TPH1R306P1 is an advanced U-MOSIX-H process product, and its main target applications are the secondary synchronous rectifier of DC-DC converters and AC-DC converters, and motor drives. We have been mass-producing TPH1R306PL since December 2015. For low $R_{DS(ON)}$ products of the SOP Advance, which are often used in secondary synchronous rectifiers and motors, we are preparing a lineup of products that can reduce spike voltage, as well as high-efficiency standard products. TPH1R306P1 with low $V_{DS}$ spike characteristics can reduce spike voltage and shorten ringing periods by making the internal gate resistance ($r_g$) value larger than the standard gate resistance one.

This application note compares and verifies the $V_{DS}$ spike levels and ringing periods of TPH1R306PL and TPH1R306P1 on a power supply to confirm their effectiveness and also explains the mechanism of low $V_{DS}$ spikes.

### Description

**<Major Product Characteristics>**

<table>
<thead>
<tr>
<th>Part number</th>
<th>Generation</th>
<th>$V_{DSS}$ (V)</th>
<th>$R_{DS(ON)}$ (mΩ) @ $V_{GS}$=10 V</th>
<th>Package</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPH1R306P1</td>
<td>U-MOSIX-H</td>
<td>60</td>
<td>1.28</td>
<td>SOP Advance</td>
<td>Low $V_{DS}$ spike product</td>
</tr>
<tr>
<td>TPH1R306PL</td>
<td>U-MOSIX-H</td>
<td>60</td>
<td>1.34</td>
<td>SOP Advance</td>
<td>Standard product</td>
</tr>
</tbody>
</table>
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Table 2.2  Electrical characteristics of standard product “TPH1R306PL” ............................................ 6
1. On-resistance Improvement for Each Generation

Our low voltage MOSFETs have continuously improved their performance by optimizing device structures using superior fine process. The features are as follows.

- Low on-resistance characteristics using superior fine process
- Low-loss performance with improved trade-off between on-resistance and gate charge
- Lineup of a wide range of breakdown-voltage and packages for many kinds of applications
- High durability, represented by avalanche withstandability
- Device structure with suppressed switching noise to make the design easy

![Figure 1.1 Continuous improvements of chip on-resistance (SOP Advance 30V products)](image)

※ Ron•A: Drain-source on-resistance per unit area

2. Loss Improvements and Structures of U-MOSVIII-H and IX-H Generations

The U-MOSVIII-H and U-MOSIX-H generations have excellent MOSFET performance in "conduction loss and drive loss", "conduction loss and switching loss" and "conduction loss and output charge loss". The U-MOSIX-H generation, in particular, has been miniaturized and cell structure has been optimized to greatly reduce output charge losses, which are critical for power supply and motor-drive applications, from the U-MOSVIII-H generation.

![Figure 2.1 Reduction of conduction loss](image)
※ For each parameter
  ・$R_{DS(ON)}$: Drain-source on-resistance [mΩ] (an indicator of conduction loss)
  ・$Q_g$: Total gate charge [nC] (an indicator of driving loss)
  ・$Q_{sw}$: Gate switch charge [nC] (an indicator of switching loss)
  ・$Q_{oss}$: Output charge [nC] (an indicator of output charge loss)

2.1. Structures of U-MOSVIII-H and IX-H Generations

The U-MOSVIII-H and U-MOSIX-H generations adopt new structures in the gate trench to achieve the above-mentioned performance. Since the new structure has parasitic capacitance and parasitic resistance between the drain and source and the snubber (CR) circuit is constructed, the U-MOSVIII-H and IX-H generations can suppress spike voltage compared to conventional U-MOSVII-H generation.

![Parasitic snubber circuit](image)

Figure 2.2 Parasitic snubber circuit

2.2. Structure of TPH1R306P1

As described in 2.1, the U-MOSIX-H generation TPH1R306PL adopts new trench structures and can achieve snubber effects. TPH1R306P1 optimizes the resistances of the gate and source by optimizing the patterns on the MOSFET surfaces in order to suppress spike voltage.

