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1500V IGBT FOR CRT HORIZONTAL DEFLECTION CIRCUIT

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1. FOREWORD

Recently, color television picture by CRT as the mass media or picture of CRT display as man machine interface has been increasing certainly in our life. Moreover, more higher difinition and higher resolution pictures than current pictures are demanded from the market. Now, technology of CRT picture has been turning toward new technological innovation.

With the rapid increase in the popularity of large screen color television, clear vision (EDTV) and high vision (HDTV) are attracting attention. Partial broadcasting has already begun and special television receivers are being marketed as high quality sets and have become a topic of conversation. In this need for advanced CRT pictures, the need for technology to control the electron beam at a higher speed and higher precision than in the past and the semiconductor power devices that support has increased. The Fuji Electric 1,500V withstand voltage, high speed IGBT (1MB12-150) developed by focusing attention on the characteristics of the IGBT as a new semiconductor device for horizontal deflection circuit which can deflect the CRT of the monitor display which are increasingly demanded at high speed is introduced.

Table 1 Absolute maximum ratings (T_a = 25°C)

Item		Symbol	Maximum rating	Units
Collector-emitter voltage		V_{CE}	1500	V
Gate-emitter voltage		V_{GE}	±20	V
Collector current		I_C	12	A
Collector current	Pulse 50μs	I_{CP}	60	A
Collector power loss		P_C	100	W
Junction temperature		T_j	+150	°C
Storage temperature range		T_{stg}	−40~+150	°C

Table 2 Typical electrical characteristics (T_a = 25°C)

Item	Symbol	Conditions	MIN	MAX	Units
Collector-emitter breakdown voltage	$V_{(BR)CES}$	I_C = 1mA, V_{GE} = 0V	1500		V
Gate leakage current	I_{GES}	V_{CE} = 20V, V_{GE} = 0V		100	nA
Collector cutoff current	I_{CES}	V_{CE} = 1,500V, V_{GE} = 0V		1	mA
Gate-emitter threshold voltage	$V_{GE(th)}$	V_{CE} = V_{GE}, I_C = 10mA		4	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	I_C = 12A, V_{GE} = 15V		5	V
Input capacitance	C_{iss}	V_{GE} = 0V, V_{CE} = 25V, f = 1MHz		2000	pF
Switching characteristic ①	t_{f1}	I_C = 12A, V_{CE} = 15V		0.2	μs
Switching characteristic ②	t_{f2}			1.0	μs
Switching characteristic ③	t_{off}			1.2	μs
Switching characteristic ④	I_{off}			1.0	A
Thermal resistance	$R_{th(j-c)}$			1.25	°/W

2. OVERVIEW OF PRODUCT

The ratings and typical characteristics of the IGBT 1MB12-150 developed as new product are shown in *Table 1* and *Table 2*. Considering ease use, the package was made the TO-3P full molded type shown in *Figure 1*. The basic construction and equivalent circuit are shown in *Fig. 2* for reference.

