Description

This application note first describes the basic operation of the 300W isolated DC-DC converter adopted for the reference design (Note1). After that, the efficiency evaluation results are explained. Furthermore, the loss of the switching devices is analyzed using a high accuracy electric circuit model that simulates this reference design. The device model (SPICE model) of the switching devices for the loss simulation uses a sub-circuit model originally developed by Toshiba (hereinafter referred to as the G2 model). The G2 model is a SPICE model that expresses the nonlinearity of the capacitance of a power device and is suitable for transient simulations of power devices.

(Note1) Reference design refers to the data information about application design listed at the Reference Design Center on the Toshiba Device & Storage website. The reference design includes schematics, board data, BOM information, reference guides and design guides.
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1. 300W Isolated DC-DC Converter

This converter operates over an input voltage range of 36 to 75VDC and provides 300W power at 12VDC output. This converter is suitable for various applications, including telecommunication equipment with 48VDC lines and industrial systems powered by 48V batteries. This reference design provides various design information, which can help reduce the time and effort in designing a DC-DC converter according to actual required specifications. This converter uses Toshiba’s latest small surface-mount power MOSFETs (TPN1200APL, TPH2R408QM) as switching devices on both the primary and secondary sides and small surface-mount components for other types of devices. Consequently, despite the use of a general-purpose winding transformer, small PCB size (82mm x 82mm x 24mm) and high efficiency (94%) are achieved.

Table 1.1 Input and output characteristics of 300W DC-DC converter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Condition</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input voltage</td>
<td></td>
<td>36</td>
<td>75</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Input current</td>
<td>$\text{Vin} = 48 \text{ V}, \text{Iout} = 25 \text{ A}$</td>
<td></td>
<td>12</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>Output characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage</td>
<td></td>
<td>11.4</td>
<td>12.0</td>
<td>12.6</td>
<td>V</td>
</tr>
<tr>
<td>Output current</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Output power</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td>W</td>
</tr>
<tr>
<td>Ripple</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>Switching frequency</td>
<td></td>
<td>185</td>
<td></td>
<td></td>
<td>kHz</td>
</tr>
</tbody>
</table>
1.1. Schematic diagram of 300W isolated DC-DC converter

Fig. 1.2 is a schematic diagram of DC-DC converter used in this evaluation. With the transformer T₁ as
the boundary, the primary side (input side) is composed of four switching devices TR₁ to TR₄ consisting of
two arms, the secondary side (output side) is composed of two devices TR₅, TR₆ that is intended for
synchronous rectification and output smoothing filter circuits consisting of inductance L₂ and capacitor C₂.
Fig. 1.3 shows a detailed schematic diagram of the secondary side MOSFET. TR₅ and TR₆ have two
MOSFETs connected in parallel. This converter generates 12V output voltage by phase-shifted full-bridge
(PSFB) topology. The output voltage is regulated by phase-shifted operation between an arm of TR₁, TR₂
and the other arm of TR₃, TR₄ with a 50% duty cycle. In the dead time between the high side MOSFET and
low side MOSFET to prevent shoot-through, zero voltage switching(ZVS) is achieved and reduces the
switching loss of the power converter.
1.2. Operating waveforms of the 300W isolated DC-DC converter

This chapter introduces the principle of switching operation by describing the eight different modes. Fig.1.4 and Fig.1.5 show the current path in each operation mode, and Fig.1.6 shows the waveforms of each switching device and L2.

・Operation mode-1: TR1 and TR4 are ON state, TR2, TR3 and TR5 are OFF state
As shown by the dotted arrows in Fig.1.4(a), while TR1 and TR4 are ON state, current flows through TR1 and then flows through the primary end of T1, and then flows through TR4. Here, the energy is transferred from the primary side(n1) to the secondary side(n3) through the transformer T1, and C2 is charged through TR6 and L2.