2.3. Features of TPH1R306P1

TPH1R306P1 (low $V_{DS}$ spike product) optimizes $r_g$ and $r_s$ by optimizing surface patterns from TPH1R306PL (standard product). TPH1R306P1 has a lower $R_{DS(ON)}$ than TPH1R306PL does. The product characteristics are shown in Table 2.1 and 2.2.
### Table 2.1  Electrical characteristics of low V_DS spike product “TPH1R306P1”

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Measurement conditions</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate leakage current</td>
<td>$I_{GSS}$</td>
<td>$V_{DS} = \pm20\ V$, $V_{GS} = 0\ V$</td>
<td>-</td>
<td>-</td>
<td>$\pm0.1$</td>
<td>nA</td>
</tr>
<tr>
<td>Drain cut-off current</td>
<td>$I_{CSD}$</td>
<td>$V_{DS} = 60\ V$, $V_{GS} = 0\ V$</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>nA</td>
</tr>
<tr>
<td>Drain-source breakdown voltage</td>
<td>$V_{BRDSS}$</td>
<td>$I_D = 10\ mA$, $V_{GS} = 0\ V$</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Drain-source breakdown voltage</td>
<td>$V_{BRDSSX}$</td>
<td>$I_D = 10\ mA$, $V_{GS} = -20\ V$</td>
<td>45</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Gate threshold voltage</td>
<td>$V_{th}$</td>
<td>$V_{DS} = 10\ V$, $I_D = 1.0\ mA$</td>
<td>1.5</td>
<td>-</td>
<td>2.5</td>
<td>V</td>
</tr>
<tr>
<td>Drain-source on-resistance</td>
<td>$R_{DS(ON)}$</td>
<td>$V_{GS} = 4.5\ V$, $I_D = 42\ A$</td>
<td>-</td>
<td>1.5</td>
<td>2.3</td>
<td>mΩ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{GS} = 10\ V$, $I_D = 50\ A$</td>
<td>-</td>
<td>0.96</td>
<td>1.28</td>
<td>mΩ</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td>$V_{DS} = 30\ V$, $V_{GS} = 0\ V$</td>
<td>-</td>
<td>6250</td>
<td>8100</td>
<td>pF</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{iss}$</td>
<td>$V_{GS} = 0\ V$, $f = 1\ MHz$</td>
<td>-</td>
<td>80</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Output capacitance</td>
<td></td>
<td>$f = 1\ MHz$</td>
<td>-</td>
<td>1160</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Gate resistance</td>
<td>$r_g$</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>1.0</td>
<td>Ω</td>
</tr>
<tr>
<td>Switching time (rise time)</td>
<td>$t_r$</td>
<td>-</td>
<td>-</td>
<td>8.3</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Switching time (turn-on time)</td>
<td>$t_{on}$</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Switching time (fall time)</td>
<td>$t_f$</td>
<td>-</td>
<td>-</td>
<td>14.7</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Switching time (turn-off time)</td>
<td>$t_{off}$</td>
<td>-</td>
<td>-</td>
<td>70</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_{rr}$</td>
<td>$V_A = 30\ V$, $I_{DR} = 25\ A$, $V_{DS} = 0\ V$, $-dI_{DS}/dt = 100\ A/\mu s$</td>
<td>-</td>
<td>47</td>
<td>-</td>
<td>ns</td>
</tr>
</tbody>
</table>

