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## EXECUTIVE SUMMARY

The purpose of this report is to inform prospective corporate partners about Integrated Power Semiconductor, Ltd. (Integrated Power, or IPS) and its technology, position, and outlook in the power integrated-circuit (smartpower) business. For the first time, the company's newly developed technologies allow the combination of usable power-drive capabilities (in terms of volts and amperes) with both digital and analog logic level control circuitry on one monolithic integrated-circuit (IC) chip that can be manufactured in volume at low cost.

Integrated Power believes that corporate alliances are critical to help further define product applications of monolithic, smartpower ICs and to establish Integrated Power as the preferred choice for power controls and power drives. Such alliances will provide the corporate partner with high-performance, low-cost, proprietary alternatives to its power-control needs; in turn, it will establish Integrated Power's reputation in semicustom and custom monolithic smartpower ICs.

### BUSINESS OVERVIEW

Integrated Power designs, develops, and manufactures monolithic, semicustom, full-custom, and standard high-current, high-power ICs (smartpower ICs or power ICs). Integrated Power's products address high-power IC applications for power controls and power drives, and they dramatically raise the power levels available from monolithic ICs.

The firm's charter was conceived in 1983, and the company was formed in April 1984 to fill the void left when most semiconductor manufacturers moved to digital ICs. Integrated Power produces innovative power ICs (smartpower ICs) that combine digital and analog logic level control circuitry on one chip with multiple power elements to drive electronic motors, solenoids, power supplies, switches, in modern electronic equipment.

Equipment markets for the company's markets typically require high-current motor drives and other actuator drives supplied by several power devices, which are in turn controlled by intermediate logic circuitry commanded by a microprocessor or a computer. Integrated Power now puts these multiple power elements all on one chip and, furthermore, it integrates all the logic circuitry necessary onto the same chip so that the interface between motor and microprocessor (or controlling computer) is simply one power IC.

High-power monolithic IC applications, which Integrated Power considers its primary market, are defined as handling up to 10 amperes with voltages up to 400 volts. There has been no adequate source of power ICs for this market. In the past, these applications have been served by circuit boards of discrete components or by hybrid packaging techniques, but these approaches have the inherent problems of being more expensive, more space consuming, and less reliable than Integrated Power's monolithic solution.

## Distinctive Competence

Integrated Power has the broadest range of power supply control ICs, motor-drive ICs, and low-cost power IC packages available. Integrated Power also attempts to be the most responsive supplier to customers' specific power IC needs through its large CAD design center. In addition, Integrated Power has a greater concentration of engineers and scientists experienced in high-power ICs than any other manufacturer.

This combination defines Integrated Power's key strength: its ability to design and manufacture innovative, monolithic, application-specific custom and semicustom power ICs that combine multiple power elements at new increased power levels with sophisticated low-power logic controls on the same chip.

## Products

Examples of specific company products are:

- 4-amp stepper motor "H" bridge drives with logic
- 2.5-amp, three-phase, DC brushless motor drives with servo logic
- Switchmode, power supply control ICs
- 4-amp, dual-solenoid actuators
- 5-phase stepper motor drives (five "H" bridges on one chip)
- 6-amp, voltage-regulating ICs

All products are in high heat-dissipating, low-cost, power packages; their ranges include surface-mount and high pin-count power packages.

## Applications

Examples of applications for Integrated Power's high-ampere and high-voltage products are:

- Automobiles and aircraft: replace wiring harness with coded (multiplexed), single-wire electronic controls for all motorized functions

- Factory automation equipment and robotics: replace hydraulic and electromechanical components with electronic servo controls and direct computer interfaces

- Winchester disk drives and office printers: replace power discretes with power ICs that are lower in cost, dissipate less heat, and require less space

- Environmental and process controls: replace electromechanical relays, solenoids, and switches with direct, computer-interfaced electronic ICs and sensors

- Military equipment: reduce interconnections, size, and weight to increase reliability, speed, and performance of electronic equipment

## MARKET POSITION

The equipment market for Integrated Power's technology is presently growing at nearly 30 percent per year, but it is served by expensive circuit boards of older, discrete components and simpler logic ICs. Integrated Power projects the smartpower market will be more than $1 billion worldwide by 1990. Few suppliers will have the engineering and process technology available to meet the needs of this market and, as a result, many users will continue to use older, discrete components. This situation leaves near-term growth for smartpower ICs unlimited, but the reality of supply suggests that total power IC sales growth will average 25 percent per year (Dataquest).

### Product Position

Integrated Power believes it is the technology leader in these power applications with a solid product base being manufactured in a new class 10/100 wafer fab and manufacturing facility. Established reliability with military vendors, major customers in the United States and Europe, and a large R&D organization provide firm support levels from which it can expand.

### Competition

Integrated Power's competitors appear to be a few small IC manufacturers with a limited commitment to this market. No other IC manufacturer competes with the company across its full product range or market range. Large IC manufacturing companies are confining all their management efforts and resources to compete in the digital computer-chip markets, competing against the Japanese and against each other. Most have no expertise in power ICs.

## FINANCIAL BRIEF

| FY '86 ended March 31, 1986 | Actual 1986 | Forecast 1987 | Forecast 1988 | Forecast 1989 | Forecast 1990 |
|---|---|---|---|---|---|
| Sales Plan ($M) | $1.0 | $ 8.0 | $20.0 | $40.0 | $60.0 |
| Profit before Tax ($M) | ($6.93) | ($ 8.8) | $ 2.0 | $ 7.2 | $10.8 |
| Percent | | | 10% | 18% | 18% |
| Profit from Grants ($M) | $1.2 | $2.6 | $ 2.0 | $ 1.2 | $ 1.2 |
| Profit before Tax with Grants | ($5.7) | ($6.2) | $ 4.0 | $ 8.4 | $12.0 |
| Percent | | | 20% | 21% | 20% |
| Head Count | 112 | 200 | 300 | 500 | 750 |

Source: Integrated Power

The company plans breakeven, P&L, during first quarter of fiscal 1988 (April through June, 1987) and breakeven, cash flow, six months thereafter. Integrated Power is seeking additional investment for funding the working capital for growth until breakeven.

## FACILITIES

The company's headquarters and manufacturing facilities are located in Livingston, Scotland, near Edinburgh. With American management and California technologists all located in Scotland's Silicon Glen alongside companies such as IBM, Hewlett-Packard, Motorola, and National Semiconductor, competitive costs and fast design cycles are assured. The company plans to locate a second facility in the United States within the next three years.

## OWNERSHIP

The ownership of the company as of March 31, 1986, on a fully diluted basis, is shown in Table 1.

Table 1

IPS STOCK OWNERSHIP

| | Shares | | |
|---|---|---|---|
| | Convertible (Preferred) | Ordinary (Common) | Percent Ownership |
| Institutional Investors | 10,775,165 | 125,000 | 79. % |
| Founders and Early Investors | 0 | 2,319,635 | 16.9% |
| Employee Investors | 485,333 | | 3. % |
| Total | 11,260,498 | 2,444,635 | |

Last share purchase: June 1986 at $2.50 per share.

Source: Integrated Power

The institutional investors have participated in three rounds of financing that total $22 million:

| | |
|---|---|
| Investors in Industry | 15.7% |
| Newmarket | 11.4% |
| Scottish Development Agency | 8.3% |
| Flemings (Robert Flemings & Assoc) | 7.7% |
| Charterhouse Venture Fund | 5.8% |
| APA | 3.8% |
| CIN | 4.6% |
| Employee's Venture Funds | 3.4% |
| Warburgs/Legal & Gen'l/ECI/Melville St./ Baronsmead/Citicorp/Prudential Mgmt. | 21.1% |
| Management and Employees | 18.2% |

PERSONNEL

A departmental breakdown as of June 3, 1986, of Integrated Power's personnel is as follows:

| | |
|---|---|
| Administration and Finance | 13 |
| Marketing and Sales | 22 |
| Research and Development | 5 |
| Engineering | 25 |
| Manufacturing | 65 |
| Total | 130 |

## BUSINESS STRATEGY

Integrated Power's goal is to be the leader in semicustom and full-custom, high-power monolithic smartpower ICs. To meet this objective, Integrated Power has accomplished the following:

- Assembled a top team of management and technical personnel who have proven success in the past (more proven power IC designers than any other company, for example).

- Chosen specific applications and designed the highest performance and highest quality ICs available. Integrated Power now has the broadest line of motor-drive ICs and power supply control ICs in the world.

- Added innovative proprietary power ICs at a rate of more than one per month. These ICs increase users' equipment performance and thus reduce costs by 20 percent to 30 percent.

- Implemented key account customer relationships with blue-chip equipment manufacturers for which power control and power-drive custom ICs are planned to be 60 percent of the company's business. These relationships help to define future, more sophisticated, products while at the same time cementing custom and semicustom sales opportunities.

- Installed local sales and service offices, complete with applications engineers, throughout the United States and Europe. These offices are augmented with a network of distributors' and manufacturers' representatives.

- Focused the R&D organization on developing technologies that will be needed three to four years in the future. This R&D organization is separate from the product design engineering group, but it supports that group.

- Created a large CAD design center to support customers' complex custom and semicustom IC needs.

## INTRODUCTION

Digital IC development has grown phenomenally in the past decade to the exclusion of linear IC development. Increased amounts of money, personnel, and resources have been applied to digital IC technology to reduce the cost, size, and power consumption of digital products.

While digital computer chips, memory chips, and logic chips help to do the "thinking" in modern electronic equipment, other electronics are required to do something--to perform work and to control motion. This work requires linear circuitry and electronics. Linear and power ICs must get more attention and more resources to gain full benefit from digital computer chips.

The power electronics to run motors, actuators, lights, and switches in all this equipment often costs much more than the digital computer chips. Because low-cost complex power chips have not been available, equipment design engineers are frustrated in solving the problem. Modern microcircuit technology needs to make design easier and reduce costs in other parts of machines the way the computer chip has for the "thinking" part, but engineers have had to use old (often 20-year old) electronics to interface between the computer and the motors, actuators, lights, and switches.

These old electronics are circuit boards full of separate resistors, capacitors, inductors, power transistors, and so on, which are collectively called discrete components and which must be individually connected to the equipment. Billions of dollars are spent on these components annually, but they often limit the performance, cost effectiveness, reliability, and size reduction for any given type of equipment.

Many of the manufacturers of discrete components want to participate further in power electronics. They are marketing their discretes (very often new discretes such as MOS power devices, but still discretes) packaged in hybrid circuits with four or more separate discrete chips inside the package. While it is too early to know how successful such hybrids will be, it is already evident from many users that such hybrids are too expensive for motor-drive applications in computer peripherals, office products, and perhaps automobiles. A fully monolithic approach appears to be preferred.

Power electronics generally have not received attention from the microcircuit manufacturers because power electronics are used where voltages and currents (hence, power) are many, many times greater than those used by digital computer chips. The techniques and manufacturing processes used for computer chips simply cannot be used to make IC components for such high-power applications. Hence chip manufacturers, who have devoted their resources to digital computer and logic ICs, have not developed ICs capable of handling high-power equipment functions.

## SMARTPOWER SUBMARKETS

Some semiconductor companies have recently begun attempts to alleviate the large gap in IC development between very low-power computer chips and high-power ICs. Different specific technologies are being tried for different applications, but all efforts at integrating power and interfacing logic on one chip now come under the general heading of smartpower.

Three distinct categories of equipment needs have developed into submarkets for smartpower applications as shown in Table 2.

Market sizes shown are built up from equipment needs and are smartpower opportunities which may not be all filled by new products due to limited smartpower suppliers.

## Table 2

### SMARTPOWER SUBMARKETS

| Submarket Competitors | Application | Electrical Function | Electronic Characteristics | Process Technology |
|---|---|---|---|---|
| **Medium-Power ICs**<br>Siliconix<br>Supertex<br>Texas Instruments<br>Sprague | Flat panel displays<br>Telephone switchgear<br>Communications equipment | Display drives<br>SLIC and telecomm switches<br>Line multiplexing | Up to 200 volts<br>Up to 100 milliamperes output<br>Up to 5 watts dissipation | CMOS/DMOS |
| **High-Power ICs**<br>Integrated Power<br>Silicon General<br>Unitrode<br>SGS<br>Sprague<br>Hitachi | Computer peripherals<br>Office equipment<br>Automobiles/vehicles<br>Factory systems/robotics<br>Aircraft<br>Small appliances<br>Power supplies<br>Hand tools | Motor controls<br>Motor drives<br>Solenoid drives<br>Actuator drives<br>Power supply control<br>Servo systems<br>Light/relay switches<br>Power regulation<br>Power supervision<br>Power multiplexing | Up to 400 volts<br>Up to 10 amperes output<br>Up to 50 watt dissipation | Bipolar at present<br>BiMOS for future |
| **Very High-Power Discretes**<br>Motorola<br>International Rectifier<br>Siliconix<br>Siemens<br>RCA<br>General Electric<br>Ixys<br>Elantec | Factory systems<br>Power supplies<br>Power tools<br>Television/CRT terminals | Large motor drives<br>Power supply outputs<br>Deflection circuits<br>AC speed controls | Up to 1,500 volts<br>Up to 100 amperes<br>Up to 200 watts dissipation | Hybrids; segment not likely to be monolithic |

Source: Integrated Power
Dataquest
May 1986

## Medium-Power ICs

The first submarket for smartpower applications is for medium-power ICs. As shown in Table 3, all applications for medium-power ICs used to be served by discrete components. However, as the demand for digital switching techniques for telephone systems and data transmission became more prevalent, the digital IC efforts of computer-chip engineers began to be applied to them. The ICs needed for these telecommunications applications require voltages in excess of 100 volts and low currents of only a few milliamperes.

Similarly, flat-panel display developers were looking desperately for lower-cost electronic row-and-column drives. The same electrical environment existed for these display drives as for telecommunications switches, so the developers of high-voltage, low-current switches also worked to develop display drive ICs. There now exists a rapidly growing market for such devices--a medium-power IC segment of the smartpower market.

Table 3

MEDIUM-POWER ICs

| Total Available Market* | Application | Electronic Characteristics | Competitors |
|---|---|---|---|
| 1986--$400M | Display drives | To 200 volts | Siliconix |
| 1990--$750M | Telecomm switches | To 100 milliamps output | Sprague |
| CAGR 17% | High-voltage SLIC | To 5 watts dissipation | Texas Instruments |
| | Very small DC-DC converters | | Maxim |
| | | | Japan Inc. |

*"Total Available Market" represents linear and discrete semiconductor markets vulnerable to displacement by smartpower products, not necessarily the total market that will be served.

Source: Integrated Power
Dataquest
May 1986

## High-Power ICs

The second submarket for smartpower applications is for high-power ICs. High-power ICs are needed to provide high currents of from 1.0 to 10 amperes to drive small motors, operate power supplies, and provide power regulation. Table 4 shows the categories of the high-power IC market.

Table 4

HIGH-POWER ICs

| Total Available Market* | Application | Electronic Characteristics | Competitors |
|---|---|---|---|
| 1986--$500M<br>1990--$1.2Billion<br>CAGR 24% | DC motor drives in computer/office peripherals, automobiles<br>AC motor control in robotics, industrial controls<br>Power regulation<br>Power supervision | To 10 amperes output<br>To 400 volts<br>To 50 watts dissipation | Integrated Power<br>SGS<br>Sprague<br>Hitachi<br>Unitrode<br>Silicon General |

*"Total Available Market" represents linear and discrete semiconductor markets vulnerable to displacement by smartpower products, not necessarily the total market that will be served.

Source: Integrated Power
Dataquest
May 1986

## Small Motors

The myriad uses of small DC and AC motors--especially with the explosion over the last 10 years of personal computers and computer peripheral equipment growth--provided a tremendous impetus for motor manufacturers to develop special types of motors (stepper motors and DC brushless motors) and to make them at lower costs. This development in turn added to the uses for such motors and hence to the growth of the small-motor market. Table 5 shows a breakdown of the categories and relative size of the small-motor market, in unit shipments.

Table 5

1985 SMALL-MOTOR MARKET
(Millions of Units)

| Small DC Motors | Small AC Motors | Small Stepper Motors |
|---|---|---|
| 120 | 220 | 50 |

Source: Frost & Sullivan
Integrated Power

## Power Supplies

The switchmode power supply market had an allied need for power ICs, and some progress was made in this area several years ago. Virtually all electronic equipment needs a power supply of some kind, often with high-current, power voltage regulators. Companies making small linear ICs began to make control circuits for power supplies. As their sophistication grew, they found that some power supply chips could be used in motor-control circuits, although those power supply ICs did not produce the current and power necessary to actually drive the motors; a discrete power transistor stage was still required. Table 6 shows the market size for power supply ICs and power regulators.

Table 6

**1985 POWER SUPPLY AND POWER REGULATOR MARKETS**

Power Supplies--180 Million Units Annually
(Millions of Dollars)

| Power Supply Control Market | Power Regulator Market |
|---|---|
| $260 | $80 |

Source: Salzar Technology
Integrated Power

From expertise in power supply ICs and power transistors, and from a market knowledge of the huge need for motor-drive power ICs, Integrated Power was started more than two years ago to develop high-power IC chips, plus the packages for them, with an undivided focus that has already produced the broadest range of power supply, motor-drive, and high-current, voltage-regulating ICs available.

## Very High-Power Discretes

The third submarket for smartpower applications is still that of discretes--discrete power transistors of all types. Manufacturers of discrete power transistors are beginning to include a few sensing elements on the surface of power chips to add features such as thermal shutdown and current limiting. However, because of their vertical structure and their very high-power and high-voltage levels, they are still discrete devices with only one individual power element per chip. Table 7 shows the very high-power discrete market.

Table 7

1985 VERY HIGH-POWER DISCRETE MARKET

| Total Available Market* | Application | Electronic Characteristics | Competitors |
|---|---|---|---|
| 1986--$300M<br>1990--$500M<br>CAGR 14% | Large DC motor drives<br>Large AC motor drives<br>Power supply outputs | To 100 amps output<br>To 1,500 volts<br>To 100 watts dissipation | Motorola<br>General Electric<br>RCA<br>Toshiba<br>Ixys<br>Siemens<br>General Instrument<br>Siliconix<br>Texas Instruments<br>Int'l Rectifier |

*"Total Available Market" represents linear and discrete semiconductor markets vulnerable to displacement by smartpower products, not necessarily the total market that will be served.

Source: Integrated Power
Dataquest
May 1986

As stated previously, many of the manufacturers of discrete components participated in the smartpower motor-drive market by marketing their discretes in hybrid form with four or more separate chips inside the package. For many applications such hybrids are too expensive for motor-drive applications in computer peripherals, office products, and perhaps automobiles.

## KEY ISSUES OF HIGH-POWER SMARTPOWER

Integrated Power understands and anticipates both users' needs for high-power, monolithic smartpower devices and the constraints of the technology. The following are the key issues faced by users when they review the high-power smartpower suppliers. Integrated Power addresses these issues with innovative solutions that meet or exceed the smartpower users' needs:

- No user can seriously consider high-power monolithic ICs unless they provide power packaging for the chips. Major considerations that must be met are:

  - Reliability

  - Cost

  - Usability

  Integrated Power has a broader range of packages for power ICs than any other manufacturer, and it is developing more.

- No user can seriously consider high-power monolithic ICs unless they can reduce heat and increase efficiency. Reduced heat and increased efficiency mean:

  - Greater reliability

  - Lower cost

  - Higher performance

  Integrated Power's R&D physics program has targeted major improvements in a chip's power-handling ability.

- No user can seriously consider high-power monolithic ICs unless they provide process and manufacturing technologies that address the needs of the equipment manufacturers.

  Integrated Power's developments in bipolar power and logic combinations, MOS power and CMOS logic combinations, and mergers of bipolar and CMOS, either provide or will provide innovative solutions to complex applications and cost issues.

- No user can seriously consider high-power smartpower ICs, in the present state of the market, unless many resources are applied to circuit design because so few products currently exist.

  Integrated Power has attracted many design engineers, and it is backing its custom and proprietary design capability by developing a cell library, a mask-configurable technology, and a CAD software system to provide fast delivery of application-specific products. The company has already designed the broadest range of power supply ICs, the broadest range of motor-drive ICs, and the broadest range of power-regulating ICs available.

## DEVELOPING MARKET FOR HIGH-POWER ICs

The following is a brief summary of the development of smartpower ICs and a prediction of the primary markets for the devices over the next few years.

### Market Characterization: 1986

Rapid design cycles and fierce competition in the computer peripherals/office products field have been the driving force for new applications of complex smartpower ICs with 1 ampere or more output per cell. Some of the products being developed are brushless DC motor drives (three phases with control logic), stepper motor drives (up to five phases, one H bridge per phase, and logic all on one chip), single- and dual-power op amps, power transconductance amplifiers, various forms of servo motor drives, and various forms of single- and dual-H bridge drives, and solenoid drives.

Smartpower technology is being sought by all equipment manufacturers, both OEM and captive, in these markets. Simple drive arrays have often been used in these applications, but there is an increasing demand for full drives with logic control as part of the monolithic IC.

Tables 8, 9, and 10 show this increasing production demand for high-power ICs.

Table 8

1986 HIGH-POWER IC SHIPMENTS
(Millions of Dollars)

| Power-Drive ICs | Power Supply ICs | Power-Regulating ICs |
|---|---|---|
| $20 | $260 | $80 |

Source: Integrated Power

### Market Characterization: 1987

Automotive electronics companies, captive and noncaptive, are developing multiplex systems to reduce wiring and weight (see Figure A). Aircraft companies have the same goal with the added objective of replacing much of the hydraulics (see Figure B).

Smartpower IC technology is an obvious fit with this development because decoding, logic, and power drive can all appear on the same low-cost monolithic chip.

Tentative steps toward multiplexing will occur in 1987, with the pace quickening in 1988. This market available to high-power ICs is huge, but limited supply will mean limited shipments in the next few years.

Figure A

MULTIPLEX WIRING SYSTEMS FOR AUTOMOTIVE

# *MULTIPLEX WIRING SYSTEMS*

Multiplexing is a means whereby many different sets of data may be communicated along a single data highway. It offers considerable opportunities for the simplification of complex multicore wiring harnesses, which ordinarily require at least one copper conductor for every circuit. A large number of signals can be handled efficiently, and multiplex wiring systems offer scope for controlling additional functions as well as providing inbuilt diagnostic testing facilities without resort to excessively complex wiring looms and their attendant problems.

