# English in Marine Electrical and Electronic Engineering

王 丹 刘 彤 主编
徐殿国 主审

# 船舶电子电气专业英语

大连海事大学出版社

# 船舶电子电气专业英语

**English in Marine Electrical and Electronic Engineering**

王　丹　刘　彤　主编

徐殿国　主审

大连海事大学出版社

**图书在版编目(CIP)数据**

船舶电子电气专业英语 = English in Marine Electrical and Electronic Engineering / 王丹，刘彤主编．—大连：大连海事大学出版社，2011.8(2012.5 重印)
ISBN 978-7-5632-2612-2

Ⅰ.①船… Ⅱ.①王… ②刘… Ⅲ.①船用电气设备—英语 Ⅳ.①H31

中国版本图书馆 CIP 数据核字(2011)第 163774 号

**大连海事大学出版社出版**
地址:大连市凌海路1号 邮政编码:116026 电话:0411-84728394 传真:0411-84727996
http://www.dmupress.com E-mail:cbs@dmupress.com
大连印刷三厂印装 大连海事大学出版社发行
2011 年 8 月第 1 版 2012 年 5 月第 2 次印刷
幅面尺寸:185 mm×260 mm 印张:15
字数:297 千 印数:501～1500 册
责任编辑:董玉洁 版式设计:冰 清
封面设计:王 艳 责任校对:陈 亮
ISBN 978-7-5632-2612-2 定价:27.00 元

# 前　言

伴随电气技术、计算机技术和信息技术的快速发展，船舶自动化水平不断提高、船舶电气系统和导航通信系统呈现网络化趋势，系统复杂程度越来越高，维护维修难度加大，对专业技术人员的需求急剧增加，适应这一情况，国际海事组织已决定设立船舶电子电气员岗位。为培养适任的专业技术人员，经教育部批准，大连海事大学率先设立了船舶电子电气工程专业。《船舶电子电气专业英语》是为船舶电子电气工程专业的教学需要而编写的。

本书为大连海事大学规划资助的特色教材。全书共二十二个单元，分三个部分，分别是阅读理解、文件和业务写作、国际公约和标准。本书的编写充分考虑了船舶电子电气工程专业对学生的培养目标和未来工作岗位的职业需求，具有如下特点：

1. 选材广泛。教材涉及船舶电子电气工程专业的主要专业基础及专业课程的教学内容，如电力电子技术、电机学、可编程控制器、主机遥控、船舶航向控制、船舶电力系统、船舶电力推进、船舶通信导航等。

2. 专业特色突出。教材充分考虑船舶电子电气专业未来就业岗位特点，除了专业基础部分的阅读材料以外，其余均为船舶实际系统的技术资料，专业性很强。

3. 内容新颖。教材内容主要节选于近年出版的同类教材和技术说明书等，代表电子电气的最新技术成就，注重吸收当前船舶电气行业的新知识、新内容，不仅可以学习英语，也可以从中学习最新的专业知识。

4. 原汁原味。教材内容主要取材于英文原版素材，是原汁原味的英文专业读物。

5. 注重实用。除了专业技术资料外，教材吸收了船舶电子电气工作人员的常用业务表格、文件、书信以及相关国际公约和标准等内容，有助于学生熟悉船舶电子电气技术人员岗位业务。

本书适合船舶电子电气工程及船舶电气工程专业学生用作“专业英语”课程教材，也可供海员和造船、修船等船舶及航运相关行业电子电气技术人员作为提高专业英语阅读和写作能力的参考书。

本书由大连海事大学轮机工程学院王丹、航海学院刘彤担任主编，负责全书的整理和统稿工作。第 1 至 12 单元、第 16 和 17 单元由王丹编写。第 13 至 15 单元和第 18 至 22 单元由刘彤编写。在本书编写过程中，王天序、朱景伟、吴志良、邱赤东、牛小兵、孙广辉等老师提供了原始素材和相关协助，在此一并表示感谢。

