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NGTB30N60L2WG

High speed SW & Low VCE(sat) Application of the IGBT

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Overview

NGTB30N60L2WG newly developed is one of FS2*-IGBT series, which enables fast switching and low VCE(sat) at the same time. It is considered common to take the absolute maximum Ic rating as reference when selecting a device. However, actually the values of VCE(sat) and Icpeak(=Icp) described in electrical characteristics need to be focused. VCE(sat) is a critical value that directly affect the operating efficiency of the equipment, while Icp is a value that indicates the actually usable area. So, VCE(sat) and Icp are important parameters for selecting a device.

*FS2 is explained in section 4.

1. Current specification and actual performance of IGBT

Ic rating is one of the specifications of IGBT. Typically, Ic rating is expressed as the current under the condition of Tc=100°C. On the other hand, because IGBTs are used in various energy conversion circuits, low loss is also important. VCE(sat) is used as an indication to show the degree of the loss. The lower the VCE(sat) is, the more advantageous the IGBT is in terms of loss reduction.

· Comparison of VCE(sat) values (1)

Fig.1 shows VCE(sat) comparison result among NGTB30N60L2WG and competitors @ Ic=30A.

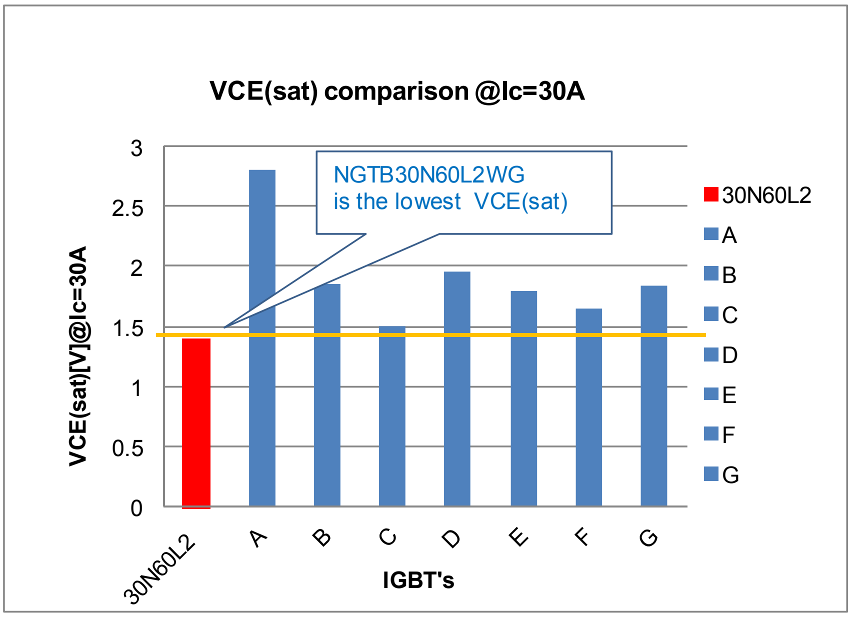


Fig.1 VCE(sat) comparison

Fig.1 proves that NGTB30N60L2WG has the lowest VCE(sat) among the IGBTs with 30A rating. This characteristic is very important for IGBT as a switching device. When Ic flows between Collector and Emitter of the IGBT, the loss is as below:

PVsatloss=VCE(sat) × Ic [W]

This validates that, the lower the VCE(sat) is, the smaller the value becomes.

· Comparison of VCE(sat) values (2)

We also compared VCE(sat) of NGTB30N60L2WG with competitors with Ic rating higher than that of NGTB30N60L2WG. As shown in Fig.2, transverse is Ic rating, vertical is VCE(sat) reading from Spec. sheet @Ic=30A. This proves VCE(sat) of NGTB30N60L2WG is even lower than those of the IGBTs with Ic rating higher than 40A.

In the circuit applications where low VCE(sat) is critical, the performance of NGTB30N60L2WG is superior to those of high Ic spec.

