



Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!



Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



General Description

The AAT2601 and AAT2601A are members of Skyworks' Total Power Management IC (TPMIC™) product family. They contain a single-cell Lithium Ion/Polymer battery charger, a fully integrated step-down converter and 5 low dropout (LDO) regulators. The device also includes 2 load switches for dynamic power path/sleep mode operation, making it ideal for small handheld portable GSM or CDMA mobile telephones.

The battery charger is a complete thermally regulated constant current/constant voltage linear charger. It includes an integrated pass device, reverse blocking protection, high accuracy current and voltage regulation, charge status, and charge termination. The charging current, charge termination current, and recharge voltage are programmable with an external resistor and/or by a standard I²C interface. The AAT2601 has a typical battery under-voltage lockout of 2.35V and the AAT2601A has a typical battery under-voltage lockout of 2.9V.

The step-down DC/DC converter is integrated with internal compensation and operates at a switching frequency of 1.5MHz, thus minimizing the size of external components while keeping switching losses low and efficiency greater than 92%. All LDO output voltages are programmable using the I²C interface.

The five LDOs offer 60dB power supply rejection ratio (PSRR) and low noise operation making them suitable for powering noise-sensitive loads.

All six voltage regulators operate with low quiescent current. The total no load current when the step-down converter and 2 LDOs are enabled is only 170μA.

The AAT2601 and AAT2601A are available in a thermally enhanced low profile 5x5x0.75mm 36-pin TQFN package.

Features

- Voltage Regulator V_{IN} Range: 4.5V to 6V
- Complete Power Integration
 - Integrated Load Switches to Power Converters from AC Adapter or Battery Automatically
- Low Standby Current
 - 170μA (typ) w/ Buck (Core), LDO1 (PowerDigital), and LDO2 (PowerAnalog) Active, No Load
- One Step-Down Buck Converter (Core)
 - 1.8V, 300mA Output
 - 3.3V, 300mA Output (AAT2601A-3.3 ONLY)
 - 1.5MHz Switching Frequency
 - Fast Turn-On Time (100μs typ)
- Five LDOs Programmable with I²C
 - LDO1: 3.0V, 300mA (PowerDigital)
 - LDO2: 3.0V, 150mA (PowerAnalog or PLL)
 - LDO3: 3.0V, 150mA (TCXO)
 - LDO4: 3.0V, 150mA (TX)
 - LDO5: 3.0V, 150mA (RX)
 - PSRR: 60dB@10kHz
 - Noise: 50μVrms for LDO3, LDO4, and LDO5
- One Battery Charger
 - Digitized Thermal Regulation
 - Charge Current Programming up to 1.4A
 - Charge Current Termination Programming
 - Automatic Trickle Charge for Battery Preconditioning (2.8V Cutoff)
- Adapter OK (\overline{ADPP}) and Reset (\overline{RESET}) Timer Outputs
- AAT2601 Typical UVLO: 2.35V
- AAT2601A Typical UVLO: 2.9V
- Separate Enable Pins for Supply Outputs
- Over-Current Protection
- Over-Temperature Protection
- 5x5mm TQFN55-36 Package

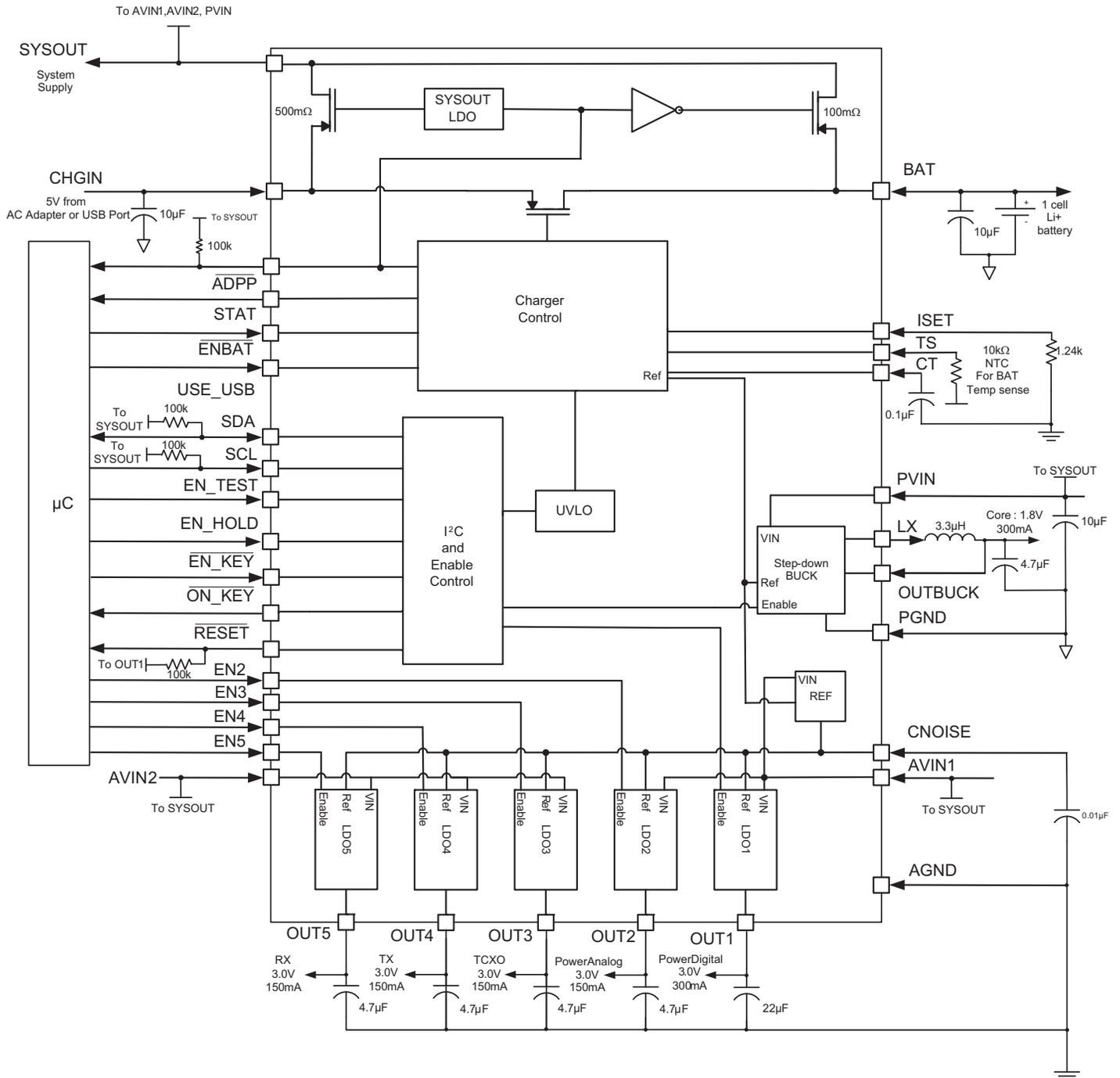
Applications

- Digital Cameras
- GSM or CDMA Cellular Phones
- Handheld Instruments
- PDAs and Handheld Computers
- Portable Media Players

AAT2601/2601A

Total Power Solution for Portable Applications

Typical Application



AAT2601/2601A**Total Power Solution for Portable Applications****Pin Descriptions**

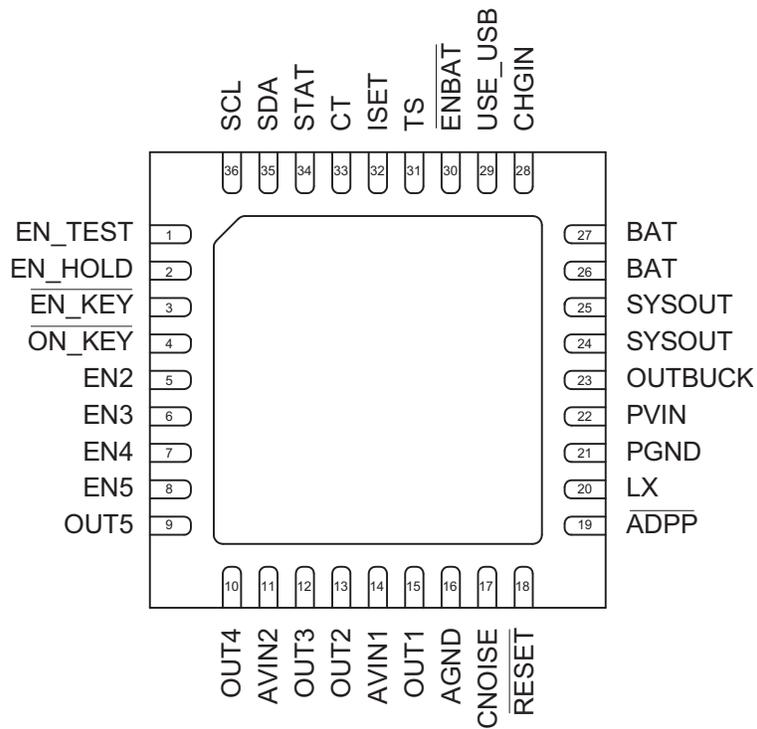
Pin #	Symbol	Function
1	EN_TEST	Similar to EN_HOLD but intended for use with the automatic tester or as a hands free enable input pin indicating hands free phone operation with a headset. It is also internally pulled to GND when floating.
2	EN_HOLD	Enable for the system. EN_HOLD must be held high by the processor to maintain core power. It is internally pulled to GND when floating.
3	$\overline{\text{EN_KEY}}$	Enable for the system. An internal pull-up resistor keeps the pin pulled up to an internal supply to keep the system off when there is no CHGIN input. Connect a normally-open pushbutton switch from this pin to GND. There is an internal 300ms debounce delay circuit to filter noise.
4	$\overline{\text{ON_KEY}}$	Buffered logic output of the $\overline{\text{EN_KEY}}$ pin with a logic signal from ground to OUT1.
5	EN2	Enable for LDO2 (PowerAnalog or PLL). (Internally pulled low when floating)
6	EN3	Enable for LDO3 (TCXO). (Internally pulled low when floating)
7	EN4	Enable for LDO4 (TX) (Internally pulled low when floating)
8	EN5	Enable for LDO5 (RX) (Internally pulled low when floating)
9	OUT5	Output for LDO5 (RX) (when shut down, pulled down with 10k Ω)
10	OUT4	Output for LDO4 (TX) (when shut down, pulled down with 10k Ω)
11	AVIN2	Analog voltage input. Must be tied to SYSOUT on the PCB.
12	OUT3	Output for LDO3 (TCXO)
13	OUT2	Output for LDO2 (PowerAnalog)
14	AVIN1	Analog voltage input. Must be tied to SYSOUT on the PCB.
15	OUT1	Output for LDO1 (PowerDigital)
16	AGND	Signal ground
17	CNOISE	Noise Bypass pin for the internal reference voltage. Connect a 0.01 μF capacitor to AGND.
18	$\overline{\text{RESET}}$	$\overline{\text{RESET}}$ is the open drain output of a 65ms reset timer. $\overline{\text{RESET}}$ is released after the 50ms timer times out. $\overline{\text{RESET}}$ is active low and is held low during shutdown. $\overline{\text{RESET}}$ should be tied to a 10K or larger pullup to OUTBUCK.
19	$\overline{\text{ADPP}}$	Open Drain output. Will pull low when $V_{\text{CHGIN}} > 4.5\text{V}$. When this happens, depending on the status of the USE_USB pin, the charge current will be reset to the default values (see Battery Charger and I ² C Serial Interface and Programmability section)
20	LX	Step-down Buck converter (Core) switching node. Connect an inductor between this pin and the output.
21	PGND	Power Ground for step-down Buck converter (Core)
22	PVIN	Input power for step-down Buck converter (Core). Must be tied to SYSOUT.
23	OUTBUCK	Feedback input for the step-down Buck converter (Core)
24, 25	SYSOUT	System Power output. Connect to the input voltage pins PIN, AVIN1/2 for the step-down converter and LDOs and other external supply requirements.
26, 27	BAT	Connect to a Lithium Ion battery.
28	CHGIN	Power input from either external adapter or USB port.
29	USE_USB	When pulled high, fast charge current is set to 100mA regardless of the resistor value present on the ISET pin. Additionally, the CHGIN-SYSOUT LDO will be disabled and the BAT-SYSOUT load switch will be enabled.
30	$\overline{\text{ENBAT}}$	Active low enable for the battery charger (Internally pulled low when floating)
31	TS	Battery Temperature Sense pin with 75 μA output current. Connect the battery's NTC resistor to this pin and ground.
32	ISET	Charge current programming input pin (Tie a 1k to GND for maximum fast charge current). Can be used to monitor charge current.
33	CT	Charger Safety Timer Pin. A 0.1 μF ceramic capacitor should be connected between this pin and GND. Connect directly to GND to disable the timer function.
34	STAT	Battery charging status pin output. Connected internally between GND and OUT1 (PowerDigital). Used to monitor battery charge status.
35	SDA	I ² C serial data pin, open drain; requires a pullup resistor.
36	SCL	I ² C serial clock pin, open drain; requires a pullup resistor.
EP	EP	The exposed thermal pad (EP) must be connected to board ground plane and pins 16 and 21. The ground plane should include a large exposed copper pad under the package for thermal dissipation (see package outline).

