19-2848; Rev 1; 11/03

EVALUATION KIT AVAILABLE

Highly Integrated Level 2 SMBus Battery Charger

MAX1535A

General Description

The MAX1535A is a highly integrated, multichemistry battery charger that simplifies construction of advanced smart chargers with a minimum number of external components. It uses Intel's system management bus (SMBus™) to control the charge voltage, charge current, and the maximum current drawn from the AC adapter. High efficiency is achieved through use of a constant off-time step-down topology with synchronous rectification.

In addition to support of the Smart Battery Charger Specifications Rev 1.1, the MAX1535A includes additional features. The maximum current drawn from the AC adapter is programmable to avoid overloads when supplying the load and the battery charger simultaneously. This enables the user to reduce the cost of the AC adapter. The MAX1535A provides a digital output that indicates the presence of an AC adapter. Based on the presence or absence of the AC adapter, the MAX1535A automatically selects the appropriate source for supplying power to the system by controlling two external P-channel MOSFETs. Under system control, the MAX1535A allows the battery to undergo a relearning or conditioning cycle in which the battery is completely discharged through the system load and then recharged.

The MAX1535A is capable of charging 2, 3, or 4 lithium-ion (Li+) cells in series, providing charge currents as high as 8A. The DC-to-DC converter in the MAX1535A uses a high-side P-channel switch with an N-channel synchronous rectifier. The charge current and input current-limit sense amplifiers have low input-offset errors and can use small-value sense resistors (0.01Ω, typ).

The MAX1535A is available in a 5mm x 5mm 32-pin thin QFN package and operates over the extended -40°C to +85°C temperature range. An evaluation kit is available to reduce design time.

Applications

Notebook and Subnotebook Computers

Tablet PCs

Portable Equipment with Rechargeable Batteries

SMBus is a trademark of Intel Corp.

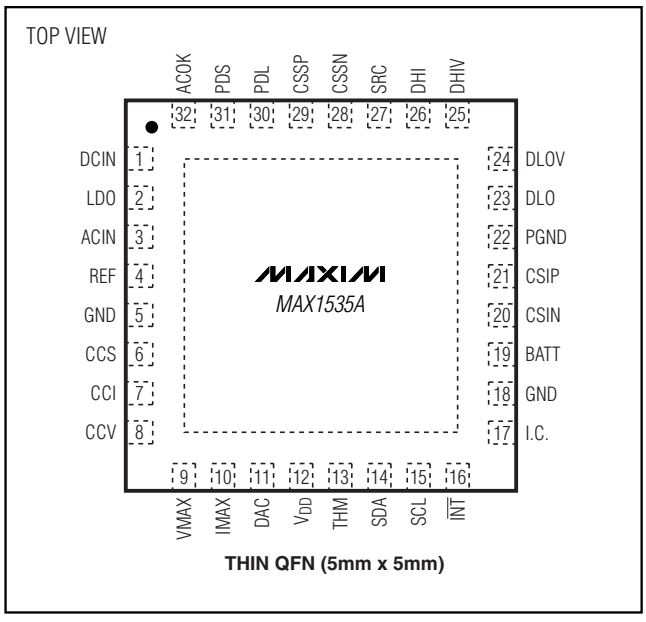
Features

- **Compliant with Level 2 Smart Battery Charger Specifications Rev 1.1**
- **Intel SMBus 2-Wire Serial Interface**
- **±0.5% Charge-Voltage Accuracy**
- **11-Bit Charge-Voltage Resolution**
- **±3% Input Current-Limit Accuracy**
- **Uses Small (10mΩ) Current-Sense Resistors**
- **8A Maximum Charge Current**
- **6-Bit Input and Charge-Current Resolution**
- **8V to 28V Input Voltage Range**
- **175s Charge Safety Timer**
- **Automatic Selection of System Power Source**
- **Charges any Battery Chemistry (Li+, NiCd, NiMH, Lead Acid, etc.)**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX1535AETJ	-40°C to +85°C	32 Thin QFN (5mm x 5mm)

Pin Configuration



THIN QFN (5mm x 5mm)

