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SWITCHING TRANSISTORS FOR RINGING-CHOKE CONVERTER

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1. FOREWORD

Television sets, audio equipment, and other electrical home appliances and OA equipment, typified by the personal computer, and other electronic equipment require a DC regulated power supply. Because of the social demand for energy-saving, miniaturization, and high performance of recent years, the switching system has become the mainstream of the DC regulated power supply used with these equipment. There are various switching power supply systems. However, because its circuit configuration is simple and cost reduction is possible, the RCC (Ringing-Choke Converter) is most widely used as power supplies with a comparatively low output capacity.

Fuji Electric has serialized various power transistors for switching power supply use and has now developed and commercialized a bipolar transistor suitable for RCC switching power supplies use.

2. RCC SWITCHING POWER SUPPLY

2.1 Low capacity switching power supply

The recent trend of switching power supplies is the use of one-transistor type converter from the standpoints of number of parts, cost, and size and this system has become the mainstream for low capacity use. One-transistor power supplies can be roughly grouped into RCC system and Forward converter system. These two systems are compared in *Table 1*. As shown in *Table 1*, the RCC system and Forward converter system have advantages and disadvantages. However, the RCC system has become the mainstream of low capacity power supplies up to 100W class because the circuit is simple, the number of parts is small, and it is cheap.

Table 1 Comparison of RCC system and forward converter system

Item	RCC	Forward converter
Number of parts	Small	Large
Drive circuit	Simple	Complex
Filtering choke	Unnecessary	Necessary
Operation	ON-OFF	ON-ON
Power supply capacity	100W or less	50 ~ 100W

2.2 Basic circuit and operation of RCC system

The basic circuit of the RCC system is shown in *Fig. 1* and its operation waveforms are shown in *Fig. 2*.

Fig. 1 Basic circuit of RCC system

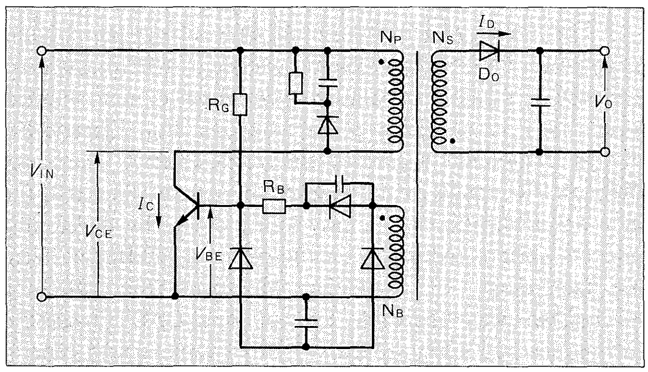
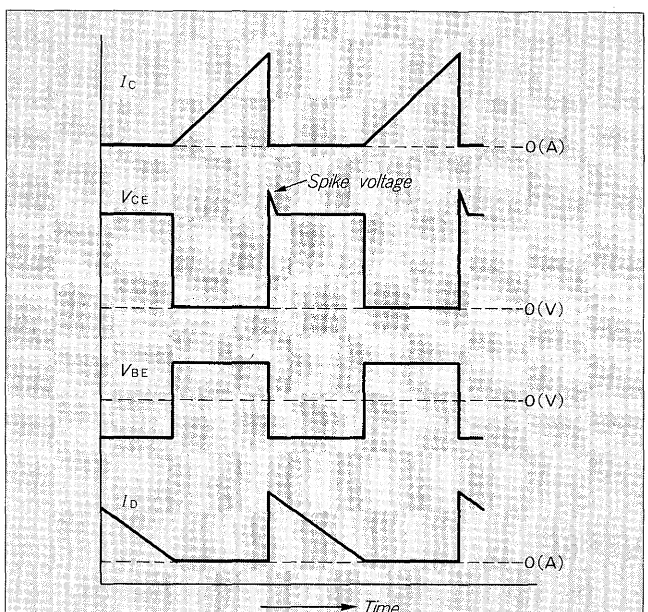


Fig. 2 Operation waveform of each part of RCC system



Referring to *Fig. 1*, when the input voltage is applied, base current flows to the transistor through starting resistor R_G, the transistor is turned on, transformer primary winding (N_p) is excited, the transistor is forward biased by the voltage induced in the base winding (N_B), and as a result, the collector current increases. This increases the voltage induced in the base winding (N_B) and the transistor is turned on quickly. The collector current increases linearly as shown in *Fig. 2*, and if the relationship with h_{FE} is made,

$$h_{FE} \leqq I_C/I_B$$

the transistor shifts to the active region, the collector voltage rises, the EMF of transformer primary winding (N_P) and base winding (N_B) drop, and the transistor is turned off. The RCC system repeats the above switching and stores energy in the transformer during the period the transistor is on and outputs this energy to the load through rectifier diode D_O when the transistor is turned off. The operating frequency changes with the input voltage and state of the load and decreases as the input voltage decreases and the load increases.

