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大学电子信息科学与技术英汉实验丛书

电工学综合实验教程

沈一骑　孔令红　编著

南京大学出版社

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编委会

序

为了培养高质量的人才，在高等学校的教学计划中，应该充分重视实验课的设置，并把课程的各个环节抓紧、抓好。尤其在本科生阶段，更要让学生接受全面的训练，从常见仪器的使用、基本量的测量，到按照一定的要求搭建系统以满足特定的性能指标，到有意地探寻和隔离非主要因素、探寻和突出主要因素，并观察其对于最终结果的影响。这样，由易而难、由简单而复杂，环环相扣、步步升高，教学工作才能扎实有效。

南京大学电子科学与工程学院李元教授长期从事电子技术教学工作，对于实验教学一向十分重视。他转往南京大学金陵学院后，一度执掌全院教务处和信息科学与工程学院的领导岗位。在他的带领下，陈孝桢教授、吴宗森教授、王均义教授、沈一骑高工、何菁博士等一批在大学电子信息科学与技术领域内有重要影响的专家学者齐心协力，先后开设了模拟电路实验、数字电路实验、电工学综合实验、通信原理实验、嵌入式系统实验、大学物理实验等课程，并编写了相应的教材，集结为丛书。经过多年的使用和实践，证明这些课程和教材在基础的层面上恰如其分地反映了学科发展的趋势，符合当前学生的实际，对于培养学生的独立工作能力发挥了很好的作用，也得到了国内同行的高度认同。

这些课程和教材也吸引了国外同行的注意，有英国 ESSEX 大学、法国勒芒大学、加拿大罗里尔大学、日本北海道情报大学等学校主动要求交流。可惜，由于教材原来都用中文写成，语言的障碍使有关部门无法把这些教材送往国外，或者送出后没有起到其应有的作用。与此同时，随着学校国际化程度的日益提高，在学生这一层面上的涉外活动也不断增多，要求学校在关心学生能否通过四级或六级英语考试的同时，注意加强对他们专业英语能力的培养。

这样，李元等教授就萌发了一个想法，将原有的实验教材进行重新整理、出新，并进行初译，然后交由吴宗森教授、加拿大罗里尔大学 Sturtevant 教授进行英语文字上的加工与译审，使之成为英汉实验丛书，正式出版以飨国内外广大读者。

我很高兴地得知，经过有关教授一年多的努力，这套英汉实验丛书即将完成，并陆续付印。希望这套丛书的出版，对于培养我国电子信息科学与技术领域的专门人才、对于促进国际交流都能有所裨益。

南京大学教授
中国科学院院士
2013. 12

Foreword
前 言

Welcome to Electrotechnology Labs. Electrotechnology is a basic course considering the analyses of electric and magnetic circuits and the analyses for motor and relay controls. It covers the areas of both strong and weak electricities, which makes it become the cornerstone of modern sciences and technologies. The followed curriculum, such as the programmable logic controller (PLC) and automatic controls, enjoys a much tighter connection with the modern technologies. However, the ubiquitous phenomenon, strong in weak electricities, whilst weak in strong electricities can be found in most college students whose majors are electronics related (excluding the specialty of electromechanical control), which manifests the unreasonable knowledge structure. It also opposes the objective in cultivating new-century comprehensive talents. Understanding and mastering the knowledge concerning strong electricity and modern control technology cannot only lead to a deeper understanding about the specialty itself, but also a comprehensive understanding about the integrated mechanical and electrical systems, therefore establishing the holistic view, as well as the global view is of utmost importance.

In the situation of not adding more courses in both theoretically and experimentally specialized fields, for the sake of supplementing the knowledge concerning strong electricity and modern control technology, as well as improving the structure of knowledge and expanding knowledge scope, some professional experiments regarding to the modern control technologies are induded. These experiments focused in this book are characterized by their progressiveness, practicability and wholeness. Basically, we hope students can master one elementary control technique by doing one corresponding experiment. However, due to the inherent difficulties and challenges in these experiments, great efforts from the students are needed. On the other hand, looking from the angles of efficacy, efficiencies and effects, the experiments arranged here will be great beneficial.