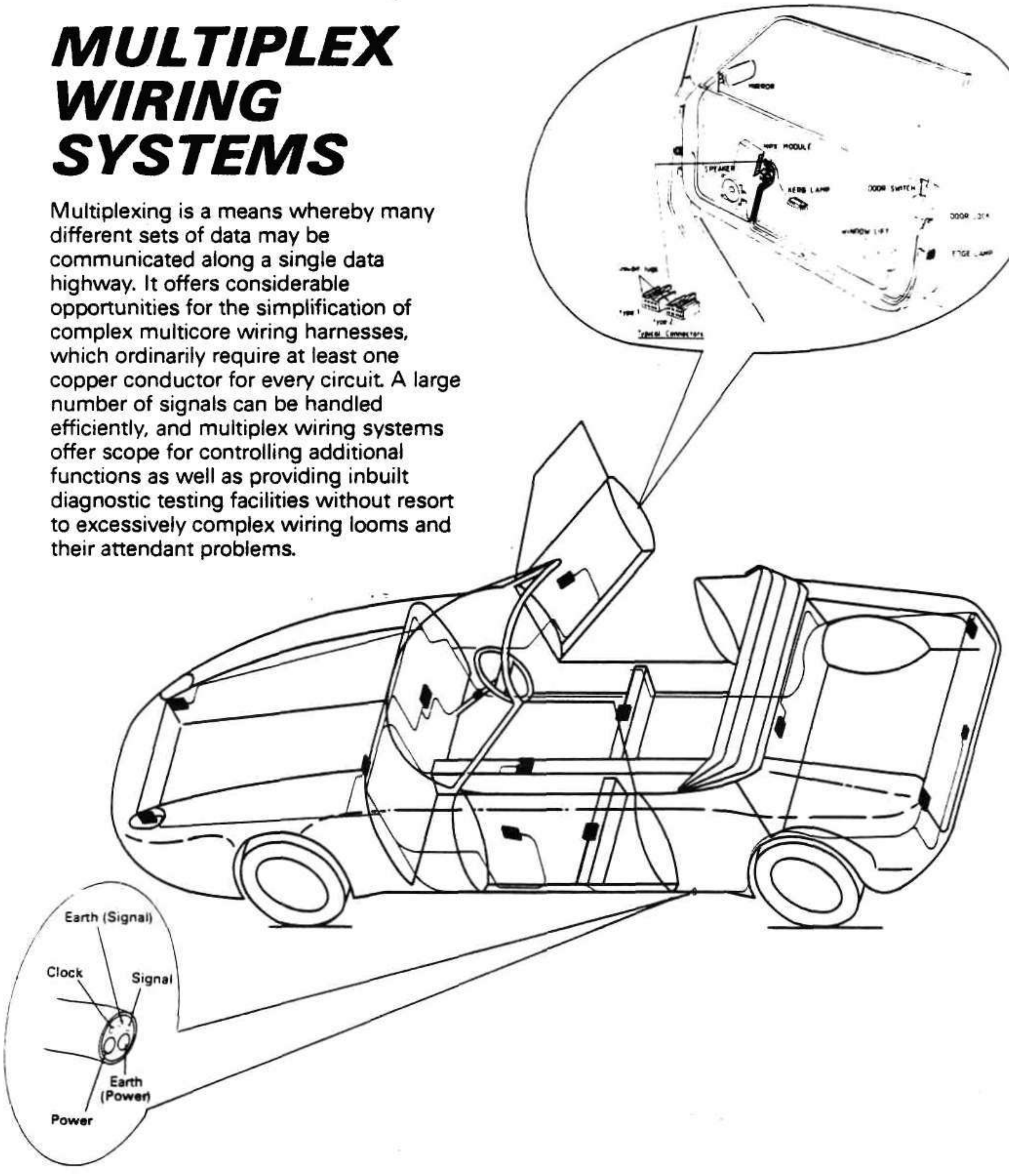
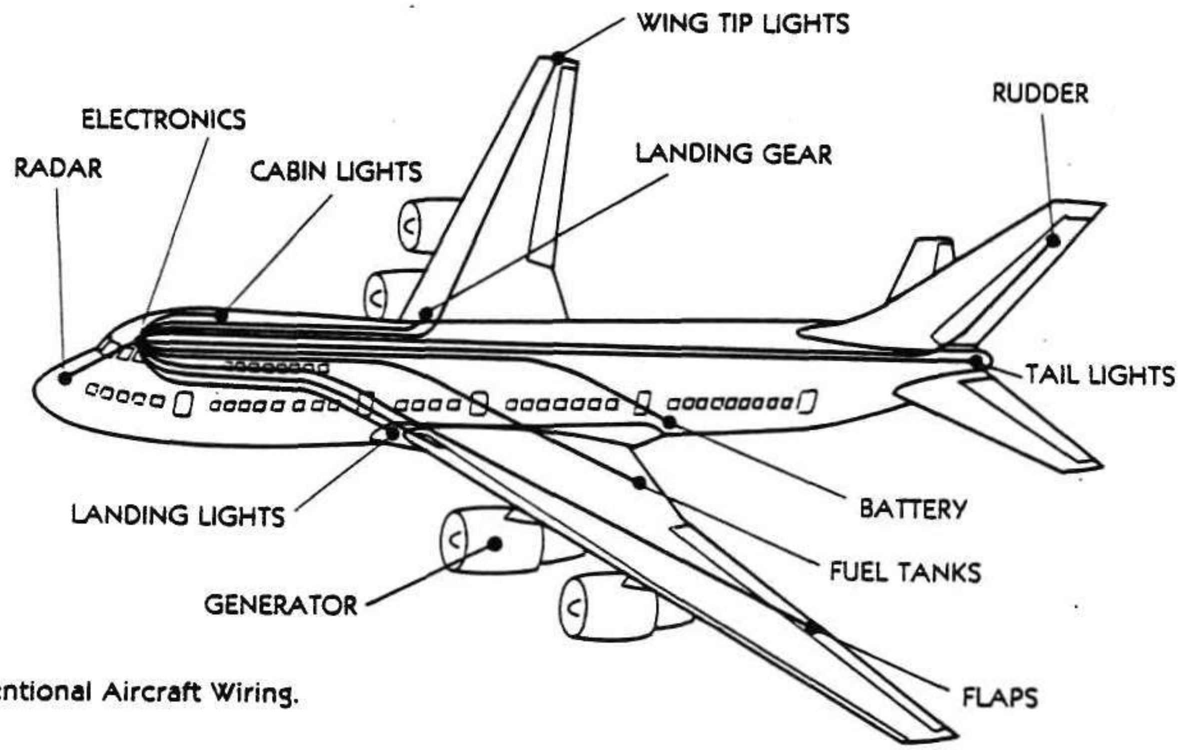
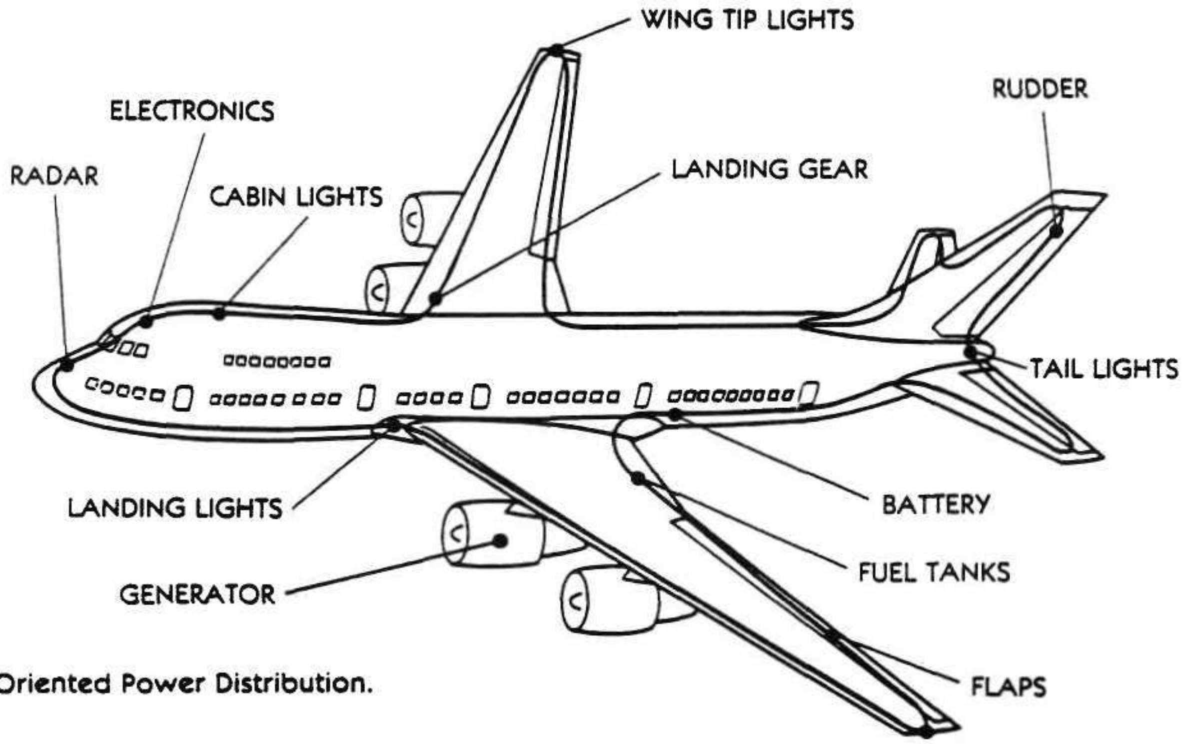


Figure B

MULTIPLEX WIRING SYSTEMS FOR AIRCRAFT




Conventional Aircraft Wiring.




Bus-Oriented Power Distribution.

Computer peripherals and power supplies will continue to be the major use for most shipments in 1987 (see Table 9), especially if the projected market surge for computer equipment in 1987 materializes.

Table 9
1987 HIGH-POWER IC SHIPMENTS
(Millions of Dollars)

| Automobiles/Aircraft | Computer Peripherals | Power Supply and Power Regulating ICs |
|---|---|---|
| Power-Drive ICs $20 | Power Drive ICs $100 | $400 |

Source: Integrated Power

Market Characterization: 1988

Enthusiasm is building in industry for factory automation and process automation because they can finally be done successfully. With the leadership of some of the largest corporations, this enthusiasm should carry through the remainder of the 1980s and into the 1990s.

Computers, computer networking, software, and interface standards are all being put into place for this push in factory automation. At the working end, electromechanical devices and motors are already in place. Corporations are investigating and deciding on sensors.

A programmable controller handles all the electrical signals (115 volts, 220 volts AC), the electronic signals, and their electronic interfaces. It is a costly device for adapting electronics to the mechanical world. Inside the programmable controller are those circuit boards expensively stuffed with discrete components.

High-power IC technology will not only reduce the costs of the programmable controller enormously, but will also enhance the performance of the controllers. IC voltage handling up to 400 volts provides an ideal solution to interfacing 115-volt DC and 24-volt DC standards to electronic signals. Switches and relays can become electronic. The use of sensor technology can be expanded.

High-voltage logic, memory, and simple electronic computing functions will all be done on smartpower chips, from sensor inputs, which then drive actuators, lamps, relays, and motors. In many cases, central or distributed computers on the factory floor will never be involved.

Smartpower IC product definition should begin in 1987, with shipments of such products commencing in 1988 and advancing rapidly thereafter.

Automotive uses of power ICs will also advance rapidly, but much of that production will come from captive manufacture with technology licensed or internally developed.

Table 10 shows the anticipated shipments of high-power ICs for 1988.

Table 10

**1988 HIGH-POWER IC SHIPMENTS**
**(Millions of Dollars)**

| Factory Automation | Automobiles/ Aircraft | Computer Peripherals | Power Supply and Power Regulating ICs |
|---|---|---|---|
| Power ICs | Power-Drive ICs | Power-Drive ICs | |
| $20 | $150 | $220 | $400 |

Source: Integrated Power
May 1986

## MARKET SUMMARY

The previous section outlined the rapid development of the high-power IC market, a specific part of the total smartpower market. Figures C1 and C2 graphically outline the growth of the three primary segments of the smartpower market. In Figure C1, from 1986 to 1990, the total smartpower market is expected to grow from $1.2 billion to $2.45 billion, a compounded annual growth rate of 17 percent. However, the high-power IC market, which is Integrated Power's primary market, is expected to grow from $500 million in 1986 to $1.2 billion by 1990, which represents a 25 percent compounded annual growth.

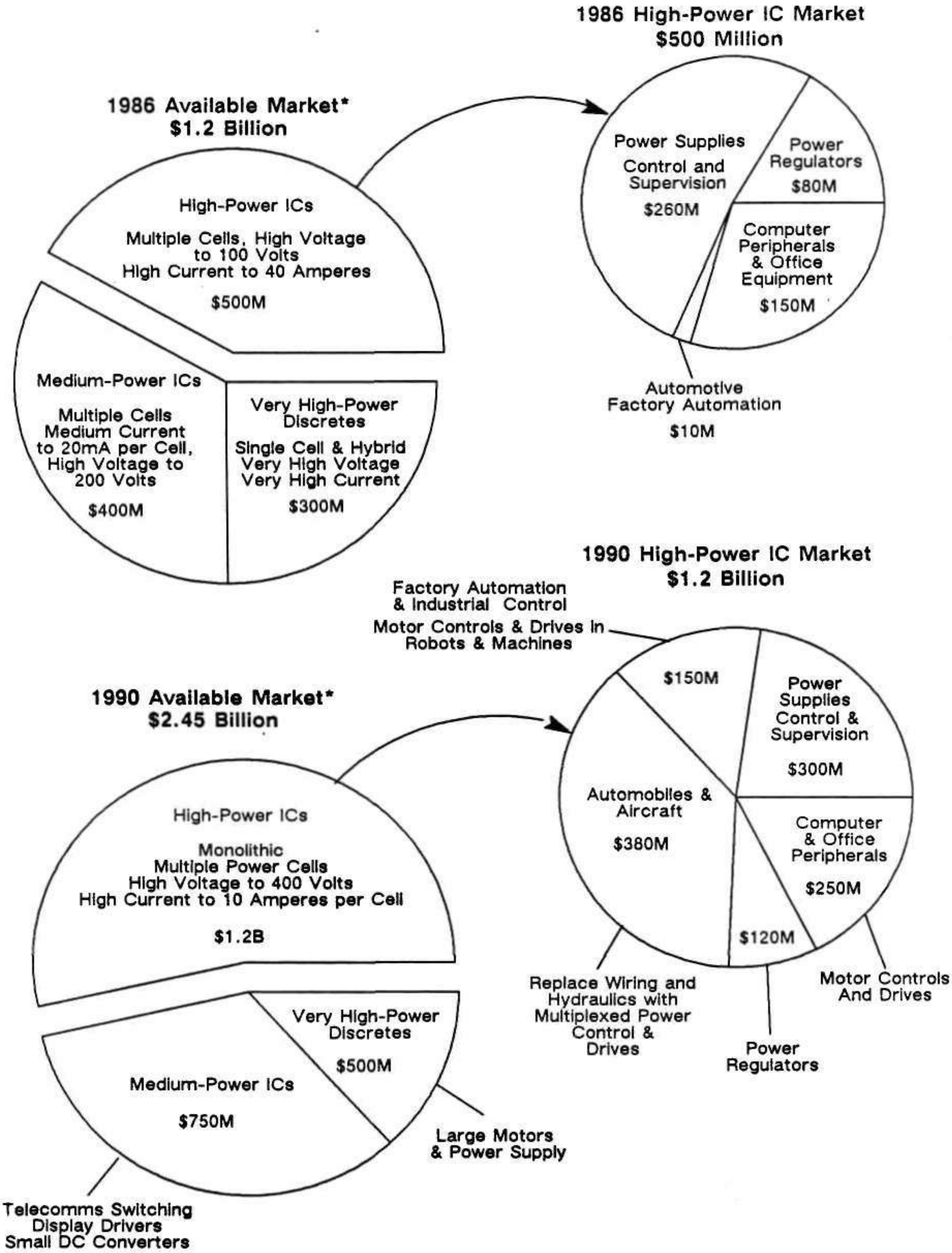
The breakdown of the primary high-power IC applications is highlighted in Table 4. In 1986 the market consists of five major groups: power supplies, computer peripherals, power regulators, automobile and aircraft, and factory automation equipments. In 1986, power supply ICs represent more than 50 percent of the high-power IC market.

By 1990, the market will remain basically the same: power supplies, computer peripherals, power regulators, automobile and aircraft, and factory automation equipment. However, by 1990 the primary market will shift to automobiles and aircraft, which will comprise roughly 44 percent of the high-power IC market. This dramatic shift is due to the fact that each of the 30 million cars, trucks, buses, and other vehicles made each year ultimately needs between $25 and $100 of smartpower devices for dashboard functions, engine, fuel, and steering controls, and the "extras" of mirror, seat, window, door lock, air, and other controls. Lack of supply is the limit to shipments into this market.

Markets for high-power ICs will become very large by 1995 (see Figure C2). The markets are expected to be divided into seven major categories: power supplies and regulators; automobiles and aircraft; factory automation and industrial control; computer peripherals; consumer appliances; lighting; and television deflection circuits. The automobile and aircraft market will remain the largest single user of smartpower devices, controlling more than 40 percent of the market.

Figure C1

1986 AND 1990 SMARTPOWER MARKET

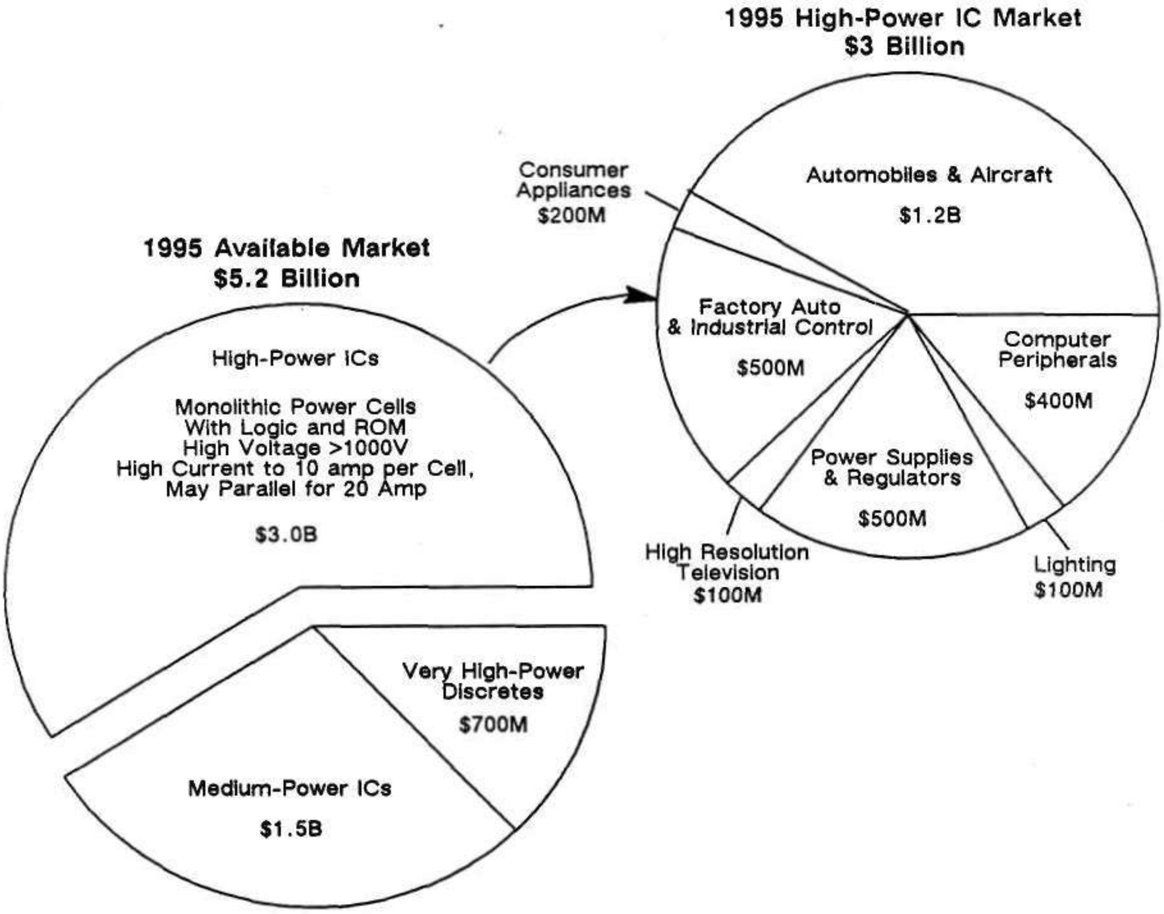



*Some "Available Market" is not/will not be served due to limited suppliers.

Source: Integrated Power

Figure C2

1995 SMARTPOWER MARKET




Notes to Figures C1 and C2:

1. Automotive High-Power ICs assumed to be captive manufacturers.
2. Computer Peripherals will become single-chip equipments (Example: Optical and Magnetic disk drives will have power and logic on one chip—technology now being developed at Integrated Power).
3. Consumer applications will be new markets starting to develop—technology to lower costs now being developed at Integrated Power. However, no speculation at this time on the profit margins of this business or Japanese involvement.
4. Factory Automation, Robotics, Industrial Controls will continue to need specialized custom/semicustom power ICs with on-board logic and ROM abilities; target markets for Integrated Power.
5. All *market* numbers represent what could be done if sources of supply existed to serve the market; i.e., the numbers are positions or "slots" available.

The technology exists, or will exist, easily for the applications. The limitation is/will be resources of the suppliers to develop and produce the products.

Source: Integrated Power

SUMMARY OF HIGH-POWER IC TREND

The following is a list of the major trends that are expected to occur as a result of high-power smartpower ICs. The high-power IC technology will:

- Replace the older, expensive, inefficient, power discrete circuit boards in computer peripherals and office equipment with efficient modern ICs at low cost. As an example, the disk drive will have a single chip for its electronics.

- Replace the heavy wiring harnesses in automobiles and aircraft with lightweight, small, multiplexed, coded control systems at low cost.

- Replace the bulky hydraulic systems in robotics, aircraft, and factory automation equipment with simpler electronic control-and-drive systems at low cost.

- Replace slow, unreliable electromechanical components in industrial and process control equipment with fast reliable electronics at low cost.

- Change the shape, cost, and reliability of actuator equipment throughout the 1990s by the placement of ROM capacity (memory), along with algorithm control (simple computer functions), on the same chip as high-voltage (1,000 volts), high-current (10 amperes) power cells.

- Move high-power ICs into household appliances, lighting controls, and consumer entertainment equipment. (By 1990 costs will be reduced so that this move into consumer products is feasible.)

