

BENEFITS and FEATURES

- **Simple Design**
 - Single chip charger and power bank control
 - Power path and battery charge control
 - Charge/Discharge/Power path control
 - Automatic output plug-in detection wakeup and no load detection sleep mode
- **USB Compatible**
 - Vin = 4.5V to 5.5V
 - Vout = 5.07V +/- 1%
 - Auto Detection support USB BC1.2, Chinese YD/T 1591-2009, Apple, and Samsung
 - Pass MFi Test
 - Automatically accommodates weak input power sources.
- **High Power Capability**
 - 3.3A Load Current
 - 1.5A Charge Current
 - Dual Li-Ion Cells – 8.4V/8.7V +/-0.5%
- **Built in Safety**
 - Over/Under-voltage Protection
 - Low Power Short Circuit Protection
 - Battery Over charge/discharge protection
 - Charge/Discharge Thermal Regulation
- **Space Savings**
 - Single Chip Design - fully integrated FETs
 - Integrated LED status reporting
 - TQFN5x5-40 Package
- **Power Savings**
 - >92% Efficient
 - 400kHz
 - <10uA Battery drain current
- **Easy system level design**
 - I2C programmability 1MHz
 - Configurable operating modes and fault conditions
 - Meets EN55022 Class B Radiated EMI Standard

APPLICATIONS

- Backup Battery Pack
- Power Bank
- Dual Cell Boost Battery Charger
- Bluetooth Speaker
- Wearables
- POS Machine
- Standalone Battery Charger with USB Output

GENERAL DESCRIPTION

The ACT2823 is a space-saving, dedicated single-chip solution for dual-cell battery charge and discharge control. It is optimized for power bank and battery backup systems. The ACT2823 operates in three modes: charge mode, discharge mode and HZ mode.

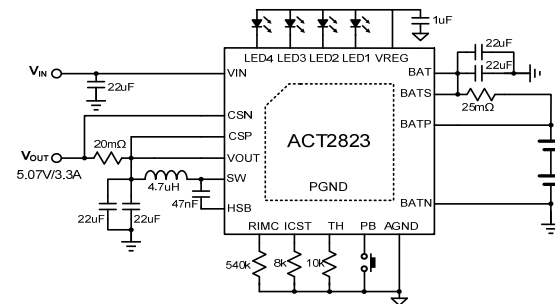
It charges dual Li-Ion batteries from a USB input while also delivering power to the load. Automatic power path control always gives priority to the load.

When the USB input is not present, the ACT2823 powers the load at 5.07V from the batteries. The cycle-by-cycle peak current mode control, constant current regulation, short circuit protection and over voltage protection maximize safe operation.

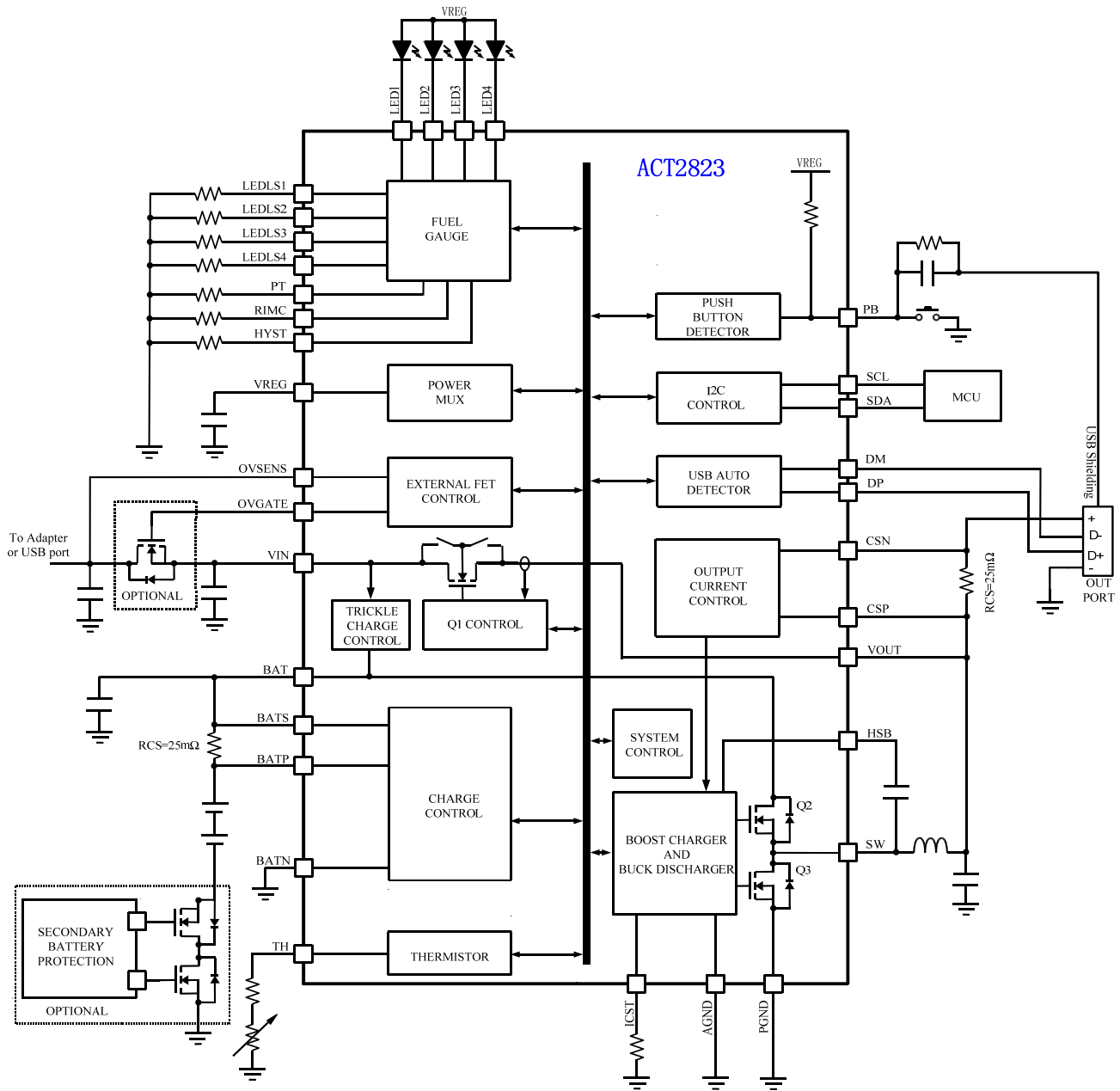
ACT2823's HZ mode minimizes the batteries current drain to less than 10µA to help maintain fully charged batteries for products with long storage, shipping, and shelf life.

ACT2823 provides 4 LED drive pins for battery capacity level and charge status indication to indicate 25%, 50%, 75% and 100% battery charge levels. Multiple LED indications patterns are programmable.

ACT2823 is available in a thermally enhanced 5mmx5mm QFN55-40 package with exposed pad.



FUNCTIONAL BLOCK DIAGRAM



ORDERING INFORMATION

PART NUMBER	BATTERY EOC VOLTAGE	JUNCTION TEMPERATURE	PACKAGE	PINS
ACT2823QJ-T1000	8.4V	-40°C to 150°C	QFN55-40	40

Note 1: All Active-Semi components are RoHS Compliant and with Pb-free plating unless specified differently. The term Pb-free means semiconductor products that are in compliance with current RoHS (Restriction of Hazardous Substances) standards.