・Operation mode-2: TR1 and TR6 are ON state, TR2, TR3 and TR5 are OFF state, TR4 is turn-off
When TR4 turns off, the current that flows on the primary side causes a freewheeling operation through the body-diode of TR3 after charging the output capacitance Coss of TR2 and TR4 as shown by the dotted arrows in Fig. 1.4(b). Because of the freewheeling operation, energy is not transferred from the primary side (n1) to the secondary side (n3) through the transformer T1, but on the secondary side, the current that flows along the path of the blue dotted arrow comes from L2 due to energy stored. In addition, the current also flows along the red dashed arrow through body diode of TR5.

・Operation mode-3: TR1 and TR6 are ON state, TR2 and TR4 are OFF state, TR3 and TR5 is turn-on
When TR3 turns on, the freewheeling current in TR3 flows through the transistors rather than through the body diodes. In addition, when TR5 turns on, current in TR5 flows through the transistors rather than through the body diode along the red dashed arrows.

・Operation mode-4: TR3 and TR5 are ON state, TR2 and TR4 are OFF state, TR1 and TR6 are turn-off
When TR1 turns off, the freewheeling operation stops and no current flows at the primary. However, on the secondary, the current flows along the red dashed arrow through the on-state TR5 from L2 due to energy stored.

![Fig. 1.4 300W DC-DC converter operation mode 1~4](image-url)
Efficiency Evaluation and Loss Analysis of 300W isolated DC-DC converter

Application Note

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- Operation mode-5: TR2, TR3 and TR5 are ON state, TR1, TR4 and TR6 are OFF state
  As shown by the dotted arrows in Fig.1.5(a), while TR2 and TR3 are ON state, the current flows through TR3 and then flows through the primary (n1) of T1, and then flows through TR2. Here, the energy is transferred from the primary side (n1) to the secondary side (n2) through the transformer T1, and C2 is charged through TR5 and L2.

- Operation mode-6: TR2 and TR5 are ON state, TR1, TR4 and TR6 are OFF state, TR3 turn off
  When TR3 turns off, the current flows on the primary side causes a freewheeling operation through body-diode of TR4 after charging the output capacitance Coss of TR1 and TR3 as shown by the dotted arrows in Fig. 1.5(b). Because of the freewheeling operation, energy is not transferred from the primary side (n1) to the secondary side (n2) through the transformer T1, but on the secondary side, the current that flows along the path of the blue dotted arrow comes from L2 due to energy stored. In addition, the current also flows along the red dashed arrow through body diode of TR6.

- Operation mode-7: TR2 and TR5 are ON state, TR1 and TR3 are OFF state, TR4 and TR6 are turn-off
  When TR4 turns on, the freewheeling current in TR4 flows through the transistors rather than through the body diodes. In addition, when TR5 turns on, current flows in TR6 through the transistors rather than through the body diode along the red dashed arrows.

- Operation mode-8: TR4 and TR6 are ON state, TR1 and TR3 are Off state, TR2 and TR5 are turn-off
  When TR2 turns off, the freewheeling operation stops and no current flows at the primary. However, on the secondary, the current flows along the red dashed arrow through the on-state TR6 from L2 due to energy stored.

Fig. 1.5 300W DC-DC converter operation mode 5~8
Fig. 1.6 shows the simplified operating waveforms of 300W isolated DC-DC converter. For the operation modes 1 to 8 shown in Fig. 1.4 and Fig. 1.5, the gate voltage ($V_G$) and drain current ($I_D$) of the switching devices TR1 to TR6, drain-source voltage ($V_{sync1}, V_{sync2}$) of TR5 and TR6, and the inductance voltage ($V_L$) and current ($I_L$) of L2 are described. The current through TR5 and TR6 are denoted by a negative value because the current flows from the source to the drain.