## COMPETITION

Brief summaries of the major competitors in the high-power smartpower market follow. These summaries provide an overview of the company, its principal products, and a financial brief.

### SGS-ATES

SGS is an Italian-based semiconductor manufacturer with sales of approximately $300 million. The company has a long history of serving consumer applications, primarily with discrete transistor and linear IC products. Their military sales are very small. SGS has long been the prime supplier of Olivetti, the large Italian office products company which is part owner of SGS. (The other owner of SGS is the state organization STET.)

SGS has excellent high-power IC technology except that it is somewhat limited in power packaging. In spite of this capability, SGS has introduced only a few power IC products in recent years, and each of those products was generated for Olivetti and thereafter released as standard to the rest of the market.

It is a well-documented fact that SGS has diverted most of its resources to CMOS digital technology to gain a foothold in the larger digital IC market. SGS's new CMOS facility in Phoenix, Arizona, was put on hold in 1985, but it may be completed in 1987.

Fiat and other automotive/consumer applications with high volumes of standard products will find SGS a willing supplier of good power ICs.

### Principal Products

Consumer ICs, both linear and digital (radio, television, automotive, and appliance), and consumer discretes. Digital computer ICs, many from technology exchanges with Toshiba and AT&T. SGS is relatively unknown in the power supply field, with only one PWM device. It is well known in the peripherals motor-drive business, with three or four devices (Darlington arrays, dual H bridge drives) as standard products.

## Financial Brief

| | Millions of Dollars | | | |
|---|---|---|---|---|
| | 1984 | 1985 | 1986E | 1987E |
| Total Sales | $335 | $300 | - | - |
| Estimated Power IC Sales (Including captive to Olivetti) | $ 15 | $ 15 | $ 20 | $ 35 |

## UNITRODE

A power discrete company with a small, but growing, five-year IC group making power supply control chips. With IC sales estimated at $12 million for 1986, Unitrode is leading in new control ICs for power supplies. It has a limited product exchange agreement with SGS, which may provide Unitrode with sales of SGS motor-drive ICs. Unitrode's IC group is limited to SGS or other open-tool power package sources, but their emphasis on power supply control chips at relatively low power mitigates their need for power packing.

## Principal Products

Power diodes, transistors, Darlington arrays, hybrids, power supplies, power supply ICs, and voltage regulators.

## Financial Brief

| | Millions of Dollars | | | |
|---|---|---|---|---|
| | 1984 | 1985 | 1986E | 1987E |
| Total Sales | $106 | $104 | - | - |
| Estimated Power IC Sales | $ 6 | $ 8 | $ 12 | $ 15 |

## SPRAGUE SEMICONDUCTORS

Long a manufacturer of linear ICs, Sprague makes perhaps the broadest line of transistor and Darlington arrays available. Many of the Sprague products are second-source products which they manufacture at low-cost in high-volume. Consumer ICs have been a major thrust of the company when it has been able to take advantage of volume production capabilities. Sprague is not, however, known in the industry for its innovative product leadership, nor does it pursue military and custom business where a great amount of customer interaction and service is required. It is hard to see a market strategy in Sprague's product groups, and Sprague does not respond to custom or semicustom requests.

## Principal Products

Consumer ICs, both linear and digital, with high-voltage and/or high-power content.

## Financial Brief

| | Millions of Dollars | | | |
|---|---|---|---|---|
| | 1984 | 1985 | 1986E | 1987E |
| Total Sales | - | - | - | - |
| Estimated Power IC Sales | $ 10 | $ 10 | $ 15 | $ 18 |

## SILICON GENERAL

Silicon General is a small company with two divisions, only one of which produces ICs, mainly power supply ICs and voltage regulators for the military market. The company's thrust has been standard products, with limited resources applied to new products or power packaging. Upper management turnover has been substantial and has led to some turnover at lower levels.

## Principal Products

Power supply control ICs and voltage regulators. Some older analog ICs and Darlington arrays.

Financial Brief

| | Millions of Dollars | | | |
|---|---|---|---|---|
| | 1984 | 1985 | 1986E | 1987E |
| Total Sales | $47 | $46 | $33 | $46.5 |
| Estimated Power IC Sales | $20 | $15 | $15 | $ 15 |

## JAPANESE

The Japanese are well behind in power IC developments for even their own equipment. (For example, all Epson printers still use discretes.) The market recession in digital ICs may provide them with an incentive to consider such development. While Japan's huge semiconductor resources are mainly in digital CMOS technology, good linear and power expertise exists within Toshiba, Hitachi, and others. Their own equipment needs will eventually force them to develop a technology base. The Japanese must be considered major competitors in the future, but not market killers. (For example, high-power discrete applications have never been overrun by the Japanese, nor has the power supply market.)

Hitachi has introduced one DC brushless motor-drive IC for disk-drive spindle motor applications. This product's performance and reliability are limited (it operates at a very high temperature), but it does indicate a willingness to supply externally those ICs made for in-house use.

No Japanese company has responded to users' requests for custom or semicustom ICs.

## VERY HIGH-POWER DISCRETE COMPONENTS

The manufacturers of very high-power discrete components include well-established companies such as Texas Instruments, General Electric/RCA, International Rectifier, Siemens, Motorola, and a start-up named Ixys. The majority of these companies are large, established manufacturers that have large commitments to digital ICs in factory, engineering, and management. They are financed mainly by their continuing business in older discrete power devices. Even Motorola, which has a very large business in power discretes, has not made commitments to power ICs. Instead, it has traded products with small linear IC manufacturers to complement much of its product portfolio gap (Cherry Semiconductors, Integrated Power, and Silicon General).

To maximize market penetration using discrete devices, these companies often package multiple chips in hybrid packages (General Electric's smartpower devices, for example). This packaging has proven to be too costly for much of the market, however.

These companies are likely to lead the very high-power discrete segment of smartpower because they are entrenched in this field, but these same companies will find it difficult to obtain the people, the plants, and the management mindset required for complex high-power monolithic ICs.

# MARKETING AND SALES

## SALES STRATEGY

Because Integrated Power is responsive to market and customer needs and directions, its sales strategy is to concentrate on key accounts. Eventually, more than 60 percent of the its business will be from key customers for custom and semicustom products.

Integrated Power does not intend to be a standard parts supplier for multisourced products. Its customers are in the military, industrial, and professional equipment markets, and its management group, sales staff, and engineering organization are all experienced in key account strategies with proven performance in this higher-than-average margin segment of the semiconductor market.

Its ability to provide custom products is essential to the company's strategy. Its development of application-specific or semicustom technology, now so profitable for the digital IC world, will be a first in the power IC field.

Integrated Power's application engineering staff, coupled with its design engineers, its sales force, and its key account management, makes a formidable team for any given customer's project. A four-man team with one person from each group for each key account overwhelms the competition, which usually relies on a single sales person.

## GEOGRAPHIC STRATEGY

To gain entrance quickly into a wide geographic area, Integrated Power has installed seven offices with experienced direct sales managers. To serve customers' needs, these sales offices are augmented by manufacturers' representatives in each territory. Distributors in each territory are also used to provide local sources of products, and the company has a separate distribution manager.

To date Integrated Power has sales offices as follows:

- United States
  - Santa Clara, California (Northwest, Rocky Mountains)
  - Irvine, California (Southwest)
  - North Andover, Massachusetts (Northeast)
  - Warwick, Rhode Island (Southeast and Special)

- Europe

  - Munich, West Germany (Central Europe)
  - Livingston, Scotland (Great Britain, Scandinavia)
  - Paris, France (Southern Europe)

## APPLICATIONS OF THE KEY ACCOUNT STRATEGY

Integrated Power's key account strategy is necessary for the equipment market the company has targeted. Through this strategy, Integrated Power will be able to work closely with customers, and it will have the advantage of being able to "design-in" smartpower ICs that prohibit or exclude competitors' products. The following are examples of Integrated Power's strategy applied to unusual situations.

### Printers

Printers compete with each other as to print quality, print speed, and cost, and the motor and print hammer controls alone differentiate these performance/cost specifications--exactly the business of Integrated Power. Each competing printer designer wants a unique specialized (i.e., custom) circuit to control performance, and for the first time such a custom circuit is available in IC form from Integrated Power.

At present, Integrated Power is working on several separate requests from major printer equipment manufacturers to provide prototype control and motor-drive ICs. Many of these designs have been completed and the ICs are being demonstrated.

### Disk Drives

Winchester disk drives burn up much of their input power in inefficient spindle motor drives that currently use discrete components. How much of the input power is burned up is a major competitive point among disk drives. Integrated Power is developing a proprietary electronic drive IC technology that reduces the heat by 50 percent and thus reduces the customer costs in power dissipative components. Such a capability has not been available to disk-drive manufacturers in the past.

Integrated Power has demonstrated new circuit techniques and has established timetables with major disk-drive manufacturers to review cost benefits and performance enhancement. These reviews have led to purchase orders.

Such heat-saving and cost-saving motor techniques will have immediate benefits for other motor-drive applications as well.

## Large AC Motor Controls

Integrated Power has learned that its technology and product capabilities are ideal for the large AC motor controls used in industrial equipment markets. Discussions with prospective customers, ranging from manufacturers of whitegoods to manufacturers of process equipment controls, are leading to inquiries for the company's PWM control circuit capabilities coupled with power IC amplifiers for single-phase and three-phase solid-state drives (GTO's, thyristors, transistors, power MOSFETS, and other discretes).

It appears that the programmable controllers used in factory automation can be considerably enhanced in both performance and reliability using Integrated Power's high-voltage, high-power ICs. Computer and sensor inputs can be processed into power drives for motors, relays, lamps, and switches at a much lower cost with smartpower IC technology.

## Automobile and Aircraft Controls

Initial discussions with automotive electronics manufacturers indicate that Integrated Power's capabilities are ideal for motor, lamp, and power drives that are controlled by multiplexing functions throughout automotive electronic systems. This high-power IC capability extends to aircraft controls where the replacement of wire harnesses and hydraulics is the key to future aircraft control systems.

## Power Supplies

Power supply manufacturers have long suffered from the inability to place the control of their switchmode regulation circuitry at the output of the supply where the control really should be. This problem has been caused because IC manufacturers cannot provide control ICs that can operate on transformer secondaries with isolated feedback to the primary side.

Integrated Power has test-marketed in the power supply industry a circuit that has led to the development of a pair of ICs which provides the desired secondary control and supervisory functions for today's modern switching power supplies.

Additionally, Integrated Power is proposing even more advanced control techniques, such as current-mode control and synchronous rectification, to selected power supply customers. These advanced techniques will provide benefits in performance not yet available to power supply designers.

## Voltage Regulators

Electronic equipment manufacturers of high-voltage/current regulators have recently required 3-, 5- and 10-ampere voltage regulators. Such regulators have been generated by one or two suppliers; however, only old-style technologies and packages are being used for these regulators, and excessive heat generation is still a problem.

At the urging of a major blue-chip computer manufacturer that has a close relationship with many employees of Integrated Power, the company is generating a whole series of voltage regulators that reduces the heat generated by 40 percent. In addition, they are housed in better and lower cost packaging. The customer realizes performance benefits, for which the customer pays a premium of 40 percent to 50 percent, but the actual costs to Integrated Power are even less than they have been in the past.

Several power supply manufacturers are also interested in these new voltage regulators.

## SALES PROJECTIONS

The sales strategy described previously is expected to produce the level of sales shown in Tables 11 and 12 for 1987 and the next five years. Table 11 shows actual and projected shipments and projected orders for each month to meet the goal for fiscal 1987. This expansion assumes adequate capital equipment and labor.

## Table 11

### INTEGRATED POWER'S 1987 PROJECTED SALES PLAN
### (Thousands of Dollars)

(Fiscal Year Ends March 31)

| March 31, 1987 | Jan | Feb | Mar | Apr | May | Jun | 1Q | 2Q | 3Q | 4Q |
|---|---|---|---|---|---|---|---|---|---|---|
| Actual Shipments | $135 | $140 | $250 | $170 | $190 | | | | | |
| Projected Shipments | | | | | | $240 | $ 600 | $1,000 | $2,100 | $4,300 |
| Actual Incoming Orders | | | $ 90 | $306 | $605 | | | | | |
| Projected Incoming Orders (Backlog) | | | | | | $600 | $1,406 | $1,800 | $3,000 | $5,000 |
| Build Added Inventory | ---------------$3M--------------- | | | | | | | --------$1M--------- | | |

## Table 12

### INTEGRATED POWER'S PROJECTED FIVE-YEAR SALES PLAN
### (Millions of Dollars)

(Fiscal Year Ends March 31)

| | 1986 | 1987E | 1988E | 1989E | 1990E | 1991E |
|---|---|---|---|---|---|---|
| Net Sales | $1 | $8 | $20 | $40 | $60 | $80 |

Manufacturing Capacity

In Place for Shipments

- $100 Building
- $ 30 Equipment
- $ 30 Professional Staff

Two Years to
Add People and Equipment
for $40 to $60 Capacity

Assumptions for the $8M shipment plans are:

- Only modest growth in the semiconductor market during 1986.
- All products for shipment are in production by August, before the year's midpoint.
- Only custom orders now on the books with customer equipment are included.
- The year's average selling price (ASP) is $1.75. (The present backlog has an ASP of $2.05.)
- The shipment of military products to commence in June and rise to $200K per month at year's end at an ASP of more than $5.00. (The present military backlog is $300K at an ASP of $6.05.)
- $3 million shippable product in inventory, prepared in anticipation of the year's steep shipment growth. Another $1 million in inventory prior to the third quarter.

## Sales Forecast for 1988

A review of the annual shipments forecast for the third and fourth quarters of fiscal 1987 shows that the fiscal 1988 goal of $20M is conservative; i.e., fourth quarter shipments of $4300M, extended to a full year, would equal more than $17 million. Therefore, it is quite possible for Integrated Power to reach its goal of $20M in sales and turn profitable early in fiscal 1988.

Furthermore, extra capacity will be available to increase fiscal 1988 shipments if orders are received for new products for prospective markets, such as automotive and factory automation, or if existing product demand exceeds expectations.

## OPERATIONS AND MANUFACTURING

### BUILDING

Integrated Power's manufacturing facility and its present headquarters are located in Livingston, Scotland because:

- The government of Great Britain provided the company with its new facility ($9 million).

- The government of Great Britain provided $8 million in capital and R&D grants.

- Integrated Power wanted to pursue the European as well as the American market.

- There was (and is) a large indigenous semiconductor and American community in Scotland.

- High employee turnover rates and the business tax climate in California's Silicon Valley posed potential problems.

- Key American management, engineers, and scientists were willing to relocate to Scotland.

- Integrated Power's growth will require and finance new headquarters and manufacturing facilities in the United States.

The company's facility is comprised of 45,000 square feet of ultramodern class 10/100.

The manufacturing area includes complete testing, military assembly, quality assurance, burn-in, cage, and dock facilities.

### MANUFACTURING RATES

The wafer fab is equipped to handle 5,000 4-inch wafer starts per month, with floor space available inside the clean room to double that by adding more equipment.

The test facility can presently handle 400,000 per month of the various mixes of package styles used. Floor space is available to double the equipment, and additional shifts could greatly increase the present capability.

The assembly of most of Integrated Power's products is accomplished through offshore subcontractors so that the company can take advantage of low labor costs and existing management and equipment. However, full quality testing and inspection are carried out by the company at its own facility.

The total cost of the equipment used within the company is $10 million. It is expected that continued growth will require approximately $3 million per year for additional equipment until a new facility is constructed in the United States.

The company anticipates that economies of assembly offshore may change sufficiently within two years to make consideration of in-plant assembly feasible. In-plant assembly may become necessary if demand rises rapidly for the special packaging capabilities the company is currently developing. Package tooling and handling would then become a competitive asset and would be better protected at an in-house assembly facility than at a subcontractor's location. The cost for such in-house assembly has not yet been analyzed.

## GROSS MARGINS

Some simpler ICs in the company's product line are more competitive with lower manufacturing gross margins than the company's target (50 percent). However, because these products are well known, high yield, and are relatively high volume, less overhead in engineering and sales is applied (below-the-line costs) so that bottom-line profits for all product lines are about the same.

## RESEARCH, DEVELOPMENT, AND ENGINEERING

### SHORT-TERM TECHNOLOGY

Integrated Power's research has led to conclusions for its short-term technology base that have been confirmed by the users' equipment market. Like many user engineers and technical managers, Integrated Power originally assumed that MOS structures may be the best alternative for much of the power switching in its product field. The company has determined, however, that where more than one power switching element is required per monolothic chip (90 percent of the applications that the company serves), MOS structures require at least 30 percent more area on a silicon chip than do power-equivalent bipolar structures. Thus, at currents of one-half ampere or more, MOS multiple power element ICs are prohibitively expensive. At currents less than one-half ampere, where the power elements are much smaller, the extra cost for a power MOS being larger can be overcome by shrinking other chip orders, such as logic circuitry, by using compatible CMOS.

Hence, where Integrated Power's market is predominantly motor controls, motor drives, power supplies, solenoid drives, and relay drives, all of which require the control of currents of one-half ampere or more through multiple power elements on one chip, bipolar technology is the only sensible IC technology at the present time. The company's real strength comes from exploiting its design talent for innovative and unique bipolar circuitry. (Remember that Integrated Power has more proven power IC design engineers on its staff than any other semiconductor company.)

These distinctions in the power field help explain that for the near term:

- Only bipolar technology can be used at present for cost effective ICs in motor-drive applications.
- Only bipolar technology is presently used for cost effective ICs in power supply control applications.
- MOS is used in such applications only in power hybrid and power discrete circuits where a single, discrete MOS power chip is manufactured separately from its adjacent power elements. Of course, Integrated Power's business is to replace these expensive discrete and hybrid circuits with its lower cost monolithic ICs.
- Power IC packaging is critical for effective use of power IC chips, and Integrated Power has such packaging available.

- Integrated Power has now combined its broad array of power packages and bipolar processes to produce cost-effective, high-performance, high-quality, 20-volt, 60-volt, and 80-volt bipolar power ICs.

Integrated Power has high-level expertise in design and process services where up to 10 amperes per cell, with control logic, are possible.

A 110-volt process that already has customer interest for certain applications will soon be on-line.

LONG-TERM TECHNOLOGY

Integrated Power believes it must pursue four areas of technology development for its markets:

- MOS power structures (CMOS logic and "merged technology," CMOS and bipolar combinations) processes will be needed for certain applications, especially at 400 volts and more.
- Higher-voltage processes will be needed. 400 volts is a key level for off-line use at 115 volts AC; 1,000 volts is a level allowing off-line use at 220 volts AC.
- Semicustom IC design techniques, similar in concept to today's digital gate array and standard cell techniques, will be needed for rapid turnaround and lower volume.
- Cost-effective, high-power, high heat-dissipating packages will be needed for power IC chips at high pin-count.

Integrated Power's R&D group has dedicated projects underway in each of these four areas. The company already has more power package choices available than any other company, and it is working to increase its flexibility of application, to create power surface-mount packaging (none exists today), and to maintain cost control with such products. Innovation in materials, tooling, and assembly concepts plays a key role.

The company is now designing proprietary products with metal mask configurability to allow customers for certain applications to configure specific characteristics of the IC to their specific needs. The company's R&D group is beginning to develop a functional cell library that will be used in the future with CAD equipment for semicustom circuit design. The company believes it is alone in developing such techniques for monolithic power ICs.

Similarly, Integrated Power's R&D group is now developing MOS power structures for those applications where the characteristics of MOS power switching are required. It is also studying merged MOS and bipolar technologies for its own applications.

These technologies can be pulled together by the company's design engineers and custom IC users to provide cost-effective (i.e., affordable) power IC products that will greatly increase equipment performance and reliability and reduce size requirements. Such products will:

- Control and drive motors at 30 percent to 50 percent more efficiency
- Reduce motor sizes and costs
- Allow certain industrial equipment and whitegoods manufacturers to replace AC motors with brushless DC motors for better control
- Replace discrete power transistors and Darlington arrays with power ICs at much reduced costs
- Allow switching power supplies to increase switching frequency at reduced costs
- Allow much higher currents and power out of ICs
- Provide "low drop-out" voltage regulators at much higher efficiencies and current outputs
- Shrink the size and weight of much equipment
- Control high-power industrial three-phase AC motors
- Improve the reliability of whole ranges of equipment
- Make possible certain functions that heretofore have not been affordable in robotics (precision movements), automobiles (multiplexing of controls to reduce wiring), lighting (increase fluorescent efficiencies by 30 percent), and other industries.

## PRODUCT CHARACTERISTICS

The technology thrusts we have just mentioned are being used to define, with users, innovative products to be used by a forward looking marketplace. The following figures show the company's existing power supply control and power-drive ICs (Tables 13 and 14, respectively). Various packaging alternatives are shown in Figure D.

INTEGRATED POWER SEMICONDUCTORS, LTD.

