Hydraulic Systems Volume 2

# Electro-Hydraulic Components and Systems

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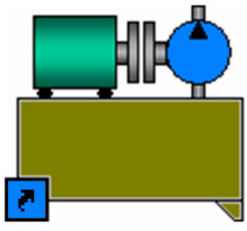

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Disclaimer

It is always advisable to review the relevant standards and the recommendations from the system manufacturer. However, the content of this book provides guidelines based on the author's experience.

Any portion of information presented in this book could be not applicable for some applications due to various reasons. Since errors can occur in circuits, tables, and text, the author/publisher assumes no liability for the safe and/or satisfactory operation of any system designed based on the information in this book.

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# PREFACE

Questions being asked that are: “should a machine built based on electrical or hydraulic power transmission and control system?” and “what are the benefits of converting a legacy hydro-mechanical system into an electro-hydraulic system?”

This book is intended for industry professionals who would like to achieve a deeper understanding of the principles of electro-hydraulic control, and who would like to improve their practical skills in building an EH-driven machine. Unlike similar books, the contents of this book are presented in a unique way. It fills the gap between the very academic style of fluid power books and the very commercial style of books that are produced by fluid power manufacturers basically to promote their products.

The book contains *Animated Circuits Files* to download. The files are produced by Automation Studio to presents examples of electrical circuits that drive switching valves. Other circuits are to present examples of open-loop and closed-loop electro-hydraulic control systems.

Hydraulic system builders and users will find this book beneficial in understanding the construction and the operating principles of the electro-hydraulic systems. The book is written to cover the knowledge of electro-hydraulic components including solenoid operated valves, proportional valves, servo valves and amplifiers. The book also covers the technicalities of in-field tuning of open-loop and closed-loop electro-hydraulic systems. The book also presents guideline to select a valve for an application and how to read data sheet of a valve. The book covers the basic functions contained in the electronic control units that drive EH valves such as gain adjustor, maximum current limiter, ramp generator, pulse width modulation, dead band eliminator, null adjustment, and much more.

With more than twenty-five years of experience in teaching fluid power for industry professionals, the author had effectively applied his solid understanding to the subject and his post-doctoral level of academic education in the preparation of this book. The book features in brief are easy language, brand non-biased, practical oriented, associated with a workbook, colored, and demonstrative.

The author wants to continue on his goal of supporting fluid power and motion control professional education by developing the following series of volumes:

- Hydraulic Systems Volume 1: Introduction to Hydraulics for Industry Professionals.
- Hydraulic Systems Volume 2: Electro-Hydraulic Components and Systems.
- Hydraulic Systems Volume 3: Hydraulic Fluids and Contamination Control.
- Hydraulic Systems Volume 4: Hydraulic Fluids Conditioning.
- Hydraulic Systems Volume 5: Best Practices for Safety and Maintenance.
- Hydraulic Systems Volume 6: Troubleshooting and Failure Analysis.
- Hydraulic Systems Volume 7: Hydraulic Systems Modeling and Simulation for Application Engineers.
- Hydraulic Systems Volume 8: Design Strategies of Hydraulic Systems.
- Hydraulic Systems Volume 9: Design Strategies of Electro-Hydraulic Systems.
- Hydraulic Systems Volume 10: Hydraulic Components Modeling and Simulation.

# ACKNOWLEDGEMENT

***All praise is to Allah who granted me the knowledge, resources and health to finish this work.***

***To the soul of my parents who taught me the values of ISLAM***

***To my family: wife, sons, daughters in law, and grandson "Adam"***

***To my best teachers and supervisors***

***To friends who were always supportive***

***The author wishes to thank these companies: (Bosch Rexroth, Assofluid, Atos, Wandfluh, Hydraforce, Moog, Parker, and others) who permit us to use some of their copyrighted material to make this book more demonstrative.***

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- ***Tom Wanke, Director of Fluid Power Institute at Milwaukee School of Engineering.***
- ***Kamara Sheku, Dean of Applied Researches at Milwaukee School of Engineering.***

# ABOUT THE BOOK

## Book Description:

The book is a learning package for students and professionals who are looking to advance their fluid power careers. The package includes colored ***textbook***, electronic files ***for the animated hydraulic circuits***, and a ***colored workbook*** (separate price) that contains printed power point slides, chapter reviews and assignments. The book is the second in a series that the author plans to publish to offer complete and comprehensive teaching and design tools for the fluid power industry. This book is an attempt to fill the gap between the very academic style of fluid power books and the very commercial style of books that are produced by fluid power manufacturers basically to promote their products.

