普通高等院校“十二五”规划教材

大学光电与电子专业实验双语教程

University Labs for Photonics & Electronics

张永康 主编

吴宗森 盛克敏 陈明阳 编

国防工業出版社
National Defense Industry Press

普通高等院校“十二五”规划教材

大学光电与电子专业实验双语教程

University Labs for Photonics & Electronics

张永康　主编

Terry Sturtevant
吴宗森　盛克敏　陈明阳　编

国防工業出版社

·北京·

内 容 简 介

本书是为大学本科光电及电子类专业实验课程进行双语教学而编写的一本新型教材，主要取材于加拿大劳瑞尔大学(Wilfrid Laurier University)光子专业(Photonics Program)和计算机电子专业(Computing and Computer Electronics Program)本科二、三年级的实验教材。本书共包含32个实验，由三部分组成：第一部分为数字电子电路；第二部分为模拟和通信电路；第三部分为光学、激光和光纤。为了便于学生的学习，每个以英文为主体的实验教材后均配以中文的实验简介、科技词汇和注释。

本书可以作为光通信、光电、信息工程和电子科学与技术类专业本科生的实验教材，也可作为相关专业的本科生、研究生和工程技术人员的参考书，也可作为本科生“科技英语”课程的教材。

图书在版编目(CIP)数据

大学光电与电子专业实验双语教程：英、汉 / 张永康主编. —北京：国防工业出版社，2012.7
普通高等院校“十二五”规划教材
ISBN 978-7-118-08059-9

Ⅰ ①大.. Ⅱ ①张 Ⅲ ①光电子技术-实验-双语教学-高等学校-教材-英、汉 Ⅳ. ①TN2-33

中国版本图书馆CIP数据核字(2012)第124874号

※

国防工业出版社出版发行
(北京市海淀区紫竹院南路23号 邮政编码100048)
北京奥鑫印刷厂印刷
新华书店经售

*

开本 787×1092 1/16 印张 14½ 字数 344 千字
2012年7月第1版第1次印刷 印数 1—2000册 定价 30.00元

(本书如有印装错误，我社负责调换)

国防书店：(010)88540777 发行邮购：(010)88540776
发行传真：(010)88540755 发行业务：(010)88540717

出 版 前 言

本书主要参考加拿大位于滑铁卢市(Waterloo)的劳瑞尔大学(Wilfrid Laurier University)光子和电子专业(Photonic and Electronic Program)二、三年级的实验教材。她的姐妹篇《大学物理实验(双语教学用书)》(University Physics Experiments)同样取材于该校一年级的物理实验讲义,已于2011年在国防工业出版社出版。本书编者大都在美国和加拿大的大学中留学或教学过,深知国外和我国教学体系、课程设置和教学方法的差别,也深刻体验到两地学生的不同。我们尤其了解美国、加拿大大学实验课的特长。我们感到,他们的实验教材经常更新;甚至,有的实验连讲义都没有,但极具启发性和创新力。因此我们把他们过去几年用过的实验讲义收集起来整理成册,并加上中文的实验简介、科技词汇和注释,编写了这本适用于我国光电与电子专业的实验双语教材。

光子学(Photonics)和电子学(Electronics)一样是一个具有极强应用背景的学科,并由此而形成了一系列的光子技术,如光子发生技术(激光技术)、光子传输技术(如光纤技术)、光子调制与开关技术、光子存储技术、光子探测技术、光子显示技术等。其实,在国内不少大学的光电专业(如江苏大学)从事的就是光子技术。最早赋之以科学定义规范的当数1970年。这一年,在第九届国际高速摄影会议上,荷兰科学家Poldervaart首次提出关于光子学的定义规范,他认为,光子学是"研究以光子为信息载体的科学"。光子学作为一门新兴学科,目前正处于成长与发展时期,它尚有一个逐步充实、完善,最后走向成熟的必然过程。