Note 2: Package Code designator "Q" represents QFN

Note 3: Pin Count designator "J" represents 40 pins

PIN CONFIGURATION– QFN55-40

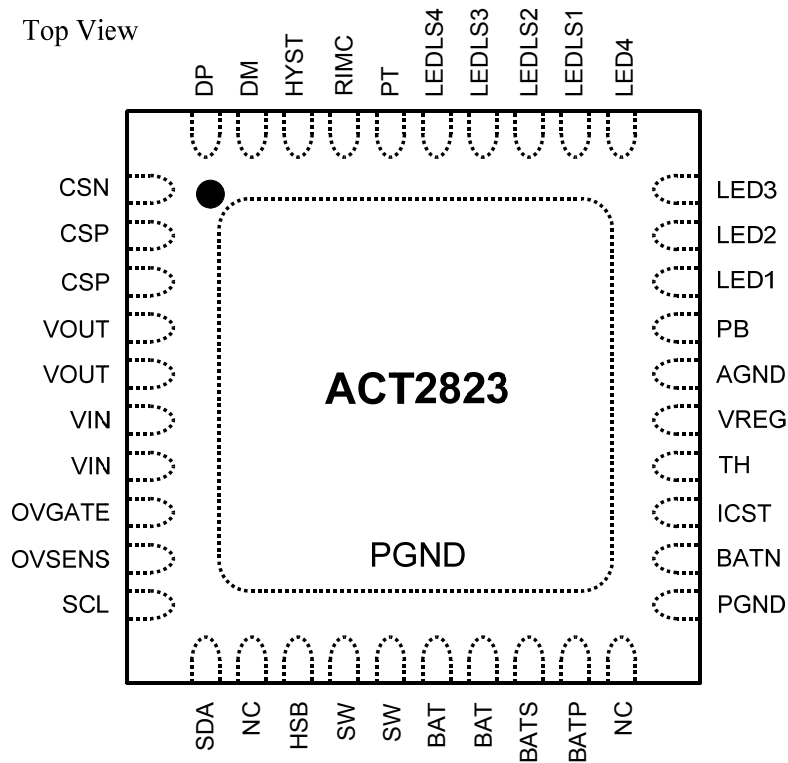


Figure 1: Pin Configuration – Top View – QFN55-40

PIN DESCRIPTIONS - QFN

PIN	NAME	DESCRIPTION
1	CSN	Output current sense negative input.
2,3	CSP	Output current sense positive input.
4, 5	VOUT	Power Output Pin.
6, 7	VIN	USB or AC Adapter input.
8	OVGATE	Output to drive optional external NMOS protect IC from over voltage.
9	OVSENS	USB or AC Adapter input sense pin.
10	SCL	I2C clock input.
11	SDA	I2C data input.
12	NC	Not connected. This pin must be floating. Do not connect this pin to any etch on the PCB.
13	HSB	High side bias pin used for high side FET gate drive. Connect a 47nF ceramic capacitor from HSB to SW.
14,15	SW	Internal switch connected to a terminal of the output inductor.
16,17	BAT	Charging output pin. Bypass to PGND with high quality ceramic capacitors placed as close to the IC as possible. Connect to the charging current sense resistor.
18	BATS	Battery current sense positive input. Connect to CS resistor positive terminal with Kevin connection.
19	BATP	Battery current sense negative input. Connect to CS resistor negative terminal with Kevin connection.
20	NC	Not connected. This Pin must be floating. Do not connect this pin to any etch on the PCB.
21	PGND	Power ground.
22	BATN	Battery negative terminal. Connect directly to PGND.
23	ICST	Fast charge current setting pin. Connect a resistor from this pin to AGND to set the charging current. The current setting ranges from 0.5A-1.5A. The voltage at this pin reflects the charge current and discharge current in charge mode and discharge mode, respectively.
24	TH	Temperature sensing input. Connect to a battery thermistor terminal.
25	VREG	+5V Bias output. Connect a 1.0uF to this pin. This pin supplies up to 50mA output current. The bias turns on in charge mode and discharge mode. Internal register bit can shut down the bias. Bias turns off in HZ mode.
26	AGND	Logic ground output. Connect this pin to the exposed PGND pad on same layer with IC.
27	PB	Push button input. When this pin is pushed for more than 40ms, LED1-4 indicators are enabled for 5 seconds.
28	LED1	Battery level indicator.
29	LED2	Battery level indicator.
30	LED3	Battery level indicator.
31	LED4	Battery level indicator.
32	LEDLS1	LED1 threshold level shift. Connect a resistor from the pin to AGND to shift LED1 threshold voltage.
33	LEDLS2	LED2 threshold level shift. Connect a resistor from the pin to AGND to shift LED2 threshold voltage.
34	LEDLS3	LED3 threshold level shift. Connect a resistor from the pin to AGND to shift LED3 threshold voltage.
35	LEDLS4	LED4 threshold level shift. Connect a resistor from the pin to AGND to shift LED4 threshold voltage.
36	PT	LED indication mode input. The 5 modes of LED indication patterns are set by a voltage at this pin. Connect a resistor at the pin to set the voltage and an LED indication pattern.
37	RIMC	Battery impedance compensation input. Connect a resistor to this pin to offset the LED threshold voltages in charge mode and discharge mode.
38	HYST	Hysteresis window setting input. Connect a resistor to ground to set LED1, 2, 3, 4 hysteresis windows.
39	DM	Output port auto detection input. Connected to portable device D-.
40	DP	Output port auto detection input. Connected to portable device D+.
Exposed Pad	PGND	Electrically connected to AGND and PGND. Also used as thermal pad to remove heat from the IC. Connect to the top layer ground plane and use recommended thermal vias to internal and back side PCB ground planes.

ABSOLUTE MAXIMUM RATINGS

PARAMETER	VALUE	UNIT
LEDLS1, LEDLS2, LEDLS3, LEDLS4, RIMC, HYST and PT to GND	-0.3 to +6	V
LED1, LED2, LED3 and LED4 to GND	-0.3 to +6	V
PB, DM, DP, TH, SCL, SDA and ICST to GND	-0.3 to +6	V
OVSENS to GND	-0.3 to +16	V
OVGATE to GND	-0.3 to +12	V
VIN, VOUT and VREG to GND	-0.3 to +6	V
CSP to CSN, CSP to VOUT	-0.3 to +0.3	V
BAT to BATS, BATS to BATP	-0.3 to +0.3	V
BAT to BATN	-0.3 to +12	V
BATN to GND	-0.3 to +0.3	V
SW to PGND	-0.3 to +12	V
HSB to SW	-0.3 to +6	V
Junction to Ambient Thermal Resistance (θ_{JA})	40	°C/W
Operating Junction Temperature (T_J)	-40 to 150	°C
Operating Temperature Range (T_A)	-40 to 85	°C
Store Temperature	-55 to 150	°C
Lead Temperature (Soldering, 10 sec)	300	°C

Note1: Do not exceed these limits to prevent damage to the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.

Note2: Measured on Active-Semi Evaluation Kit

ELECTRICAL CHARACTERISTICS TABLE

($V_{IN} = 5V$, $T_A = 25^{\circ}C$, unless otherwise specified.)

Input Current Limit, Over Voltage Protection, Output Under Voltage Protection					
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input Voltage Range		4.5		5.5	V
Input Over Voltage Protection	VIN rising, V_{IN_OVP}	5.5	5.7	6.0	V
Input Over Voltage Hysteresis	VIN falling, $V_{IN_OVP_HYST}$		290		mV
Input Under Voltage Lock-Out	VIN rising, V_{IN_UVLO}		4.2		V
Input Under Voltage Lock-Out Hysteresis	VIN falling, $V_{IN_UVLO_HYST}$		200		mV
Input Current Limit Setting Range			3.8		A
Output Under Voltage Protection (UVP)	VOUT falling, V_{OUT_UVP}		3.65		V
Output Under Voltage Protection Hysteresis	VOUT rising, $V_{OUT_UVP_HYST}$		200		mV
Q1 Wait Time in Hiccup Mode			3		s
Boost Mode/Charge Mode					
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Switching Frequency		-15%	400	+15%	kHz
Precondition Voltage Threshold of Total Cells	VBAT rising		5.6		V
Preconditioning Current	Percentage of fast charge current		15		%
Boost Charger UVLO	VOUT rising, BST_UVLO		4.2		V
Battery End-Of-Charge Voltage		-0.5%	8.4	+0.5%	V
Fast Charge Current Setting	Ricst=8k Ω	-10%	1.0	+10%	A
End of Charge Detection Current	Percentage of fast charge current		10		%
Shielding cable Detection Threshold at PB	PB falling In charge mode. $V_{IN} = 5V$		VIN-1.5V		V
Charge Current Foldback Threshold with VIN, Without Shielding Cable Connected	Start point		4.7		V
	End point		4.6		V
Charge Current Foldback Threshold with VIN, With Shielding Cable Connected	Start point		4.92		V
	End point		4.82		V
Continuous Charging Time after EOC	TEOC		45		min
Charger Thermal Regulation Temperature		100	110	120	$^{\circ}C$



ACT2823
Dual Cell Li-Ion Battery Charger
and Power Bank Manager

Buck mode/Discharge					
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Buck Under Voltage Lock-Out	VBAT falling, VBAT1,2		5.8		V
VOUT Output Regulation Voltage	REG3[1:0]=00,Default		5.07		V
	REG3[1:0]=01		5.12		V
	REG3[1:0]=10		5.17		V
	REG3[1:0]=11		5.22		V
VOUT Current Limit	RCS=20mΩ		3.3		A
Buck Converter Under Voltage Protection Threshold	VOUT falling goes into hiccup		3.65		V
Buck Converter Over Voltage Protection Threshold	VOUT rising		5.7		V
Buck Convert Hiccup Time			3.4		s
Buck Converter Light-Load Cut-off Current		5	10	15	mA
Buck Converter Light-Load Cut-off Deglitch Time			12.5		s
High Side Switch Peak Current Limit	All condition	4.5			A
Over Temperature Protection	OTP		160		°C
Over Temperature Protection Hysteresis	OTP_HYST		20		°C
Battery Protection					
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Battery Over Charge Current		2.6	3		A
Battery Over Voltage	Percentage of EOC Voltage	101	102.5	104	%
Battery Under Voltage and Short Circuit Protection			3.2		V
Preconditioning timer	If timer expires, goes to latch-off		1		hr
TH Pull-up Current	Charge mode		140		μA
	Discharge mode		100		μA
TH High Threshold	Charge mode		2.5		V
	Discharge mode		2.5		V
TH Low Threshold	Charge mode		1		V
	Discharge mode		0.57		V
System Management					
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
VREG Output Current			50		mA
PB Rising Threshold	PB Rising, discharge mode		0.95		V
PB Falling Threshold	PB Falling, discharge mode with VIN=5V		0.75		V
PB internal pull up resistance	Pull up to internal supply		1.2		MΩ
Fault Condition Alarm Frequency	0.5s on and 0.5s off		1.0		Hz
Fault Condition Alarm Timer			10		s

LED Indication					
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
LED1-4 Indication Level Setting		5.5		8.8	V
LED1-4 Sink Current			3		mA
LED1-4 Scan Interval	For each LED pattern before lighting LEDs		0.5		s
I2C Interface					
SCL, SDA Input Low	VIN = 5V			0.4	V
SCL, SDA Input High	VIN = 5V	1.25			V
SDA Leakage Current	SDA=5V			1	μA
SDA Output Low	IOL = 5mA			0.35	V
SCL Clock Frequency, fSCL		0		1000	kHz
SCL Low Period, tLOW		0.5			μs
SCL High Period, tHIGH		0.26			μs
SDA Data Setup Time, tSU		50			ns
SDA Data Hold Time, tHD	(Note1)	0			ns
Start Setup Time, tST	For Start Condition	260			ns
Stop Setup Time, tSP	For Stop Condition	260			ns
Capacitance on SCL or SDA Pin				10	pF
SDA Fall Time SDA, Tof	Device requirement			120	ns
Rise Time of both SDA and SCL, tr	See Note: 3			120	ns
Fall Time of both SDA and SCL, tf	See Note: 3			120	ns
Pulse Width of spikes must be suppressed on SCL and SDA		0		50	ns

Note1: No internal timeout for I²C operations.