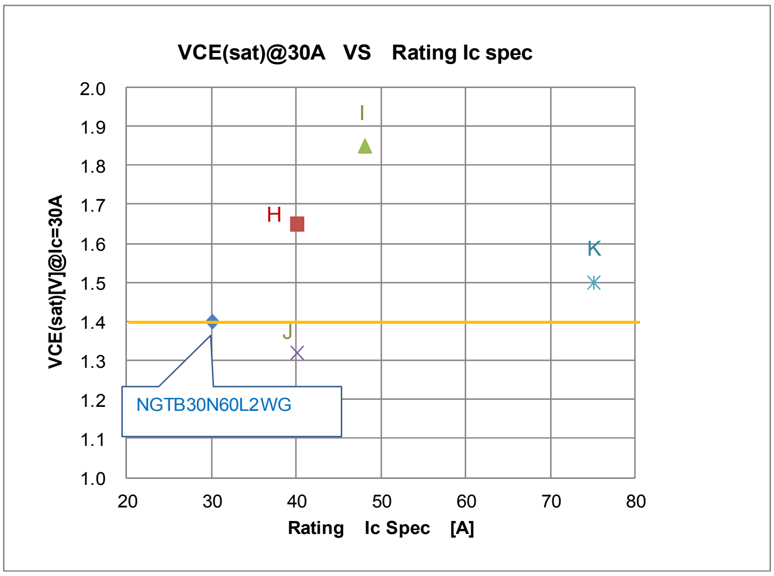


Fig.2 VCE(sat)@30A VS Rating Ic spec

2. Difference in VCE(sat) and loss in actual circuit

Next, let's see the relation between VCE(sat) and loss in partial switching circuit where presents large difference in VCE(sat) values. Partial switching is used in PFC circuit of room air-conditioners & etc. This circuit is switching circuit, but the frequency is very low (100 to 120Hz), so switching loss is extremely low, VCE(sat) loss is dominant.

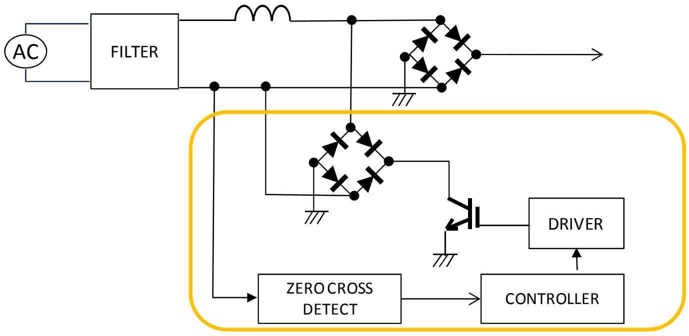


Fig.3 part switching circuit

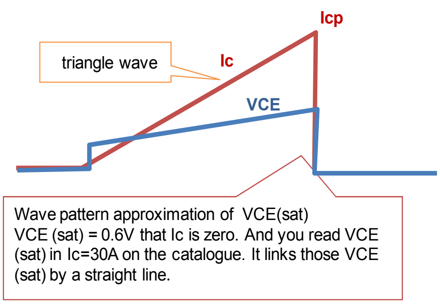


Fig.4 The wave form of partial SW to calculate

Partial switching loss is calculated as Fig.4.

Difference in VCE(sat) makes predominant difference in the loss. (Condition: Icp=30A)

