

SECOND EDITION
COMPREHENSIVE
DICTIONARY
OF
ELECTRICAL
ENGINEERING

EDITOR-IN-CHIEF
Phillip A. Laplante



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Taylor & Francis
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Boca Raton London New York Singapore

CRC PRESS, a Taylor & Francis title, part of the Taylor and Francis Group.

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Advanced Micro Devices, Inc., Pensando Systems, Inc. - Ex. 1023, Page 000003

Published in 2005 by
CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

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CRC Press is an imprint of Taylor & Francis Group

No claim to original U.S. Government works
Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-10: 0-8493-3086-6 (Hardcover)
International Standard Book Number-13: 978-0-8493-3086-5 (Hardcover)
Library of Congress Card Number 2004058572

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Library of Congress Cataloging-in-Publication Data

Comprehensive dictionary of electrical engineering / editor-in-chief Phillip A. Laplante.-- 2nd ed.
p. cm.

ISBN 0-8493-3086-6 (alk. paper)

1. Electric engineering--Dictionaries. I. Title: Electrical engineering. II. Laplante, Phillip A.

TK9.C575 2005
621.3'03--dc22

2004058572



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Preface to the Second Edition

Since the publication of the first edition of this dictionary more than 5 years ago, many changes in technology have occurred, particularly in the rapidly changing fields of image processing, computer electronics, fuel cells, and nanotechnology. I must say, however, that preparing the second edition of this dictionary was significantly easier than the first edition (see [preface to first edition](#)). It was easier to prepare because, fortunately, I had a set of handy resources that included terms related to these technological changes. That is, I was able to incorporate new terms from the many new CRC handbooks published within the last 2 years including, the *Fuel Cell Technology Handbook*, *Electric and Hybrid Vehicles: Design Fundamentals*, *The Computer Engineering Handbook*, *Digital Color Imaging Handbook*, *Handbook of Nanoscience Engineering and Technology*, *The RF and Microwave Handbook*, *The Power Electronics Handbook*, *Biomedical Photonics Handbook*, and *The Mechatronics Handbook*. I was also able to incorporate new terms and corrections suggested by readers of the first edition (for which I heartily thank those readers), as well as additions and corrections that are invariably needed after even the fifth read-through.

In total, more than 1500 terms were added, updated, expanded, improved, or corrected, resulting in a dictionary with over 11,000 terms and abbreviations related to electrical engineering. However, if readers discover any errors or think that any important terms have been omitted, please inform me at plaplante@psu.edu with your proposed changes. I will be happy to consider those changes for future printings and editions.

In keeping within the scope established with the first edition, most terms pertaining to computer science, information technology, and software engineering that are not directly linked to the underlying hardware were omitted. For these, please refer to *Comprehensive Dictionary of Computer Science, Engineering and Technology* (CRC Press).

Once again I want to thank Nora Konopka and the fine editorial and production staff at Taylor & Francis, especially Helena Redshaw and Amy Rodriguez, for helping to bring this second edition into being. These folks have always been a pleasure to work with.

Finally, I want to thank my family for their patience and support as I worked countless hours on this project, which most certainly would never have been completed without their blessing. Therefore, this dictionary is dedicated to Nancy, Christopher, and Charlotte.

Phillip A. Laplante, P.E., Ph.D.

Preface to the First Edition

One can only appreciate the magnitude of effort required to develop a dictionary by actually experiencing it. Although I had written nine other books, I certainly did not know what I was getting into when in January of 1996 I agreed to serve as Editor-in-Chief for this project. Now, after $2\frac{1}{2}$ years I understand.

Unlike other books that I have written, creating this dictionary was more a test of will and stamina and an exercise in project management than mere writing. And although I have managed organizations of up to 80 academics, nothing is more like “herding cats” than motivating an international collection of more than 100 distinguished engineers, scientists, and educators scattered around the globe almost entirely via email. Yet, I think there is no other way to undertake a project like this. I still marvel at how Noah Webster must have managed to construct his English Dictionary without the benefits of modern communication.

But this project, as much as it is a monument to individual will, is really the collaborative work of many brilliant and dedicated men and women. This is their dictionary and your dictionary.

Phillip A. Laplante, P.E., Ph.D.
Editor-in-Chief

Foreword

How was the dictionary constructed?

