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

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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, there by 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:

$$V_{IN} = 3.3V\ (\pm 10\%)$$
$$V_{o1} = 9V\ (\pm 10\%)\ \text{(Isolated)}$$
$$V_{o2} = 5V\ (\pm 5\%)\ \text{(Isolation not a must)}$$
$$I_{o1} = 0\ mA–120\ mA$$
$$I_{o2} = 0\ mA–200\ mA$$

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:

$$\frac{N_{s1}}{N_p} = \frac{(V_{o1} + V_d)}{V_{IN\,(min)} - V_{ce\,(sat)}} \frac{D_{max}}{1 - D_{max}} = \frac{(9 + 0.7)}{(3 - 0.3)} \frac{0.5}{1 - 0.5} = 3.6 \quad (1)$$

$$\frac{N_{s2}}{N_p} = \frac{(V_{o2} + V_d)}{V_{IN\,(min)} - V_{ce\,(sat)}} \frac{D_{max}}{1 - D_{max}} = \frac{(5 + 0.7)}{(3 - 0.3)} \frac{0.5}{1 - 0.5} = 2.1 \quad (2)$$

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

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

Hence, the average switch current is:

$$I_{sw\,(avg)} = \frac{I_{IN\,(dc)}}{D} = \frac{0.87}{0.5} = 1.74A \quad (4)$$

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

$$L_p = \frac{(V_{IN\,(min)} - V_{ce\,(sat)})\,D_{max}}{\Delta i_p f_s} = \frac{(3 - 0.3)\,0.5}{80000 \times 1.74/2} = 19.5\ \mu H \quad (5)$$

Peak primary current is given by:

$$I_p = I_{sw\,(avg)} + \Delta i_p/2 = 1.74 + 1.74/4 = 2.2A \quad (6)$$

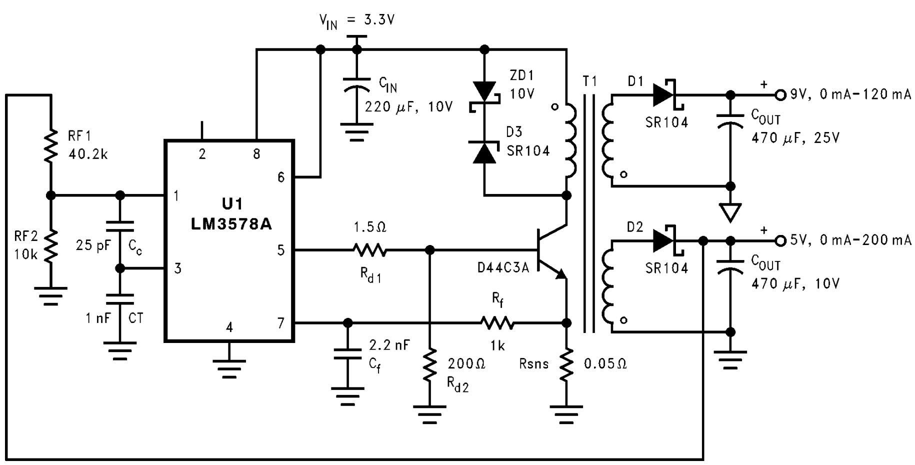

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FIGURE 1

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 ΔT is the estimated temperature rise, the resistance of 1 oz/ft^2 copper sheet is given by

$$R_c(T) = 0.5\times10^{-3}\,[1 + 3.9\times10^{-3}\,(T_A - 20 + \Delta T)] \quad (7)$$

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

$$w = \frac{1000 \times I_{lim}}{\sqrt{\Delta T/(55\,R_c(T))}} \quad (8)$$

$$l = w\,\frac{R_{sn}}{R_c(T)} \quad (9)$$

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 (R_1, R_2).

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 (R_1 and R_2) 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

Designator	Quantity	Value/Rating	Description
U1	1	—	LM3578A Switching Regulator
Q1	1	5A, 30V	D44C3A, NPN Transistor
D1, D2	2	1A, 40V	Output Diodes, SR104
D3	1	1A, 40V	Clamping Diode, SR104
ZD1	1	10V	Zener diode for clamping
T1	1	Lp-24.2 μH, Ip-2.1A	Transformer
C_{IN}	1	220 μF, 6.3V	Input bulk capacitor
C_{o1}	1	470 μF, 16V	Output 1 capacitor
C_{o2}	1	470 μF, 10V	Output 2 capacitor
R_{sn}	1	0.05Ω, ½W	Current limiting resistor
R_1	1	40.2 kΩ, ¼W	Feedback resistor
R_2	1	10 kΩ, ¼W	Feedback resistor
R_{d1}	1	1.5Ω, ¼W	Base drive resistor
R_{d2}	1	200Ω, ¼W	Base drive resistor
R_f	1	1 kΩ, ¼W	Resistor for spike suppression
C_f	1	2.2 nF	Capacitor for spike suppression
C_T	1	1 nF	Timing capacitor
C_c	1	1 nF	Compensation capacitor

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