

# RECENT DEVELOPMENTS IN SWITCHING POWER TRANSISTORS

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## 1. FOREWORD

The growth of power electronics, centered about the motor control field and the power supply field for information machines and other electronic equipments, has been amazing, and it is no exaggeration to say that the development of the switching bipolar junction power transistor and its application know-how have played the main role in its promotion in the past. At a glance, power semiconductor devices are considered a mature technological field, but device manufacturers are developing new products and new technologies furiously against a background of a strong demand for a technological revolution from the application engineers and the rapid advance of semiconductor technology so that it can be said that it is a field in which technological advances are being made very quickly.

The following three currents can be given as noticeable trends in recent power transistor technology.

First is the application of device technology developed for microelectronics (LSI). MOS technology, poly-crystalline silicon technology, fine patterning technology, isolation technology, etc. are applied directly or slightly arranged and efforts in developing more functional power devices or new types of devices are continuing.

Second is the strengthening of the trend toward use of the most suitable device for each application accompanying the appearance of the power MOSFET, MBT (MOS-Gate Bipolar Transistor, generally called IGBT), etc.

The third current is composite and intelligent devices. At Fuji Electric, the power transistor has advanced from single molded or can packages to composite modules incorporating multiple transistor chips and free wheeling diode chips, etc. in a single package. Recently, the "Z series" of modules with current limiting function has been commercialized as described later. For more convenient use, a module with built-in sensing function, self-protection function, drive circuit, etc. is considered to become generalized in the near future and more sophisticated thereafter.

Fuji Electric is following these technology trends and is putting special effort into the development of new products and new technology in the power transistor field.

Recent results are outlined and future development topics are discussed below.

## 2. BIPOLAR JUNCTION TRANSISTOR (BJT)

The capacity of the Fuji bipolar transistor is being increased year by year as shown in Fig. 1. By using these devices, the performance and efficiency of power conversion equipment of several hundred kVA can be increased and smaller and lighter equipment is realized.

Concurrently with high capacity, still higher performance centered about  $h_{FE}$ , switching characteristic, short-circuit withstand capability, etc. is planned by the positive advance of fine patterning technology, carrier lifetime control techniques, CVD technology, and other production process sophistication.

The short-circuit withstand capability of the "Z series" power transistor module was improved through Fuji Electric's original technology and broke through the performance limits barrier of the bipolar transistor (see Fig. 2) and expands its range of applications to new fields.

The ringing-choke-type converter is widely used in the of small electronic equipment because of power supply field its circuit configuration ease. This time, the TO-220 and

Fig. 1 Power transistor development process

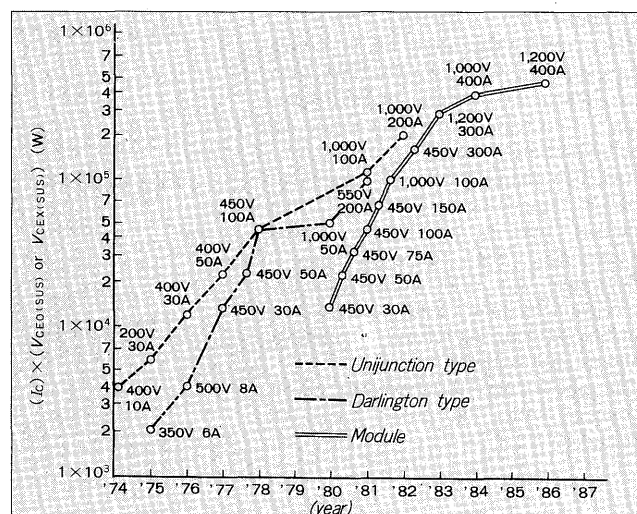
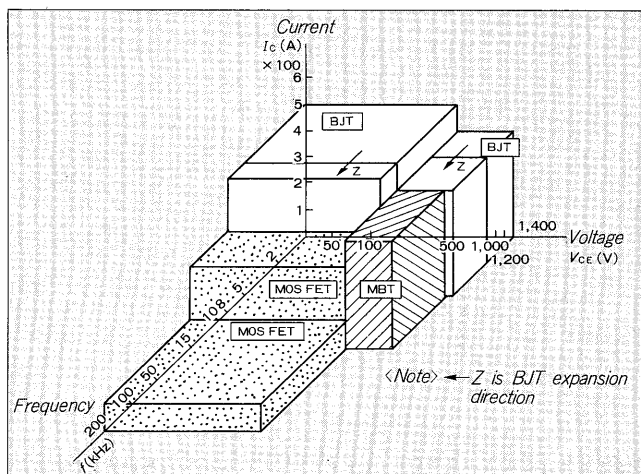