AAT2601/2601A

Total Power Solution for Portable Applications

Pin Configuration

TQFN55-36
(Top View)



AAT2601/2601A*Total Power Solution for Portable Applications***Absolute Maximum Ratings¹** $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Description	Value	Units
V_{IN}	Input Voltage, CHGIN, BAT	-0.3 to 6.5	V
Power and logic pins	Maximum Rating	$V_{IN} + 0.3$	V
T_A	Operating Temperature Range	-40 to 85	$^\circ\text{C}$
T_S	Storage Temperature Range	-65 to 150	$^\circ\text{C}$
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec)	300	$^\circ\text{C}$

Recommended Operating Conditions²

Symbol	Description	Value	Units
θ_{JA}	Thermal Resistance	25	$^\circ\text{C}/\text{W}$
P_D	Maximum Power Dissipation	4	W

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied.
2. Thermal Resistance was measured with the AAT2601 device on the 4-layer FR4 evaluation board in a thermal oven. The amount of power dissipation which will cause the thermal shutdown to activate will depend on the ambient temperature and the PC board layout ability to dissipate the heat. See Figures 11-14. Measurements are also valid for the AAT2601A device.

AAT2601/2601A**Total Power Solution for Portable Applications****Electrical Characteristics¹**
 $V_{IN} = 5V$, $V_{BAT} = 3.6V$, $-40^{\circ}C \leq T_A \leq +85^{\circ}C$, unless noted otherwise. Typical values are $T_A = 25^{\circ}C$.

Symbol	Description	Conditions	Min	Typ	Max	Units	
Power Supply							
V_{IN}	CHGIN Input Voltage		4.5		6	V	
I_Q	Battery Standby Current	Buck, LDO1 + LDO2, no load		170		μA	
I_{SHDN}	Battery Shutdown Current	EN_TEST, EN_HOLD, EN2, EN3, EN4, EN5 = GND, $\overline{EN_KEY}$ floating			10.0	μA	
UVLO	Under-Voltage Lockout for CHGIN	CHGIN rising		4.25	4.5	V	
		CHGIN falling		4.15			
	Battery Under-Voltage Lockout	AAT2601	BAT rising		2.6		V
			BAT falling		2.35		
		AAT2601A	BAT rising	3.0	3.1	3.2	V
			BAT falling	2.8	2.9	3.0	
I_{BAT}	Leakage Current from BAT Pin	$V_{BAT} = 4V$, $V_{CHGIN} = 0V$		2	5	μA	
Startup Timers							
\overline{RESET}	Reset Timer	Initiated when OUT1 = 90% of final value	35			ms	
Charger Voltage Regulation							
V_{BAT_REG}	Output Charge Voltage Regulation	$0^{\circ}C \leq T_A \leq +70^{\circ}C$	4.158	4.200	4.242	V	
V_{MIN}	Preconditioning Voltage Threshold	(No trickle charge option available)	2.6	2.8	3.0	V	
V_{RCH}	Battery Recharge Voltage Threshold	I ² C Recharge Code = 00 (default)		4.00		V	
		I ² C Recharge Code = 01		4.05		V	
		I ² C Recharge Code = 10		4.10		V	
		I ² C Recharge Code = 11		4.15		V	
Charger Current Regulation							
I_{CH_CC}	Constant-Current Mode Charge Current	$R_{ISET} = 1.24k$ (for 0.8A), USE_USB = Low, I ² C ISET code = 000, $V_{BAT} = 3.6V$, $V_{CHGIN} = 5.0V$	720	800	880	mA	
		USE_USB = High, I ² C ISET Code = 000, $V_{BAT} = 3.6V$	85	100	115		
KI_SET	Charge Current Set Factor: I_{CH_CC}/I_{ISET}	Constant Current Mode, $V_{BAT} = 3.6V$		800		mA	
I_{CH_PRE}	Preconditioning Charge Current	$R_{ISET} = 1.24k\Omega$, USE_USB = Low		12		% I_{CH_CC}	
		I ² C ISET Code = 000, USE_USB = High		50		mA	
I_{CH_TERM}	Charge Termination Threshold Current	I ² C Term Code = 00 (default)		5		% I_{CH_CC}	
		I ² C Term Code = 01		10			
		I ² C Term Code = 10		15			
		I ² C Term Code = 11		20			
Charging Devices							
$R_{DS(ON)}$	Charging Transistor ON Resistance	$V_{IN} = 5V$		0.6	0.9	Ω	
Logic Control / Protection							
V_{EN_HOLD} , V_{EN_KEY} , V_{EN_TEST}	Input High Threshold		1.4			V	
	Input Low Threshold				0.4	V	
V_{ADPP}	Output Low Voltage	Pin Sinks 4mA			0.4	V	
I_{ADPP}	Output Pin Current Sink Capability				8	mA	
V_{STAT}	Output High Voltage				V_{OUT1}	V	
I_{STAT}	Output Pin Current Source Capability				1.5	mA	
V_{OVP}	Over-Voltage Protection Threshold			4.3		V	

1. Specification over the $-40^{\circ}C$ to $+85^{\circ}C$ operating temperature range is assured by design, characterization and correlation with statistical process controls.

AAT2601/2601A*Total Power Solution for Portable Applications***Electrical Characteristics¹**
 $V_{IN} = 5V$, $V_{BAT} = 3.6V$, $-40^{\circ}C \leq T_A \leq +85^{\circ}C$, unless noted otherwise. Typical values are $T_A = 25^{\circ}C$.

Symbol	Description	Conditions	Min	Typ	Max	Units	
Logic Control / Protection (continued)							
V_{OCP}	Over Current Protection Threshold			105		% V_{CS}	
T_C	Constant Current Mode Time Out	$C_{CT} = 100nF$, $V_{CHGIN} = 5V$		3		Hours	
T_K	Trickle Charge Time Out			$T_C/8$		Hours	
T_V	Constant Voltage Mode Time Out			3		Hours	
I_{TS}	Current Source from TS Pin		71	75	79	μA	
TS_1	TS Hot Temperature Fault	Falling Threshold	318	331	346	mV	
		Hysteresis		25			
TS_2	TS Cold Temperature Fault	Rising Threshold	2.30	2.39	2.48	V	
		Hysteresis		25		mV	
T_{LOOP_IN}	Thermal Loop Entering Threshold			115		$^{\circ}C$	
T_{LOOP_OUT}	Thermal Loop Exiting Threshold			85		$^{\circ}C$	
T_{REG}	Thermal Loop Regulation			100		$^{\circ}C$	
Load Switches / SYSOUT LDO							
$R_{DS(ON),BAT-SYSOUT}$	On-Resistance of BAT-SYSOUT Load Switch	$V_{BAT} = 3.6V$		100	150	m Ω	
$R_{DS(ON),CHGIN-SYSOUT}$	On-Resistance of CHGIN-SYSOUT Load Switch	$V_{CHGIN} = 4.5V$		0.5	0.75	Ω	
	Sysout LDO Input Voltage Range		4.5			V	
	Sysout LDO Output Voltage	$I_{SYSOUT} < 900mA$, $V_{CHGIN} = 4.5V \sim 6.0V$	3.4	3.9	4.2	V	
Step-Down Buck Converter (Core)							
$V_{OUTBUCK}$	Output Voltage Accuracy	$V_{OUT} \leq 2V$	$I_{OUTBUCK} = 0 \sim 300mA$; $V_{IN} = 2.7V \sim 5.5V$	1.71	1.80	1.89	V
		$V_{OUT} > 2V$	$I_{OUTBUCK} = 0 \sim 300mA$; $V_{IN} = V_{OUTBUCK} + 1V \sim 5.5V$	-5		5	%
$I_{LIMOUTBUCK}$	P-Channel Current Limit			0.8		A	
$R_{DS(ON)L}$	High Side Switch On-Resistance			0.8		Ω	
$R_{DS(ON)H}$	Low Side Switch On-Resistance			0.8		Ω	
F_{OSC}	Oscillator Frequency	$T_A = 25^{\circ}C$		1.5		MHz	
T_S	Start-Up Time	From Enable to Regulation; $C_{OUTBUCK} = 4.7\mu F$, $C_{NOISE} = On$		100		μs	
LDO1 (PowerDigital)							
V_{OUT1}	Output Voltage Accuracy	$I_{OUT1} = 0 \sim 300mA$, $V_{AVINX} = 3.3V \sim 5.5V$	-3		+3	%	
I_{OUT1}	Output Current		300			mA	
I_{LIM1}	Output Current Limit			1000		mA	
V_{DO1}	Dropout Voltage	$I_{OUT1} = 300mA$		150	300	mV	
$\Delta V_{OUT1}(V_{OUT1}\Delta V_{IN1})$	Line Regulation	$I_{OUT1} = 100mA$, $3.3V < V_{AVINX} < 5.5V$		0.07		%/V	
ΔV_{OUT1}	Load Regulation	$I_{OUT1} = 0.5mA \sim 150mA$		40		mV	
PSRR	Power Supply Rejection Ratio	$I_{OUT1} = 10mA$, $C_{OUT1} = 22\mu F$, $100Hz \sim 10KHz$		60		dB	
T_S	Start Up Time	From Enable to Regulation; $C_{OUT1} = 22\mu F$, $C_{NOISE} = On$		175		μs	

1. Specification over the $-40^{\circ}C$ to $+85^{\circ}C$ operating temperature range is assured by design, characterization and correlation with statistical process controls.

