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Realization of BCD and Binary Inter Conversions and Coil Control Operations for Ladder Diagram based Programmable Controller

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Abstract

Complex automation in all branches of industry is one of the dominating tendencies in technical development nowadays. Programmable controllers are among the most important devices, implementation of which makes possible this complex automation. The varying control specifications of today's flexible and agile manufacturing systems are challenging the use of Ladder Logic Diagrams. This paper proposes the algorithms for BCD to Binary and Binary to BCD conversion operations as well as Coil controller operations of Programmable Controller using ladder diagrams. RTL verilog code has also been designed for these operations using the developed algorithm. The design has been validated by simulation using Modelsim.

Keywords: Programmable Controller, Ladder Logic, Conversion, RTL and Xilinx.

1. INTRODUCTION

Control engineering has evolved over time. Due to the complexity of control programs and manufacturing systems, either verification option is time-consuming and expensive. Also, there are too many different logic control-programming languages used by the industry. The development of low cost computer has brought the most recent revolution, the Programmable Controller. Programmable Controllers have been gaining popularity on the factory floor and has become the most common choice for manufacturing controls. The Ladder Diagram represents hardware design models, much simplified when compared to real relay schemes. One of the primary reasons why maintenance personnel have accepted the programmable controller on the factory floor is because the fundamental program elements of ladder logic are the familiar relay-contact symbols. The overall design of Ladder diagram based Programmable Controller is experience-based, and verification is typically done only through experiments or simulation.

2. RELATED WORK

A Programmable Controller uses VLSI circuits instead of Electro mechanical devices that provides intelligent control of unlimited number of complex operations. The system suffers from none of the disadvantages of relay based logic control. Logic can be easily programmed for any application using ladder diagrams or mnemonic instructions. Ladder logic is preferred because it is easy to use and interpret and is widely accepted in industry. It is one of the standardized languages for Programmable controllers. It is a graphical programming language with representation similar to that of circuit diagrams which can be implemented using FPGA [1]. A novel architecture has been implemented for a high performance Ladder Logic Diagram implementation in which each computation of the underlying ladder logic is performed at a fixed number of clock cycles per ladder rung [2]. In recent years, several dedicated architectures for large scale Programmable Controllers have been proposed, and some of them are used in commercial programmable controllers. Many outstanding large scale Programmable Controllers are based on the multi-processor architecture or array processor architecture [3]. The Ladder solving Processor is an example of array processor architecture. Research work has been reported for a redundant PLC by considering ladder diagrams to be equivalent to a gate and a flip-flop based logic [4]. Modern manufacturing systems have been increasingly complex and large scale. Hence it requires systematic and efficient programming approaches for system modeling, analysis, simulation and evaluation [5]. The likenesses between the ladder diagrams for programmable controllers and the relay ladder logic once used to control industrial systems, improved the transition from hardwired relay systems to Programmable Controller-based systems in the industry[6-12]. For the past decades, researchers have developed many design methods based on Ladder Diagram for control systems using Programmable Controllers. But none of the Programmable Controller discussed in the above work has Conversion and Coil control operations defined in it. Proposed work describes conversion and coil controller operations. The previous works were the design and simulation of the attributes of Ladder diagram and design of timers, counters and shift operations [13-16]. This paper proposes a novel method in which the algorithms are developed for BCD to Binary conversion, Binary to BCD conversion and Coil control operations like Skip and Master Control Relay. The rest of the paper is organized as follows. Section 3 describes ladder circuit for the proposed operations. Section 4 briefs architecture conversion and coil control operations. Section 5 presents the Simulation results. Conclusion is presented in the last section.

