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HIGH h_{FE} POWER TRANSISTOR MODULE

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1. FOREWORD

Bipolar power transistor modules are widely used in transistorized inverter circuits, i.e. general purpose inverters, NC machine tools, or robots and the other power electronics products. The demand for bipolar power transistor modules suitable for these applications is increasing yearly. In these power electronics products, the need to reduce the drive power of power transistors for increase the efficiency and reduce the size of equipment and the need to apply common drive circuits to inverter circuits of various capacities to rationalize equipment design and production are increasing. To meet these needs, a new high h_{FE} power transistor modules line-up was developed. This line-up is backed by the optimum chip pattern design and the fine patterning technology and the analysis and application technology which are developed by the Fuji Electric. An h_{FE} (DC current gain) of tens times as high as that of existing types was realized and drive by a 0.1A base current was made possible by optimizing the n-p-n structure triple Darlington chip pattern and miniatrizing the cell size. Moreover, by specifing the h_{FE}, which did not depend on the rated collector current but was fixed in the past, in propotional to the rated collector current transistors of different current ratings can be driven by the same base current. The base drive power is reduced, the power supply for driving is made smaller, and the drive circuit is made common by means of these features. This paper outlines the development aim and chip design, line-up, and rated characteristics of the 30A to 150A models of the 500V class high h_{FE} power transistor developed this time.

2. DEVELOPMENT AIM

2.1 Reduction of base driving power

Since the bipolar transistor is a current control type semiconductor device, base current (I_B) must flow continuously to maintain the on-state. Because the h_{FE} of conventional power transistors for inverter circuits is about 75, to obtain a suffeciently low saturation voltage even when the junction temperature is high, an I_B of 1/50 of the rated current is necessary. If this I_B can be made small, since the power consumption of the base driving power supply can be made small and a smaller power supply than in the past can be used, the equipment becomes smaller. The high h_{FE} type is aimed at raising the h_{FE} as shown and allowing drive by an I_B of 1/10 or less than that of existing types as shown in *Table 1*.

Table 1 Comparison of h_{FE}, base current, and t_{stg} of existing type and high h_{FE} type

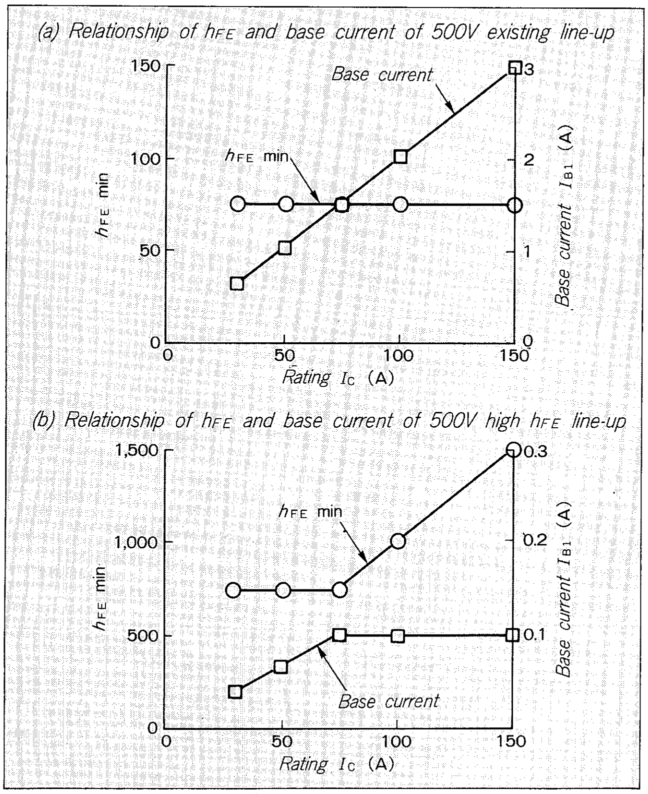
Item	Existing type 2DI50D050A	High h_{FE} type 2DI50M-050
Rated collector voltage (V_{CBO})	600V	600V
Rated collector current (I_C)	50A	50A
DC current gain (h_{FE})	min 75 (I_C = 50A, V_{CE} = 2V, T_j = 25°C)	min 750 (I_C = 50A, V_{CE} = 2.5V, T_j = 125°C)
Base current necessary for drive	1.0A	67mA
Storage time (t_{stg})	max. 12μs (I_C = 50A, I_{B1} = 1A, I_{B2} = −1A, T_j = 25°C)	max. 8μs (I_C = 50A, I_{B1} = 67mA, I_{B2} = −1A, T_j = 25°C)

2.2 Standardization of base current

Power transistors of various collector current ratings matched to the rated inverter capacity are used in inverter equipments.