### Table 2.2  Electrical characteristics of standard product “TPH1R306PL”

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Measurement conditions</th>
<th>Minimum</th>
<th>Typical</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate leakage current</td>
<td>$I_{GSS}$</td>
<td>$V_{DS} = \pm20\ V$, $V_{GS} = 0\ V$</td>
<td>-</td>
<td>-</td>
<td>$\pm0.1$</td>
<td>nA</td>
</tr>
<tr>
<td>Drain cut-off current</td>
<td>$I_{CSD}$</td>
<td>$V_{DS} = 60\ V$, $V_{GS} = 0\ V$</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>nA</td>
</tr>
<tr>
<td>Drain-source breakdown voltage</td>
<td>$V_{BRDSS}$</td>
<td>$I_D = 10\ mA$, $V_{GS} = 0\ V$</td>
<td>60</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Drain-source breakdown voltage</td>
<td>$V_{BRDSSX}$</td>
<td>$I_D = 10\ mA$, $V_{GS} = -20\ V$</td>
<td>45</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Gate threshold voltage</td>
<td>$V_{th}$</td>
<td>$V_{DS} = 10\ V$, $I_D = 1.0\ mA$</td>
<td>1.5</td>
<td>-</td>
<td>2.5</td>
<td>V</td>
</tr>
<tr>
<td>Drain-source on-resistance</td>
<td>$R_{DS(ON)}$</td>
<td>$V_{GS} = 4.5\ V$, $I_D = 42\ A$</td>
<td>-</td>
<td>1.5</td>
<td>2.3</td>
<td>mΩ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{GS} = 10\ V$, $I_D = 50\ A$</td>
<td>-</td>
<td>0.96</td>
<td>1.28</td>
<td>mΩ</td>
</tr>
<tr>
<td>Input capacitance</td>
<td>$C_{iss}$</td>
<td>$V_{DS} = 30\ V$, $V_{GS} = 0\ V$</td>
<td>-</td>
<td>6250</td>
<td>8100</td>
<td>pF</td>
</tr>
<tr>
<td>Reverse transfer capacitance</td>
<td>$C_{iss}$</td>
<td>$V_{GS} = 0\ V$, $f = 1\ MHz$</td>
<td>-</td>
<td>80</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Output capacitance</td>
<td></td>
<td>$f = 1\ MHz$</td>
<td>-</td>
<td>1160</td>
<td>-</td>
<td>pF</td>
</tr>
<tr>
<td>Gate resistance</td>
<td>$r_g$</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>1.0</td>
<td>Ω</td>
</tr>
<tr>
<td>Switching time (rise time)</td>
<td>$t_r$</td>
<td>-</td>
<td>-</td>
<td>8.3</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Switching time (turn-on time)</td>
<td>$t_{on}$</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Switching time (fall time)</td>
<td>$t_f$</td>
<td>-</td>
<td>-</td>
<td>14.7</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Switching time (turn-off time)</td>
<td>$t_{off}$</td>
<td>-</td>
<td>-</td>
<td>70</td>
<td>-</td>
<td>ns</td>
</tr>
<tr>
<td>Reverse recovery time</td>
<td>$t_{rr}$</td>
<td>$V_A = 30\ V$, $I_{DR} = 25\ A$, $V_{DS} = 0\ V$, $-dI_{DS}/dt = 100\ A/\mu s$</td>
<td>-</td>
<td>47</td>
<td>-</td>
<td>ns</td>
</tr>
</tbody>
</table>
3. Effects on the Secondary Side of DC-DC Converter

3.1. Effects of optimized \( r_s \)

The secondary-side synchronous rectifier is often in the \( t_r \) mode (reverse recovery mode of diode) and ringing occurs between the drain and the source. TPH1R306P1 suppresses ringing in \( t_r \) mode by optimizing the parasitic resistor \( r_s \) with slight effect on power supply efficiency.

3.2. Theoretical Calculation of Voltage Spike

This section explains the mechanism for reducing \( V_{DS} \) spike by referring to the DC-DC buck converter shown in Figure 3.1 as LCR series resonant circuit. \( L \) is the stray inductance of the wire \( L_p \), \( C_{ds} \) is capacitance between Drain and Source of the low-side MOSFET, and \( R \) is the \( r_s \) of the low-side MOSFET.

※ For each parameter
- \( L(L_p) \): wiring parasitic inductance
- \( C(C_{ds}) \): Drain-source capacitance of low-side MOSFET
- \( R(r_s) \): \( r_s \) of the low-side MOSFET

![Figure 3.1 LCR series resonant circuit](image)

When treated as an LCR series resonant circuit, it can be expressed as follows.