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ABSOLUTE MAXIMUM RATINGS

DCIN, CSSP, CSSN, SRC, ACOK to GND .....-0.3V to +30V
DHIV to SRC .....-6V to +0.3V
DHI, PDL, PDS to GND .....-0.3V to V_{SRC} + 0.3V
BATT, CSIP, CSIN to GND .....-0.3V to +20V
CSIP to CSIN, or CSSP to CSSN .....-0.3V to +0.3V
CCI, CCS, CCV, DAC, REF to GND .....-0.3V to V_{LDO} + 0.3V
V_{DD}, ACIN, SCL, SDA, DLOV, LDO, THM, $\overline{INT}$, IMAX, VMAX to GND .....-0.3V to +6V
DLOV to LDO .....-0.3V to +0.3V
DLO to PGND .....-0.3V to V_{DLOV} + 0.3V
PGND to GND .....-0.3V to +0.3V
LDO Short-Circuit Current 50mA
Continuous Power Dissipation (T_A = +70°C)
32-Pin Thin QFN (derate 21.3mW/°C above +70°C) ...1702mW
Operating Temperature Range .....-40°C to +85°C
Junction Temperature .....+150°C
Storage Temperature Range .....-60°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = 0°C to +85°C**. Typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
CHARGE-VOLTAGE REGULATION					
Charge-Voltage Accuracy	ChargeVoltage() = 0x41A0 and 0x3130	-0.5		+0.5	%
	ChargeVoltage() = 0x20D0	-0.8		+0.8	
	ChargeVoltage() = 0x1060	-1.0		+1.0	
Full-Charge Voltage	ChargeVoltage() = 0x41A0	16.716	16.800	16.884	V
	ChargeVoltage() = 0x3130	12.529	12.592	12.655	
	ChargeVoltage() = 0x20D0	8.332	8.400	8.468	
	ChargeVoltage() = 0x1060	4.150	4.192	4.234	
CHARGE-CURRENT REGULATION					
CSIP-to-CSIN Full-Scale Current-Sense Voltage	V_{BATT} = 12V	76.60	80.64	84.67	mV
Compliance Current Accuracy	10mΩ sense resistor (R2 in Figure 1) between CSIP and CSIN; ChargeCurrent() = 0x1F80	-5		+5	%
Charge Current	10mΩ sense resistor (R2 in Figure 1) between CSIP and CSIN; ChargeCurrent() = 0x1F80	7.660	8.064	8.467	A
	10mΩ sense resistor (R2 in Figure 1) between CSIP and CSIN; ChargeCurrent() = 0x0080		128		mA
BATT/CSIP/CSIN Input Voltage Range		0		19	V
CSIP/CSIN Input Current	V_{DCIN} = 0V, or charger not switching		0.1	1.0	µA
	V_{CSIP} = V_{CSIN} = 12V		300	700	
INPUT-CURRENT REGULATION					
CSSP-to-CSSN Full-Scale Current-Sense Voltage	V_{DCIN} = 18V	104.5	110.0	115.5	mV

ELECTRICAL CHARACTERISTICS (continued)

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = 0°C to +85°C**. Typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Current-Limit Accuracy	10mΩ sense resistor (R1 in Figure 1) between CSSP and CSSN; InputCurrent() = 0x1580 (11.008A)	-5		+5	%
	10mΩ sense resistor (R1 in Figure 1) between CSSP and CSSN; InputCurrent() = 0x1000 (8.192A)	-3		+3	
	10mΩ sense resistor (R1 in Figure 1) between CSSP and CSSN; InputCurrent() = 0x0800 (4.096A)	-6.5		+6.5	
	POR (InputCurrent() = 0x0080)		256		mA
CSSP/CSSN Input Voltage Range		8		28	V
CSSP/CSSN Input Current	V_{DCIN} = 0V		0.1	1.0	µA
	V_{CSSP} = V_{CSSN} = V_{DCIN} > 8.0V		300	750	
SUPPLY AND LINEAR REGULATOR					
DCIN Input Voltage Range		8		28	V
DCIN Undervoltage Lockout Trip Point	DCIN falling	7.0	7.4		V
	DCIN rising		7.50	7.85	
DCIN Quiescent Current	8V < V_{DCIN} < 28V		2.7	6.0	mA
BATT Input Current	V_{BATT} = 19V, V_{DCIN} = 0V, or charger not switching		0.1	1.0	µA
	V_{BATT} = 2V to 19V, V_{DCIN} > V_{BATT} + 0.3V		200	500	
LDO Output Voltage	8V < V_{DCIN} < 28V, no load	5.25	5.40	5.50	V
LDO Load Regulation	0 < I_{LDO} < 10mA		34	100	mV
LDO Undervoltage Lockout Trip Point	V_{DCIN} = 8V	3.20	4.00	5.15	V
V_{DD} Range		2.7		5.5	V
V_{DD} UVLO Rising Threshold			2.5	2.7	V
V_{DD} UVLO Hysteresis			100		mV
V_{DD} Quiescent Current	V_{DCIN} < 6V, V_{DD} = 5.5V, V_{SCL} = V_{SDA} = 5.5V		17	27	µA
REFERENCE					
REF Output Voltage	0 < I_{REF} < 500µA	4.083	4.096	4.109	V
REF Undervoltage Lockout Trip Point	REF falling		3.1	3.9	V
TRIP POINTS					
BATT POWER_FAIL Threshold	V_{DCIN} falling	50	100	150	mV
BATT POWER_FAIL Threshold Hysteresis		100	200	300	mV
ACIN Threshold	ACIN rising	1.966	2.048	2.130	V
ACIN Threshold Hysteresis		10	20	30	mV
ACIN Input Bias Current	V_{ACIN} = 2.048V	-1		+1	µA