As I knew this project would require a divide-and-conquer approach with fault-tolerance, I sought to partition the dictionary by defining areas that covered all aspects of electrical engineering. I then matched these up to IEEE-defined interest areas to ensure that complete coverage was provided. This created a great deal of overlap, which was intentional. I knew that terms needed to be defined several different ways, depending on usage, and I needed to ensure that every term would be defined at least once.

The mapping of the dictionary's areas to the IEEE interest areas are as follows:

Power systems	Circuits and systems
• Power engineering	• Circuits and systems
• Power electronics	• Instruments and measurements
Electric motors and machines	Control systems
• Power engineering	• Control systems
• Power electronics	• Robotics and automation
Digital electronics, VLSI, hardware description language	Electromagnetics
• Consumer electronics	• Electromagnetic compatibility
• Electronic devices	• Magnetics
• Industrial electronics	Computer engineering (processors)
• Instruments and measurements	• Computer
Microelectronics and solid state devices	Computer engineering (I/O and storage)
• Industrial electronics	• Computer
• Instruments and measurements	Microwave systems
RF, radio, and television	• Antennas and propagation
• Broadcast technology	• Microwave theory and techniques
Communications and information processing	Electro-optical and lightwave systems
• Communications	• Lasers and electro-optics
• Information theory	Illumination
• Systems, man, and cybernetics	Properties of materials
• Reliability	• Dielectrics and electrical insulation
Signal and image processing	Packaging
• Signal processing	• Components, packaging
• Systems, man, and cybernetics	• Manufacturing technology

Note that software engineering was not included as an area, and most software terms have been omitted. Those that were included were done so because they relate to some aspect of assembly language

programming or low-level control, or artificial intelligence and robotics. For those interested in software engineering terms, CRC's *Comprehensive Dictionary of Computer Science, Engineering, and Technology* includes those terms.

Several other IEEE interest areas were not explicitly assigned to area editors. However, after discussing this fact with the editorial board, it was decided that relevant terms of a general nature would be picked up and terms that were not tagged for the dictionary from these areas were probably too esoteric to be included.

These interest areas encompass:

Aerospace and electronic systems	Geosience and remote sensing
Education	Industry applications
Engineering in medicine and biology	Nuclear and plasma science
Engineering management	Oceanic engineering
Professional communications	Ultrasonic, ferroelectrics, and frequency control
Social implications of technology	Vehicular technology

Given the area editor structure, constructing the dictionary then consisted of the following steps:

1. Creating a terms list for each area
2. Defining terms
3. Cross-checking terms within areas
4. Cross-checking terms across areas
5. Compiling and proofing the terms and definitions
6. Reviewing compiled dictionary
7. Final proofreading

The first and most important task undertaken by the area editors was to develop a list of terms to be defined. A terms list is a list of terms (without definitions), proper names (such as important historical figures or companies), or acronyms relating to electrical engineering. What went into each terms list was left to the discretion of the area editor based on the recommendations of the contributing authors. However, lists were to include all technical terms that relate to the area (and subareas). Technical terms of a historical nature were only included if it was noted in the definition that the term is “not used” in modern engineering or that the term is “historical” only. Although the number of terms in each list varied somewhat, each area’s terms list consisted of approximately 700 items.

Once the terms lists were created, they were merged and scrutinized for any obvious omissions. These missing terms were then assigned to the appropriate area editor. At this point the area editors and their contributing authors (there were 5 to 20 contributing authors per area) began the painstaking task of term definition. This process took many months. Once all of the terms and their definitions were collected, the process of converting, merging, and editing began.

The dictionary included contributions from over 100 contributors from 17 countries. Although authors were provided with a set of guidelines to write terms definitions, they were free to exercise their own judgment and to use their own style. As a result, the entries vary widely in content from short, one-sentence definitions to rather long dissertations. While I tried to provide some homogeneity in the process of editing, I neither wanted to tread on the feet of the experts and possibly corrupt the meaning of the definitions (after all, I am not an expert in any of the representative areas of the dictionary) nor did I want to interfere with the individual styles of the authors. As a result, I think the dictionary contains a diverse and rich exposition that collectively provides good insights into the areas intended to be covered by the dictionary.

Moreover, I was pleased to find the resultant collection much more lively, personal, and user-friendly than typical dictionaries.

Finally, we took advantage of the rich CRC library of handbooks, including *The Control Handbook*, *Electronics Handbook*, *Image Processing Handbook*, *Circuits and Filters Handbook*, and *The Electrical Engineering Handbook*, to pick up any definitions that were missing or incomplete. About 1000 terms were taken from the CRC handbooks. We also borrowed, with permission from IEEE, about 40 definitions that could not be found elsewhere or could not be improved upon.