Fig. 1 1MB12-150

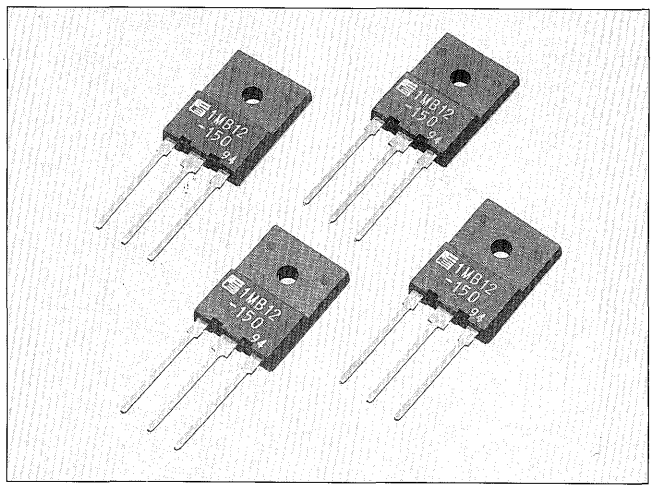

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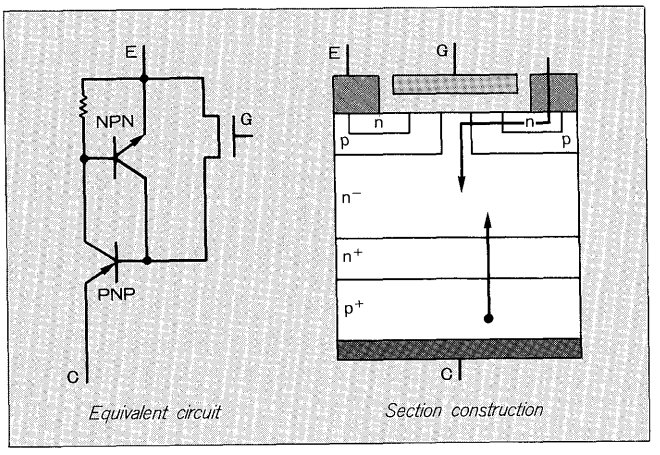
Fig. 2 IGBT equivalent circuit and section construction



3. CHARACTERISTICS

Figure 3 is an example of a typical horizontal deflection circuit used in modern color television sets with IGBT applied. The horizontal deflection circuit consists of a half-wave resonant converter. Its voltage waveform is a since wave 90° out of phase with the current. When switched ideally, the swiching loss is minimized. However, when an actual semiconductor device was used, the minority carrier storage effect produced switching loss. That is, the biggest problem in IGBT development was, of course, how to speed up this switching characteristic.

3.1 Switching characteristic

The principal causes of generation of a switching characteristic in a horizontal circuit is commutation of the energy ($=1/2Li^2$) of the deflection coil at the resonant capacitor and generation of a sine wave voltage when the current ($= i_c$) flowing in the deflection coil L at the circuit of *Fig. 3* is interrupted. This voltage is applied to the IGBT. The operation mode inside the IGBT at this time is outlined as a concept drawing in *Figure 4*. The IGBT shifts from the conducting state of *Figure 4* (a) to the voltage impression state of *Figure 4* (b) simultaneously with turn off. At this time, the depletion layer spreads to the n^- layer according to the applied voltage and the carrier holes and electrons are pushed out to the p^+ and n^- layers, respectively. Part of these pushed out electrons are injected to the p^+ layer region and holes are injected to the n layer from the p^+ layer and become a current and a switching characteristic is exhibited. The problem is how to suppress the effect of these injected carriers at switching. The new 1MB12-150 solves this problem by the following method:

(1) Study and selection of optimum lifetime killer.
(2) n^- layer impurity density and thickness
(3) n^+ buffer layer impurity density and thickness.
(4) Optimization of device structure

The switching characteristic when actually operated at a horizontal deflection circuit is shown in *Fig. 5*. It can be seen that it is a very sharp switching characteristic waveform. At the same time, the operating waveform of a high-speed type bipolar transistor current used in EDTV under the same conditions is shown as reference for comparison. (*Figure 5*).

