

Charger Controller with Fuel-Guage & LCD/LED Display

Product Features

- 2-3 cells, NiCd or NiMH battery fast-charger controller for battery-embedded devices
- Precise 7-bit fuel-gauge-counter measures charging and discharging current through battery pack. Make it possible to accurately indicate battery capacity through LCD (PT8A2707-09/2717-19) or LEDs (PT8A2710-12).
- Integrated with a DC/DC step-down controller make it possible for customers to manufacture just one PCB module that can:
 - Cover different product models that requires different charging current/speed by changing only one resistor;
 - Work with different kinds of AC/DC adapters with wide input voltage ranges.
- Motor also can work in both corded or cordless conditions. When motor is used in cord-mode, the charging current to battery is regulated at a maximum value of 1/10 of the fast-charging current. The battery is just like being slowly-charged and prevented from being exposed to a prolonged high-current charging profile.
- Provide excellent charge and discharge protections.
- Available with different parts to cover products employing slide switch (PT8A2707/10/17), tact switch (PT8A2708/09/11/12/18/19) input to control motor ON/OFF. Two-step motor-speed control (70%, 100%) is also available in PT8A2708/2711/2718.
- Very low standby current of typical 20 μ A. Products could typically work in standby-mode for a few months, depends on battery capacity.

Technology Highlights

- Employing 5 major charging states: cool-down / pre-charge / fast charge / trickle charge / stop charge, taking the best care for different battery conditions, especially for aged or dry batteries
- Excellent battery protection and full-charge detection schemes
 - Negative delta voltage detection ($-\Delta V$) with precision of ± 1 mV step
 - Maximum battery voltage detection to turn to maintenance
 - Rate of change of temperature detection (dT/dt) best for NiMH batteries full-charge termination (use with NTC)
 - Abnormal high battery temperature (55 $^{\circ}$ C) detection to stop charging (use with NTC)
 - Flexible fast charge time-out setting (30mins/60mins/90mins/150mins)
- Fuel-gauge counter takes into account the battery self-discharge compensation based on time.
- Provide excellent battery over-discharge protection through auto-stop motor at once (<0.2 s) when
 - discharging current is higher than preset limit value for 3sec (3 limit values selectable externally)
 - battery pack voltage is lower than No-Power value (adjustable externally)
 - NTC measures battery pack temperature higher than preset high-temp value (adjustable externally)
- Key delay to reject multiple inputs at Tact switch (about 0.125s ignorance).
- Internal voltage regulator provides better rejection to interference.
- Integrated DC/DC step-down controller to regulate constant charging currents at different charging
- Available with 24-pin SOIC and SSOP lead-free package

Description

The PT8A2707-12/2717-19 integrates charger controller and fuel-gauge into a single-chip. It detects full-charge through $-\Delta V$, dT/dt , safety-timer and maximum battery voltage, and learns the battery capacity from each charging/discharging cycle. Since PT8A2707-12/2717-19 measures charge/discharge current to account for the battery capacity in/out respectively, the battery capacity can be accurately recorded and displayed in 6-level (10%/20%/40%/60%/80%/100%) LED or LCD pattern. The continuous-learning capability enables the devices to take care of battery aging effect so that the capacity level is always accurately displayed throughout the life-span of the battery pack. In the charging control, a DC/DC controller is regulated to regulate constant currents for pre-charge, fast-charge and trickle-charge conditions. The charging current is determined by the value of a current-sense resistor such that it is tunable upon different applications requirements. When motor is turned on during charging, the charge current to battery pack is regulated at 1/10 of the fast-charge current so that motor can draw current from the adapter while battery is charged in a safe and under-controlled condition. The PT8A2707-12/2717-19 employs NTC as the means to measure the battery pack temperature. When a high temperature is measured during charging, the charging current will be cut off. The devices also detect NTC short/open at which all activities will be disabled if any one of these conditions is observed.

Function comparison table

Family members	TACT Switch (ON/OFF)	SLIDE Switch (ON/OFF)	DSTACT Switch (ON(70%)/100% /OFF)	LCD	LED	Motor Speed (70% PWM)	LCD/LED display in idle mode
PT8A2707		√		√			√
PT8A2708			√	√		√	√
PT8A2709	√			√			√
PT8A2710		√			√		
PT8A2711			√		√	√	
PT8A2712	√				√		
PT8A2717		√		√			
PT8A2718			√	√		√	
PT8A2719	√			√			

```

stateDiagram-v2
    [*] --> IDLE
    IDLE --> PRE_CHARGE: cord on/off
    PRE_CHARGE --> IDLE: cord off
    PRE_CHARGE --> FAST_CHARGE: fast chg
    FAST_CHARGE --> PRE_CHARGE: 
    FAST_CHARGE --> STOP_CHARGE: > 55°C
    STOP_CHARGE --> PRE_CHARGE: ≤ 45°C
    STOP_CHARGE --> FAST_CHARGE: > 55°C
    FAST_CHARGE --> FULL_CHARGE: Full Bat.
    FULL_CHARGE --> STOP_CHARGE: > 55°C
    FULL_CHARGE --> MOTOR: motor on/off
    MOTOR --> FULL_CHARGE: motor on/off
    MOTOR --> IDLE: motor on/off
    IDLE --> MOTOR: motor on/off
    MOTOR --> FAST_CHARGE: motor on/off
    FAST_CHARGE --> MOTOR: motor on/off
    STOP_CHARGE --> IDLE: cord off
    IDLE --> STOP_CHARGE: cord on/off
    STOP_CHARGE --> FULL_CHARGE: motor on/off
  