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ELECTRICAL CHARACTERISTICS (continued)

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = 0°C to +85°C**. Typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SWITCHING REGULATOR					
Off-Time	V_{BATT} = 16.0, V_{DCIN} = 21.0	540	600	660	ns
	V_{BATT} = 19.0, V_{DCIN} = 21.0	230	270	310	
DLOV Supply Current	ChargerMode() = 0x0001		5	10	µA
Maximum Discontinuous Mode Peak Current			0.5		A
Battery Undervoltage Charge Current	V_{BATT} = 2.6V per cell		128		mA
DHIV Output Voltage	With respect to SRC	-4.5	-5.0	-5.5	V
DHIV Sink Current		10			mA
DHI On-Resistance Low	V_{DHI} = V_{DHIV}, I_{DHI} = -10mA		4	7	Ω
DHI On-Resistance High	V_{DHI} = V_{SRC}, I_{DHI} = 10mA		1	3	Ω
DLO On-Resistance High	V_{DLOV} = 4.5V, I_{DLO} = 100mA		4	7	Ω
DLO On-Resistance Low	V_{DLOV} = 4.5V, I_{DLO} = -100mA		1	3	Ω
ERROR AMPLIFIERS					
GMV Transconductance	ChargeVoltage () = 0x41A0, V_{BATT} = 16.8V	0.0625	0.1250	0.2500	µA/mV
GMI Transconductance	ChargeCurrent () = 0x1F80, V_{CSIP} - V_{CSIN} = 80.64mV	0.5	1	2	µA/mV
GMS Transconductance	InputCurrent () = 0x1580, V_{CSSP} - V_{CSSN} = 110.08mV	0.5	1	2	µA/mV
CCI Clamp Voltage	0.25V < V_{CCI} < 2.0V	150	300	600	mV
CCV Clamp Voltage	0.25V < V_{CCV} < 2.0V	150	300	600	mV
CCS Clamp Voltage	0.25V < V_{CCS} < 2.0V	150	300	600	mV
ACOK					
ACOK Input Voltage Range		0		28	V
ACOK Sink Current	V_{ACOK} = 0.4V, ACIN = 1.5V	1			mA
ACOK Leakage Current	V_{ACOK} = 28V, ACIN = 2.5V			1	µA
PDS, PDL SWITCH CONTROL					
PDS Switch Turn-Off Threshold	DCIN with respect to BATT, DCIN falling	50	100	150	mV
PDL Switch Turn-On Threshold	DCIN with respect to BATT, DCIN falling	50	100	150	mV
PDS Switch Threshold Hysteresis	DCIN with respect to BATT		200		mV
PDL Switch Threshold Hysteresis	DCIN with respect to BATT		200		mV
PDS Output Low Voltage, PDS Below SRC	I_{PDS} = 0V	8	10	12	V
PDS Turn-On Current	PDS = SRC	6	12		mA
PDS Turn-Off Current	V_{PDS} = V_{SRC} - 2V, V_{DCIN} = 16V	10	50		mA
PDL Turn-On Resistance	PDL = GND	50	100	150	kΩ
PDL Turn-Off Current	V_{CSSN} - V_{PDL} = 1.5V	6	12		mA
PDL and PDS Transition Delay Time	PDS and PDL are unloaded	4	10	15	µs