Despite the incredible support from my area editors, individual contributors, and staff at CRC Press, the final tasks of arbitrating conflicting definitions, rewording those that did not seem descriptive enough, and identifying missing ones were left to me. I hope that I have not failed you terribly in my task.

How to use the dictionary

The dictionary is organized like a standard language dictionary except that not every word used in the dictionary is defined (this would necessitate a complete embedding of an English dictionary). However, we tried to define most non-obvious technical terms used in the definition of another term.

In some cases more than one definition is given for a term. These are denoted (1), (2), (3), . . . , etc. Multiple definitions were given in cases where the term has multiple distinct meanings in differing fields, or when more than one equivalent but uniquely descriptive definition was available to help increase understanding. In a few cases, I just couldn't decide between two definitions. Pick the definition that seems to fit your situation most closely. The notation 1., 2., etc. is used to itemize certain elements of a definition and are not to be confused with multiple definitions.

Acronym terms are listed by their expanded name. Under the acronym the reader is referred to that term. For example, if you look up "RISC" you will find "See [reduced instruction set computer](#)," where the definition can be found. The only exceptions are in the cases where the expanded acronym might not make sense, or where the acronym itself has become a word (such as "laser" or "sonar").

While I chose to include some commonly used symbols (largely upon the recommendations of the contributors and area editors), this was not a principle focus of the dictionary and I am sure that many have been omitted.

Finally, we tried to avoid proprietary names and tradenames where possible. Some have crept in because of their importance, however.

Acknowledgments

A project of this scope literally requires hundreds of participants. I would like to take this moment to thank these participants both collectively and individually. I thank, in no particular order:

- The editorial board members and contributors. Although not all participated at an equal level, all contributed in some way to the production of this work.
- Ron Powers, CRC President of Book Publishing, for conceiving this dictionary, believing in me, and providing incredible support and encouragement.
- Frank MacCrory, Norma Trueblood, Nora Konopka, Carole Sweatman, and my wife Nancy for converting, typing, and/or entering many of the terms.

- Jill Welch, Nora Konopka, Ron Powers, Amy Rodriguez, Susan Fox, Karen Feinstein, Joe Ganzi, Gerry Axelrod, and others from CRC for editorial support.
- *CRC Comprehensive Dictionary of Mathematics* and *CRC Comprehensive Dictionary of Physics* editor Stan Gibilisco for sharing many ideas with me.
- My friend Peter Gordon for many of the biographical entries.
- Lisa Levine for providing excellent copy editing of the final manuscript.

Finally to my wife Nancy and children Christopher and Charlotte for their incredible patience and endurance while I literally spent hundreds of hours to enable the birth of this dictionary. This achievement is as much theirs as it is mine.

Please accept my apologies if anyone was left out—this was not intentional and will be remedied in future printings of this dictionary.

How to Report Errors/Omissions

Because of the magnitude of this undertaking and because we attempted to develop new definitions completely from scratch, we have surely omitted (though not deliberately) many terms. In addition, some definitions are possibly incomplete, weak, or even incorrect. But we wish to evolve and improve this dictionary in subsequent printings and editions. You are encouraged to participate in this collaborative, global process. Please send any suggested corrections, improvements, or new terms to be added (along with suggested definitions) to me at p.laplante@ieee.org or plaplante@psu.edu. If your submission is incorporated, you will be recognized as a contributor in future editions of the dictionary.

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Editor-in-Chief

Phillip A. Laplante, Ph.D. is associate professor of software engineering at Pennsylvania State's Great Valley Graduate Center. In this capacity he conducts research and teaches graduate courses in software and computer systems engineering. He also serves as the chief technology officer for the Eastern Technology Council and founded and leads its CIO community of practice, the CIO Institute.

Before joining Penn State, Dr. Laplante was president of Pennsylvania Institute of Technology, a 2-year, private college that focuses on technology training and retraining. Prior to that, he was the founding dean of the BCC/NJIT Technology and Engineering Center in southern New Jersey. He was also associate professor of computer science and chair of the Mathematics, Computer Science and Physics Department at Fairleigh Dickinson University in New Jersey.