Fig. 2 Application region of various power transistors



TO-3P type high  $h_{FE}$  switching transistors have been developed and the realization of an efficient power supply has been made possible.

### 3. POWER MOSFET

The fields of application of the voltage-gate-driving-type power MOSFET, which has excellent switching characteristics, is steadily expanding even while its main application today is switching power supplies. Fuji Electric has almost completed a current and voltage series which can meet the demands of the market. In this serialization, the aim was realization of an easy-to-use device by developing on-state voltage reduction technology and cell fine patterning technology, in particular. Moreover, the switching mechanism was analyzed by applying CAD simulation techniques and a high-speed switching type second generation product series with improved input capacity ( $C_{iss}$ ) related to the gate charge characteristic was provided.

In an actual circuit it is of primary importance that the semiconductor devices used do not be destroyed easily. With the power MOSFET, improvement of the L-load ruggedness at the switching circuit is a specific demand. Therefore, Fuji Electric have made an effort and developed new line-up of MOSFET with improved L-load ruggedness. Against the demand for high power, Fuji Electric developed the power modules which eliminate troubles of parallel connection of small devices and contribute to the miniaturization of electronic equipment. The market demand for higher performance and functions is increasing and improvement of on-state resistance, low evingor threshold voltage (logic level), speeding up of internal diodes, integrating of control circuit (smart power), etc. are steadily being realized.

### 4. MBT

The bipolar type and MOS type transistors have built a position in today's application fields while being compe-

titive by utilizing their individual features. However, in the high frequency and high power fields which intervene between both types, it is considered that the technological revolution toward its realization will continue in the future under the close cooperation of the device engineers and the application engineers. Fuji Electric has begun development of an MBT (MOS-Gate Bipolar Transistor) and is advancing commercialization aimed at the ideal switching device based on our long power element experience. The 600V series and 1,200V series MBT modules are available and application to all power supply systems is intended. From the standpoint of performance, a noticeable improvement of the audio frequency band noise and dead-time control trouble which are problems with PWM control is expected.

Currently, the application region of various power transistors visualized by Fuji Electric is Fig. 2. It is considered that the technology revolution of these devices in the future will be accompanied by an expansion of this region.

## 5. APPLICATION TECHNOLOGY

Power transistor application technology is an old and new problem. Because of the large difference in the performance of devices brought out by the different level of application technology, the development of the application technology is very important. The systemization of power transistor application technology also involves difficult problems, which Fuji Electric is tackling. The summarization of drive technology, protection technology, parallel operation technology, etc. was recently completed.

## 6. FUTURE DEVELOPMENT TOPICS

In the power electronics field, increasing the power and frequency is the focus of attention. Based on expansion of the application fields of electronic equipment and the accumulation of experiences, there are some examples where the usage conditions of semiconductor devices press these limits at times. For semiconductor elements to amply display their performance, the incorporation of basic protection functions against overvoltage, overcurrent, and overheating which were performed by an external control circuit in the past is being attempted. Such "intelligent switching device" with "ease-of-use" and "multiple functions" added is a big topic of the future. In addition, the "intelligent switching device" can be expected to play the role of ASIC in the field of power devices by adding series-arm-short-circuit protection, sequence circuit, etc. according to the application.

Fuji Electric is forcefully promoting improvement of the performance of various devices and research and development of new devices. Furthermore, by collecting and analyzing market demands Fuji Electric will promote the commercialization of "intelligent switching devices" which are easy to use and highly reliable to the user.