3. LADDER CIRCUIT FOR VARIOUS PROPOSED OPERATIONS

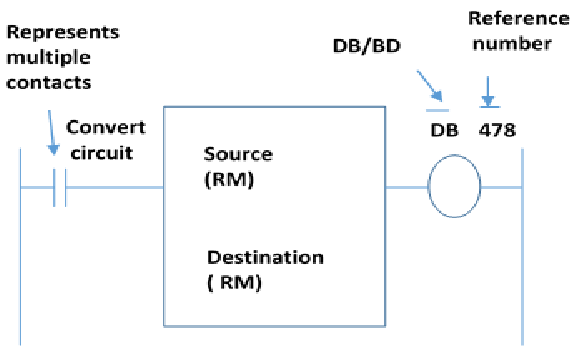

Fig.1: Ladder Logic for Conversion operation

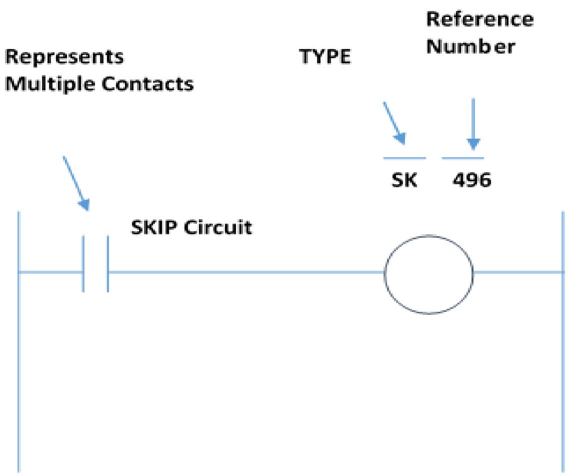

Fig. 2: Ladder Logic for Skip operation

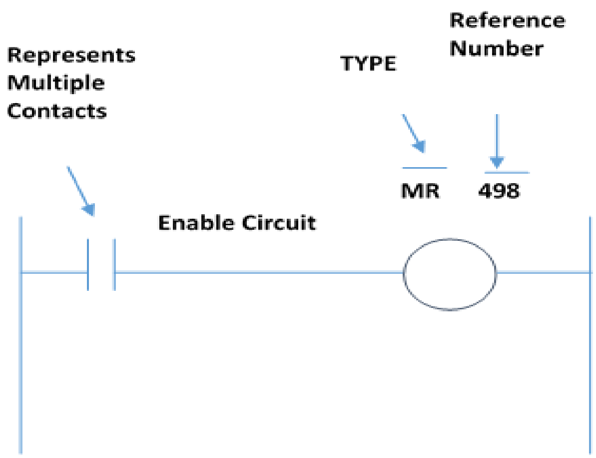

Fig. 3: Ladder Logic for MCR operation

Two types of conversion is performed in the proposed work. They are Binary to BCD and BCD to Binary operations. Realization of conversion is done using the circuit shown in Fig.1. The BCD to Binary conversion function (DB) allows upto four BCD digits to be converted to a 16-bit binary number. The conversion is made when 'Convert Circuit' signal is activated. The DB coil is energized if the BCD number is invalid (any digit exceeds 9). The DB coil is de-energized when the 'Convert Circuit' signal is not activated. The binary to BCD conversion function (BD) allows up to 14 bit binary bits to be converted to four BCD digits. The conversion is made when 'Convert Circuit' signal is activated. The BD coil is energized if the binary number exceeds 9999. The BD coil is de-energized when the 'Convert Circuit' signal is not activated. Coil Controller operations control number of coils to be skipped without not changing their status or to operate normally. The two kinds of coil controlling operations proposed in this work are Skip and Master Control Relay, whose circuits are as shown in Fig.2 and Fig.3. The operation of the both operations depends only upon the condition of control signal. The skip (SK) function allows a prescribed condition or set of conditions to determine when all or part of the circuits programmed into the processor will be skipped. When the 'Skip Circuit' signal is activated, all coils under SK control are skipped i.e. they are left in the state they were in prior to energizing the SK coil. The coils being controlled are those programmed immediately after the SK coil. When the 'Skip Circuit' signal is not conducting, all coils under SK control operate normally and SK coil is de-energized. The coils controlled by the skip function are specified by a preset constant (1 thru 256). The Master Control Relay (MR) function allows prescribed condition or set of conditions to disable all or part of the circuits programmed into the processor. When the 'Enable Circuit' signal is conducting, all coils under MR control operate normally; otherwise, all coils under MR control are de-energized. The coils controlled by the MCR function are specified by a preset constant (1 thru 256). The coils being controlled are those programmed immediately after the MCR coil.

