# Chapter three
# System and Components

## 3.1 Introduction

SEMG is a noninvasive method for the measurement of muscle activity. The amplitude of the surface EMG signal (SEMG) varies from the microvolt to the few millivolts depending on the muscle under observation. In prosthetic hand small motor provide functions of hand and control is being done through proper sensing of movements of muscles. This is called myoelectric controlled or electrically powered Prosthesis. The signal can be acquired by electrodes and passed through amplifier section. The signal can be passed through filter section to remove noise. The (rms) to dc converter is used to output the dc signal. The level of that dc signal represents the EMG signal. It has been observed that the (rms) value for the upper movement of the arm is more than the (rms) value for the down movement of arm. Similarly (rms) value for the clockwise movement of the arm is more than the (rms) value for the anticlockwise movement of arm. Based on this a microcontroller is programmed to perform up/down and clockwise/anticlockwise movements in steps depending on the level of dc voltage.

## 3.2 Component Description:

The main components used in this dissertation are microcontroller, dc motors, motor drivers and electrodes.

### *3.2.1 Microcontroller:*

Atmel ATmega16 is a low-power CMOS microcontroller. It is based on the AVR enhanced RISC architecture. Atmega16 is an 8-bit microcontroller. The pin diagram of Atmega16 is shown in Figure 3.1. By executing powerful instructions in a single clock cycle; the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the designer to optimize power consumption versus processing speed. The Atmel ATmega16 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications.

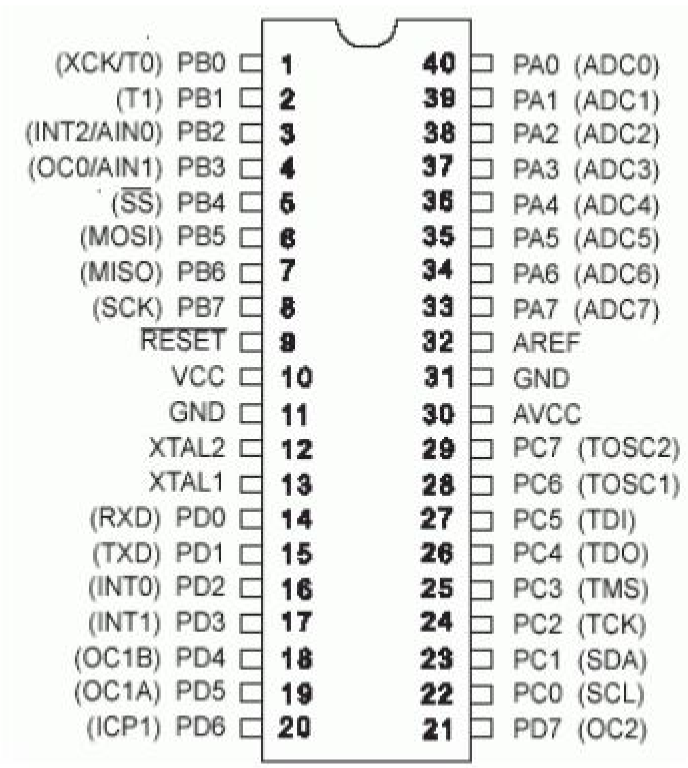


Figure 3.1: Pin diagram of Atmega16

### *3.2.1.1 Pin Descriptions:*

- ***VCC:*** Digital supply voltage.
- ***GND:*** Ground.
- ***Port A (PA0...PA7)***

  Port A serves as the analog inputs to the A/D Converter. Port A 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 PA7 are 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.
- ***Port B (PB0...PB7)***

  Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port B also serves the functions of various special features of the ATmega16.

- ***Port C (PC0...PC7)***

  Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. Port C also serves the functions of the JTAG interface and other special features of the ATmega16.

- ***Port D (PD0...PD7***

  Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port D also serves the functions of various special features of the ATmega16.

- ***RESET:***

  Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. Shorter pulses are not guaranteed to 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:***

  AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

## *3.2.1.2 The main features of ATmega16:*

The ATmega16 provides the following features:

40 pins, 16K bytes of In-System Programmable Flash Program memory, 512 bytes EEPROM.1K byte SRAM, 32 general purpose I/O lines, Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes, One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode, Internal and External Interrupts.8-channel 10-bit ADC, Four PWM Channels, Speed grades 0-16 MHz and Operates between 4.5 - 5.5 volts.

## *3.2.1.3 Port Operation Registers:*

There are three registers that are related to the various port operations that we can perform:

- ***DDRx Register: (Data Direction Register)***

  The DDRx Register (Data Direction Register), The DDxn bit in the DDRx Register selects the direction of this pin. If DDxn is written logic one, pin is configured as an output pin. If DDxn is written logic zero, pin is configured as an input pin.