# Switching Power Supply Circuit Selection Guide

## PWM Circuits

| Part Number | Outputs | Output Type | Reference Precision | Output Transistor rating | Under Volyage lockout | soft start | Double Pulse Suppression | Current Limit CM Range | Dead Time Adjust | Error Amp CM Range | Sutdown |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IP494A | 2 | Uncommitted | 1% | 40V/200mA | Yes | Ext. | N/A | N/A | No | 0 to $V_{CC}$ - 2 | No |
| IP1524 | 2 | Uncommitted | 1% | 40V/50mA | No | Ext. | No | -1 to 1V | No | 1.8 to 3.4 | Yes |
| IP1524B | 2 | Uncommitted | 1% | 60V/200mA | Yes | Ext. | Yes | 0 to $V_{CC}$ -2 | No | 2.3 to 5.2 | Yes, Dig. |
| IP1525A | 2 | Totem Pole | 1% | 35V/100mA | Yes | Yes | Yes | N/A | Yes | 1.8 to $V_{CC}$ -2 | Yes Dig. |
| IP1527A | 2 | Totem Pole | 1% | 35V/100mA | Yes | Yes | Yes | N/A | Yes | 1.8 to $V_{CC}$ -2 | Yes, Dig. |
| IP1526 | 2 | Totem Pole | 1% | 35V/100mA | Yes | Yes | Yes | 0 to $V_{CC}$ -3 | Yes | 0 to $V_{CC}$ -2 | Yes, Dig. |
| IP1526A | 2 | Totem Pole | 1% | 35V/100mA | Yes | Yes | Yes | 0 to $V_{CC}$ -2 | Yes | 0 to $V_{CC}$ -2 | Yes, Dig. |
| IP1842 | 1 | Totem Pole | 1% | 30V/200mA | Yes | Yes | N/A | 0 to 1V | Yes | N/A | N/A |
| IP1843 | 1 | Totem Pole | 1% | 30V/200mA | Yes | Yes | N/A | 0 to 1V | Yes | N/A | N/A |
| IP5560/1060 | 1 | Uncommitted | 1% | 18V/40mA | Yes | Ext. | N/A | N/A | Yes | N/A | Yes |
| IP5561 | 1 | Open Collector | 1% | 18V/40mA | Yes | Ext. | N/A | N/A | Yes | N/A | Yes |
| IP35060A | 1 | Uncommitted | 1% | 40V/200mA | Yes | Ext. | N/A | N/A | No | 0 to $V_{CC}$ -2 | No |
| IP35063 | 1 | Uncommitted | 5% | 40V/1.5A | N/A | Ext. | N/A | N/A | No | N/A | No |

## Supply Monitor Circuits

| Part Number | Function | Fault Condition | Voltages Monitored | Reference Accuracy |
|---|---|---|---|---|
| 1543 | Voltage Sense | OV/UV/CL | 2.5 - 40V | 1% |
| 1544 | Voltage Sense | OV/UV/CL | 0 - 40V | 1% |

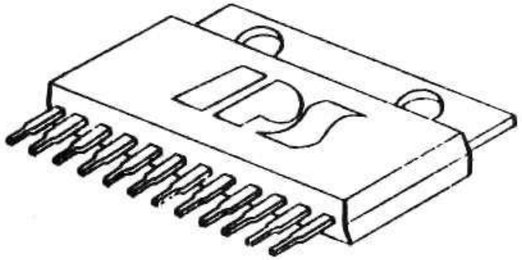
**POWER**
**SEMICONDUCTORS, LTD.**

# Motor Driver Selection Guide

| Function | Part Number | Volts | Amps | Logic | Chop Mode | Internal Clamp Diodes | Current Feedback Sense Resistor | Split Supply | Package |
|---|---|---|---|---|---|---|---|---|---|
| H Bridge | IP3D10* | 80 | 4.0 | Yes | | Yes | External | | SOT 93 (TO218) 7 Pins |
| Dual Bridge | IP293 | 36 | 1.0 | Yes | | | | | Pwr 16 Pin DIP |
| | IP293D | 36 | .6 | Yes | | Yes | | | Pwr 16 Pin DIP |
| | IP293DA | 36 | 1.0 | Yes | | Yes | | | Pwr 16 Pin DIP |
| | IP293E/ED | 36 | 1.0 | Yes | | | External | | Pwr 20 Pin DIP |
| | IP293C/CD | 36 | 1.0 | Yes | | Yes | | | Pwr 20 Pin DIP |
| Quad Darlington Driver | IP2064,66 | 50 | 1.5 | | | Yes | | | Pwr 16 Pin DIP |
| | IP2065,67* | 80 | 1.5 | | | Yes | | | Pwr 16 Pin DIP |
| | IP2068,70 | 50 | 1.5 | | | Yes | | | Pwr 16 Pin DIP |
| | IP2069,71* | 80 | 1.5 | | | Yes | | | Pwr 16 Pin DIP |
| | IP2074,76 | 50 | 1.5 | | | No | | Yes | Pwr 16 Pin DIP |
| | IP2075,77* | 80 | 1.5 | | | No | | Yes | Pwr 16 Pin DIP |
| Octal Darlington Driver | IP2801-05 | 50 | 0.5 | | | Yes | | | Pwr 18 Pin DIP |
| | IP2811-15 | 50 | 0.6 | | | Yes | | | Pwr 18 Pin DIP |
| | IP2821-25* | 95 | 0.5 | | | Yes | | | Pwr 18 Pin DIP |
| Seven Segment Darlington Driver | IP2001-05 | 50 | 0.5 | | | Yes | | | Pwr 16 Pin DIP |
| | IP2011-15 | 50 | 0.6 | | | Yes | | | Pwr 16 Pin DIP |
| | IP2021-25* | 95 | 0.5 | | | Yes | | | Pwr 16 Pin DIP |
| Stepper Motor Control/Driver | IP3717 | 40 | 0.8 | Yes | Yes | Yes | External | | Pwr 16 Pin DIP |
| | IP3717A* | 40 | 0.8 (Lowersat) | Yes | Yes | Yes | External | | Pwr 16 Pin DIP |
| | IP3770* | 40 | 1.2 (Lowersat) | Yes | Yes | | External | | Pwr 16 Pin DIP |
| Three-Phase Brushless DC Motor Controller/ Driver | IP3M05* | 15 | 2.5 | Yes | | Yes | Internal | | Power SIP |
| | IP3M06* | 15 | 1.5 | Yes | | Yes | Internal | | Power SIP |
| | IP3M13* | 15 | 4.0 | Yes | | Yes | Internal | | Power SIP |

*New Products to be announced

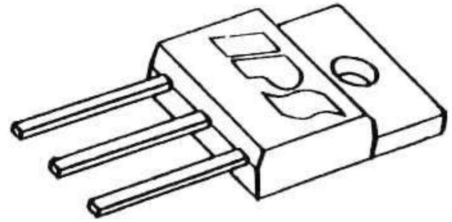
## PACKAGE DEVELOPMENT



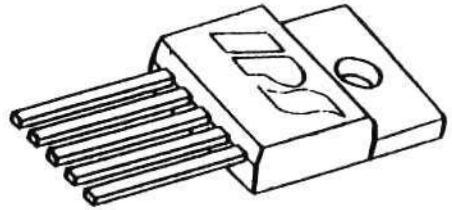
12 PIN SIP

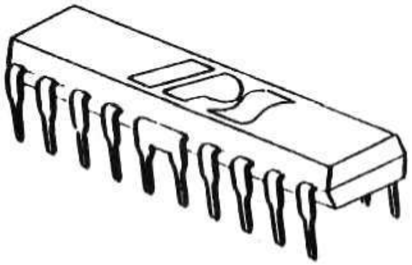
TO218

- 3 PIN



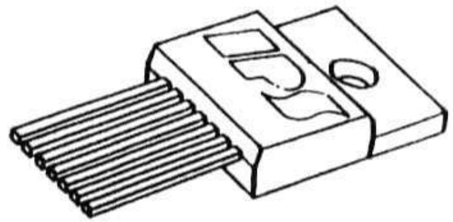
- 5 PIN

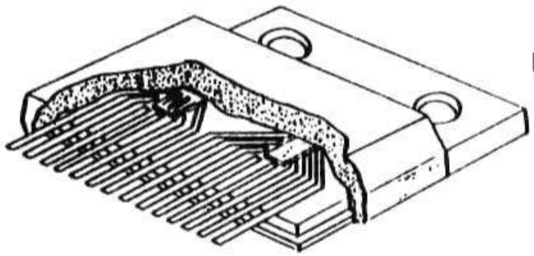




20 PIN BATWING

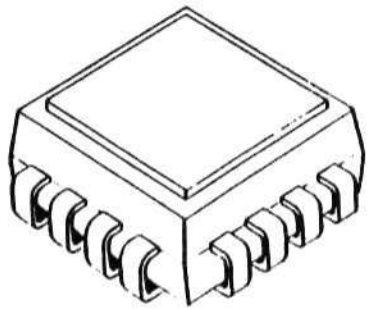
- 7 PIN





MODULAR SIP

CHIP CARRIER



# MANAGEMENT AND PERSONNEL

## DIRECTORS AND EXECUTIVE OFFICERS

Table 15 lists the key executive officers and directors of Integrated Power. Twelve Californians experienced in power semiconductors reside in Scotland and fill key management and engineering posts. Their experience is augmented by board members who represent major European venture capital companies and a chairman who has an extensive background with Allen Bradley, known for its factory automation, robotics, and programmable controller expertise.

Table 15

OFFICERS AND DIRECTORS

| Name | Present Position |
|---|---|
| David Wood | Managing Director, CEO, and Director |
| Robert Genesi | Director of Operations and Director |
| Tony Lear | Director of R&D and Director |
| Thomas Valentine | Controller |
| Jack Armstrong | Chairman of the Board |
| John Wesley | Director, 3I Ventures |
| Alan Henderson | Director, Newmarket Ventures |
| Peter English | Director, Fleming Ventures |

Source: Integrated Power

## BACKGROUND OF KEY EMPLOYEES

David Wood: Managing Director & CEO. Age 42. Served as Director of Engineering for TRW's semiconductor division, which specialized in power semiconductors. Mr. Wood became Director of R&D and then Division Plant Manager at TRW before joining Silicon General Inc. in 1979 to establish a linear IC operation in Europe. Thus Mr. Wood has an intimate knowledge of the European market for power ICs as well as of the U.S. market. In 1983 Mr. Wood left Silicon General to start Integrated Power. Mr. Wood holds a BSEE from Oregon State University.

Robert Genesi: Director of Operations. Age 47. Served as Manager of IC Design at Sprague Semiconductors where he formed Sprague's Custom Linear IC Division, which grew to $10 million in 5 years. In 1979, Mr. Genesi became president of Silicon General's Semiconductor Division and remained in that position until joining Integrated Power in 1984. Mr. Genesi holds a BSEE from the University of Massachusetts.

Tony Lear: R&D Manager. Age 39. Served for 16-1/2 years with Texas Instruments Ltd., Bedford, England, in a number of key engineering, design and R&D roles that resulted in his being European Power R&D and Market Development Manager. During this period, Mr. Lear established Bedford as the worldwide center for the corporation's R&D and process technology in power semiconductors. Mr. Lear, who holds several patents in the power semiconductor area, joined Integrated Power in 1984. Mr. Lear holds a Bachelor of Science in physics from the University of Leeds.

Herb Scott: Director of U.S. Sales and Marketing. Age 41. Served for 15 years in OEM sales at Texas Instruments, becoming Western Manager of OEM Sales. Mr. Scott left TI to become National Sales Manager for Silicon General. In 1986 he joined Integrated Power. Mr. Scott holds a Bachelor of Science in mathematics from the University of Indiana and an MBA from the University of Southern California.

Thomas Valentine: Controller. Age 43. Served for the last 10 years as Finance Director (Europe) for Beckman Industrial Components. In this position Mr. Valentine was responsible for the Scottish factory with 500 employees and the European subsidiaries in Belgium, France, Italy, and Germany. He was involved in the transition of the manufacturing from trimming potentiometers and turns-counting dials over to dual and single in-line resistor networks. During this time he also had the responsibility for all European financial corporate matters. Mr. Valentine holds a Bachelor of Arts from Strathclyde University.

Norm Matzen: Applications Manager. Age 46. First developed power supply ICs at Signetics Corporation. After developing the industry standard NE 5560 (and its European counterpart, the TDA 1060), Mr. Matzen joined Astec Power Supply Company to build that company's IC design organization. From Astec, he helped to found Integrated Power and leads its power supply IC thrust. Mr. Matzen holds a BSEE from the University of Santa Clara.

Eric Joseph: Engineering Manager. Age 29. Served as Product Design Manager for power ICs at Motorola Semiconductors where he led the company's efforts in developing voltage regulators, power supply ICs, and other power ICs. After developing a total of 22 new products, Mr. Joseph joined Integrated Power to head the design group for power-drive ICs. Mr. Joseph holds a BSEE from the University of New Mexico.

Jack Armstrong: Chairman of the Board. Age 49. Presently Managing Director, European Electronics Division for Allen Bradley Company. Previously was President of Harmon Europe, a large consumer electronics distributor. An American with 20 years electronics industrial experience.

John Wesley: Director. A member of Investors in Industry's venture capital group. Previous to his participation in the venture capital business, Mr. Wesley worked in the mechanical engineering field.

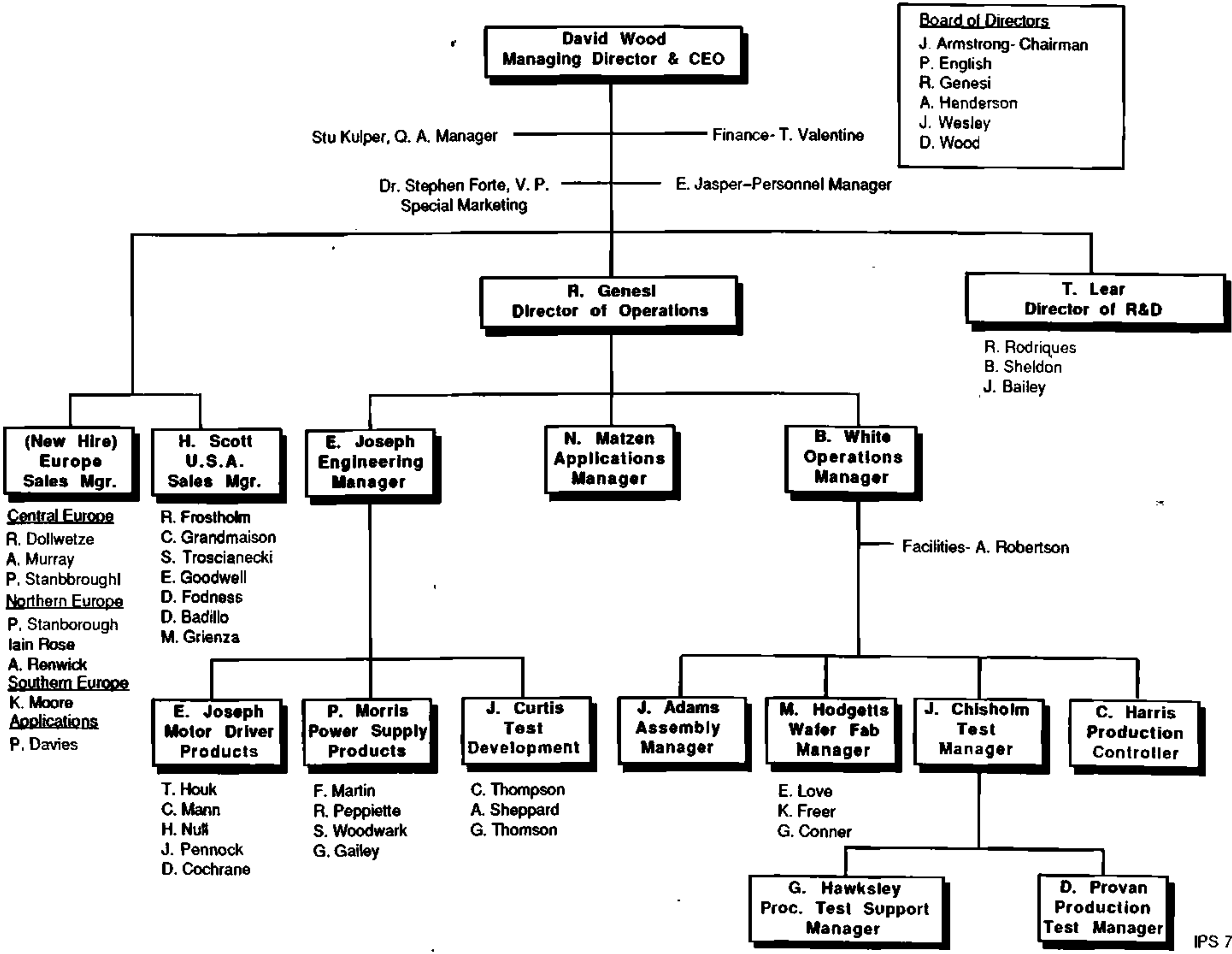
Alan Henderson: Director. Chairman of Newmarket Venture Capital Ltd. For a long period Mr. Henderson has been active in the London institutional and venture investment community as Chairman and President of Newmarket Company Ltd., Newcastle Company Ltd., and New Cambridge Research Company Ltd., all active in venture capital.

Peter English: Director. Mr. English is a partner in Venture Capital Funding, Ltd., venture advisors to the London-based investment bank Robert Fleming and Associates. Mr. English previously worked in the United States in the semiconductor and electronics industries.

Because Great Britain has a greater density of semiconductor manufacturers and research groups than any other European country, it was easy for Integrated Power to augment the American staff with local technical expertise and management skills of the highest caliber. Many of the local experts come from subsidiaries of other American manufacturers.

Integrated Power has separated its engineering design group from its R&D organization, a unique structure in a developing company (see the organization chart in Figure E). This separation was done purposefully from the beginning so that the focus on technology needs three to four years in the future could be assured in R&D, separate from the press of new product design in engineering. Integrated Power's management feels this is critical to technology leadership in smartpower.

# Figure E




IPS 7/86

**Integrated Power Semiconductors Ltd.**
**GROUP CASH FLOW PROJECTIONS**
**1987 Through 1990**
**(Thousands of Dollars)**

(Fiscal Year Ends March 31)

| | 1987 | 1988 | 1989 | 1990 | Total |
|---|---|---|---|---|---|
| Sales | $ 8,000 | $20,000 | $40,000 | $60,000 | |
| Cash Outflows | | | | | |
| Loss Outflows Tax | ($ 6,200) | - | - | | ($ 6,200) |
| Noncash Depreciation | $ 1,749 | - | - | - | $ 1,749 |
| Change in Working Capital Requirements | ($ 3,529) | ($ 3,163) | ($ 7,072) | ($ 6,878) | ($20,642) |
| Equipment | | | | | |
| Lease Payments and Deposits | ($ 2,243) | ($ 1,837) | ($ 1,837) | ($ 1,837) | ($ 7,754) |
| Capital Purchases | ($ 2,632) | ($ 2,340) | ($ 2,106) | ($ 1,680) | ($ 8,758) |
| | ($12,855) | ($ 7,340) | ($11,015) | ($10,395) | ($41,605) |
| Cash Inflows | | | | | |
| Profit before Tax | - | $ 4,000 | $ 8,400 | $12,000 | $24,400 |
| Noncash Depreciation | - | $ 2,072 | $ 2,300 | $ 2,900 | $ 7,272 |
| Grants - R.D.G. | $ 1,263 | $ 883 | $ 464 | $ 370 | $ 2,981 |
| Misp (R&D) | $ 718 | - | - | - | $ 718 |
| Round III Financing | $ 6,000 | - | - | - | $ 6,000 |
| Lease Finance | $ 1,400 | - | - | - | $ 1,400 |
| Lease Deposits Refunded | $ 790 | $ 749 | $ 749 | $ 749 | $ 3,057 |
| "Mezzanine" Financing | $ 3,000 | | | | $ 3,000 |
| | $13,171 | $ 7,705 | $11,913 | $16,019 | $48,808 |
| Net Cash Flow | ($ 1,316) | $ 365 | $ 898 | $ 5,624 | $ 7,203 |
| Balance B/fwd | $ 2,106 | $ 200 | $ 565 | $ 1,463 | $ 2,106 |
| Balance C/fwd | $ 2,422 | $ 3,107 | $ 8,605 | $ 9,309 | $ 9,309 |

INTEGRATED POWER SEMICONDUCTORS (HOLDINGS) LTD.

BALANCE SHEET AS OF May 31, 1986

(Unaudited)

| ASSETS | | LIABILITIES AND STOCKHOLDERS' EQUITY | |
|---|---|---|---|
| Current Assets | $ 4,108,414 | Current Liabilities | $ 3,642,973 |
| Cash and Deposits | $ 4,108,414 | | |
| Receivables | 3,286,320 | | |
| Inventory | 1,524,008 | Long-Term Liabilities | $ 4,605,732 |
| Total Current Assets | $ 8,464,302 | Total Liabilities | $ 8,248,745 |
| Fixed Assets | $ 6,605,091 | Stockholders' Equity | |
| | | Stock | $ 1,629,846 |
| | | Paid-in Capital | 15,323,464 |
| | | Retained Earnings | ( 9,527,316) |
| | | Total Stockholders' Equity | $ 7,425,994 |
| Total Assets | $15,674,739 | Total Liabilities & Stockholder Equity | $15,674,739 |

# APPENDIX

A. SELECTED PRODUCT SPECIFICATIONS

B. COMPANY BROCHURE

# INTEGRATED POWER SEMICONDUCTORS, LTD.

# IP1526A
# IP2526A
# IP3526A

## *Regulating Pulse Width Modulators*

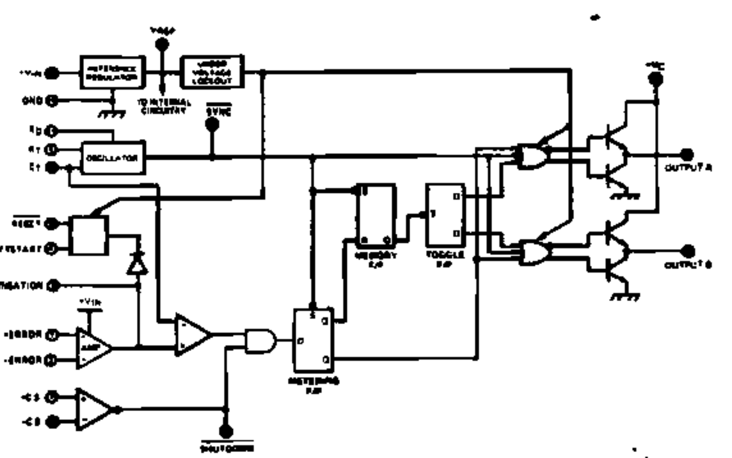
## Description

The IP1526A series of high performance pulse width modulator circuits is a direct replacement for the IP1526 series in all applications and features improved performance in several key areas (highlighted below). Functions included are a temperature compensated voltage reference, sawtooth oscillator, error amplifier, PWM comparator, pulse metering and steering logic, and two low impedance power drives. Also included are protective features such as soft-start, under-voltage lockout, digital current limiting, double pulse inhibit, a data latch for single pulse metering, adjustable dead-time and provision for symmetry correction inputs. For ease of interface, all digital control ports are TTL and B-series CMOS compatible. Active LOW logic design allows wired-OR connections for maximum flexibility. This versatile device can be used to implement single-ended or push-pull switching regulators of either polarity, both transformerless and transformer coupled.