Note2: This is an I2C system specification only. Rise and fall time of SCL & SDA not controlled by the device.

Note2: Device Address is 7'h5A

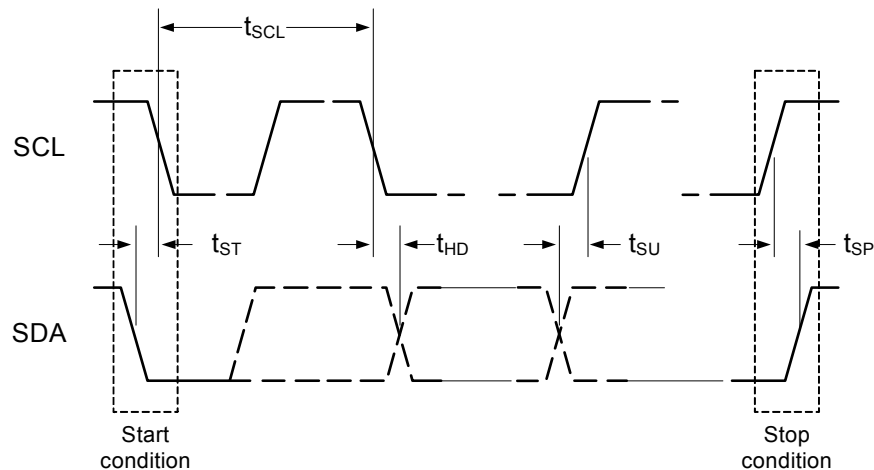


Figure 2: I2C Data Transfer

I2C PROGRAMMABLE PARAMETER LIST

ITEMS	STEP/STATUS	DEFAULT
Input Current Limit and Q1		
Input Current Limit	0.6A, 1.25A, 2.75A, 3.8A	3.8A
VIN UVLO	4.2V, 4.5V	4.2V
Buck Converter/Discharge Mode		
Discharge Cut-Off Voltage	5.4V, 5.6V, 5.8V, 6.0V	5.8V
VOUT Voltage	5.07V, 5.12V, 5.17V, 5.22V	5.07V
Boost Converter/Charge Mode		
Battery EOC Voltage	8.7V, 8.4V, 8.3V, 8.2V	8.4V
Pre-charge voltage threshold	5.6V, 6.0V	5.6V
Pre-charge Current	10%, 15%, 20%, 25%	15%
EOC Current	6%, 10%, 14%, 18%	10%
Fast charge current	60%, 80%, 100%, 120%	100%
System		
VREG ON/OFF in HZ Mode	ON, OFF	OFF

CUSTOMER REGISTER MAP

The ACT2823 address is 7'h5A – Write address is 8'hB4 and read address is 8'hB5
Default values for the ACT2823QJ-T are in bold.

REG1: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	Spare	00	Spare
6			
5	Force Standby	0	0: No Force 1: Force
4	Disable Light Load	0	0: Enable 1: Disable
3	Spare	0	Spare
2	Mask Faults	0	0: No Mask 1: Mask
1	Clear Faults	0	0: No Clear 1: Clear
0	Soft Reset	0	0: No Reset 1: Reset

REG2: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	Spare	000	Spare
6			
5			
4	LED Indication Lock-out	0	0: 0s 1: 30s
3	Spare	0	Spare
2	LED Scan Disable	0	0: Enable 1: Disable
1	LED Always Display During Discharge	0	0: Diable 1: Enable
0	LED Breathing PWM Period	0	0: 2s 1: 3s

REG3: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	VIN Current Limit	10	00: 2.75A 01: 0.6A 10: 3.8A 11: 1.15A
6			
5	VIN UVLO Level	0	0: 4.2V 1: 4.5V
4	Spare	0	Spare
3	Battery Discharge Cut-off Voltage	10	00: 5.4V 01: 5.6V 10: 5.8V 11: 6.0V
2			
1	Spare	00	Spare
0			

REG4: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	Charging Time after EOC	1	0: 0s 1: 45 mins
6	Battery Pre-condition Voltage Level	0	0: 5.6V 1: 6.0V
5	Battery Pre-condition Current Level	01	00: 10% 01: 15%
4			10: 20% 11: 25%
3	Battery EOC Voltage Level	10	00: 8.2V 01: 8.3V 10: 8.4V 11: 8.7V
2			Default = 8.4V (10)
1	Battery EOC Current Level	01	00: 6% 01: 10%
0			10: 14% 11: 18%

REG5: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	Battery Fast Charge Current Level	10	00: 60% 01: 80%
6			10: 100% 11: 120%
5	VREG ON/OFF in HZ Mode	0	0: OFF 1: ON
4	HZ Latch-off	1	0: No Latch-off 1: Latch-off
3	Spare	00	Spare
2			
1	Thermistor Thresholds	1	0: Single 1: Dual
0	Spare	0	Spare

REG6: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	Operation Mode	00	00: Disabled 01: Charge
6			10: Discharge 11: Not Used
5	Battery Charging Status	00	00: Trickle 01: Pre-condition
4			10: Fast Charge 11: Top Off
3	USB Device Status	0	0: Not Connected 1: Connected
2	Spare	000	Spare
1			
0			

REG7: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	VIN UV/OV	0	0: No Fault 1: Fault
6	VOUT UV/OV	0	0: No Fault 1: Fault
5	OTP	0	0: No Fault 1: Fault
4	Charge Thermal Foldback	0	0: No Fault 1: Fault
3	Spare	0000	Spare
2			
1			
0			

REG8: Config Discharge (R/W)

Bit	Name	Reset Value	Description
7	Battery Over Temperature	0	0: No Fault 1: Fault
6	Battery Under Temperature	0	0: No Fault 1: Fault
5	Battery Over Voltage	0	0: No Fault 1: Fault
4	Battery Cut-off	0	0: No Fault 1: Fault
3	Battery Short & Pin Fault	0	0: No Fault 1: Fault
2	Battery Over Current	0	0: No Fault 1: Fault
1	Battery Trickle/Pre-condition Timer Expire	0	0: No Fault 1: Fault
0	Battery Low	0	0: No Fault 1: Fault

GENERAL INFORMATION

ACT2823 is a complete battery charging and discharging power management solution for applications of dual-cell, lithium-based backup battery pack or power bank. With a USB input, the ACT2823 charges a dual cell Li-Ion battery and provides power to the output. When USB power is removed, it powers the output from the battery. The ACT2823 contains a fully integrated, advanced, bidirectional, synchronous boost/buck converter. The converter automatically configures itself as a boost or a buck, depending on the system level conditions. No microprocessor or user intervention is needed to switch between operating modes.

ACT2823 operates in three modes: charge mode, discharge mode, and high-impedance (HZ) mode. It operates in charge mode when an input voltage is present. It operates in discharge mode when the input source is not present. It also contains a High Impedance (HZ) Mode to minimize standby power when input power is not present and a load is not connected.

The ACT2823 automatically prioritizes power to the load. If the input voltage drops due to a weak input source, the charger reduces charging current to ensure the load can continue to operate.

FEATURES

Charger

The ACT2823 charger contains a boost converter that charges a dual Li-Ion battery from a USB input. If a battery is connected, charging is accomplished with a fully integrated boost converter and consists of five phases: trickle charge, preconditioning, fast charge, top off, and end of charge. It contains full, built in charging protection, including over-charge protection, over discharge protection, thermal regulation, and automatic power path priority to the load.

Trickle Charge

When the battery is over-discharged, it must be charged with a very small current to prevent battery damage. The ACT2823 provides this protection by charging the battery with 40mA directly from VIN when the battery voltage is lower than 96% of VIN. When the battery voltage increases to greater than 96% of VIN, the charger transitions to Precondition Charge mode. Note that Q1 is turned off and VOUT is not present in Trickle Charge mode.

Precondition Charge

When the battery voltage is below the precondition threshold, typically 5.6V, the charger operates in Precondition mode. In this mode, it charges the battery with a constant current that is set to 15% of the programmed fast charge current. This prevents damage to a heavily discharged battery. When the battery voltage increases above the precondition threshold, the charger transitions to Fast Charge mode. The battery voltage is measured between the BATH and BATN pins.

Fast Charge

When the battery voltage is above precondition threshold, the charger operates in Fast Charge mode. Fast Charge mode charges the battery with a constant current set to the programmed fast charge current. The fast charge current is set by the resistor on the ICST pin. The charger stays in Fast Charge mode until the battery voltage reaches the End-of-Charge Voltage, typically 8.4V or 8.7V.

Figure 3 shows a block diagram with current sensing.

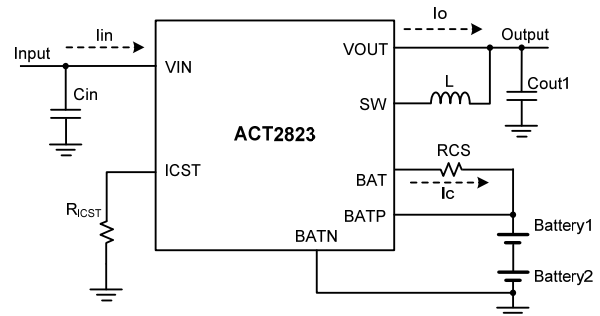


Figure 3: Battery Current Monitoring

The following equation calculates the fast charge current, Ic.

$$I_c(A) = \frac{200}{R_{CS} * R_{ICST}} \quad (1)$$

Where R_{CS} is the current sense resistor in mΩ and R_{ICST} is the fast charge current setting resistor in kΩ. As an example, setting R_{CS}=25mΩ and R_{ICST}=8kΩ results in a 1A fast charge current. Always design for a current sense resistor voltage between 20mV-75mV in fast charge mode.