```

- 1) The system goes to idle when it is power-up. The system is waked up when cord is plugged, motor is turned on or both.
- 2) Motor is turned on/off by tact switch or slide switch.
- 3) Motor will be turned off automatically when:
 - a) the voltage of the battery pack is lower than 1.8V or (adjustable externally);
 - b) the motor is drawing current more than the preset limit or (adjustable externally);
 - c) the battery pack temperature is higher than 55°C (adjustable externally)
- 4) During charging when motor is turned on, the charging current is regulated at 1/10 of the fast-charging current. When motor is turned off, the system will determine to go back to pre-charge/fast-charge/full-charge according to the battery usage condition (more details could be obtained in the operation description).
- 5) Enter fast-charging when
 - a) battery temperature is less than 45°C
 - b) battery voltage is higher than 2V or after pre-charging for 3 minutes
- 6) Enter full-charge state when one of the following full-charge criteria is reached:
 - a) safety timer timeout (4 external selections)
 - b) max. voltage 3.4V (adjustable externally)
 - c) $-\Delta V$
 - d) dT/dt (adjustable by component selections)
- 7) If the battery pack is previously fully-charged without any usage or self-discharged enough, the charger goes directly to maintenance (trickle charge) when cord is plugged again.
- 8) Charger stops charging current when battery temperature is higher than 55°C but resume for charging when battery temperature falls below 45°C

Pin Assignment and Description

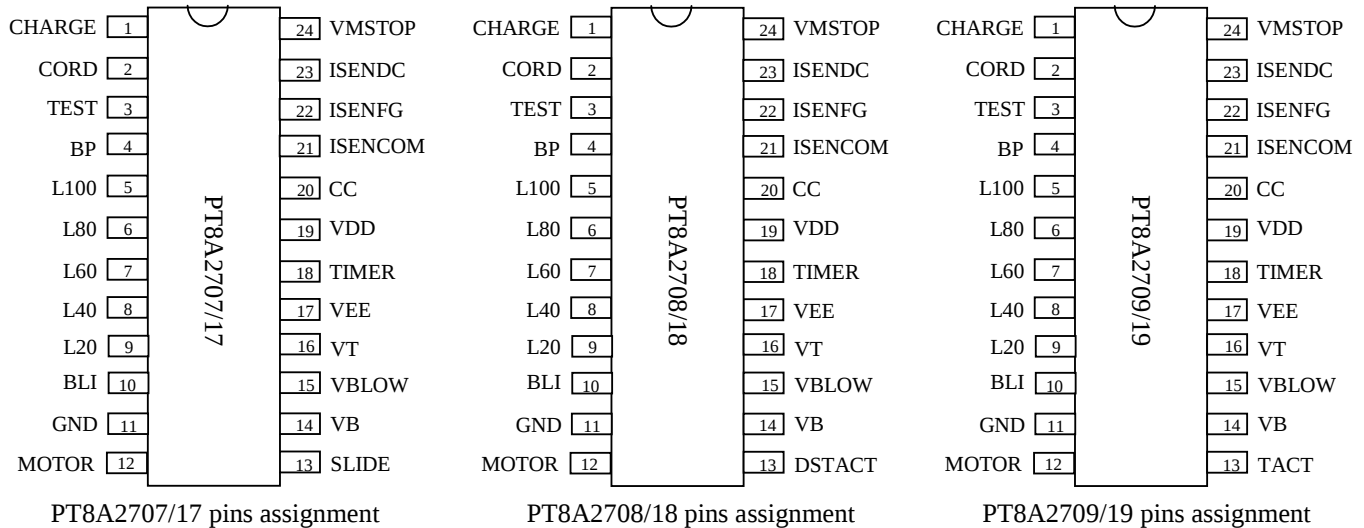
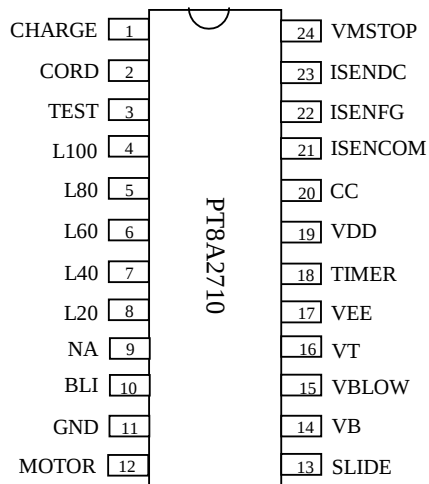
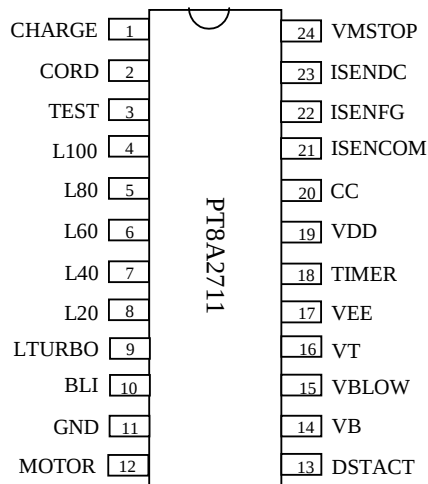