In addition to his academic career, Dr. Laplante spent almost 8 years as a software engineer and project manager working on avionics (including the space shuttle), computer-aided design (CAD), and software test systems. He has published more than 120 papers and articles and 20 books, including *Dictionary of Computer Science, Engineering, and Technology* and *Software Engineering for Image Processing Systems*, both through CRC Press. He also edits two book series, including the Image Processing series for CRC Press, and cofounded the journal *Real-Time Imaging*, which he edited for 5 years.

Dr. Laplante earned his B.S., M.Eng., and Ph.D. in computer science, electrical engineering, and computer science, respectively, from Stevens Institute of Technology, and an M.B.A. from the University of Colorado. He is a senior member of IEEE and a member of numerous other professional societies, program committees, and boards, and is a licensed professional engineer in Pennsylvania.

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Earle M. Alexander IV
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Dexter Magnetic Materials
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Dion Fralick

NASA
Langley Research Center
Hampton, Virginia

Lawrence Fryda

Central Michigan University
Mt. Pleasant, Michigan

Mumtaz B. Gawargy

Concordia University
Montreal, Quebec, Canada

Frank Gerlitz

Washtenaw College
Ann Arbor, Michigan

Antonio Augusto Gorni
COSIPA
Cubatao, Brazil

Lee Goudelock
Laurel, Mississippi

Alex Grant
Institut für Signal- und
Informationsverarbeitung
Zurich, Switzerland

Thomas G. Habetler
Georgia Tech
Atlanta, Georgia

Haldun Hadimioglu
Brooklyn, New York

Dave Halchin
RF MicroDevices
Greensboro, North Carolina

Thomas L. Harman
University of Houston
Houston, Texas

P. R. Hemmer
RL/EROP
Hanscom Air Force Base
Massachusetts

Vincent Heuring
University of Colorado
Boulder, Colorado

Robert J. Hofinger
Purdue University School of Technology
at Columbus
Columbus, Indiana

Michael Honig
Northwestern University
Evanston, Illinois

Gregor Hoogers
Trier University of Applied Sciences,
Umwelt Campus
Birkenfeld, Germany

Yan Hui
Northern Telecom
Nepean, Ontario, Canada

Suresh Hungenahally
Griffith University
Nathan, Queensland, Australia

Iqbal Husain
University of Akron
Akron, Ohio

Eoin Hyden
Madison, New Jersey

Marija Ilic
MIT
Cambridge, Massachusetts

Mark Janos

Albert Jelalian
Jelalian Science and Engineering
Bedford, Massachusetts

Anthony Johnson
New Jersey Institute of Technology
Newark, New Jersey

C. Bruce Johnson
Phoenix, Arizona

Brendan Jones
Optus Communications
Sydney, Australia

Suganda Jutamulia
In-Harmony Technology Corporation
Petaluma, California

Richard Y. Kain

University of Minnesota
Minneapolis, Minnesota

Dikshitulu K. Kalluri

University of Massachusetts
Lowell, Massachusetts

Alex Kalu

Savannah State University
Savannah, Georgia

Gary Kamerman

FastMetrix
Huntsville, Alabama

Avishay Katz

EPRI
Palo Alto, California

Wilson E. Kazibwe

Telegyr Systems
San Jose, California

David Kelley

Penn State University
University Park, Pennsylvania

D. Kennedy

Ryerson Polytechnic Institute
Toronto, Ontario, Canada

Mohan Ketkar

University of Houston
Houston, Texas

Jerzy Klamka

Silesian Technical University
Gliwice, Poland

Krzysztof Kozlowski

Technical University of Poznan
Poznan, Poland

Ron Land

Penn State University
New Kensington, Pennsylvania

Robert D. Laramore

Cedarville College
Cedarville, Ohio

Joy Laskar

Georgia Institute of Technology
Atlanta, Georgia

Matti Latva-aho

University of Oulu
Linannmaa, Oulu, Finland

Thomas S. Laverghetta

Indiana University-Purdue University
at Fort Wayne
Fort Wayne, Indiana

J. N. Lee

Naval Research Laboratory
Washington, D.C.