双语教学的必要性是不言而喻的。随着我国经济高速蓬勃地发展和快速地融入全球经济一体化,势必要求我们的学生不仅有扎实数理理论及实验的功底,还要求他们能流畅地阅读英语文献和资料,更希望他们能用英语无障碍地表达他们的观点以及和同行交流。大多数学生对双语教学持欢迎的态度,因为他们中的一部分将有机会在毕业后出国继续深造或去外企工作。如果他们在校就受到很好的外语熏陶,他们就能较快地适应国外大学的学习或在应聘时立刻显示其水平的高低,受聘以后,更会体会到英语的重要性。其实,早在20世纪三四十年代,一些大学(如上海交通大学和清华大学)的理工科课程不少就是用英语或双语讲授的。正因为大学时期受到过良好的训练,那些仍健在的科学家和工程师至今还能用英语朗朗上口地讲述他们的

科技观点。

双语教学是一个长期坚持才能见效的方针。学校不应半途而废，教育主管单位更不应改弦易张。双语教学要长期坚持下去，关键是教师。因此，双语教学的主课教师在钻研自身业务的同时还要不断提高自己的英语水平，特别要提升自己的英语口语能力。其次，没有合适的双语或英语教材也是困扰双语教学开展的另一个主要原因。虽然，有的学校干脆购买国外原版教科书作为他们学生用书，但是，并非所有学校的学生都能买得起相对昂贵的泊来货。我国大学用英语或双语教授光电以及电子学实验目前还是空白，也没有一本可供师生选用的合适的教材。这本书的出版无疑填补了国内这一领域的空白。衷心希望大学相关系科的师生喜欢这本书并从中受益。

本书的主编是东南大学机械学院的张永康教授。编写者中一位是加拿大劳瑞尔大学从事光电实验教学已逾20年的Terry Sturtevant，他撰写了本书大部分实验的英文原稿。另三位分别是南京大学的吴宗森教授、西南交通大学的盛克敏教授和江苏大学的陈明阳副教授。张永康教授和陈明阳副教授多年来在江苏大学一直致力激光及其应用的研究和教学，书中也加入了他们的几个激光实验。吴宗森教授自南京大学退休后曾在劳瑞尔大学教授物理课及相关实验，书中的一些实验的英文原稿也是他在劳瑞尔大学任教时撰写的。盛克敏教授曾在西南交通大学教授电磁场理论数十年。他们四位都长年耕耘于激光、光电学、声学、机械和微波等领域，在实验方面有着丰富的经验。本书就是来自两国（加拿大和中国）四地（滑铁卢、南京、镇江和成都）四校（劳瑞尔大学、南京大学、江苏大学和西南交通大学）的作者们多年教授光电和电子学实验合作的结晶。

非常感谢劳瑞尔大学科技学院院长Paul Jessop教授也为本书撰写了序言。我们将此放在本书正文的前面。

本书共分三部分：数字电子电路（10个实验）；模拟和通信电路（12个实验）；光学、激光和光纤（10个实验）。总共32个实验。

本实验教材适用于大学光电专业和大学电子工程及光通信专业。

作 者

2012年4月

Foreword

In 2006, Wilfrid Laurier University (WLU), Waterloo, Canada and Jiangsu University (JU), Zhenjian, China opened a new page. The two universities signed the 2 + 2 cooperation agreement that allows JU students to take the final two years of a Photonics program at WLU. Since then many JU students have participated and received a Canadian B. Sc. degree in photonics. Some of the graduates from the 2 + 2 program have gone on to pursue advanced degrees in Canada or the USA, and some returned to China to devote their efforts to Photonics.

"University Labs for Photonics & Electronics Experimenis" originated from the manuals and lab notes for the Photonics and Computer Electronics Programs at WLU. A companion manual, "University Physics Experiments (bilingual teaching book)", was published in 2011 from the National Defense Industry Press, China.