**Fig. 1.6 Simplified operating waveforms of 300W DC-DC converter**
2. Power MOSFETs lineup for efficiency evaluation device

Toshiba offers the U-MOSⅧ-H, U-MOSⅨ-H and U-MOSⅩ-H low-voltage MOSFET series which suits the primary (main switch) and secondary (synchronous rectification) sides of DC-DC converters. Toshiba provides MOSFETs with a wide range of VDSS from 30V to 250V and various on-resistance types in each VDSS class so it is easy to find proper MOSFETs when designing a DC-DC converter, according to the desired circuit topology, input and output voltages, output current, and the locations of MOSFETs on the circuit (primary or secondary side). Fig. 2.1 shows the lineup of the U-MOSⅧ-H, U-MOSⅨ-H and U-MOSⅩ-H MOSFET series.

![Fig. 2.1 Product lineup of the U-MOSⅧ-H, U-MOSⅨ-H, and U-MOSⅩ-H MOSFET series](image)

### 2.1. List of Switching devices to be compared

Table 2.1 shows the main specifications of MOSFETs used in this evaluation. The dominant losses on secondary MOSFET are conduction loss and reverse recovery loss in general, therefore the better efficiency especially on mid-load to heavy load is expected on the latest generation U-MOSX-H 80V product TPH2R408QM which has a lower on-resistance(R\(_{DS(ON)}\)) and a smaller reverse recovery charge(Q\(_{rr}\)) compared with other products.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Symbol</th>
<th>Unit</th>
<th>Primary Side</th>
<th>Secondary Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain-source breakdown voltage (Min)</td>
<td>(V_{BROSS})</td>
<td>V</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>Gate threshold voltage (Max)</td>
<td>(V_{th})</td>
<td>V</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Drain-source on-resistance (Typ)</td>
<td>(R_{DS(ON)})</td>
<td>mΩ</td>
<td>9.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Input capacitance (Typ)</td>
<td>(C_{iss})</td>
<td>pF</td>
<td>1425</td>
<td>5870</td>
</tr>
<tr>
<td>Reverse transfer capacitance (Typ)</td>
<td>(C_{rss})</td>
<td>pF</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Output capacitance (Typ)</td>
<td>(C_{oss})</td>
<td>pF</td>
<td>205</td>
<td>840</td>
</tr>
<tr>
<td>Gate resistance (Typ)</td>
<td>(r_{g})</td>
<td>Ω</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Switching time (rise time) (Typ)</td>
<td>(t_{r})</td>
<td>ns</td>
<td>6</td>
<td>10.8</td>
</tr>
<tr>
<td>Switching time (turn-on time) (Typ)</td>
<td>(t_{on})</td>
<td>ns</td>
<td>19</td>
<td>29</td>
</tr>
<tr>
<td>Switching time (fall time) (Typ)</td>
<td>(t_{f})</td>
<td>ns</td>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>Switching time (turn-off time) (Typ)</td>
<td>(t_{off})</td>
<td>ns</td>
<td>34</td>
<td>123</td>
</tr>
<tr>
<td>Total gate charge (Typ)</td>
<td>(Q_{g})</td>
<td>nC</td>
<td>24</td>
<td>87</td>
</tr>
<tr>
<td>Gate-drain charge (Typ)</td>
<td>(Q_{gd})</td>
<td>nC</td>
<td>4.9</td>
<td>19</td>
</tr>
<tr>
<td>Gate switch charge (Typ)</td>
<td>(Q_{gw})</td>
<td>nC</td>
<td>7.5</td>
<td>28</td>
</tr>
<tr>
<td>Output charge (Typ)</td>
<td>(Q_{oss})</td>
<td>nC</td>
<td>24</td>
<td>90</td>
</tr>
<tr>
<td>Reverse recovery charge (Typ)</td>
<td>(Q_{rr})</td>
<td>nC</td>
<td>47</td>
<td>74</td>
</tr>
</tbody>
</table>
3. Efficiency evaluation results of actual device

In this evaluation, we verified the efficiencies of our 300W isolated DC-DC converter using the products listed in Table 2.1. The switching frequency of PSFB circuit is set by an external resistor connected to the RT terminal of the PWM controller. In this evaluation, the external resistor is set to 27kΩ and PSFB switching frequency is set to 370kHz. The PWM controller switches MOSFET (TR₁, TR₂ and TR₃, TR₄) of the left and right arms of the primary bridge at 1/2 of PSFB switching frequency (185kHz).