哈尔滨工业大学徐殿国教授担任本书主审，提出了宝贵意见，在此深表感谢！

由于时间仓促和编者能力有限，书中难免存在不足和疏漏之处，恳请广大读者批评指正。

**编　者**

2011 年 5 月 18 日

# Contents

## Part I  Reading Comprehension



## Part II  Documents and Business Writing



## Part III  International Conventions and Standards

# Part I Reading Comprehension

## Unit 1 Power Semiconductor Devices

### 1.1 Introduction

Power semiconductor devices constitute the heart of modern power electronic apparatus. They are used in power electronic converters in the form of a matrix of on-off switches, and help to convert power from AC-to-DC (rectifier), DC-to-DC (chopper), DC-to-AC (inverter), and AC-to-AC at the same (AC controller) or different frequencies (cycloconverter). The switching mode power conversion gives high efficiency, but the disadvantage is that due to the nonlinearity of switches, harmonics are generated at both the supply and load sides. The switches are not ideal, and they have conduction and turn-on and turn-off switching losses. Converters are widely used in applications such as heating and lighting controls, AC and DC power supplies, electrochemical processes, DC and AC motor drives, static VAR generation, active harmonic filtering, etc. Although the cost of power semiconductor devices in power electronic equipment may hardly exceed 20 ~ 30 percent, the total equipment cost and performance may be highly influenced by the characteristics of the devices. An engineer designing equipment must understand the devices and their characteristics thoroughly in order to design efficient, reliable, and cost-effective systems with optimum performance. It is interesting to note that the modern technology evolution in power electronics has generally followed the evolution of power semiconductor devices. The advancement of microelectronics has greatly contributed to the knowledge of power device materials, processing, fabrication, packaging, modeling, and simulation.

Today's power semiconductor devices are almost exclusively based on silicon material and can be classified as follows:

- Diode;
- Thyristor or silicon-controlled rectifier (SCR);
- Triac;
- Gate turn-off thyristor (GTO);
- Bipolar junction transistor (BJT or BPT);
- Power MOSFET;
- Insulated gate bipolar transistor (IGBT);
- Integrated gate-commutated thyristor (IGCT).

In this unit, we will briefly study the operational principles and characteristics of these devices.

## 1.2 Diodes

Power diodes provide uncontrolled rectification of power and are used in applications such as electroplating, anodizing, battery charging, welding, power supplies (DC and AC), and variable-frequency drives. They are also used in feedback and the freewheeling functions of converters and snubbers. A typical power diode has P-I-N structure, that is, it is a P-N junction with a near-intrinsic semiconductor layer (I-layer) in the middle to sustain reverse voltage.

Figure 1.1 shows the diode symbol and its volt-ampere characteristics. In the forward-biased condition, the diode can be represented by a junction offset drop and a series-equivalent resistance that gives a positive slope in the V-I characteristics. The typical forward conduction drop is 1.0 V. This drop will cause conduction loss, and the device must be cooled by the appropriate heat sink to limit the junction temperature. In the reverse-biased condition, a small leakage current flows due to minority carriers, which gradually increase with voltage. If the reverse voltage exceeds a threshold value, called the breakdown voltage, the device goes through avalanche breakdown, which is when reverse current becomes large and the diode is destroyed by heating due to large power dissipation in the junction.

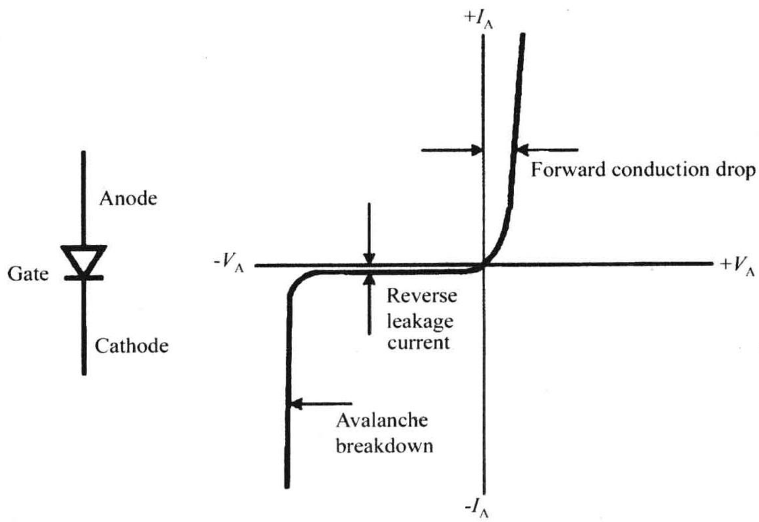


**Figure 1.1 Diode symbol and volt-ampere characteristics**

## 1.3 Thyristors

Thyristors, or silicon-controlled rectifiers (SCRs) have been the traditional workhorses for bulk power conversion and control in industry. The modern era of solid-state power electronics started due to the introduction of this device in the late 1950s. The term "thyristor" came from its gas tube equivalent, thyratron. Often, it is a family name that includes SCR, triac, GTO, MCT, and IGCT. Thyristors can be classified as standard, or slow phase-control-type and fast-switching, voltage-fed inverter-type. The inverter-type has recently become obsolete and will not be discussed further.