- ***PORTx Pins: (Pin Output Register)***

  If PORTxn is written logic one when the pin is configured as an input pin, the pull-up resistor is activated. To switch the pull-up resistor off, PORTxn has to be written logic zero or the pin has to be configured as an output pin. If PORTxn is written logic one when the pin is configured as an output pin, the port pin is driven high (one). If PORTxn is written logic zero when the pin is configured as an output pin, the port pin is driven low (zero).

- ***PINx Register: (Pin Input Register)***

  The PINx register gets the reading from the input pins of the microcontroller.

### *3.2.1.4 Analog to Digital Converter (ADC):*

- ***Features:***

The feature of (ADC) are: 10-bit Resolution, 0.5 LSB Integral Non-linearity, ±2 LSB Absolute Accuracy, 13 µs- 260 µs Conversion Time, 8 Multiplexed Single Ended Input Channels, 7 Differential Input Channels, Optional Left adjustment for ADC Result Readout, 0 - VCC ADC Input Voltage Range, Selectable 2.56V ADC Reference Voltage, Free Running or Single Conversion Mode, ADC Start Conversion by Auto Triggering on Interrupt Sources, Interrupt on ADC Conversion Complete, Sleep Mode Noise Canceler.

The ATmega16 features a 10-bit successive approximation ADC. The ADC is connected to an 8-channel Analog Multiplexer which allows

8 single-ended voltage inputs constructed from the pins of Port A. The single-ended voltage inputs refer to 0V (GND).

The ADC has a separate analog supply voltage pin, AVCC. AVCC must not differ more than ±0.3V from VCC. Internal reference voltages of nominally 2.56V or AVCC are provided On-chip. The voltage reference may be externally decoupled at the AREF pin by a capacitor for better noise performance.

- ***ADC Voltage Reference:***

The reference voltage for the ADC (VREF) indicates the conversion range for the ADC. Single ended channels that exceed VREF will result in codes close to 0x3FF. VREF can be selected as AVCC, internal 2.56V reference, or external AREF pin.

- ***ADC Conversion Result:***

After the conversion is complete (ADIF is high), the conversion result can be found in the ADC Result Registers (ADCL, ADCH).
For single ended conversion, the result is:

$$ADC = \frac{V_{IN} * 1024}{V_{REF}} \qquad \text{EQ.NO (1)}$$

Where:

VIN is the voltage on the selected input pin and,

VREF is the selected voltage reference.

### *3.2.1.5 Difference between microcontroller and microprocessor:*

Microprocessor is an IC which has only the CPU inside them i.e. only the processing powers such as Intel's Pentium 1,2,3,4, core 2 duo, i3, i5 etc. These microprocessors don't have RAM, ROM, and other peripheral on the chip. A system designer has to add them externally to make them functional. Application of microprocessor includes Desktop PC's, Laptops, notepads etc.

But this is not the case with Microcontrollers. Microcontroller has a CPU, in addition with a fixed amount of RAM, ROM and other peripherals all embedded on a single chip. At times it is also termed as a mini computer or a computer on a single chip. Today different manufacturers produce microcontrollers with a wide range of features available in different versions. Some manufacturers are ATMEL, Microchip, TI, Free scale, Philips, Motorola etc.

Microcontrollers are designed to perform specific tasks. Specific means applications where the relationship of input and output is defined. Depending on the input, some processing needs to be done and output is delivered. For example, keyboards, mouse, washing machine, digicam, pendrive, remote, microwave, cars, bikes, telephone, mobiles, watches, etc. Since the applications are very specific, they need small resources like RAM, ROM, I/O ports etc and hence can be embedded on a single chip. This in turn reduces the size and the cost.

Microprocessor find applications where tasks are unspecific like developing software, games, websites, photo editing, creating documents etc. In such cases the relationship between input and output is not defined. They need high amount of resources like RAM, ROM, I/O ports etc.

The clock speed of the Microprocessor is quite high as compared to the microcontroller. Whereas the microcontrollers operate from a few MHz to 30 to 50 MHz, today's microprocessor operate above 1GHz as they perform complex tasks.

Comparing microcontroller and microprocessor in terms of cost is not justified. Undoubtedly a microcontroller is far cheaper than a microprocessor. However microcontroller cannot be used in place of microprocessor and using a microprocessor is not advised in place of a microcontroller as it makes the application quite costly. Microprocessor cannot be used stand alone. They need other peripherals like RAM, ROM, buffer, I/O ports etc and hence a system designed around a microprocessor is quite costly.

