

NGTB20N60L2TF1G



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High speed SW Application of the IGBT Application Note

ABSTRACT

Generally, I_c 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 be addressed.

To respond to this situation, FS2-IGBT is developed that I_c tailing hardly occurs at the time of switching, so it can be used in interleaved 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 $V_{CE(sat)}$ 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 interleaved 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, I_c waveform inclines. Concerning the switching loss, $E_{off(fall)}$ is more dominant than $E_{on(rise)}$.

L-load switching operation test & comparison

First compare the two in L-load switching circuit. With regard to switching time (t_f , t_{on} & etc) and switching loss (E_{on} , E_{off}), the observed points are shown in fig.1.

We changed I_c and observed that, for NPT type (WP.1), I_c tailing prominently occurred at the time of cut-off.

But I_c tailing hardly occurred for FS-2 (WP.2).

This shows that I_c 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 E_{off} , 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 E_{off} .

Take Operating Frequency as f [Hz], then $P(E_{off}) = f \times E_{off}$ [W]

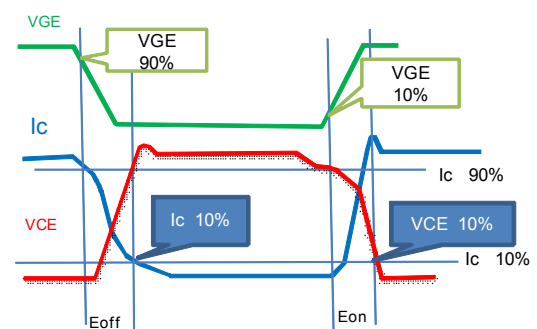
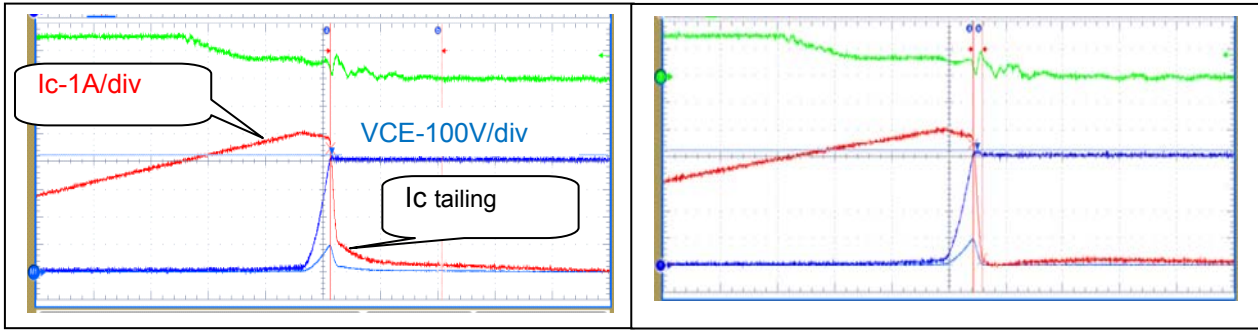


fig.1 SW time parameters

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In case of continuous mode operation, E_{on} is further added. But because the actual waveform is with slope, $E_{on} < E_{off}$. Therefore, influenced of E_{off} on switching loss becomes large.



WP.1 NPT IGBT SW(5A)

WP.2 FS2 IGBT SW(5A)

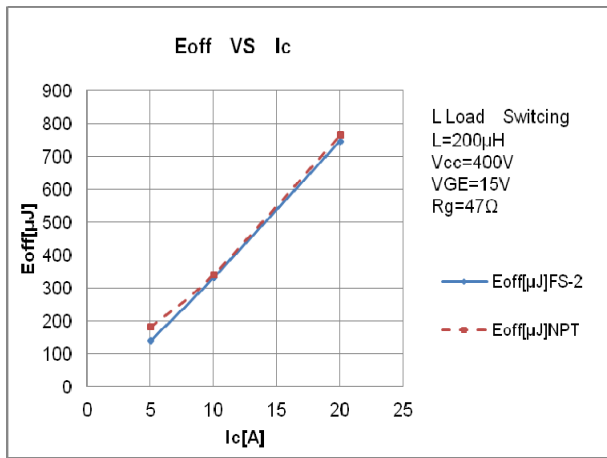


fig.2 Eoff VS Ic

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.

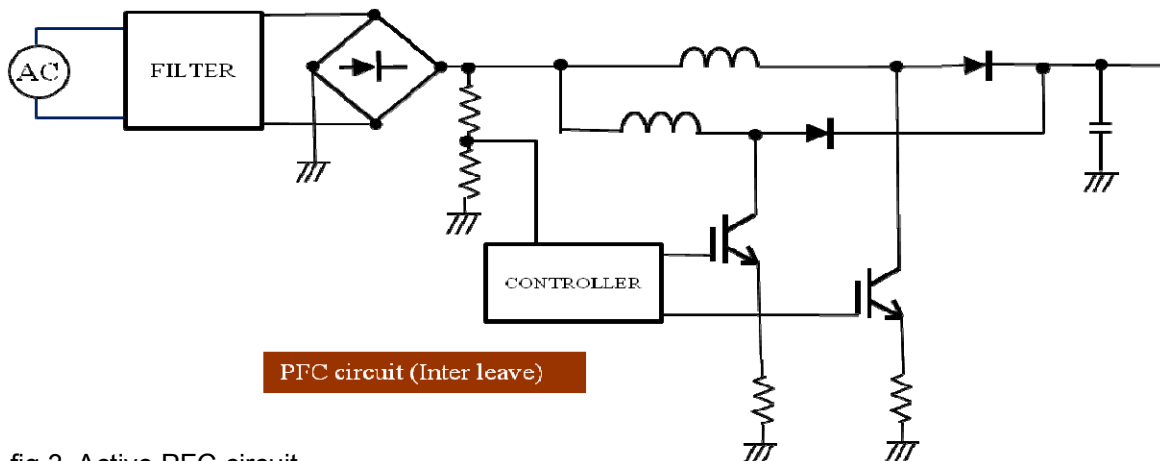


fig.3 Active PFC circuit

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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.