AAT260I/260IA**Total Power Solution for Portable Applications****Electrical Characteristics¹**V_{IN} = 5V, V_{BAT} = 3.6V, -40°C ≤ T_A ≤ +85°C, unless noted otherwise. Typical values are T_A = 25°C.

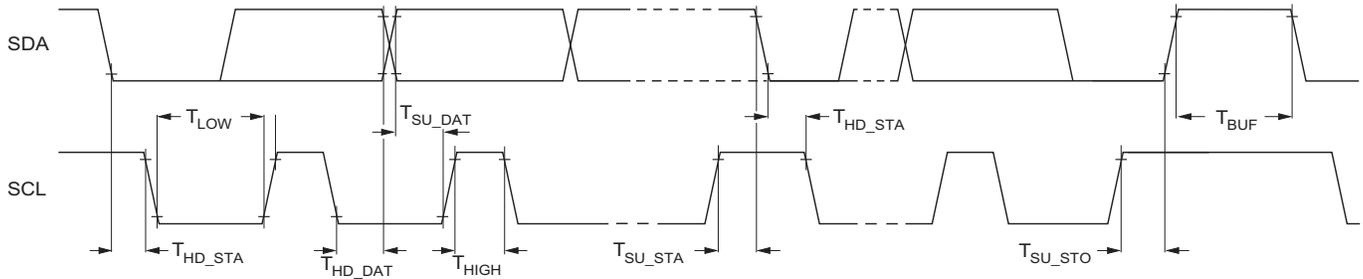
Symbol	Description	Conditions	Min	Typ	Max	Units
LD02 (PowerAnalog)						
V _{OUT2}	Output Voltage Accuracy	I _{OUT2} = 0 ~ 150mA, V _{AVINx} : 3.3V ~ 5.5V	-3		+3	%
I _{OUT2}	Output Current		150			mA
I _{LIM2}	Output Current Limit			1000		mA
V _{DO2}	Dropout Voltage	I _{OUT2} = 150mA		150		mV
$\frac{\Delta V_{OUT2}}{(V_{OUT2} \Delta V_{IN2})}$	Line Regulation	I _{OUT2} = 100mA, 3.3V < V _{AVINx} < 5.5V		0.07		%/V
ΔV_{OUT2}	Load Regulation	Load: 0.5mA~150mA		40		mV
PSRR	Power Supply Rejection Ratio	I _{OUT2} = 10mA, C _{OUT2} = 4.7μF, 10 ~ 10KHz		60		dB
T _s	Start Up Time	From Enable to Regulation; C _{OUT2} = 4.7μF, C _{NOISE} = On		65		μs
LD03 (TCXO), LD04 (TX) and LD05 (RX)						
V _{OUTx}	Output Voltage Accuracy	I _{OUTx} = 0 ~ 150mA, V _{AVINx} = 3.3V ~ 5.5V	-3		+3	%
I _{OUTx}	Output Current		150			mA
I _{LIMx}	Output Current Limit			1000		mA
V _{DOx}	Dropout Voltage	I _{OUTx} = 150mA		150		mV
$\frac{\Delta V_{OUTx}}{(V_{OUTx} \Delta V_{INx})}$	Line Regulation	I _{OUTx} = 100mA, 3.3V < V _{AVINx} < 5.5V		0.07		%/V
ΔV_{OUTx}	Load Regulation	I _{OUTx} = 0.5mA ~ 150mA		40		mV
PSRR	Power Supply Rejection Ratio	I _{OUTx} = 10mA, C _{OUTx} = 4.7μF, 10 ~ 10KHz		60		dB
e _N	Output Noise Voltage	I _{OUTx} = 10mA, Power BW: 10kHz ~ 100KHz		40		μVrms
T _s	Start Up Time	From Enable to Regulation; C _{OUTx} = 4.7μF, C _{NOISE} = On		65		μs
Logic Control						
V _{IH}	Enable Pin Logic High Level	For EN2, EN3, EN4 and EN5	1.4			V
V _{IL}	Enable Pin Logic Low Level				0.4	V
Thermal						
T _{SD}	Over Temperature Shutdown Threshold			140		°C
T _{HYS}	Over Temperature Shutdown Hysteresis			15		°C
SCL, SDA (I²C Interface)						
F _{SCL}	Clock Frequency		0		400	KHz
T _{LOW}	Clock Low Period		1.3			μs
T _{HIGH}	Clock High Period		0.6			μs
T _{HD_STA}	Hold Time START Condition		0.6			μs
T _{SU_STA}	Setup Time for Repeat START		0.6			μs
T _{SU_DTA}	Data Setup Time		100			ns
T _{SU_STO}	Setup Time for STOP Condition		0.6			μs
T _{BUF}	Bus Free Time Between STOP and START Condition		1.3			μs
V _{IL}	Input Threshold Low	2.7V ≤ V _{IN} ≤ 5.5V			0.4	V
V _{IH}	Input Threshold High	2.7V ≤ V _{IN} ≤ 5.5V	1.4		-	V
I _I	Input Current		-1.0		1.0	μA
V _{OL}	Output Logic Low (SDA)	I _{PULLUP} = 3mA			0.4	V

1. Specification over the -40°C to +85°C operating temperature range is assured by design, characterization and correlation with statistical process controls.

AAT2601/2601A

Total Power Solution for Portable Applications

Basic I²C Timing Diagram

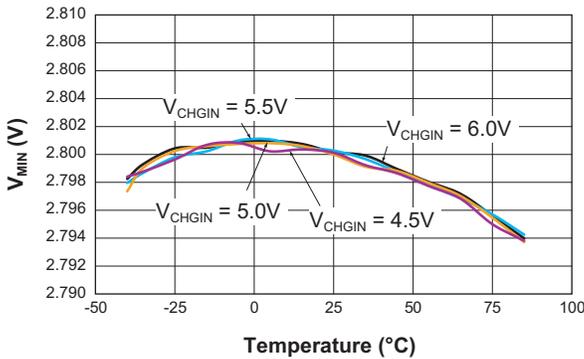


AAT2601/2601A

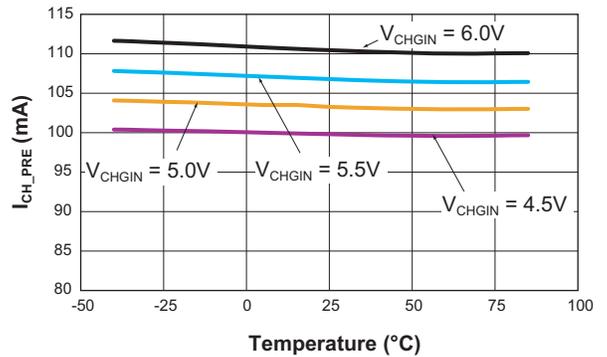
Total Power Solution for Portable Applications

Typical Characteristics—Charger

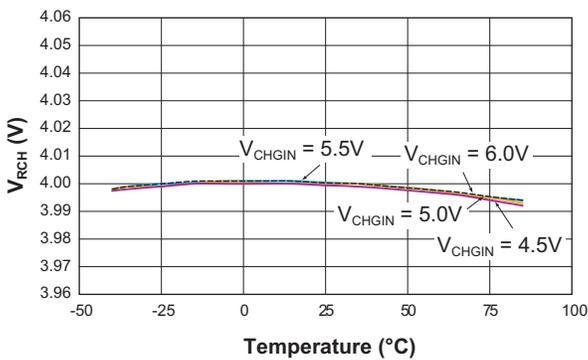
Preconditioning Threshold Voltage vs. Temperature



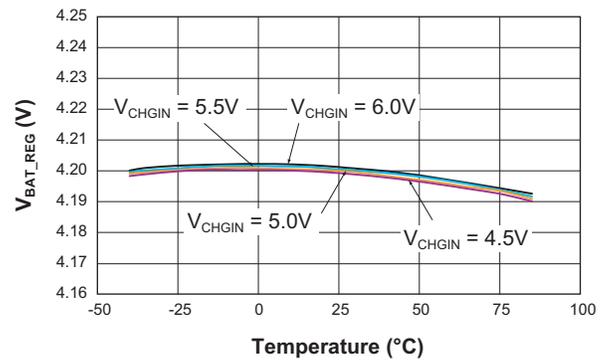
Preconditioning Charge Current vs. Temperature
($V_{BAT} = 2.5V$, $R_{ISET} = 1.24k\Omega$)



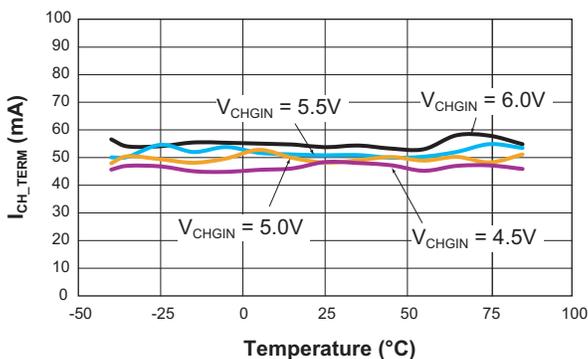
Recharge Voltage Threshold vs. Temperature
(V_{RCH} set to 4.0V)



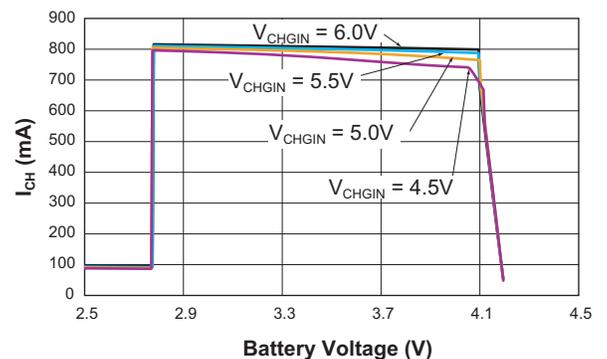
Output Charge Voltage Regulation vs. Temperature
(End of Charge Voltage)



Charge Termination Threshold Current vs. Temperature



Charging Current vs. Battery Voltage
($R_{ISET} = 1.24k\Omega$)

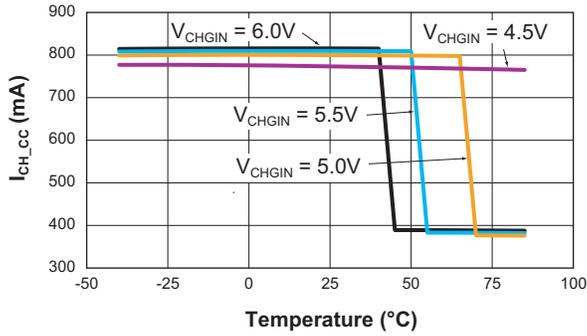


AAT2601/2601A

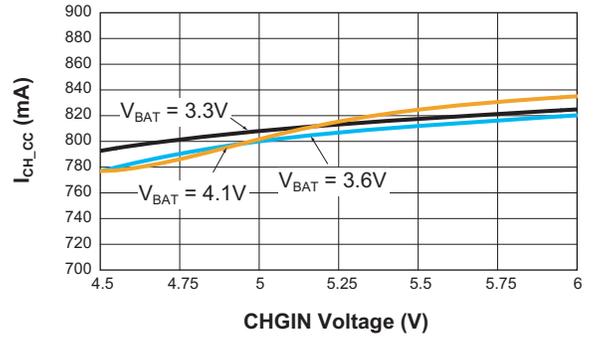
Total Power Solution for Portable Applications