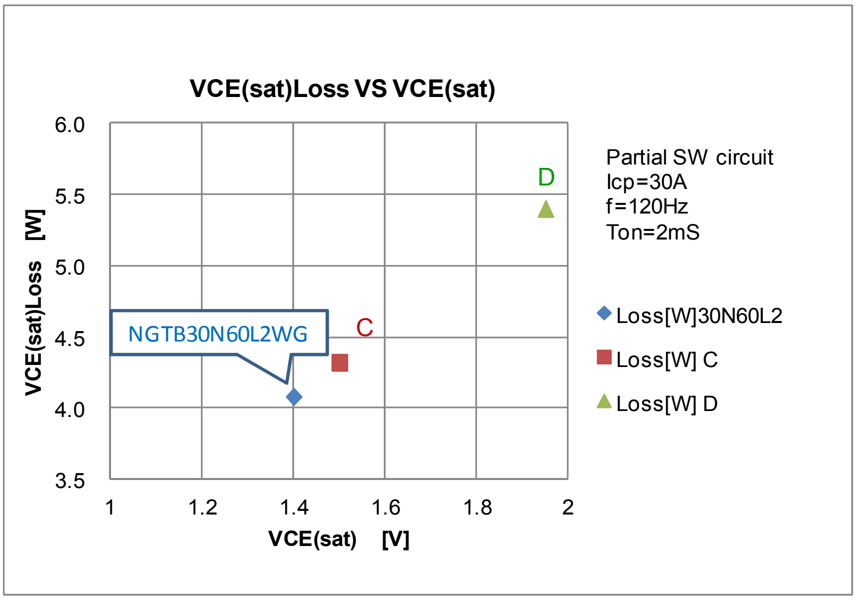


Fig.5 VCE(sat)Loss VS. VCE(sat) @Partial SW circuit

3. Compatibility of RF switching characteristics and RF operation

3-1) IGBT's behavior and operation efficiency comparison in interleave PFC circuit

NGTB30N60L2WG, featuring both low VCE(sat) characteristic and fast switching characteristic, is applicable to interleave circuit with operating frequency higher than 30kHz. Interleave circuit is one of the active PFC circuits, its circuit configuration is shown as Fig.6: the two switching devices turn on and off alternately.

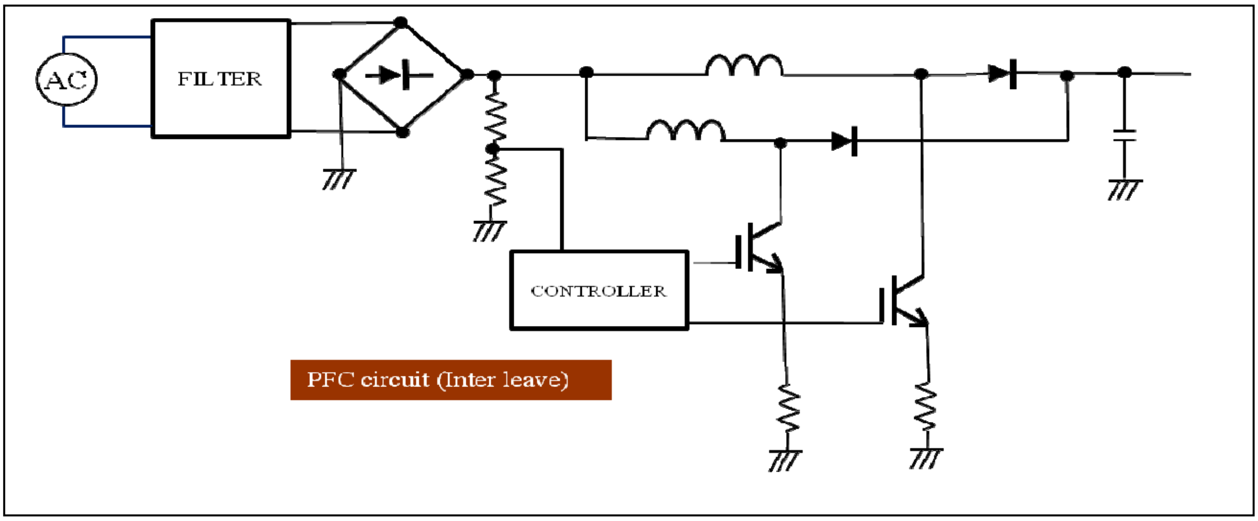


Fig.6 Active PFC circuit

Flowing current into 2 circuits enables reduction in IGBT peak current, inductor peak current and current ripple. This method is positively adopted in large-current circuits such as room air-conditioner.