Efficiency is one of the most important characteristics of DC-DC converters. Efficiency is the ratio of the output power to the input power to DC-DC converter and it is calculated by the following formula.

\[
\text{Efficiency} = \frac{(V_{\text{out}} \times I_{\text{out}})}{(V_{\text{in}} \times I_{\text{in}})} \times 100\%\
\]

In this evaluation, we measured \( V_{\text{in}}, I_{\text{in}}, V_{\text{out}} \) and \( I_{\text{out}} \) for 2 patterns of switching device combinations under the following conditions, then calculated and compared the efficiency. Fig.3.1 shows the connection diagram for efficiency measurement. DC-DC converter circuit board is forcibly air-cooled by cooling –fan located nearby.

- Input voltage \( (V_{\text{in}}) \) = 48V
- Output voltage \( (V_{\text{out}}) \) = 12V
- Ambient temperature \( (T_a) \) = 25°C
- Output-load current \( (I_{\text{out}}) \) = 1A, 3A, 5A, 7A, 10A, 14A, 16A, 18A, 20A, 25A

![Fig. 3.1 Connection between evaluation board and each equipment for efficiency measurement](image-url)
3.1. Effect of secondary-side switching device on power conversion efficiency

Figures 3.2 (a) to (c) show the efficiency curves when TPN1200APL is chosen as the primary MOSFET and TPH2R408QM or Company A’s MOSFET is chosen as the secondary side MOSFET. Since conduction loss is dominant in medium to heavy loads, TPH2R408QM with the smallest drain-source on-resistance is superior. The maximum efficiency is 94.83% at 16A of output load and 94.12% at 25A of full load. On the other hand, the on-resistance of Company A is about 16% larger than that of TPH2R408QM, resulting in 94.65% at 16A of output load and 93.89% at 25A of full load. Fig.3.2 (d) shows the results of measuring MOSFET device temperatures of the secondary side. Even under heavy loads, TPH2R408QM has a temperature lower than 45°C, which indicates that it generates less heat than MOSFET produced by Company A.

(a) Efficiency comparison of secondary side MOSFETs (TR5 and TR6)

(b) Light load (Iout=1 to 10A)

(c) Medium load to heavy load (Iout=10 to 25A)

(d) Device temperature of the secondary side MOSFETs (TR5 and TR6)

Fig. 3.2 Output load dependency of secondary MOSFET efficiencies and temperatures
4. Spike voltage

Low-spike performance is one of the advantages of TPH2R408QM used on the secondary side. TPH2R408QM adopts a new structure in the gate trench. As shown in Fig. 4.1, parasitic capacitance and parasitic resistance exist between the drain and source, and a CR-snubber circuit is constructed, thereby suppressing the spike voltage. This effect is explained in this chapter using the secondary synchronous rectifier of DC-DC converter with the parasitic inductances $L_p$ of the circuit boards shown in Fig. 4.2. The damping coefficient ($\zeta$) of this circuit is expressed by Equation (1). Since the numerator has $r_s$ and $C_{ds}$, the larger each value, the larger the damping coefficient, the faster the damping speed, and the faster the ringing converges. Also, since the spike voltage ($V_{Cds}$) expressed by Equation (2) has $r_s$ and $C_{ds}$ in the denominator, it can be understood that the larger the value, the smaller the value of the spike voltage. The spike voltage reduction reduces noise and ringing concern and enables easier to design power supply circuit such as voltage safety margins. Fig. 4.3 shows the R-load switching evaluation board circuit and TPH2R408QM and Company A’s turn-off waveform ($V_{DS}$). TPH2R408QM has a $V_{DS}$ spike voltage of 50.91V and a ringing time of 48ns. On the other hand, $V_{DS}$ spike voltage of Company A is 56.61V and the ringing time is 71ns, indicating that TPH2R408QM is superior in both $V_{DS}$ spike voltage and the ringing time.