During discharge mode, the IC inverts the inputs to the battery current sense amp and the voltage on ICST can be used to measure the discharge current. The

following equation calculates the discharge current.

$$I_{DISCHARGE} = \frac{20 * V_{ICST}}{R_{ICST}} \quad (2)$$

Where V_{ICST} is the voltage on the ICST pin in volts, R_{ICST} is the fast charge current setting resistor in $k\Omega$, and $I_{DISCHARGE}$ is the battery discharge current in amps. As an example, measuring $V_{ICST}=0.4V$ with $R_{ICST}=8k\Omega$ indicates 1A discharge current.

The following table provides the recommended R_{ICST} values based on $R_{CS}=25m\Omega$ and $50m\Omega$.

Ic (A)	R _{icst}		Units
	R _{CS} =25mΩ	R _{CS} =50mΩ	
0.8	10	5	kΩ
0.9	8.89	4.44	kΩ
1	8	4	kΩ
1.1	7.27	3.64	kΩ
1.2	6.67	3.33	kΩ
1.3	6.15	3.08	kΩ
1.4	5.71	2.86	kΩ
1.5	5.33	2.67	kΩ

Top Off

When the battery voltage reaches the End-of-Charge Voltage, the ACT2823 transitions to Top Off mode. Top Off mode charges the battery with a constant voltage. In Top Off mode, the charging current slowly decreases as the actual battery voltage increases and the voltage across the battery's ESR decreases. The charger stays in Top Off mode until the charging current drops below the EOC (End-of-Charge) current which is 10% of the programmed fast charge current. At this point the battery is considered fully charged and the charger transitions into the End of Charge mode.

End-of-Charge

When the charging current drops to 10% of the fast charge current, the charger enters End-of-Charge mode. If register 0x04h, bit 7 = 0, the charger immediately turns off. If this bit = 1, the charger continues to charge in constant voltage mode for 45 minutes. In this case, the charge current continues to drop while the battery voltage is held at the End-of-Charge voltage. If the battery voltage drops below 95% of the End-of-Charge voltage, the charger transitions back into Top Off mode. The charger automatically transitions between these four charging modes as the battery voltage increases and decreases during charging and discharging cycles.

If a battery is not present during charging mode, the charger regulates its output to the End-of-Charge voltage. If a battery is then connected, the charger automatically transitions to the proper operating mode that is appropriate for the battery's voltage. If the battery disconnected from the charger, it regulates its output to the End-of-Charge voltage

Thermal Regulation

The charger contains a thermal regulation feature that prevents the IC from reaching thermal shutdown in high temperature environments. It works in both charge and discharge modes. The charger operates at full charging current when the ACT2823 die temperature is below 110°C. If the die temperature increases above 110°C, the IC reduces charging current at a rate of -10%/°C. This ensures that the output voltage on VOUT has priority over charging the battery. In discharge mode, the IC delivers full current at rated voltage when the temperature is below 130°C. If the die temperature increases above 130°C, the IC decreases the output voltage by -115mV/°C.

End-of-Charge Timer

When the charger enter the End-of-Charge mode, it either immediately stops charging or continues to charge for 45 minutes. If register 0x04h, bit 7 = 0, the charger immediately turns off. If this bit = 1, the charger continues to charge in constant voltage mode for 45 minutes.

Power Path Priority

The ACT2823 always gives priority to the system voltage on VOUT. If the input voltage source is current limited and cannot simultaneously provide the full charge current plus the full system current (current out of VOUT), the input voltage would drop and cause a brownout situation on VOUT. The ACT2823 avoids the brownout condition by reducing the charging current if the input voltage drops. If the IC detects that a USB cable is connected, the Charge Current Foldback Threshold voltage starts at 4.92V. If no USB cable is detected, the starting voltage is 4.7V. The charger linearly reduces charge current from full charge current to 0A as the voltage on VIN drops from 4.7V to 4.6V or from 4.92V to 4.82V, depending on whether or not a USB cable is detected.

The charger also reduces the charging current if the total input current (charging current plus system current) exceeds 80% of the programmed input current limit (ILIM) threshold of 3.8A. Charging current is linearly

reduced from full charge current to 0A as the input current increases from 80% of ILIM to 100% of ILIM.

Operating Modes

The ACT2823 automatically switches between several different operating modes, depending on circuit conditions.

Charge Mode

When input power is applied and there are no faults, the IC operates in Charge Mode. Charge Mode turns on Q1 to power VOUT with the input voltage. Note that Q1 stays off and VOUT is not present in Trickle Charge mode. Charge mode configures the switches Q2 and Q3 as a boost converter to charge the battery. The IC automatically enters Charge Mode when input power is applied. There is a 2s delay when transitioning from Discharge Mode to charge mode. During this time, the IC goes into HZ mode

Discharge Mode

In Discharge Mode, the ACT2823 turns off Q1 and reconfigures Q2 and Q3 as a buck converter. It powers the VOUT pin from the battery. The default VOUT voltage is 5.07V and current limit is set at 3.3A. If a charged battery is present when input power is removed, the IC enters Discharge Mode. There is a 2s transition between Charge Mode and Discharge Mode. During this time, the IC goes into HZ mode.

HZ Mode

HZ mode is a low power mode that minimizes current draw from the battery. All switches are turned off, and only the push button circuit is kept alive. The IC draws less than 10uA current from VBAT in HZ Mode. The IC transitions from Discharge Mode to HZ Mode when the load current is less than 10mA for greater than 12.5s or when the pushbutton is pressed for greater than 5s. The IC also enters HZ Mode when a battery fault is detected. The IC stays in HZ Mode indefinitely until input voltage is applied. When input voltage is applied and there are no faults, it enters Charge Mode. The user can force a transition from HZ Mode to Discharge Mode by asserting the push button for greater than 40ms.

Push Button

The ACT2823 push button serves several purposes. It can be automatically pulled low when a shielded cable or a portable device is connected to VOUT. When in HZ Mode, and PB is pulled low for greater than 40ms, it turns on the LEDs for 5s and the IC transitions to Discharge Mode. This allows the user to wake up the IC

to power a portable device. The PB falling threshold is 0.95V when in HZ Mode.

When in Charge Mode, pulling PB below 3.5V tells the IC that a shielded USB cable or a downstream portable device is connected to VOUT. This changes the Charge Current Foldback Voltage threshold from 4.7V to 4.92V. Increasing this threshold gives more current priority to the portable device connected to VOUT. If the portable device is removed and PB rises above 3.5V, the Current Foldback Threshold drops back to 4.7V.

Figure 8 shows the recommended circuit for automatically detecting the shielded cable or portable device connection. R26, R14 and C16 form the detection circuit. Connect R14 and C16 to the USB output connector shield to detect the insertion of a shielded cable. Connect to the USB cable's output voltage to detect insertion of a portable device.

LED Indication

ACT2823 has 4 LED inputs to visually communicate the battery status. A resistor from PT to AGND programs the LED mode. In all modes, when the battery is discharging, LED1 flashes to indicate a low battery when the battery voltage is lower than the VLED1 threshold. In all modes, all LEDs turn on solid when the battery charger is in the End-of-Charge Mode.

Conventional – Always On Mode

Setting $R_{PT}=4k\Omega$ programs Conventional – Always On Mode. The LEDs are always active when the IC is in Charge or Discharge Mode. The LEDs are solid to indicate Charge Mode and flash to indicate Discharge Mode. Figure 4 shows each LED function relative to the VBAT voltage.

Conventional Mode

Setting $R_{PT}=12k\Omega$ programs Conventional Mode. The LEDs are always active when the IC is in Charge Mode. They only turn on for 5s when PB is pulled low for greater than 40ms in Discharge Mode. The LED pattern is identical to Conventional – Always On Mode. Figure 4 shows each LED function relative to the VBAT voltage.

Breathing Mode

Setting $R_{PT}=24k\Omega$ programs Breathing Mode. The LEDs are always active when the IC is in Charge Mode. They only turn on for 5s when PB is pulled low for greater than 40ms in Discharge Mode. In Charge Mode, the LEDs appear to “breathe” as the IC ramps the current back and forth between 0mA and 3mA at a 2s rate. In Discharge mode, the LED pattern is identical to Conventional

Mode. Figure 4 shows each LED function relative to the VBAT voltage.

Bottom Charging Mode

Setting $R_{PT}=40k\Omega$ programs Bottom Charging Mode. The LEDs are always active when the IC is in Charge Mode. They only turn on for 5s when PB is pulled low for greater than 40ms in Discharge Mode. In Charge Mode, the LED cycle starts with all LEDs off. LED1 turns on, then the LED2 turns on, etc. until the highest LED corresponding to the battery voltage turns on.

Then all LEDs turn off. This cycle repeats every 0.5s. In Discharge mode, the LED pattern is identical to Conventional Mode. Figure 4 shows each LED function relative to the VBAT voltage.

Circulating Mode

Setting R_{PT} greater than $56k\Omega$ programs Circulating Mode. R_{PT} can be left open to program Circulating Mode. The LEDs are always active when the IC is in Charge Mode. They only turn on for 5s when PB is pulled low for greater than 40ms in Discharge Mode. In Charge Mode, when the battery voltage is over an LED's threshold, that LED stays on. The higher threshold LEDs turn on one at a time until they are all on. They then turn off. The cycle repeats every 0.5s. In Discharge mode, the LED pattern is identical to Conventional Mode. Figure 4 shows each LED function relative to the VBAT voltage.