Terry Sturtevant and Zongsen Wu taught Electronics and Photonics courses at WLU for many years and have a great deal of experience as undergraduate laboratory instruction. They worked with Yongkang Zhang and Mingyang Chen and Kemin Sheng on the publication of this book. The book is a product of the close cooperation involving two countries (Canada and China), four cities (Waterloo, Nanjing, Zhenjiang and Chengdu) and four universities (WLU, Nanjing University, Jiangsu University and Southwest Jiaotong University).

Electronics and Photonics are essential technologies in modern society and essential elements in many undergraduate programs. I am confident that this experimental book is suitable for use in university level programs in photonics, optical communications and electrical engineering.

Congratulations to all editors for publishing the lab book.

Paul Jessop, Ph. D.

Dean of Science,

Wilfrid Laurier University

March 2012

CONTENTS
目　　录

Part 1　Digital Electronics
第一部分　数字电子电路

Part 2　Analog and Communication Circuits
第二部分　模拟和通信电路

Part 3 Optics, Lasers and Optical Fibers
第三部分 光学、激光和光纤

Part 1 Digital Electronics
第一部分 数字电子电路

Lab 1 Characteristics of Logic Gates
实验一 逻辑门的特性

Purpose

(1) To measure the voltage characteristics for various digital logic families.

(2) To measure the propagation delay for various digital logic families.

(3) To obtain and interpret information from a data sheet.

Preparation

The operation of an ideal logic gate can be summarized by the following rules:

Input and output voltages will be at either the high or the low value specified for that family; (e. g. 5 and 0 volts, respectively for TTL). Inputs will draw no current from whatever drives them, and outputs can supply as much current as necessary for whatever follows. Any change of an input will immediately be effected on the output. In practice, these rules do not hold. A real logic gate operates under the following restrictions:

Input voltages will not always be at their ideal values, and so a range of input values must be considered high and another range of input values must be considered low. Similarly output voltages will not always be at their ideal values, and so a range of output voltages should be considered as high, while another range of output voltages should be considered low. Inputs must draw a small but finite amount of current from the driving devices and outputs have a limited current capacity for maintaining the output voltage at the desired level. Changes made at the inputs will take a finite amount of time to be effected on the outputs.

Note that in most labs comparing "real" to "ideal" values involves seeing how close one number (the "real" value), is to another (the "ideal" value). With digital logic chips, however, rather than having a single "ideal" value for a parameter, the manufacturers give parameter bounds. These specifications are not values that should be matched, but rather they are values that should be considered as limits during real operation. For instance, TTL logic has a nominal input "high" voltage of 5 volts, but in practice any voltage above 2.0 volts will be considered "high". Normally, voltage parameters will be different for input and output. For the same TTL logic family, a "high" output will be any output voltage above 2.4 volts.

Note that for some parameters the specifications will give an upper bound, for some they will give a lower bound, and for others they will provide a range. Which one is given will make sense if you understand what each parameter means.

Supply Voltages

Digital logic chips have a power pin(s) and a ground pin(s). These supply voltages have names which are based on the type of transistors used in the construction of that particular logic family.

TTL gates are made with bipolar transistors, which have a collector and an emitter; so the supply voltages are shown as V_{CC} (power) and Ground (occasionally shown as V_{EE}) on most data sheets.

CMOS gates are built with field-effect transistors, which have a drain and a source; so the supply voltages are shown as V_{DD} (power) and V_{SS} (ground) on most data sheets.