The book presents constructional and operational qualitative analogies between electrical, hydraulic and electro-hydraulic systems. The book considers presenting real-life examples for various types of electro-hydraulic valves. The book also covers the technicalities of in-field tuning of open-loop and closed-loop electro-hydraulic systems. The book also presents guideline to select a valve for an application and how to read data sheet of a valve. The book covers the basic functions contained in the electronic control units that drive EH valves such as gain adjustor, maximum current limiter, ramp generator, pulse width modulation, dead band eliminator, null adjustment current, and much more.

The textbook is produced in letter size (8.5 x 11) inches, and weighs 3.5 lb. The textbook contains a total of ten chapters distributed on 498 pages. The workbook is produced in the same size and weighs 2 lb. The associated software is online downloadable.

## Book Objectives:

### Chapter 1: Hydraulic versus Electrical Systems

This chapter presents structural and operational comparisons between hydraulic and electrical power transmission and control systems. Similarities and differences between the inductive, capacitive, and resistive elements are discussed.

### Chapter 2: Hydro-Mechanical versus Electro-Hydraulic Solutions

This chapter explores the features and challenges of electro-hydraulic systems. Additionally the chapter introduces the benefits of converting the classical hydro-mechanical systems into electro-hydraulic ones. Pressure control, flow control, power control, and sequence control are among the systems discussed.

## Chapter 3: Switching Valves Construction and Operation

This chapter covers the principle of operation and the construction of various types of switching (ON/OFF) solenoids that are used to actuate hydraulic valves. The chapter discusses, qualitatively, the pros and cons of wet type versus dry type switching solenoids and DC type versus AC type switching solenoids. The chapter also discusses the undesirable effects of using AC switching solenoids such as AC hum, eddy current, and inrush current, and constructional considerations to minimize their effects. The chapter concludes by presenting examples of using switching solenoids in directional, pressure, and control functions.

## Chapter 4: Electrical Circuits for Switching Valves

This chapter covers the basic safety precautions that must be considered when building an electrohydraulic circuit that drives a switching valve. The chapter also presents the electrical devices and their symbols that are most commonly used with switching valves including: switches, buttons, relays, and PLCs. The chapter also covers the rules to read and write various forms of electrical circuit diagrams including: Joint Industrial Council (JIC) schematic diagrams, wiring diagram, and sequence diagram. The chapter concludes with various electrohydraulic circuits that simulate typical applications.

## Chapter 5: Proportional Valves

This chapter introduces the technology of proportional valves and discusses the construction differences as compared to conventional switching valves. The chapter also introduces the conceptual construction of force-controlled versus stroke-controlled types of proportional valves. Additionally, the chapter presents the control schemes when a proportional valve is used in open-loop and closed-loop control system. More important, the chapter concludes by exploring examples of actual proportional directional, pressure, and flow control valves from various suppliers.

## Chapter 6: Servo Valves

This chapter covers the construction and wiring methods of the main electric components in servo valves including torque motors. The chapter also covers the conceptual construction and the operation of flapper-nozzle and jet-pipe servo valves. The chapter introduces examples of typical valves with mechanical or electrical feedback.

## Chapter 7: Electro-Hydraulic Valve Selection Criteria

This chapter presents the various criteria to select a specific valve for an application. These criteria include, valve type, spool design, operating conditions, static and dynamic characteristics. The chapter also provides examples of the current valves that are produced by existing manufacturers.

### Chapter 8: Open-Loop versus Closed-Loop EH Applications

This chapter explores the differences between electro-hydraulic open-loop and closed-loop systems. Several examples have been presented to discuss various ways to control load, speed and position of a hydraulic actuator. The chapter concludes by introducing examples from industrial and mobile applications.