Table 1: PT8A2707-2709 and PT8A2717-2719 LCD Pattern Pin Description

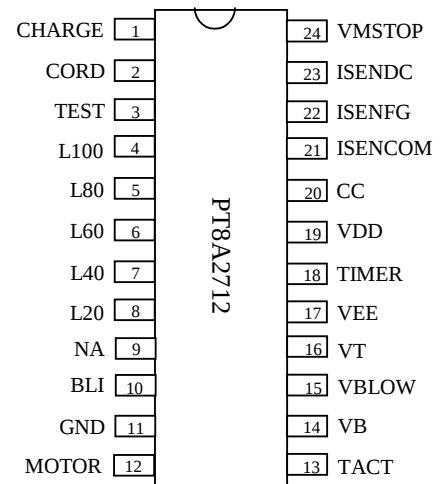
PIN	I/O	Name	Descriptions		
1	O	CHARGE	PWM DC/DC controller output for constant current regulation		
2	I	CORD	External DC supply existence detection		
3	I	TEST	Quick test mode		
4	O	BP	BP for LCD back plane driver		
5	O	L100	Fuel gauge output (Remaining 100% capacity, full charge indication)		
6	O	L80	Fuel gauge output (Remaining 80% capacity)		
7	O	L60	Fuel gauge output (Remaining 60% capacity)		
8	O	L40	Fuel gauge output (Remaining 40% capacity)		
9	O	L20	Fuel gauge output (Remaining 20% capacity)		
10	O	BLI	Battery-low output (Remaining <10% capacity)		
11	-	GND	Ground		
12	I/O	MOTOR	Motor driver control		
13	I	SLIDE	Slide switch (PT8A2707/17) input to control motor running		
		DSTACT	Tact switch (PT8A2708/18) input to control motor running with dual speeds		
		TACT	Tact switch (PT8A2709/19) input to control motor running		
14	I	VB	Charging battery voltage sense input		
15	I	VBLOW	Low-battery voltage sense input		
16	I	VT	Temperature sensor (NTC) input		
17	O	VEE	Regulated output voltage		
18	O	TIMER	Charging protection timer		
19	-	VDD	Supply voltage		
20	I/O	CC	Compensation capacitor for DC/DC converter		
21	I	ISENCOM	Current sense reference plane		
22	I	ISENFG	Fuel gauge current sense input		
23	I	ISENDC	DC/DC controller current sense input		
24	I	VMSTOP	Motor stop current limit value select input	Pin Config	Current Limit
				GND	4.2x charging current
				0.6-1.0V	5x charging current
				VDD	3x charging current



PT8A2710 pins assignment



PT8A2711 pins assignment



PT8A2712 pins assignment

Table 2: PT8A2710-2712 LED Pattern Pin Description

PIN	I/O	Name	Descriptions		
1	O	CHARGE	PWM DC/DC controller output for constant current regulation		
2	I	CORD	External DC supply existence detection		
3	I	TEST	Quick test mode		
4	O	L100	Fuel gauge output (Remaining 100% capacity, full charge indication)		
5	O	L80	Fuel gauge output (Remaining 80% capacity)		
6	O	L60	Fuel gauge output (Remaining 60% capacity)		
7	O	L40	Fuel gauge output (Remaining 40% capacity)		
8	O	L20	Fuel gauge output (Remaining 20% capacity)		
9	O	NA	NA for PT8A2710/12		
		LTURBO	Motor “Turbo-Mode” Indicator (PT8A2711)[Normal speed, OFF]		
10	O	BLI	Battery-low output (Remaining <10% capacity)		
11	-	GND	Ground		
12	I/O	MOTOR	Motor driver control		
13	I	SLIDE	Slide switch (PT8A2710) input to control motor running		
		DSTACT	Tact switch (PT8A2711) input to control motor running with dual speeds		
		TACT	Tact switch (PT8A2712) input to control motor running		
14	I	VB	Charging battery voltage sense input		
15	I	VBLOW	Low-battery voltage sense input		
16	I	VT	Temperature sensor (NTC) input		
17	O	VEE	Regulated output voltage		
18	O	TIMER	Charging protection timer (1hr/1.5hrs/2.5hrs/4hrs)		
19	-	VDD	Supply voltage		
20	I/O	CC	Compensation capacitor for DC/DC converter		
21	I	ISENCOM	Current sense reference plane		
22	I	ISENFG	Fuel gauge current sense input		
23	I	ISENDC	DC/DC controller current sense input		
24	I	VMSTOP	Motor stop current limit value select input	Pin Config	Current Limit
				GND	4.2x charging current
				0.6-1.0V	5x charging current
				VDD	3x charging current

Function description (refer to Flow Chart)

1. Battery Voltage Definitions:

Table 3: Battery Voltage Definition

Item	General Setting	Suggested Value	Remark
No-Power value	0.9V-1.0V/cell	1.8-2V for 2cells battery pack	Adjustable externally, please refer to 'application instruction'
Battery-Low value	1.0V-1.1V/cell	2.0-2.2V for 2cells battery pack	
Max VB	1.65V-1.7V/cell	3.3-3.4V for 2cells battery pack	

2. Charging Mechanism (cord is connected but motor is off)

When a cord is detected, pre-charge begins. If the battery voltage is higher than Battery-Low threshold (usually set between 0.95V-1.1V/cell) and the battery pack temperature is less than 45°C, fast-charge starts. Otherwise, the battery will be kept in pre-charge status until its voltage is higher than the preset Battery-Low value or a 3 minutes time-out is reached to enter fast-charge mode. If battery temperature is found increasing to 55°C during pre-charge state, battery charging is stopped (DC/DC cuts power) to enter cool down state. Nevertheless, pre-charge will continue in any case until the battery temperature is cooled down below 45°C.

When entering fast-charge mode, if the battery voltage is below a preset voltage level (usually set at about 1.3V-1.4V/cell, measured with charging current), a start-up timer is effective to avoid false triggering of $-\Delta V$ and dT/dt to have early fast-charge termination. During the start-up time, $-\Delta V$ and dT/dt detections are ignored but maximum temperature of 55°C will always be observed to stop fast-charge. The start-up timer is dependent to the external fast-charge timer setting as tabled below. The dT/dt data is valid for battery temperature in range of 35°C to 55°C.

Table 4: Start-up Time

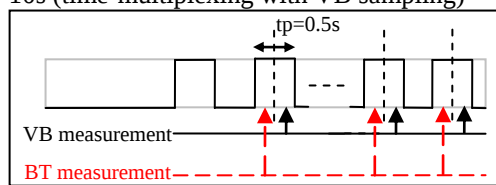
Timer	Tmax (User programmable externally)	
Start-up timer for inhibiting negative ΔV and dT/dt measurement	tmax/20	
	tmax (min)	Start-up time (s)
	30	90
	60	180
	90	270
	150	450

Fast charge mode is terminated when any one of the following conditions meet:

- 1) Minus-delta-V Detection ($-\Delta V$):** The battery pack voltage is sampled by high precision A/D converter every 10s, with 0.5s sampling time. For each sampling interval (0.5s), the charging current is cut down. Averaging is performed on the collected data and the result is stored into registers after passing through high-order digital filter. The minus-delta-V is qualified when a voltage drop of about 5mV/cell from the maximum voltage recorded. The second minus-delta-V is qualified when a voltage drop of about 5mV/cell after the first minus-delta-V has been qualified. Every minus-delta-V happened, fuel-gauge increased one level up, and so and so until fuel-gauge is full.

