Chapter 2

ELEMENTS

INTRODUCTION

The basic elements of quantum computing are easy to identify: quantum bits, quantum registers, quantum gates and quantum networks. However, at this point an analogy with classical computing ends. Quantum bits, registers, gates and networks are very different, have other properties and larger power than their classical counterparts.

A quantum bit can be in any state within an infinite set of states. A quantum register of n quantum bits can be, at the same time, in any of the infinitely many superpositions of 2^n basis states. The parallelism a quantum register can exhibit is striking. The key new feature is that a quantum register can be in an entangled state. On one side, entangled states with their non-locality features are a hallmark of quantum mechanics. On the other side, quantum entanglement is an important resource of quantum information processing.

There is a larger variety of quantum gates than of classical gates. There are already infinitely many one-input/output quantum gates. In addition, almost any two-input/output quantum gate is universal. A simple two input/output gate together with one-input rotation gates form a set of universal gates.

LEARNING OBJECTIVES

The aim of the chapter is to learn:

1. the basic concepts concerning quantum bits and registers;
2. the concept of quantum entanglement and the examples of its power;
3. the basic examples of quantum gates and of quantum circuits;
4. some examples of universal quantum gates and a method to show universality of quantum gates;
5. the basic quantum arithmetical circuits;
6. the concept of quantum superoperator circuits.