## Features

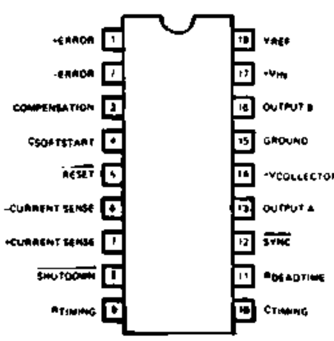
- **Low drain current**
- 8 to 35 volt operation
- **High performance 5V ±1% reference**
- **Low t.c. 1Hz to 400kHz oscillator**
- Dual 100 mA source/sink outputs
- Digital current limiting
- Double pulse suppression
- Programmable deadtime
- **Accurate current limit sense voltage**
- Undervoltage lockout
- Single pulse metering
- Programmable soft-start
- Wide current limit common mode range
- TTL/CMOS compatible logic ports
- Symmetry correction capability
- Guaranteed 6 unit synchronization

## Block Diagram



## Connections

**CONNECTION DIAGRAM (TOP VIEW)**



**N AND J PACKAGE TO-116 STYLE**

# Absolute Maximum Ratings (Note 1)

| | |
|---|---|
| Input Voltage ($+V_{IN}$) | +40V |
| Collector Supply Voltage ($+V_C$) | +40V |
| Logic Inputs | −0.3V to +5.5V |
| Analog Inputs | −0.3V to $+V_{IN}$ |
| Source/Sink Load Current (each output, continuous) | 200 mA |
| Reference Load Current | Internally Limited |
| Logic Sink Current | 15 mA |
| Power Dissipation at $T_A$ = +25°C (Note 2) | 1000 mW |
| Power Dissipation at $T_C$ = +25°C (Note 3) | 3000 mW |
| Operating Junction Temperature | +150°C |
| Storage Temperature Range | −65°C to +150°C |
| Lead Temperature (soldering, 10 seconds) | +300°C |

Note 1. Values beyond which damage may occur.
Note 2. Derate at 10 mW/°C for ambient temperatures above +50°C.
Note 3. Derate at 24 mW/°C for case temperatures above +25°C.

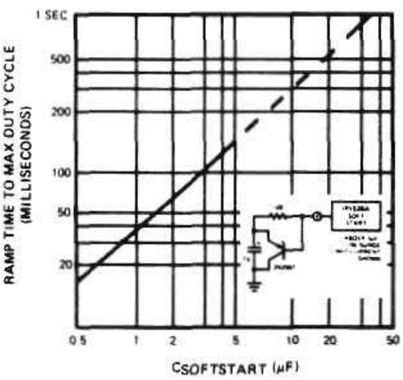
# Recommended Operating Conditions (Note 4)

| | |
|---|---|
| Input Voltage | +8V to +35V |
| Collector Supply Voltage | +4.5V to +35V |
| Sink/Source Load Current (each output) | 0 to 100 mA |
| Reference Load Current | 0 to 20 mA |
| Oscillator Frequency Range | 1 Hz to 400 kHz |
| Oscillator Timing Resistor | 2 kΩ to 150 kΩ |
| Oscillator Timing Capacitor | 1 nF to 20 µF |
| Available Deadtime Range at 40 kHz | 3% to 50% |
| Operating Ambient Temperature Range | |
| IP1526A | −55°C to +125°C |
| IP2526A | −25°C to +85°C |
| IP3526A | 0°C to +70°C |

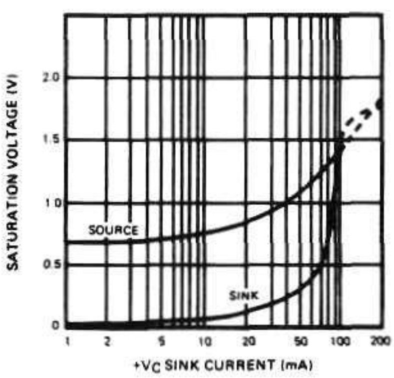
Note 4. Range over which the device is functional and parameter limits are guaranteed.

# Typical Performance Characteristics

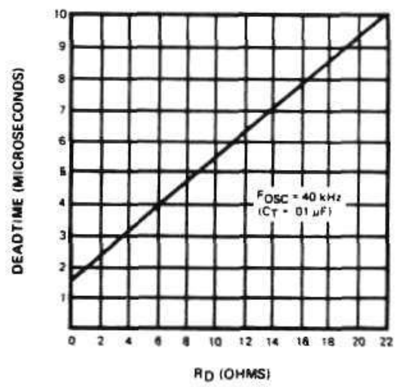
**Soft-start Time vs. $C_S$**



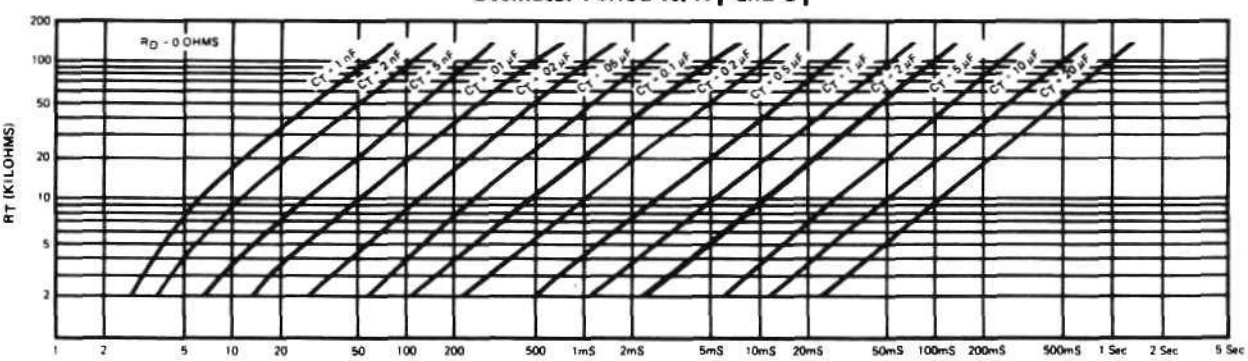

**Output Driver Saturation Voltage**




**Output Driver Deadtime vs. $R_D$ Value**




**Oscillator Period vs. $R_T$ and $C_T$**



# Electrical Characteristics

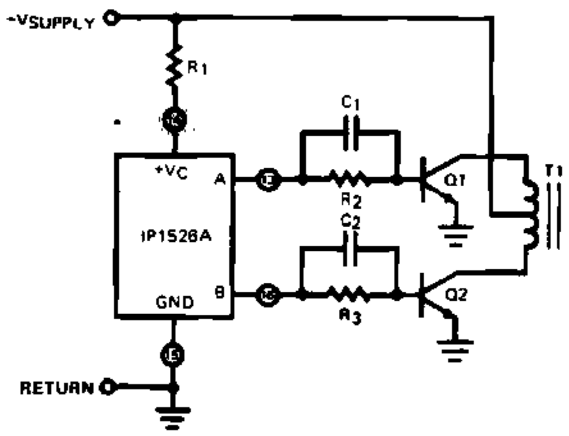
(+$V_{IN}$ = 15V, and over operating temperature, unless otherwise specified)

| PARAMETER | CONDITIONS | | IP1526A/2526A | | | IP3526A | | | UNITS |
|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| **REFERENCE SECTION** | | | | | | | | | |
| Output Voltage | $T_j$ = +25°C | | 4.95 | 5.00 | 5.05 | 4.90 | 5.00 | 5.10 | V |
| Line Regulation | +$V_{IN}$ = 8 to 35V | ● | | 2 | 10 | | 2 | 15 | mV |
| Load Regulation | $I_L$ = -5mA to +20mA | ● | | 5 | 10 | | 5 | 20 | mV |
| Temperature Stability[5] | Over Operating Range | | | 15 | 50 | | 15 | 50 | mV |
| Total Output Voltage Range | | ● | 4.90 | 5.00 | 5.10 | 4.85 | 5.00 | 5.15 | V |
| Short Circuit Current | $V_{REF}$ = 0V | ● | 30 | 80 | 140 | 30 | 80 | 140 | mA |
| **UNDERVOLTAGE LOCKOUT** | | | | | | | | | |
| $\overline{RESET}$ Output Voltage | $V_{REF}$ = 3.8V | ● | | 0.2 | 0.4 | | 0.2 | 0.4 | V |
| $\overline{RESET}$ Output Voltage | $V_{REF}$ = 4.8V | ● | 2.4 | 4.8 | | 2.4 | 4.8 | | V |
| **OSCILLATOR SECTION**[6] | | | | | | | | | |
| Initial Accuracy | $T_j$ = +25°C | | | ± 3 | ± 8 | | ± 3 | ± 8 | % |
| Voltage Stability | +$V_{IN}$ = 8 to 35V | ● | | 0.5 | 1 | | 0.5 | 1 | % |
| Temperature Stability[5] | Over Operating Range | | | 1 | 3 | | 1 | 3 | % |
| Minimum Frequency | $R_T$ = 150kΩ, $C_T$ = 0.2 µF | ● | | | 100 | | | 100 | Hz |
| Maximum Frequency | $R_T$ = 2kΩ, $C_T$ = 470 pF | ● | 400 | | | 400 | | | kHz |
| Sawtooth Peak Voltage | +$V_{IN}$ = 35V | ● | | 3.0 | 3.5 | | 3.0 | 3.5 | V |
| Sawtooth Valley Voltage | +$V_{IN}$ = 8V | ● | 0.5 | 1.0 | | 0.5 | 1.0 | | V |
| **ERROR AMPLIFIER SECTION**[7] | | | | | | | | | |
| Input Offset Voltage | $R_S \leq 2k\Omega$ | ● | | 2 | 5 | | 2 | 10 | mV |
| Input Bias Current | | ● | | -350 | -1000 | | -350 | -2000 | nA |
| Input Offset Current | | ● | | 35 | 100 | | 35 | 200 | nA |
| DC Open Loop Gain | $R_L \geq 10$ MegΩ, $T_j$ = 25°C | | 64 | 72 | | 60 | 72 | | dB |
| High Output Voltage | Vpin 1−Vpin 2≥150mV, $I_{source}$=100µA | ● | 3.6 | 4.2 | | 3.6 | 4.2 | | V |
| Low Output Voltage | Vpin 2−Vpin 1≥150mV, $I_{sink}$=100µA | ● | | 0.2 | 0.4 | | 0.2 | 0.4 | V |
| Common Mode Rejection | $R_S \leq 2k\Omega$ | ● | 70 | 94 | | 70 | 94 | | dB |
| Supply Voltage Rejection | +$V_{IN}$ = 12 to 18V | ● | 66 | 80 | | 66 | 80 | | dB |
| **P.W.M. COMPARATOR**[6] | | | | | | | | | |
| Minimum Duty Cycle | Vcompensation = +0.4V | ● | | | 0 | | | 0 | % |
| Maximum Duty Cycle | Vcompensation = +3.6V | ● | 45 | 49 | | 45 | 49 | | % |
| **DIGITAL PORTS ($\overline{SYNC}$, $\overline{SHUTDOWN}$, and $\overline{RESET}$)** | | | | | | | | | |
| HIGH Output Voltage | $I_{source}$ = 40 µA | ● | 2.4 | 4.0 | | 2.4 | 4.0 | | V |
| LOW Output Voltage | $I_{sink}$ = 3.6 mA | ● | | 0.2 | 0.4 | | 0.2 | 0.4 | V |
| HIGH Input Current | $V_{IH}$ = +2.4V | ● | | -125 | -200 | | -125 | -200 | µA |
| LOW Input Current | $V_{IL}$ = +0.4V | ● | | -225 | -360 | | -225 | -360 | µA |
| **CURRENT LIMIT COMPARATOR**[8] | | | | | | | | | |
| Sense Voltage | $R_S \leq 50\Omega$ | ● | 90 | 100 | 110 | 80 | 100 | 120 | mV |
| Input Bias Current | | ● | | -3 | -10 | | -3 | -10 | µA |
| **SOFT-START SECTION** | | | | | | | | | |
| Error Clamp Voltage | $\overline{RESET}$ = +0.4V | ● | | 0.1 | 0.4 | | 0.1 | 0.4 | V |
| $C_S$ Charging Current | $\overline{RESET}$ = +2.4V | ● | 50 | 100 | 150 | 50 | 100 | 150 | µA |
| **OUTPUT DRIVERS (Each Output)**[9] | | | | | | | | | |
| HIGH Output Voltage | $I_{source}$ = 20 mA | ● | 12.5 | 13.5 | | 12.5 | 13.5 | | V |
| | $I_{source}$ = 100 mA | ● | 12 | 13 | | 12 | 13 | | V |
| LOW Output Voltage | $I_{sink}$ = 20 mA | ● | | 0.2 | 0.3 | | 0.2 | 0.3 | V |
| | $I_{sink}$ = 100 mA | ● | | 1.2 | 2.0 | | 1.2 | 2.0 | V |
| Collector Leakage | $V_C$ = 40V | ● | | 50 | 150 | | 50 | 150 | µA |
| Rise Time | $C_L$ = 1000 pF | ● | | 0.3 | 0.6 | | 0.3 | 0.6 | µSec |
| Fall Time | $C_L$ = 1000 pF | ● | | 0.1 | 0.2 | | 0.1 | 0.2 | µSec |
| **POWER CONSUMPTION**[10] | | | | | | | | | |
| Standby Current | $\overline{SHUTDOWN}$ = +0.4V, $V_{IN}$ = 35V | ● | | 14 | 20 | | 14 | 20 | mA |

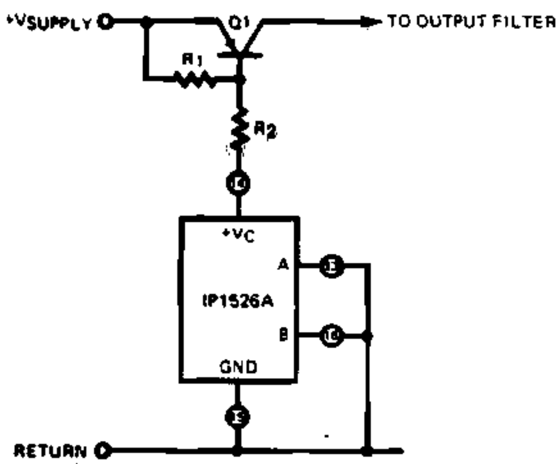
Note 5. These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.
Note 6. $F_{OSC}$ = 40 kHz ($R_T$ = 4.12 kΩ ±1%, $C_T$ = .01 µF ±1%, $R_D$ = 0Ω. Note 7. $V_{CM}$ = 0 to +5.2V Note 8. $V_{CM}$ = 0 to +12V
Note 9. $V_C$ = +15V Note 10. +$V_{IN}$ = +35V, $R_T$ = 4.12kΩ

The ● denotes the specifications which apply over the full operating range, all others apply at $T_j$ = 25°C unless otherwise specified.

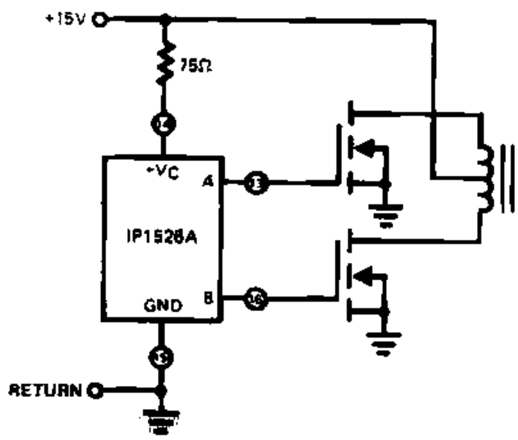
# Applications Information




Push-Pull Configuration




Single-Ended Configuration




Driving N-Channel Power MOSFETS

# Order Information

| Part Number | Temperature Range | Package |
|---|---|---|
| IP1526AJ | −55° C to +125° C | 18 Pin Ceramic DIP |
| IP2526AJ | −25° C to +85° C | 18 Pin Ceramic DIP |
| IP3526AJ | 0° C to +70° C | 18 Pin Ceramic DIP |
| IP3526AN | 0° C to +70° C | 18 Pin Plastic DIP |

**INTEGRATED POWER SEMICONDUCTORS, LTD.**

*IP293 · IP293D · IP293DA · IP293E*

# *Push-Pull Four Channel Driver*

## Description

The IP293 is a quad push-pull driver capable of delivering output currents to 1 ampere per channel Each channel is controlled by a TTL compatible logic input and each full-bridge driver is equipped with an enable input for a high impedance output state. A seperate supply input allows the logic to be operated at lower voltages to reduce power dissipation.

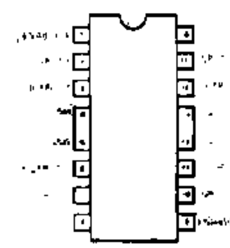
The IP293 is packaged in a plastic power DIP which uses the four center pins to conduct heat to the printed circuit board.

## Features

- 1 ampere continuous output current per channel
- 2 ampere peak non-repetitive output current per channel
- Enable facility for dual full-bridge configuration
- TTL compatible logic inputs
- High noise immunity
- Seperate logic supply
- Thermal shutdown protection
- Cross-over current protection
- Internal output clamp diodes (IP293D & IP293DA)
- External current sense (IP293E)

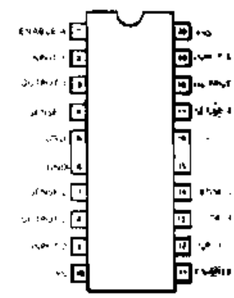
## Connections

**DIL-16 N PACKAGE**



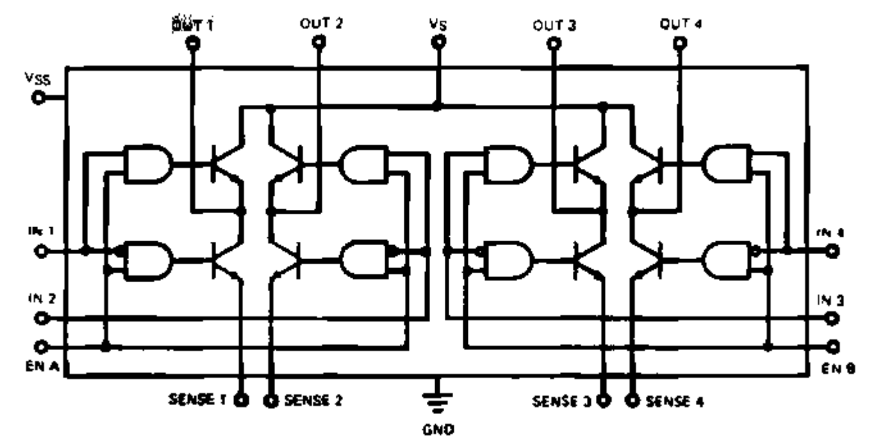
**IP293 · IP293D · IP293DA**

**DIL-20 N PACKAGE**



**IP293E**

## Block Diagram




**Note: for IP293, IP293D, IP293DA sense 1, 2, 3, 4 are grounded for IP293 and IP293DA outputs include internal diode protection**

**IPS**

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2727 Walsh Avenue, Suite 201 Santa Clara, CA 95051 Telephone 408/727 2772 Telex 350073 (IPS SNTA) Fax 408 588 6185

8 Quaker Drive West Warwick RI 02893 Telephone 401 821 4260 Telex 332948 (IPS RI) Fax 401 823 7260

# Absolute Maximum Ratings

| | | | |
|---|---|---|---|
| Supply Voltage | 36V | Continuous Output Current | |
| Logic Supply Voltage | 36V | IP293 | 1A |
| Peak Non-repetitive Output Current (t ≤ 5ms) | 2A | IP293E | 1A |
| Operating Ambient Temperature | 0°C to 70°C | IP293D | 600mA |
| Junction Temperature | 150°C | IP293DA | 1A |
| Storage Temperature | −40°C to 150°C | | |

# Electrical Characteristics

$V_S$ = 24V, $V_{SS}$ = 5V, and $T_A$ = 25°C unless otherwise specified

| Parameter | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| Supply Voltage | | • | | | 36 | V |
| Logic Supply Voltage | | • | 4.5 | | 36 | V |
| Quiescent Supply Current | $V_{IN}$=L $V_{EN}$=H $I_O$=0 | • | | 2 | 6 | mA |
| | $V_{IN}$=H $V_{EN}$=H $I_O$=0 | • | | 10 | 15 | mA |
| (per channel) | $V_{EN}$=L | • | | | 1 | mA |
| Quiescent Logic Supply Current | | • | | 3 | 6 | mA |
| Logic Input Low Voltage | | • | -0.3 | | 0.8 | V |
| Logic Input High Voltage | | • | 2.0 | | $V_S$ | V |
| Logic Input Low Current | Logic Input Voltage≤$V_{IL\ MAX}$ | • | | -50 | -100 | μA |
| Logic Input High Current | Logic Input Voltage≥$V_{IH\ MIN}$ | • | | | 10 | μA |
| Source Output Saturation Voltage | $I_O$ = $I_{MAX\ CONTINUOUS}$ | • | | 1.4 | 1.8 | V |
| Sink Output Saturation Voltage | $I_O$ = $I_{MAX\ CONTINUOUS}$ | • | | 1.2 | 1.8 | V |
| Diode Forward Voltage | $I_D$ = 1A (IP293DA) | • | | 1.3 | 1.8 | V |
| | $I_D$ = 0.6A (IP293D) | • | | 1.1 | 1.8 | V |
| External Sense Voltage (IP293E) Note 1 | | • | | | 2 | V |

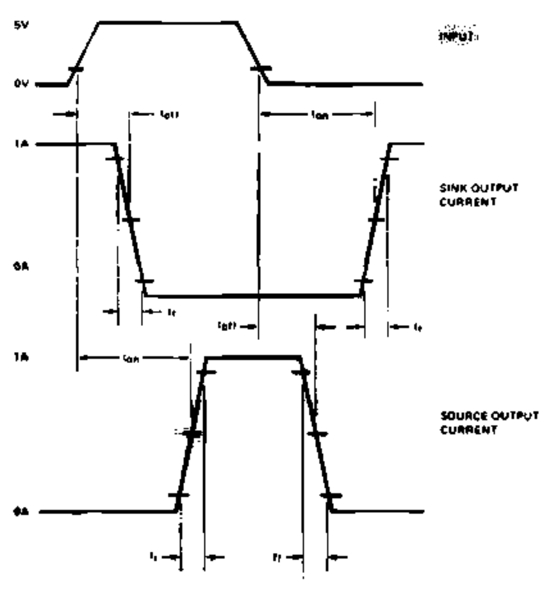
**Note 1. For Logic supply voltages ($V_{SS}$)<5 volts, Maximum recommended external sense voltage ($V_{SENS}$) should not exceed 1.5 volts**
**The • denotes the specifications which apply over the full operating ambient temperature range.**

# Switching Characteristics

$V_S$ = 24V, $V_{SS}$ = 5V, $f_c$ = 30 kHz, $T_A$ = 25°C

| Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|
| Sink Current Turn-on Delay | | 2000 | | ns |
| Sink Current Rise Time | | 200 | | ns |
| Sink Current Turn-off Delay | | 600 | | ns |
| Sink Current Fall Time | | 200 | | ns |
| Source Current Turn-on Delay | | 2000 | | ns |
| Source Current Rise Time | | 600 | | ns |
| Source Current Turn-off Delay | | 700 | | ns |
| Source Current Fall Time | | 400 | | ns |
| Sink to Source Deadtime | 0 | 1000 | | ns |
| Source to Sink Deadtime | 0 | 1000 | | ns |

**(Note: Switching times apply for resistive loads only)**




**(per channel)**

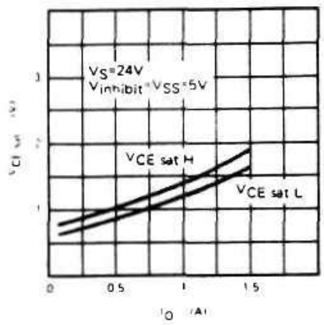
| INPUT | ENABLE* | OUTPUT |
|---|---|---|
| H | H | H |
| L | H | L |
| H | L | Z |
| L | L | Z |

***relative to the considered channel**
**Z = High impedance**

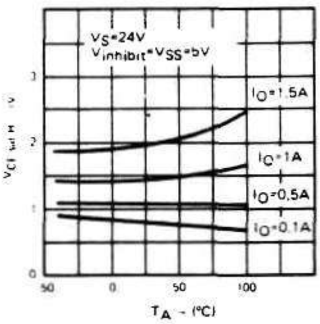
$$td1 = (t_{on} - t_r/2)_{source} - (t_{off} + t_f/2)_{sink}$$
$$td2 = (t_{on} - t_r/2)_{sink} - (t_{off} + t_f/2)_{source}$$

# Performance Characteristics

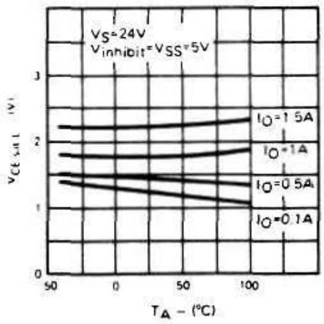
Saturation Voltage vs Output Current



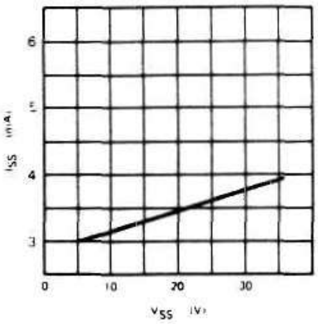

Source Saturation vs Ambient Temperature




Sink Saturation vs Ambient Temperature




Quiescent Logic Supply Current vs Logic Supply Voltage




# Mounting Instructions

The $R\theta_{JA}$ of the IP293D can be reduced by the soldering the GND pins to a suitable copper area of the printed circuit board or to an external heatsink.

