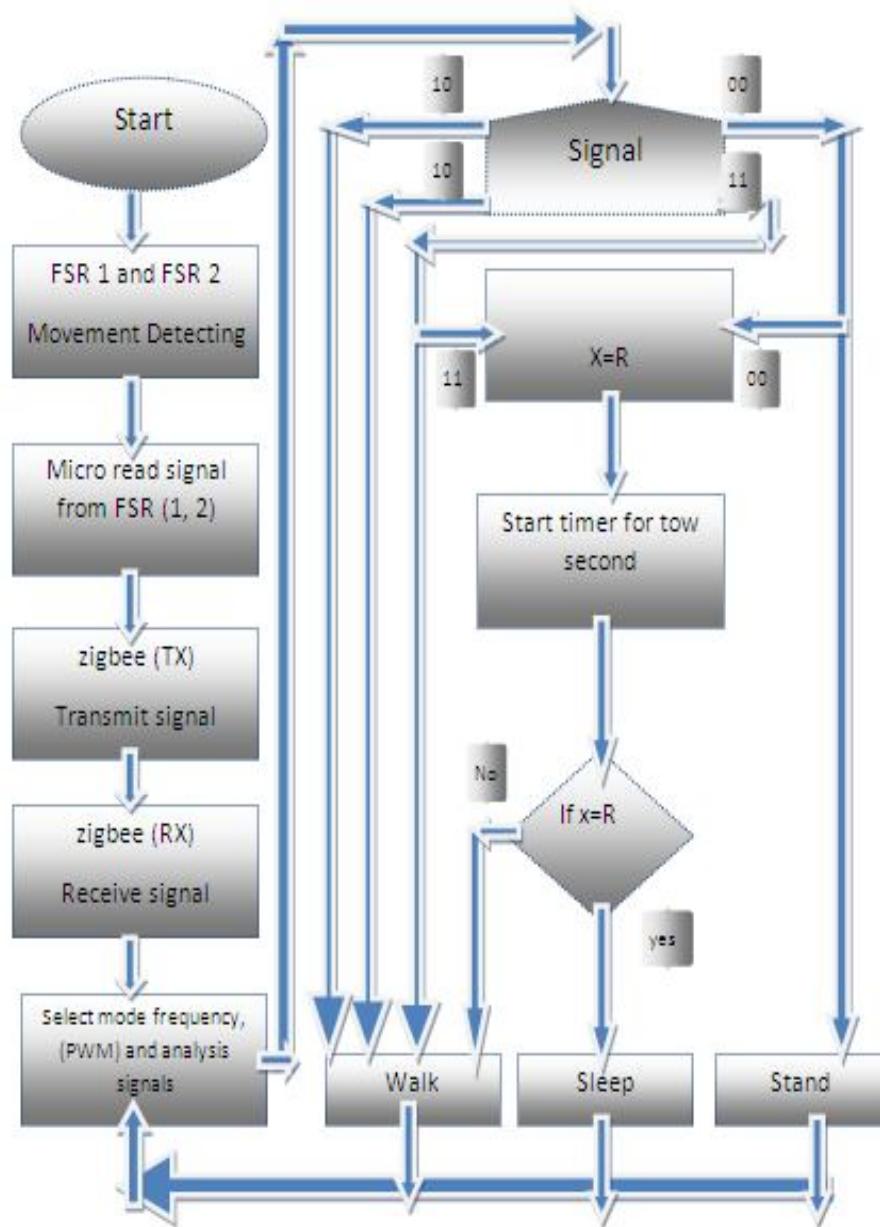


Figure (3.5): flow chart.

The system starts by analyzing the microcontroller chip. The first step is for the sensors to read the foot state. Then the microcontroller transmits the sensor value to the receiver using zigbee transceiver unit at the receiver side. The microcontroller analyzes the received signal and takes the

decision according to the foot state. Three possible cases can be occurred.

- 1- The Case (00): stand mode.
- 2- The Cases (10, 01 and 11): walking mode.
- 3- The cases (00 and 11): sleep mode (after pass two seconds).