Figure 1.2 shows the thyristor symbol and its volt-ampere characteristics. Basically, it is a three-junction P-N-P-N device, where P-N-P and N-P-N component transistors are connected in regenerative feedback mode. The device blocks voltage in both the forward and reverse directions (symmetric blocking). When the anode is positive, the device can be triggered into conduction by a short positive gate current pulse; but once the device is conducting, the gate loses its control to turn off the device. A thyristor can also turn on by excessive anode voltage, its rate of rise ($dv/dt$), by a rise in junction temperature ($T_J$), or by light shining on the junctions.

The volt-ampere characteristics of the device indicate that at gate current $I_G = 0$, if forward voltage is applied on the device, there will be a leakage current due to blocking or the middle junction. If the voltage exceeds a critical limit (breakover voltage), the device switches into conduction. With increasing magnitude of $I_G$, the forward breakover voltage is reduced, and eventually at $I_{G3}$, the device behaves like a diode with the entire forward blocking region removed. The device will turn on successfully if a minimum current, called a latching current, is maintained. During conduction, if the gate current is zero and the anode current falls below a critical limit, called the holding current, the device reverts to the forward blocking state. With reverse voltage, the end P-N junctions of the device become reverse-biased and the V-I curve becomes essentially similar to that of a diode rectifier. Modern thyristors are available with very large voltage (several kV) and current (several kA) ratings.

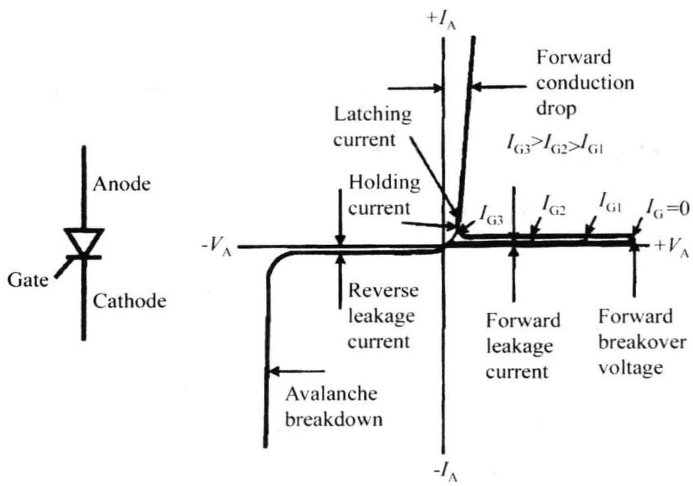


**Figure 1.2 Thyristor symbol and volt-ampere characteristics**

## 1.4 Triacs

A triac has a complex multiple-junction structure, but functionally, it is an integration of a pair of phase-controlled thyristors connected in inverse-parallel on the same chip. Figure 1.3(a) shows the triac symbol and Figure 1.3(b) shows its volt-ampere characteristics. The three-terminal device can be triggered into conduction in both positive and negative half-cycles of supply voltage by applying gate trigger pulses. In I + mode, the terminal $T_2$ is positive and the device is switched on by positive gate current pulse. In III- mode, the terminal $T_1$ is positive and it is switched on by negative gate current pulse. A triac is more economical than a pair of thyristors in anti-parallel and its control is simpler, but its integrated construction has some disadvantages. The gate current sensitivity of a triac is poorer and the turn-off time is longer due to the minority carrier storage effect. For the same reason, the reapplied $dv/dt$ rating is lower, thus making it difficult to use with inductive load. A well-designed RC snubber is essential for a triac circuit. Triacs are used in light dimming, heating control, appliance-type motor drives, and solid-state relays with typically 50/60 Hz supply frequency.

