Discrete IGBT datasheet understanding

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Discrete IGBT datasheet understanding

Infineon IGBT Chip Technology

Datasheet understanding

- Electrical characteristic
- Switching characteristic
- Thermal features
Behaviour: IGBT vs MOSFET

The IGBT is characterized by its pn threshold voltage. Conduction loss are in linear relation to $I_C$
The MOSFET behaves like a resistor. Conduction loss are proportional to $I_D^2$

The IGBT has a characteristic current tail. Turn off losses are dominated by the tail current.

IGBT is basically the preferred device for higher currents at limited pulse frequencies.
Infineon’s IGBT history for Drives
Product Technologies

Performance

1st Gen. BUP-IGBT
- 70% lower Turn-off Loss (600V)

Fast-IGBT
- 30% lower Conduction Losses, but higher switching losses (1200V)

TrenchStop-IGBT
- 25% lower Switching Losses, same Conduction Losses

TrenchGate & Fieldstop

PT-IGBT
- Worldwide first NPT-IGBT
Vertical IGBT Concepts

**Punch Through**
- ROW: 1988
- Emitter
- Gate
- Collector
- *n*⁻ basis (epi)
- *n*⁺ buffer (epi)
- *p*⁺ emitter (substrate)

**Non Punch Through**
- IFX: 1990
- ROW: 1997
- Emitter
- Gate
- Collector
- *n*⁻ basis (substrate)

**Trench + Field-Stop**
- IFX: 2000
- Emitter
- Gate
- Collector
- *n*⁻ basis (substrate)

**Advantage**
- Implanted Back-Emitter
- Implanted Fieldstop enables thinner base region

**Performance**
- Lower VCEsat
- Lower Switching Losses
- Higher Switching Robustness
- Robustness like NPT

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Standard planar IGBT are still good, but they have...

- ...high conduction losses, due to high $V_{CE(sat)}$
- ...low switching performance, due to low switching speed
- ...poor thermal properties, due to thick wafers

New Technologies are necessary to meet tomorrows requirements
How to improve the standard IGBT-technology?

- Improvement of thin wafer technology (Fieldstop) reduces $V_{\text{CE(sat)}}$ dramatically
  - Reduction of Conduction Losses for higher Efficiency and improved thermal properties
  - Reduction of Switching Losses for higher Efficiency

- Introduction of trench gate technology reduces $V_{\text{CE(sat)}}$ further
  - Reduction of Conduction Losses for higher Efficiency

- Well established thin wafer technology lowers $V_{\text{CE(sat)}}$ & $E_{\text{off}}$ furthermore
- Introduction of RC Diode technology
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# Current parameters (IKW50N60T)

## Nominal current (Ic)

<table>
<thead>
<tr>
<th>DC collector current, limited by $T_{j_{\text{max}}}$</th>
<th>$I_c$</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_c = 25^\circ\text{C}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_c = 100^\circ\text{C}$</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

Ic is calculated as below:

$$T_c = T_{j_{\text{max}}}^\circ\text{C} - V_{\text{cesat, max}} @ T_{j_{\text{max}}}^\circ\text{C} \times I_c \times R_{\text{thjc}}$$

---

**IKW50N60T**

- $T_j = 175^\circ\text{C}$
- $V_{\text{cesat}} = 2.4\text{V}$
- $I_c = 50\text{A}$
- $R_{\text{thjc}} = 0.45^\circ\text{C/W}$

**IKW50N60T**

- $T_c = 121^\circ\text{C}$

**IKW50N60T**

- $T_c > 100^\circ\text{C}$
- $T_c$ set to $100^\circ\text{C}$

All nominal current is specified at 100 /110\(^\circ\text{C}, 25^\circ\text{C}\) value is also given as reference.

