NGTB20N60L2TF1G

High speed SW Application of the IGBT Application Note

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ABSTRACT

Generally, Ic tailing phenomenon occurs to Power IGBT at the time of cutoff of switching operation. Therefore, when IGBT is used in the application of SMPS or INVERTER, the operating frequency is restricted and only a narrow-range applications can addressed.

To respond to this situation, FS2-IGBT is developed that Ic tailing hardly occurs at the time of switching, so it can be used in interleave PFC circuit. It is the optimal device for PFC circuit of the air-conditioners with an output higher than 1kW.

IGBT's SW performance evaluation

Characteristics of IGBT that are critical to the circuit efficiency are VCE(sat) characteristic and SW characteristic, but when the frequency exceeds 15~20kHz, SW characteristic becomes dominating. We compared the switching characteristic between NPT type that is used as Power IGBT and FS-2 type newly developed.

When considering application in interleave PFC circuit, the circuit becomes discontinuous mode or critical mode when the load is light. Also because the value of Inductor is less than 1mH, Ic waveform inclines. Concerning the switching loss, Eoff(fall) is more dominant than Eon(rise).

L-load switching operation test & comparison

First compare the two in L-load switching circuit. With regard to switching time(tf, ton & etc) and switching loss(Eon, Eoff), the observed points are shown in fig.1.

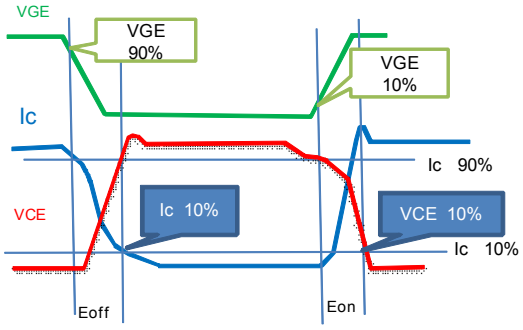
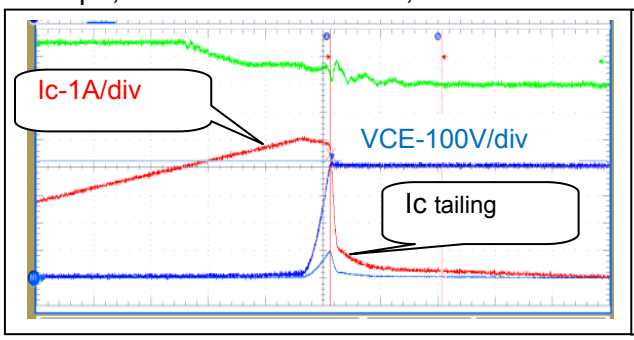


fig.1 SW time parameters

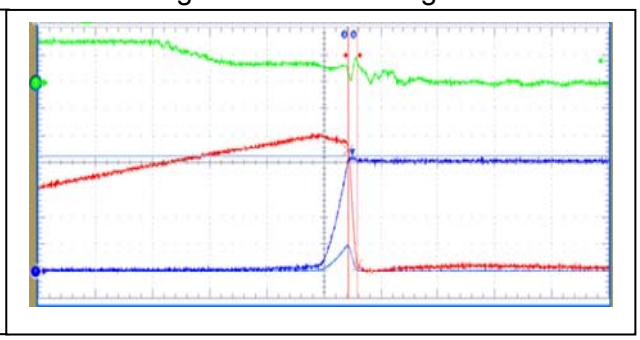
We changed Ic and observed that, for NPT type (WP.1), Ic tailing prominently occurred at the time of cut-off.
But Ic taling hardly occurred for FS-2 (WP.2).
This shows that Ic tailing can be seen prominently at a comparatively low current in NPT. By contrast, FS-2 shows a good fall characteristic in a wide current range. From the aspect of current-dependency of Eoff, difference was seen in the current region like shown in fig.2, but in the other current regions, there was almost no difference.

Here are the calculation for switching loss using frequency and Eoff.
Take Operating Frequency as f[Hz], then P(Eoff) =f × Eoff [W]

In case of continuous mode operation, Eon is further added. But because the actual waveform is with slope, Eon < Eoff. Therefore, influenced of Eoff on switching loss becomes large.



WP.1 NPT IGBT SW(5A)



WP.2 FS2 IGBT SW(5A)

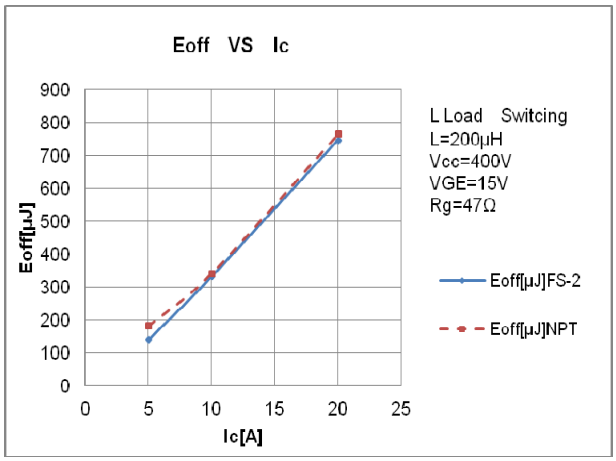


fig.2 Eoff VS Ic

Adaptability of IGBT to Interleave PFC circuit

Interleave PFC circuit is one of the active PFC circuits, which as shown in fig.3 becomes the circuit configuration to let two switching element have ON/OFF in turn.