Fred Leonberger

UT Photonics
Bloomfield, Connecticut

Rodney LeRoy

Townsend and Townsend and Crew, LLP
San Francisco, California

Yilu Liu

Virginia Tech
Blacksburg, Virginia

Ging Li-Wang

Dexter Magnetic Materials
Fremont, California

Jean Jacques Loiseau

Institute Recherche en Cybernetique
Nantes, France

Harry MacDonald
San Diego, California

Chris Mack
FINLE Technologies
Austin, Texas

Krzysztof Malinowski
Warsaw University of Technology
Warsaw, Poland

S. Manoharan
University of Auckland
Auckland, New Zealand

Horacio J. Marquez
University of Alberta
Edmonton, Alberta, Canada

Francesco Masulli
University of Genoa
Genoa, Italy

Vincent P. McGinn
Northern Illinois University
DeKalb, Illinois

John A. McNeill
Worcester Polytechnic Institute
Worcester, Massachusetts

David P. Millard
Georgia Institute of Technology
Atlanta, Georgia

Monte Miller
Rockwell Semiconductor Systems
Newbury Park, California

Linn F. Mollenauer
AT&T Bell Labs
Holmdel, New Jersey

Mauro Mongiardo
University of Perugia
Perugia, Italy

Michael A. Morgan
Naval Postgraduate School
Monterey, California

Amir Mortazawi
University of Central Florida
Orlando, Florida

Michael S. Munoz
TRW Corporation

Paolo Nesi
University of Florence
Florence, Italy

M. Nieto-Vesperinas
Instituto de Ciencia de Materiales
Madrid, Spain

Kenneth V. Noren
University of Idaho
Moscow, Idaho

Behrooz Nowrouzian
University of Alberta
Edmonton, Alberta, Canada

Terrence P. O'Connor
Purdue University School of Technology
at New Albany
New Albany, Indiana

Ben O. Oni
Tuskegee University
Tuskegee, Alabama

Thomas H. Ortmeier
Clarkson University
Potsdam, New York

Ron P. O'Toole
Cedar Rapids, Iowa

Tony Ottosson
Chalmers University of Technology
Goteburg, Sweden

J. R. Parker
University of Calgary
Calgary, Alberta, Canada

Stefan Parkval
Royal Institute of Technology
Stockholm, Sweden

Joseph E. Pascente
Downers Grove, Illinois

Russell W. Patterson
Tennessee Valley Authority
Chattanooga, Tennessee

Steven Pekarek
University of Missouri
Rolla, Missouri

Marek Perkowski
Portland State University
Portland, Oregon

Roman Pichna
University of Oulu
Oulu, Finland

A. H. Pierson
Pierson Scientific Associates, Inc.
Andover, Massachusetts

Pragasen Pillay
Clarkson University
Potsdam, New York

Aun Neow Poo
Postgraduate School of Engineering
National University of Singapore
Singapore

Ramas Ramaswami
MultiDisciplinary Research
Ypsilanti, Michigan

Satiskuman J. Ranade
New Mexico State University
Las Cruces, New Mexico

Lars K. Rasmussen
Centre for Wireless Communications
Singapore

Walter Rawle
Ericsson, Inc.
Lynchburg, Virginia

C. J. Reddy
NASA Langley Research Center
Hampton, Virginia

Greg Reese
Dayton, Ohio

Joseph M. Reinhardt
University of Iowa
Iowa City, Iowa

Nabeel Riza
University of Central Florida
Orlando, Florida

John A. Robinson
Memorial University of Newfoundland
St. John's, Newfoundland
Canada