Table 5: Sample Description

Bypass Start-up timer	$V_B > 2.6V$ (measured by sampling)
V_B sampling period (tp)	10s
V_B sampling time	0.5s (fast-charging inhibition)
BT sampling period (tp)	10s (time-multiplexing with V_B sampling)



- 2) Maximum Battery Voltage Detection:** When the averaged battery pack voltage reaches a preset maximum voltage limit (usually set about 1.6V-1.7V/cell) during the charging interval, fast-charge is terminated.
- 3) Battery Temperature Detection (Max. Temp and dT/dt):** The PT8A2707-12/2717-19 employs thermistor(NTC) as battery temperature sensor. When the battery temperature reaches 55°C, fast-charge is terminated and the battery will then go to cool down mode; or the rate of temperature change (dT/dt) reaches preset value, fast-charge is terminated and the battery will then be under trickle-charge mode at a rate of 1/10 of the fast-charge current. If NTC is not employed, the pin "VT" should be biased at an equivalent voltage as for 10°C-20°C or else the PT8A2707-12/2717-19 determines the NTC is opened and will stop all charging activity forever.

4) **Fast-Charge Timer Cut-Off:** The PT8A2707-12/2717-19 comes with 4 timer settings (30mins/60mins/90mins /150mins) selectable externally through resistor divider. The fast-charge timer works as the last protection to prevent over-charging the battery if none of the above 3 terminations takes effect. In general, the timer is chosen according to the required time to fully-charge an empty battery with about 20-30% margins. The timer can be easily calculated at a given charging current and battery capacity.

5) **NTC Open or Short**

During battery charging, the PT8A2707-12/2717-19 always detects NTC status by measure VT voltage value. If NTC open/short is detected, all charging activities will be stopped and go to stop-charging mode.

After fast-charge, the battery is charged at a rate of 1/10C to compensate for the self-discharge rate so as to maintain the battery capacity always at full as long as the cord is still connected. If the battery temperature continues to rise to 55°C during maintenance, the PT8A2707-12/2717-19 will cut-off the charge current until the battery temperature reduces to below 55°C to resume.

After full-charge is detected, the PT8A2707-12/2717-19 will restore the full-charge status until it measures its capacity drops 5% of charge due to self-discharge (cord was removed) of battery or motor is turned on. During the time the PT8A2707-12/2717-19 keeps the full-charge status internally, if user detaches motor and plugs-in cord to charge the shaver again, the PT8A2707-12/2717-19 will go to trickle-charge mode.

3. Discharging Mechanism (Motor is On while Cord is Not Connected)

SLIDE, TACT and DSTACT are motor running control switch inputs.

- 1) **SLIDE Switch Mode:** PT8A2707/17/10 uses a pull high slide switch to control motor running through SLIDE pin. When slide switch is closed, the SLIDE pin is pulled high, and the motor is always turned on at 100% speed (full speed), else if slide switch is open, the motor is always turned off to stop motor running.
- 2) **TACT Switch Mode:** PT8A2709/19/12 uses a pull high tact switch to control motor running through TACT pin. With 1st pressing of TACT switch, the motor is always turned on at 100% speed (full speed), and with 2nd pressing of TACT switch, the motor is always turned off to stop motor running. When using TACT switch mode, the key delay for tact switches to reject multiple inputs are typically about 0.125s.
- 3) **DSTACT Switch Mode:** PT8A2708/18/11 uses a pull high tact switch to control motor running with Dual Speed through DSTACT pin. With 1st pressing tact switch, the motor is turned on at 70% speed, with 2nd pressing of tact switch, the motor is turned to 100% speed (full speed), and motor is turn off to stop running with 3rd pressing of tact switch. When using DSTACT switch mode, the key delay for tact switches to reject multiple inputs are typically about 0.125s.

In above 3 models, battery over-discharge protection is available through auto-stop motor at once (<0.2s) when

- Battery discharging current is higher than preset current limit for 3sec (there are three limit values selectable refer to 'motor-over-current protection settings')
- Battery pack voltage is lower than the preset No-Power limit value (typically about 0.9-1.0V per cell).
- NTC measures battery pack temperature higher than the preset limit (usually about 55-60°C)

The motor can be resumed when any of the above criteria is cleared. But for SLIDE switch model, user needs to turn off and turn on SLIDE switch to start motor again; for TACT and DSTACT switch models, the user needs to press the tact switch once to start motor.

- 4) **Battery Low Alarm:** The PT8A2707-12/2717-19 detects battery capacity through output voltage level by VBLOW pin. When battery voltage is down to Battery-Low value (battery capacity is below 10%), Battery-Low alarm is alert, and controls Battery-Low LCD screen or LED (which is connected to BLI pin10) to remind user that battery is under low capacity condition. If battery voltage continues go down and decreases to No-Power value, the motor will self shut down to protect battery be over discharged.

The Battery-Low LCD segment and LED indications as below table.