The diagram of Figure 3 shows the maximum package power $P_{tot}$ and the $\theta_{JA}$ as a function of the side "ℓ" of two equal square copper areas having a thickness of 35μ (see figure 1).

In addition, it is possible to use an external heatsink (see Figure 2).

During soldering the pins' temperature must not exceed 260°C and the soldering time must not be longer than 12 seconds.

The external heatsink or printed circuit copper area must be connected to electrical ground.

Figure 1 - Example of P.C. Board Copper Area which is used as Heatsink

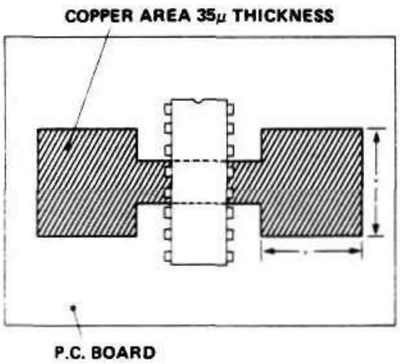



Figure 2 - External Heatsink Mounting Example ($\theta_{JA}$ = 25°C/W)

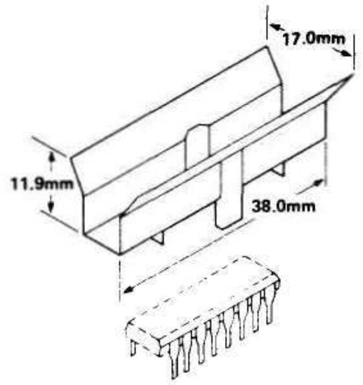



Figure 3 - Maximum Package Power and Junction to Ambient Thermal Resistance vs Size "ℓ"

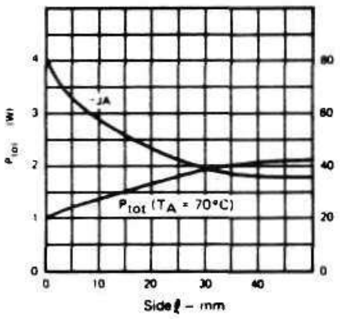
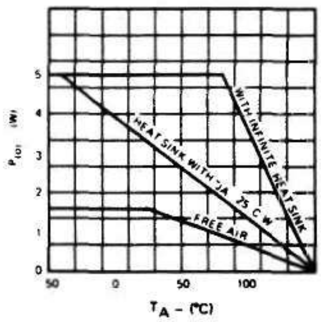


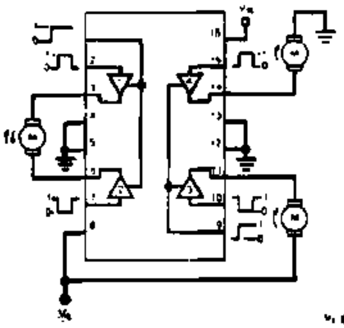

Figure 4 - Maxumum Allowable Power Dissapation vs Ambient Temperature



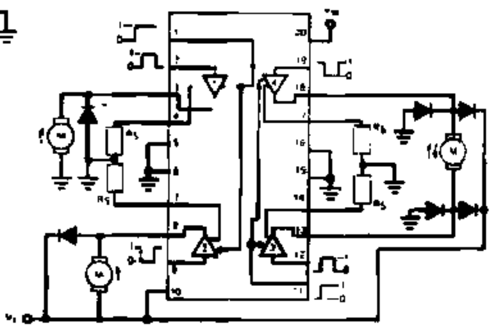

**THERMAL DATA**

| | |
|---|---|
| **$R\theta_{JC}$** | **MAX 14° C/W** |
| **$R\theta_{JA}$** | **MAX 80° C/W** |

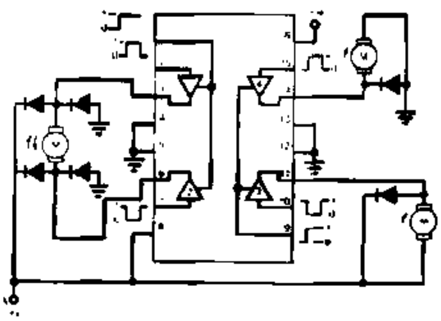
# Typical Applications



IP293D, IP293DA

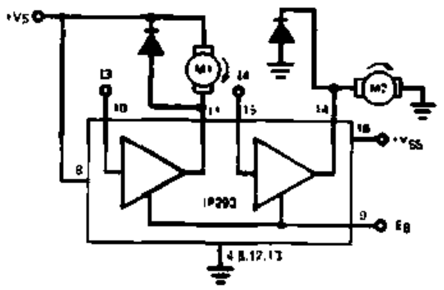


IP293E

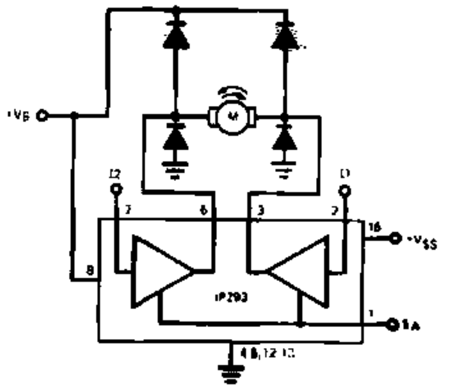


IP293

DC motor controls (with connection to ground and to the supply voltage)



Bidirectional DC motor control



| $E_B$ | I3 | M1 | I4 | M2 |
|---|---|---|---|---|
| H | H | Fast Motor Stop | H | Run |
| H | L | Run | L | Fast Motor Stop |
| L | X | Free Running Motor Stop | X | Free Running Motor Stop |

L = Low H = High X = Don't care

| INPUTS | | FUNCTION |
|---|---|---|
| $E_A$ = H | I2 = H; I1 = L | Turn Right |
| | I1 = L; I2 = H | Turn Left |
| | I1 = I2 | Fast Motor Stop |
| $E_A$ = L | I1 = X; I2 = X | Free Running Motor Stop |

L = Low H = High X = Don't care

# Ordering Information

| | | Rated Continuous Output Current |
|---|---|---|
| IP293N | DIL - 16 | 1 Ampere |
| IP293EN | DIL - 20 | 1 Ampere |
| IP293DN | DIL - 16 | 0.6 Ampere |
| IP293DAN | DIL - 16 | 1 Ampere |

**INTEGRATED POWER SEMICONDUCTORS, LTD.**

*IP138 IP238 IP338*

*IP138A IP238A IP338A*

# *5 Amp Positive Adjustable Regulators*

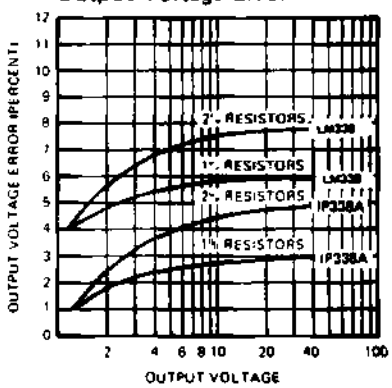
## Description

The IP138A Series are 3-Terminal positive adjustable voltage regulators capable of supplying in excess of 5A over a 1.25V to 35V output range. These regulators are exceptionally easy to use and require only two external resistors to set the output voltage. In addition to improved line and load regulation, a major feature of the "A" series is the initial **output voltage tolerance, which is guaranteed to be less than 1%.** Over full operating conditions, including load, line, and power dissipation, the reference voltage is guaranteed not to vary more than 2%. These devices exhibit current limit, thermal overload protection, and improved power device safe operating area protection, making them essentially indestructible.

## Features

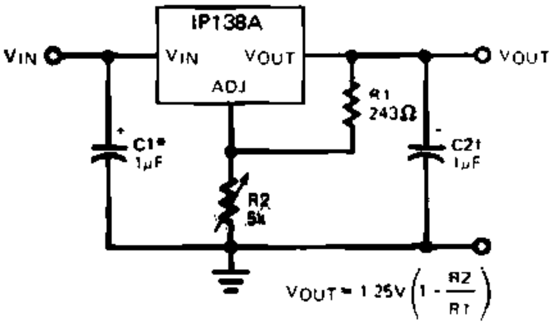
- Available in Low Cost TO-218
- **Guaranteed 1% Output Voltage Tolerance**
- **Guaranteed 0.3% Load Regulation**
- **Guaranteed 0.01%/V Line Regulation**
- Internal Current Limiting Constant with Temperature
- Internal Thermal Overload Protection
- Improved Output Transistor Safe Operating Area Compensation
- Output Adjustable Between 1.25V and 35V
- **100% Burn-in** in Thermal Overload

**Output Voltage Error**




## Applications

- Improved Linear Regulators
- Adjustable Power Supplies
- Constant Current Regulation
- Battery Chargers




**1.2V–25V Adjustable Regulator**

* Needed if device is far from filter capacitors

† Optional – improves transient response

IPS

HQ: Sidlow House, Almondvale, Livingston, EH54 5NJ, Scotland. Telephone: 0506 37375 Telex: 727368 (INTPOW G)

Peter-Kolbe-Straße 7, 8044 Lohhof/München, W. Germany. Telefon 0 89 / 3 10 40 47 Telex: 17 897 133 Teletex 897 133

2727 Walsh Avenue, Suite 201, Santa Clara, CA 95051 Telephone: 408/727 2772 Telex: 350073 (IPS SNTA) Fax: 408/980-6105

8 Quaker Drive, West Warwick, RI 02893 Telephone: 401/821-4260 Telex: 332948 (IPS RI) Fax: 401/823 7260

# Absolute Maximum Ratings

Power Dissipation . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . Interna

Input to Output Voltage Differential . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Operating Junction Temperature Range

IP138A • IP138 . . . . . . . . . . . . . . . . . . . . . . . . . .−55°

IP238A • IP238 . . . . . . . . . . . . . . . . . . . . . . . . . . −25°

IP338A • IP338 . . . . . . . . . . . . . . . . . . . . . . . . . . . 0°

Storage Temperature Range . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . −65°

Lead Temperature (Soldering, 10 seconds) . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

# Preconditioning: 100% THERMAL LIMIT BU…

# Electrical Characteristics

(See Notes 1 and 3)

| SYMBOL | PARAMETER | CONDITIONS | | | IP138A IP238A MIN | IP138A IP238A TYP | IP138A IP238A MAX | IP13… IP23… MIN | IP13… IP23… TYP |
|---|---|---|---|---|---|---|---|---|---|
| $V_{REF}$ | Reference Voltage | $I_{OUT}$ = 10 mA, $T_j$ = 25° C | | | 1.238 | 1.250 | 1.262 | | |
| | | 3V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V<br>10 mA ≤ $I_{OUT}$ ≤ 5A, P ≤ 50W | | ● | 1.225 | 1.250 | 1.270 | 1.19 | 1.24 |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$ | Line Regulation | 3V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V<br>(See Note 2) | | | | 0.005 | 0.010 | | 0.005 |
| | | | | ● | | 0.020 | 0.040 | | 0.020 |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation | 10 mA ≤ $I_{OUT}$ ≤ 5A<br>(See Note 2) | $V_O$ ≤ 5V | | | 5 | 15 | | 5 |
| | | | $V_O$ ≥ 5V | | | 0.100 | 0.300 | | 0.100 |
| | | | $V_O$ ≤ 5V | ● | | 20 | 30 | | 20 |
| | | | $V_O$ ≥ 5V | ● | | 0.300 | 0.60 | | 0.300 |
| | Thermal Regulation | $T_A$ = 25° C, 20 msec PULSE | | | | 0.002 | 0.01 | | .002 |
| | Ripple Rejection | $V_{OUT}$ = 10V, f = 120 Hz $C_{ADJ}$ = 0 | | ● | | 60 | | | 60 |
| | | VOUT = 10V, f = 120 Hz $C_{ADJ}$ = 10µF | | ● | 60 | 75 | | 60 | 75 |
| $I_{ADJ}$ | Adjust Pin Current | | | ● | | 46 | 100 | | 46 |
| $\Delta I_{ADJ}$ | Adjust Pin Current Change | 10 mA ≤ $I_{OUT}$ ≤ 5A<br>3.0V ≤ ($V_{IN}$ − $V_{OUT}$) ≤ 35V | | ● | | 0.2 | 5 | | 0.2 |
| $I_{MIN}$ | Minimum Load Current | ($V_{IN}$ − $V_{OUT}$) = 35V | | ● | | 3.5 | 5 | | 3.5 |
| $I_{SC}$ | Current Limit | ($V_{IN}$ − $V_{OUT}$) ≤ 10V | DC | ● | 5 | 8 | | 5 | 8 |
| | | | 0.5ms peak | ● | 7 | 12 | | 7 | 12 |
| | | ($V_{IN}$ − $V_{OUT}$) = 30V, $T_j$ = 25°C | | | | 1 | | | 1 |
| $\frac{\Delta V_{OUT}}{\Delta TEMP}$ | Temperature Stability | $T_{MIN}$ ≤ $T_j$ ≤ $T_{MAX}$ | | ● | | 1 | 2 | | 1 |
| $\frac{\Delta V_{OUT}}{\Delta TIME}$ | Long Term Stability | $T_A$ = 125°C, 1000 HRS | | | | 0.3 | 1 | | 0.3 |
| $e_n$ | RMS Output Noise (% of $V_{out}$) | $T_A$ = 25° C, 10Hz ≤ f ≤ 10khz | | | | 0.001 | | | 0.003 |
| $\theta_{jc}$ | Thermal Resistance Junction To Case | K PACKAGE | | | | | 1 | | |

The ● denotes the specifications which apply over the full operating temperature range.

# Electrical Characteristics

(See Note 1)

| SYMBOL | PARAMETER | CONDITIONS | | | IP338A MIN | IP338A TYP | IP338A MAX | IP338 MIN | IP338 TYP | IP338 MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $V_{REF}$ | Reference Voltage | $I_{OUT} = 10$ mA, $T_j = 25°C$ | | | 1.238 | 1.250 | 1.262 | | | | V |
| | | $3V \leq (V_{IN} - V_{OUT}) \leq 35V$<br>$10 mA \leq I_{OUT} \leq 5A$, $P \leq 50W$ | | ● | 1.225 | 1.250 | 1.270 | 1.19 | 1.24 | 1.29 | V |
| $\frac{\Delta V_{OUT}}{\Delta V_{IN}}$ | Line Regulation | $3V \leq (V_{IN} - V_{OUT}) \leq 35V$ (See Note 2) | | | | 0.005 | 0.010 | | 0.005 | 0.03 | %/V |
| | | | | ● | | 0.02 | 0.04 | | 0.020 | 0.06 | %/V |
| $\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$ | Load Regulation | $10 mA \leq I_{OUT} \leq 5A$ (See Note 2) | $V_O \leq 5V$ | | | 5 | 15 | | 5 | 25 | mV |
| | | | $V_O \geq 5V$ | | | 0.100 | 0.3 | | 0.100 | 0.5 | % |
| | | | $V_O \leq 5V$ | ● | | 20 | 30 | | 20 | 50 | mV |
| | | | $V_O \geq 5V$ | ● | | 0.300 | 0.6 | | 0.300 | 1 | % |
| | Thermal Regulation | $T_A = 25°C$ 20 msec PULSE | | | | 0.002 | 0.020 | | 0.002 | 0.02 | %/W |
| | Ripple Rejection | $V_{OUT} = 10V$, f = 120 Hz $C_{ADJ} = 0$ | | ● | | 60 | | | 60 | | dB |
| | | VOUT = 10V, f = 120 Hz $C_{ADJ} = 10\mu F$ | | ● | 60 | 75 | | 60 | 75 | | dB |
| $I_{ADJ}$ | Adjust Pin Current | | | ● | | 45 | 100 | | 45 | 100 | μA |
| $\Delta I_{ADJ}$ | Adjust Pin Current Change | $10 mA \leq I_{OUT} \leq 5A$, $3V \leq (V_{IN} - V_{OUT}) \leq 35V$ | | ● | | 0.2 | 5 | | 0.2 | 5 | μA |
| $I_{MIN}$ | Minimum Load Current | $(V_{IN} - V_{OUT}) = 35V$ | | ● | | 3.5 | 10 | | 3.5 | 10 | mA |
| $I_{CS}$ | Current Limit | $(V_{IN} - V_{OUT}) \leq 10V$ | **DC** | ● | 5 | 8 | | 5 | 8 | | A |
| | | | **0.5 ms peak** | ● | 7 | 12 | | 7 | 12 | | A |
| | | $(V_{IN} - V_{OUT}) = 30V$, $T_j = 25°C$ | | | | 1 | | | 1 | | A |
| $\frac{\Delta V_{OUT}}{\Delta TEMP}$ | Temperature Stability | $0°C \leq T_j \leq 125°C$ | | ● | | 1 | 2 | | 1 | | % |
| $\frac{\Delta V_{OUT}}{\Delta TIME}$ | Long Term Stability | $T_A = 125°C$, 1000 HRS | | | | 0.3 | 1 | | 0.3 | 1 | % |
| $e_n$ | RMS Output Noise (% of $V_{out}$) | $T_A = 25°C$, $10Hz \leq f \leq 10khz$ | | | | 0.001 | | | 0.003 | | % |
| $\Theta_{jc}$ | Thermal Resistance Junction To Case | K PACKAGE | | | | | 1 | | | 1 | °C/W |
| | | V PACKAGE | | | | | 1 | | | 1 | °C/W |

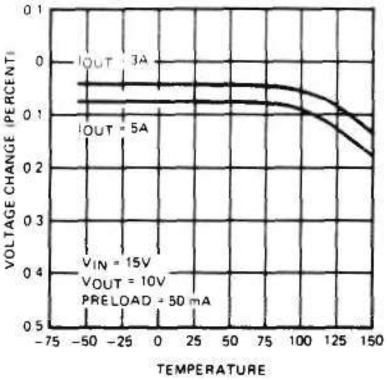
**The ● denotes the specifications which apply over the full operating temperature range.**

**Note 1:** *Unless otherwise specified, these specifications apply for* $T_{min} \leq T_j \leq T_{max}$, where $T_{min} = -55°C$ and $T_{max} = +150°C$ correspond to the IP138A, IP138
$T_{min} = -25°C$ and $T_{max} = +150°C$ correspond to the IP238A, IP238
and $T_{min} = 0°C$ and $T_{max} = +125°C$ correspond to the IP338A, IP338
$V_{in} - V_{out} = 5V$, $I_{out} = 2.5A$. Although power dissipation is internally limited, these specifications apply for dissipations of 50W for the TO-3 and TO-218, and $I_{max} = 5A$.

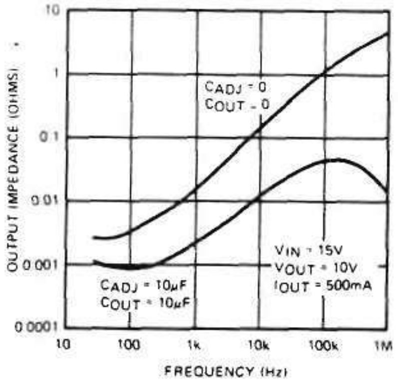
**Note 2:** Regulation is measured at constant junction temperature, using pulse testing at a low duty cycle. Changes in output voltage due to heating effects are covered under thermal regulation specifications. Load regulation is measured from the bottom of the package for the TO-3, and at the junction of the wide and narrow portion of the output lead for the TO-218.