Typical Characteristics—Charger (continued)

Constant Current Mode Charge Current vs. Temperature
 ($V_{BAT} = 3.6V$; $R_{ISET} = 1.24k\Omega$)



Constant Current Mode Charge Current vs. Input Voltage
 ($R_{ISET} = 1.24k\Omega$)

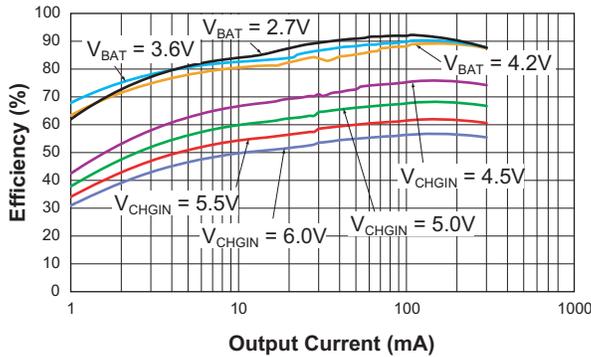


AAT2601/2601A

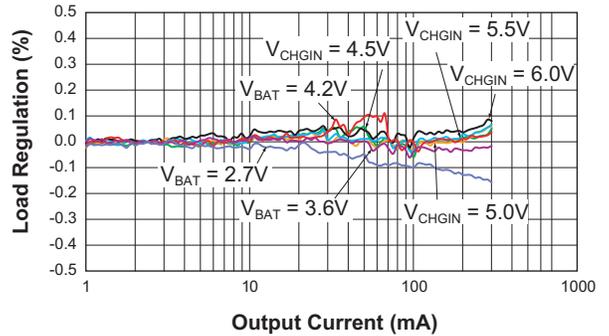
Total Power Solution for Portable Applications

Typical Characteristics—Step-Down Buck Converter

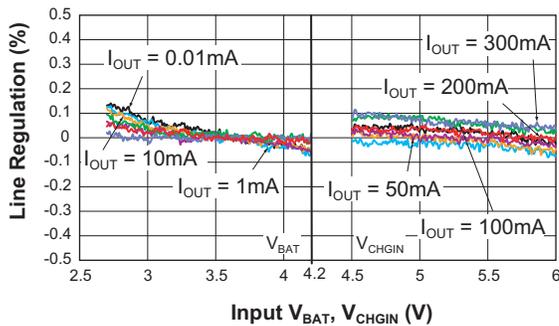
Step-Down Buck Efficiency vs. Output Current
($V_{OUT} = 1.8V$; $L = 3.3\mu H$)



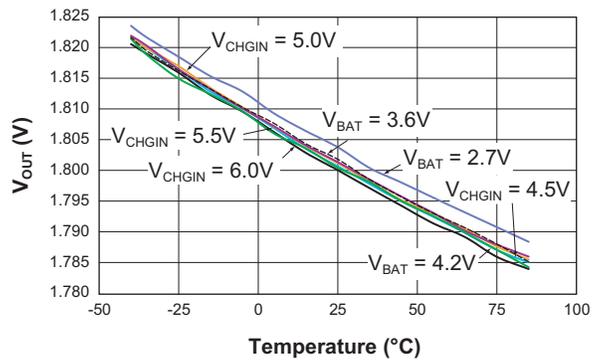
Step-Down Buck Load Regulation vs. Output Current
($V_{OUT} = 1.8V$; $L = 3.3\mu H$)



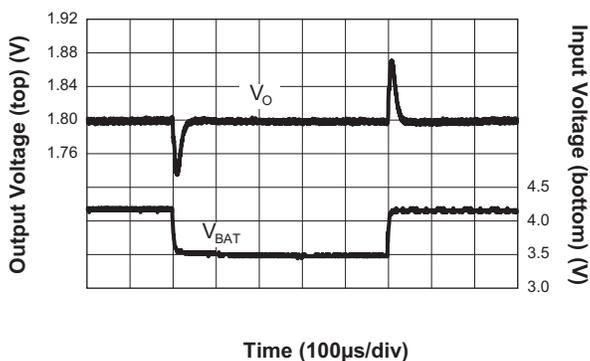
Step-Down Buck Line Regulation vs. CHGIN and Battery Input Voltage
($V_{OUT} = 1.8V$; $L = 3.3\mu H$)



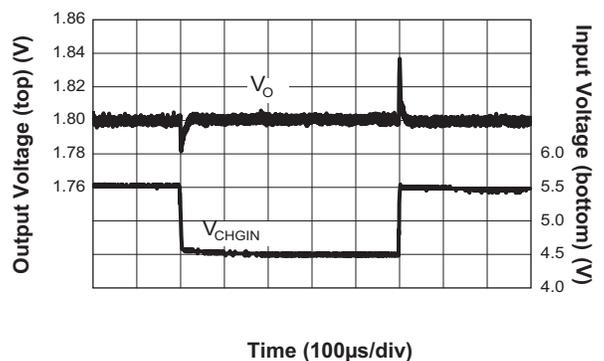
Step-Down Buck Output Voltage vs. Temperature
($I_{OUT} = 10mA$)



V_{BAT} Line Transient Response Step-Down Buck
($V_{BAT} = 3.5V$ to $4.2V$; $I_{OUT} = 300mA$; $V_{OUT} = 1.8V$; $C_{OUT} = 4.7\mu F$)



V_{CHGIN} Line Transient Response Step-Down Buck
($V_{CHGIN} = 4.5V$ to $5.5V$; $I_{OUT} = 300mA$; $V_{OUT} = 1.8V$; $C_{OUT} = 4.7\mu F$)



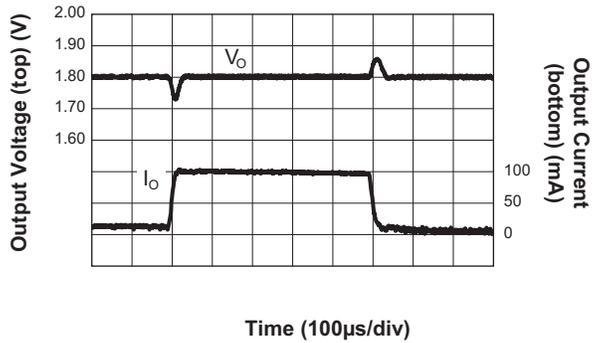
AAT2601/2601A

Total Power Solution for Portable Applications

Typical Characteristics—Step-Down Buck Converter (continued)

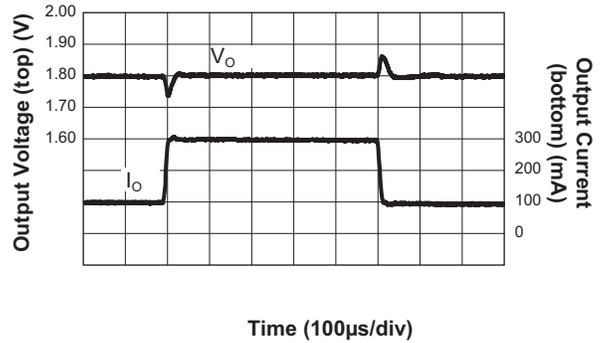
Load Transient Response Step-Down Buck

($I_{OUTBUCK} = 10\text{mA to }100\text{mA}$; $V_{BAT} = 3.6\text{V}$;
 $V_{OUT} = 1.8\text{V}$; $C_{OUT} = 4.7\mu\text{F}$)



Load Transient Response Step-Down Buck

($I_{OUTBUCK} = 100\text{mA to }300\text{mA}$; $V_{BAT} = 3.6\text{V}$;
 $V_{OUT} = 1.8\text{V}$; $C_{OUT} = 4.7\mu\text{F}$)

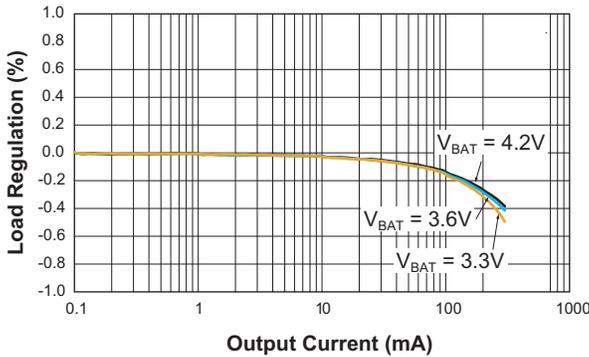


AAT2601/2601A

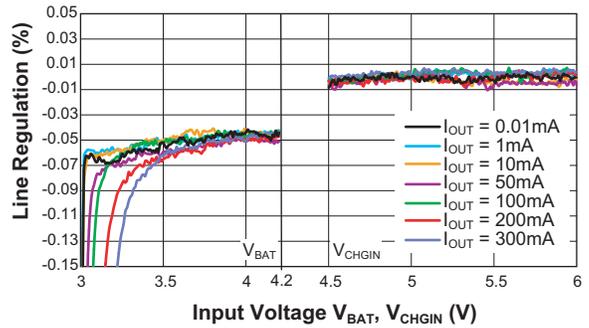
Total Power Solution for Portable Applications

Typical Characteristics—LDO1

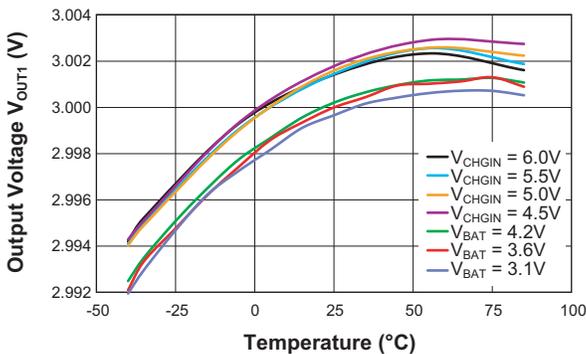
LDO1 Load Regulation vs. Output Current
($V_{OUT1} = 3.0V$)



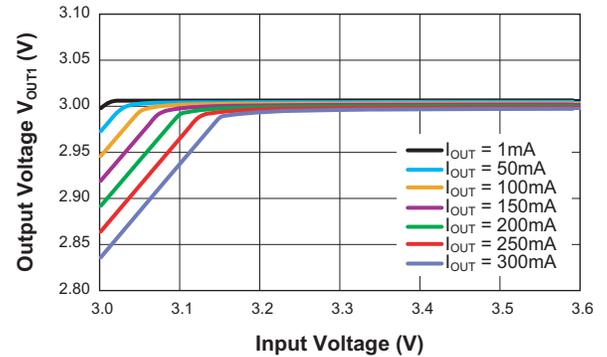
LDO1 Line Regulation vs. Battery and CHGIN Input Voltage
($V_{OUT1} = 3.0V$)



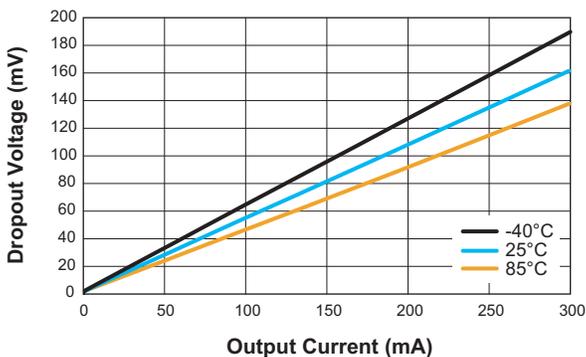
LDO1 Output Voltage vs. Temperature
($I_{OUT1} = 10mA$)