Table 6: Battery Alarm Conditions

Item	Condition	Battery-Low LED	Battery-Low LCD
No cord	Motor on	on	on
	Motor off	blinking 5s	on
Cord is on	Motor on	on	
	Motor off	on	

4. Cord is Connected While Motor is On

When cord is connected while motor is on, or vice versa, there are two scenarios:

- 1) **The motor is turned on and draws more current than the AC/DC adapter can supply:** In all cases, the PT8A2707-12/2717-19 will enable the external PMOSFET to fully turn on to supply maximum current to the motor. There are three sub-cases to observe:

- a) If the motor is turned on during the pre-charge state, obviously there is no charging current to battery. The PT8A2707-12/2717-19 will return to discharging mode while fuel-gauge is continuing to count the discharge amount. The discharging is stopped at the same criteria described in the Discharging Mechanism section.
- b) If the motor is turned on during the fast-charge state, the fast-charge safety timer is held. If the motor is turned on less than 5% of the battery maximum capacity, fast-charge resumes with fast-charge timer continue to count (but start-up timer starts from beginning). However, when the motor is accumulatively turned on over 5% of the battery maximum capacity while cord is still connected, the fast-charge timer is cleared and the battery pack will be recharged from pre-charge state again once motor is off.
- c) If the motor is turned on during the trickle-charge state, if the motor is turned on to accumulatively consume less than 5% (not necessarily in single operation) of the battery maximum capacity, the PT8A2707-12/2717-19 resumes trickle-charge state. However, when the motor is turned on over 5% of the battery maximum capacity during the trickle-charge state, the battery pack will be recharged from pre-charge state again after motor is off.

Besides, at any time when the battery pack voltage is lower than the No-Power value or discharging current is higher than the preset limit levels for 3sec, the motor will be stopped and the devices return to charging status.

- 2) **The motor is turned on but draws less current than the AC/DC adapter can supply:** In all cases, when the battery is not discharged, the PT8A2707-12/2717-19 regulates a charging current of 1/10 of the fast-charge current to battery pack. In this case, the battery pack is under slow charging. Similarly, there are three more situations to observe:
 - a) If the motor is turned on during the pre-charge state, once motor is turned off, the PT8A2707-12/2717-19 will resume back to the pre-charge state.
 - b) If the motor is turned on during the fast-charge state, the fast-charge timer is held until motor is turned off to resume fast-charging.
 - c) If the motor is turned on during the trickle-charge state, once motor is turned off, the PT8A2707-12/2717-19 will resume back to the maintenance state.

In any charging states, if the battery temperature is measured higher than 55°C, the motor is stopped and the 0.1C charging current is cut off. The LED/LCD still displays as in “Charging Mode”. The motor will draw current from battery pack until the battery temperature is below 55°C to resume 0.1C charging current. However, no matter whether it is in fast-charging or trickle-charging modes, when the motor is turned on to consume over 5% (accumulatively, not necessarily in single operation) of the battery maximum capacity during battery is over-temperature, the battery pack will be recharged from pre-charge state again after motor is off.

5. Fuel-Gauge Counter

- 1) **Charge Counting:** Charge activity is detected based on positive voltage difference (VFUEL) between the pins ISENFG and ISENCOM. When voltage of ISENFG is higher than the voltage of ISENCOM, the PT8A2707-12/2717-19 increments its fuel-gauge counter at a rate proportional to VFUEL. VFUEL is sampled and converted into digital data through high-precision A/D converter. When the fuel-gauge counter accumulates up to 99% level but none of the full-charge criteria ($-\Delta V$, dT/dt , safety timer, maximum battery voltage) is detected, the fuel-gauge will wait at 99% level. Right after the battery is fully-charged, the PT8A2707-12/2717-19 displays full-charge and learns the capacity of the battery pack such that the display will be more and more accurate in both charging and discharging cycles later.
- 2) **Discharge Counting:** Discharge activity is detected based on a negative voltage difference (VFUEL) between the pins ISENFG and ISENCOM. When voltage of ISENFG is lower than the voltage of ISENCOM, the PT8A2707-12/2717-19 decrements its fuel-gauge counter at a rate proportional to VFUEL. VFUEL is sampled and converted into digital data through high-precision A/D converter. In case the fuel-gauge counter rolls to zero count while the battery voltage is still higher than the preset No-Power level, the Battery-Low LED is still flashing while user can still use motor. Motor will be stopped when battery voltage is below the No-Power level. The maximum fuel value is not updated, but will be updated when necessary for next time the battery is fully charged. The fuel value will be adjusted to 10% if the battery voltage gradually falls below Battery-Low threshold.

6. Idle Mode

- 1) **Standby:** When cord is not connected and motor is off, the PT8A2707-12/2717-19 turn to idle state to save power. Some internal circuits are shut-down to keep the standby power at about 20 μ A.
- 2) **Background Offset Cancellation:** when the PT8A2707-12/2717-19 is waked up by user, an offset cancellation is performed for the internal precise A/D converter before entering cord or motor modes. It normally takes 0.2~0.3s. The PT8A2707-12/2717-19 returns to idle state after use.

7. First-Time Power-Up

Initial Fuel Count & First-Time Charging: Upon power-up, the PT8A2707-12/2717-19 resets for all internal memory and resumes all default settings, the fuel-gauge counter will be initialized as zero count. The initialization may take a few seconds before PT8A2707-12/2717-19 boots up to operate normally.

For the first-time charging, the fuel-gauge counter counts up to a default internal maximum fuel value (which is determined by the fast-charge timer selected externally. E.g. a 90mins timer means roughly it is a 1-hour charger, the initial maximum fuel value is assumed for 1hr for 1C charging current. Similarly, a 150min timer is assumed for a 120mins for 0.5C charging current, etc.) measured by the external current sense resistor. Fuel-gauge LCD segments or LEDs are light up according to the initial maximum fuel value. The 100% fuel LCD segment (or LED) keeps on flashing even though the fuel-gauge count reaches the default maximum value. In this moment, the fuel-gauge counter learns the battery capacity by continuing to roll up its counter until fast-charging is completed. This new battery capacity is therefore memorized and used as the maximum value for next charging cycles. Similarly, if full-charge is detected earlier than the counter reaches its initial maximum fuel value, the maximum fuel value is updated but progressively.