Eric Rogers
University of Southampton
Highfield, Southampton, England

Christian Ronse
Université Louis Pasteur
Strasbourg, France

Pieter van Rooyen
University of Pretoria
Pretoria, South Africa

Ahmed Saifuddin
Communication Research Lab
Tokyo, Japan

Robert Sarfi
ABB Power T&D Corporation
Cary, North Carolina

Simon Saunders
University of Surrey
Guildford, England

Helmut Schillinger
IOQ
Jena, Germany

Manfred Schindler
ATN Microwave
North Billerica, Massachusetts

Warren Seely
Motorola
Scottsdale, Arizona

Yun Shi
New Jersey Institute of Technology
Newark, New Jersey

Mikael Skoglund
Chalmers University of Technology
Goteborg, Sweden

Rodney Daryl Slone
University of Kentucky
Lexington, Kentucky

Keyue M. Smedley
University of California
Irvine, California

William Smith
University of Kentucky
Lexington, Kentucky

Babs Soller
University of Massachusetts Medical Center
Worcester, Massachusetts

Y. H. Song
Brunel University
Uxbridge, England

Janusz Sosnowski
Institute of Computer Science
Warsaw, Poland

Elvino Sousa
University of Toronto
Toronto, Ontario, Canada

Philip M. Spray
Amarillo, Texas

Joe Staudinger
Motorola
Tempe, Arizona

Roman Stemprok
Denton, Texas

Francis Swarts
University of the Witwatersr and
Johannesburg, South Africa

Andrzej Swierniak
Silesian Technical University
Gliwice, Poland

Daniel Tabak
George Mason University
Fairfax, Virginia

Tadashi Takagi
Mitsubishi Electric Corporation
Ofuna, Kamakura, Japan

Jaakko Talvitie
University of Oulu
Oulu, Finland

Hamid A. Toliyat
Texas A&M University
College Station, Texas

Austin Truitt
Texas Instruments
Dallas, Texas

Pieter van Rooyen
University of Pretoria
South Africa

Jonas Vasell
Chalmers University of Technology
Gateborg, Sweden

John L. Volakis
University of Michigan
Ann Arbor, Michigan

Annette von Jouanne
Oregon State University
Corvallis, Oregon

Liancheng Wang
ABB Power T&D Corporation
Cary, North Carolina

Ronald W. Waynant
FDA/CDRH
Rockville, Maryland

Larry Wear
Sacramento, California

Wilson X. Wen
AI Systems
Talstra Labs
Clayton, Australia

Barry Wilkinson
University of North Carolina
Charlotte, North Carolina

Robert E. Wilson
Western Area Power Administration
Montrose, California

Stacy S. Wilson
Western Kentucky University
Bowling Green, Kentucky

Denise M. Wolf
Lawrence Berkeley National Laboratory
Berkeley, California

E. Yaz
University of Arkansas
Fayetteville, Arkansas

Pochi Yeh
University of California
Santa Barbara, California

Jeffrey Young
University of Idaho
Moscow, Idaho

Stanislaw H. Zak
Purdue University
West Lafayette, Indiana

Qing Zhao
University of Western Ontario
London, Ontario, Canada

Jizhong Zhu
National University of Singapore
Singapore

Omar Zia
Marietta, Georgia

$R_- < |z| < R_+$, where R_- and R_+ denote real parameters that are related to the causal and anticausal components, respectively, for the signal whose z -transform is being sought.

(3) an area on a display device where the image displayed meets an accepted criteria for raster coordinate deviation. *See* [region of absolute convergence](#).

region of interest (ROI) a restricted set of image pixels upon which image processing operations are performed. Such a set of pixels might be those representing an object that is to be analyzed or inspected.

region of support the region of variable or variables where the function has non-zero value.

register a circuit formed from identical flip-flops or latches and capable of storing several bits of data.

register alias table *See* [virtual register](#).

register direct addressing an instruction addressing method in which the memory address of the data to be accessed or stored is found in a general purpose register.

register file a collection of CPU registers addressable by number.

register indirect addressing an instruction addressing method in which the register field contains a pointer to a memory location that contains the memory address of the data to be accessed or stored.

register renaming dynamically allocating a location in a special register file for an instance of a destination register appearing in an instruction prior to its execution. Used to remove antidependencies and output dependencies. *See also* [reorder buffer](#).

register transfer notation a mathematical notation to show the movement of data from one register to another register by using a backward arrow. Notation used to describe elementary operations that take place during the execution of a machine instruction.

register window in the SPARC architecture, a set or window of registers selected out of a larger group.

registration (1) *See* [overlay](#).

(2) the process of aligning multiple images obtained from different modalities, at different time-points, or with different image acquisition parameters. *See* [fusion](#).

regression the methods which use backward prediction error as input to produce an estimation of a desired signal. Quantitatively, the regression of y on X , denoted by $r(y)$, is defined as the first conditional moment, i.e.,

$$r(y) = E(X|y)$$

regular controllability a dynamical system is said to be regularly controllable in time interval $[t_0, t_1]$ if every dynamical system of the form

$$\begin{aligned} x'(t) &= Ax(t)x(t) + b_j u_j(t) \\ j &= 1, 2, \dots, m \end{aligned}$$

is controllable where b_j is the j th column of the matrix B and $u_j(t)$ is the j th scalar admissible control.

regular cue any regular recurring point/element of a signal that can be used to signal the start of a new signal sequence; e.g., the leading edge of a 60-Hz square wave is a regular cue.

regular form a particular form of the state space description of a dynamical system. This form is obtained by a suitable transformation of