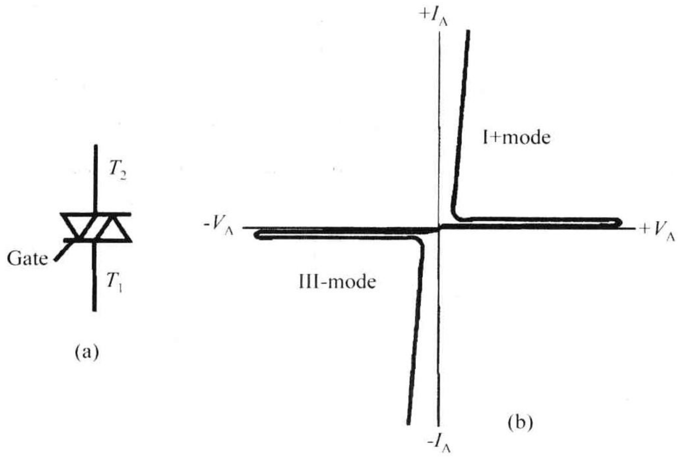


**Figure 1.3 Triac symbol and volt-ampere characteristics**

## 1.5 Gate Turn-Off Thyristors (GTOs)

A gate turn-off thyristor (GTO), as the name indicates, is basically a thyristor-type device that can be turned on by a small positive gate current pulse, but in addition, has the capability of being turned off by a negative gate current pulse. The turn-off capability of a GTO is due to the diversion of P-N-P collector current by the gate, thus breaking the P-N-P/N-P-N regenerative feedback effect. GTOs are available with asymmetric and symmetric voltage-blocking capabilities, which are used in voltage-fed and current-fed converters, respectively. The turn-off current gain of a GTO, defined as the ratio of anode current prior to turn-off to the negative gate current required for turn-off, is very low, typically 4 or 5. This means that a 6000 A GTO requires as high as −1500 A gate current pulse. However, the duration of the pulsed gate current and the corresponding energy associated with it is small and can easily be supplied by low-voltage power MOSFETs. GTOs are used in motor drives, static VAR compensators (SVCs), and AC/DC power supplies with high power ratings. When large-power GTOs became available, they ousted the force-commutated, voltage-fed thyristor inverters.

## 1.6 Bipolar Power or Junction Transistors (BPTs or BJTs)

A bipolar junction transistor (BPT or BJT), unlike a thyristor-like device, is a two-junction, self-controlled device where the collector current is under the control of the base drive current. Bipolar junction transistors have recently been ousted by IGBTs (insulated gate bipolar transistors) in the higher end and by power MOSFETs in the lower end. The DC current gain ($h_{FE}$) or a power transistor is low and varies widely with collector current and temperature. The gain is increased to a high value in the Darlington connection, as shown in Figure 1.4. However, the disadvantages are higher leakage current, higher conduction drop, and reduced switching frequency. The shunt resistances and diode in the base-emitter circuit help to reduce collector leakage current and establish base bias voltages. A transistor can block voltage in the forward direction only (asymmetric blocking). The feedback diode, as shown, is an essential element for chopper and voltage-fed converter applications. Double or triple Darlington transistors are available in module form with matched parallel devices for higher power rating.

Power transistors have an important property known as the second breakdown effect. This is in contrast to the avalanche breakdown effect of a junction, which is also known as first breakdown effect. When the collector current is switched on by the base drive, it tends to crowd on the base-emitter junction periphery, thus constricting the collector current in a narrow area of the reverse-biased collector junction. This tends to create a hot spot and the junction fails by thermal runaway, which is known as second breakdown. The rise in junction temperature at the hot spot accentuates the current concentration owing to the negative temperature coefficient of the drop, and this regeneration effect causes collapse of the collector voltage, thus destroying the device. A similar problem arises when an inductive load is turned off. As the base-emitter junction becomes reverse-biased, the collector current tends to concentrate in a narrow area of the collector junction.

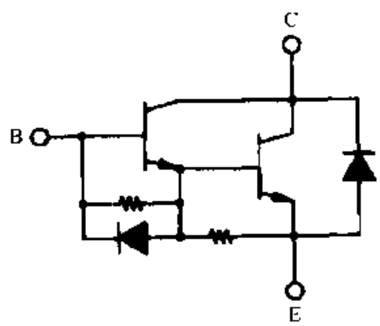


**Figure 1.4 Darlington transistor symbol**

## 1.7 Power MOSFETs

Unlike the devices discussed so far, a power MOSFET (metal-oxide semiconductor field-effect transistor) is a unipolar, majority carrier, "zero junction", voltage-controlled device. Figure 1.5(a) shows the symbol of an N-type MOSFET and Figure 1.5(b) shows its volt-ampere characteristics. If the gate voltage is positive and beyond a threshold value, an N-type conducting channel will be induced that will permit current flow by majority carrier (electrons) between the drain and the source. Although the gate impedance is extremely high at steady state, the effective gate-source capacitance will demand a pulse current during turn-on and turn-off. The device has asymmetric voltage-blocking capability, and has an integral body diode, as shown, which can carry full current in the reverse direction. The diode is characterized by slow recovery and is often bypassed by an external fast-recovery diode in high-frequency applications.

The V-I characteristics of the device have two distinct regions, a constant resistance [ $R_{DS(on)}$ ] region and a constant current region. The $R_{DS(on)}$ of a MOSFET is an important parameter which determines the conduction drop of the device. For a high voltage MOSFET, the longer conduction channel makes this drop large [ $R_{DS(on)}$ & $V^{2.5}$ ]. It is interesting to note that modern trench gate technology tends to lower the conduction resistance. The positive temperature coefficient of this resistance makes parallel operation of MOSFET easy. In fact, large MOSFETs are fabricated by parallel connection of many devices.