\[
\zeta = \frac{r_s}{2} \times \sqrt{\frac{C_{ds}}{L_p}} \quad \text{... equation(1)}
\]

\[
V_{Cds} = \frac{1}{r_s} \times \frac{V_s}{\omega_0 \times C_{ds}} \quad \text{... equation(2)}
\]

- $C_{ds}$: Drain-source capacitance of MOSFET
- $r_s$: Embedded source-wire resistor for MOSFET
- $L_p$: Substrate parasitic inductance
- $\omega_0$: Angular frequency of the LCR series resonant circuit
- $V_s$: Secondary voltage

Fig. 4.1 Parasitic snubber circuit

![Parasitic snubber circuit diagram](image1)

Fig. 4.2 Synchronous rectifier circuit of DC-DC converter secondary side

![Synchronous rectifier circuit diagram](image2)

Fig. 4.3 R-load switching circuit diagram and turn off waveform comparison of $V_{DS}$

![R-load switching circuit diagram](image3)
5. Loss Analysis using the high accuracy simulator circuit (Note2)

Fig.5.1 is a schematic diagram of the simulation circuit. The reference model uses a phase-shifted full-bridge PWM controller IC, but this simulation circuit uses the alternative control model making feedback according to the voltage and current sensing. All sensing points are connected to the control model, and primary or secondary side’s MOSFET are controlled by this control model to regulate the output voltage. The transformer and reactors which greatly affect the simulation accuracy use equivalent circuit models created based on actual measurement results. (Note2) The high accuracy simulation circuit is originally developed for loss analysis.

![Simulation circuit diagram]

**Fig. 5.1 Simulation circuit**

In addition, this simulator uses a high-accuracy device model (G2 model) that enhances the reproducibility of the high-current-domain characteristics of $I_D-V_{DS}$ curve and the voltage-dependent characteristics of the parasitic capacitance, and allows closer switching simulations to actual measurements. Fig.5.2 (a) to (d) show the comparison results between actual measurements and simulations of the main characteristics ($I-V$ and $C-V$). Fig. (e) and (f) show turn off characteristics of $R$-load switching using this device model. The simulated waveform (Fig.(e)) is accurately reproduced the actual measured waveform(Fig.(f)).

![Comparison of actual measurement and simulation characteristics of device model]

**Fig. 5.2 Comparison of actual measurement and simulation characteristics of device model**
5.1. Loss definition of secondary MOSFET

Figure 5.3 shows the timing chart of the secondary MOSFET that operate as synchronous rectification and each loss calculation section defined as $E_{\text{diode}1}$, $E_{\text{sync}}$, $E_{\text{diode}2}$, $E_{\text{recovery}}$, $E_{\text{block}}$, and $E_{\text{gate}}$. Each loss is defined with the conduction state in mind, and $E_{\text{diode}1}$, $E_{\text{sync}}$, $E_{\text{diode}2}$, $E_{\text{recovery}}$ and $E_{\text{block}}$ are calculated by the time integration of the product of the drain-to-source voltage $V_{DS}$ and the drain current $I_D$. On the other hand, $E_{\text{gate}}$ is calculated by time integration of the product of gate-to-source voltage $V_{GS}$ and gate current $I_G$.

<table>
<thead>
<tr>
<th>Loss calculation section</th>
<th>Loss name</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_1$ - $t_2$</td>
<td>$E_{\text{diode}1}$</td>
<td>Body-diode conduction loss-1</td>
<td>Calculate time integration of $V_{DS} \times I_D$</td>
</tr>
<tr>
<td>$t_2$ - $t_3$</td>
<td>$E_{\text{sync}}$</td>
<td>MOSFET conduction loss</td>
<td>same as above</td>
</tr>
<tr>
<td>$t_3$ - $t_4$</td>
<td>$E_{\text{diode}2}$</td>
<td>Body-diode conduction loss-2</td>
<td>same as above</td>
</tr>
<tr>
<td>$t_4$ - $t_5$</td>
<td>$E_{\text{recovery}}$</td>
<td>Recovery loss</td>
<td>same as above</td>
</tr>
<tr>
<td>$t_5$ - $t_6$</td>
<td>$E_{\text{block}}$</td>
<td>MOSFET blocking loss</td>
<td>same as above</td>
</tr>
<tr>
<td>$t_6$ - $t_7$</td>
<td>$E_{\text{gate}}$</td>
<td>MOSFET gate drive loss</td>
<td>Calculate time integration of $V_{GS} \times I_G$</td>
</tr>
</tbody>
</table>