Angular frequency of the LCR series resonant circuit

\[
\omega_0 = \frac{1}{\sqrt{L_p \times C_{ds}}}\quad \text{-- equation (a)}
\]

Damping of the LCR series resonant circuit

\[
\alpha_s = \frac{r_s}{2L_p}\quad \text{-- equation (b)}
\]

Attenuation coefficient of the LCR series resonant circuit

\[
\zeta_s = \frac{\alpha_s}{\omega_0}\quad \text{-- equation (c)}
\]

When equations (a) and (b) are substituted into equation (c), the attenuation coefficient of the LCR series resonance circuit \( \zeta_s \) is,

\[
\zeta_s = \frac{r_s}{2L_p} \times \sqrt{L_p \times C_{ds}} = \frac{r_s}{2} \times \sqrt{\frac{C_{ds}}{L_p}}\quad \text{-- equation (d)}
\]

On the other hand, the voltage \( V_{Cds} \) across \( C_{ds} \), which becomes spike voltage, is

\[
V_{Cds} = \frac{1}{\omega_0 \times C_{ds}} \times I_s
\]

Here, \( I_s = \frac{V_{Vin}}{r_s} \) is substituted for \( I \times \frac{V}{R} \) in the equation of the LCR series resonance circuit,
From equations (d) and (e), the attenuation coefficient and spike voltage can be expressed by the following equations.

Attenuation coefficient \[ \zeta_s = \frac{r_s}{2} \times \frac{\sqrt{C_{ds} L_p}}{r_s} \] -- equation (f)

Spike voltage \[ V_{Cds} = \frac{1}{r_s} \times Q \] -- equation (g)

Where \( Q = \frac{V_{in}}{\omega_0 C_{ds}} \).

Since there is an \( r_s \) in the numerator in equation (f), the larger the \( r_s \), the larger the attenuation factor \( \zeta_s \), and the faster the rate of attenuation. Therefore, the larger the \( r_s \), the faster the ringing converges. Equation (g) also shows that the larger the \( r_s \), the smaller the spike voltage \( V_{Cds} \), since the denominator has the \( r_s \). Considering TPH1R306P1 and TPH1R306PL, the \( C_{ds}, L_p, \) and \( Q \) are the same. TPH1R306P1 (low \( V_{DS} \) spike product) is designed to have a larger \( r_s \) than the TPH1R306PL (standard product), so the following effects can be obtained.

[1] Spike voltage decreases.
[2] Ringing converges become faster

### 3.3. Measurement of \( t_{rr} \) Value of MOSFET

The operation waveforms and effects of our products were checked under the \( t_{rr} \) mode, which is the most problematic of the secondary synchronous rectifiers of switching power supplies. The \( V_{DS} \) spike at the beginning of \( t_{rr} \) mode was reproduced by the evaluation circuit shown in Figure 3.2, and the \( t_{rr} \) was measured.

![Figure 3.2 t_{rr} test circuit](image)

Figure 3.3 shows the measured operating waveforms.

![Figure 3.3 t_{rr} operation waveforms](image)
Figure 3.3 shows that TPH1R306P1 has smaller $V_{DS}$ spike and shorter ringing periods than TPH1R306PL. The results show that the TPH1R306P1 is suitable for secondary synchronous rectification because of low-noise performance.

3.4. Actual Measurement by Isolated DC-DC Converter Evaluation Board

The effect of low $V_{DS}$ spike product is confirmed by MOSFET device test. Thus, we evaluate MOSFET in the power supply. We compare the $V_{DS}$ spike, ringing periods and efficiency on the 500 W AC-DC converter evaluation board of the circuit shown in Figure. 3.4.

The operating waveforms of MOSFET are shown in Figure 3.5.

<table>
<thead>
<tr>
<th>Test condition</th>
<th>Input Voltage: 120 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage: 12 V</td>
<td></td>
</tr>
<tr>
<td>Load Current: 18.7 A</td>
<td></td>
</tr>
<tr>
<td>LLC Frequency: 80-115 kHz</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.4  500W AC-DC converter evaluation board

The waveforms show that TPH1R306P1 reduced ringing from 650 ns to 100 ns compared to TPH1R306PL. On the other hand, the levels of $V_{DS}$ spike remained same on this board. However, $V_{DS}$ spike is expected to be reduced in some power supplies.

We also compared the efficiencies of TPH1R306P1 and TPH1R306PL. The results are shown in Figure 3.6.

The operating waveforms of MOSFET are shown in Figure 3.5.