Fig. 1 shows the relationship of the power transistor collector current rating and h_{FE} and required base current. Because the h_{FE} of the conventional power transistor module line-up does not depend on the collector current rating, but is constant as shown in *Fig. 1*(a), I_B must be increased in proportion to the current rating. However, to increase I_B, it is not only necessary to change the resistor in the drive circuit, but also to increase the capacity of the driving power supply and change the transistor for forward biasing. The inverter designer had to design a different base driver circuit board for each inverter of different capacity. The desire to drive power transistors of various rated

Fig. 1 Relationship of rated current and h_{FE} and base current of existing line-up and high h_{FE} line-up



collector current with the same circuit is a need of the inverter designers. The aim of the high h_{FE} type was the ability to be driven by the same I_B as shown in *Fig. 1*(b) setting the h_{FE} value proportional to rated collector current, especially for modules of 75A or higher on which this problem is large.

2.3 Shortening of t_{stg}

In an inverter circuit, to prevent the transistors of the upper and lower arm from getting to the on-state simultaneously and short-circuiting, the interlock time (t_d) is set and circuit is designed so that the transistor storage time (t_{stg}) does not exceed t_d. However, this t_d causes the inverter output sine wave to be distorted and should be as short as possible. Since the length of t_d is determined by the t_{stg} of the transistor, shortening of t_{stg} is need of the inverter designer.

The high h_{FE} module was aimed at shortening of the t_{stg} to 2/3 of that of existing types as shown in *Table 1* to improve the inverter output waveforms.

3. HIGH h_{FE} POWER TRANSISTOR CHIP DESIGN

As previously described, the high h_{FE} power transistor module is aimed at power reduction and standardization of the drive circuit by the realization of a high h_{FE} and shortening of the inverter interlock time by improvement of the t_{stg}. However, there is a tradeoff relationship between h_{FE} and t_{stg}. The higher h_{FE}, the longer t_{stg}. As the h_{FE} is increased, the transistor breakdown voltage and RBSOA decrease. Therefore, to realize a high h_{FE} and short t_{stg} simultaneously and to prevent the drop of the breakdown voltage and RBSOA, it is necessary to optimize the chip pattern design. There are the following two main points.

(1) The area ratio of each stage of the triple Darlington chip pattern must be optimized.

(2) The cell size must be made fine.

The high h_{FE} power transistor chip has the npn triple Darlington structure shown by the equivalent circuit shown in *Fig. 2.*

The h_{FE} characteristics and t_{stg} characteristics of this Darlington transistor change with the area ratio of the three transistors as shown in *Fig. 2.* A high h_{FE} and short t_{stg} were realized by making this area ratio the optimum value.

Moreover, a wide RBSOA was realized even with high h_{FE} characteristics by making cell sizes smaller than in the past.

4. LINE-UP AND RATED CHARACTERISTICS AND TYPICAL CHARACTERISTICS CURVES

4.1 Rated characteristics of high h_{FE} power transistor module line-up

The main rated characteristics, exterior views, and an equivalent circuit example are shown in *Table 2*, *Fig. 3* and *Fig. 2* respectively. All the models in this line-up have a V_{CBO} breakdown voltage of 600V or greater and $V_{CEO(SUS)}$ and are applicable to AC220V input voltage inverters. Two-pack modules with collector current ratings from 30A to 150A and six-pack modules with collector current ratings from 30A to 75A have been developed this time. Since the h_{FE} value are the minimum value at $T_j = 125°C$, a drop of h_{FE} due to a rise of T_j does not have to be considered. The base current necessary for drive is found from $I_B = I_c/h_{FE}$ min. Since the h_{FE} min. value of modules above 75A increases in proportion with the collector current rating as shown in *Table 2*, drive by a base current of 0.1A is possible.