While the conduction loss of a MOSFET is large for higher voltage devices, its turn-on and turn-off switching times are extremely small, causing low switching loss. The device does not have the minority carrier storage delay problem associated with a bipolar device, and its switching times are determined essentially by the ability of the drive to charge and discharge a tiny input capacitance $C_{ISS} = C_{GS} + C_{GD}$ (defined as Miller capacitance) with $C_{DS}$ shorted, where $C_{GS}$ = gate-to-source capacitance, $C_{GD}$ = gate-to-drain capacitance, and $C_{DS}$ = drain-to-source capacitance. Although a MOSFET can be controlled statically by a voltage source, it is normal practice to drive it by a current source dynamically followed by a voltage source to minimize switching delays. MOSFETs are extremely popular in low-voltage, low-power, and high-frequency (hundreds of kHz) switching applications. Application examples include switching mode power supplies (SMPs), brush less DC motors (BLDMs), stepper motor drives, and solid-state DC relays.

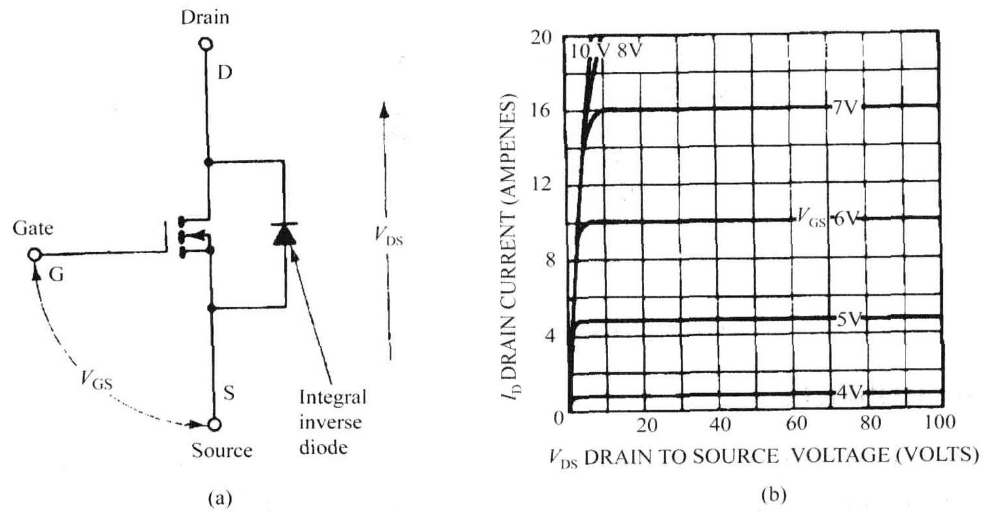


**Figure 1.5 (a) Power MOSFET symbol**
**(b) Volt-ampere characteristics (Harris 2N6757) (150 V, 8 A)**

## 1.8 Insulated Gate Bipolar Transistors (IGBTs)

The introduction of insulated gate biploar transistors (IGBTs) in the mid-1980s was an important milestone in the history of power semiconductor devices. They are extremely popular devices in power electronics up to medium power (a few kWs to a few MWs) range and are applied extensively in DC/AC drives and power supply systems. They ousted BJTs in the upper range, as mentioned before, and are currently ousting GTOs in the lower power range. An IGBT is basically a hybrid MOS-gated turn-on/off bipolar transistor that combines the advantages of both a MOSFET and BJT. Figure 1.6(a) shows the basic structure of an IGBT and Figure 1.6(b) shows the device symbol.

Its architecture is essentially similar to that of a MOSFET, except an additional $P^+$ layer has been added at the collector over the $N^+$ drain layer of the MOSFET. The device has the high-input impedance of a MOSFET but BJT-like conduction characteristics. If the gate is positive with respect to the emitter, an N-channel is induced in the P region. This forward-biases the base-emitter junction of the P-N-P transistor, turning it on and causing conductivity modulation of the N region, which gives a significant reduction of conduction drop over that of a MOSFET. At the on-condition, the driver MOSFET in the equivalent circuit of the IGBT carries most of the total terminal current. The thyristor-like latching action caused by the parasitic N-P-N transistor is prevented by sufficiently reducing the resistivity of the $P^+$ layer and diverting most of the current through the MOSFET. The device is turned off by reducing the gate voltage to zero or negative, which shuts off the conducting channel in the P region. The device has higher current density than that of a BJT or MOSFET. Its input capacitance (Ciss) is significantly less than that of a MOSFET. Also, the ratio of gate-collector capacitance to gate-emitter capacitance is lower, giving an improved Miller feedback effect.