8. Fuel-Gauge Display

The PT8A2707/08/09/17/18/19 use LCD screen for the fuel gauge display and PT8A2710/11/ 12 use LEDs for fuel gauge display. For both LCD screen and LED models, there are 3 different display modes: **Charging Mode, Discharging Mode and Idle Mode**, as described in LED/LCD pattern section in pages 12-13.

1) Charging Mode:

- a) Cord Mode with Motor off: When cord is connected, the fuel gauge display is turned on to "Charging Mode". As soon as cord is removed, the fuel-gauge LED display continues to display the fuel gauge level according to the "Discharging Mode" for 5s.
- b) Motor-On Mode with Cord: When motor is turned on while cord is plugged in, or vice versa, the PT8A2707-12/2717-19 displays fuel-gauge with accordance to the actual charge or discharge amount. The fuel-gauge always displays in the "Charging Mode" no matter whether there is net current charging into the battery or not. If the motor is drawing less current than the adapter can supply, the DC/DC converter will regulate the battery charging current at a slow-rate (1/10 of the fast charge current). The high-precision ADC in PT8A2707-12/2717-19 is still to calculate this small charging current to add into the fuel-gauge counter.

2) Discharging Mode:

- a) Motor-On Mode without Cord: When motor is turned on while no cord is connected, the fuel gauge is displayed continuously in the "Discharging Mode". After motor is turned off, the fuel-gauge display will still continue to display for 5 seconds.
- b) Motor-On Mode with Cord: The fuel-gauge always displays in the "Charging Mode" no matter whether there is net current charging into the battery or not. If the motor is drawing more current than the adapter can supply, there will be some amount of current being drawn from the battery pack. The high-precision ADC in PT8A2707-12/2717-19 is still capable to calculate this small discharging current to subtract from the fuel-gauge counter.

3) Idle Mode:

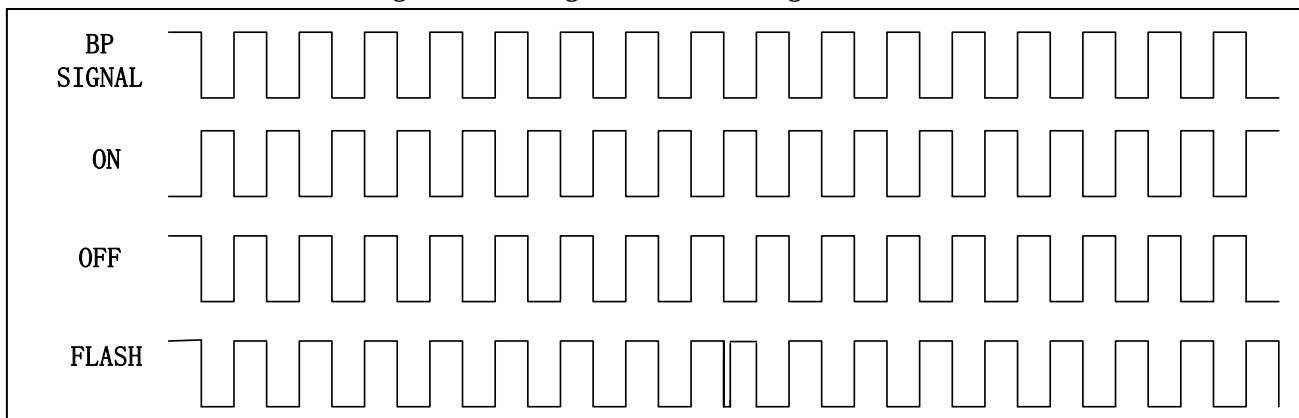
LED display will be OFF in idle state. For LCD mode, the display of PT8A2707/08/ 09 will be continued on until battery has no power; but the display of PT8A2717/18/19 will be off.

LCD output specification

Table 7: LCD Specifications

Pin	Signal Format
BP	64Hz 50% Duty Cycle Square-wave Output Signal Generated from the 32kHz Master Clock
L100, L80, L60, L40	OFF: In-phase with Back Plane Signal
	ON: 180° Out-of-phase with Back Plane Signal
	2Hz-FLASH: Blinking at 2Hz During Charging Mode. Switch between In-phase and Out-of-Phase Output Signal at 2Hz
L20	OFF: In-phase with Back Plane Signal
	ON: 180° Out-of-phase with Back Plane Signal
	2Hz-FLASH: Blinking at 2Hz During Charging Mode. Switch between In-phase and Out-of-Phase Output Signal at 2Hz
BLI	1Hz-FLASH: Blinking at 1Hz During Discharging Mode. Switch between In-phase and Out-of-Phase Output Signal at 1Hz
	OFF: In-phase with Back Plane Signal
	ON: 180° Out-of-phase with Back Plane Signal