The *Comprehensive Labs Textbook for Electotechnology* are characterized by the combination of theories, experiments and applications, as well as its great generality and flexibility. The contents are divied total 15 labs into Class A for circuit analysis (DC circuit, dynamic circuit, AC circuit and three-phase circuit) and Class B for motor and control (Three-phase asynchronous motor, relay contactor control, PLC, VFD and automatic control). Besides, each experiment is accompanied by a mini-research project

which takes efforts to cope with. These experiments can be combined independently to variously experimental courses, namely *Labs for Circuit Analysis*, *Labs for Electrotechnology*, *Comprehensive Labs for Electrotechnology* and *Labs for Motor and Control*. Besides, we have prepared five quite tough also independent experiments featured the projects for reseraching as additional labs to meet the special needs from different universities and students. The preparatory courses should be *Circuit Analysis* or *Electrotechnology*, and it is recommended to offer these courses in junior years in colleges. In order to supplement the lacking knowledge, related principles and applications (i. e. motor, relay control, speed regulated by DC PWM adjusting voltage, speed regulated by AC variable frequency, PLC, VFD, Automatic control) are incorporated into the introduction part of each experiment. After some instructions given on class, students can fulfill the experiments concerning motor and control independently.

The experiment contents and class arrangement are recommended as follows:

Labs for Circuit Analysis: 10 labs in Class A, 40 hours for labs

Labs for Electrotechnology: 12 labs in Class A plus part of Class B, 50 hours for labs

Comprehensive Labs for Electrotechnology: 10 labs in part of Class A (the strong and weak electricity experiments) plus Class B, 20 hours for theory classes and 40 hours for labs.

Labs for Motor and Control: 8 labs in part of Class A plus Class B, 20 hours for theory classes, 40 hours for labs.

The contents arranged in this book incorporate the author's teaching experiences both on class and in laboratory involved with electrical circuits and eletrotechnologies. Besides, the book has gradually been improved during the years of teaching practice in School of Electronic Science and Engineering, School of Management Science and Engineering, School of Astronomy and Space Science and Jinling College, Nanjing University. Here, I would like to express my special thanks to Ma Xiaohui at School of Electronic Science and Engineering, Nanjing University, who completed the translation work of this course book. Also, I would like to express my thanks to Prof. Zongsen Wu at Nanjing University and Terry Sturtevant at Wilfrid Laurier University, Canada, for their careful and elaborate works on the translation and proofreading in English.

Owing to limitations of our knowledge, there must be mistakes and errors in the book. Your suggestions would be welcome and appreciated.

Shen Yiqi
December 2013

前　言

电工学是一门包括电路分析、磁路分析、电机与继电控制的基础课程，涵盖强电和弱电两大领域，是现代科技的基础之一。后继课程如可编程控制器(PLC)和自动控制等与现代科技的关系更为密切。除机电控制专业外，大学理工科电子类学生普遍存在“弱电强、强电弱”的现象，知识结构不尽合理，与新世纪对人才的综合性要求也不相适应。了解和掌握有关强电和现代控制技术等知识，既有助于对本专业的深入了解，更重要的是可对机电综合系统有全面了解，以增加整体观和全局观，其迫切性和重要性不言而喻。

为了在不增加专业理论课和专业实验的情况下，使学生能够补充强电和现代控制技术等有关知识，完善知识结构和扩大知识面，我们在电工实验中加入几个以现代控制技术专业课程精华为原理的具有先进性、实用性和整体性的专业实验，并以此为重点。我们试图通过一个实验，使学生初步掌握一门控制技术。由于实验的难度和挑战性，当然需要学生的努力，但从学习的效能、效率和效果来看，实验的设置是有益的。

《电工学综合实验教程》的特点是理论、实验和应用三者兼顾和通用性、灵活性较大。实验内容包括电路分析实验(A部分，含直流电路、动态电路、交流电路和三相电路)和电机与控制实验(B部分，含三相异步电动机、继电接触器控制、PLC、变频器和自动控制)两个部分共15个实验，每一实验还附有研究性自主性小实验，均有一定的难度，可以独立组合成多种实验课程，如《电路分析实验》、《电工学实验》、《电工学综合实验》和《电机与控制实验》等。此外，还设计了5个有相当难度的研究性自主性实验作为附加实验，以满足不同学校和学生的需求。预备课程为《电路分析》或《电工学》，建议在大学低年级开设。为弥补有关理论知识的不足，编者已将电机、继电控制、直流脉宽调速、交流变频调速、PLC/变频器/自动控制的原理及应用等择要系统编入实验原理，使学生进行少量课堂学习后就能完成电机与控制实验。