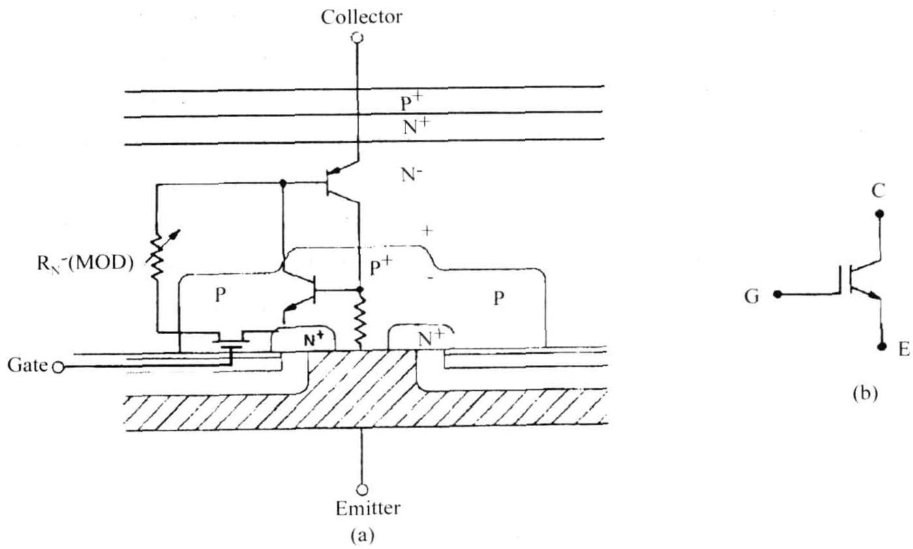


**Figure 1.6 (a) IGBT structure with equivalent circuit (b) Device symbol**

## 1.9 Integrated Gate-Commutated Thyristors (IGCTs)

The integrated gate-commutated thyristor (IGCT) is the newest member of the power semiconductor family at this time, and was introduced by ABB in 1997. Basically, it is a high-voltage, high-power, hard-driven, asymmetric-blocking GTO with unity turn-off current gain. This means that a 4500 V IGCT with a controllable anode current of 3000 A requires turn-off negative gate current of 3000 A. Such a gate current pulse of very short duration and very large $di/dt$ has small energy content and can be supplied by multiple MOSFETs in parallel with ultra-low leakage inductance in the drive circuit. The gate drive circuit is built-in on the device module. The device is fabricated with a monolithically integrated anti-parallel diode. The conduction drop, turn-on $di/dt$, gate driver loss, minority carrier storage time, and turn-off $dv/dt$ of the device are claimed to be superior to GTO. Faster switching of the device permits snubberless operation and higher-than-GTO switching frequency. Multiple IGCTs can be connected in series or in parallel for higher power applications. The device has been applied in power system intertie installations (100 MVA) and medium-power (up to 5 MW) industrial drives.

## 1.10 Power Integrated Circuits (PICs)

A discussion on power semiconductor devices is incomplete without some mention of power integrated circuits (PICs). In a PIC, the control and power electronics are generally integrated monolithically on the same chip. Loosely, a PIC is defined as "smart power". The motivations behind a PIC are reductions in size and cost, and improvement in reliability. The main problems in PIC fabrication are isolation between high-voltage and low-voltage devices and thermal management. A PIC is often differentiated from a high-voltage integrated circuit (HVIC), where the voltage is high but the current is small, that is, the loss is low. Low-voltage NMOs, CMOs, and bipolar devices can be conveniently integrated with MOS-gated power devices. Recently, a large family of PICs that includes power MOSFETs or IGBT smart switches, half-bridge inverter drivers, H-bridge inverters, two-phase step motor drivers, one-quadrant choppers for DC motor drives, three-phase brush less DC motor drivers, etc. has become available. Figure 1.7 shows a monolithic PIC (within the dotted rectangle) for driving a brushless DC motor. The simplified block diagram of the 40 V, 2 A PIC consists of a six-switch power stage, Hall sensor decoding logic, current-regulated PWM (pulse width modulated) control of the lower switches, and thermal/under voltage protection features.