LED1-4 Refresh Cycle

Every time VIN is applied or PB is pulled low, the LEDs turn on sequentially in a 0.5s interval prior to entering the mode programmed by the PT pin.

LED1-4 Fault Alarm Signal

When a fault is detected, all four LEDs turn on/off with 0.5s on and 0.5s off time for 10 seconds. The fault conditions include battery OVP, UVP, OTP.

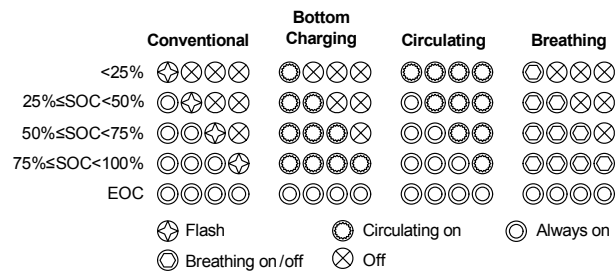


Figure 4: LED Indication Patterns

LED Threshold Setting

LED1, LED2, LED3 and LED4 thresholds are adjustable with external resistors R_{LS1} , R_{LS2} , R_{LS3} , and R_{LS4} connected from LEDLS1, LEDLS2, LEDLS3, LEDLS4 to AGND respectively, as shown in Figure 5. The LED threshold voltage, Battery Impedance Compensation voltage, and LED Hysteresis Window Setting voltage all work together to program when the LEDs turn on and off. Each of these three voltage are programmed independently. Note that the battery voltage is measured between the BATH and BATN pins.

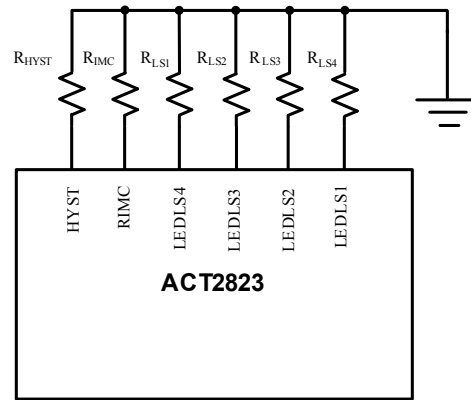


Figure 5: LED Threshold Setting

The following equation calculates the V_{LEDx} threshold in HZ mode. This threshold can be programmed between 5.5V to 8.8V.

$$V_{LEDx(V)} = 5.5V + \frac{108k\Omega}{R_{LSx}(k\Omega)} \quad (3)$$

Where R_{LSx} is the resistance from LEDLSx to AGND in $k\Omega$. For example, setting $R_{LS1} = 215k\Omega$ results in $V_{LED1}=6V$

$R_{LSx}(k\Omega)$	$V_{LEDx}(V)$	$R_{LSx}(k\Omega)$	$V_{LEDx}(V)$
33.2	8.75	105	6.53
38.3	8.32	121	6.39
44.2	7.94	140	6.27
51.1	7.61	162	6.17
59	7.33	187	6.08
68.1	7.09	215	6.00
78.7	6.87	249	5.93
90.9	6.69	287	5.88

Battery Impedance Compensation

The ACT2823 battery impedance function compensates for the battery voltage changes due to changing battery current. The battery current, charging or discharging, interacts with the battery's internal impedance to create voltage increase or drop in battery voltage. The battery

impedance compensation circuitry counteracts this changing voltage by adjusting the LED voltage thresholds. This minimizes the number of LEDs that change states as battery loading changes. Connecting a resistor between the RIMC pin and AGND adjusts for battery impedances between 100mΩ to 800mΩ. If battery impedance compensation is not used, leave RIMC open. The following equation calculates the proper R_{IMC} resistor value

$$R_{IMC} (k\Omega) = 2160k\Omega \times \frac{R_{CS} (m\Omega)}{R_{BAT} (m\Omega)} \quad (4)$$

Where R_{CS} is the current sense resistor in mΩ and R_{BAT} is the battery impedance in mΩ. For example, if R_{CS}=50mΩ and the battery impedance, R_{BAT}, is 500mΩ, then R_{IMC}=216kΩ.

The following table calculates the proper RIMC resistor for typical battery impedances and current sense resistors.

R _{BAT} (mΩ)	R _{IMC} (kΩ)	
	R _{CS} =25mΩ	R _{CS} =50mΩ
100	540kΩ	1280kΩ
200	270kΩ	540kΩ
300	180kΩ	360kΩ
400	135kΩ	270kΩ
500	108kΩ	216kΩ
600	90kΩ	180kΩ
700	77kΩ	154kΩ
800	67.5kΩ	135kΩ

The equation below calculates the ACT2823 LED voltage threshold shift due to battery impedance compensation.

$$V_{IMC} (mV) = 2160k\Omega * I_{BAT} * \frac{R_{CS} (m\Omega)}{R_{IMC} (k\Omega)} \quad (5)$$

As an example, if R_{CS}=50mΩ, R_{IMC}=216kΩ, and the battery charging current is 1.5A, then the ACT2813 increases the LED voltage threshold by 750mV.

LED Hysteresis Window Setting

The LED Hysteresis Window compensates for the increase and decrease in battery voltage associated with charging and discharging. It provides fixed voltage adjustment to the LED threshold settings. When in the

battery is charging, the LED threshold settings are increased by the LED hysteresis voltage. When the battery is discharging, the LED threshold settings are decreased by the LED hysteresis voltage. This setting has no effect in HZ Mode. Connecting a resistor between the HYST pin and AGND program the hysteresis between adjusts for battery impedances between 0mV and 720mV. Note that the ACT2823 has 100mV of built in hysteresis that cannot be changed.

The following equations calculate the proper R_{HYST} resistance. Note that LED1 and LED2 use one equation while LED3 and LED4 use another equation.

$$R_{HYST<1:2>} (k\Omega) = \frac{32.4k\Omega}{V_{HYST<1:2>} (V)} \quad (6)$$

$$R_{HYST<3:4>} (k\Omega) = \frac{27k\Omega}{V_{HYST<3:4>} (V)} \quad (7)$$

Where V_{HYST} is the desired LED hysteresis in volts. R_{HYST(1)} = 54kΩ to set LED1 hysteresis equal to 600mV. R_{HYST(3)} = 45kΩ to set LED3 hysteresis equal to 600mV.

The following table provides R_{HYST} values for different hysteresis voltages.

R _{HYST} (kΩ)	LED1 V _{HYST}	LED2 V _{HYST}	LED3 V _{HYST}	LED4 V _{HYST}
Floating	0mV	0mV	0mV	0mV
270	120mV	120mV	100mV	100mV
135	240mV	240mV	200mV	200mV
90	360mV	360mV	300mV	300mV
67.5	480mV	480mV	400mV	400mV
54	600mV	600mV	500mV	500mV
45	720mV	720mV	600mV	600mV

LED Trigger Voltage

The battery voltage that triggers each LED to turn on and off is a function of the LED voltage threshold, the impedance compensation voltage, the LED hysteresis setting, and whether the battery is charging or discharging. The figure below graphically shows the LED trip points as a function of these inputs.

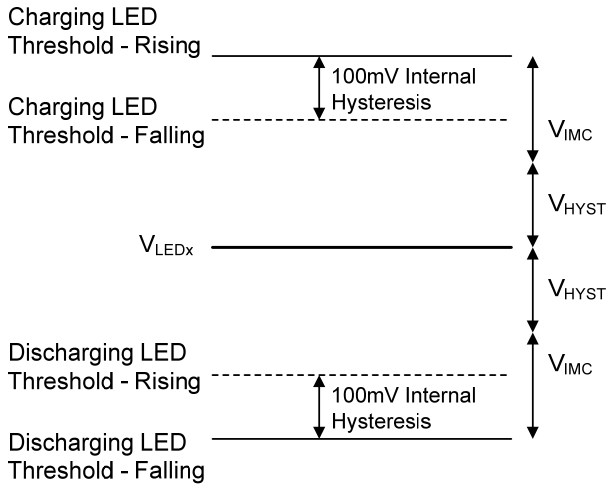


Figure 6: LED threshold setting

BATTERY TEMPERATURE MONITORING

The ACT2823 monitors the battery pack temperature by measuring the voltage at the TH pin. The TH pin is connected to the thermistor resistor network which includes a negative temperature coefficient thermistor. An internal current source provides a bias current to generate a voltage on the TH pin. The ACT2823 compares the voltage at the TH pin with the internal V_{THH} and V_{THL} thresholds to determine if charging or discharging is allowed. Charging latches off and triggers a fault in the I2C register 0x08h when $V_{TH} < V_{THL}$ or $V_{TH} > V_{THH}$. Charging cannot be started until the fault condition goes away. After V_{TH} returns to the normal range, one of the following three conditions can restart charging.