Voltage Characteristics

The voltage characteristics of a logic gate depend on the logic family used to construct the device and are always specified on the device data sheet. The voltage characteristics are always specified in terms of four values:

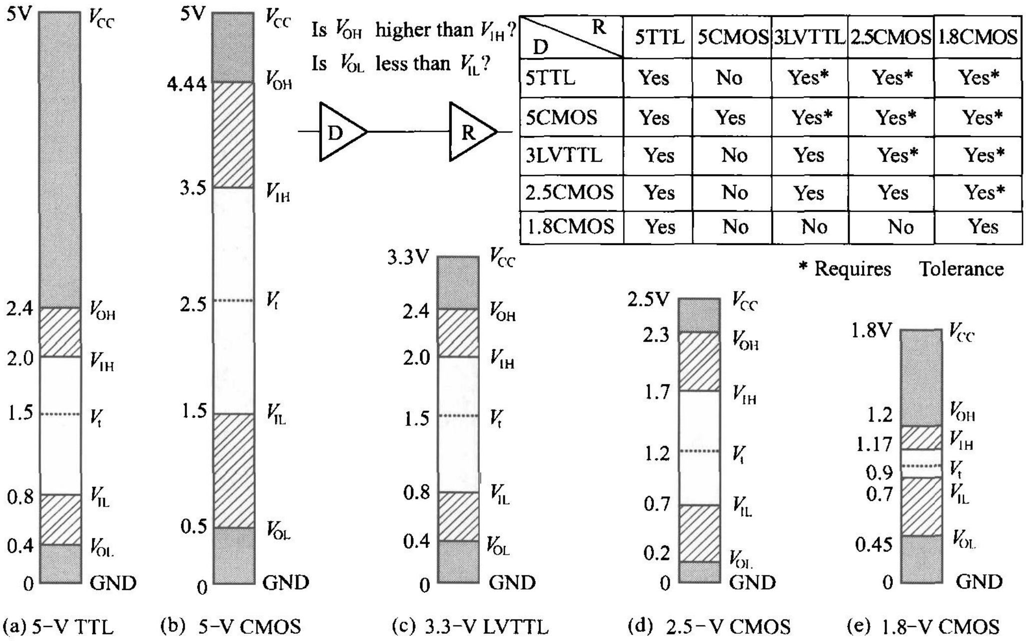
V_{IHmin}—the minimum input voltage which will be accepted as a logic 1 state.

V_{ILmax}—the maximum input voltage which will be accepted as a logic 0 state.

V_{OHmin}—the minimum output voltage representing a logic 1 state.

V_{OLmax}—the maximum output voltage representing a logic 0 state.

Figure 1 shows these voltage characteristics for five types of chips: two families (TTL and CMOS) with various supply voltage characteristics (two high voltage and three low voltage varia-



D \ R	5TTL	5CMOS	3LVTTL	2.5CMOS	1.8CMOS
5TTL	Yes	No	Yes*	Yes*	Yes*
5CMOS	Yes	Yes	Yes*	Yes*	Yes*
3LVTTL	Yes	No	Yes	Yes*	Yes*
2.5CMOS	Yes	No	Yes	Yes	Yes*
1.8CMOS	Yes	No	No	No	Yes

* Requires Tolerance

Figure 1 The voltage characteristics for five types of chips made by Texas Instruments, Logic Selection Guide, 2003 tions). All properly operating chips must work within these ranges. For example, if both inputs to a 7400 TTL NAND gate are greater than or equal to 2.0 volts, they will be considered "high" and the output should be "low", i.e. at a voltage less than or equal to 0.4 volts. Notice that the output range, either high or low, is always smaller than the input range.

For high voltage CMOS logic (see Figure 1(b)), the supply voltage V_{DD} can actually range from 3.5V to 15V. The diagram only shows the voltage characteristics at a supply voltage of 5V to allow comparison to the 5V TTL characteristics. Read the data sheet for voltage characteristics at supply voltage values greater than 5V.

Propagation Delay

Ideally changes to the inputs of a gate would be effected at the output immediately, but in reality there is a slight delay. In addition, the delay may be different depending on whether the gate's output is going from low to high or from high to low. Furthermore, the transitions themselves are not instantaneous, so they are defined as being at the 50% point of the voltage transitions. Thus there are two quantities of interest:

t_{PLH}—the time interval between the change of an input and the resulting change in output, when the output must change from low to high.

t_{PHL}—the time interval between the change of an input and the resulting change in output, when the output must change from high to low.