This value just represents IGBT DC behavior, can be a reference of choosing IGBT, but not yardstick.
**Current Limitation (IKW50N60T)**

- **Calculation of Max. DC Current**

\[
\Delta T_{jc} = P_{tot} \cdot R_{thjc}
\]

\[
P_{tot} = I_C \cdot V_{CE}
\]

\[
V_{CE} = V_{TO} + I_C \cdot R_{CE}
\]

\[
I_C = \frac{\sqrt{R_{thjc} \cdot V_{TO}^2 + 4R_{CE} \cdot (T_{j(max)} - T_c)}}{2 \cdot \sqrt{R_{thjc} \cdot R_{CE}}} - \frac{V_{TO}}{2 \cdot R_{CE}}
\]
Current Limitation

- Value limited by bondwire
  - IKW50N60T in TO-247

- IHW20N120R3 in TO-247
Pulse collector current (IKW50N60T)

Pulse current (Icpuls)

Pulsed collector current, $t_p$ limited by $T_{j,max}$

<table>
<thead>
<tr>
<th></th>
<th>$I_{C_{puls}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn off safe operating area ($V_{CE} \leq 600V$, $T_j \leq 175^\circ C$)</td>
<td>-</td>
</tr>
</tbody>
</table>

$I_{C_{puls}}$ is defined as repetitive turn on & maximum turn off pulse current

3 ~ 4 times of $I_c$, according to different technology
**$V_{\text{CES}}$ – Breakdown Voltage (IKW50N60T)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-emitter breakdown voltage</td>
<td>$V_{(BR)\text{CES}}$</td>
<td>$V_{\text{GE}}=0\text{V}$, $I_{\text{C}}=0.2\text{mA}$</td>
<td>600</td>
<td>V</td>
</tr>
</tbody>
</table>

$V_{\text{CES}}$—test condition

Max. collector–emitter voltage under condition of gate and emitter shorted, where leakage current is within spec.

$V_{\text{ces}}$ under $T_j=25^\circ\text{C}$, proportional to its junction temperature

$V_{\text{ces}}$ can not be violated at any condition, otherwise IGBT would break down.
$V_{CES} - \text{Breakdown Voltage (IKW50N60T)}$

**IKW50N60T**

| Turn off safe operating area ($V_{CE} \leq 600V$, $T_j \leq 175^\circ C$) | - | 150 |

**Max. $VCES$ can be shunt donw**

**Due to the stray inductance**

$$\Delta V = L_o \ast \frac{di}{dt}$$

**In real application, turn-off voltage need to be smaller than max. $VCES$**
Voltage parameters (IKW50N60T)

- **Vcesat**

  Vcesat is specified at nominal current

  Positive coefficient → Good for paralleling
Voltage parameters (IKW50N60T)

- $V_{cesat}$ increases with $I_c$ increasing
- $V_{cesat}$ increases with $V_{ge}$ decreasing

$V_{ge}$ is not recommended to use too small: conduction losses
VGEth (IKW50N60T)

- Threshold of IGBT turn on:

<table>
<thead>
<tr>
<th>Gate-emitter threshold voltage</th>
<th>$V_{GE(th)}$</th>
<th>$I_C=0.8,mA$, $V_{CE}=V_{GE}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.7</td>
</tr>
</tbody>
</table>

- Pay attention to **negative temperature coefficient of VGEth**.
Max operation junction temperature (IKW50N60T)

- $T_{j\text{max}}$ is the max temperature for IGBT to sustain all electrical parameters within spec.

- **Never exceed $T_{j\text{max}}$** at any condition! Otherwise, IGBT will run away $\rightarrow$ fail!

| Operating junction temperature | $T_j$ | -40...+175°C |
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## Short circuit current (IKW25N120T2)

- Different value for various start junction condition.

<table>
<thead>
<tr>
<th>Short circuit collector current$^{1)}$</th>
<th>$I_{C(SC)}$</th>
<th>$V_{GE}=15,\text{V}, t_{SC}\leq10,\mu\text{s}$</th>
<th>$V_{CC}=600,\text{V}$, $T_{j,\text{start}} = 25^\circ\text{C}$</th>
<th>$T_{j,\text{start}} = 175^\circ\text{C}$</th>
<th>-</th>
<th>-</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150</td>
<td>115</td>
<td></td>
</tr>
</tbody>
</table>
Short circuit current & time (IKW25N120T2)

- 10us guaranteed at test condition.