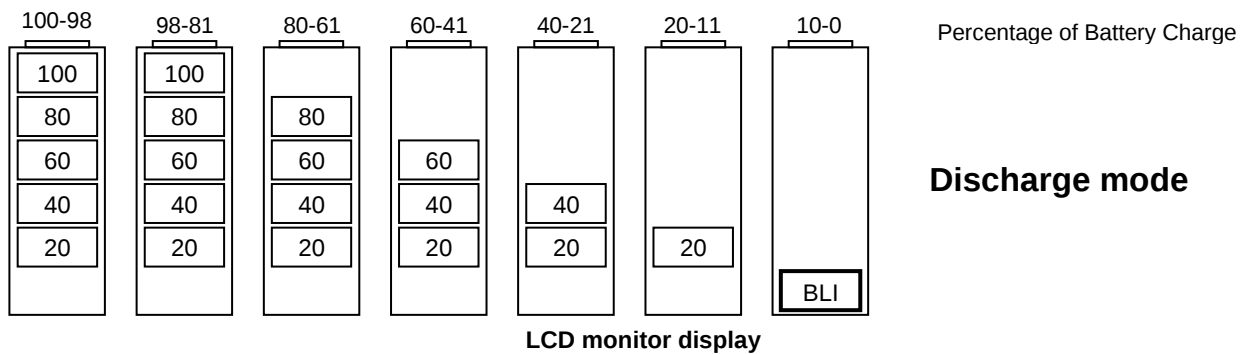
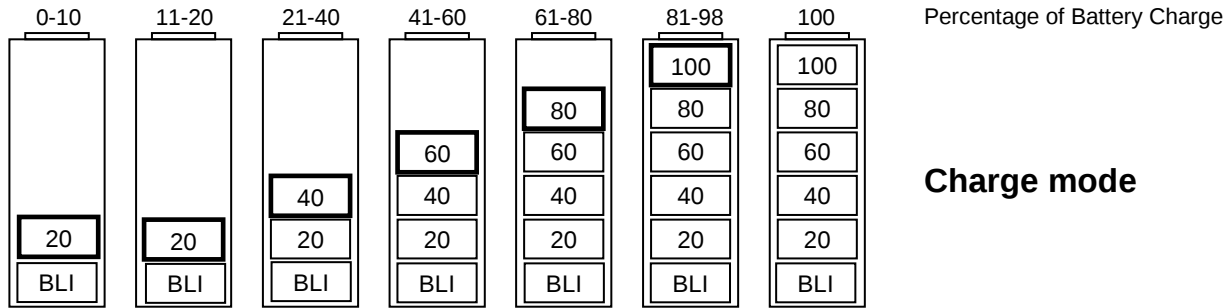
Figure 1: LCD Signal Phase vs BP Signal Phase for all states



LED/LCD Patterns Summary

LCD and LED Display Indication

-  LCD is ON
-  LCD is ON, blinking at 2 Hz during charging
-  BLI Blinking at 1Hz during discharging



-  LED is OFF
-  LED is ON
-  LED is flashing at 2 Hz

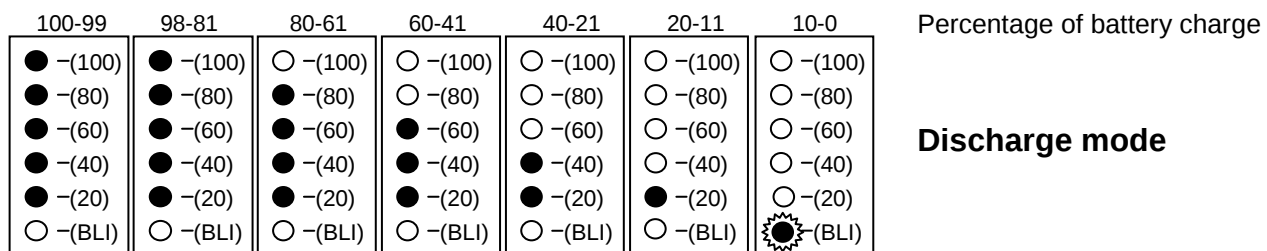
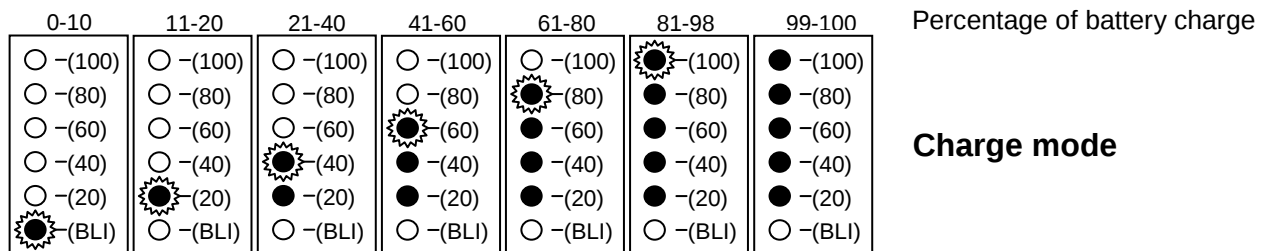


Figure 2: LCD and LED Display

Test Mode Specification

Test pin = 1.65V (or short to VDD), VDD=2.4V, ISENDC = 2.4V, ISENFG = 2.4V, ISENCOM = 2.4V, BP = 0V
VT = 0.75V (25°C)

Table 8: for Test Mode

State	INPUT		Duration	Explanation For tester test	Output			
	Timer	VT			charge	BLI	L100	motor
0			62.5msec					
1	0V	0.75V	62.5msec	(Isendc-Isencom) regulate 7mV	1	1	1	0
2	0V	0.75V	62.5msec	(Isendc-Isencom) regulate 70mV	1	1	1	0
3	0V	0.75V	62.5msec	All LEDs turn on	0	0	0	0
4	0V	0.75V	62.5msec	MOTOR outputs 100Hz 50% duty cycle	0	1	1	50% PWM @ 100Hz
5	0V	0.75V	62.5msec	BLI turns on if NTC short or open; otherwise L100 turns on	0	1	0	0
6	0V	0.75V	62.5msec	L100, BLI output refer to timer setting	0	1	1	0
7			62.5msec					
0			1sec	For manual test				
1	0V	0.75V	1sec	(Isendc-Isencom) regulate 7mV	1	1	1	0
2	0V	0.75V	1sec	(Isendc-Isencom) regulate 70mV	1	1	1	0
3	0V	0.75V	1sec	All LEDs turn on	0	0	0	0
4	0V	0.75V	1sec	MOTOR outputs 100Hz 50% duty cycle	0	1	1	50% PWM @ 100Hz
5	0V	0.75V	1sec	BLI turns on if NTC short or open; otherwise L100 turns on	0	1	0	0
6	0V	0.75V	1sec	L100, BLI output refer to timer setting	0	1	1	0
7			1sec					