2.3 Transistor characteristics demanded for RCC

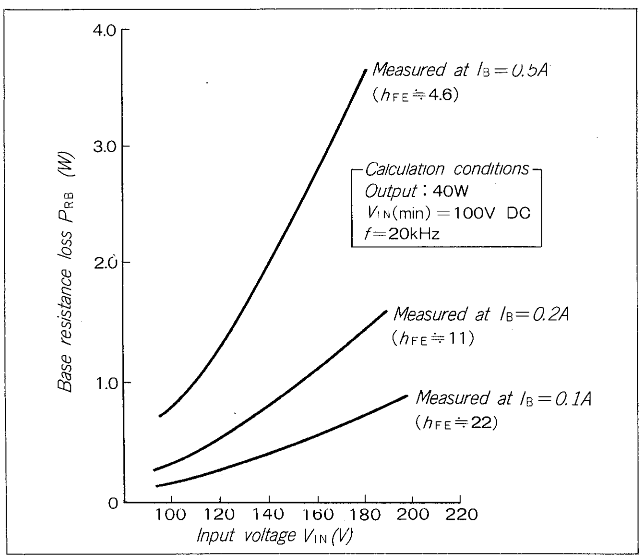
The RCC system is a switching power supply which used self-excited oscillation and considering low cost, small size, and high efficiency, transistors for RCC must have the following characteristics:

(1) High h_{FE}

If the h_{FE} is made relatively high in the low current region, the loss of the starting resistor R_G can be reduced and the transistor can be started stably.

Base resistor R_B is selected so that base current is such that the transistor can be turned on at minimum input and maximum load. Since the base current is supplied by the EMF of the base winding as shown in *Fig. 1*, it changes with the input voltage. Therefore, when a constant current circuit is not provided at the base circuit, the loss across the base resistor R_G changes with the input voltage as shown in *Fig. 3* and the input voltage dependence of the base resistance loss increases as the base current set value increases. Therefore, the value of base resistance R_B can be increased as h_{FE} is increased and the loss across R_B can be reduced.

Fig. 3 Relationship between base resistance loss and input voltage



(2) Small h_{FE} variation

Because the RCC system uses self-excited oscillation, large h_{FE} variations cause such problems as:

(a) High peak collector current at starting.

(b) Abnormal oscillation caused by delay of control system at sudden load changes.

(3) Excellent high-speed switching characteristic

To meet the demand for small size and light weight, the trend in switching power supplies is toward higher operating frequencies for the purpose of making the transformer, etc. smaller. This also applies to the RCC system. For this reason, a short transistor switching times (especially t_{stg}) and low switching loss are demanded.

(4) High withstand voltage and wide RBSOA (Reverse Biased Safety Operating Area)

During the off period, the sum of the input voltage and transformer counter EMF is applied to the transistor. The value of this voltage is double the value of the input voltage. When the transistor is turned off, a spike voltage determined by the leakage inductance of the tnrasformer and the snubber circuit is superimposed on this voltage. Therefore, the transistor must have a high withstand voltage of about 2.5 times the input voltage. A wide RBSOA is also necessary.

3. FUJI SWITCHING TRANSISTORS FOR RCC POWER SUPPLIES

3.1 General

(1) Packaging

Packaging of the RCC transistors are shown in *Fig. 4*. Two packages are available: TO-220AB and TO-3P molded type.

(2) Series and characteristics

The main ratings and characteristics of the RCC transistors are shown in *Table 2*. The h_{FE}–I_C characteristics, switching time characteristics, and RBSOA of the 2SC4273 are shown in *Figs. 5, 6, 7,* and *8* as a typical example of the RCC transistors.