<table>
<thead>
<tr>
<th>TPH1R306P1</th>
<th>TPH1R306PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DS}=20V/Div$</td>
<td>$V_{DS}=10V/Div$</td>
</tr>
<tr>
<td>$t=400ns/Div$</td>
<td>$t=400ns/Div$</td>
</tr>
</tbody>
</table>

Figure 3.5  Measured waveforms on 500W AC-DC converter evaluation board
As shown in Figure 3.6, there are no significant differences in efficiency, but the results show that the standard product is slightly more efficient in the low current range, and that the low V_DS spike product is slightly more efficient in the high current range.

The switching loss of the low V_DS spike product is large in the low current range due to the effect of \( r_g \), and the conduction loss is small in the high current range due to the effect of \( R_{DS(ON)} \).

### 3.5. Conclusion of the Evaluation on the Secondary Side of Isolated DC-DC Converter

It has been confirmed that the low-V_DS spike product, TPH1R306P1, with TPH1R306PL cell layout modified, can significantly reduce ringing periods in the secondary synchronous rectifier.

### 4. Effects on the Primary Side of DC-DC Converter

#### 4.1. \( r_g \) Effects

The low V_DS spike product has a larger \( r_g \) than the standard product, so when used on the primary side of the power supply, it switches slowly and is less efficient, but the V_DS spike is suppressed.

#### 4.2. MOSFET Switching Times and Gate Current

This section briefly explains the effect of the gate resistance \( r_g \) on the switching time \( t_{off} \).

\[
\begin{align*}
\text{Than } Q &= It \\
Q_g &= I_g \ t_{off} \\
\leftrightarrow t_{off} &= \frac{Q_g}{I_g} \quad \text{--- equation (h)}
\end{align*}
\]

From \( V = IR \),

\[
\begin{align*}
V_{GS} &= I_g \ (r_g + R_G) \\
\leftrightarrow I_g &= \frac{V_{GS}}{(r_g + R_G)} \quad \text{--- equation (i)}
\end{align*}
\]

It can be seen from equation (h) that the larger the \( r_g \), the smaller the \( I_g \). It can be seen from equation (f) that the smaller the \( I_g \), the larger the \( t_{off} \), since \( Q_g \) remains unchanged. That is, the larger the \( r_g \), the smaller the \( I_g \) and the slower the \( t_{off} \) (turn-off time).

※ The symbols shown here represent the following:

- \( Q_g \): Total gate charge (nC),
- \( I_g \): Gate current (A),
- \( t_{off} \): Turn-off time (ns),
- \( V_{GS} \): G-S voltage (V),
- \( r_g \): Internal gate resistance (Ω),
- \( R_G \): External gate resistance (Ω)
Detailed description of gate drive is omitted. Please refer to our application note "MOSFET gate drive circuits" for more information.

4.3. Measurement of Switching Time of MOSFET

As described above, theoretically, a large $r_g$ can reduce $V_{DS}$ spike. We compared the switching characteristics of low-$V_{DS}$ spike products with those of standard products using the test circuit shown in Figure 4.1. Test condition is $V_{DS} = 30$ V, $I_D = 50$ A, $R_{GG} = R_{GS} = 4.7$ Ω.

![Switching test circuit](image)

**Figure 4.1 Switching test circuit**

Figure 4.2 shows the results of comparison of switching characteristics. The spike voltage was 73.7 V for TPH1R306P1, while the spike voltage was 84.8 V for TPH1R306PL. TPH1R306P1 shows ability to suppress $V_{DS}$ spike.

<table>
<thead>
<tr>
<th>TPH1R306P1</th>
<th>TPH1R306PL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Comparison of switching characteristics" /></td>
<td><img src="image" alt="Comparison of switching characteristics" /></td>
</tr>
</tbody>
</table>

**Figure 4.2 Comparison of switching characteristics**

4.4. Actual Measurement by Non-isolated DC-DC Converter Evaluation Board

Similar evaluation is performed on power supply to verify the effects of increasing the $r_g$. The following shows comparison of $V_{DS}$ spike and ringing on a non-isolated DC-DC converter evaluation board as shown in Figure 4.3.
The results are shown in Figure 4.4. V_DS spike decreased from 44.0 V to 32.0 V, and ringing periods decreased from 88 ns to 40 ns. From this result, the TPH1R306P1 of low V_DS spike product can be expected to reduce V_DS spike and ringing periods even on the primary side.