1. Assert PB when the latch off bit in register 0x05h = 0
2. Clear the fault status bits in register 0x08h standby
3. Recycle input power

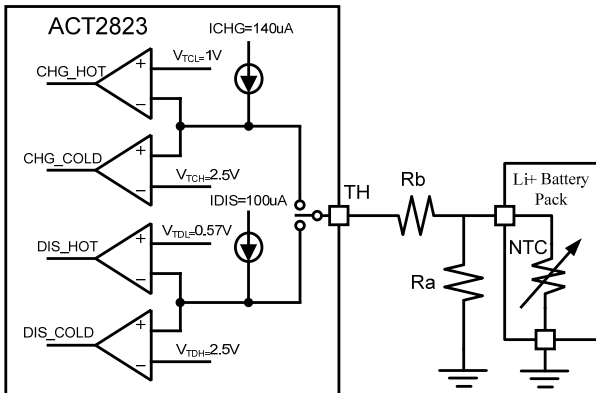


Figure 7: Thermistor Resistor Network

R_{NTCc} : NTC Resistor at cold temperature (T_{cold})

R_{NTCh} : NTC Resistor at hot temperature (T_{hot})

The following equations calculate the proper external resistor network to set the upper and lower charging temperature thresholds.

$$V_{TCL} = I_{CHG} \times R_{chot} \quad (8)$$

$$V_{TCH} = I_{CHG} \times R_{cold} \quad (9)$$

$$R_{chot} = R_b + \frac{R_a \times R_{NTCh}}{R_a + R_{NTCh}} \quad (10)$$

$$R_{cold} = R_b + \frac{R_a \times R_{NTCc}}{R_a + R_{NTCc}} \quad (11)$$

From (7) (8) (9) and (10) calculate R_a and R_b in charge mode, as the same method, the resistors in discharge mode can be calculated.

For example, using an NXRT15XH103 NTC resistor and a temperature charging range of 0°C to 45°C , we know $R_{NTCc}=27.219\text{k}\Omega$ and $4.917\text{k}\Omega$ at 0°C and 45°C respectively. We can calculate $R_a=33\text{k}\Omega$ and $R_b=2.87\text{k}\Omega$ based on the above formulas. Follow this procedure for any other NTC and charging temperature range. If temperature sensing is not used, connect TH to ground through a $10\text{k}\Omega$ resistor.

I2C Serial Interface

The ACT2823 provides the user with the ability to change operating parameters via I2C commands. The Customer Register Map section of the datasheet shows the parameters that can be modified. All changes to I2C registers are volatile. All registers reset to their default settings when power is recycled.

The ACT2823 operates as a slave device, and is addressed using a 7-bit slave address of 0x5Ah, followed by an eighth bit, which indicates whether the transaction is a read-operation or a write-operation, 1011010x. "x" is a 0 for write operation and 1 for a read operation. Use address 0xB4h for write operations and 0xB5h for read operations.

There is no timeout function in the I2C packet processing state machine, however, any time the I2C state machine receives a start bit command, it immediately resets the packet processing, even if it is in the middle of a valid packet.

APPLICATION INFORMATION

Inductor Selection

The ACT2823 uses current-mode control and a proprietary internal compensation scheme to simplify external component selection. It is optimized for operation with 4.7µH inductors. Choose an inductor with a low DC-resistance, and avoid inductor saturation by choosing inductors with DC ratings that exceed the maximum output current by at least 30%. Design for an inductor ripple current that is approximately 30% of the maximum output current. The following equation calculates the inductor ripple current is

$$\Delta I_L = \frac{\left(1 - \frac{V_{OUT}}{V_{BAT}}\right) * V_{OUT}}{F_{SW} * L} \quad (12)$$

Where V_{OUT} is the 5V output voltage, V_{BAT} is the battery voltage, F_{SW} is the switching frequency, and L is the inductor value.

Output Capacitor Selection

V_{OUT} requires high quality, low-ESR, ceramic capacitors. Three 22µF capacitors are typically suitable. An additional smaller 0.1µF capacitor assists with high frequency filtering. Smaller capacitors can be used with smaller loads but the capacitance should not go below 44µF for stability reasons. Choose the capacitance to keep the output ripple voltage less than approximately 50mV. The following equation calculates the output voltage ripple.

$$V_{RIPPLE} = \frac{\Delta I_L}{8 * F_{SW} * C_{OUT}} \quad (13)$$

Be sure to consider the capacitor's DC bias effects and maximum ripple current rating when using capacitors smaller than 0805.

A capacitor's actual capacitance is strongly affected by its DC bias characteristics. The output capacitor is typically an X5R, X7R, or similar dielectric. Use of Y5U, Z5U, or similar dielectrics are not recommended due to their wide variation in capacitance over temperature and voltage ranges.

Input Capacitor Selection

The input capacitor on V_{IN} requires a high quality, low-ESR, ceramic input capacitor. A 22µF capacitor is typically suitable, but this value can be increased without limit. Smaller capacitor values can be used with lighter output loads. Choose the input capacitor value to keep the input voltage ripple less than 50mV.

Battery Capacitor Selection

The BAT pin requires high quality, low-ESR, ceramic capacitors. Two 22µF capacitors are typically suitable. An additional smaller 0.1µF capacitor assists with high frequency filtering. Smaller capacitors can be used with smaller loads but the capacitance should not go below 22µF. These capacitors are the output capacitors to the charging boost converter and the input capacitors to a discharging buck converter, so they must be placed as close as possible to the BAT pin and be directly to the PGND plane. Choose the capacitance to keep the ripple voltage less than 50mV. Use the following equation to calculate the minimum input capacitance.

$$C_{BAT} = I_{OUT} * \frac{\frac{V_{OUT}}{V_{BAT}} * \left(1 - \frac{V_{OUT}}{V_{BAT}}\right)}{F_{SW} * V_{RIPPLE}} \quad (14)$$

Where I_{OUT} is the load current, V_{OUT} is the 5V output voltage, V_{BAT} is the battery voltage, F_{SW} is the switching frequency, and V_{RIPPLE} is the desired ripple voltage.

Charge Current Sense Resistor

Choose a charge current sense resistor so the fast charge current through it results in a current sense voltage between 20mV-75mV. Typical resistor values are 25mΩ to 50mΩ. The traces to the BATS and BATS pins must be Kelvin sensed to ensure accuracy. In noisy environments placing a 100nF capacitor between BATS and BATS will improve noise immunity.

Output Sense Resistor

Choose an output current sense resistor so the maximum load current through it results in a current sense voltage greater than 10mV. The traces to the CSP and CSN pins must be Kelvin sensed to ensure accuracy. The following equation sets the output current limit

$$I_{OUT_CL} = \frac{0.066V}{R_{CS}} \quad (15)$$

Where R_{CS} is the current sense resistor between CSN and CSP.

PCB Board Layout Guidance

When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the IC.

1. Place the BAT decoupling capacitors as close to the Bat pin as possible. Minimize the loop area between the BAT pin to the capacitors to the PGND pin. If using different sized capacitors, place the physically smaller capacitors closer to the IC to get better high frequency filtering.
2. Arrange the power components to reduce the overall AC loop area.
3. Place the VOUT decoupling ceramic capacitors close to the VOUT pin. Connect the ground side to the PGND plane.
4. Place the VIN decoupling ceramic capacitors close to the VIN pin. Connect the ground side to the PGND plane.
5. Use Kelvin sense connections from the output current

sense resistor to CSP and CSN pins, and from the battery charging current sense resistor to BATS and BATP.

6. SW node is noisy and should be isolated from other sensitive circuitry. Make the connection from SW to the inductor with a short, wide trace for good EMI and low noise operation.
7. The exposed pad is must be connected to the top layer GND plane. Connect it to the internal and bottom layer ground planes using thermal vias. PGND and AGND should be single-point connected to the exposed pad under the IC.
8. An RC snubber and external Schottky diode across SW to PGND can be added as needed for reducing switching spikes and better EMI performance.

Application Circuit

The following schematic represents a typical application circuit.

