

Battery Management Systems for Large Lithium-Ion Battery Packs

Davide Andrea



**ARTECH
HOUSE**

BOSTON | LONDON
artechhouse.com

Contents

Preface	<i>xi</i>
---------	-----------

CHAPTER 1

Introduction	1
1.1 Naming Conventions	1
1.1.1 Cells, Batteries, and Packs	1
1.1.2 Resistance	1
1.2 Li-Ion Cells	1
1.2.1 Formats	2
1.2.2 Chemistry	3
1.2.3 Safety	4
1.2.4 Safe Operating Area	6
1.2.5 Efficiency	6
1.2.6 Aging	9
1.2.7 Modeling	10
1.2.8 Unequal Voltages in Series Strings	12
1.3 Li-Ion BMSs	15
1.3.1 BMS Definition	16
1.3.2 Li-Ion BMS Functions	16
1.3.3 Custom Versus Off-the-Shelf	16
1.4 Li-Ion Batteries	18
1.4.1 SOC, DOD, and Capacity	18
1.4.2 Balance and Balancing	22
1.4.3 SOH	31
References	33

CHAPTER 2

BMS Options	35
2.1 Functionality	35
2.1.1 CCCV Chargers	35
2.1.2 Regulators	37
2.1.3 Meters	38
2.1.4 Monitors	39
2.1.5 Balancers	40
2.1.6 Protectors	41
2.1.7 Functionality Comparison	41

2.2	Technology	41
2.2.1	Simple (Analog)	42
2.2.2	Sophisticated (Digital)	43
2.2.3	Technology Comparison	43
2.3	Topology	44
2.3.1	Centralized	44
2.3.2	Modular	45
2.3.3	Master-Slave	46
2.3.4	Distributed	47
2.3.5	Topology Comparison	49

CHAPTER 3

	BMS Functions	51
3.1	Measurement	51
3.1.1	Voltage	52
3.1.2	Temperature	54
3.1.3	Current	54
3.2	Management	58
3.2.1	Protection	58
3.2.2	Thermal Management	63
3.2.3	Balancing	64
3.2.4	Redistribution	84
3.2.5	Distributed Charging	87
3.3	Evaluation	88
3.3.1	State of Charge and Depth of Discharge	89
3.3.2	Capacity	95
3.3.3	Resistance	96
3.3.4	State of Health (SOH)	97
3.4	External Communications	97
3.4.1	Dedicated Analog Wire	98
3.4.2	Dedicated Digital Wire	99
3.4.3	Data Link	102
3.5	Logging and Telemetry	105
	References	105

CHAPTER 4

	Off-the-Shelf BMSs	107
4.1	Introduction	107
4.1.1	Simple	107
4.1.2	Sophisticated	111
4.1.3	Cell Manufacturers' BMSs	117
4.1.4	Comparison	118

CHAPTER 5

	Custom BMS Design	121
5.1	Using BMS ASICs	121
5.1.1	BMS ASIC Selection	121

5.1.2	BMS ASIC Comparison	124
5.2	Analog BMS Design	125
5.2.1	Analog Regulator	125
5.2.2	Analog Monitor	127
5.2.3	Analog Balancer	138
5.2.4	Analog Protector	144
5.3	Ready-Made, Digital BMS Designs	144
5.3.1	ATMEL's BMS Processor	144
5.3.2	Elithion's BMS Chip Set	145
5.3.3	National Semiconductors' Complete BMS	146
5.3.4	Peter Perkin's Open Source BMS	147
5.3.5	Texas Instruments' bq29330/bq20z90	149
5.3.6	Texas Instruments' bq78PL114/bq76PL102	151
5.4	Custom Digital BMS Design	152
5.4.1	Voltage and Temperature Measurement	152
5.4.2	Current Measurement	175
5.4.3	Evaluation	178
5.4.4	Communications	192
5.4.5	Optimization	202
5.4.6	Switching	215
5.4.7	Logging	218
5.5	Cell Interface	219
5.5.1	Nondistributed	219
5.5.2	Distributed	220
5.6	Distributed Charging	226

CHAPTER 6

	Deploying a BMS	229
6.1	Installing	229
6.1.1	Battery Pack Design	229
6.1.2	BMS Connections to Pack	243
6.1.3	BMS Connections to System	247
6.2	Configuring	252
6.2.1	Cell Configuration	252
6.2.2	Pack Configuration	252
6.2.3	System Configuration	253
6.3	Testing	253
6.4	Troubleshooting	255
6.4.1	Grounding	255
6.4.2	Shielding	255
6.4.3	Filtering	255
6.4.4	Wire Routing	256
6.4.5	Nuisance Cutouts	256
6.5	Using	256
	Reference	256

List of Acronyms and Abbreviations	257
Glossary	261
About the Author	269
Index	271