实验内容和课时安排建议如下：

《电路分析实验》：　10个实验(A部分)，实验课时40学时；

《电工学实验》：　12个实验(A部分＋B部分中的电机和继电控制实验)，实验课时50学时；

《电工学综合实验》：　10个实验(A部分中的部分强、弱电实验＋B部分)，理论课时20学时、实验课时40学时；

《电机与控制实验》：　8个实验(A部分中的强电实验＋B部分)，理论课时20学时、实验课时40学时。

本教程的实验设计融入了编者多年电路、电工的理论和实验教学心得，并经南京大学电子学院、工程管理学院、天文学院、金陵学院等多届学生的实践而逐步完善。教程的翻译主要由南京大学电子学院马晓辉同学完成，并经南京大学吴宗森教授、加拿大 Wilfrid Laurier 大学 Terry 教授精心修改审定，在此一并深表谢意！由于编者水平有限，加之时间仓促，误漏之处恳请读者批评指正。

沈一骑

2013 年 12 月于南京大学

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Introduction
绪 论

My goals in writing this lab book can be reduced to one overriding aim: to merge rigorous theories into various experiments ranged from electrotechnology to motor controls in our book.

To achieve these goals, I established three aspects as follows:

1. Course Objectives

(1) Through conventional electrotechnology labs, students can consolidate and deepen their theoretical knowledge; study and master the experimental skills, meanwhile obtaining a rigorous, meticulous scientific style as well as good experimental habits.

(2) Through extended electrotechnology labs, students can learn and master the latest motor control technology, meanwhile expanding their outlooks and acquiring capabilities in technology applications and technology design.

2. Experimental Procedure

(1) Preparations in advance

Due to the great challenges and limited hours on class of this experiment course, adequate and sufficient preparations in advance should be in need for the sake of completing the experiments on time and achieving the intended purposes. Therefore, students should read the experimental course book carefully, understand the experimental principles and methods, and then conduct so called "Mental Experiments", that is to say, students can imagine the whole experiment process in their mind, thereby they can get a pretty good idea of the experiment. In order to cultivate the ability to work independently, no instruction on class is given. Instructors only perform the on-the-spot guidance. Therefore, students without adequate preparations cannot conduct a good experiment they expect!

(2) Experiment process

a. Preparation work

Check instruments and experimental units needed in corresponding experiments. Keep them in good and neat shape. Note that all power supplies should output to 0.

b. Wiring circuit

Wiring circuit is prohibited when the power is supplied on. A conventional rule for connecting circuit can be stated as: main series circuits come first, then the sub-circuits are next. Basically, two kinds of wire are available: strong electric cables and weak

electric cables. Strong electric cables are practically used by jackets, whilst weak electric cables are of normal style. Note that the two kinds of cables cannot substitute by each other, especially it is forbidden to plug a weak electric wire into a strong electric slot. Wire connectors are not advised to stack up together on a single slot, as a better way, distributing these connectors on different slots is more preferable. Besides, when plucking wires, notice that no direct force should apply on the wire itself, otherwise the wire may be easy to be broken. Alternatively, you can use wire connectors. Once completing your wiring circuit, you should remove all the excess wires away, and guarantee there is no suspended one. In addition, make sure that all instruments are set to their maximum ranges, and you can adjust them to proper ranges while doing experiments.

c. Power on

When completing all connections for your circuit, you should check it carefully, and then turn on the power. Pay close attention to the work states of all experimental components, for instance, if there exist any reverse polarity and any over range for dial instrument. Be careful particularly if any smoke, abnormal odor or sound and extremely hot take place. If there are unusual events, you should first cut off the power and then check the circuit loop again. Only after all the potential faults are eliminated, you can turn on the power again.

d. During experiments

Before doing the experiments, you should have a clear idea of the whole experiment process as well as its objectives in your mind. During the experiment process, a correct attitude: bold, cautious and calm is needed. Obverse the experimental phenomena carefully, record the experiment data and determine the rationality according to the theoretical knowledge. Note that all experimental phenomena and data should be true, accurate, complete and clear.

e. After experiment

When completing the experiment, all experimental data should be approved by the instructor. Only after getting a positive response, you can finish the entire process. Note that before leaving the laboratory, you should first cut off the power, and tidy up all experimental instruments, parts and wires, and make sure tables and chairs back to the right positions.

(3) Complete the experiment report

Data process, analysis and study after the experiment are crucial steps towards a correct experiment conclusion, meanwhile it is also an vital link in cultivating and enhancing the capacity of comprehensive analysis and doing scientific research. A experiment report is a comprehensive summary of the experiment you do, so you should conform to the following rules: clear handwriting, well organization, authentic data,