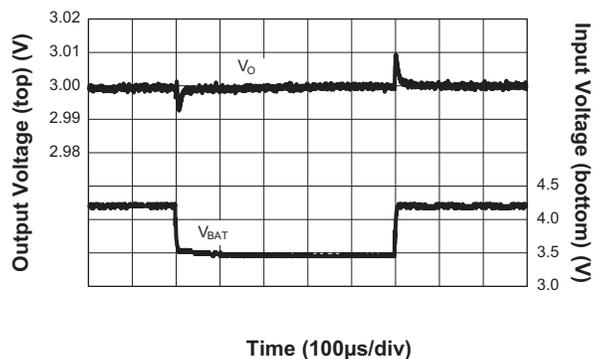
LDO1 Dropout Characteristics vs. Input Voltage
($V_{OUT1} = 3.0V$)



LDO1 Dropout Voltage vs. Output Current
($V_{OUT1} = 3.0V$)



V_BAT Line Transient Response LDO1
($V_{BAT} = 3.5V$ to $4.2V$; $I_{OUT1} = 300mA$; $V_{OUT1} = 3V$)

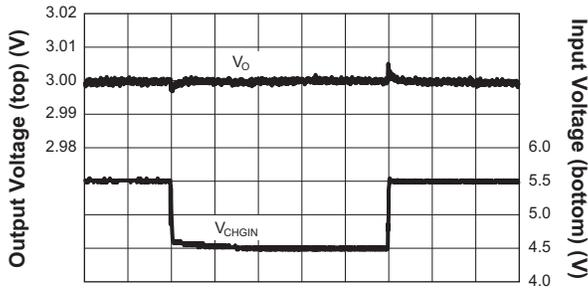


AAT2601/2601A

Total Power Solution for Portable Applications

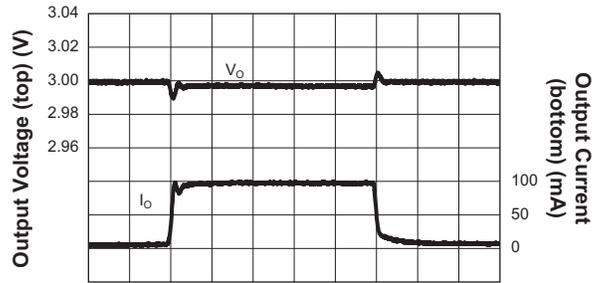
Typical Characteristics—LDO1 (continued)

V_{CHGIN} Line Transient Response LDO1
 ($V_{CHGIN} = 4.5V$ to $5.5V$; $I_{OUT} = 300mA$; $V_{OUT} = 3V$)



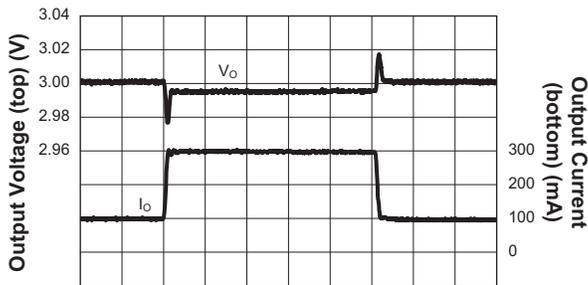
Time (100µs/div)

Load Transient Response LDO1
 ($I_{OUT1} = 10mA$ to $100mA$; $V_{BAT} = 3.6V$; $V_{OUT1} = 3V$)



Time (100µs/div)

Load Transient Response LDO1
 ($I_{OUT1} = 100mA$ to $300mA$; $V_{BAT} = 3.6V$; $V_{OUT1} = 3V$)



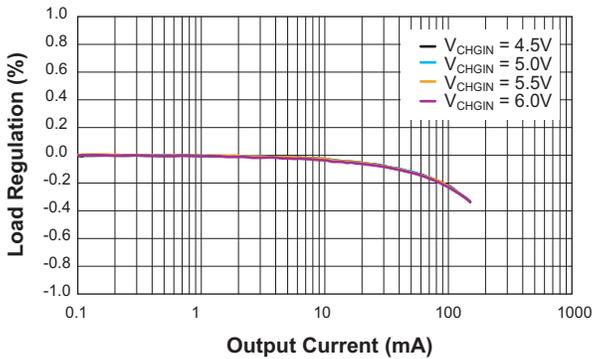
Time (100µs/div)

AAT2601/2601A

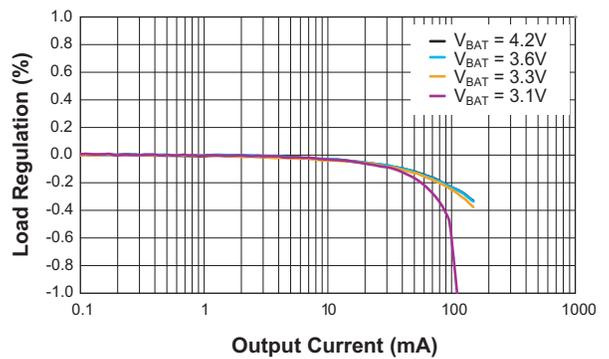
Total Power Solution for Portable Applications

Typical Characteristics—LDO4

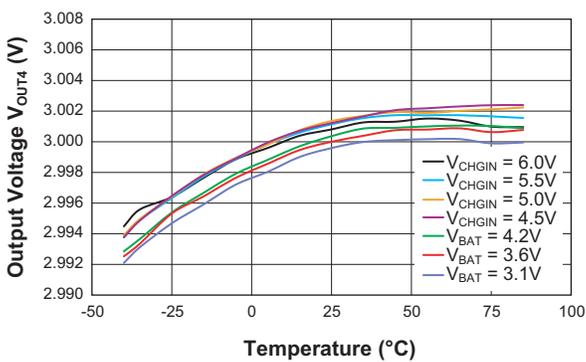
LDO4 Load Regulation vs. Output Current
($V_{OUT4} = 3.0V$)



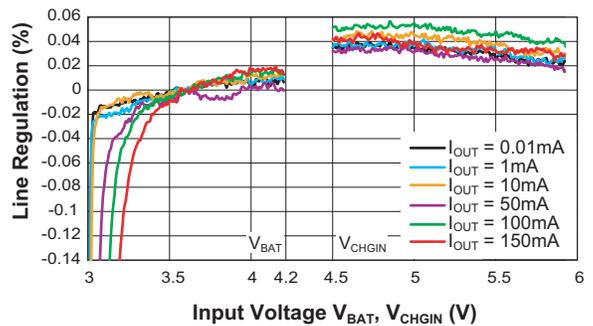
LDO4 Load Regulation vs. Output Current
($V_{OUT4} = 3.0V$)



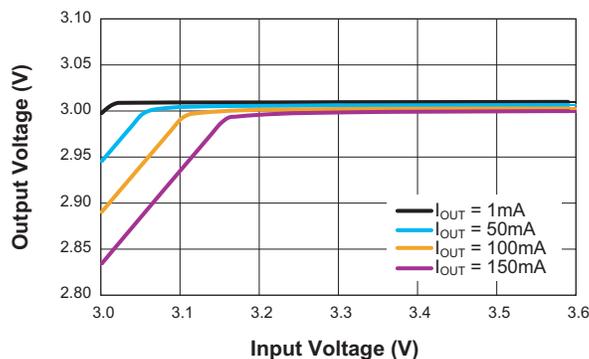
LDO4 Output Voltage vs. Temperature
($I_{OUT4} = 10mA$)



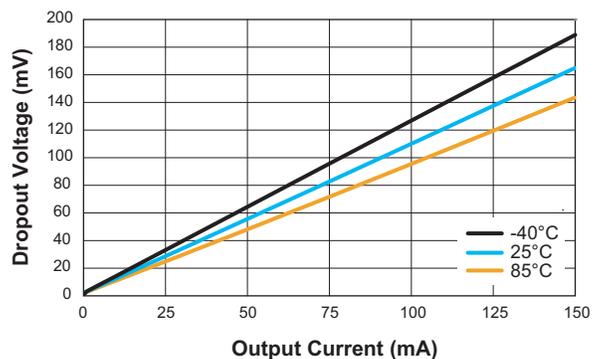
LDO4 Line Regulation vs. Battery and CHGIN Input Voltage
($V_{OUT4} = 3.0V$)



LDO4 Dropout Characteristics vs. Input Voltage
($V_{OUT4} = 3.0V$)



LDO4 Dropout Voltage vs. Output Current
($V_{OUT4} = 3.0V$)

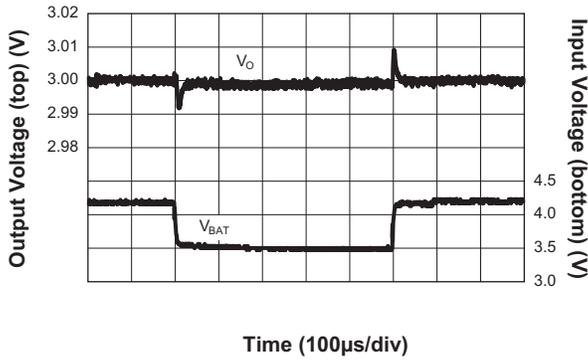


AAT2601/2601A

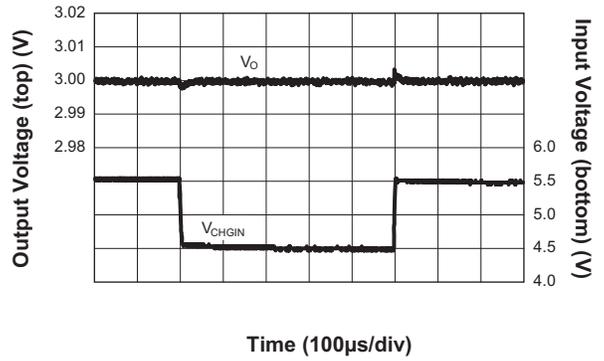
Total Power Solution for Portable Applications

Typical Characteristics—LDO4 (continued)

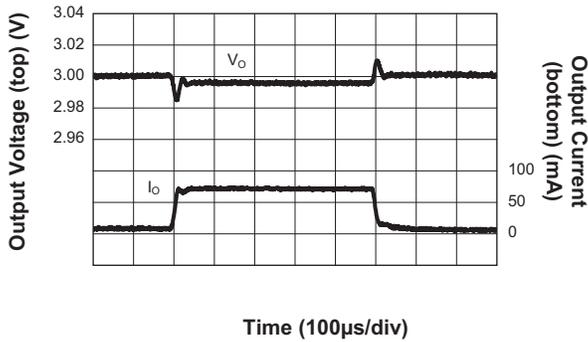
V_{BAT} Line Transient Response LDO4
(V_{BAT} = 3.5V to 4.2V; I_{OUT4} = 150mA; V_{OUT4} = 3V)