· Comparison between NGTB30N60L2WG and competitor(IGBT K) of which Ic rating is larger than that of NGTB30N60L2WG

We tested the operation of NGTB30N60L2WG. Below is the test result of IGBT K (Ic rating is larger than that of NGTB30N60L2WG) for comparison. You can see from Table 1 that the operating efficiency of NGTB30N60L2WG is superior. As previously stated, the result below suggests that VCE(sat) characteristic actually affects more than Ic rating does. However, what is more remarkable is that the influence of Eoff is not negligible in this circuit's approx. 35kHz operation. As one of IGBT's switching performance, tf of NGTB30N60L2WG is very fast (1/2 as shown in Table.1), also Eoff is small, so switching loss becomes low. This characteristic is a merit of NGTB30N60L2WG which has adopted FS2 process.

Table.1 Test result Comparison between NGTB30N60L2WG(FS2)and IGBT K
@ Inter leave PFC circuit VAC=100V Iout=2.0A Vout=385.3V f=35kHz

Device	**Ic rating[A]**	**tf[ns]**	**η[%]**	Pin[W]	Pout[W]	Icp[A]	Eoff[μJ]	VCE(sat)[V] @30A
NGTB30N60L2WG	**30**	**100**	**94.0**	818	769	11	317	1.4
IGBT K	**75**	**219**	**92.1**	835	769	11	585	1.5

*In this operation, Ic waveform is almost triangle-wave. Observe Eoff loss.

· Comparison between NGTB30N60L2WG and competitor (IGBT J) of which VCE(sat)@Ic=30A is smaller than that of NGTB30N60L2WG

In addition, we conducted tests to compare NGTB30N60L2WG with IGBT J. The result is shown as Table.2. Despite larger VCE(sat), the operating efficiency η of NGTB30N60L2WG is slightly better than that of IGBT J. The reason is that, under operation of f=35kHz, NGTB30N60L2WG has fast tf (2/3 as shown in Table.2) as well as small Eoff that allows low switching loss and as a result the efficiency is good. In high-frequency full switching operation like PFC, switching performance contributes more than VCE(sat) does. NGTB30N60L2WG is also superior in that regard. So, we could argue that NGTB30N60L2WG is an IGBT that excels in both VCE(sat) and switching characteristics.

Table.2 Test result Comparison between NGTB30N60L2WG(FS2)and IGBT J
@ Inter leave PFC circuit VAC=100V Iout=2.0A Vout=385.3V f=35kHz

Device	**VCE(sat)[V] @30A**	**tf[ns]**	**η[%]**	Pin[W]	Pout[W]	Icp[A]	Eoff[μJ]
NGTB30N60L2WG	**1.40**	**100**	**94.0**	818	769	11	317
IGBT J	**1.32**	**156**	**93.9**	819	769	11	328

3-2) operating efficiency comparison in inverter circuit

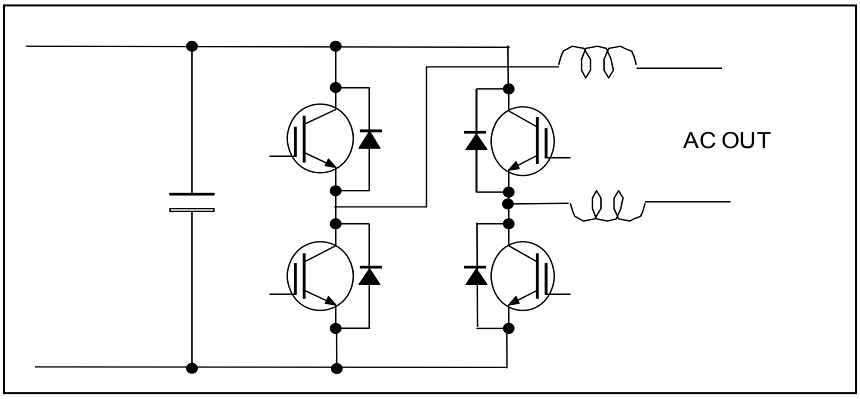


Fig.7 Inverter circuit

We examined the loss when NGTB30N60L2WG operates on the assumption of ordinary inverter circuit. In inverter circuit, which loss is dominant, VCE(sat) loss(ON loss) or switching loss(Eon, Eoff, additionally trr loss of the diode), depends on operating frequency.
We show the inverter of power conditioner as example. In case of assuming carrier frequency is 15kHz, the loss of IGBT and the loss of FWD per device are calculated as below (sine wave operation, Icp=28A):

