

ON Semiconductor

Is Now

onsemi™

To learn more about onsemi™, please visit our website at
www.onsemi.com

onsemi and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

NGTB20N60L2TF1G



ON Semiconductor®

<http://onsemi.com>

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 dominant. 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]

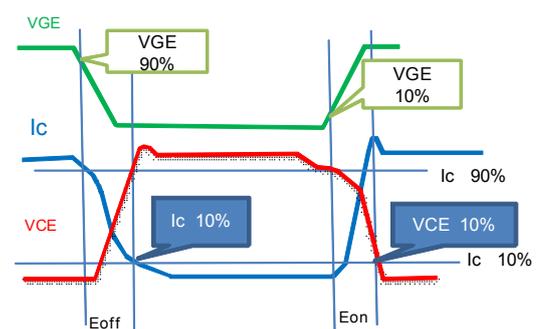
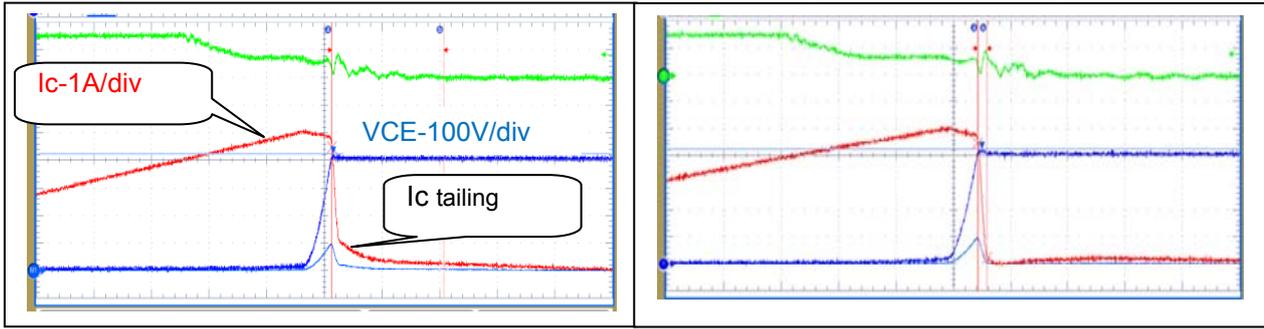


fig.1 SW time parameters

NGTB20N60L2TF1G Application Note

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)

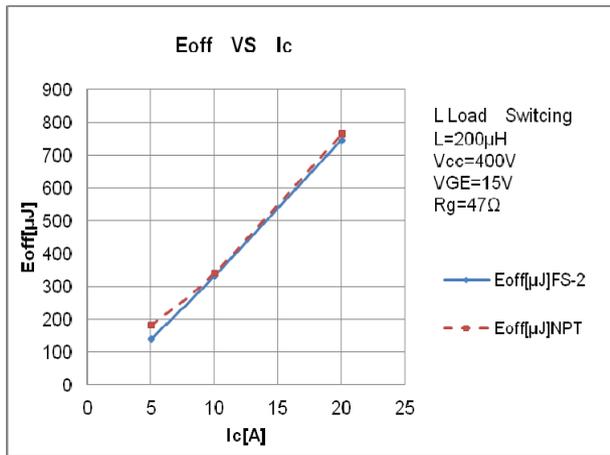


fig.2 Eoff VS Ic

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.

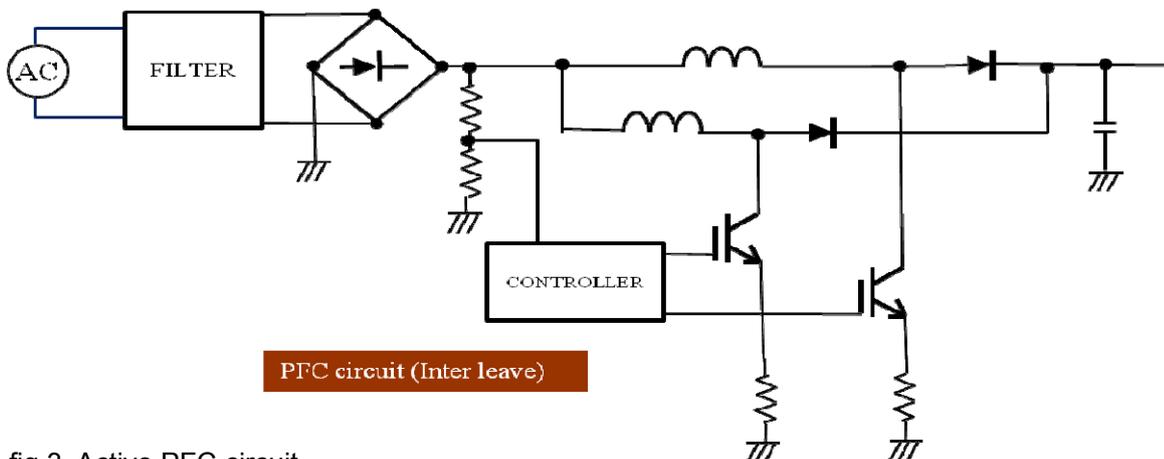


fig.3 Active PFC circuit

NGTB20N60L2TF1G Application Note

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.

