7. SUMMARY AND SUGGESTIONS FOR FUTURE WORK

7.1 Summary

7.1.1 Part I

Part I of this dissertation concentrated on the simplification of the traditional two-stage front-end designs typically utilized in computer system power architectures (see Figs. 1.2 and 1.4):

The analysis, design, and experimental results were detailed for an improved, pulse-width-modulated, zero-voltage switched, full-bridge DC/DC converter ideally suited as the second-stage converter in the two-stage front-end design scheme. It was demonstrated how the inclusion of secondary-side switching achieves a load independent ZVS range by utilizing the energy stored in the isolation transformer's magnetizing inductance. This secondary-side switching concept was then extended to control of the output bus voltage, resulting in a considerable simplification in the methods used to maintain control and isolation of the DC bus. An analysis of the ZVS characteristics, along with the details of implementing the high-current, secondary-side switches with magnetic amplifiers (magamps) was detailed. Experimental results from a prototype converter verified the principles of operation and confirmed the simplicity of the design.

It was demonstrated how two-stage approach could be simplified to a front-end design consisting of an isolated PFC converter. This is suitable for computing systems power architectures where tight and fast regulation of the DC bus voltage is not necessary. This approach forces the post-regulators to take up the function of what was the front-end DC/DC converter. The development of zero-voltage switched active-clamp flyback converters and their application in low-to-medium power (~ 200 W – 600 W) operation from a universal line input was presented. Initially, the soft-switching characteristics and design concepts of the active-clamp flyback utilizing unidirectional magnetizing current were derived and experimental results were provided that illustrated not only the principles of operation, but also the dramatically improved efficiency over traditional RCD flybacks. This demonstration was necessary in order to illustrate the potential for the active-clamp flyback in higher power level applications. An experimental comparison demonstrated the utility of the active-clamp network operating as a loss-less turn-off snubber for IGBTs – facilitating the replacement of multiple MOSFET switches in parallel with a single(less expensive) IGBT, without a compromise of the switching frequency. The design concepts developed were then extended to the design of active-clamp flybacks for PFC applications. Both 500 W single and 600 W interleaved PFC to 48 Vdc prototype converters were demonstrated.

To meet the necessity for higher-power operation from a single-phase universal input AC line, the development of a new soft-switched, full-bridge boost converter was detailed. After providing a description of the concept of phase-shift control and the resulting zero-current-switching (ZCS) obtained as a result of its application, the need for the addition of an active-clamp network is shown. It is then demonstrated how the combination of phase-shift control and the active-clamp network is able to realize ZVS for all four bridge switches. Experimental results from a prototype are then presented which verify the theory of operation. Also, at an operating point of 220 Vac input and 48 Vdc output, a 3 % efficiency improvement over a 1 kW two stage ZVT boost + ZVS FB converter is experimentally demonstrated.

7.1.2 Part II

Part II deals with simplification of the entire computer power system through the elimination of a conversion step, resulting in the change over from DC power distribution methods to AC power distribution methods.

The design and development of a new high-frequency AC distributed power system was described. After introducing the basic issues that confront such a distributed power system and limiting the scope (or application) of the proposed system, a tradeoff study was performed to determine, from a purely topological standpoint, the merits and limitations of processing sinewave or square-wave power distribution waveforms. This was done by essentially "designing" the two types of systems and subsequently comparing their performance (including cost performance). Noise issues were then addressed. A combination of the use of finite element analysis methods, circuit simulation, and development of a test bed for experimentation purposes was employed to accomplish the following for a 300 kHz square-wave AC DPS:

1) Identification of the major mechanisms for induced system noise when utilizing printed circuit board bus structures.

2) Identification and verification of solutions to the induced noise problem through the development of unique PCB bus structures coupled with the use of bi-phase voltage waveforms for power distribution.

3) Characterization, using FEA methods, of the near-field magnetic field characteristics and relative loss of the PCB bus structures developed.

4) Experimental characterization of the near-field E-field, demonstrating its reduction in strength as a function of bus voltage transition times.

After developing the prototype AC DPS, the methods used and results of an experimental comparison between identically configured DC and AC distributed power systems was described. After establishing the "ground rules" of the comparison, it was shown that the efficiency of the AC DPS exceeded that of the DC DPS by about 5 % to 7

% as the system power levels were increased to between 100 W and the maximum power of 300 W. Near-field E-field measurements indicated a substantially higher magnitude for the DC DPS when compared with the AC DPS. This was primarily due to the choice of front-end DC/DC and post-regulator topologies for the DC DPS. Near-field B-field measurements were also performed and verified that the AC DPS's bus currents do result in stronger radiated magnetic fields in the immediate vicinity of the distribution bus. A crude cost analysis indicated a potential reduction of about 20 % in piece-parts cost for the AC DPS front-end inverter over the DC DPS DC/DC front-end converter. Piece-parts cost savings were about 15 % (per regulator) for the AC DPS post-regulators over their DC DPS counterparts.

7.2 Suggestions for Future Work

7.2.1 Part I

The small-signal characteristics and large-signal transient response behavior for both the boost and flyback topologies which incorporate the active-clamp technique needs in-depth analytical and experimental treatment. Work of this nature has been reported for the forward converter topology [68], but the operation of the active-clamp network in boost and flyback converters is fundamentally different. Methods to reduce the circulating energy introduced by the clamp network, perhaps through modulation of the active-clamp switch "on-time," (as briefly discussed in Chapter 4) might further improve converter efficiency. Also, methods to realize "self-driven" active-clamp switches might reduce costs associated with the extra control circuitry these networks require.