The t_{stg} characteristic is a guaranteed maximum 8 μs for all models, which is 2/3 shorter than the 12 μs of the existing type.

Since the package of this line-up is the same as the

Fig. 2 2DI50M-050 equivalent circuit

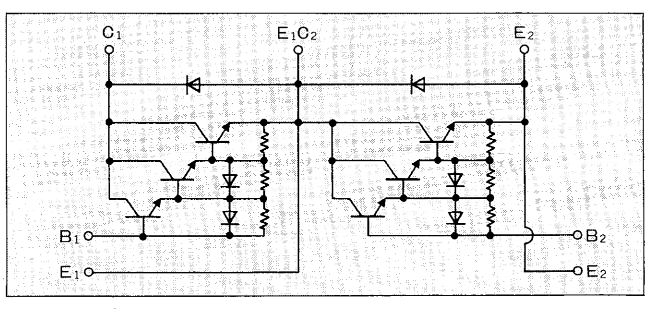


Table 2 Rated characteristics of high h_{FE} power transistor module line-up

	Type designation	V_{CBO} (V)	V_{CEO} (V)	V_{CEO} (sus) (V)	I_C (A)	P_C (W)	h_{FE} (T_j = 125°C)			Switching time (T_j = 25°C)					
								I_C (A)	V_{CE} (V)	t_{ON} (μs)	t_{stg} (μs)	t_f (μs)	I_C (A)	I_{B1} (A)	I_{B2} (A)
2-pack module	2DI30M-050	600	600	450	30	250	750	30	2.5	3.0	8.0	3.0	30	0.04	–0.6
	2DI50M-050	600	600	450	50	310	750	50	2.5	3.0	8.0	3.0	50	0.067	–1.0
	2DI75M-050	600	600	450	75	350	750	75	2.5	3.0	8.0	3.0	75	0.1	–1.5
	2DI100M-050	600	600	450	100	620	1000	100	2.5	3.0	8.0	3.0	100	0.1	–2.0
	2DI150M-050	600	600	450	150	690	1500	150	2.5	3.0	8.0	3.0	150	0.1	–3.0
6-pack module	6DI30MA-050	600	600	450	30	200	750	30	2.5	3.0	8.0	3.0	30	0.04	–0.6
	6DI50MA-050	600	600	450	50	250	750	50	2.5	3.0	8.0	3.0	50	0.067	–1.0
	6DI75MA-050	600	600	450	75	350	750	75	2.5	3.0	8.0	3.0	75	0.1	–1.5

Fig. 3 Exterior view of high h_{FE} power transistor line-up

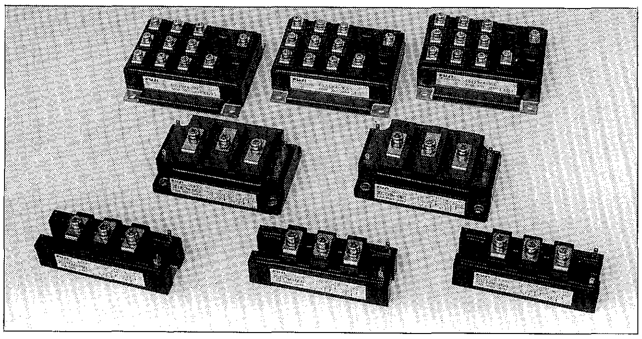
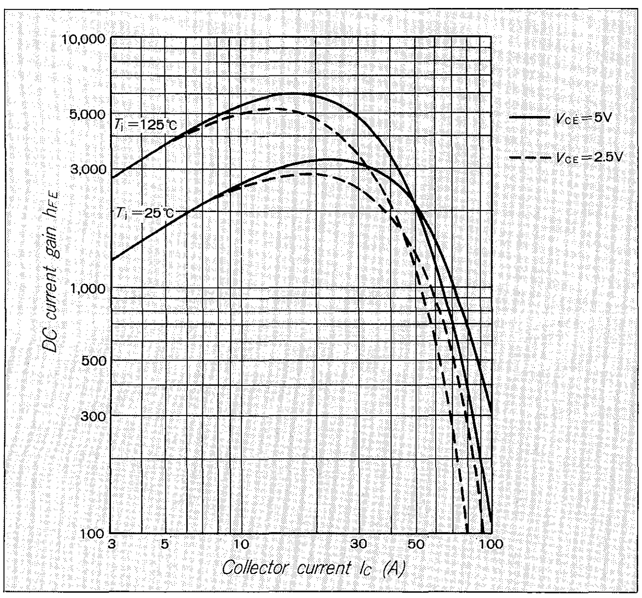