<table>
<thead>
<tr>
<th>TPH1R306P1</th>
<th>TPH1R306PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_GS</td>
<td>V_GS</td>
</tr>
<tr>
<td>V_DS:10V/div</td>
<td>V_DS:1V/div</td>
</tr>
<tr>
<td>Time:20ns/div</td>
<td>Time:20ns/div</td>
</tr>
<tr>
<td>32.0V</td>
<td>44.0V</td>
</tr>
<tr>
<td>40ns</td>
<td>88ns</td>
</tr>
</tbody>
</table>

Figure 4.4  Comparison of switching waveforms on non-isolated DC-DC converter

4.5. Actual Measurement by Isolated DC-DC Converter Evaluation Board

In addition, the same evaluation was performed on the isolated DC-DC converter evaluation board as shown in Figure 4.5.

Test condition
- Input Voltage: 24 V
- Output Voltage: 5 V
- Frequency: 160 kHz
- Gate Drive Voltage: 5 V

The switching waveform is shown in Figure 4.6.
TPH1R306P1 (low VDS spike product) is effective in reducing VDS spike and ringing period on primary side compared to TPH1R306PL.

The results show that VDS spike and ringing are reduced by using TPH1R306P1 for the primary side of isolated DC-DC converter.

The efficiency results are shown in Figure 4.7.

TPH1R306P1 is slightly less efficient when used on the primary side.

4.6. Conclusion of the evaluation on the primary side of isolated DC-DC converter

TPH1R306P1 (low VDS spike product) is effective in reducing VDS spike and ringing period not only in synchronous rectification operation on the secondary side but also in switching operation on the primary side.

5. Product Selection According to the Purpose of Use

Low VDS spike product TPH1R306P1 is a product with rg larger than TPH1R306PL. This is useful for reducing VDS spike and ringing period on both the primary and secondary sides. In particular, the secondary side can be expected to reduce VDS spike and ringing period by optimizing rs.

On the other hand, we reaffirmed that the standard product TPH1R306PL is more efficient on the primary side than the low VDS spike product TPH1R306P1.
Our U-MOSIX-H 60 V lineup includes both TPH1R306P1 of low $V_{DS}$ spike product and a TPH1R306PL of standard product. We recommend to select the most appropriate product for the equipment.

Points of Attention Regarding the Content

1. **Block diagram**
   Some of the functional blocks, circuits, constants, etc. in the block diagram may be omitted or simplified in order to explain the functions.

2. **Equivalent circuit**
   Some of the equivalent circuits may be omitted or simplified to explain the circuits.

Precautions and Requests for Use

Notes on Handling

(1) Absolute Maximum Rating is a specification that must not exceed any one value of multiple ratings at any instant in time. It cannot be exceeded for any of several ratings. Exceeding the absolute maximum rating may cause damage, damage, and deterioration, which may result in damage due to rupture or combustion.

(2) Use an appropriate power supply fuse to prevent a large current from continuing to flow in the event of an overcurrent or IC failure. The IC may be damaged due to usage exceeding the absolute maximum rating, incorrect wiring, abnormal pulse noise induced by wiring or load, etc. As a result, a large current may continue to flow through the IC, resulting in smoke and fire. It is necessary to set the capacity of the fuse, the blowing time, the position of the inserted circuit, etc. in order to minimize the influence by assuming the inflow and outflow of a large current in the case of breakage.

Points to Remember on Handling

(1) Overcurrent detection circuit
   The overcurrent detection circuit does not protect the IC in any case. After operation, promptly cancel the overcurrent condition. Otherwise, the over-current limiting circuit may not operate properly or the IC may be damaged before operating. If an overcurrent continues to flow for a long time after operation, the IC may be damaged due to heat generation, depending on the operation method and conditions.

(2) Heat-blocking circuit
   A thermal shutdown circuit (usually a thermal shutdown circuit) does not protect the IC in any case. Release the heating condition immediately after operation. If the product is used in excess of the absolute maximum rating, the heat interruption circuit may not operate properly or the IC may be damaged before it operates.
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