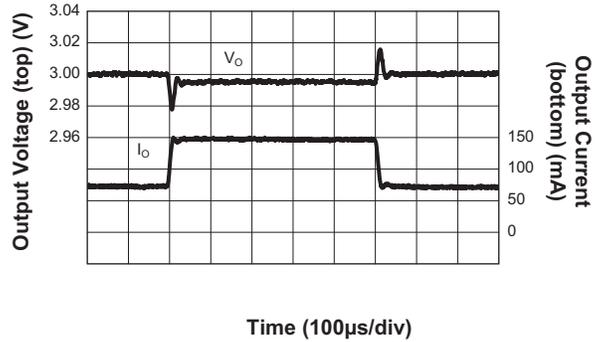
V_{CHGIN} Line Transient Response LDO4
(V_{CHGIN} = 4.5V to 5.5V; I_{OUT4} = 150mA; V_{OUT4} = 3V)



Load Transient Response LDO4
(I_{OUT4} = 10mA to 75mA; V_{BAT} = 3.6V;
V_{OUT4} = 3V; C_{OUT} = 4.7µF)



Load Transient Response LDO4
(I_{OUT4} = 75mA to 150mA; V_{BAT} = 3.6V;
V_{OUT4} = 3V; C_{OUT} = 4.7µF)

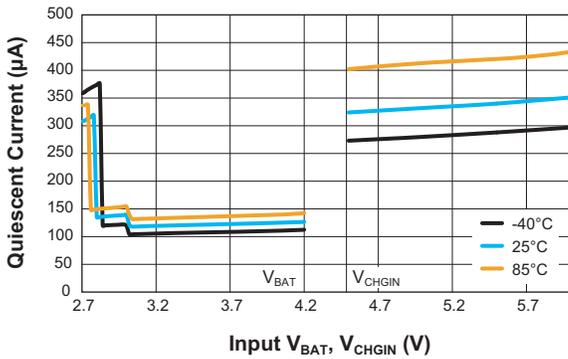


AAT2601/2601A

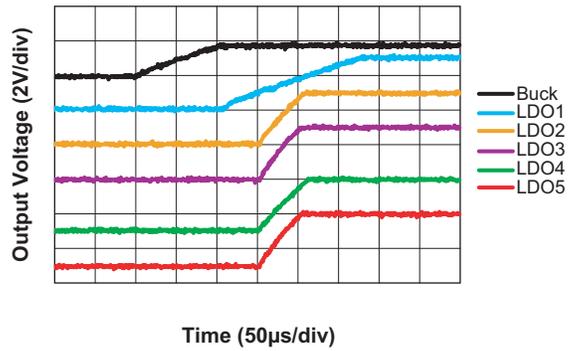
Total Power Solution for Portable Applications

Typical Characteristics—General

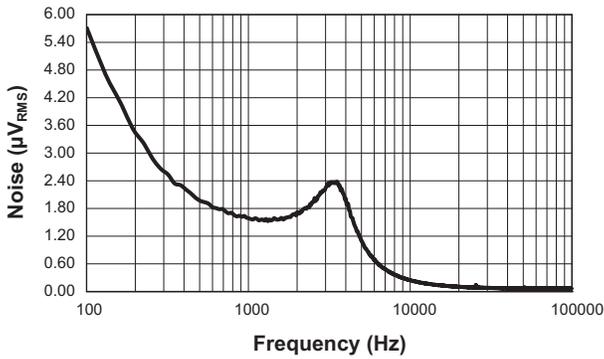
Quiescent Current vs. Input Voltage
($V_{OUT} = 1.8V$; $L = 3.3\mu H$)



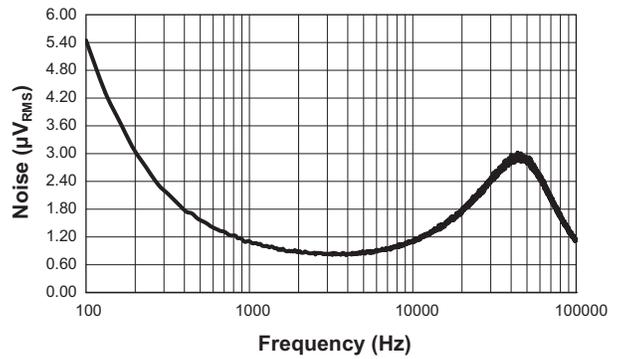
Start-up Sequence
($V_{CHGIN} = 5.0V$)



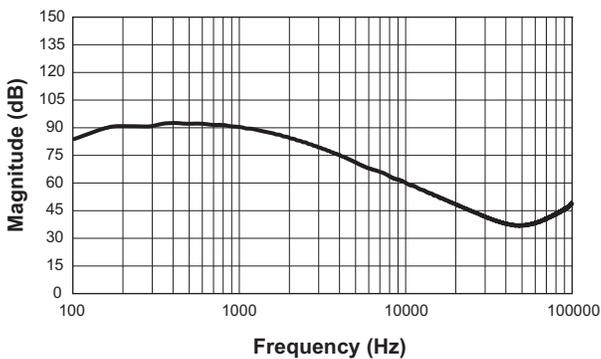
LDO Output Voltage Noise
(No Load; Power BW: 100~100KHz)



LDO Output Voltage Noise
($I_{OUT3} = 10mA$, Power BW = 100~100KHz)



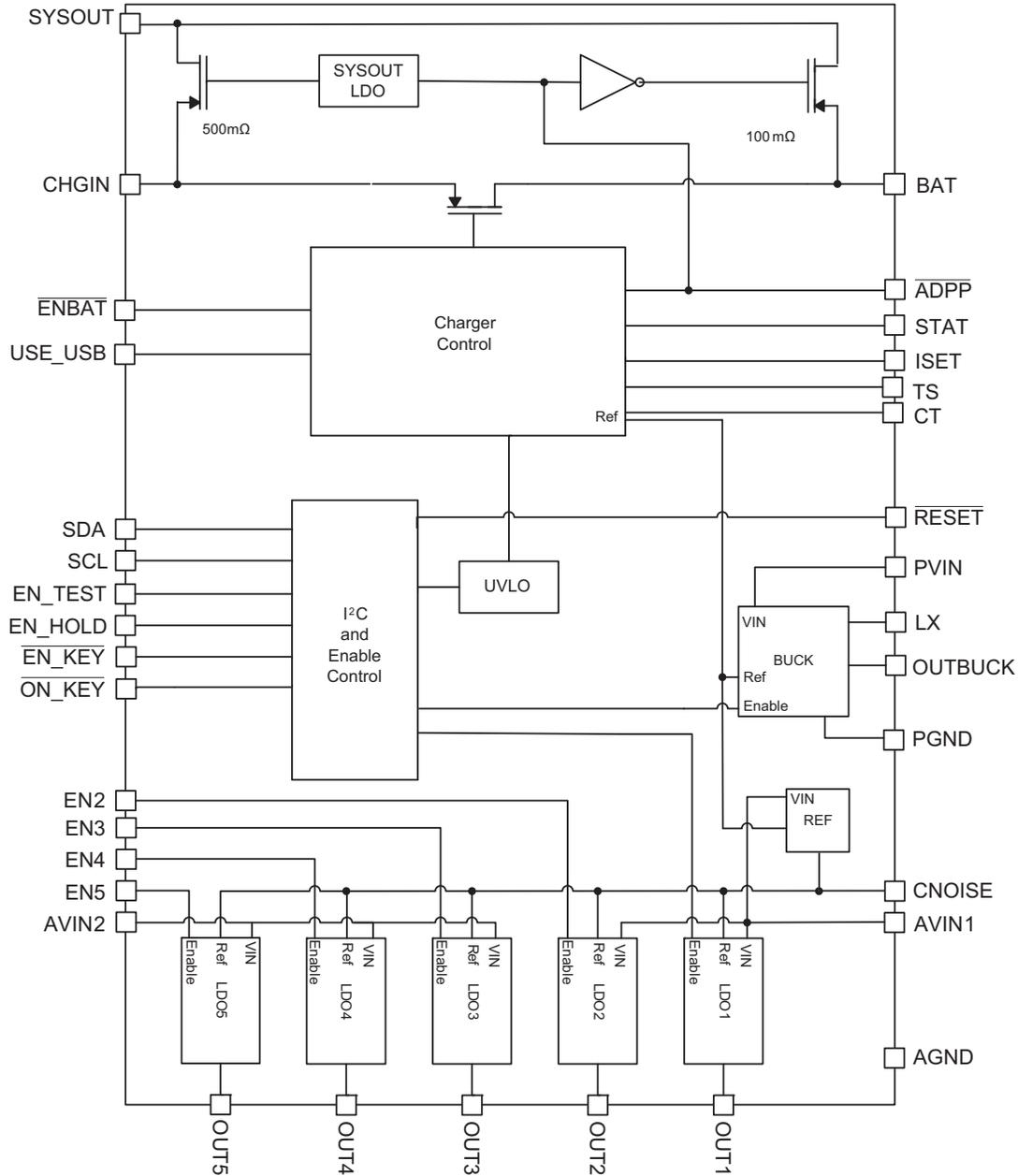
LDO Power Supply Rejection Ratio, PSRR
($I_{OUT3} = 10mA$, BW = 100~100KHz)



AAT2601/2601A

Total Power Solution for Portable Applications

Functional Block Diagram



Functional Description

The AAT2601 and AAT2601A are complete power management solutions which seamlessly integrate an intelligent, stand-alone CC/CV (Constant Current/Constant Voltage), linear-mode single-cell battery charger with one step-down Buck converter and five low-dropout (LDO) regulators to provide power from either a wall adapter or a single-cell Lithium Ion/Polymer battery.

Internal load switches allow the LDO regulators and DC-DC converter to operate from the best available power source of either an AC wall adapter, USB port supply or battery.

If only the battery is available, then the voltage regulators and converter are powered directly from the battery through a 100mΩ load switch. (The charger is put into sleep mode and draws less than 1μA quiescent current.)

AAT2601/2601A

Total Power Solution for Portable Applications

If the system is connected to a wall adapter, then the voltage converters are powered directly from the adapter through a 500mΩ load switch and the battery is disconnected from the voltage converter inputs. This allows the system to operate regardless of the charging state of the battery or with no battery.

System Output (SYSOUT)

Intelligent control of the integrated load switches is managed by the switch control circuitry to allow the Step-down converter and the LDOs to have the best available power source. When the CHGIN pin voltage is above 4.5V, the system automatically turns on and the power to the SYSOUT pin will be provided by either the CHGIN pin or the BAT pin. When the USE_USB pin is low, the CHGIN provides power to SYSOUT through an internal LDO regulated to 3.9V. When the USE_USB pin is high or if forced through use of an I²C command, the BAT pin is shorted to SYSOUT through a 100mohm switch. If a CHGIN voltage is not present and the system is enabled, SYSOUT will be shorted to BAT.

This system allows the step-down converter and LDOs to always have the best available source of power. This also allows the voltage converters to operate with no battery, or with a battery voltage that falls below the precondition trickle charge threshold.

Typical Power Up Sequence

The AAT2601 and AAT2601A support a variety of push-button or enable/disable schemes. A typical startup and shutdown process proceeds as follows (referring to Figures 1 and 2): System startup is initiated whenever one of the following conditions occurs:

- 1) A push-button is used to assert $\overline{\text{EN_KEY}}$ low.
- 2) A valid supply (>CHGIN UVLO) is connected to the charger input CHGIN.
- 3) A hands free device or headset is connected, asserting EN_TEST high.