### *3.2.1.6 Differences between microcontroller and PLC:*

A PLC is a special microcontroller designed for industrial use that is for controlling machinery or processes. Usually a PLC is programmed using Ladder diagrams and specialized control software. The advantages of PLC control it has industrial properties such as isolated IO and noise of environment can't effect on PLC. But microcontroller has more powerful functions. The disadvantages of PLC control are too much work required in connecting wires, difficulty with changes or replacements, difficulty in finding errors; requiring skillful work force, when a problem occurs, hold-up time is indefinite, usually long, high voltage power supply. PLC has high voltage but microcontroller has small voltage usually 3V-5V.

### *3.2.2 Motor Driver (H-bridge):*

To control the direction of the DC motor L293D IC, which is an H bridge converter is used. An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards. The great ability of an H-bridge circuit is that the motor can be driven forward or backward at any speed, optionally using a completely independent power source. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. The L293D are quadruple high-current half-H drivers. The L293D is a quadruple push-pull 4 channel driver capable of delivering 600 mA (1.2 A peak surge) per channel. The L293D is ideal for controlling the forward/reverse/brake motions of small DC motors controlled by a microcontroller such as ATMEL, PIC or BASIC stamp.

The L293D is a high voltage, high current four channel driver designed to accept standard TTL logic levels and drive inductive loads (such as relays solenoids, DC and stepping motors) and switching power transistors. The L293D is suitable for use in switching applications at frequencies up to 5 KHz. The L293D is a 16 pin IC. The pin diagram of this IC is shown in Figure 3.2.

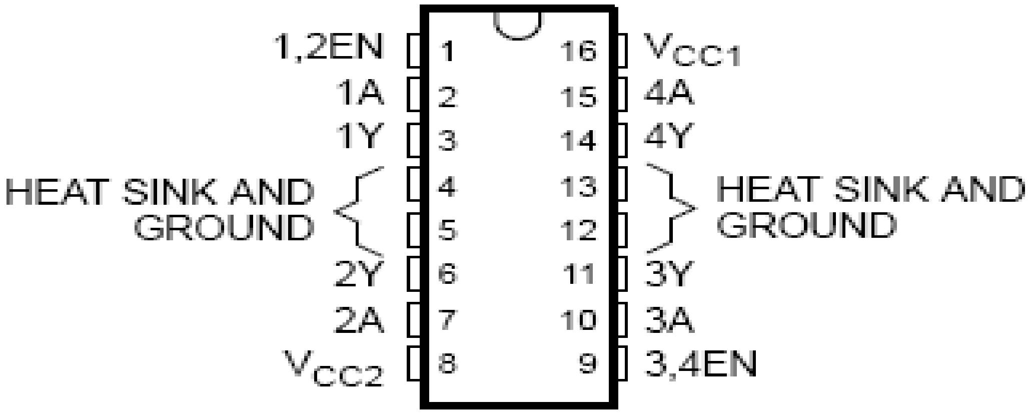


Figure 3.2: Pin diagram of L293D

L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2 and 7 and 10 and 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively. Enable pins 1 and 9 (corresponding to the two motors) must be high for motors to start operating. When an enable input is high, the associated driver gets enabled. As a result, the outputs become active and work in phase with their inputs. Similarly, when the enable input is low, that driver is disabled, and their outputs are off and in the high-impedance state. The motor action according to the input pins is shown is Table 3.1.

Table 3.1: Motor action based on status of input pins

| **Input(1A,4A)** | **Input(2A,3A)** | **Motor action** |
|---|---|---|
| Logic 0 | Logic 0 | Stop |
| Logic 0 | Logic 1 | Moves clockwise |
| Logic 1 | Logic 0 | Moves anticlockwise |
| Logic 1 | Logic 1 | Stop |

Thus, the motors behave as per the control signals generated using the microcontroller with the excitation from the external battery voltage.

### *3.2.3 DC Motor:*

DC motors are inexpensive, small, and powerful motors that are widely used. DC geared motor is shown in Figure 3.3. Gear-train reductions are typically needed to reduce the speed and increase the torque output of the motor. A DC motor is an electric motor that runs on direct current (DC) electricity. DC motors are normally very easy to reverse simply by changing the polarity of the DC input. This changeover process can be achieved via a simple changeover switch or for remote or electronic control, via a suitable relay. A big advantage of DC motors is that variable speed control is easy and can achieve with just a suitable variable resistor / rheostat or variable DC power supply.

DC motors use DC voltage (Direct Current, Gleichspannung) to achieve rotary motion. They have two pins with which to control the speed and direction of their rotary motion.