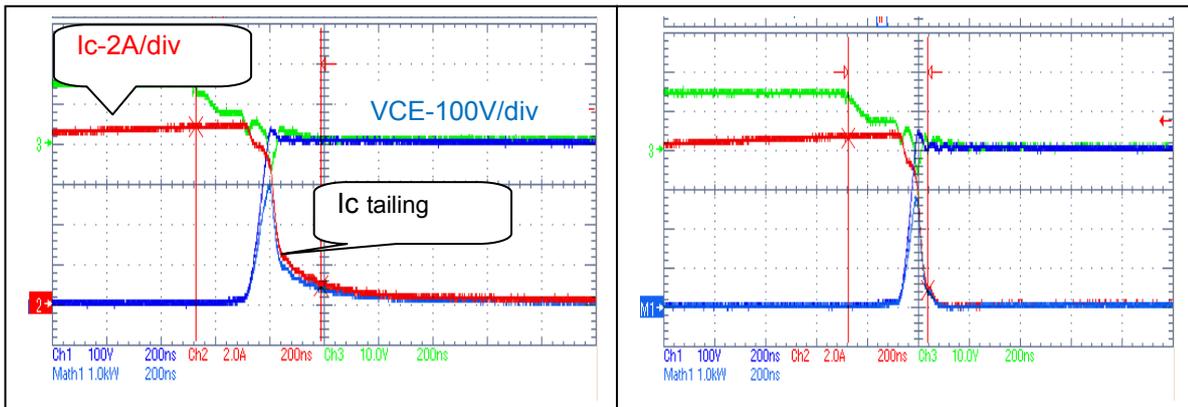
IGBT behavior in Interleave PFC circuit – (1)

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.

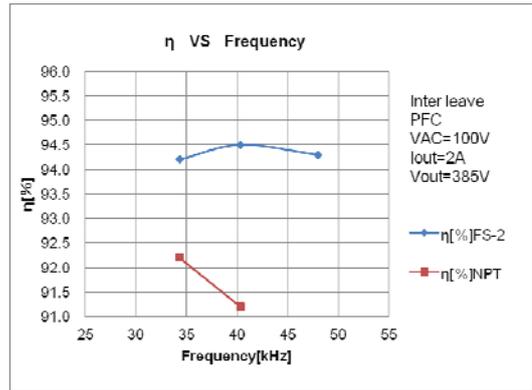


fig.4 Efficiency VS Frequency

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).

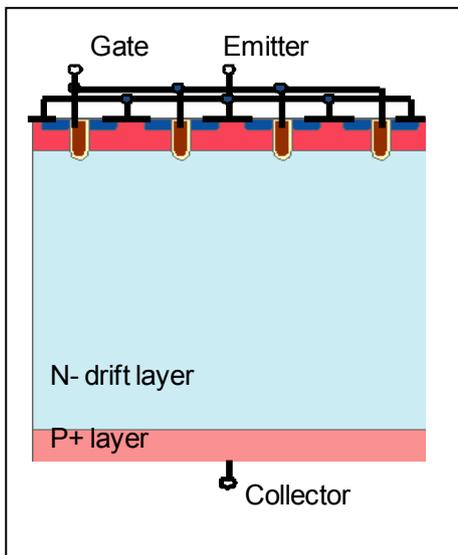


fig.5 NPT IGBT structure

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

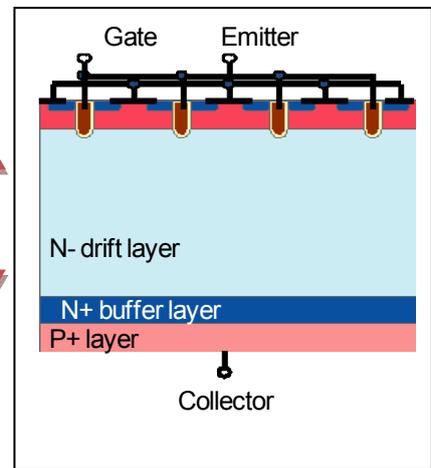


fig.6 FS-2 IGBT structure

NGTB20N60L2TF1G Application Note

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

ON Semiconductor and the ON logo are registered trademarks of Semiconductor Components Industries, LLC (SCILLC). SCILLC owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of SCILLC's product/patent coverage may be accessed at www.onsemi.com/site/pdf/Patent-Marking.pdf. SCILLC reserves the right to make changes without further notice to any products herein. SCILLC makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does SCILLC assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. "Typical" parameters which may be provided in SCILLC data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. SCILLC does not convey any license under its patent rights nor the rights of others. SCILLC products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the SCILLC product could create a situation where personal injury or death may occur. Should Buyer purchase or use SCILLC products for any such unintended or unauthorized application, Buyer shall indemnify and hold SCILLC and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SCILLC was negligent regarding the design or manufacture of the part. SCILLC is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.