![Fig. 5.3 Timing chart of loss calculation for secondary MOSFET](image)

5.2. Comparative analysis of efficiency between actual evaluation board and simulation

Fig. 5.4 shows the Efficiency-Output current(load) dependency of the evaluation board and the simulated circuit when TPN1200APL is chosen as the primary MOSFET and TPH2R408QM or Company A’s MOSFET is chosen as the secondary side MOSFET. The efficiency difference between the evaluation board and the simulation result from medium load to heavy load region is 1 % or less. The main reason for this difference is the loss not considered in this simulation circuit such as the loss of the controller and the change in characteristics caused by the heat generated by each component constituting the circuit. However, since there is no discrepancy on relative merits between TPH2R408QM and Company A’s MOSFET in the evaluation with evaluation board and simulation, it can be said that the operation of this simulation circuit can almost simulate the actual evaluation board. In the next section, we use this simulator to analyze the loss of components mounted on the evaluation board including the secondary MOSFET for one cycle.

![Fig. 5.4 Load dependent characteristics comparison (Reference model and Simulation circuit)](image)
5.3. Loss analysis

Fig. 5.5 shows the results of loss-simulation for a 300W isolated DC-DC converter using TPN1200APL for the primary MOSFET and TPH2R408QM for the secondary MOSFET on the high-accuracy simulation circuits. The loss ratios of the components at the output current of 25 [A] are 24.9% for the primary MOSFET (Pri_Side), 17.7% for the secondary MOSFET (Sec_Side), 20.2% for the transformer (Transformer), 15.2% for the reactor (Reactor), 6.1% for the snubber (Snubber), and 15.9% for the rest (others), indicating that approximately 43% of the loss is generated by MOSFET on the primary and secondary sides. The rate of MOSFET loss increases as the output current decreases. This shows that it is crucial to reduce MOSFET losses to improve the efficiency of DC-DC converter. Fig. 5.6 shows the power loss amount for one cycle of TPH2R408QM used on the secondary side. Recovery loss ($E_{\text{recovery}}$) of the body diodes is dominant, but the increment is not sensitive to the output current. On the other hand, looking at the conduction loss ($E_{\text{sync}}$), it increases greatly as the output current increases. Therefore, for secondary MOSFET, it is desirable to select products with low recovery charge ($Q_{\text{rr}}$) associated with recovery loss and low drain-to-source on-resistance ($R_{\text{DS(ON)}}$).

![Fig. 5.5 Results of loss analysis for each mounted component](image1)

![Fig. 5.6 Secondary MOSFET loss analysis results](image2)
6. Conclusion

The loss of the secondary MOSFET of the 300W isolated DC-DC converter is dominated by conduction and recovery losses as shown in Fig. 5.6. Therefore, it is recommended to select a MOSFET with low drain-source on-resistance and low reverse-recovery charge. Finally, it was confirmed in this evaluation that using TPH2R408QM on the secondary side resulted in the highest efficiency this time.

7. Application support

Detailed information on the reference designs adopted for this application note can be found at the following URL:

8. Device Model (SPICE Model) Support

The SPICE models used in this application note are available at the following URLs.

Primary switching MOSFET: TPN1200APL

Secondary switching MOSFET: TPH2R408QM

Description of grade notation for device models (SPICE models).
https://toshiba.semicon-storage.com/info/docget.jsp?did=139481

Notes on Contents

1. Block Diagrams
   Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

2. Equivalent Circuits
   The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.
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