Despite decades of advancements; modern computing systems which are based on the von Neumann architecture still carry its shortcomings. Moore's law, which had substantially masked the effects of the inherent memory-processor bottleneck of the von Neumann architecture, has slowed down due to transistor dimensions nearing atomic sizes. On the other hand, modern computational requirements, driven by machine learning, pattern recognition, artificial intelligence, data mining, and IoT, are growing at the fastest pace ever. By their inherent nature, these applications are particularly affected by communication-bottlenecks, because processing them requires a large number of simple operations involving data-retrievals and storage. The need to address the problems associated with conventional computing systems at the fundamental level has given rise to several unconventional computing paradigms. Some examples are distributed computing, in-memory computing, approximate computing, stochastic computing. In this dissertation, we have made advancements for automated syntheses of (1) in-memory computing, (2) stochastic computing systems. In-memory computing circumvents the problem of limited communication bandwidth by unifying processing and storage at the same physical locations. The advent of nano-electronic devices in recent years has made in-memory computing an energy, area, and cost-effective alternative to conventional computing. We have used Binary Decision Diagrams (BDDs) for in-memory computing on memristor crossbars. Specifically, we have used Free-BDDs, a special class of Binary Decision Diagrams, for synthesizing crossbars for flow-based in-memory computing. Stochastic computing is a re-emerging discipline with several times smaller area/power requirements as compared to conventional computing systems. It is especially suited for fault-tolerant applications like image processing, artificial intelligence, etc. We have used 'Decision Procedures' to synthesize Linear Finite State Machines (LFSM) for stochastically computing non-linear functions such as polynomials, exponentials, and hyperbolic functions.