3.2 Features of RCC transistors

As described in paragraph 2.3, an important characteristic of an RCC transistor is h_{FE}. The h_{FE}, V_{CEO} and

Fig. 4 Exterior views of RCC transistors

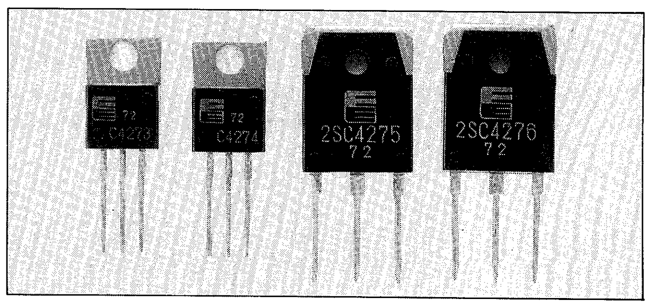


Table 2 RCC transistor ratings and characteristics

Model	V_{CBO} (V)	V_{CEO} (V)	$V_{CEO(SUS)}$ (V)	I_C (A)	P_C (W)	h_{FE} min			Switching time			Package
							I_C (A)	V_{CE} (V)	t_{on} (μs)	t_{stg} (μs)	t_f (μs)	
2SC4273	500	400	400	5	40	20	2	5	1.0	2.5	0.5	TO-220AB
2SC4274	500	400	400	10	40	20	4	5	1.0	2.5	0.5	TO-220AB
2SC4275	500	400	400	10	80	20	4	5	1.0	2.5	0.5	TO-3P
2SC4276	500	400	400	15	80	20	6	5	1.0	2.5	0.5	TO-3P

