

$$N = \frac{V_{OUT} + V_F}{16 + 7k \left(\frac{V_{FB}}{R2} \right)} \quad (92)$$

The term $7k (V_{FB}/R2)$ is normally set to $\approx 2V$ to allow some adjustment range in V_{OUT} . Solving for N in Figure 5.25, with $V_{OUT} = 15V$:

$$N = \frac{15 + 0.7}{16 + 2} = 0.872$$

The smallest integer ratio with N close to 0.872 is $7:8 = 0.875$. T1 is to be wound with this turns *ratio* for each output. The *total* number of turns is determined by the required primary inductance (L_{PRI}). This inductance has no optimum value; it is a trade-off between core size, regulation requirements and leakage inductance effects. A reasonable starting value is found by assigning a maximum magnetizing current (ΔI) of 10% of the peak switch current of the LT1070. Magnetizing current is the difference between the primary current at the start of switch “on” time and the current at the end of switch “on” time. This gives a value for L_{PRI} of:

$$L_{PRI} = \frac{V_{IN}}{(\Delta I)(f) \left(1 + \frac{V_{IN}}{V_{PRI}} \right)} \quad (93)$$

ΔI = primary magnetizing current

V_{PRI} = regulated primary flyback voltage

For $V_{IN} = 5V$, $\Delta I = 0.5A$, $V_{PRI} = 18V$:

$$L_{PRI} = \frac{5}{(0.5)(40 \cdot 10^3)(1 + 5/18)} = 196\mu H$$

Again, this value is not an optimum figure, it is simply a compromise between maximum output current and core size.

A second consideration on primary inductance is the transition from continuous mode to discontinuous mode. At light output loads, the flyback pulse across the primary will drop toward zero before the end of switch “off” time. The LT1070 interprets this as a drop in output voltage and raises duty cycle to compensate. This results in an abnormally high output voltage. To avoid this situation, the output should have a minimum load equal to:

$$I_{OUT(MIN)} = \frac{(V_{PRI} \cdot V_{IN})^2}{(V_{PRI} + V_{IN})^2 (2V_{OUT})(f)(L_{PRI})} \quad (94)$$

with $V_{PRI} = 18V$, $V_{IN} = 5V$, $V_{OUT} = 15V$, $L_{PRI} = 200\mu H$:

$$I_{OUT(MIN)} = \frac{(18 \cdot 5)^2}{(18 + 5)^2 (2 \cdot 15)(40 \cdot 10^3)(200 \cdot 10^{-6})} = 64mA$$

This current may be shared equally on each output at 32mA per output. If a lighter minimum load is desired,

primary inductance must be increased. This also increases leakage inductance, so some care must be used.

Leakage inductance is a portion of the primary which is not coupled to the secondary. This leakage inductance will create a flyback spike following switch opening. The height of this spike must be clamped with a snubber ($R4$, $C3$, $D2$) to avoid overvoltage on the switch. (Please read snubber details in the section on normal mode flyback regulators). The *width* of the leakage inductance spike is equal to:

$$t_L = \frac{(I_{PRI})(L_L)}{V_M - V_{PRI} - V_{IN}} \quad (95)$$

L_L = leakage inductance

I_{PRI} = peak primary current

V_M = peak switch voltage

This spike width is important because it must be less than $1.5\mu s$ wide. The LT1070 has internal blanking for $\approx 1.5\mu s$ following switch turn-off. This blanking time ensures that the flyback error amplifier will not interpret the leakage inductance spike as the actual flyback voltage to be regulated. To avoid poor regulation, the spike must be less than the blanking time.

If transformer T1 is trifilar wound for minimum leakage inductance, L_L may have a typical value of 1.5% of L_{PRI} . Assuming $L_{PRI} = 200\mu H$, L_L would be $3\mu H$. To calculate t_L , we still need to assign a value to V_M . In this case, with $V_{IN} = 5V$, a conservative value for maximum switch voltage would be $V_M = 50V$. If we assume a maximum primary current of 5A for maximum output current, spike width is:

$$t_L = \frac{5(3 \cdot 10^{-6})}{50 - 18 - 5} = 0.56\mu s$$

This is well within the maximum value of $1.5\mu s$. Note, however, that the pulse width grows rapidly as the sum of $V_{PRI} + V_{IN}$ approaches maximum switch voltage. The following formula will allow one to calculate the maximum ratio of leakage inductance to primary inductance in a given situation.

$$\frac{L_L}{L_P}(\text{MAX}) = \frac{t_L(V_M - V_P - V_{IN})(\Delta I)(f) \left(1 + \frac{V_{IN}}{V_P} \right)}{I_{PRI}(V_{IN})} \quad (96)$$

With a fairly large V_{IN} (36V), even if we use a less conservative value of 60V for V_M , with $t_L = 1.5\mu s$, $V_P = 18V$, $\Delta I = 0.5A$ and $I_{PRI} = 5A$:

$$\begin{aligned} \frac{L_L}{L_P}(\text{MAX}) &= \frac{(1.5 \cdot 10^{-6})(60 - 18 - 36)(0.5)(40 \cdot 10^3) \left(1 + \frac{36}{18} \right)}{5(36)} \\ &= 0.003 = 0.3\% \end{aligned}$$

This low ratio of leakage inductance to primary inductance would be nearly impossible to wind, so some compromises must be made. If maximum output current is not required,