

Contents

List of Figures	v
List of Tables	xiii
1 Introduction	1
1.1 Background	1
1.1.1 Evolution of Microprocessors	1
1.1.2 Power Distribution System in Mobile Computers	2
1.1.3 Intel Mobile Voltage Positioning Technology	4
1.2 Voltage Regulators (VR)	6
1.2.1 Evolution of the VR	6
1.2.2 VR Design Challenges	12
1.3 State-of-the-art VR Solutions	13
1.4 Objectives and Scope of the Thesis	15
1.5 Thesis Outline	17
2 Literature Survey	19
2.1 Introduction	19
2.2 Overview of Existing VR Topologies for Duty Cycle Extension	20
2.2.1 Tapped-Inductor Buck Converter	20
2.2.2 Active-Clamp Coupled-Buck Converter	23
2.2.3 Non-Isolated Forward Converter	24
2.2.4 Non-Isolated Double-ended Topologies	26
2.2.5 Two-Stage Buck Converter	28
2.2.6 Quasi-Parallel VR Architecture	30
2.3 Existing Hybrid VR Solutions	31
2.3.1 Single Shot Transient Suppressor (SSTS)	31
2.3.2 Transient Voltage Clamp (TVC) Circuit	32

2.3.3	Fast Response Double Buck (FRDB) Converter	33
2.3.4	Active Transient Voltage Compensator (ATVC)	35
2.4	Other VR Solutions	37
2.4.1	DC-DC Stepping Inductance VR	37
2.4.2	Inductor Coupling Schemes	39
2.5	Summary	40
3	Analysis and Design of the Proposed Converter	47
3.1	Introduction	47
3.2	Coupled Inductor HBCDR Topology	48
3.2.1	Operation and Equivalent Circuit of the Converter	48
3.2.2	Design of the Converter	60
3.2.2.1	Selection of Turns Ratio	60
3.2.2.2	Selection of Inductor	60
3.2.2.3	Selection of Capacitor	61
3.2.2.4	Design of the Balancing Winding	63
3.2.2.5	Control Circuit Design	63
3.2.3	Simulation Results	66
3.2.4	Limitations	69
3.3	FBCDR with Parallel Buck Converter	72
3.3.1	Operation of the Power Circuit	72
3.3.2	Proposed Control Scheme	75
3.3.2.1	Hysteretic Constant Turn-off Control	76
3.3.2.2	Benefits of the Lead-Lag Compensator	77
3.3.3	System Design	79
3.3.3.1	Selection of Turns Ratio	79
3.3.3.2	Selection of Inductors	79
3.3.3.3	Selection of Capacitor	81
3.3.3.4	Selection of the Auxiliary Buck Converter Current Reference	81
3.3.3.5	Compensator Design	82
3.4	Summary	85
4	Practical Realization and Experimental Verification	87
4.1	Introduction	87

4.2	Experimental Setup	89
4.3	Experimental Results	91
4.3.1	Steady-State Operating Waveforms	91
4.3.2	Transient Performance	96
4.3.2.1	Load Current Step-down Transient	100
4.3.2.2	Load Current Step-up Transient	104
4.3.3	Steady-state Performance	109
4.3.4	Effect of Load Transient Frequency on Efficiency	112
4.4	Summary	117
5	Conclusions and Scope for Future Work	119
5.1	Conclusions	119
5.2	Limitations	121
5.3	Scope for Future Work	121
A	Detailed Control Circuit Design	123
A.1	Reference Voltage Generator	123
A.2	Generation of Droop Voltage	124
A.3	Clock Generator Circuit	125
A.4	Amplification of the Primary-side Sensed Current	127
A.5	Generation of the PWM Signals for the FBCDR Converter	128
A.6	Generation of the Control Signals for the Buck Converter	131
A.7	Compensator Circuit	133
B	Design of the Planar Transformer	135
C	PCB Design and Layout	143
C.1	DC Parasitics	143
C.2	AC Parasitics	145
C.3	Noise	147
C.4	Grounds and Grounding	148
C.5	Radiated Electro-Magnetic Interference (EMI)	149
C.6	PCB Layout of the Power Circuit	151
	References	153
	Author's Publications/Patent	165