Schematic

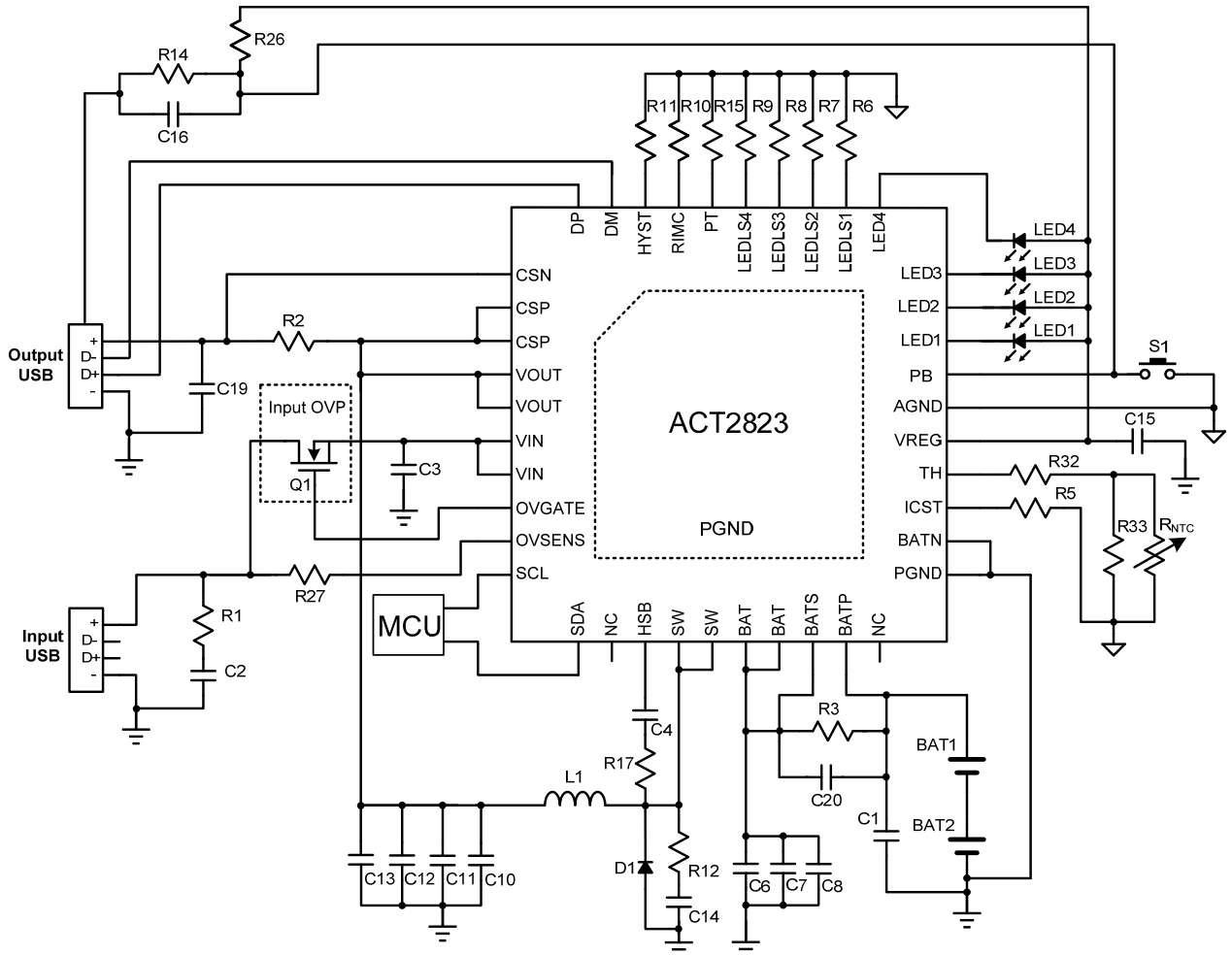


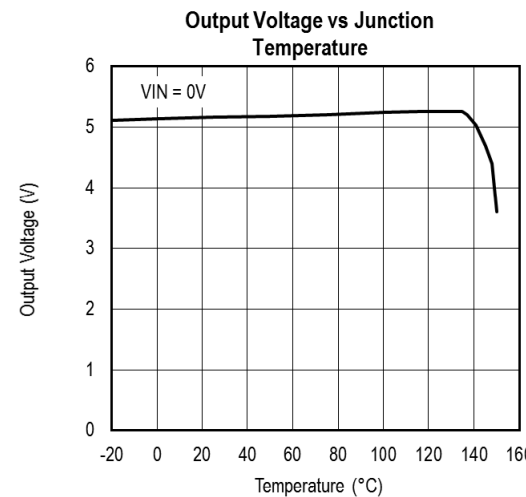
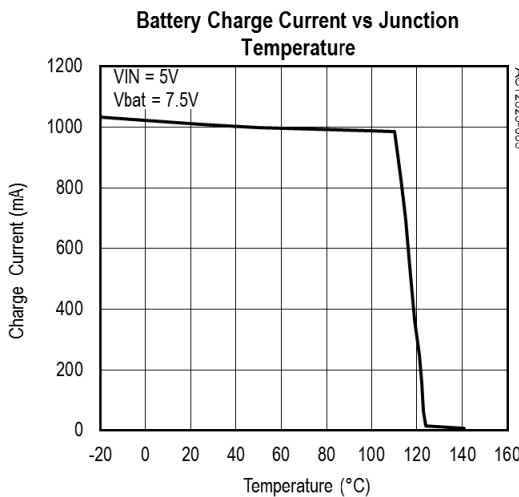
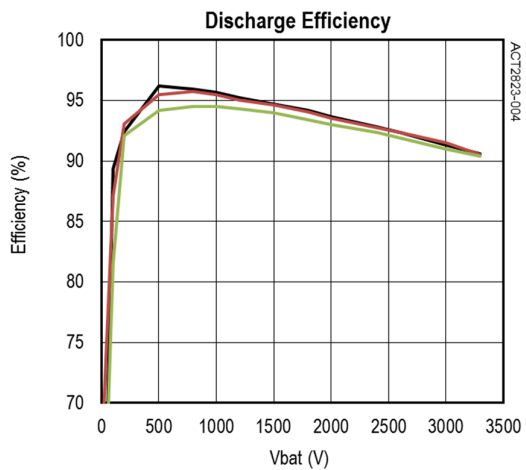
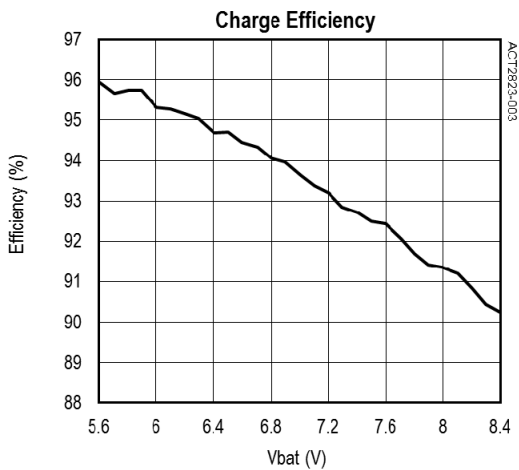
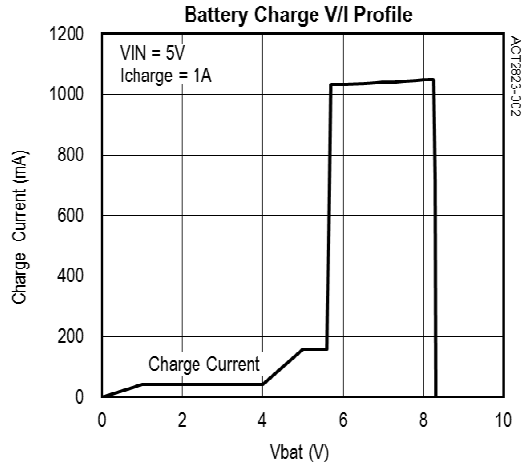
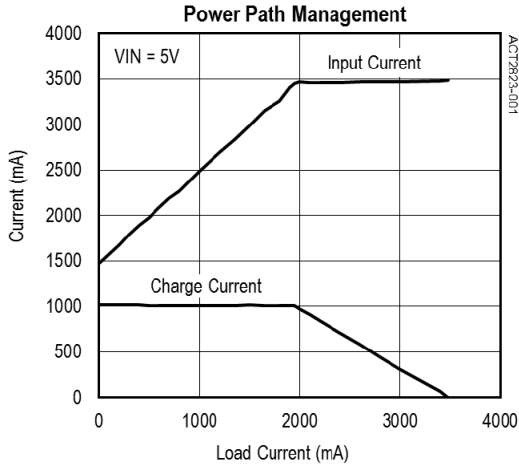
Figure 8: Typical Application Circuit

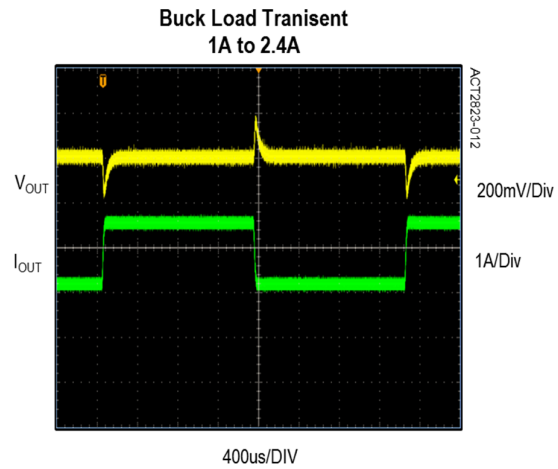
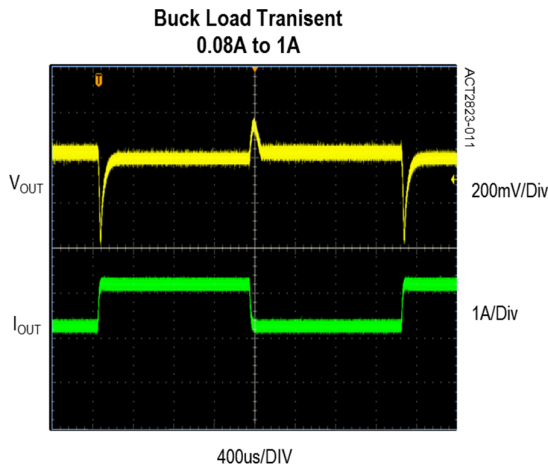
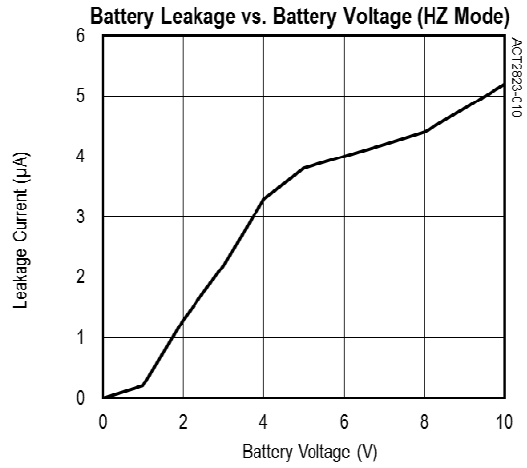
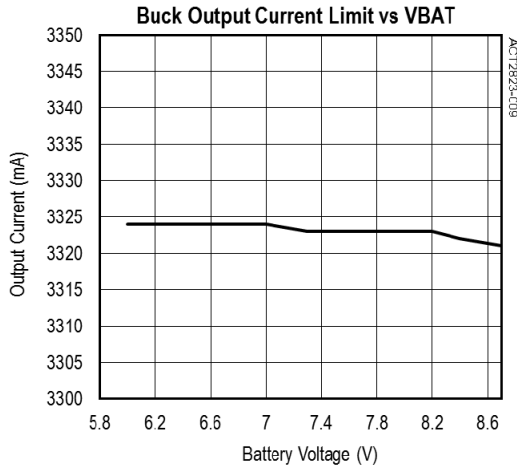
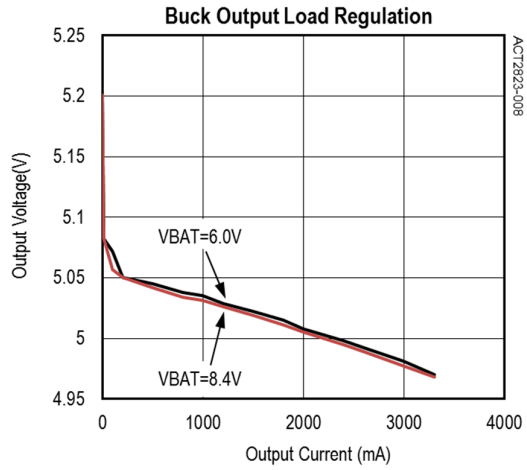
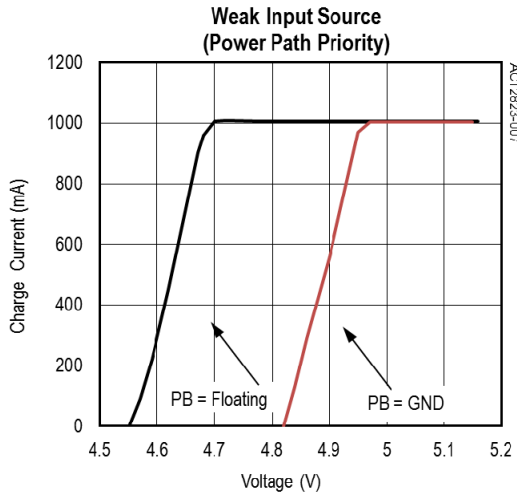
BOM