7.2.2 Part II

7.2.2.1 Front-end inverter

Future work with the front-end inverter should revolve around efforts to integrate the inverter function with the PFC function. The ideal goal might be to form a single-switch implementation to form a more nearly optimum single conversion stage approach to the front-end design [69]. This is shown conceptually in Fig. 7.1.

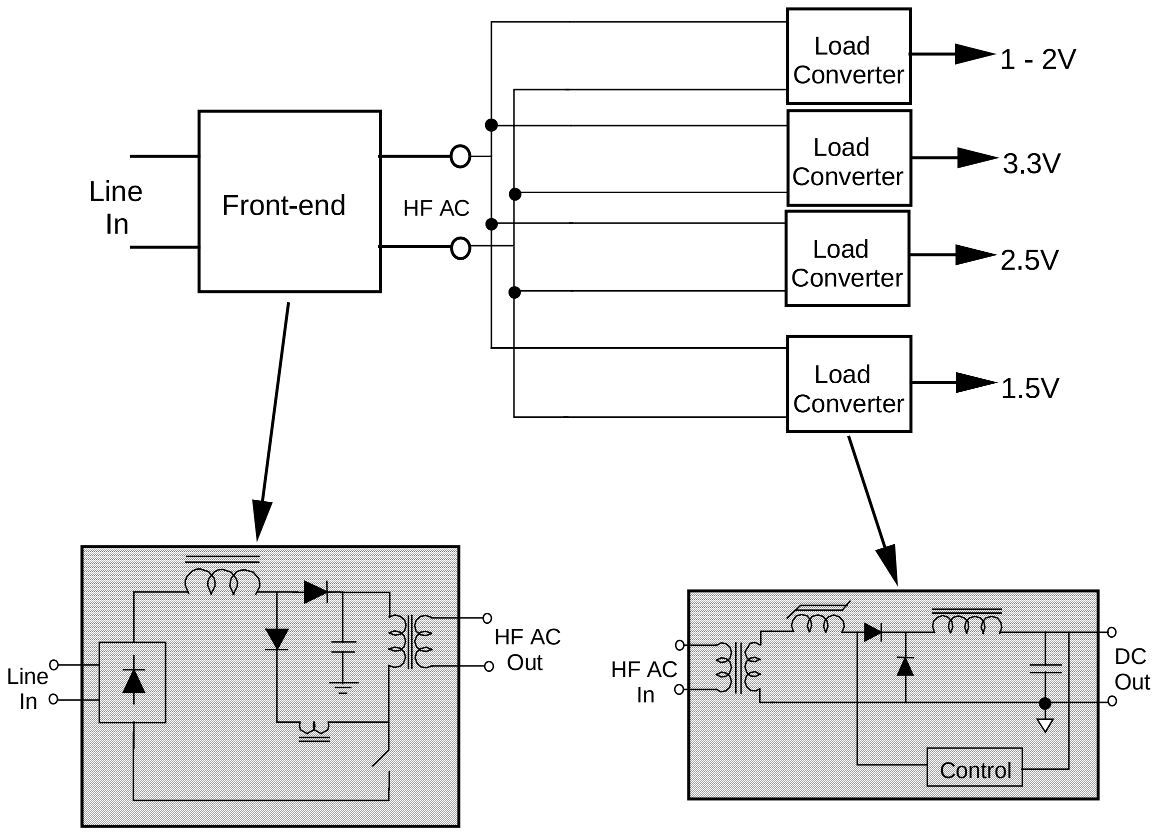
7.2.2.2 Bus structure

Future efforts here could be targeted at refinement of the characterization of induced system noise, particularly for different signal line structures than what were assumed in Chapter 5. In addition to changing the signal line PCB structure, the effects of changing the source and receiver impedances (for example, by assuming circuitry other than CMOS logic is sourcing and terminating the line) should also be considered.

7.2.2.3 Post-regulation

All performance issues that face DC/DC post-regulators (and in particular, VRMs) that are being designed for present and future applications as computer system power components will have to be addressed by potential AC DPS post-regulators as well. Some of these issues include:

1) The mandatory need for synchronous rectification when dealing with low-voltage, high-current loads. Various integrated magnetic techniques being applied to DC/DC post-regulators [70, 71, 72, 73, 74, 75] should also be considered for application to AC DPS post-regulators.
2) Fault-protection and current limiting – since there is no switch directly in series with the AC distribution input to the post-regulator (as there *always* is for a DC/DC converter), taking a regulator “off-line” becomes more problematic. Hot-swapping



[69]

Fig. 7.1 Conceptual design for a future AC distributed power system.

or hot plug-in are unique issues as well.

4) Large-signal transient response performance, like that required for microprocessor loads, needs exploration.

5) Various methods to achieve closed-loop post-regulation, in addition to magamp control should be investigated. As indicated in Chapter 6, magamps are expensive.

7.2.2.4 Overall system

Battery-backup of the distribution bus becomes an issue when the power distribution method is a high-frequency AC type, as is being discussed here. Also, the issues of system stability (both small and large-signal) need to be addressed.