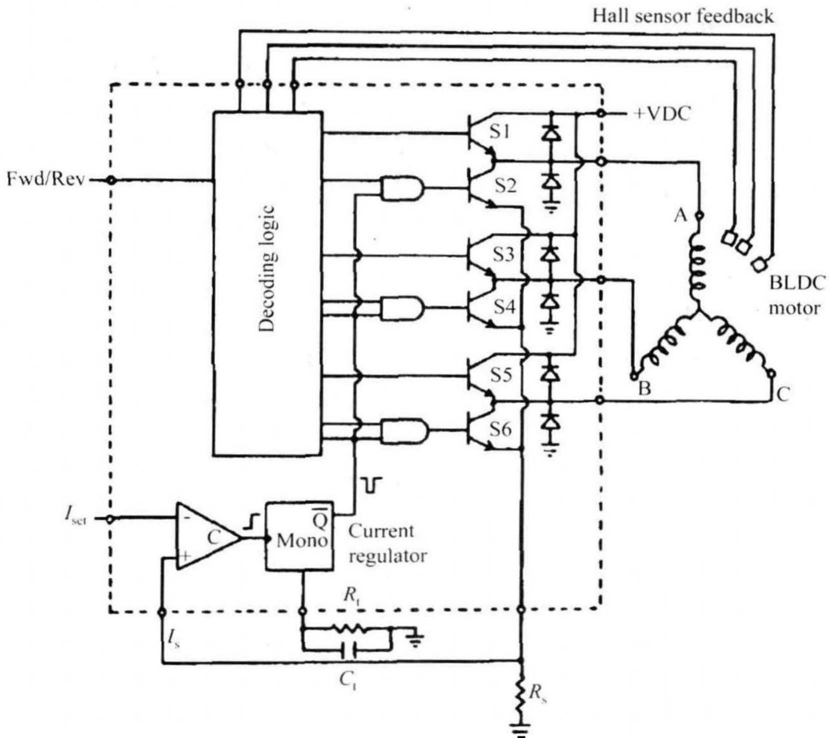


**Figure 1.7 Monolithic PIC for brushless DC motor (BLDC) drive (Unitrode UC3620)**

## New Words and Expressions

| | |
|---|---|
| constitute [ˈkɒnstɪtjuːt] *v.* | 组成，建立 |
| chopper [ˈtʃɒpə(r)] *n.* | 斩波器 |
| rectifier [ˈrektɪfaɪə(r)] *n.* | 整流器 |
| cycloconverter [ˌsaɪkləukənˈvɜːɪə(r)] *n.* | 周波变换器 |
| harmonic [hɑːˈmɒnɪk] *n.* | 谐波 |
| characteristic [ˌkærəktəˈrɪstɪk] *n.* | 特性 |
| evolution [ˌiːvəˈluːʃn] *n.* | 进化 |
| fabrication [ˌfæbrɪˈkeɪʃn] *n.* | 制作 |
| exclusively ***adv.*** | 独占地，专有地 |
| electroplate *v.* | 电镀 |
| anodize [ˈænəʊdaɪz] *v.* | 阳极电镀，作阳极化处理 |
| freewheel *v.* | 轻快地行动，凭惯性前进 |
| snubber *n.* | 缓冲器 |
| intrinsic [ɪnˈtrɪnsɪk] ***adj.*** | 固有的，本质的，内在的 |
| sustain [səˈsteɪn] *v.* | 承受，承担 |
| offset [ˈɒfset] *n.* | 抵消 |
| avalanche [ˈævəlɑːnʃ] *n.* | 雪崩 |