Fig. 5 2SC4273 $h_{FE}-I_C$ characteristics

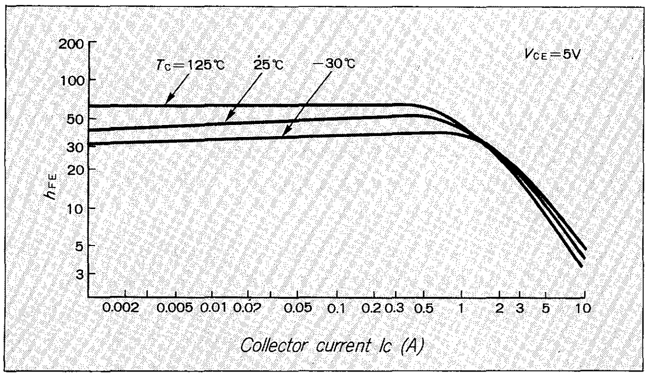


Fig. 6 2SC4273 saturation voltage characteristics

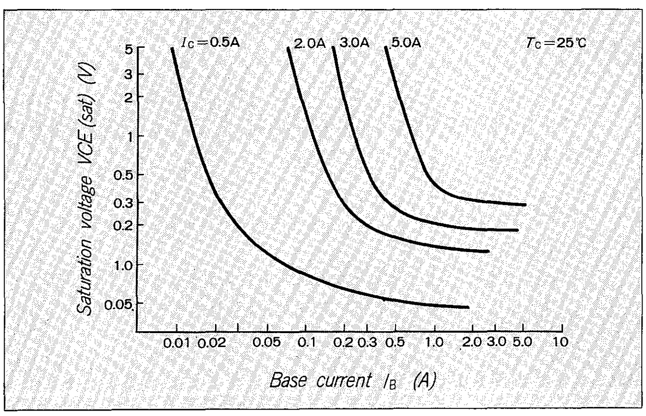


Fig. 7 2SC4273 switching time characteristics

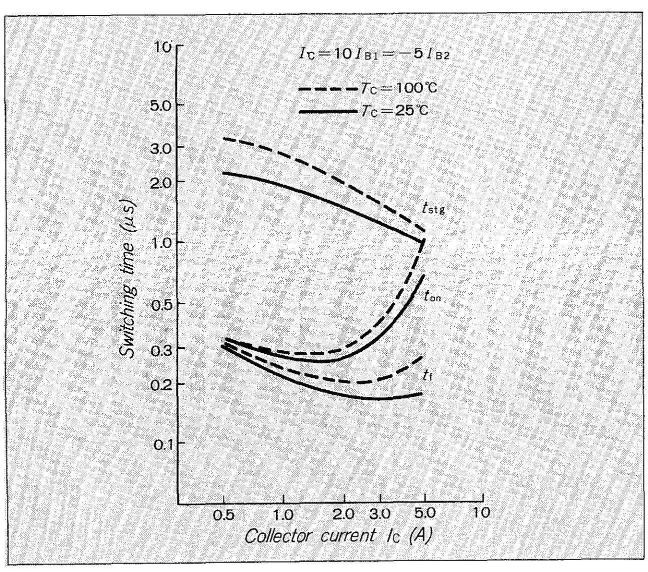


Fig. 8 2SC4273 RBSOA

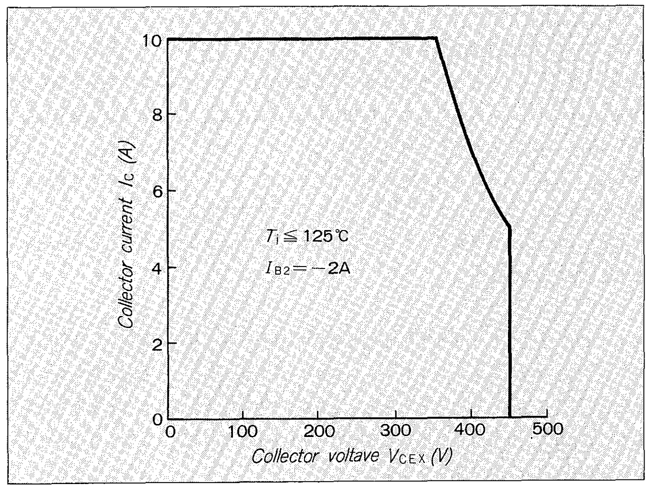
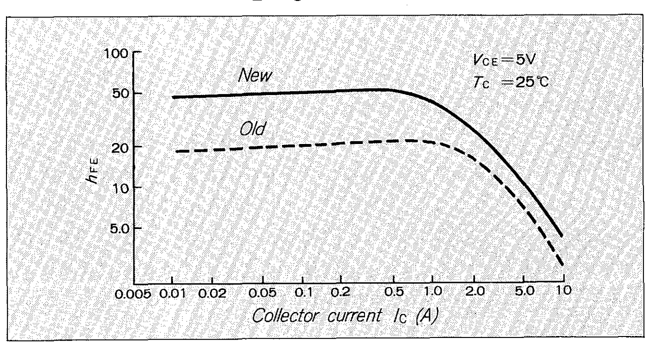


Fig. 9 Comparison of $h_{FE}-I_C$ characteristics



t_{stg} of a transistor have a trade-off relationship and improving the h_{FE} only is difficult. Fuji RCC transistors are designed to optimize the crystal resistivity, thickness of high impedance layer (N^-) and lifetime control and have the features described below.

The features of the 400V/5A transistor are described here as a typical example while comparing them to our old product.

(1) High h_{FE}

As shown in *Fig. 9*, the $h_{FE}-I_C$ characteristic is higher than that of the old product over the entire I_C region. A high h_{FE} is also obtained in the low current region which is a problem at starting.

The relationship between the output and base current when a transistor having the h_{FE} cahracteristic shown in *Fig. 9* was used is shown in *Fig. 10*. From *Fig. 10*, when this transistor is used with a 50W power supply, the base

Table 3 RCC transistor h_{FE} ranking

h_{FE} rank	h_{FE} range
01	25 ~ 40
02	35 ~ 55

Fig. 10 Relationship between output capacity of power supply and base current (calculated value)

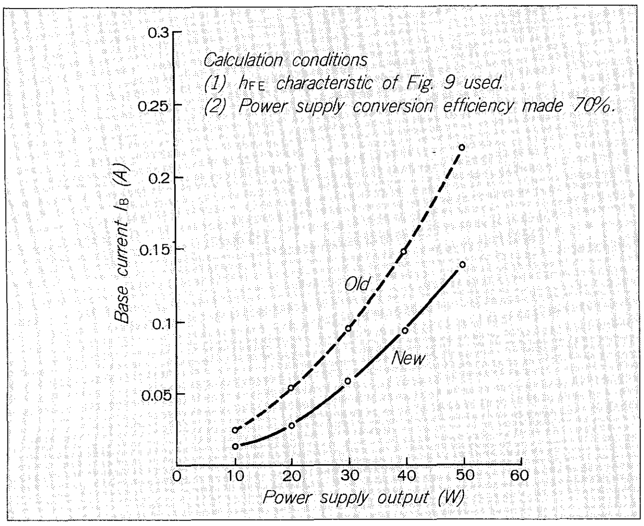
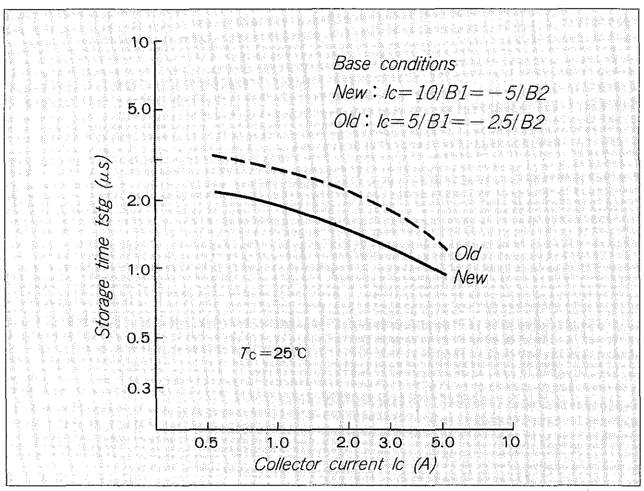