Fig. 3 Concrete example of horizontal deflection circuit using an IGBT

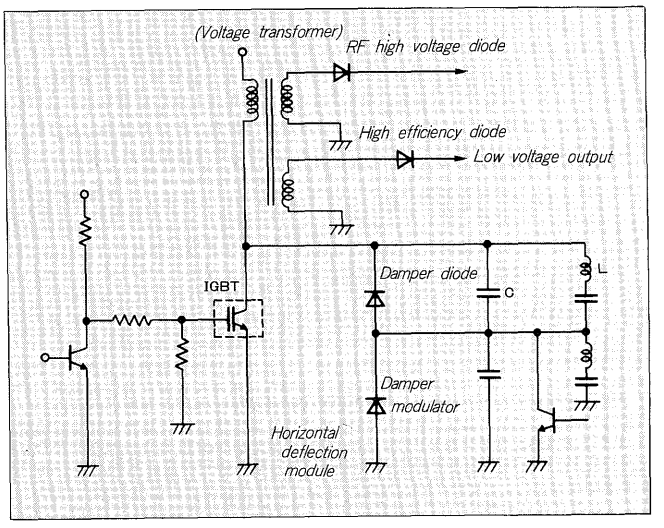


Fig. 4 Switching characteristic generation mechanism

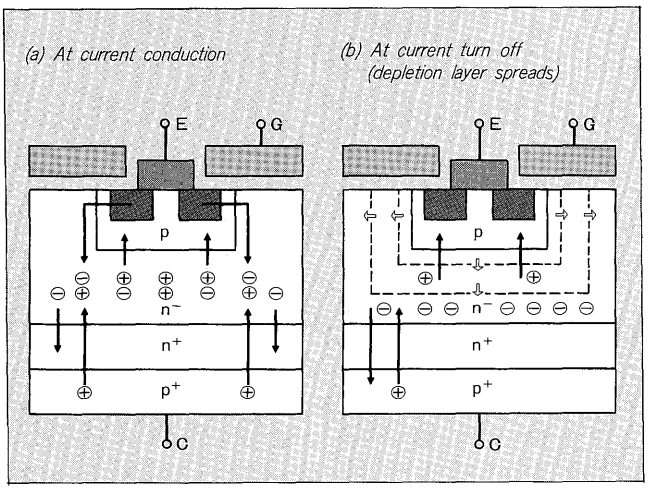
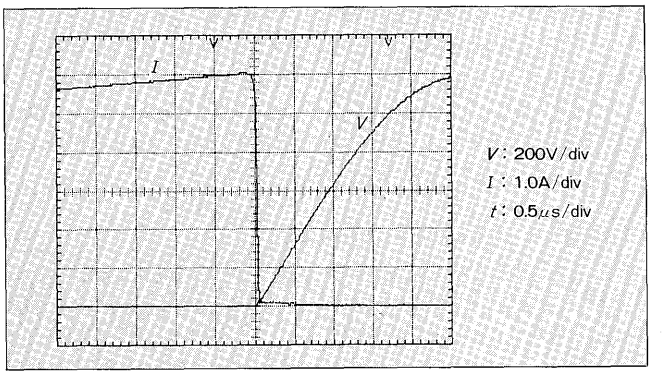


Fig. 5 Typical switching characteristics of 1MB12-150 (T_a = 25°C)



3.2 1500V high withstand voltage design

A general horizontal deflection circuit usually

Fig. 6 Switching characteristics of bipolar transistor (T_a = 25°C)

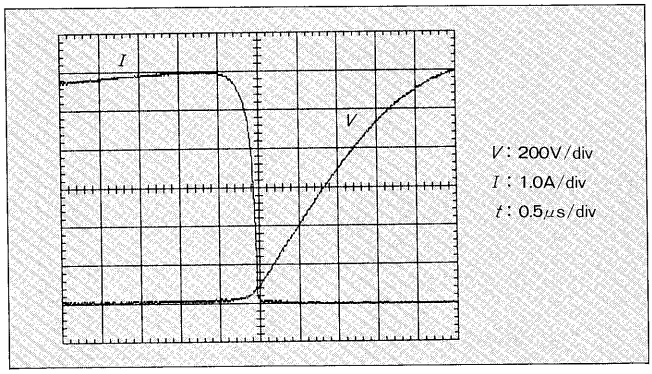
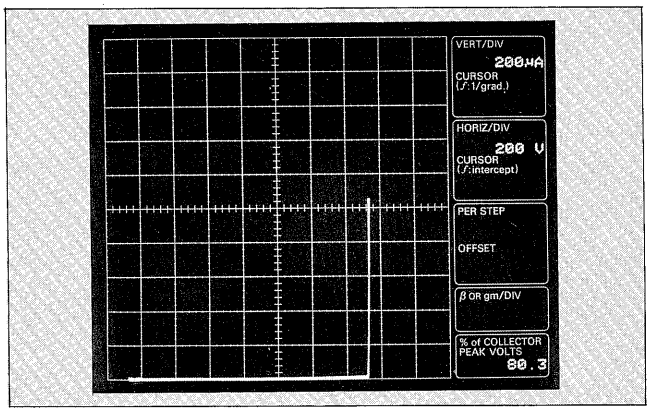


Fig. 7 Withstand voltage characteristics of 1MB12-150



generates a flyback voltage of 1,000 to 1,200V. Therefore, a high withstand voltage of 1,500V is necessary as the element withstand voltage (V_{CES}). A high withstand voltage was achieved with the new 1MB12-150 by using a guard ring and field plate construction. The withstand characteristics when a collector current (i_c) of 1mA was passed by transistor curve tracer is shown in *Figure 7*.

3.3 Low on voltage (resistance) characteristic

The 1MB12-150 displays the features of the IGBT to the full and realizes $V_{CE(sat)}$ = 4 Vtyp. (Ron=0.33M) at i_c=12A, gate input voltage (V_{GE})=15V and also realizes a high withstand voltage and high current that cannot be seen with MOSFET. (*Figure 8*)

3.4 ASO (Area of Safe Operation)

The EBSOA (Forward Bias Safe Operation Area) of the 1MB12-150 is shown in *Fig. 9*. It shows the same wide ASO as an MOSFET. For a voltage resonant type switching circuit, in normal operation, the RBSOA (Reverse Bias Safe Operation Area) problem need not be considered. Here, the distribution characteristic is shown in *Figure 10* for the avalanche withstand capability characteristic.