### Chapter 9: Control Electronics for Electro-Hydraulic Valves

This chapter explores the differences between electro-hydraulic open-loop and closed-loop systems. Several examples have been presented to discuss various ways to control load, speed and position of a hydraulic actuator. The chapter concludes by introducing examples from industrial and mobile applications.

### Chapter 10: Electro-Hydraulic Valves Commissioning and Maintenance

This chapter introduces guidelines for commissioning and maintenance of EH valves.

## Book Statistics:

The table shown below contains interesting statistical date about the textbook:

| *Chapter #* | *Pages* | *Figures* | *Animated Circuits* | *Equations* | *Tables* | *Lines* | *Words* | *Characters* |
|---|---|---|---|---|---|---|---|---|
| ***Chapter 1*** | 27 | 26 | 1 | 11 | 0 | 522 | 3086 | 21373 |
| ***Chapter2*** | 40 | 31 | 16 | 0 | 0 | 1310 | 6046 | 38834 |
| ***Chapter 3*** | 50 | 75 | 0 | 6 | 3 | 1086 | 7477 | 46084 |
| ***Chapter 4*** | 57 | 48 | 17 | 0 | 1 | 1361 | 6746 | 39681 |
| ***Chapter 5*** | 69 | 76 | 0 | 0 | 0 | 1106 | 7022 | 38398 |
| ***Chapter 6*** | 49 | 41 | 0 | 5 | 1 | 917 | 5484 | 34027 |
| ***Chapter 7*** | 83 | 83 | 0 | 5 | 3 | 1459 | 7349 | 46195 |
| ***Chapter 8*** | 45 | 45 | 0 | 1 | 0 | 908 | 6104 | 38171 |
| ***Chapter 9*** | 77 | 58 | 0 | 1 | 1 | 891 | 4249 | 22092 |
| ***Chapter 10*** | 9 | 7 | 0 | 1 | 0 | 209 | 1157 | 6316 |
| ***Other*** | 45 | - | - | - | - | - | - | - |
| ***Total*** | **550** | **490** | **34** | **30** | **9** | **9769** | **54720** | **331171** |

# ABOUT THE AUTHOR

Medhat Khalil, Ph.D., Director of Professional Education & Research Development at the Applied Technology Center, Milwaukee School of Engineering, Milwaukee, WI, USA. Medhat got his bachelor's degree in mechanical engineering from Military Technical College (MTC), Cairo, Egypt. He got his master's degree in Mechanical Engineering from Cairo University, Cairo, Egypt. Medhat has been granted his Ph.D. in Mechanical Engineering and Post-Doctoral Industrial Research Fellowship from Concordia University in Montreal, Quebec, Canada. Medhat, so far, published three textbooks. Medhat participated in many technical conferences and published several reviewed technical papers and he is in the process of registering number of patents. Medhat has been certified by the International Fluid Power Society (IFPS) as: Certified Fluid Power Hydraulic Specialist (CFPHS) and Certified Fluid Power Accredited Instructor (CFPAI). Medhat is a member of many grand institutions such as Center for Compact and Efficient Fluid Power Engineering Research Center (CCEFP), listed Fluid Power Consultant by the National Fluid Power Association (NFPA) and listed professional instructor by the American Society of Mechanical Engineers (ASME) and National American Die Casting Association (NADCA). Medhat has been assigned as the chair of the education committee for the International Fluid Power Exposition (IFPE2017 and 2020). Medhat developed and taught various courses for industry professionals. Medhat has a balanced academic and industrial experience. Medhat has a deep working experience in the field of Mechanical Engineering; more specifically in fluid power and motion control. Medhat had worked for several world-wide recognized industrial organizations such as Rexroth in Germany and CAE in Canada.


Medhat had designed several hydraulic systems and developed several analytical and educational software. Medhat also has vast experience in modeling and simulation of dynamic systems using Matlab-Simulink. Medhat was the designer and founder of the Universal Fluid Power Trainers. Medhat was the recipient of the "Otto Maha Pioneers in Fluid Power" award by 2012.