Figure 3.3: DC geared motor

### *3.2.3.1 Construction Principles:*

There are two basic types of DC motors, those with brushes and brushless DC motors. In DC motors with brushes, the stator generates a constant magnetic field, whereas the rotor either consists of a set of wire loops or utilizes the Lorentz force, or it consists of one or more coils to generate an electromagnet. In either case, the direction of the current flowing through the rotor wires must be changed every 180°.

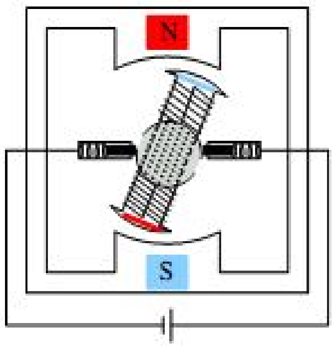


Figure 3.4: DC motor with brushes.

Figure 3.4 shows the operating principle of a DC motor with brushes. The stator generates a constant magnetic field, either through a permanent magnet or an electromagnet. The rotor is an electromagnet fitted with a commutator, that is, with two metallic contacts (the collectors), which are separated by gaps and which are connected to the ends of the rotor coil. Two (carbon) brushes protruding from the stator touch the collectors and provide a constant voltage difference, thus energizing the coil. When the rotor turns, the brushes slide over the metal band until they are directly over the gaps when the rotor reaches its apex. At this point, the rotor coils become un energized and the rotor is simply carried on by its own movement until the brushes make contact with the other collector, energizing the coil in the other direction and causing the rotor to execute another 180 turn.

Of course, an actual DC motor is slightly more complex than the one depicted in Figure 3.4, since a DC motor with only two collectors cannot start if the brushes happen to be just over the gaps when the motor is turned on.

### *3.2.3.2 DC Motor Control with H-bridge:*

Since DC motors draw a high amount of current (from hundreds of mA up to several A) and may not even use the same voltage supply as the microcontroller, they cannot be directly connected to the controller. Instead, a driver circuit is required to generate the required amount of current. DC motors are generally controlled by a four-transistor circuit called an H-bridge, see the wired diagram representing the interfacing of driver circuit with motors is given in Figure 3.5 (The circuit is greatly simplified and only shows the basic operating principle; for a practical implementation, you need free-wheeling diodes and a means to control the transistors with the microcontroller voltage levels).