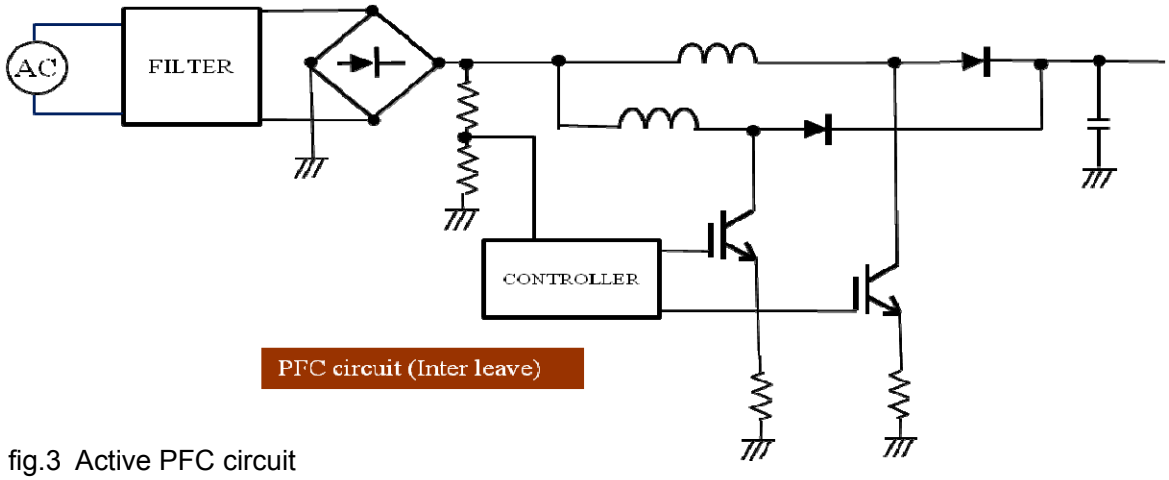


fig.3 Active PFC circuit

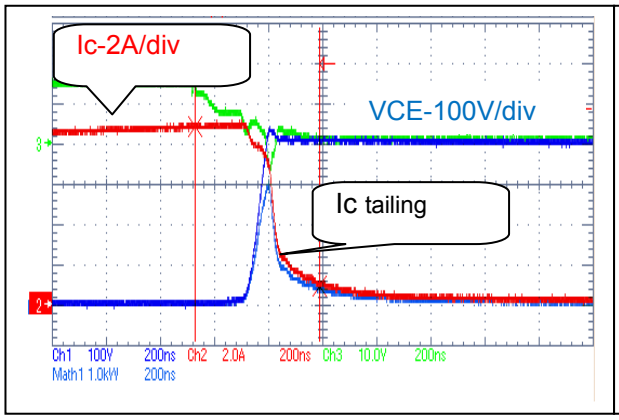
Flowing current into two paths allows reduction in IGBT's peak current and inductor's peak current as well as reduction in current ripple. It is a method that is positively adopted in room air-conditioners driving by large current.

IGBT behavior in Interleave PFC circuit – (1)

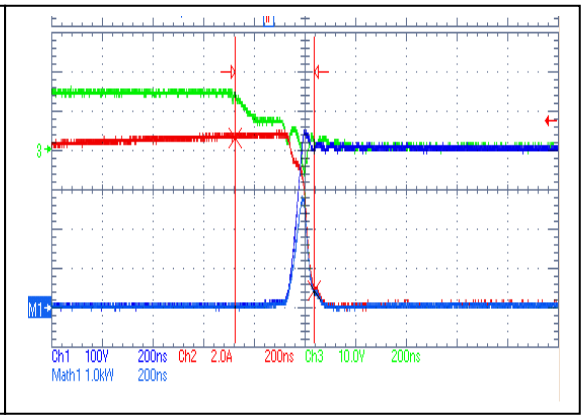
We operated NPT and FS-2 in interleave operation circuit and compared their characteristics. (Table.1) Interleave circuit controls its output current so that it is resembled to the input voltage, so IGBT's Ic constantly changes. WP.3 is the waveform of single-side IGBT at peak current of PFC operation. In NPT, prominent Ic tailing is observed from Ic waveform.

Table.1 Test result Comparison between FS-2 and NPT
@ Inter leave PFC circuit (par each) VAC=100V Iout=1.5A Vout ≈ 388V f=34kHz

	η[%]	toff[nS]	Eoff[μJ]	tf[nS]	Pin[W]	VCEp[V]	IDp[A]
FS-2	94.4	313	161	93	619	444	8.9
NPT	92.2	461	309	253	631	440	9.0



WP.3 NPT IGBT SW @PFC



WP.4 FS-2 IGBT SW @PFC

The operating efficiency at this time: η (NPT) =92.2%.