Note that in both cases above, the direction of the input transition is immaterial.

Figure 2 shows that students are doing the lab at WLU.

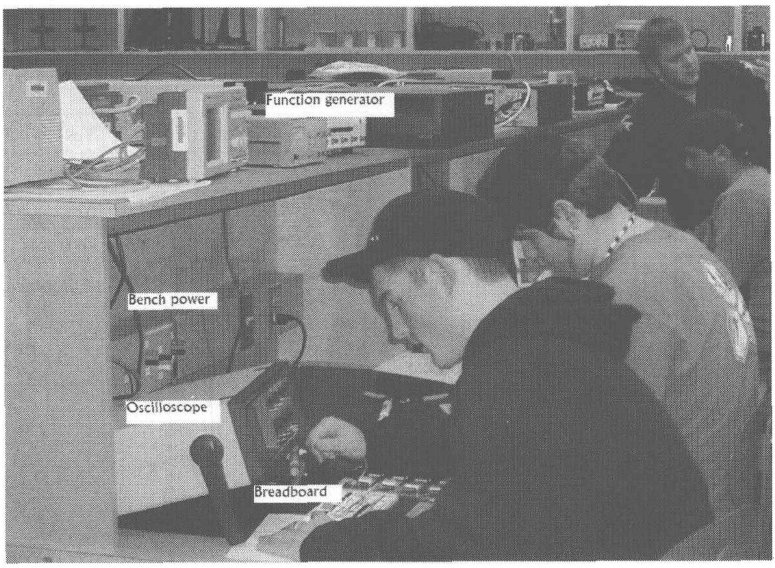


Figure 2 Students are doing the lab at WLU

Apparatus

Bench power;

Variable power supply;

Breadboard;

SN7400(1)[1988 datasheet,2003 datasheet];

CD4011UB(2)[1998 datasheet,2003 datasheet];

Signal/function generator;

Oscilloscope—one of TDS 210, TDS 1002 (old and new numbers for the same oscilloscope).

Procedure

CMOS handling procedure

Before starting the lab, review the CMOS handling procedures. Always use a ground strap. If your grounding mat doesn't have two grounding straps, one for each of the partners, see the lab instructor.

CMOS devices should be stored pin down in conductive foam when they are not in a circuit.

Never leave unused inputs floating; connect to ground or +5V to prevent excessive current consumption and erratic behaviour.

Never connect an input signal to a CMOS device when the power is off.

Part 1 Voltage Characteristics

(1) Do the following analysis first for the 7400 and then repeat for the 4011. Before starting, determine which of these chips is CMOS.

(2) If using an analog scope, connect the equipment and the component as shown in Figure 3. If using a digital scope, connect the function generator to channel B and the device to channel A (opposite of Figure 3).

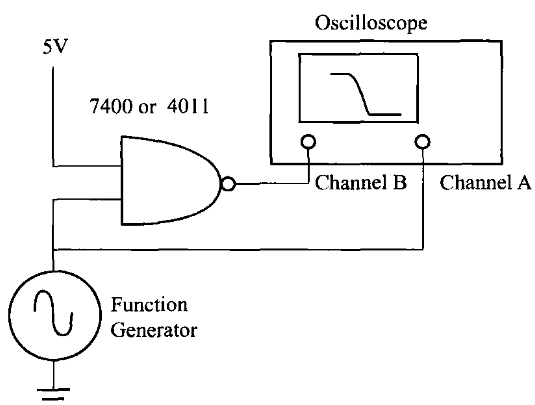


Figure 3 Measuring the transfer characteristic of the gate by oscilloscope

Make sure both the function generator and the oscilloscope have the same ground (oscilloscope ground not shown in Figure 3).

(3) For the function generator, select a 0 to 5V sine wave with a frequency of 1kHz. For the oscilloscope, select the $X-Y$ mode of operation. A trace similar to the one shown in Figure 4 should be obtained. This is called the transfer characteristic of the gate. Note that the input voltage, V_{in}, is on the x axis and the output voltage, V_{out}, on the y axis.