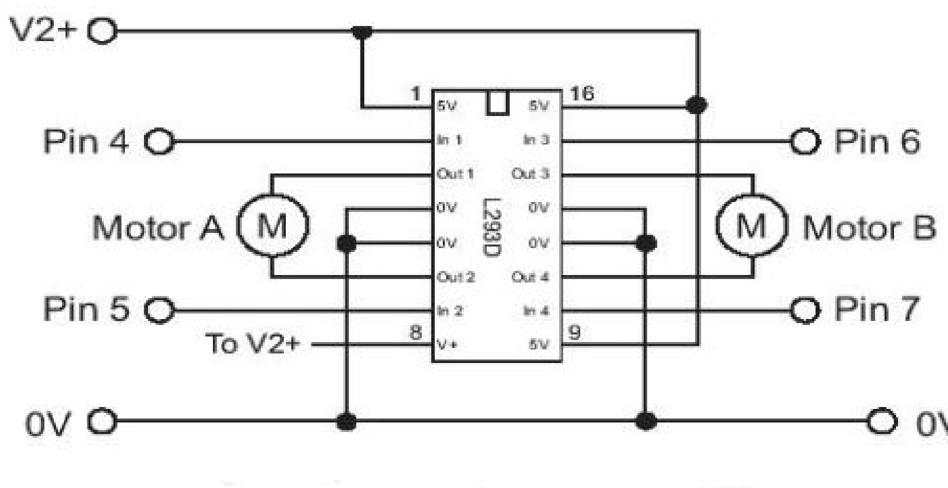


Figure 3.5: L293D interfacing with DC motor

### *3.2.4 Electrodes:*

Electromyography (EMG), also referred to as myoelectric activity, measures the electrical impulses of muscles at rest and during contraction. As with other electrophysiological signals, an EMG signal is small and needs to be amplified with an amplifier that is specifically designed to measure physiological signals. This signal can be recorded or measured with an electrode, and is then displayed on an oscilloscope, which would then provide information about the ability of the muscle to respond to nerve stimuli based upon the presence, size and shape of the wave – the resulting action potential. While the electrode could be inserted invasively into the muscle (needle electrodes), a skin surface electrode is often the preferred instrument, because it is placed directly on the skin surface above the muscle without employing the method of pinch insertion into the test subject. When EMG is measured from electrodes, the electrical signal is composed of all the action potentials occurring in the muscles underlying the electrode. This signal could either be of positive or negative voltage since it is generated before muscle force is produced and occurs at random intervals. The EMG signal is first picked up by electrode and amplified. Frequently more than one amplification stages are needed, since before the signal could be displayed or recorded, it must be processed to eliminate low or high frequency noise, or any other factors that may affect the outcome of the data. The point of interest of the signal is the amplitude, which can range between 0 to 10 volt (peak-to-peak) or 0 to 1.5 volt (rms). The frequency of an EMG signal is between 10 to 500 Hz. However, the usable energy of EMG signal is dominant between 50-150 Hz.

### *3.2.4.1 Types of EMG Electrodes:*

There are two types of surface EMG electrodes: Gelled and Dry EMG electrodes.

- ***Gelled EMG Electrodes***

  Gelled EMG electrodes contain a gelled electrolytic substance as an interface between skin and electrodes. Oxidation and reduction reactions take place at the metal electrode junction. Silver – silver chloride (Ag-AgCl) is the most common composite for the metallic part of gelled electrodes. The (AgCl) layer allows current from the muscle to pass more freely across the junction between the electrolyte and the electrode. This introduces less electrical noise into the measurement, as compared with equivalent metallic electrodes (e.g. Ag). Due to this fact, (Ag-AgCl) electrodes are used in over 80% of surface EMG applications.

  Disposable gelled EMG electrodes are most common; however, reusable gelled electrodes are also available. Special skin preparations and precautions such as (hair removal, proper gel concentration, prevention of sweat accumulation etc.) are required for gelled electrodes in order to acquire the best possible signal. Gelled EMG electrodes are shown in Figure 3.6.

Figure 3.6: Gelled EMG Electrodes

- ***Dry EMG electrodes***

Dry EMG electrodes do not require a gel interface between skin and the detecting surface. Bar electrodes and array electrodes are examples of dry electrodes. These electrodes may contain more than one detecting surface. In many examples, an in-house pre-amplification circuitry may also be employed in these electrodes. A reusable bar electrode is shown in Figure 3.7. Dry electrodes are usually heavier (>20g) as compared to gelled electrodes (<1g). This increased inertial mass can cause problems for electrode fixation; therefore, a material for stability of the electrode with the skin is required.

Figure 3.7: Dry EMG Electrode

## *3.3 Software Used:*

### *3.3.1 BASCOM AVR and Multisim:*

Multisim (Multisim 11.0) is an industry-standard, best-in-class SPICE simulation environment. It is the cornerstone of the NI circuits teaching solution to build expertise through practical application in designing, prototyping, and testing electrical circuits. The Multisim design approach helps you save prototype iterations and optimize printed circuit board (PCB) designs earlier in the process.

BASCOM AVR evaluation compiler used for programming of microcontroller. It is a C cross-compiler, Integrated Development Environment and Automatic program Generator designed for the Atmel AVR family of microcontrollers.

Since Atmel's AVR microcontrollers were introduced to the market only a few years ago, they are not so well known as the 8051 controllers. Therefore, this interesting microcontroller family should be described in more detail.

Atmel's AVR microcontrollers use a new RISC architecture which has been developed to take advantage of the semiconductor integration and software capabilities of the 1990's. The resulting microcontrollers offer the highest MIPS/mW capability available in the 8-bit microcontrollers market today.

The architecture of the AVR microcontrollers was designed together with C-language experts to ensure that the hardware and software work hand-in-hand to develop a highly efficient, high-performance code. To optimize the code size, performance and power consumption, AVR microcontrollers have big register files and fast one-cycle instructions. The family of AVR microcontrollers includes differently equipped controllers - from a simple 8-pin microcontroller up to a high-end microcontroller with a large internal memory. The Harvard architecture addresses memories up to 8 MB directly.

The register file is "dual mapped" and can be addressed as part of the on chip SRAM, whereby fast context switches are possible. All AVR microcontrollers are based on Atmel's low-power nonvolatile CMOS technology. The on-chip in-system programmable (ISP), downloadable flash memory permits devices on the user's circuit board to be reprogrammed via SPI or with the help of a conventional programming device. By combining the efficient architecture with the downloadable flash memory on the same chip, the AVR microcontrollers represent an efficient approach to applications in the "Embedded Controller" market.

BASCOM AVR also contains Automatic Program Generator that allows us to write, in a matter of minutes, all the code needed for implementing the following functions:

- ADC initialization.
- Input/output port initialization.
- LCD module initialization.