On the other hand, η(FS-2)=94.4%(2.2% up) when operating the same with FS-2. The operation waveform is WP.4, where you can confirm little tailing to Ic, which contributes much to low loss.

IGBT behavior of interleave PFC circuit -(2)

Next we compared the characteristic when changing frequency in this circuit. (See fig.4)
NPT: efficiency is low, efficiency decreases abruptly when raising frequency.
Whereas FS-2: efficiency changes little with frequency. It can be operated up to 50kHz, which is assumed high-freq. operation.

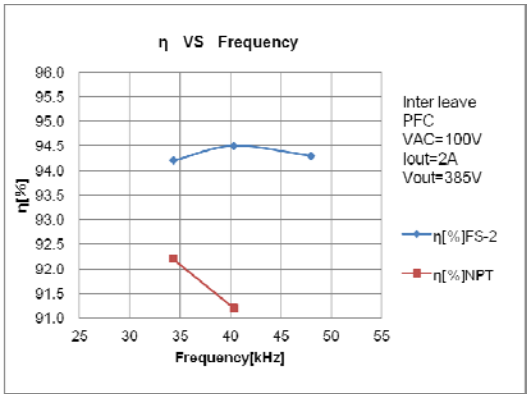


fig.4 Efficiency VS Frequency

Structure of NPT and FS-2

NPT(Non punch through) requires a certain wafer thickness of wafer to secure depletion layer of N-layer in order to ensure collector-emitter withstand voltage at the time of Ic cutoff.
FS-2 is thin-form IGBT that adopts 2nd generation Field Stop structure. A comparatively high-concentrated N-layer forms between N-layer and the backside P-layer. So compared with NPT, wafer can be made thinner. This enables better switching characteristic, especially high-quality current at the time of cutoff. Switching speeding-up and VCE(sat) lowering is in trade-off relation, FS-2 contributes to improve the trade-off relation, and meanwhile helps reduce VCE(sat). (See fig.5, fig.6).

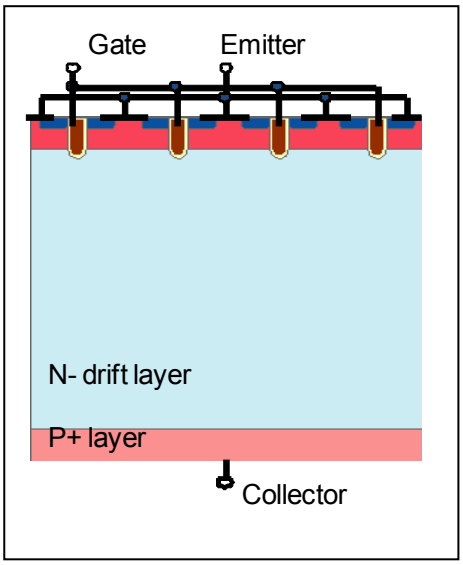


fig.5 NPT IGBT structure

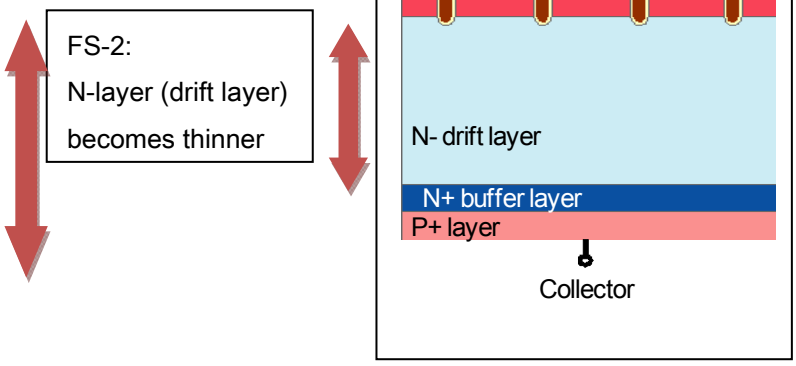


fig.6 FS-2 IGBT structure

Actual product of FS-2

As product, we have NGTB20N60L2TF1G (600V/20A), NGTB30N60L2WG (600V/30A).

Table.2 shows FS-2 IGBT Lineup.

Type No.	Package	Absolute maximum ratings				Electrical characteristics /Ta=25ºC/VGE=15V			FRD Electrical Characteristics / Ta=25ºC		
		VCES	IC @Tc= 25ºC	IC @Tc= 100ºC	PD @Tc= 25ºC	VCE(sat) typ	VCE(sat) @IC	Cies	VF max	VF @IC	trr(typ) 100A/µs
		[V]	[A]	[A]	[W]	[V]	[A]	[pF]	[V]		[ns]
NGTB20N60L2TF1G	TO-3PF-3L	600	40	20	64	1.45	20	2000	1.5	20	70
NGTB30N60L2WG	TO-247-3L	600	60	30	130	1.4	30	4130	1.7	25	70

** IF=10A,VR=50V,di/dt=100A/us