The startup sequence for the AAT2601 and AAT2601A core (Buck and LDO1) is typically initiated by pulling the EN_KEY pin low with a pushbutton switch as shown in Figure 1. The Buck (Core) is the first block to be turned on. When the output of the Buck reaches 90% of its final value, then LDO1 is enabled. When LDO1 (PowerDigital) reaches 90% of its final value, the 65ms RESET timer is initiated holding the microprocessor in reset. When the RESET pin goes High, the μP can begin a power up sequence. After the startup sequence has

commenced, LDO2 (PowerAnalog), LDO3 (TCXO), LDO4 (TX) and LDO5 (RX) can be enabled and disabled as desired using their independent enable pins, even while the Buck and LDO1 are still starting up. However, if they are shut down, then LDO2, LDO3, LDO4, and LDO5 cannot be enabled. The μP must pull the EN_HOLD signal high before the EN_KEY signal can be released by the push-button. This procedure requires that the push-button be held until the μP assumes control of EN_HOLD, providing protection against inadvertent momentary assertions of the pushbutton. Once EN_HOLD is high the startup sequence is complete. If the μP is unable to complete its power-up routine successfully before the user lets go of the push-button, the AAT2601 will automatically shut itself down. (EN_KEY and EN_HOLD are OR'd internally to enable the two core converters.)

Alternatively, the startup sequence is automatically started without the pushbutton switch when the CHGIN pin rises above its UVLO threshold. The system cannot be disabled until the voltage at the CHGIN pin drops below the falling UVLO threshold. Thirdly, the EN_TEST pin can be used to startup the device for test purposes or for hands free operation such as when connecting a headset to the system.

Typical Power Down Sequence

If only the battery is connected and the voltage level is above the BAT UVLO, then the $\overline{\text{EN_KEY}}$ pin can be held low in order to power down the AAT2601/AAT2601A. The user can initiate a shutdown process by pressing the push-button a second time. Upon detecting a second assertion of $\overline{\text{EN_KEY}}$ (by depressing the push-button), the AAT2601 asserts $\overline{\text{ON_KEY}}$ to interrupt the microprocessor which initiates an interrupt service routine that the user pressed the push-button. If EN_TEST and CHGIN are both low, the microprocessor then initiates a power-down routine, the final step of which will be to de-assert EN_HOLD, disabling LDO2, LDO3, LDO4, and LDO5.

When the voltage at the CHGIN pin is above the CHGIN UVLO, the device cannot be powered down. If the voltage at the CHGIN pin is below the CHGIN UVLO, both the $\overline{\text{EN_KEY}}$ and EN_HOLD pins must be held low in order to power down the AAT2601/AAT2601A. If LDO2, LDO3, LDO4, and LDO5 have not been disabled individually prior to global power down, then they will be turned off simultaneously with the Buck. The outputs of LDO4 and LDO5 are internally pulled to ground with 10k during shutdown to discharge the output capacitors and ensure a fast turn-off response time.

AAT2601/2601A

Total Power Solution for Portable Applications

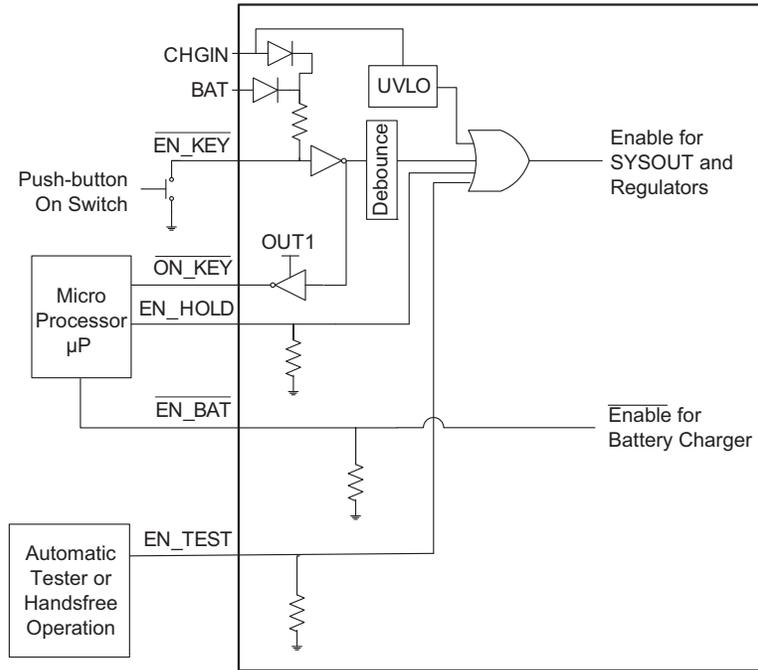


Figure 1: Enable Function Detailed Schematic.

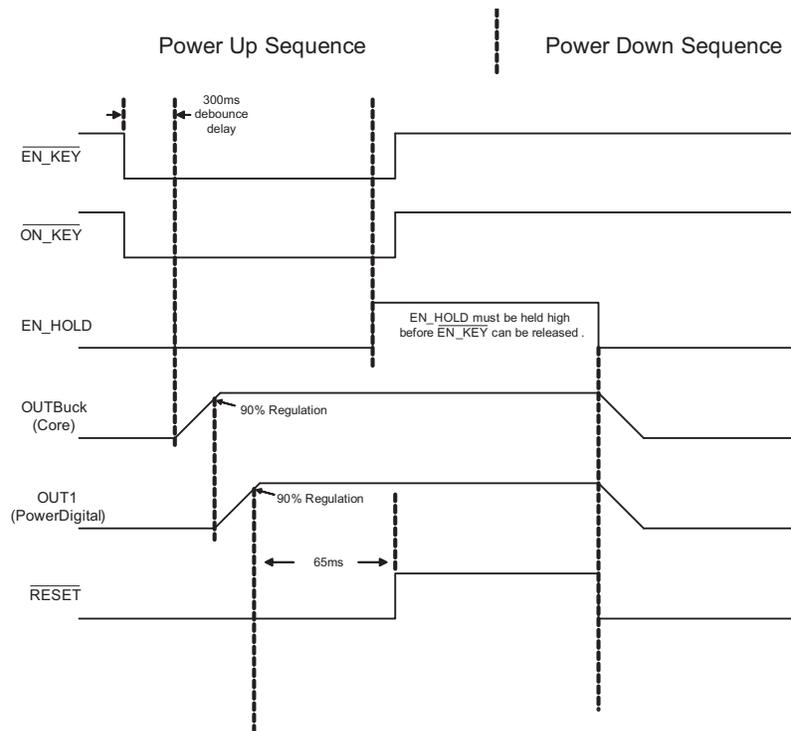


Figure 2: Typical Power Up/Down Sequence.

AAT2601/2601A

Total Power Solution for Portable Applications

Battery Charger

Figure 3 illustrates the entire battery charging profile which consists of three phases.

1. Preconditioning Current Mode (Trickle) Charge
2. Constant Current Mode Charge
3. Constant Voltage Mode Charge

Battery charging commences only after the AAT2601/AAT2601A's battery charger checks several conditions in order to maintain a safe charging environment. The system operation flow chart for the battery charger operation is shown in Figure 4. The input supply must be above the minimum operating voltage (UVLO) and the enable pin ($\overline{\text{ENBAT}}$) must be low (it is internally pulled down). When the battery is connected to the BAT pin, the battery charger checks the condition of the battery and determines which charging mode to apply.

Preconditioning Current Mode Charge Current

If the battery voltage is below the preconditioning voltage threshold V_{MIN} , then the battery charger initiates precondition trickle charge mode and charges the battery at 12% of the programmed constant-current magnitude. For example, if the programmed current is 500mA, then the trickle charge current will be 60mA. Trickle charge is a safety precaution for a deeply discharged cell. It also reduces the power dissipation in the internal series pass MOSFET when the input-output voltage differential is at its highest.

Constant Current Mode Charge Current

Trickle charge continues until the battery voltage reaches V_{MIN} . At this point the battery charger begins constant-current charging. The current level default for this mode is programmed using a resistor from the ISET pin to ground. Once that resistor has been selected for the default charge current, then the current can be adjusted through I²C from a range of 40% to 180% of the programmed default charge current. Programmed current can be set at a minimum of 100mA and up to a maximum of 1A. When the $\overline{\text{ADPP}}$ signal goes high, the default I²C setting of 100% is reset. If the USE_USB signal is high when this happens, the charge current is reset to an internally set 100mA current until the microcontroller sends another I²C signal to change the charge current. (see I²C Programming section).

Constant Voltage Mode Charge

Constant current charging will continue until the battery voltage reaches the Output Charge Voltage Regulation point $V_{\text{BAT_REG}}$. When the battery voltage reaches the regulation voltage ($V_{\text{BAT_REG}}$), the battery charger will transition to constant-voltage mode. $V_{\text{BAT_REG}}$ is factory programmed to 4.2V (nominal). Charging in constant-voltage mode will continue until the charge current has reduced to the end of charge termination current programmed using the I²C interface (5%, 10%, 15%, or 20%).

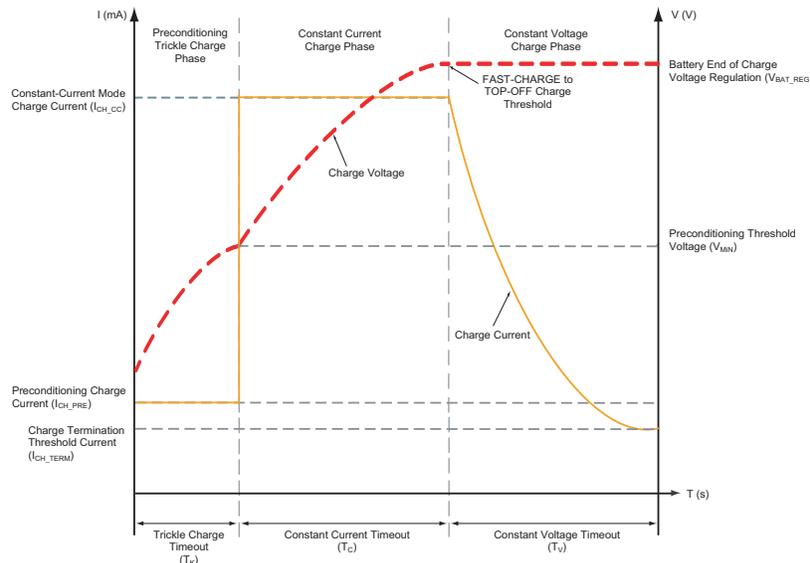


Figure 3: Current vs. Voltage and Charger Time Profile.