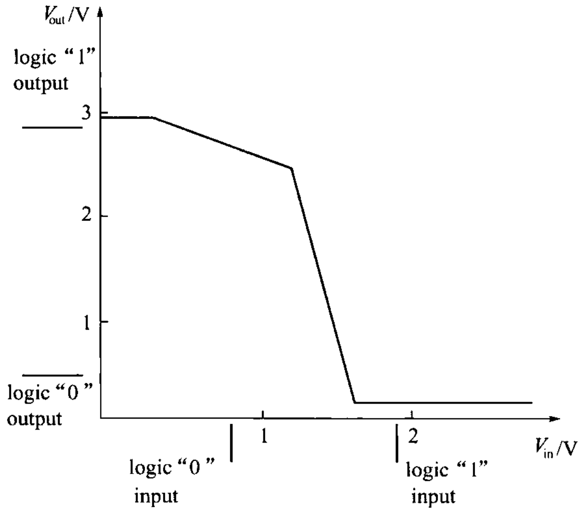


Figure 4 A typical trace of the transfer characteristic obtained

(4) Measure the values of the following parameters and compare your measurements with the values given in the appropriate data sheet to see whether the devices fit the manufacturer's specifications. Specifically, you want to answer the following questions:

(5) What output voltage is produced by an input voltage of the specified value of V_{ILmax}? This would be the measured value of V_{OHmin}. Is it within the manufacturer's specifications?

What output voltage is produced by an input voltage of the specified value of V_{IHmin}? This would be the measured value of V_{OLmax}. Is it within the manufacturer's specifications?

Demonstrate and explain your measurement to lab staff.

Part 2 Propagation Delay

(1) Using two 4011 chips, construct the circuit shown in Figure 5. Use a chain of 8 gates ($n=8$) to determine the propagation delay t_P. In order to obtain a good measurement of the delay time, a frequency of operation should be chosen sufficiently high so that the total delay in the chain (nt_P) is comparable to the period of the input clock. Obtain the delay times t_{PHL} and t_{PLH} from the data sheets. Use the oscilloscope to measure V_{in} and V_{out}. Use a square wave as input.

Note: You don't want to be in $X-Y$ mode for this part.

Why can we not measure both t_{PHL} and t_{PLH} from the circuit shown?

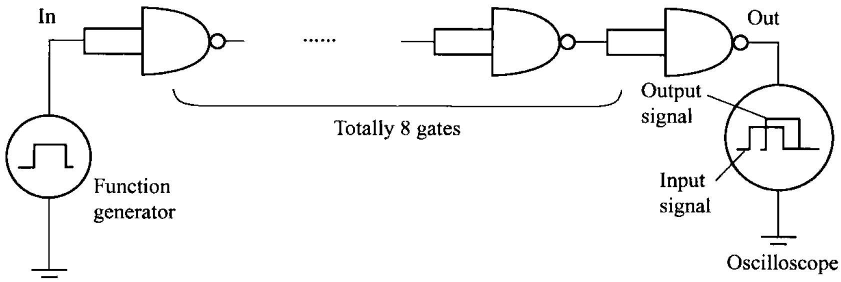


Figure 5 Measuring the propagation delay $8t_P$

Hint: how many gates do we have and what is the relationship between the input and the output?

(2) The propagation delay of a CMOS gate is a function of the load capacitance and the supply voltage V_{DD}. Determine the propagation delay t_P as a function of V_{DD}. Use a variable power supply and measure with V_{DD} at 5V, 10V, and 15V.

When using different values for the supply voltage, be sure to adjust the amplitude of the square wave input voltage appropriately. *Remember that the voltage required to obtain a "high" changes as the supply voltage changes.* The voltage diagram in this lab (in preparation section) only shows the voltage characteristics at a supply voltage of 5V to allow comparison to the 5V TTL characteristics. Read the static electrical characteristics in the data sheet for voltage characteristics at other supply voltage values. *Note, these are input voltages that can be read as exact values from the table; you do not have to figure it out from the graphs.*

Demonstrate and explain your measurement to lab staff.