4. ARCHITECTURE OF CONVERSION AND COIL CONTROL OPERATIONS

In the architecture of conversions and coil control operations proposed, some of the signals that are common to all modules are discussed. 'clk' signal is used for synchronizing all internal operations of Programmable controller. Active low signal 'reset_n' clears the register indicated by signal 'actual' that represents final result of the operation performed. The essential blocks for Conversion operation is shown in Fig.4. Binary to BCD (BD) and BCD to Binary (DB) conversions are proposed. Decoding of the conversion codes BD/DB, activates control signal 'TRIG'. The data for conversion is read from IR/OR register of Register Array Module by the signal 'RM_out'. After conversion process is completed, the result held by the signal 'actual' is stored into HR register. The blocks needed for Coil controller operation is shown in Fig.5. Coils can be controlled in two ways: skipping of coils (Skip function represented by SK code) and changing the status of coils (Master control relay function indicated as MR). When code pertaining to coil controller operations like SK/MR is decoded, the control signal 'TRIG' is activated. Number of coils to be skipped/controlled is indicated by the signal 'num_coils'. In skip function coils status remain unchanged and in MCR function coils are de-energized when 'TRIG' is not activated.

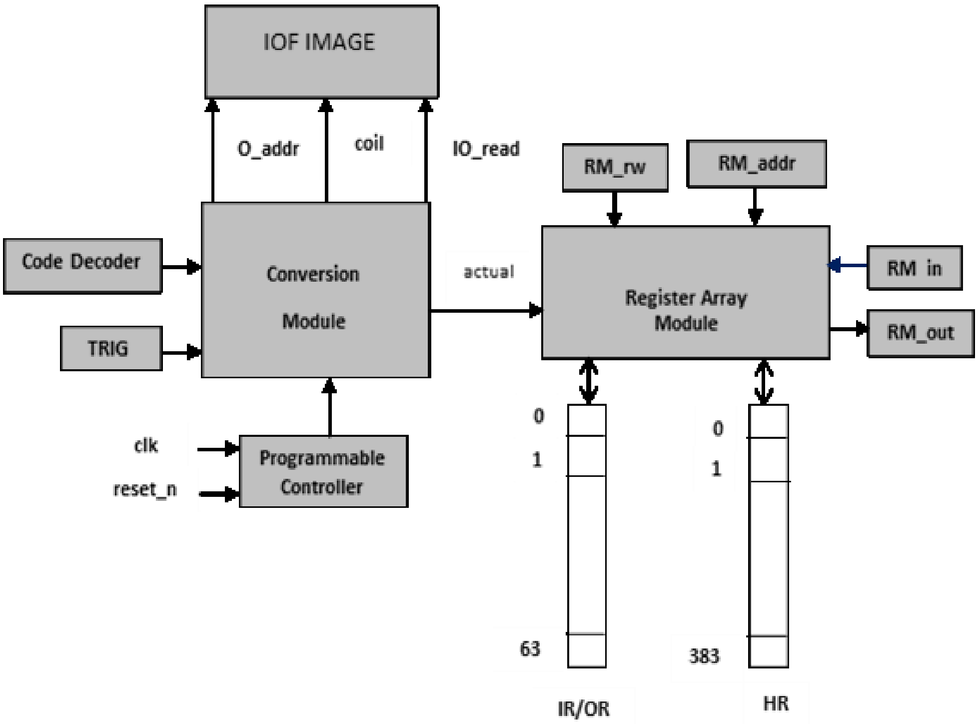

Figure 4 Processing Blocks of Conversion operation

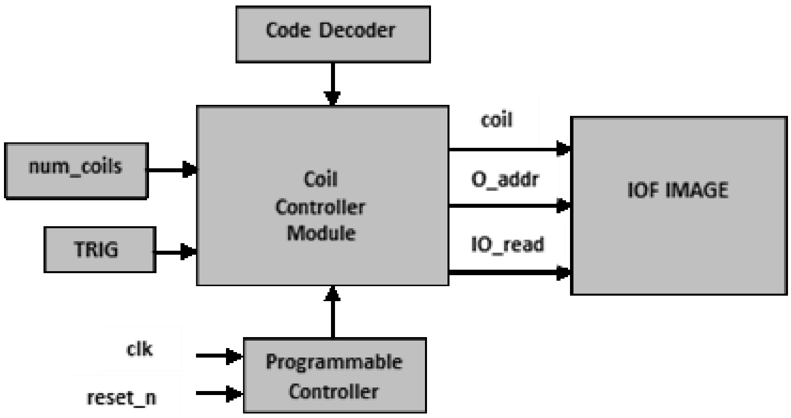

Figure 5 Processing Blocks of Coil Control Operation

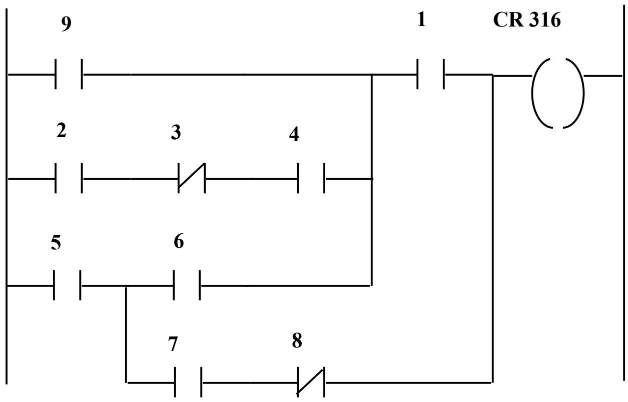

Figure 6 An Example Ladder Diagram Logic for Simulation

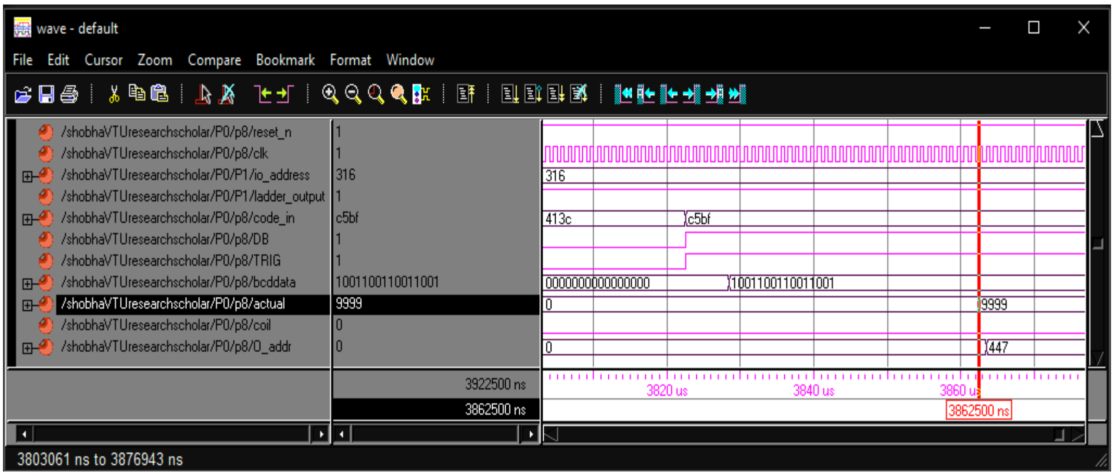

Figure 7 Simulated Waveforms for BCD to Binary Conversion Operation

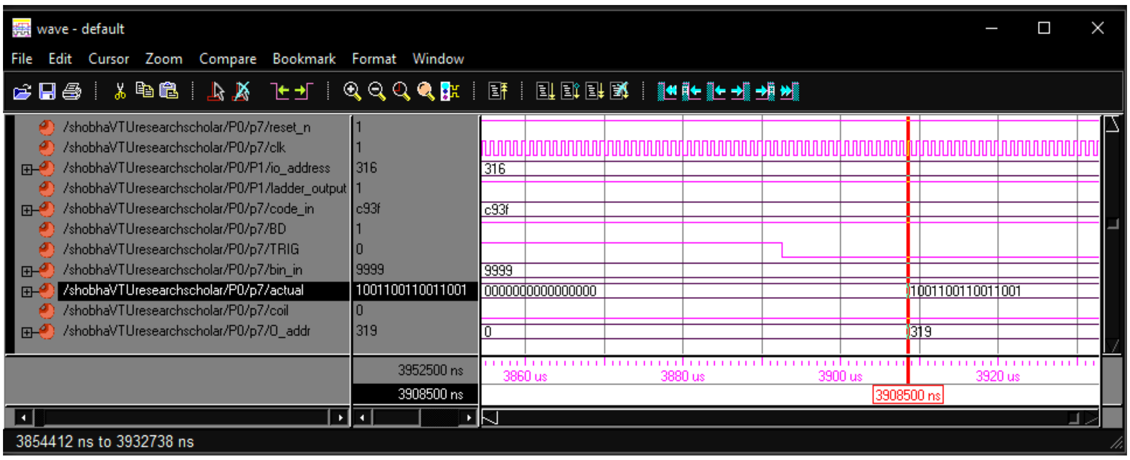

Figure 8 Simulated Waveforms for Binary to BCD Conversion Operation

5. SIMULATION RESULTS AND DISCUSSIONS

Algorithms for Conversion operations and Coil control operations were coded in Verilog as per RTL coding guidelines. In order to verify their functionality, a test bench was also written in Verilog. The RTL design was simulated using Model Sim. An example logic of ladder diagram is shown in Fig.6. The conversion operation results are shown in Fig. 7 and Fig. 8. The signal "DB" indicates bcd to binary conversion and "BD" indicates binary to bcd conversion. The signals "bcddata" in Fig. 7 and "bin_in" in Fig. 8 indicate input data required for conversion. The signal "actual" holds the result of conversion in both cases. Coil is energized only when the result exceeds the decimal value 9999. The time required for this operation is 40,000ns or 40 µs. Where as in binary to bcd, requires 86000ns or 86 µs. The number of clock cycles required in each case is 40 and 86 respectively. The controlling operation of the coils is illustrated in Fig. 9 to Fig. 10. The signal "TRIG" represent contact circuit for both Skip and Master Control Relay function. The signal "SK" indicates "Skip" function and "MR" indicates "Master Control Relay" function respectively. The signal "numofcoils" indicates the number of coils to be controlled. In skip function, coil numbers indicated by the signal "O_addr" represent those coils that are skipped without not changing their status.The coil in skip function is energized when signal "TRIG" is triggered. In master control relay function, coil numbers indicated by the signal "O_addr" represent those coils which are de-energized only when signal "TRIG" is not enabled else those coil status remain unchanged. The total time taken to execute either function is 10000ns or 10 µs. The number of clock cycles required in each case is 10.

CONCLUSIONS

New algorithm has been developed for conversion and coil control for realizing control logic of a Ladder diagram for a Programmable Controller. The design is realized using RTL Verilog. The input and output data required for these operations are stored in Register array. Test bench has been developed in Verilog and the design has been successfully simulated using Model Sim.