Loss of IGBT :

P_{IGBT}=Psat +Psw Psat: IGBT's ON loss Psw : Loss at the time of Eon and Eoff

Loss of FWD :

P_{FWD}=P_{VF} + Ptrr $P_{VF:}$ the diode's ON loss, Ptrr recovery loss

The total is: Ptotal = Psat + Psw + P_{VF} + Ptrr

Psat can be usually expressed as below:

Psat =Icp×VCE(sat)×(1/8 + m/(3π)×cosθ)…(1)

P_{VF} can be expressed as below:

P_{VF}= Iop×VF×(1/8 - m/(3π)× cosθ)…(2)

However, "m" is modulation degree, usually expressed as m=1.

Besides, cosθ is Power Factor, taken as 0.9.

With regard to Switching Loss :

Pon = Eon×f×1/π …(3) Pon: switching ON direction's operating loss

Current modulates at sine wave, Ic varies within a range of 0[A] to Icp[A], so the average value approximates the value of multiplying 1/π.

Poff is calculated in a similar way.

When estimating VCE(sat), VF, Eon, Eoff and E_{Qrr} based on Spec. Sheet and measurement data taking Icp(IFp)=28A*1, as regarding Ptrr, as the diode SW loss, EQrr=Vr×Qrr can be expressed with Qrr during trr period. Additionally, because IF varies within the range of 0[A]~Icp[A] like Ic, the average value approximates the value of multiplying 1/π.

Ptrr=E_{Qrr}×f×1/π…(4)

*1 ; Because switching data changes according to measuring environment and Rg, the measurement data @Vcc=400V, Rg=27Ω is used.

Spec. and various measurement data are shown as in Table.3.

Table.3 Value of each parameters Ic=28A Ta=25°C

	NGTB30N60L2WG	IGBT K
VCE(sat)[V]	1.35	1.48
VF[V]	1.68	1.45
Eon[μJ]	1800	1320
Eoff[μJ]	1460	2130
E_{Qrr}[μJ]	176	77

When calculating the loss based on Table.3 by using the formula (1) to (4), the result is shown in Fig.8.

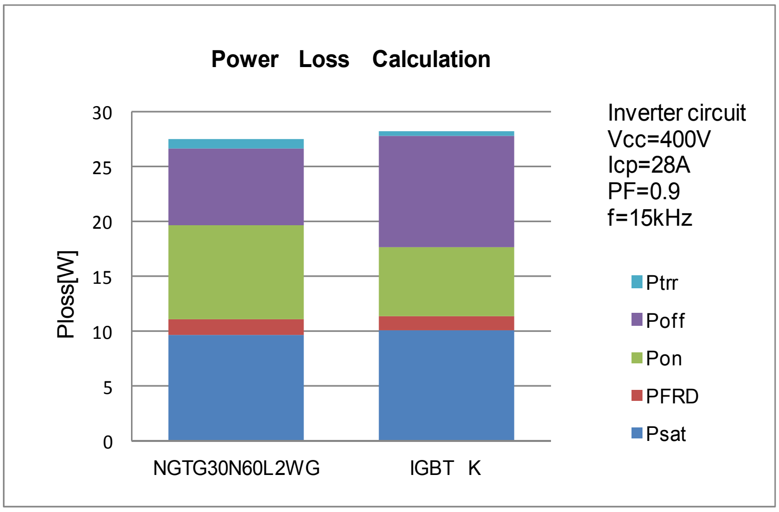
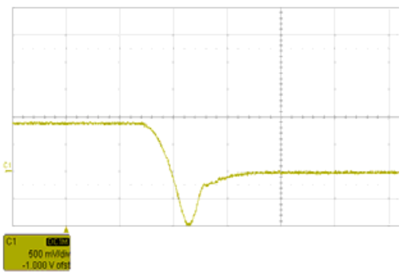


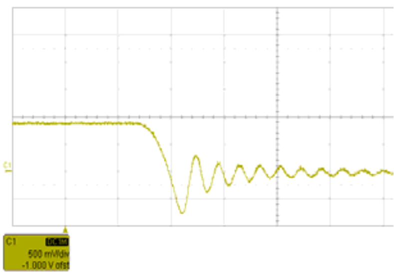
Fig.8 Loss calculation result f=15kHz

By comparing ON loss and turn-on/off switching loss (Eon/Eoff), you can see the switching loss is quite dominant in this region.