<table>
<thead>
<tr>
<th>Short circuit withstand time²</th>
<th>$t_{SC}$</th>
<th>10</th>
<th>μs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{GE} = 15V$, $V_{CC} \leq 600V$, $T_{j, \text{start}} \leq 175^\circ C$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 19.** Short circuit withstand time as a function of gate-emitter voltage ($V_{CE}=600V$, start at $T_{j} \leq 175^\circ C$)

**Figure 20.** Typical short circuit collector current as a function of gate-emitter voltage ($V_{CE} \leq 600V$, $T_{j, \text{start}} = 175^\circ C$)
Current parameters (IKW25N120T2)

- Short circuit condition:
  - $V_{ge}$: gate voltage (15V)
  - $V_{cc}$: DC bus voltage
  - $T_{vj}$: short circuit start temperature

Infineon test short circuit at maximum operation $T_j$
### Switching parameters (IKW50N60T)

- **Qgate**

<table>
<thead>
<tr>
<th>Gate charge</th>
<th>Q(_{\text{Gate}})</th>
<th>(V_{\text{CC}}=480\text{V}, \ I_{\text{C}}=50\text{A})</th>
<th>310</th>
<th>-</th>
<th>nC</th>
</tr>
</thead>
</table>

This value is specified at +15V, used to calculate driving power.

- **Ciss, Crss, Coss**

<table>
<thead>
<tr>
<th>Input capacitance</th>
<th>C(_{\text{iss}})</th>
<th>(V_{\text{GE}}=25\text{V}, \ V_{\text{CE}}=0\text{V})</th>
<th>-</th>
<th>3140</th>
<th>-</th>
<th>pF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output capacitance</td>
<td>C(_{\text{oss}})</td>
<td>(V_{\text{GE}}=0\text{V})</td>
<td>-</td>
<td>200</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>C(_{\text{rss}})</td>
<td>(f=1\text{MHz})</td>
<td>-</td>
<td>93</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

C\(_{\text{iss}}\) = C\(_{\text{GE}}\) + C\(_{\text{GC}}\): Input capacitance (output shorted)

C\(_{\text{oss}}\) = C\(_{\text{GC}}\) + C\(_{\text{EC}}\): Output capacitance (input shorted)

C\(_{\text{rss}}\) = C\(_{\text{GC}}\): Reverse transfer capacitance (Miller capacitance)

\[
P = Q_g \cdot \Delta V_{GE} \cdot f
\]
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Thermal Features

- IGBT-thermal model

\[ R_{th(j-a)} = R_{th(j-c)} + R_{th(c-s)} + R_{th(s-a)} \]

\[ T_j = \Delta T_{jc} + \Delta T_{ch} + \Delta T_{ha} + T_a \]
 IGW  B  T  R  A  S  R  e  d  Wi   0  T   (IKW50N60T)

\[ R_{\text{th JC}} ; R_{\text{th CH}} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Max. Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IGBT thermal resistance,</td>
<td></td>
<td></td>
<td>0.45</td>
<td>K/W</td>
</tr>
<tr>
<td>junction – case</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diode thermal resistance,</td>
<td></td>
<td></td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>junction – case</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal resistance,</td>
<td></td>
<td></td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>junction – ambient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**IGBT Power Dissipation & Junction Temp. (IKW50N60T)**

**Ptot-total power dissipation**

\[
T_{j\text{max}} = T_c + P_{\text{tot}} \times R_{thjc} \text{ (max)}
\]

\[
P_{\text{tot}} = \frac{(T_{j\text{max}} - T_c)}{R_{thjc} \text{ (max)}}
\]

*Rated at 25°C*

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**Figure 3.** Power dissipation as a function of case temperature \((T_i \leq 175°C)\)
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