Figure 9 Simulated Waveforms for “Skip” Operation

Figure 10 Simulated Waveforms for “Master Control Relay” Operation

REFERENCES

[1] Miyazawa, I. Nagao, T. Fukagawa, M. Itoh, Y. Mizuya, T. Sekiguchi, T. Kanagawa, “Implementation of Ladder diagram for programmable controller using FPGA” in Emerging Technologies and Factory Automation, 1999, Proceedings ETFA ’99.

[2] Zulfakar Aspar and Mohamed Khalil-Hani, “Modeling of a Ladder Logic Processor for High Performance Programmable Logic Controller”, Third Asia International Conference on modelling and Simulation, 2009.

[3] Popovic D and V. Bhatkar, "Distributed computer control for industrial automation", pp. 566-576, Marcel Dekker, Inc., 1990.
[4] A. S. Pillai, S. K. Dubey, S. J. Gupta, M. M. Patil, "An Affordable Methodology for the Design and Implementation of a PLC on a Single Chip FPGA", International Journal of Systemics, Cybernetics and Informatics, IJSCI, April 2007.
[5] G. Frey and L. Litz, "Formal Methods in PLC programming", ", IEEE International Conference on Systems, Man, and Cybernetics Vol. 4, 2000, pp. 2431-2436.
[6] Sagar P. Jain, Dr. Sanjay L. Haridas "Energy Efficient Automized Bottling Plant Using PLC And Scada With Speed Variable Conveyor Assembly", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) ISSN: 2278-8735, Vol. 9, Issue 1, Ver. II (Jan. 2014), pp. 09-14.
[7] Mallaradhya H M, K R Prakash, "Automatic Liquid Filling to Bottles of Different Height Using Programmable Logic Controller", International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Vol. 1, Issue-4, Oct-2013
[8] Shashank Lingappa M., Vijayavithal Bongale, Sreerajendra, "PLC Controlled Low Cost Automatic Packing Machine", International Journal of Advanced Mechanical Engineering, ISSN 2250-3234, Vol. 4, 2014, pp. 803-811.
[9] Dr. D.V.Pushpa Latha, Dr. K.R.Sudha, Swati Devabhaktuni "PLC Based Smart Street Lighting Control" Intelligent Systems and Applications, Vol. 1, 2014, pp. 64-72.
[10] S. Sasikala, Olivia Ramya Chitranjan and K. Muthulakshmi, "Implementation of Home Automation Safety Control Using Programmable Logic Controller", Middle-East Journal of Scientific Research, ISSN 1990-9233, Vol. 20, Issue 4, 2014, pp.492-501
[11] Vilas V Deotare, Arjun J. Khetia, Dinesh V Padole, "Design and Implementation of Programmable Logic Controller (PLC) Using System on Programmable Chip (SOPC)",International Journal of Innovative Research in Computer and Communication Engineering, Vol. 3, Issue 8, August 2015,pp. 7546-7552.
[12] Maria G. Ioannides, "Design and Implementation of PLC-Based Monitoring Control System for Induction Motor", IEEE Transactions on Energy Conversion, Vol. 19, No. 3, September 2004, pp.469-476.
[13] Shobha S, S. Ramachandran "RTL Logic Realization Using Ladder Diagram For Programmable Controller", International Journal of Computer Engineering and Applications, Volume 7 Issue I, Part I, July 2014.
[14] Shobha S, S. Ramachandran "Realization of Timers, Counters and Shift Registers for Programmable Controller Using Ladder Diagram", International Journal of Scientific and Engineering Research, Volume 7, Issue 4, April 2016.
[15] Shobha S, S. Ramachandran "A Survey on the Techniques of Ladder Diagram Applications", International Conference on Convergent Innovative Technologies, (ICCIT- 2014) Volume 1, pp. 82-86, April 2014.

[16] Shobha S, S. Ramachandran "Implementation Of Programmable Controller Using IEC 6113-1 Standard- A Survey" International Conference on Convergent Innovative Technologies, (ICCIT- 2014) Volume 1, pp. 87-90, April 2014.