ELECTRICAL CHARACTERISTICS (continued)

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = 0°C to +85°C**. Typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
PDL-to-PDS Switchover Time in Relearn Mode	PDS and PDL are unloaded	4	10	16	µs
MAXIMUM CHARGE-VOLTAGE SETTING					
V_{BATT} to V_{VMAX} Ratio	V_{MAX} = 2V, ChargeVoltage () = 0x4B00	4.95	5.0	5.05	V/V
V_{MAX} Input Voltage Range		0		V_{REF}	V
V_{MAX} Input Bias Current	0 < V_{VMAX} < V_{REF}			1	µA
MAXIMUM CHARGE-CURRENT SETTING					
I_{CHARGE} to V_{IMAX} Ratio	V_{IMAX} = 0.8V, ChargeCurrent () = 0x1F80	4.75	5	5.25	A/V
IMAX Input Voltage Range		0		V_{REF}	V
IMAX Input Bias Current	0 < V_{IMAX} < V_{REF}			1	µA
THERMISTOR COMPARATOR					
Thermistor Overrange Threshold	V_{DD} = 2.7V to 5.5V, THM falling	89.5	91	92.5	% of V_{DD}
Thermistor Cold Threshold	V_{DD} = 2.7V to 5.5V, THM falling	73.5	75	76.5	% of V_{DD}
Thermistor Hot Threshold	V_{DD} = 2.7V to 5.5V, THM falling	21.5	23	24.5	% of V_{DD}
Thermistor Underrange Threshold	V_{DD} = 2.7V to 5.5V, THM falling	3.5	5	6.5	% of V_{DD}
Thermistor Comparator Hysteresis	All four comparators, V_{DD} = 2.7V to 5.5V		50		mV
SMBus INTERFACE LEVEL SPECIFICATIONS (V_{DD} = 2.7V TO 5.5V)					
SDA/SCL Input Low Voltage	V_{DD} = 2.7V to 5.5V			0.8	V
SDA/SCL Input High Voltage	V_{DD} = 2.7V to 5.5V	2.1			V
SDA/SCL Input Bias Current	V_{DD} = 2.7V to 5.5V	-1		+1	µA
SDA, $\overline{INT}$ Output Sink Current	VSDA = 0.4V	6			mA
$\overline{INT}$ Output High Leakage Current	$V_{\overline{INT}}$ = 5.5V			1	µA
$\overline{INT}$ Output Low Voltage	$I_{\overline{INT}}$ = 1mA		25	200	mV
SMBus TIMING SPECIFICATIONS (V_{DD} = 2.7V TO 5.5V)					
SMBus Frequency		10		100	kHz
SMBus Free Time		4.7			µs
Start Condition Setup Time from SCL		4.7			µs
Start Condition Hold Time from SCL		4			µs
Stop Condition Setup Time from SCL		4			µs
SDA Hold Time from SCL		300			ns
SDA Setup Time from SCL		250			ns
SCL Low Timeout	(Note 1)	25		35	ms

Highly Integrated Level 2 SMBus Battery Charger

ELECTRICAL CHARACTERISTICS (continued)

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = 0°C to +85°C**. Typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SCL Low Period		4.7			µs
SCL High Period		4			µs
Maximum Charging Period Without a ChargeVoltage() or ChargeCurrent() Command		140	175	210	s

