Chapter 9

High-Stress Part and Power Dissipation

9.1 Introduction

All electronic parts, no matter what they are, will eventually fail. The mechanism of failure can roughly be attributed to three factors: the operating stress, the environment in which it operates, and the aging process imposed naturally upon the part. To a large extent these seemingly independent mechanisms are also crosslinked. For instance, a higher operating current undoubtedly will generate more internal dissipation for some parts, which in turn raises the local temperature profile. Also, a higher thermal environment most likely will exacerbate the material degradation, for example, fatigue, of those components within the vicinity. Therefore, in considering the possible sequence of events and in terms of controllability, the part operating stress measured in current, voltage, power, and temperature can be considered to be the most important.

As a result of the above understanding, this chapter attempts to provide a solid analytical base on which many essential circuit performances of the forward converter are quantified. The approaches presented are generalized mathematically such that applications of a given method are not restricted to an unique converter topology.

9.2 Stresses on Parts of a Power Chain

For a forward PWM converter in the continuous conduction mode, there are several major parts that are subjected to high stress. Among them are the transformer, the main switch on the primary side, all rectifier diodes on the secondary side, and the snubber components if included.

During a normal steady-state switching cycle, the main switch sustains an ideal repetitive voltage waveform as shown in Fig. 9-1. In the real world,
the waveform is somewhat distorted (Fig. 9-2), by the transformer parasitic reactance ringing and the rectifier reverse recovery. For all practical purposes, the first waveform is sufficient for the evaluation of main switch voltage stress.

As is shown in Fig. 9-1, the main switch voltage excursion can be roughly partitioned into three time segments corresponding to the three distinctive phases through which the switch traverses during a complete cycle. When the switch is turned on, \( V_{on} \) equals the collector-to-emitter saturation voltage for bipolar transistor switch or the drain-to-source ohmic on-voltage for MOSFET. When the switch is turned off and the transformer core is being reset, a conducting \( CR3 \) (Fig. 9-3), clamps the reset winding at \( (v_{CR3} + V_{reset}) \) and

\[
V_{clamp} = \left( \frac{N_1}{N_R} \right) \cdot (v_{CR3} + V_{reset}) \tag{9.1}
\]

develops on top of \( V_{idle} \). After core reset and while the switch is still dormant,