# Typical Performance Characteristics

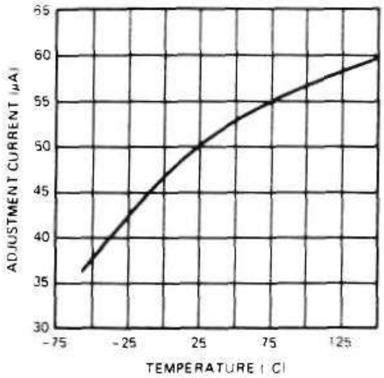
### Load Regulation



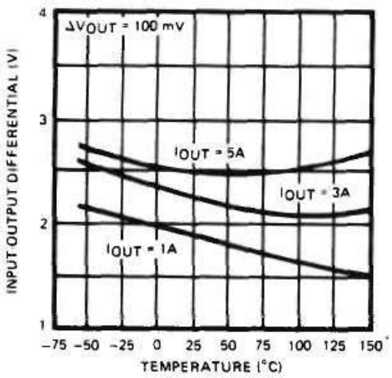

### Output Impedance



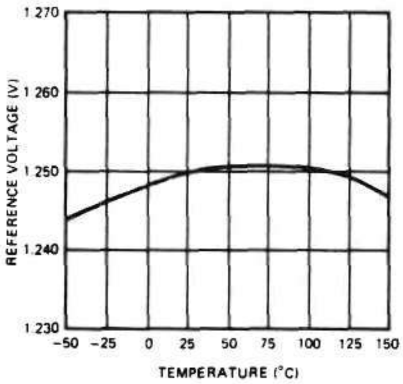

### Adjustment Current



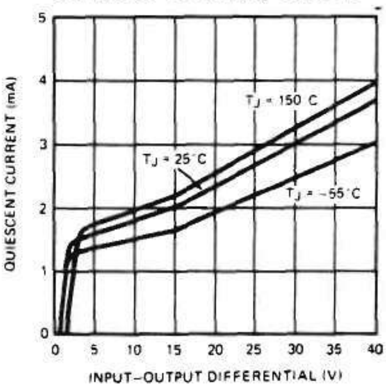

### Dropout Voltage



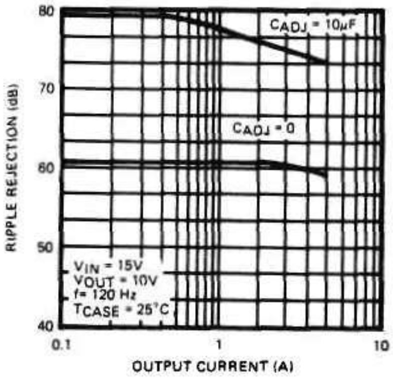

### Temperature Stability



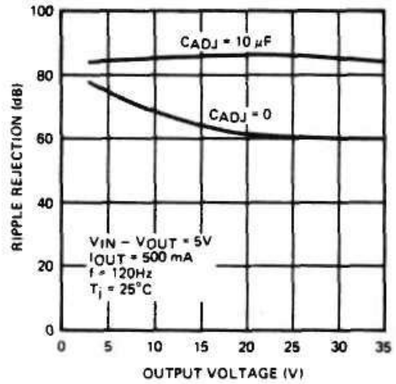

### Minimum Operating Current



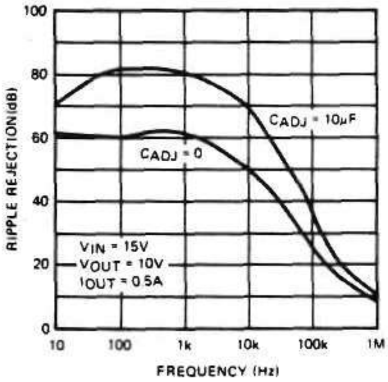

### Ripple Rejection



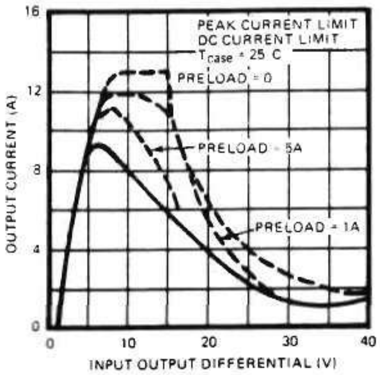

### Ripple Rejection



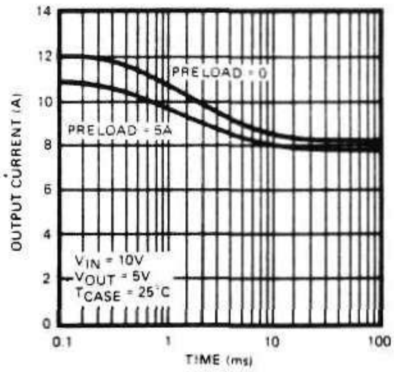

### Ripple Rejection



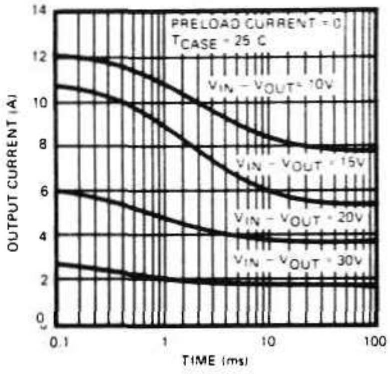
Current Limit



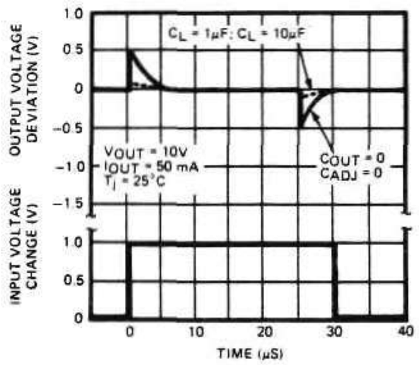

Current Limit



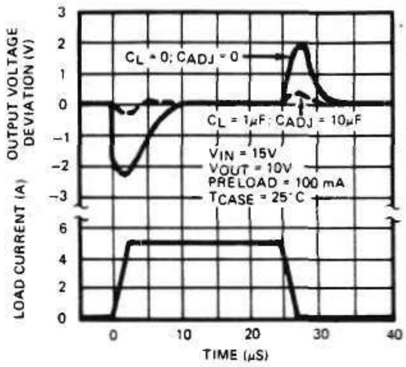

Current Limit




Line Transient Response




Load Transient Response




# Application Hints

**General:**

Functioning as a three terminal floating regulator, the IP138A develops and maintains a nominal 1.25V reference voltage ( $V_{ref}$ ) between its output and adjustment terminals, as illustrated below in Figure 1. If this reference voltage is applied across R1, a constant current $I_1$ is caused to flow through R2, thereby adjusting the output voltage to

$$V_{out} = V_{ref} \quad (1 + R2/R1) + I_{adj} \quad R2$$

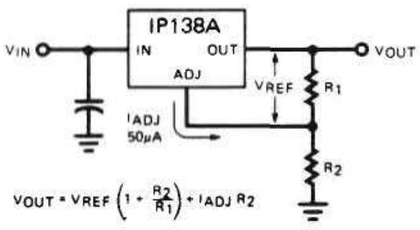



**Figure 1. Basic Adjustable Regulator**

Because the 50µA of adjustment current represents an error term in the output voltage expression, the IP138A was designed to minimize both the value of $I_{adj}$ and its variation with line and load changes. As a result, all but 50µA of the circuit's quiescent operating current appears at the output terminal, thereby establishing a minimum load current requirement. If the value of R1 is such that the minimum load current is not exceeded, the output voltage will rise.

**Accuracy of the Output Voltage:**

From the expression above it is evident that even if the resistors R1 and R2 are of exact value, the accuracy of the output voltage is limited by errors in $V_{ref}$. Earlier adjustable regulators have had a reference tolerance of ±4%, which is dangerously close to the ±5% supply tolerance required in many logic and analog systems. In addition, 1% resistors can drift up to ±0.01%/°C, increasing the output voltage tolerance even further. For example, using 2% resistors and a ±4% tolerance for $V_{ref}$ , calculations indicate that a 5V regulator design will vary between 4.66V and 5.36V, which is a tolerance of ±7%. If the same procedure were used in the design of a 15V regulator instead, the expected tolerance would increase to ±8%. As a result of these errors most applications require some method of trimming, which is both expensive and not conducive to volume production.

One of design enhancements featured in IP's adjustable regulators is the tightened initial tolerance in the value of $V_{ref}$. Production wafer-level trimming techniques now enable the reference voltage to be specified within 1%. This allows relatively inexpensive 1% or 2% film resistors to be used for R1 and R2 to set the output voltage, and acceptable system output voltage tolerances to be achieved.

With a guaranteed 1% reference, a 5V power supply design, using 2% resistors, would have a worst case manufacturing tolerance of ±4%. If 1% resistors were used, the tolerance would drop to ±2.5%.

For convenience, a table of standard 1% resistor values is shown below.

Table of ½% and 1% Standard Resistance Values

| | | | | | |
|---|---|---|---|---|---|
| 1.00 | 1.47 | 2.15 | 3.16 | 4.64 | 6.81 |
| 1.02 | 1.50 | 2.21 | 3.24 | 4.75 | 6.98 |
| 1.05 | 1.54 | 2.26 | 3.32 | 4.87 | 7.15 |
| 1.07 | 1.58 | 2.32 | 3.40 | 4.99 | 7.32 |
| 1.10 | 1.62 | 2.37 | 3.48 | 5.11 | 7.50 |
| 1.13 | 1.65 | 2.43 | 3.57 | 5.23 | 7.68 |
| 1.15 | 1.69 | 2.49 | 3.65 | 5.36 | 7.87 |
| 1.18 | 1.74 | 2.55 | 3.74 | 5.49 | 8.06 |
| 1.21 | 1.78 | 2.61 | 3.83 | 5.62 | 8.25 |
| 1.24 | 1.82 | 2.67 | 3.92 | 5.76 | 8.45 |
| 1.27 | 1.87 | 2.74 | 4.02 | 5.90 | 8.66 |
| 1.30 | 1.91 | 2.80 | 4.12 | 6.04 | 8.87 |
| 1.33 | 1.96 | 2.87 | 4.22 | 6.19 | 9.09 |
| 1.37 | 2.00 | 2.94 | 4.32 | 6.34 | 9.31 |
| 1.40 | 2.05 | 3.01 | 4.42 | 6.49 | 9.53 |
| 1.43 | 2.10 | 3.09 | 4.53 | 6.65 | 9.76 |

Standard Resistance Values are obtained from the Decade Table by multiplying by multiples of 10. As an example, 1.21 can represent 1.21Ω, 12.1Ω, 121Ω, 1.21KΩ etc.

**Bypass Capacitors:** Input bypassing using a 1µF tantalum or 25µF electrolytic is recommended when the input filter capacitors are more than 5 inches from the device. Improved ripple rejection (80 dB) can be achieved by adding a 10µF capacitor from the adjust pin to ground. Increasing the size of the capacitor to 20µF will help ripple rejection at low output voltage since the reactance of this capacitor should be small compared to the voltage setting resistor, R2. For improved AC transient response and to prevent the possibility of oscillation due to unknown reactive load, a 1µF capacitor is also recommended at the output. Because of their low impedance at high frequencies, the best type of capacitor to use is solid tan–talum.

**Protection Diodes:** The IP138A/238A/338A do not require a protection diode from the adjustment terminal to the output (see Figure 2). Improved internal circuitry eliminates the need for this diode when the adjustment pin is bypassed with a capacitor to improve ripple rejection.

If a very large output capacitor is used, such as a 100µF shown is Figure 2, the regulator could be damaged or destroyed if the input is accidentally shorted to ground or crowbarred. This is due to the output capacitor discharging into the output terminal of the regulator. To prevent damage a diode D1 is recommended to safely discharge the capacitor.

**Load Regulation:** Because the IP138A is a three-terminal device, it is not possible to provide true remote load sensing. Load regulation will be limited by the resistance of the wire connecting the regulator to the load. The datasheet specification for load regulation is measured at the bottom of the package. Negative side sensing is a true Kelvin connection, with the bottom of the output divider returned to the negative side of the load. Although it may not be immediately obvious, best load regulation is obtained when the top of the resistor divider (R1) is connected directly to the case not to the load. This is illustrated in Figure 3. If R1 were connected to the load, the effective resistance between the regulator and the load would be

$$R_P \times \left(\frac{R2 + R1}{R1}\right),\ R_P = \text{Parasitic Line Resistance.}$$

Connected as shown, $R_P$ is not multiplied by the divider ratio. $R_P$ is about 0.004Ω per foot using 16 gauge wire. This translates to 4mV/ft at 1A load current, so it is important to keep the positive lead between regulator and load as short as possible, and use large wire or PC board traces.

# Application Hints (CONTINUED)

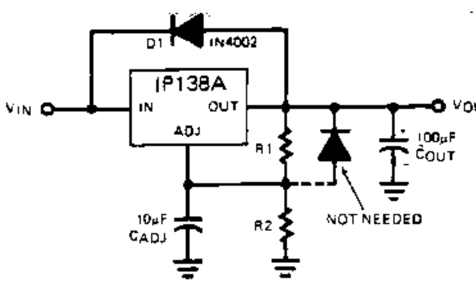



Figure 2.

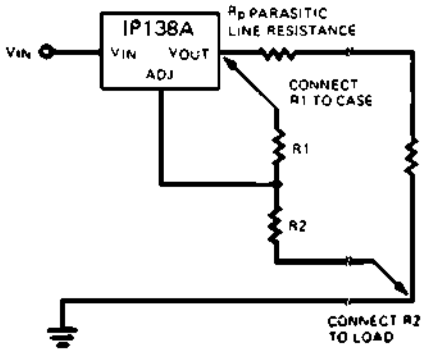
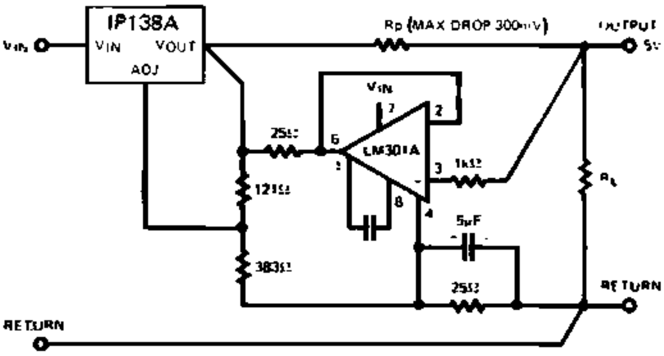
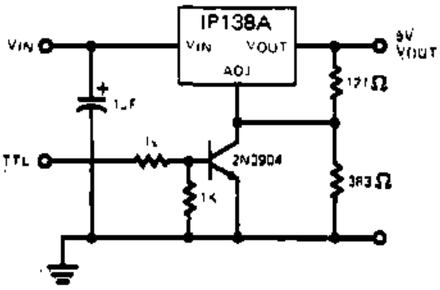



Figure 3. Connections for Best Load Regulation

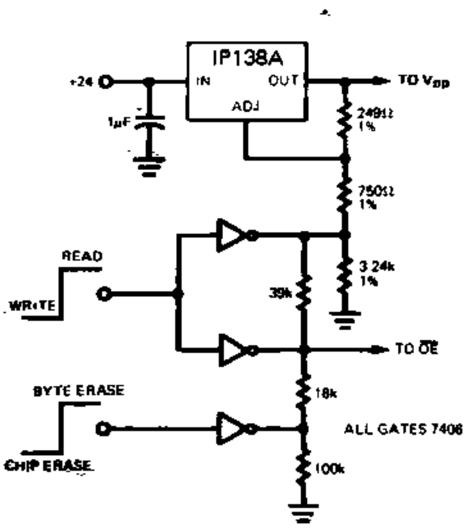
# Typical Applications




Remote Sensing

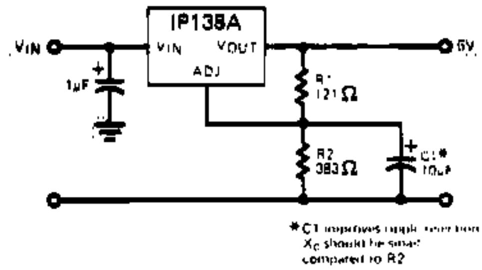



5V Regulator with Shut Down

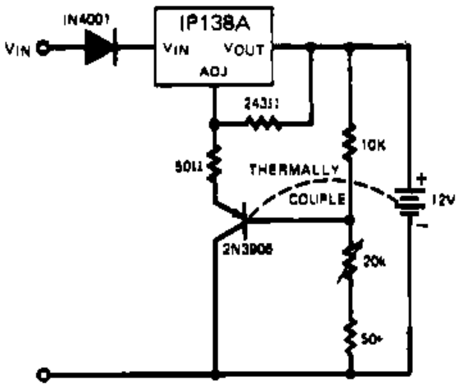



| | $\overline{OE}$ | Vpp |
|---|---|---|
| READ | 0V | 5V |
| WRITE | | |
| BYTE | 5V | 21V |
| CHIP ERASE | 12V | 21V |

2816 EEPROM Supply Programmer for Read/Write Control




Improving Ripple Rejection

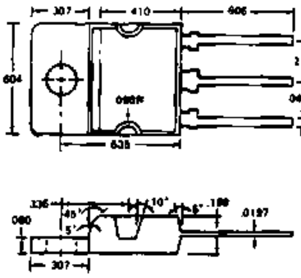


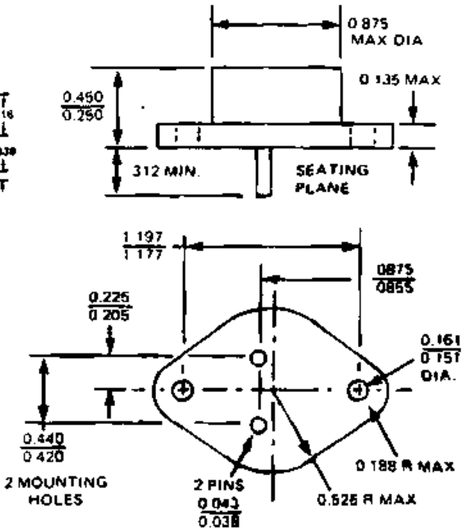

Temperature Compensated Lead Acid Battery Charger

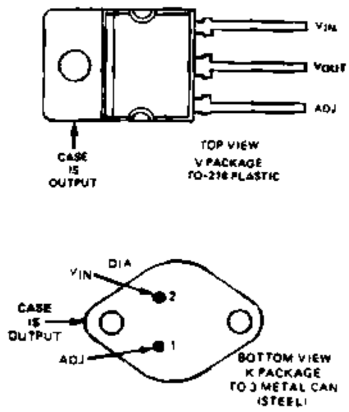


IPS

# Package Dimensions



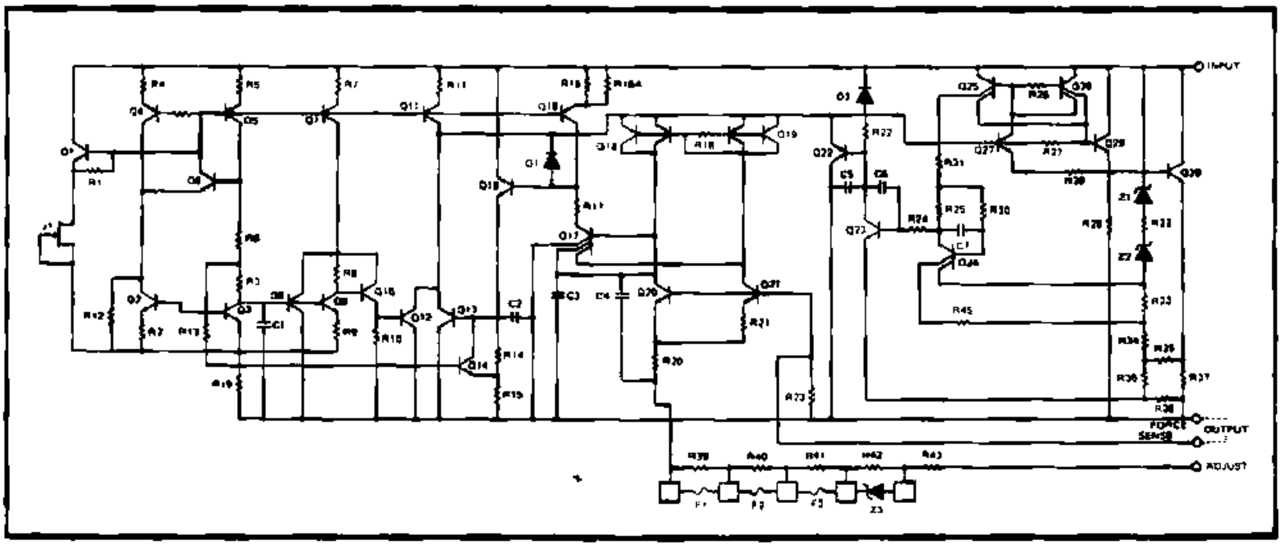



# Ordering Information

| TO-3 | | | TO-218 |
|---|---|---|---|
| IP138AK<br>IP138K | IP238AK<br>IP238K | IP338AK<br>IP338K | IP338AV<br>IP338V |

# Schematic Diagram



# INTEGRATED POWER SEMICONDUCTORS Ltd

## IP3M05 (2.5A)
## IP3M06 (1.5A)
## IP3M13 (4A)

**ADVANCE DATA**



# *3Phase DC Brushless Motor Control/Drive Circuits*

## Description

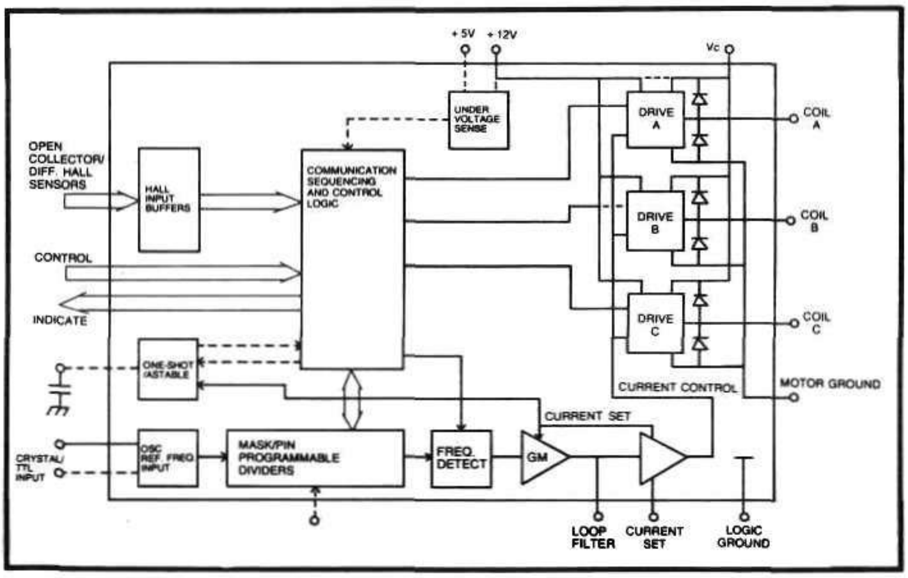
The IP3M05, IP3M06, IP3M13 linear current mode motor control/drive circuits contain all the functions necessary to run DC brushless motors in fixed speed applications. Included on the chip are: reference divider, frequency detector, loop filter, current control amps, hall amplifiers (open-collector or differential), commutation logic, motor drivers (push-pull),. flyback diodes, thermal shutdown and user defined logic inputs/outputs for various system control functions.