3.5 Latch up

The latch up characteristic is given an IGBT characteristic that must be given attention.

Fig. 8 Collector current-collector voltage characteristics of 1MB12-150

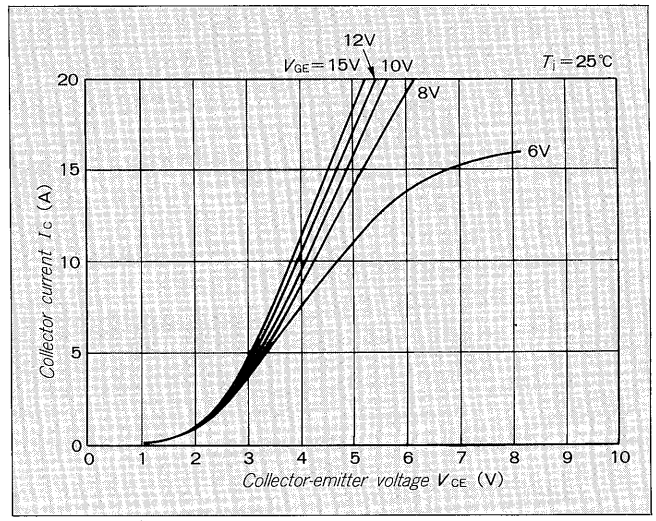


Fig. 9 FBSOA

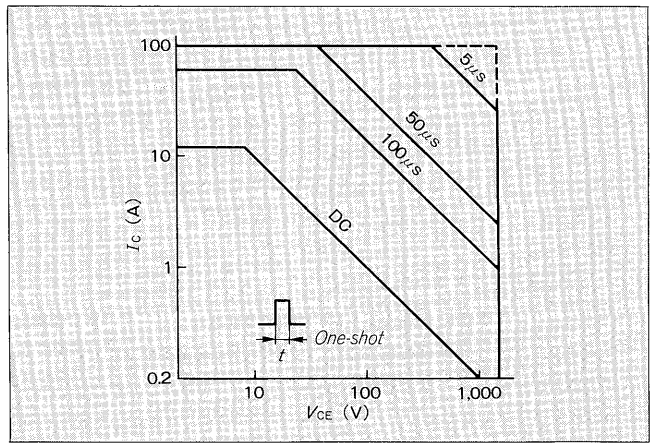
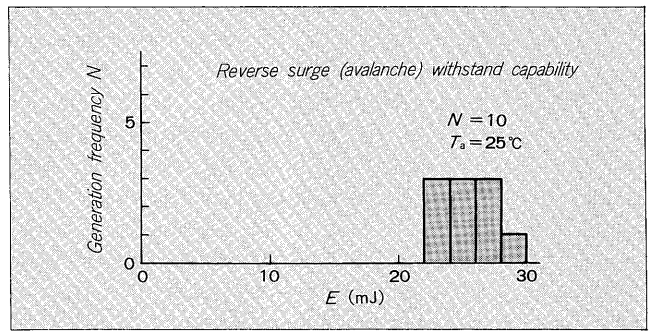


Fig. 10 1MB12-150 reverse surge characteristic



The new 1MB12-150 has a pulse (50μs) current capacity of more than 60A to garantee high ruggedness in practical operation conditions.

4. ADVANTAGES OF APPLICATION OF IGBT TO HORIZONTAL DEFLECTION CIRCUIT

The basic features of the IGBT are:

(1) It is an MOS gate voltage drive type device.
(2) It is a conductivity modulation type device. Therefore, its operating resistance is low.
(3) It is a high current density type device. [(2) and (3) also contribute to chip miniaturization and enable cost-cutting.]
(4) Excellent high speed switching characteristic.

The specific advantages shown by actual horizontal deflection circuit studies based on these features are introduced below.

