Low-Cost Multiple Output Flyback Converter for I/O Cards

INTRODUCTION
Isolated power supplies for I/O cards are required to provide multiple outputs (typically 9V at 0 mA–120 mA and 5V at 0 mA–200 mA) from a 3.3V input. The transformer peak primary currents are generally very high, thereby eliminating the choice of many popular low-cost integrated circuits. The circuits shown in Figure 1 performs the required conversion using LM3578A and D44C3A npn transistor. The LM3578A is a switching regulator featuring an internal comparator, oscillator, protection circuitry and a transistor. The transistor can handle currents only up to 750 mA. However, this internal transistor can be used to drive an external transistor of higher current rating such as D44C3A, in order to handle the required currents.

CONVERTER DESIGN EQUATIONS
System Specifications:

\[
\begin{align*}
V_{IN} &= 3.3V \ (\pm 10\%) \\
V_{o1} &= 9V \ (\pm 10\%) \ (Isolated) \\
V_{o2} &= 5V \ (\pm 5\%) \ (Isolation not a must) \\
I_{o1} &= 0 mA–120 mA \\
I_{o2} &= 0 mA–200 mA \\
\end{align*}
\]

In the following equations, the switching frequency is assumed to be 80 kHz and the maximum duty cycle is assumed to be 50%.

Transformer Specification:
Transformer turns ratio is:

\[
\frac{N_{p}}{N_{s}} = \frac{(V_{o1} + V_{o2})}{V_{IN} \ (min) - V_{ce\ (sat)}} \frac{D_{\max}}{1 - D_{\max}} = \frac{(5 \pm 0.7)}{(3 \pm 0.3)} \frac{0.5}{1 - 0.5} = 3.6 \quad (1)
\]

Assuming an efficiency of 80%, the average input current at max. load is:

\[
l_{IN} (dc) = \frac{V_{o1} I_{o1} (max) + V_{o2} I_{o2} (max)}{\eta \ V_{IN} (min)} = \frac{2.08}{0.8} = 0.87A \quad (3)
\]

Hence, the average switch current is:

\[
l_{sw\ (avg)} = \frac{l_{IN} (dc)}{D} = \frac{0.87}{0.5} = 1.74A \quad (4)
\]

Assuming the primary inductance current ripple to be 25% of the average switch current, the primary inductance is given by:

\[
L_{p} = \frac{(V_{IN} (min) - V_{ce\ (sat)}) D_{\max}}{\Delta I_{p}/\eta} = \frac{(3 - 0.3) 0.5}{80000 \times 1.74/2} = 19.5 \mu H \quad (5)
\]

Peak primary current is given by:

\[
l_{p} = l_{sw\ (avg)} + \Delta I_{p}/2 = 1.74 + 1.74/4 = 2.2A \quad (6)
\]

FIGURE 1

TL/H/12878–1

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Transistor Selection:
The transistor should be able to handle the peak current calculated above. The internal transistor in LM3578 can handle up to 750 mA. So the current gain of the external transistor should be greater than 30 at the peak primary current. The off state voltage rating of the switch should be at least 10V. One npn transistor meeting these requirements is D44C3A.

Current Limiting with LM3578A:
Current limiting is activated whenever pin 7 is pulled 110 mV (typically) above the ground. In this application, voltage across the resistor \( R_{sn} \) is sensed in order to determine excess current through the external switch. Typical value for \( R_{sn} \) is 0.05Ω. \( R_{sn} \) can also be fabricated on a copper trace. If \( \Delta T \) is the estimated temperature rise, the resistance of 1 oz/ft² copper sheet is given by

\[
R_c(T) = 0.5 \times 10^{-3} \left[ 1 + 3.9 \times 10^{-3} (T_A - 20 + \Delta T) \right]
\]

where \( T_A \) is the ambient temperature. The required length (l) and width (w) of copper trace can be calculated using the following equations:

\[
w = \frac{1000 \times I_{lim}}{\sqrt{T(55 R_c(T))}} \quad (8)
\]

\[
l = \frac{w \times R_{sn}}{R_c(T)} \quad (9)
\]

where \( I_{lim} \) is the desired current limit set point.

Feedback:
Isolation between the 9V output and the input is maintained by using the 5V output for feedback (since the specification does not require isolation between 5V output and the input). Thus, the need for an opto-isolator or other type of feedback-isolation is eliminated. The reference pin (pin 1) is set at 1V using a resistor divider network (R1, R2).

Compensation:
The switching frequency is set by using the timing capacitor \( C_T \). Choosing a value of 1 nF for \( C_T \) sets the switching frequency at 80 kHz. Capacitor \( C_1 \) (typically between 10 pF–25 pF), together with the feedback resistors (R1 and R2) is used for compensation. For more details on choice of the above components, please refer to National Semiconductor data sheet for LM3578A.

RESULTS
The output voltage ripple was measured to be equal to 63 mV at the 5V output and 43 mV at the isolated 9V output. Efficiency of this converter was around 78% under nominal conditions. Less than 10% cross-regulation was observed.

PARTS LIST

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<thead>
<tr>
<th>Designator</th>
<th>Quantity</th>
<th>Value/Rating</th>
<th>Description</th>
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<tbody>
<tr>
<td>U1</td>
<td>1</td>
<td>—</td>
<td>LM3578A Switching Regulator</td>
</tr>
<tr>
<td>Q1</td>
<td>1</td>
<td>5A, 30V</td>
<td>D44C3A, NPN Transistor</td>
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<tr>
<td>D1, D2</td>
<td>2</td>
<td>1A, 40V</td>
<td>Output Diodes, SR104</td>
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<td>D3</td>
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<td>1A, 40V</td>
<td>Clamping Diode, SR104</td>
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<td>10V</td>
<td>Zener diode for clamping</td>
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<td>Lp-24.2 µH, Ip-2.1A</td>
<td>Transformer</td>
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<td>470 µF, 10V</td>
<td>Output 2 capacitor</td>
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<td>R4</td>
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<tr>
<td>R5</td>
<td>1</td>
<td>1 kΩ, 1/4W</td>
<td>Resistor for spike suppression</td>
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<td>2.2 nF</td>
<td>Capacitor for spike suppression</td>
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<tr>
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<td>Compensation capacitor</td>
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