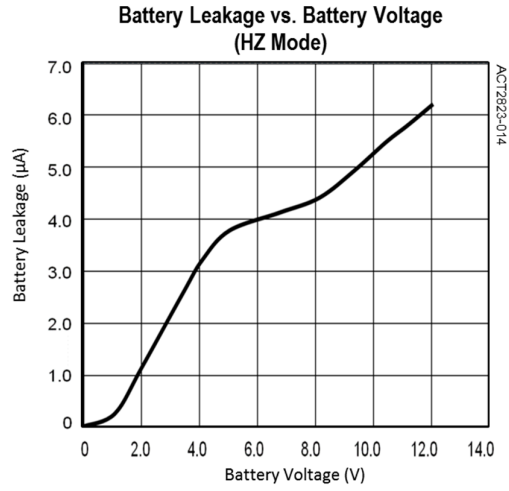
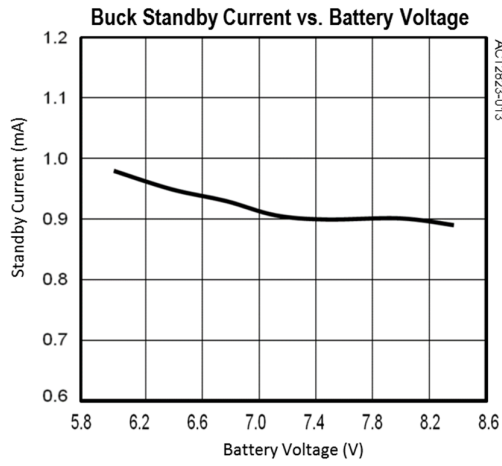
Item	Reference	Description	QTY	Manufacturer
1	L1	SWPA8040S4R7NT 4.7uH 5.9A(8*8*4mm)	1	Sunlord
2	D1	MBR1020VL, 20V/1A Schottky, SMA, Optional	1	Panjit
3	Q1	AO3400A, Rds(on)<32mΩ at V _{GS} =4.5V, optional	1	AOS
4	C1,C7,C8	Ceramic capacitor, 22uF/16V, X7R, 1206	3	Murata/TDK
5	C2	Ceramic capacitor, 4.7uF/10V, X7R, 0805	1	Murata/TDK
6	C3,C10,C11,C12	Ceramic capacitor, 22uF/10V, X7R, 1206	4	Murata/TDK
7	C4	Ceramic capacitor, 47nF/16V, X7R, 0603	1	Murata/TDK
8	C6,C13	Ceramic capacitor, 0.1uF/16V, X7R, 0603	2	Murata/TDK
9	C14	Ceramic capacitor, 2.2nF/10V, X7R, 0603	1	Murata/TDK
10	C15	Ceramic capacitor, 1uF/10V, X7R, 0603	1	Murata/TDK
11	C16	Ceramic capacitor, 2.2uF/10V, X7R, 0603	1	Murata/TDK
12	C19	Ceramic capacitor, 3.3uF/10V, X7R, 0603	1	Murata/TDK
13	C20	Ceramic capacitor, 100nF/10V, X7R, 0603	1	Murata/TDK
14	R1	Chip Resistor, 2.7Ω, 1/8W, 5%, 0805	1	Murata/TDK
15	R2	Chip Resistor, 20mΩ, 1/2W, 1%, 1206	1	SART
16	R3	Chip Resistor, 25mΩ, 1/2W, 1%, 1206	1	SART
17	R5	Chip Resistor, 8kΩ, 1/10W, 1%, 0603	1	Murata/TDK
18	R6	Chip Resistor, 83kΩ, 1/10W, 1%, 0603	1	Murata/TDK
19	R7	Chip Resistor, 63.5kΩ, 1/10W, 1%, 0603	1	Murata/TDK
20	R8	Chip Resistor, 51.4kΩ, 1/10W, 1%, 0603	1	Murata/TDK
21	R9	Chip Resistor, 41.5kΩ, 1/10W, 1%, 0603	1	Murata/TDK
22	R10,R11	Chip Resistor, 540kΩ, 1/10W, 1%, 0603	2	Murata/TDK
23	R12	Chip Resistor, 0.47Ω, 1/8W, 1%, 0805	1	Murata/TDK
24	R14,R26	Chip Resistor, 715kΩ, 1/10W, 5%, 0603	2	Murata/TDK
25	R15	Chip Resistor, 12kΩ, 1/10W, 1%, 0603	1	Murata/TDK
26	R17	Chip Resistor, 10Ω, 1/10W, 5%, 0603	1	Murata/TDK
27	R27	Chip Resistor, 100Ω, 1/10W, 1%, 0603	1	Murata/TDK
28	R32	Chip Resistor, 3kΩ, 1/10W, 1%, 0603	1	Murata/TDK
29	R33	Chip Resistor, 32kΩ, 1/10W, 1%, 0603	1	Murata/TDK
30	R _{NTC}	103AT NTC Thermistor, NXRT15XH103V	1	Murata/TDK
31	LED1,LED2, LED3,LED4	LED, 0603, Blue	4	LED Manu
32	PB	Push Button Switch	1	
33	Output USB	10.2*14.6*7mm,4P	1	
34	Micro-USB	MICRO USB 5P/F SMT B	1	
35	U1	IC, ACT2823 QFN 5X5-40	1	ACT

Typical Performance Characteristics

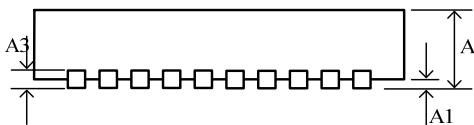
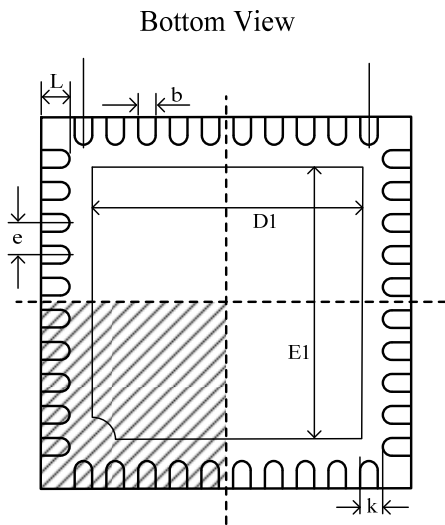
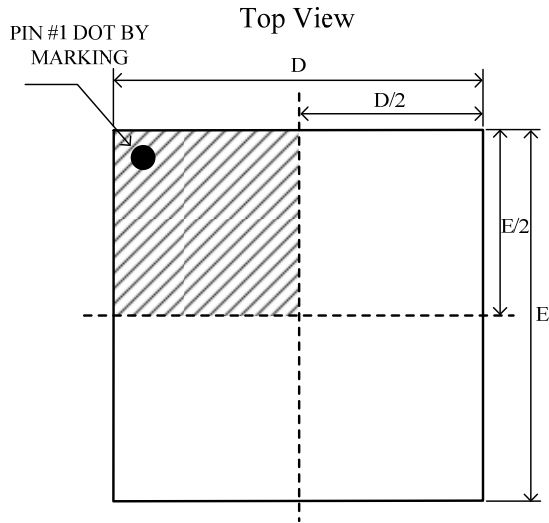
(Schematic as shown in Figure 8, Ta=25°C unless otherwise specified)







PACKAGE OUTLINE AND DIMENSIONS QFN55-40



SYMBOL	DIMENSION IN MIL-LIMETERS		DIMENSION IN INCHES	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.203 REF		0.008 REF	
b	0.150	0.250	0.006	0.010
D	4.924	5.076	0.194	0.200
E	4.924	5.076	0.194	0.200
D1	3.300	3.500	0.130	0.138
E1	3.300	3.500	0.130	0.138
e	0.400 TYP		0.016 TYP	
L	0.324	0.476	0.013	0.019
k	0.200 MIN		0.008 MIN	



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