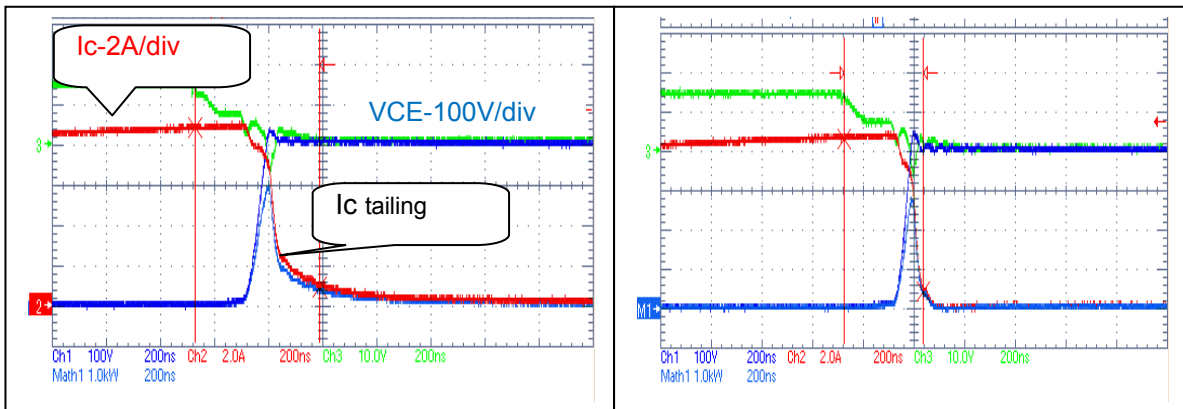
IGBT behavior in Interleave PFC circuit – (1)

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 I_c constantly changes. WP.3 is the waveform of single-side IGBT at peak current of PFC operation. In NPT, prominent I_c tailing is observed from I_c 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[μ J]	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 I_c , 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.

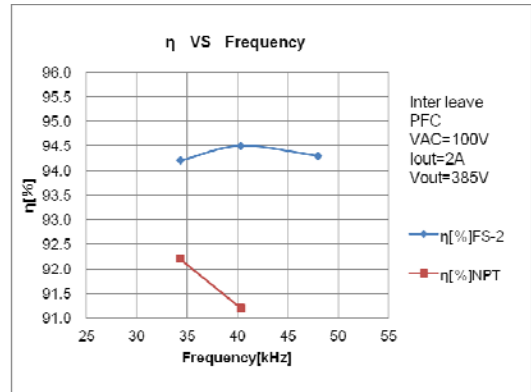


fig.4 Efficiency VS Frequency

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 I_c 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 $V_{CE(sat)}$ lowering is in trade-off relation, FS-2 contributes to improve the trade-off relation, and meanwhile helps reduce $V_{CE(sat)}$. (See fig.5, fig.6).

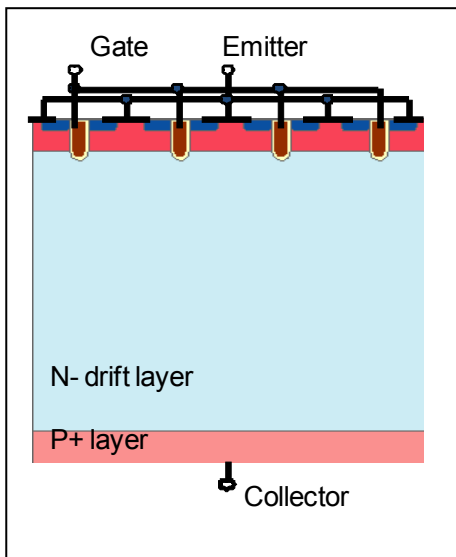


fig.5 NPT IGBT structure

FS-2:
N-layer (drift layer)
becomes thinner

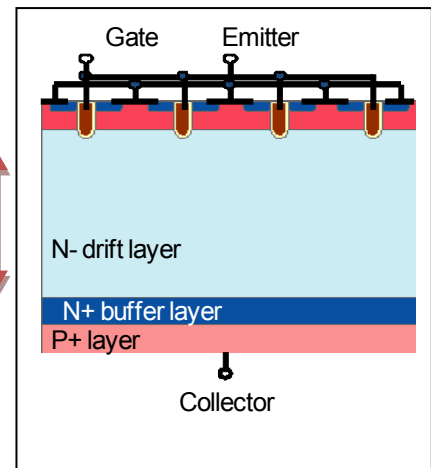


fig.6 FS-2 IGBT structure

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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=25°C/VGE=15V			FRD Electrical Characteristics /Ta=25°C		
		VCES	IC		PD	VCE(sat)		Cies	VF		trr(typ)
			@Tc=25°C	@Tc=100°C	@Tc=25°C	typ	@IC		max	@IC	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

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