AAT2601/2601A

Total Power Solution for Portable Applications

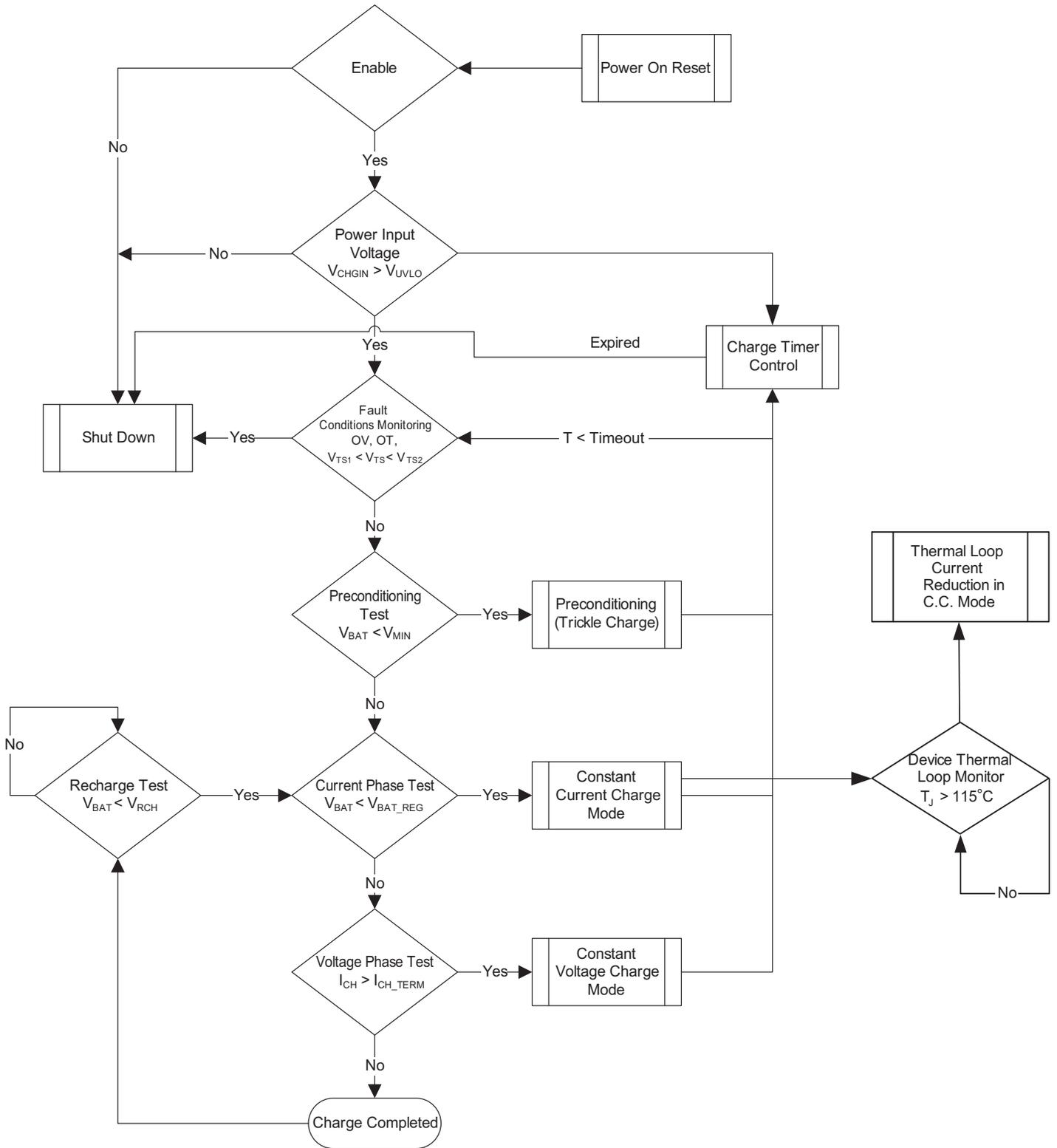


Figure 4: System Operation Flow Chart for the Battery Charger.

AAT2601/2601A

Total Power Solution for Portable Applications

Power Saving Mode

After the charge cycle is complete, the battery charger turns off the series pass device and automatically goes into a power saving sleep mode. During this time, the series pass device will block current in both directions to prevent the battery from discharging through the battery charger.

The battery charger will remain in sleep mode even if the charger source is disconnected. It will come out of sleep mode if either the battery terminal voltage drops below the V_{RCH} threshold, the charger EN pin is recycled, or the charging source is reconnected. In all cases, the battery charger will monitor all parameters and resume charging in the most appropriate mode.

Temperature Sense (TS)

The TS pin is available to monitor the battery temperature. Connect a 10k NTC resistor from the TS pin to ground. The TS pin outputs a 75 μ A constant current into the resistor and monitors the voltage to ensure that the battery temperature does not fall outside the limits depending on the temperature coefficient of the resistor used. When the voltage goes above 2.39V or goes below 0.331V, the charging current will be suspended.

Charge Safety Timer (CT)

While monitoring the charge cycle, the AAT2601/AAT2601A utilizes a charge safety timer to help identify damaged cells and to ensure that the cell is charged safely. Operation is as follows: upon initiating a charging cycle, the AAT2601/AAT2601A charges the cell at 12% of the programmed maximum charge until $V_{BAT} > 2.8V$. If the cell voltage fails to reach the preconditioning threshold of 2.8V (typ) before the safety timer expires, the cell is assumed to be damaged and the charge cycle terminates. If the cell voltage exceeds 2.8V prior to the expiration of the timer, the charge cycle proceeds into fast charge. There are three timeout periods: 1 hour for Trickle Charge mode, 3 hours for Constant Current mode, and 3 hours for Constant Voltage mode.

The CT pin is driven by a constant current source and will provide a linear response to increases in the timing capacitor value. Thus, if the timing capacitor were to be doubled from the nominal 0.1 μ F value, the time-out periods would be doubled. If the programmable watchdog timer function is not needed, it can be disabled by terminating the CT pin to ground. The CT pin should not be left floating or unterminated, as this will cause errors

in the internal timing control circuit. The constant current provided to charge the timing capacitor is very small, and this pin is susceptible to noise and changes in capacitance value. Therefore, the timing capacitor should be physically located on the printed circuit board layout as close as possible to the CT pin. Since the accuracy of the internal timer is dominated by the capacitance value, a 10% tolerance or better ceramic capacitor is recommended. Ceramic capacitor materials, such as X7R and X5R types, are a good choice for this application.

Programming Charge Current (ISET)

The default constant current mode charge level is user programmed with a set resistor placed between the ISET pin and ground. The accuracy of the constant charge current, as well as the preconditioning trickle charge current, is dominated by the tolerance of the set resistor. For this reason, a 1% tolerance metal film resistor is recommended for the set resistor function. The constant charge current levels from 100mA to 1A may be set by selecting the appropriate resistor value from Table 1 and Figure 5. The ISET pin current to charging current ratio is 1 to 800. It is regulated to 1.25V during constant current mode unless changed using I²C commands. It can be used as a charging current monitor, based on the equation:

$$I_{CH} = 800 \cdot \left(\frac{V_{ISET}}{R_{ISET}} \right)$$

During preconditioning charge, the ISET pin is regulated to 12% of the fast charge current I_{SET} voltage level (Figure 5), but the equation stays the same. During constant voltage charge mode, the ISET pin voltage will slow down and be directly proportional to the battery current at all times.

Constant Charging Current I_{CH_CC} (mA)	Set Resistor Value (k Ω)
100	10
200	4.99
300	3.32
400	2.49
500	2
600	1.65
700	1.43
800	1.24
900	1.1
1000	1

Table 1: Constant Current Charge vs. I_{SET} Resistor Value.

AAT2601/2601A

Total Power Solution for Portable Applications

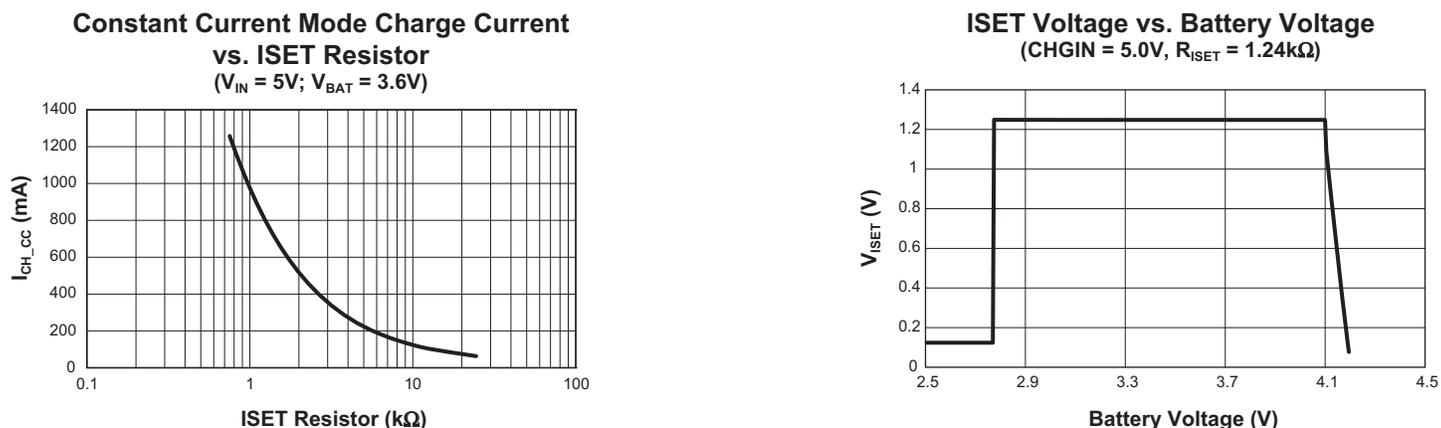


Figure 5: Constant Current Mode Charge I_{CH_CC} Setting vs. I_{SET} Resistor and I_{SET} Voltage vs. Battery Voltage.

Reverse Battery Leakage

The AAT2601/AAT2601A includes internal circuitry that eliminates the need for series blocking diodes, reducing solution size and cost as well as dropout voltage relative to conventional battery chargers. When the input supply is removed or when CHGIN goes below the AAT2601's under voltage-lockout (UVLO) voltage, or when CHGIN drops below V_{BAT} , the AAT2601/AAT2601A automatically reconfigures its power switches to minimize current drain from the battery.

Adapter Power Indicator (ADPP)

This is an open drain output which will pull low when $V_{CHGIN} > 4.5V$. When this happens, depending on the status of the USE_USB pin, the charge current will be reset to the default ISET values or I²C programmed values.

Charge Status Output (STAT)

The AAT2601/AAT2601A provides battery charging status via a status pin. This pin is a buffered output with a supply level up to the LDO1 output (PowerDigital). The status pin can indicate the following conditions:

Event Description	STAT
No battery charging activity	Low (to GND)
Battery charging	High (to V_{OUT1})
Charging completed	Low (to GND)

Table 2: Charge Status Output (STAT).

CHGIN Bypass Capacitor Selection

CHGIN is the power input for the AAT2601/AAT2601A battery charger. The battery charger is automatically enabled whenever a valid voltage is present on CHGIN. In most applications, CHGIN is connected to either a wall adapter or USB port. Under normal operation, the input of the charger will often be "hot-plugged" directly to a powered USB or wall adapter cable, and supply voltage ringing and overshoot may appear at the CHGIN pin. A high quality capacitor connected from CHGIN to G, placed as close as possible to the IC, is sufficient to absorb the energy. Wall-adapter powered applications provide flexibility in input capacitor selection, but the USB specification presents limitations to input capacitance selection. In order to meet both the USB 2.0 and USB OTG (On The Go) specifications while avoiding USB supply under-voltage conditions resulting from the current limit slew rate (100mA/μs) limitations of the USB bus, the CHGIN bypass capacitance value must be between 1μF and 4.7μF. Ceramic capacitors are often preferred for bypassing due to their small size and good surge current ratings, but care must be taken in applications that can encounter hot plug conditions as their very low ESR, in combination with the inductance of the cable, can create a high-Q filter that induces excessive ringing at the CHGIN pin. This ringing can couple to the output and be mistaken as loop instability, or the ringing may be large enough to damage the input itself. Although the CHGIN pin is designed for maximum robustness and an absolute maximum voltage rating of +6.5V for tran-