| | |
|---|---|
| avalanche breakdown | [电子]雪崩击穿 |
| thyratron ['θaɪrətrɒn] ***n.*** | 闸流管 |
| thyristor ['θaɪ'rɪstə] ***n.*** | 〈美〉半导体闸流管，晶闸管 |
| threshold ['θreʃhəuld] ***n.*** | 门槛，入口 |
| threshold value | 阈值，临界值 |
| dissipation [ˌdɪsɪ'peɪʃn] ***n.*** | 消散 |
| power dissipation | 功率耗散，功率消耗 |
| obsolete ['ɒbsəliːt] ***adj.*** | 陈旧的 |
| regenerative [rɪ'dʒenərətɪv] ***adj.*** | 再生的,正反馈 |
| symmetric [sɪ'metrɪk] ***adj.*** | 对称性的,均衡的 |
| anode ['ænəud] ***n.*** | 阳极,正极 |
| trigger ['trɪgə(r)] ***v.*** | 触发 |
| excessive [ɪk'sesɪv] ***adj.*** | 过度的，极端的 |
| latch [lætʃ] ***v.*** | 闩上，擎住 |
| appliance [ə'plaɪəns] ***n.*** | 应用,设备，装置 |
| diversion [daɪ'vɜːʃn] ***n.*** | 转移 |
| asymmetric [ˌæsɪ'metrɪk] ***adj.*** | 不均匀的,不对称的 |
| oust [aust] ***v.*** | 驱逐，撵走 |
| shunt [ʃʌnt] ***n.*** | 转轨，分流 |
| crowd [kraud] ***v.*** | 聚集,挤满 |
| periphery [pə'rɪfrɪ] ***n.*** | 外围 |
| constrict [kən'strɪkt] ***v.*** | 压缩,束紧 |
| thermal ['θɜːml] ***adj.*** | 热的，烫的，热量的 |
| runaway ['rʌnəweɪ] ***n.*** | 逃走的人，亡命者，逃亡 |
| accentuate [ək'sentʃueɪt] ***v.*** | 强调，以重音念，重读 |
| collapse [kə'læps] ***n.*** | 倒塌,失败,崩溃 |
| drain [dreɪn] ***n.*** | 漏极 |
| impedance [ɪm'piːdns] ***n.*** | 阻抗 |
| capacitance [kə'pæsɪtəns] ***n.*** | 电容,电流容量 |
| integral ['ɪntɪgrəl] ***adj.*** | 整体的 |
| distinct [dɪ'stɪŋkt] ***adj.*** | 截然不同的,明显的 |
| trench [trentʃ] ***n.*** | 沟渠，管沟 |
| fabricate ['fæbrɪkeɪt] ***v.*** | 制造,组装 |
| architecture ['ɑːkɪtektʃə(r)] ***n.*** | 布置，格局，安排 |
| induce [ɪn'duːs] ***v.*** | 劝诱,导致,促使 |
| conductivity [ˌkɒndʌk'tɪvətɪ] ***n.*** | 导电率,传导性 |
| modulation [ˌmɒdju'leɪʃn] ***n.*** | 调制 |
| parasitic [ˌpærə'sɪtɪk] ***adj.*** | 寄生的 |
| divert [daɪ'vɜːt] ***v.*** | 使转向,使改道 |

| | |
|---|---|
| differentiate [ ˌdɪfəˈrenʃɪeɪt ] ***v.*** | 使有差异,区别 |
| quadrant [ ˈkwɒdrənt/ˈkwɒd- ] ***n.*** | 四分圆，象限 |
| monolithic [ ˌmɑnəʊˈlɪθɪk ] ***adj.*** | 庞大的,整体的 |
| commutate[ ˈkɒmjuteɪt ] ***v.*** | 使方向转换,交换,换向 |
| intertie [ ˈɪntətaɪ ] ***n.*** | 〈美〉连锁电力网 |

# Unit 2 Gate Commutated Inverters (DC/AC Converters)

Most modern AC variable speed drives in the 1 kW to 500 kW range are based on gate-commutated devices such as the GTO, MOSFET, BJT and IGBT, which can be turned ON and OFF by low power control circuits connected to their control gates.

The difficulties experienced with thyristor commutation in the early days of PWM inverters have largely been overcome by new developments in power electronic technology. Diodes and thyristors are still used extensively in line-commutated rectifiers.

Starting with a DC supply and using these semiconductor power electronic switches, it is not possible to obtain a pure sinusoidal voltage at the load. On the other hand, it may be possible to generate a near-sinusoidal current. Consequently, the objective is to control these switches in such a way that the current through the inductive circuit should approximate a sinusoidal current as closely as possible.

## 2.1 Single-phase square wave inverter

To establish the principles of gate-controlled inverter circuits, the figure 2.1 below shows four semiconductor power switches feeding an inductive load from a single-phase supply.

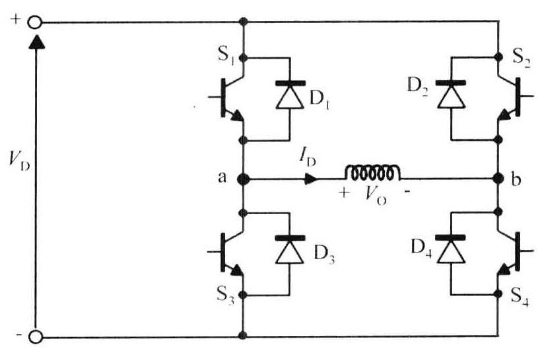


**Figure 2.1 Single-phase DC to AC inverter**

This circuit can be considered to be an electronic reversing switch, which allows the input DC voltage $V_D$ to be connected to the inductive load in any one of the following ways:

(1) $S_1$ = on, $S_4$ = on, giving $+V_D$ at the load

(2) $S_2$ = on, $S_3$ = on, giving $-V_D$ at the load

(3) $S_1$ = on, $S_2$ = on, giving zero volts at the load

$S_3$ = on, $S_4$ = on, giving zero volts at the load

(4) $S_1$ = on, $S_3$ = on, giving a short circuit fault

$S_2$ = on, $S_4$ = on, giving a short circuit fault