## Features

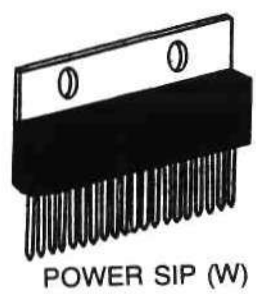
STANDARD
- Internal current sensing
- Short circuit protection
- Thermal shutdown
- Single pin loop filter
- Minimum external components
- Reference inputs to 6 MHZ

CONFIGURABLE
- Divider ratios
- Open collector/diff hall input
- Under voltage sensing (5V/12V)
- Forward/Reverse
- Start/stop run/brake
- One shot/oscillator
- Other logic functions

## Block Diagram




## Package



POWER SIP (W)

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Telex: 332948 (IPS RI)
Fax: 401/823-7260

# Absolute Maximum Ratings

| PARAMETER | MIN | MAX | PARAMETER | MIN | MAX |
|---|---|---|---|---|---|
| + 12 V Supply | | 15 V | (1) Pd (Ta = 25°C) | | 8 W |
| + 5 V Sense | | 15 V | (2) Pd (Tc = 25°C) | | 50 W |
| Logic Inputs | 0 | Vcc-2 V | | | |
| Drive Output Current | | | Storage Temperature | -55 | 150°C |
| IP3M05 | | 3.0 A | Junction Temperature | | 125°C |
| IP3M06 | | 1.8 A | (1) Derate at 80 mW°C | Above | $T_a$ = 25°C |
| IP3M13 | | 4.8 A | (2) Derate at 15 W/°C | Above | $T_c$ = 25°C |

# Electrical Characteristics (Vcc = 12V)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| | SUPPLY | | | | | |
| Vcc Supply Range | | ● | 7.0 | | 14 | V |
| Supply Current | | ● | | 35 | 45 | mA |
| | MOTOR DRIVE OUTPUTS | | | | | |
| Io (Limit) | Rset = 12.7 K | | | | | |
| IP3M05 | | ● | 2.25 | 2.5 | 2.75 | A |
| IP3MO6 | | ● | 1.35 | 1.5 | 1.65 | A |
| IP3M13 | | ● | 3.6 | 4.0 | 4.4 | A |
| V Sat | Total Drop, Both Outputs | | | | | |
| IP3M05 | Io = 2.5A | ● | | | 3.4 | V |
| | Io = 0.83A | ● | | | 2.0 | V |
| IP3M06 | Io = 1.5A | ● | | | 3.4 | V |
| | Io = 0.5A | ● | | | 2.0 | V |
| IP3M13 | Io = 4.0A | ● | | | 3.4 | V |
| | Io = 1.3A | ● | | | 2.0 | V |
| Thermal Shutdown | Junction Temperature | ● | 150 | | 180 | °C |
| | FREQUENCY DETECTOR AND TRANSCONDUCTANCE AMP | | | | | |
| $K_F$ gm | Rset = 12.7K, F = 60HZ | ● | 3.17 | 3.33 | 3.50 | µA/Hz |
| Off State Leakage | | | | .50 | | nA |
| | OUTPUT CURRENT CONTROL AMP | | | | | |
| Gain | Io/Vin | | | | | |
| IP3M05 | | ● | 0.42 | 0.60 | 0.78 | A/V |
| IP3MO6 | | ● | 0.21 | 0.30 | 0.39 | A/V |
| P3M13 | | ● | 0.56 | 0.80 | 1.04 | A/V |
| Iin | Input Bias Current | | | 50 | | nA |

# INTEGRATED POWER SEMICONDUCTORS Ltd

IP1D10 IP1D10A
IP2D10 IP2D10A
IP3D10 IP3D10A

**ADVANCE DATA**



# *4 Amp Stepper Motor Driver*

## Description

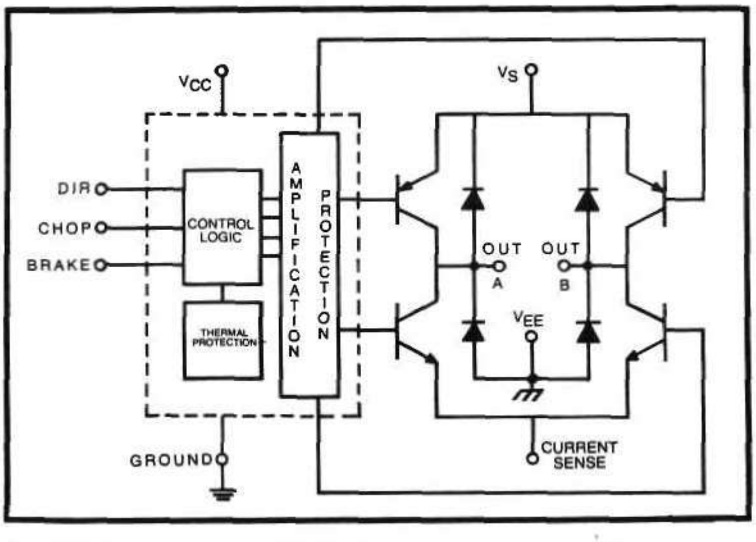
The IPXD10 and IPXD10A are high voltage, 4 Amp integrated circuits designed to drive stepper motors and other inductive loads. Configured as an H-Bridge driver these circuits provide high gain (100dB) and include internal voltage suppression diodes necessary for driving inductive loads. A separate ground pin, besides improving noise immunity, allows the device to be driven with standard TTL logic in split supply applications.The low voltage supply pin allows the device to be operated from a standard 5V supply line and helps reduce overall power dissipation. Other features include thermal protection, internal crossover current protection, complete characterisation of reverse bias safe operating area and min/max specs over the full operating temperature range.

The IPXD10 and IPXD10A are available for the military industrial and commercial temperature range and are packaged in either the 9-pin hermetic TO-66 or 10-Pin power SIP.

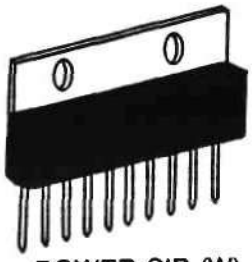
## Features

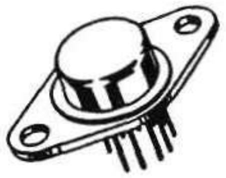
- 4 Amp Continuous Output Current
- 50/80 Volt Maximum Supply Voltage
- Internal Voltage Suppression Diodes
- Full RBSOA Specification
- External Current Sense
- Crossover Current Protection
- Thermal Shutdown Protection
- Configurable for Split Supply Operation
- TTL Compatible Input Logic
- Power Packages

## Block Diagram




## Packages


POWER SIP (W)


TO-66 (R)

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Telephone: 401/821-4260
Telex: 332948 (IPS RI)
Fax: 401/823-7260

# Absolute Maximum Ratings

| | | |
|---|---|---|
| Output Voltage, $V_S$ (referenced to $V_{EE}$) | D1O | 50V |
| | D1OA | 80V |
| Input Voltage, $V_{IN}$ | | -0.3V to $V_S$ |
| Logic Supply Voltage, $V_{CC}$ | | $V_S$ |
| Emitter Supply Voltage, $V_{EE}$ (referenced to $V_S$) | D1O | -50V |
| | D1OA | -80V |
| Diode Reverse Voltage, $V_R$ | | 80V |
| Current Sense Voltage, $V_{SENSE}$ | | 2V |
| Output Current, $I_O$ | | 5A |
| Diode Forward Current, $I_F$ | | 5A |

| | |
|---|---|
| Operating Junction Temperature | +150°C |
| Operating Ambient Temperature Range | |
| IP1D10/D10A | -55°C to + 125°C |
| IP2D10/D10A | -25°C to + 85°C |
| IP3D10/D10A | 0°C to + 70°C |
| Package Thermal Resistance | |
| TO-66, RΘJA | 35°C/W |
| RΘJC | 7°C/W |
| Power SIP, RΘJA | 35°C/W |
| RΘJC | 1.5°C/W |

# Electrical Characteristics

(Test Conditions apply for minimium and maximum values and apply for the full operating temperature range unless otherwise specified. Typical values are measured at $T_A$ = 25°C with $V_S$= 24V, $V_{CC}$ = 5V and $V_{EE}$= OV.)

| PARAMETER | SYMBOL | DEVICES | TEST CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Supply Voltage | $V_S$ | IPXD10 | | | | 50 | V |
| | | IPXD10A | | | | 80 | |
| Logic Supply Voltage | $V_{CC}$ | | | 4.5 | | $V_s$ | V |
| Logic Input High Voltage | $V_{IH}$ | | | 2.0 | | $V_{CC}$ | V |
| Logic Input Low Voltage | $V_{IL}$ | | | -0.3 | | 0.8 | V |
| Logic Input High Current | $I_{IH}$ | | | | | 10 | µA |
| Logic Input Low Current | $I_{IL}$ | | $V_{IL}$=0.8V | | -50 | | µA |
| Current Sense Voltage | $V_{SENSE}$ | | $V_{CC}$= 4.5V | | | 1 | V |
| Total Output Saturation Voltage | $V_{SAT}$ | | $I_O$= 4A | | 3 | | V |
| Clamp Diode Forward Voltage | $V_F$ | | $I_O$ = 4A | | 1.2 | | V |
| Output Leakage Current | $I_{LK}$ | IPXD10 | $V_S$ = 50V, $V_{EE}$ = 0V | | | ±100 | µA |
| | | IPXD10A | $V_S$ = 80V, $V_{EE}$ = 0V | | | | |
| Thermal Shutdown Threshold | $T_{TSD}$ | | | 150 | | | °C |

This is an advanced data sheet and specifications may change prior to product release. Complete specification including min/max values, switching characteristics, performance data and connection diagrams will be furnished on the full data sheet.

# Order Information

| DEVICE | TEMPERATURE RANGE | $V_S$(MAX) | PACKAGE | SAMPLE AVAILABILITY* |
|---|---|---|---|---|
| IP1D10R | -55°C to +125°C | 50V | TO-66 | December 1986 |
| IP2D10W | -25°C to +85°C | 50V | Power SIP | December 1986 |
| IP3D10W | 0°C to +70°C | 50V | Power SIP | December 1986 |
| IP1D10AR | -55°C to +125°C | 80V | TO-66 | To be Announced |
| IP2D10AW | -25°C to +85°C | 80V | Power SIP | To be Announced |
| IP3D10AW | 0°C to +70°C | 80V | Power SIP | To be Announced |

*Production quantities are generally available 12 weeks after samples.

**INTEGRATED POWER SEMICONDUCTORS Ltd**

*IP3M05 (2.5A)*
*IP3M06 (1.5A)*
*IP3M13 (4 A)*

**ADVANCE DATA**

# *3Phase DC Brushless Motor Control/Drive Circuits*

## Description

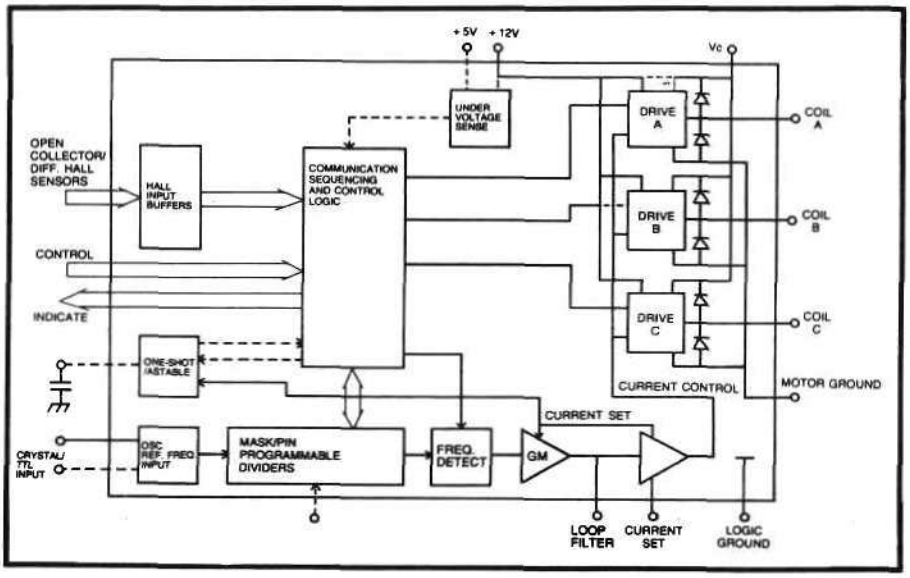
The IP3M05, IP3M06, IP3M13 linear current mode motor control/drive circuits contain all the functions necessary to run DC brushless motors in fixed speed applications. Included on the chip are: reference divider, frequency detector, loop filter, current control amps, hall amplifiers (open-collector or differential), commutation logic, motor drivers (push-pull), flyback diodes, thermal shutdown and user defined logic inputs/outputs for various system control functions.

## Features

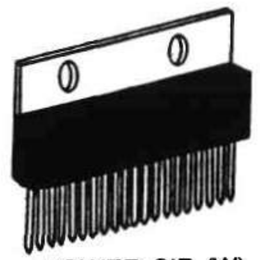
STANDARD
- Internal current sensing
- Short circuit protection
- Thermal shutdown
- Single pin loop filter
- Minimum external components
- Reference inputs to 6 MHZ

CONFIGURABLE
- Divider ratios
- Open collector/diff hall input
- Under voltage sensing (5V/12V)
- Forward/Reverse
- Start/stop run/brake
- One shot/oscillator
- Other logic functions

## Block Diagram




## Package



POWER SIP (W)

IP3M05 (2.5A) IP3M06 (1.5A) IP3M13 (4A)
3Phase DC Brushless Motor Control/Drive Circuits ADVANCE DATA

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Fax: 408/988-6185

8 Quaker Drive, West Warwick, RI 02893
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Telex: 332948 (IPS RI)
Fax: 401/823-7260

# Absolute Maximum Ratings

| PARAMETER | MIN | MAX |
|---|---|---|
| + 12 V Supply | | 15 V |
| + 5 V Sense | | 15 V |
| Logic Inputs | 0 | Vcc-2 V |
| Drive Output Current | | |
| IP3M05 | | 3.0 A |
| IP3M06 | | 1.8 A |
| IP3M13 | | 4.8 A |

| PARAMETER | MIN | MAX |
|---|---|---|
| (1) Pd ($T_a = 25°C$) | | 8 W |
| (2) Pd ($T_c = 25°C$) | | 50 W |
| Storage Temperature | -55 | 150°C |
| Junction Temperature | | 125°C |
| (1) Derate at 80 mW°C | Above | $T_a$ = 25°C |
| (2) Derate at 15 W/°C | Above | $T_c$ = 25°C |

# Electrical Characteristics (Vcc = 12V)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| | **SUPPLY** | | | | | |
| Vcc Supply Range | | ● | 7.0 | | 14 | V |
| Supply Current | | ● | | 35 | 45 | mA |
| | **MOTOR DRIVE OUTPUTS** | | | | | |
| Io (Limit) | Rset = 12.7 K | | | | | |
| IP3M05 | | ● | 2.25 | 2.5 | 2.75 | A |
| IP3MO6 | | ● | 1.35 | 1.5 | 1.65 | A |
| IP3M13 | | ● | 3.6 | 4.0 | 4.4 | A |
| V Sat | Total Drop, Both Outputs | | | | | |
| IP3M05 | Io = 2.5A | ● | | | 3.4 | V |
| | Io = 0.83A | ● | | | 2.0 | V |
| IP3M06 | Io = 1.5A | ● | | | 3.4 | V |
| | Io = 0.5A | ● | | | 2.0 | V |
| IP3M13 | Io = 4.0A | ● | | | 3.4 | V |
| | Io = 1.3A | ● | | | 2.0 | V |
| Thermal Shutdown | Junction Temperature | ● | 150 | | 180 | °C |
| | **FREQUENCY DETECTOR AND TRANSCONDUCTANCE AMP** | | | | | |
| $K_F$ gm | Rset = 12.7K, F = 60HZ | ● | 3.17 | 3.33 | 3.50 | µA/Hz |
| Off State Leakage | | | | .50 | | nA |
| | **OUTPUT CURRENT CONTROL AMP** | | | | | |
| Gain | Io/Vin | | | | | |
| IP3M05 | | ● | 0.42 | 0.60 | 0.78 | A/V |
| IP3MO6 | | ● | 0.21 | 0.30 | 0.39 | A/V |
| P3M13 | | ● | 0.56 | 0.80 | 1.04 | A/V |
| Iin | Input Bias Current | | | 50 | | nA |

# INTEGRATED POWER SEMICONDUCTORS Ltd

*IP3M05 (2.5A)*
*IP3M06 (1.5A)*
*IP3M13 (4A)*

**ADVANCE DATA**



## *3Phase DC Brushless Motor Control/Drive Circuits*

# Description

The IP3M05, IP3M06, IP3M13 linear current mode motor control/drive circuits contain all the functions necessary to run DC brushless motors in fixed speed applications. Included on the chip are: reference divider, frequency detector, loop filter, current control amps, hall amplifiers (open-collector or differential), commutation logic, motor drivers (push-pull),. flyback diodes, thermal shutdown and user defined logic inputs/outputs for various system control functions.

# Features

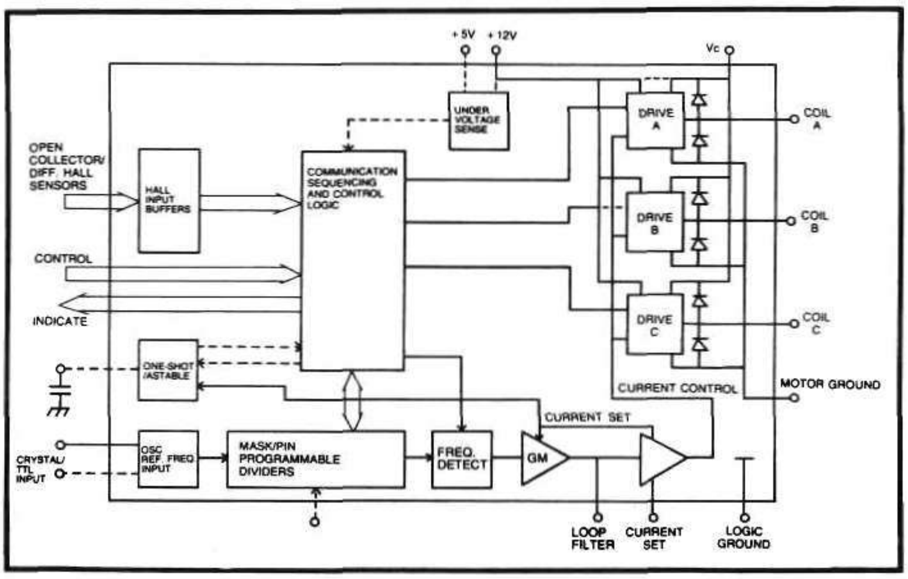
STANDARD

- Internal current sensing
- Short circuit protection
- Thermal shutdown
- Single pin loop filter
- Minimum external components
- Reference inputs to 6 MHZ

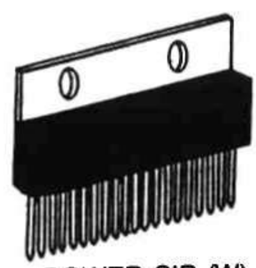
CONFIGURABLE

- Divider ratios
- Open collector/diff hall input
- Under voltage sensing (5V/12V)
- Forward/Reverse
- Start/stop run/brake
- One shot/oscillator
- Other logic functions

# Block Diagram




# Package



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# Absolute Maximum Ratings

| PARAMETER | MIN | MAX | PARAMETER | MIN | MAX |
|---|---|---|---|---|---|
| + 12 V Supply | | 15 V | (1) Pd (Ta = 25°C) | | 8 W |
| + 5 V Sense | | 15 V | (2) Pd (Tc = 25°C) | | 50 W |
| Logic Inputs | 0 | Vcc-2 V | | | |
| Drive Output Current | | | Storage Temperature | -55 | 150°C |
| IP3M05 | | 3.0 A | Junction Temperature | | 125°C |
| IP3M06 | | 1.8 A | (1) Derate at 80 mW°C | Above | $T_a$ = 25°C |
| IP3M13 | | 4.8 A | (2) Derate at 15 W/°C | Above | $T_c$ = 25°C |

# Electrical Characteristics (Vcc = 12V)

| PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **SUPPLY** | | | | | | |
| Vcc Supply Range | | ● | 7.0 | | 14 | V |
| Supply Current | | ● | | 35 | 45 | mA |
| **MOTOR DRIVE OUTPUTS** | | | | | | |
| Io (Limit) | Rset = 12.7 K | | | | | |
| IP3M05 | | ● | 2.25 | 2.5 | 2.75 | A |
| IP3MO6 | | ● | 1.35 | 1.5 | 1.65 | A |
| IP3M13 | | ● | 3.6 | 4.0 | 4.4 | A |
| V Sat | Total Drop, Both Outputs | | | | | |
| IP3M05 | Io = 2.5A | ● | | | 3.4 | V |
| | Io = 0.83A | ● | | | 2.0 | V |
| IP3M06 | Io = 1.5A | ● | | | 3.4 | V |
| | Io = 0.5A | ● | | | 2.0 | V |
| IP3M13 | Io = 4.0A | ● | | | 3.4 | V |
| | Io = 1.3A | ● | | | 2.0 | V |
| Thermal Shutdown | Junction Temperature | ● | 150 | | 180 | °C |
| **FREQUENCY DETECTOR AND TRANSCONDUCTANCE AMP** | | | | | | |
| $K_F$ gm | Rset = 12.7K, F = 60HZ | ● | 3.17 | 3.33 | 3.50 | µA/Hz |
| Off State Leakage | | | | .50 | | nA |
| **OUTPUT CURRENT CONTROL AMP** | | | | | | |
| Gain | Io/Vin | | | | | |
| IP3M05 | | ● | 0.42 | 0.60 | 0.78 | A/V |
| IP3MO6 | | ● | 0.21 | 0.30 | 0.39 | A/V |
| P3M13 | | ● | 0.56 | 0.80 | 1.04 | A/V |
| Iin | Input Bias Current | | | 50 | | nA |