(3) Plot a graph of propagation delay as a function of supply voltage, labeling everything appropriately.

How do your results compare to the device data sheet?

Part 3 Obtaining the Normal Range for Temperature and Supply Voltage from Data Sheet (For both the 7400 and the 4011)

What range of power supply voltages is allowed for normal operation of the chip?

What range of power supply voltages is guaranteed not to destroy the chip?

Over what range of temperatures may the chip be expected to operate normally?

What range of temperatures may the device be stored safely?

[**实验简介**]

这是逻辑门电路特性研究之一。实验的目的是:

(1) 测量不同数字逻辑电路的电压特性;

(2) 测量不同数字逻辑电路的传播延时;

(3) 从数据技术说明书获取和了解信息。

当使用示波器做本实验时,如果要测量不同数字逻辑电路的电压特性(图 3 和 4),则

要用 $X-Y$ 模式；反之，如果要测量不同数字逻辑电路的传播延时（图 5），则要用 $Y-t$ 模式。

[科技词汇]

data sheet, datasheet　数据纸，技术数据说明书
TTL = transistor-transistor-logic　晶体管—晶体管—逻辑（电路）
open drain gates　开路源门
drain　漏极，多数载流子从场效应晶体管沟道进入的区域
CMOS = complementary metal-oxide-semiconductor　互补型金属氧化物半导体
handling procedure　处理程序
ground strap　接地交连线
grounding mat　接地垫
analog scope　模拟示波器
digital scope　数字示波器
transistor　晶体管
bench supply　桌上电源
oscilloscope　示波器
function generator　功能发生器（包括多种函数形式波的发生器），又称函数发生器
breadboard　面包板；调试板

[注释]

（1）Input voltages will not always be at their ideal values, and so a range of input values must be considered high and another range of input values must be considered low. Similarly output voltages will not always be at their ideal values, and so a range of output voltages should be considered as high, while another range of output voltages should be considered low. Inputs must draw a small but finite amount of current from the driving devices and outputs have a limited current capacity for maintaining the output voltage at the desired level. Changes made at the inputs will take a finite amount of time to be effected on the outputs. 输入电压不会永远处在它们的理想值上，因而当输入值落在一定范围内时就可视为高电平；反之，当输入值落在另一范围内时就可视为低电平。与此类似，输出电压不会永远处在它们的理想值上，因而当输出值落在一定范围内时就可视为高电平；反之，当输出值在另一范围内时就可视为低电平。同理，输入一定会从驱动器件中吸取少量有限的电流而输出也会有有限的电流使得输出电压维持在一个期待的电平上。最后，输入的变化将延后出现在输出端。

（2）Note that in most labs comparing "real" to "ideal" values involves seeing how close one number (the "real" value), is to another (the "ideal" value). With digital logic chips, however, rather than having a single "ideal" value for a parameter, the manufacturers give parameter bounds. These specifications are not values that should be matched, but rather they are values that should be considered as limits during real operation. For instance, TTL logic has a nominal input "high" voltage of 5 volts, but in practice any voltage above 2.0 volts will be considered "high". Normally, voltage parameters will be different for input and output. For the same TTL logic family, a "high" output will be any output voltage above 2.4 volts. 我们注意到在大多数实验中，"实际值"和"理想值"之间的比较，与如何看待一个数值（"实际值"）与另一个数值（"理想值"）之间的差距有关。然而对于数字逻辑芯片而言，制造商宁愿用一定范围的参数而不用单一数字的参数。技术上的指标并不是一个一定要匹配的数值，相反，它在实际操作中被认为是一个限定的范围。例如，TTL 有一个名义上 5V 的高电压，但实际