Fig. 4 2DI50M-050 h_{FE}-I_C characteristics



existing type as shown in *Fig. 3*, the existing type can be easily replaced.

4.2 Typical characteristics

The h_{FE}-I_C characteristic, switching time character-

Fig. 5 2DI50M-050 switching time characteristics

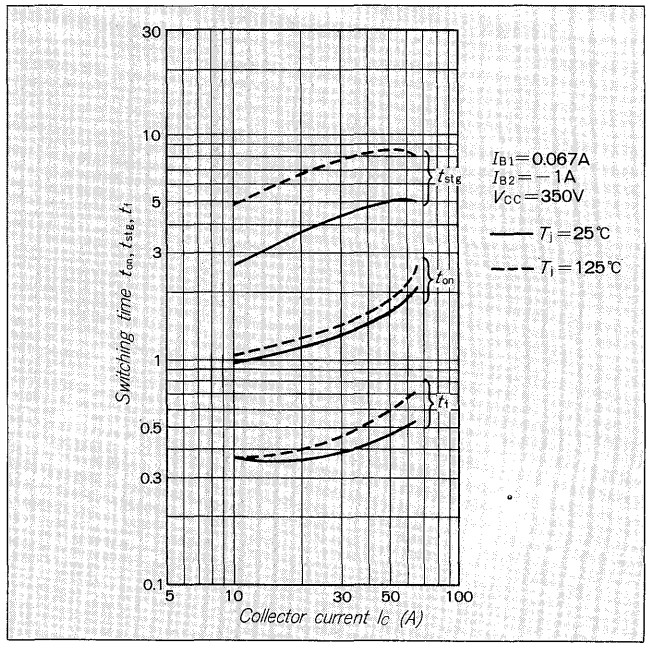
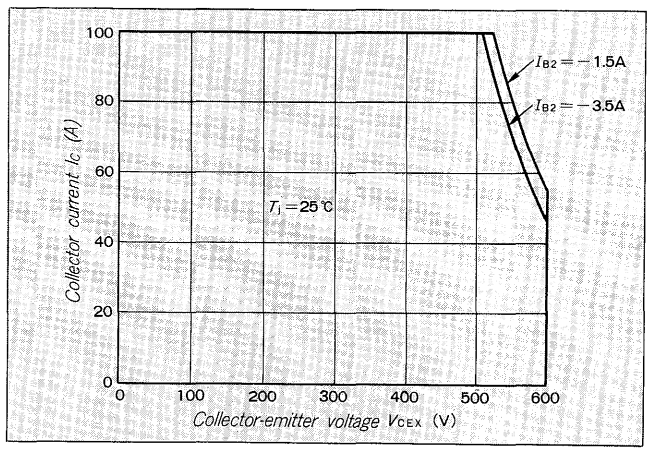


Fig. 6 2DI50M-050 RBSOA



istics, and RBSOA of the 2DI50M-050, 50A two-pack module, are shown in *Fig. 4*, *Fig. 5*, and *Fig. 6* as typical of this line-up. The high h_{FE} line-up with wide RBSOA in addition to high h_{FE} and excellent switching characteristics are easy-to-use power transistor modules.

5. CONCLUSION

The development aims, chip design, and outline of the characteristics of the high h_{FE} power transistor modules were introduced. We are confident that these new products developed to reduce drive base current, standardize the drive circuit, and shorten the storage time of the bipolar transistor will contribute to making inverter equipment more efficient and higher performance and smaller size and lighter weight. We plan to complete this line-up and to make efforts to meet the expectations of customers in the future.