(1) It is a voltage drive type divece and does not generate a carrier storage time like a bipolar transistor. This means that the output can be controlled in realtime for the gate input signal. That is, the need to ① consider the storage time and ② consider reverse bias current ($-I_B$) design to provide high speed which must be taken into account in bipolar transistor horizontal deflection circuit design does not exist with the IGBT. This is displayed as the biggest advantage in the desingn of the multi-scanning type display which occupies most of today's market. That is, for the gate drive circuit, only a gate pulse of a length corresponding to the change of frequency is different. The IGBT can be said to the perfect device for multi-scanning type horizontal deflection circuits.
(2) New advantages and shown from the standpoint of carrier storage time. This is that the deflection current linearity is excellent. This means that the CRT picture can be wide. Its excellence is generally shown in over-scanning picture linearity. Specifically, it can be understood by comparison of the current waveform immediately before turn-off with the bipolar transistor of *Figure 5* and *Figure 6* shown previously. With the bipolar transistor, the current waveform (i_c) is dull during the carrier storage time, but the IGBT maintains its linearity up to immediately before turn-off.
(3) Because it is a voltage drive device, driver circuit design is easy. Moreover, there is also a possibility of direct drive by horizontal oscillation IC in the future. Presently, it can be expected that even the still complex horizontal deflection circuit will develop as a simpler system.

5. IGBT APPLICATION RANGE

The IGBT 1MB12-150 developed this time is noticeably different depending on the operating conditions of the applied set. Specific judgment is avoided, but in our studies, it was actually driven and operation up to a 60kHz deflection frequency was confirmed. We think that the frequency will be improved further in the future and expect application of the IGBT to spread to horizontal deflection circuits.

6. APPLICATION EXAMPLE

Figure 12 shows the current which flows in the deflection coil when the 1MB12-150 was installed under the

Fig. 11 Range of CRT horizontal deflection circuit application

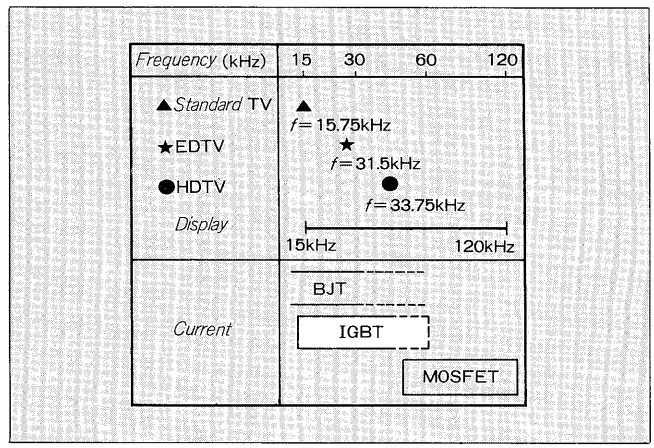
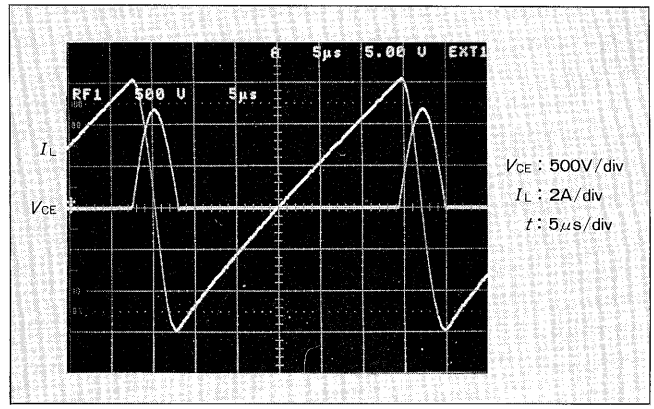


Fig. 12 Waveform when 1MB12-150 operated at f = 31.5kHz



operating conditions in at 31.5kHz EDTV and the flyback voltage (V_{CE}) at that time.

7. CONCLUSION

The features and application examples of the IGBT 1MB12-150 developed for color television or CRT display horizontal deflection circuit were introduced above.

Nowadays, technical demands of television receiver and display monitor from the market are large size picture screen and high resolution screen typified by EDTV and HDTV. Shadow mask pictch of CRT picture screen is treated minutely on account of high resolution. Moreover, technology is being directed toward ultra-high definition and is developing rapidly. One of the things which support the trend of technology is the semiconductor device typified by the IGBT introduced here. We feel that, in the future, the IGBT will take the place of the bipolar transistor with improvement of its characteristics. As a semiconductor supplier to the device market, we consider the next direction of the IGBT to be (1) positive characteristics improvement, (2) functional unification with peripheral devices, and (3) study of intelligent functions.

Finally, we wish to thank our customers and the concerned parties who cooperated in the development and commercialization of the 1MB12-150.