In addition, the diode used for NGTB30N60L2WG is designed so as to suppress current vibration at the time of recovery operation. Especially in some 20A extent region, the difference in current vibration becomes evident. This current might be the cause of noise at the time of SET operation. Therefore, NGTB30N60L2WG is optimal for design because current vibration hardly happens at the time of recovery.



WP.1 NGTB30N60L2WG
Recovery characteristic
@IF=20A



WP.2 IGBT K
Recovery characteristic
@IF=20A

The above results proves that NGTB30N60L2WG is an IGBT that excels in both VCE(sat) characteristic and switching performance.

4. Structure and Specification of NGTB30N60L2WG (FS2 process)

We compare FS2 process that enables both fast switching and low VCE(sat) with conventional NPT process.

Conventional NPT(Non Punch Through) needs a certain wafer thickness in order to secure a depletion layer of N-layer to create collector-emitter voltage at the time of Ic cutoff. While FS2 is the second generation Field Stop structured low-profile IGBT, where a comparatively high-concentration N-layer is forming between N-layer and the surface P-layer. Therefore, compared with NPT, wafer of FS2 process can be made thinner. FS2 process enables better switching characteristic, especially cutoff current than ever before. Switching's speedup and VCE(sat)'s reduction are in tradeoff relation, but FS2 process improved the tradeoff relation and meanwhile decreased VCE(sat) (refer to Fig.9,Fig.10).

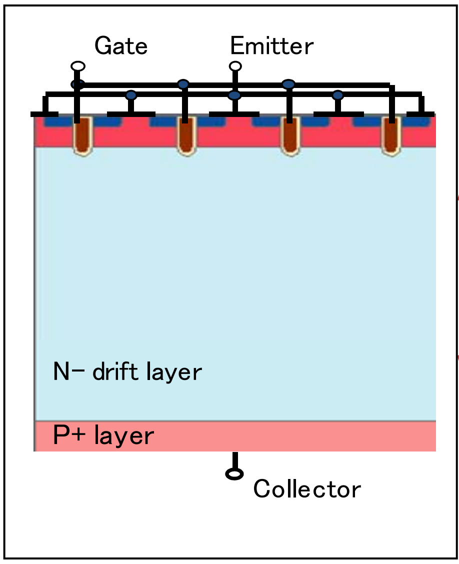


Fig.9 NPT IGBT structure

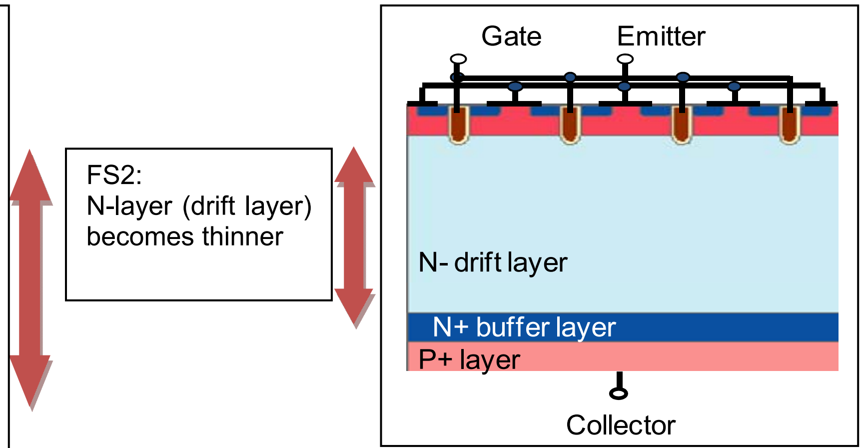


Fig.10 FS2 IGBT structure

Specifications of NGTB30N60L2WG

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

**IF=10A, VR=50V, di/dt=100A/μs