Fig. 11 Comparison of $t_{stg}-I_C$ characteristics



current and base resistance loss about 1/2 those of the old type.

(2) h_{FE} ranking

As descirbed in paragraph 2.3, RCC transistor must have small h_{FE} variations. From actual installation investigation of RCC power supplies, the variation range should be ±30% or less and the h_{FE} is ranked as shown in *Table 3.*

(3) Switching characteristics

The $t_{stg}-I_C$ characteristics are compared in *Fig. 11.* The RCC transistor shows a characteristic equal to, or better than, that of the old type over the entire I_C region.

Currently, the operating frequencies of RCC systems are mainly 20 to 30 kHz. However, as shown in *Table 2*, the maximum switching times of the new transistors are t_{on}=1.0 μs, t_{stg}=2.5 μs, and t_f=0.5 μs and they have amply applicable characteristics.

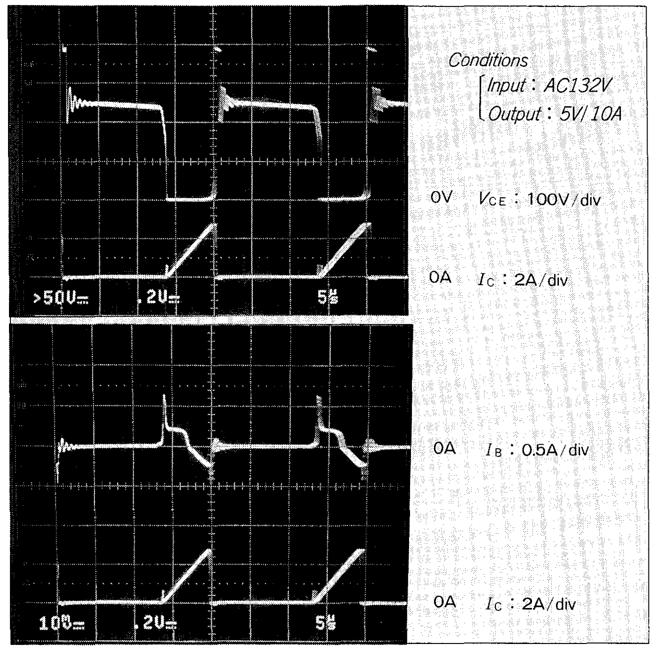
(4) RBSOA

If the input is made AC100V and the spike voltage is made 100V, the collector-emitter voltage when the transistor is turned off is,

$$V_{CE} \doteqdot 100 \times 1.1 \times \sqrt{2} \times 2 + 100 = 411(\text{V})$$

As shown in *Fig. 8*, the RBSOA of the new type is $V_{CEX} \geqq 450$(V) at the rated I_C and it has an ample withstand capacity for a 100V AC input RCC system.

Fig. 12 Operation waveforms of 2SC4276 in RCC power supply



4. APPLICATION EXAMPLE

The operation waveforms when the 2SC4276 (400V/15A) developed this time was installed in an 85 to 132V AC input, 50W output RCC type power supply are shown in *Fig. 12.*

5. CONCLUSION

The aim of development of the RCC transistors and their features were introduced above. Switching power supplies will tend to become smaller and more efficient in the future and higher performance devices will be demanded. Fuji Electric will accurately match the needs of the market and puts it efforts into developing new products which meet these needs.

Finally, we wish to thank the users and concerned parties who cooperated in the development of this transistor series and request their guidance in the future.