ELECTRICAL CHARACTERISTICS

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = -40°C to +85°C**, unless otherwise noted.) (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
CHARGE-VOLTAGE REGULATION					
Charge-Voltage Accuracy	ChargeVoltage() = 0x41A0 and 0x3130	-1.6		+1.6	%
	ChargeVoltage() = 0x20D0	-1.6		+1.6	
	ChargeVoltage() = 0x1060	-1.8		+1.8	
Full-Charge Voltage	ChargeVoltage() = 0x41A0	16.532		17.068	V
	ChargeVoltage() = 0x3130	12.390		12.794	
	ChargeVoltage() = 0x20D0	8.266		8.534	
	ChargeVoltage() = 0x1060	4.116		4.268	
CHARGE-CURRENT REGULATION					
CSIP-to-CSIN Full-Scale Current-Sense Voltage	V_{BATT} = 12V	72.58		88.70	mV
Compliance Current Accuracy	10mΩ sense resistor (R2 in Figure 1) between CSIP and CSIN; ChargeCurrent() = 0x1F80	-10		+10	%
Charge Current	10mΩ sense resistor (R2 in Figure 1) between CSIP and CSIN; ChargeCurrent() = 0x1F80	7.258		8.870	A
BATT/CSIP/CSIN Input Voltage Range		0		19	V
CSIP/CSIN Input Current	V_{CSIP} = V_{CSIN} = 12V			800	µA
INPUT-CURRENT REGULATION					
CSSP-to-CSSN Full-Scale Current-Sense Voltage	V_{DCIN} = 18V	99		121	mV
Input Current-Limit Accuracy	10mΩ sense resistor (R1 in Figure 1) between CSSP and CSSN; InputCurrent() = 0x1580 (11.008A)	-10		+10	%
	10mΩ sense resistor (R1 in Figure 1) between CSSP and CSSN; InputCurrent() = 0x1000 (8.192A)	-8		+8	
	10mΩ sense resistor (R1 in Figure 1) between CSSP and CSSN; InputCurrent() = 0x0800 (4.096A)	-10		+10	

ELECTRICAL CHARACTERISTICS (continued)

(Circuit of Figure 1. V_{DCIN} = V_{CSSP} = V_{CSSN} = 18V, V_{BATT} = V_{CSIP} = V_{CSIN} = 12V, V_{DD} = 3.3V, ACIN = PGND = GND, LDO = DLOV, VMAX = IMAX = REF, C_{LDO} = 1µF, C_{DHIV} = 0.1µF, C_{REF} = 1µF, **T_A = -40°C to +85°C**, unless otherwise noted.) (Note 2)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
CSSP/CSSN Input Voltage Range		8		28	V
CSSP/CSSN Input Current	V_{CSSP} = V_{CSSN} = V_{DCIN} > 8.0V			800	µA
SUPPLY AND LINEAR REGULATOR					
DCIN Input Voltage Range		8		28	V
DCIN Undervoltage Lockout Trip Point	DCIN falling	7.0			V
	DCIN rising			7.85	
DCIN Quiescent Current	8V < V_{DCIN} < 28V			8	mA
BATT Input Current	V_{BATT} = 2V to 19V, V_{DCIN} > V_{BATT} + 0.3V			800	µA
LDO Output Voltage	8V < V_{DCIN} < 28V, no load	5.15		5.65	V
LDO Load Regulation	0 < I_{LDO} < 10mA			100	mV
LDO Undervoltage Lockout Trip Point	V_{DCIN} = 8V	3.00		5.35	V
V_{DD} Range		2.7		5.5	V
V_{DD} Quiescent Current	V_{DCIN} < 6V, V_{DD} = 5.5V, V_{SCL} = V_{SDA} = 5.5V			27	µA
REFERENCE					
REF Output Voltage	0 < I_{REF} < 500µA	4.035		4.157	V
REF Undervoltage Lockout Trip Point	REF falling			3.9	V
TRIP POINTS					
BATT POWER_FAIL Threshold	V_{DCIN} falling	60		160	mV
BATT POWER_FAIL Threshold Hysteresis		90		310	mV
ACIN Threshold	ACIN rising	1.966		2.129	V
ACIN Threshold Hysteresis		5		35	mV
SWITCHING REGULATOR					
Off-Time	V_{BATT} = 16.0, V_{DCIN} = 21.0	540		660	ns
	V_{BATT} = 19.0, V_{DCIN} = 21.0	230		310	
DLOV Supply Current	ChargerMode() = 0x0001			10	µA
Battery Undervoltage Charge Current	V_{BATT} = 2.6V per cell	64		192	mA
DHIV Output Voltage	With respect to SRC	-4.4		-5.5	V
DHIV Sink Current		10			mA
DHI On-Resistance Low	V_{DHI} = V_{DHIV}, I_{DHI} = -10mA			7	Ω
DHI On-Resistance High	V_{DHI} = V_{SRC}, I_{DHI} = 10mA			3	Ω
DLO On-Resistance High	V_{DLOV} = 4.5V, I_{DLO} = 100mA			7	Ω
DLO On-Resistance Low	V_{DLOV} = 4.5V, I_{DLO} = -100mA			3	Ω
ERROR AMPLIFIERS					
GMV Transconductance	ChargeVoltage() = 0x41A0, V_{BATT} = 16.8V	0.0625		0.2500	µA/mV