Maximum Ratings

Storage Temperature	-40°C to +125°C
Supply Voltage to Ground Potential (Input & V _{CC} Only)	-0.5V to +6.0V
Supply Voltage to Ground Potential (Outputs & D/O Only)	-0.5V to +6.0V
DC Input Voltage	-0.5V to +6.0V
Power Dissipation	500mW

Note:

Stresses greater than those listed under MAXIMUM RATINGS may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

Recommended operation conditions

Symbol	Description	Min	Type	Max	Unit
V _{CC}	Operating Voltage	1.8	3.0	5.5	V
V _{IH}	“H” Input Voltage	0.7V _{CC}	-	-	V
V _{IL}	“L” Input Voltage	-	-	0.3V _{CC}	V
T _A	Operating temperature	-10	25	70	°C

Electrical Characteristics

(Unless otherwise noted, T_A = -10~70 °C, V_{CC}=3.0V)

Symbol	Parameter		Test Conditions	Min	Typ	Max	Unit
V _{EE}	Regulator Output Voltage		I _{OUT} = 1mA	1.6	1.65	1.7	V
ΔV _{EE}	Line regulation		1.8≤V _{CC} ≤5.5V, No load	-	40	50	mV
ΔV _{LDR}	VEE Load regulation		0mA ≤ I _L ≤ 1mA	-	3	10	mV
V _{IL}	Input Low Threshold for all digital input		-	-	-	0.90	V
V _{IH}	Input High Threshold for all digital input		-	2.1	-	-	V
I _{IH}	Input leakage current for SLIDE TACT and Turbo pins		-	20	30	100	μA
I _{IL}			-	-	-	-1	
I _{ADC}	ADC Input Current (V _B , V _T)		-	-1	-	1	μA
CT _{MAX}	Fast-Charge Timer Input voltage Range	90mins	-	-	0	0.165	V
		60mins	-	0.36	-	0.46	
		30mins	-	1.19	-	1.29	
		150mins	-	1.70	-	-	
V _{CHARGE}	Internal reference for DC-DC output current	Pre-charge mode and trickle charge mode (1/10CC)	-	4	7	9	mV
		Fast charge mode (1CC)	-	50	70	90	
V _{DISMAX}	Internal reference for discharging protection		V _{VMSTOP} = GND	-240	-300	-360	
			V _{VMSTOP} =0.6-1.0V	-280	-350	-420	
			V _{VMSTOP} = V _{CC}	-168	-210	-252	
D _{MOTOR}	Duty cycle of Motor driver output for controlling motor speed	High speed	-	-	100%	-	-
		Low speed	-	78%	80%	82%	
F _T	Motor frequency for TE trimming		-	90	100	110	Hz
F _{MOTOR}	PWM signal frequency for motor driver output		-	90	100	140	Hz
t _{DLY}	TACT and DSTACT tact switches delay time to active		-	-	125	150	ms
I _{OL1}	Output Sink Current (L100, L80, L60, L40, L20, BLI or LMON or LTURBO)		V _{CC} = 2.4V, V _{OL1} = 0.4V	6	8	-	mA

To be continued.

Continued.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
I _{OH2}	Output Source Current (MOTOR)	V _{CC} = 1.8V , V _{OH2} = 1.2V	-10	-13		mA
		V _{CC} = 3.0V , V _{OH2} = 1.2V	-13	-18		
I _{OL2}	Output Sink Current (MOTOR)	V _{CC} = 3.0V , V _{OL2} = 0.3V	0.5	2.5	-	mA
I _{OH3}	Output Source Current (CHARGE)	V _{CC} = 2.4V , V _{OH3} = 1.2V	-5	-10	-	mA
		V _{CC} = 3.0V , V _{OH2} = 1.2V	-5	-15		
I _{OL3}	Output Sink Current (CHARGE)	V _{CC} = 3.0V , V _{OL3} = 0.3V	2	4	-	mA
I _{OH4}	Output Source Current (CC pin)	V _{CC} = 3.0V , V _{OH4} = 2.7V	-10	-25	-50	μA
I _{OL4}	Output Sink Current (CC pin)	V _{CC} = 3.0V , V _{OL4} = 0.3V	0.5	0.8	2	μA
I _{OH5}	Output Source Current for BP	V _{CC} = 3.0V , V _{OH5} = 2.7V	200	500	-	μA
I _{OL5}	Output Sink Current for BP	V _{CC} = 3.0V , V _{OL5} = 0.3V	200	550	-	μA
I _{CCQ}	Operation Current	V _{CC} = 3.0V	-	2.6	5	mA
I _S	Standby Current	Cord=0, Motor=0	-	-	30	μA
-ΔV	Minus Delta Voltage to Terminate Fast-Charge detected by VB pin (per cell)	-	4	5	7	mV
V _{BMAX}	Internal reference voltage for Maximum Battery Voltage Protection	-	1.95	2.00	2.08	V
V _{BLOW}	Internal reference voltage for Low Battery	-	1.6	1.65	1.7	V
V _{BSTOP}	Internal reference voltage for No Power to Stop Motor	-	1.40	1.45	1.50	V
V _{CORD}	Threshold voltage for Cord on /off	-	0.55	0.60	0.65	V
F _{OSC}	Frequency of Internal Oscillator	-	29	32	35	kHz
ΔVT	VT voltage change value for dT/dt protection	CTMAX=90mins, Measure 90s	13.5	15	16.5	mV
		CTMAX=60mins, Measure 60s				
		CTMAX=30mins, Measure 30s				
		CTMAX=150mins, Measure 150s				
V _{TMAX}	VT voltage for Maximum Battery Temperature 55°C or NTC short	-	0.355	0.375	0.395	V
V _{TNTCO}	VT voltage for NTC open	-	1.05	1.10	1.15	V

Application Circuit

1) Typical 2-Cell 1-hr Fast-Charge Application Circuit for PT8A2707/ 17

(SLIDE Switch Model with LCD display)

AC/DC Adapter: 4V 650mA,

Battery Capacity: 650-730mAh,

Safety charge timer: 1.5hrs

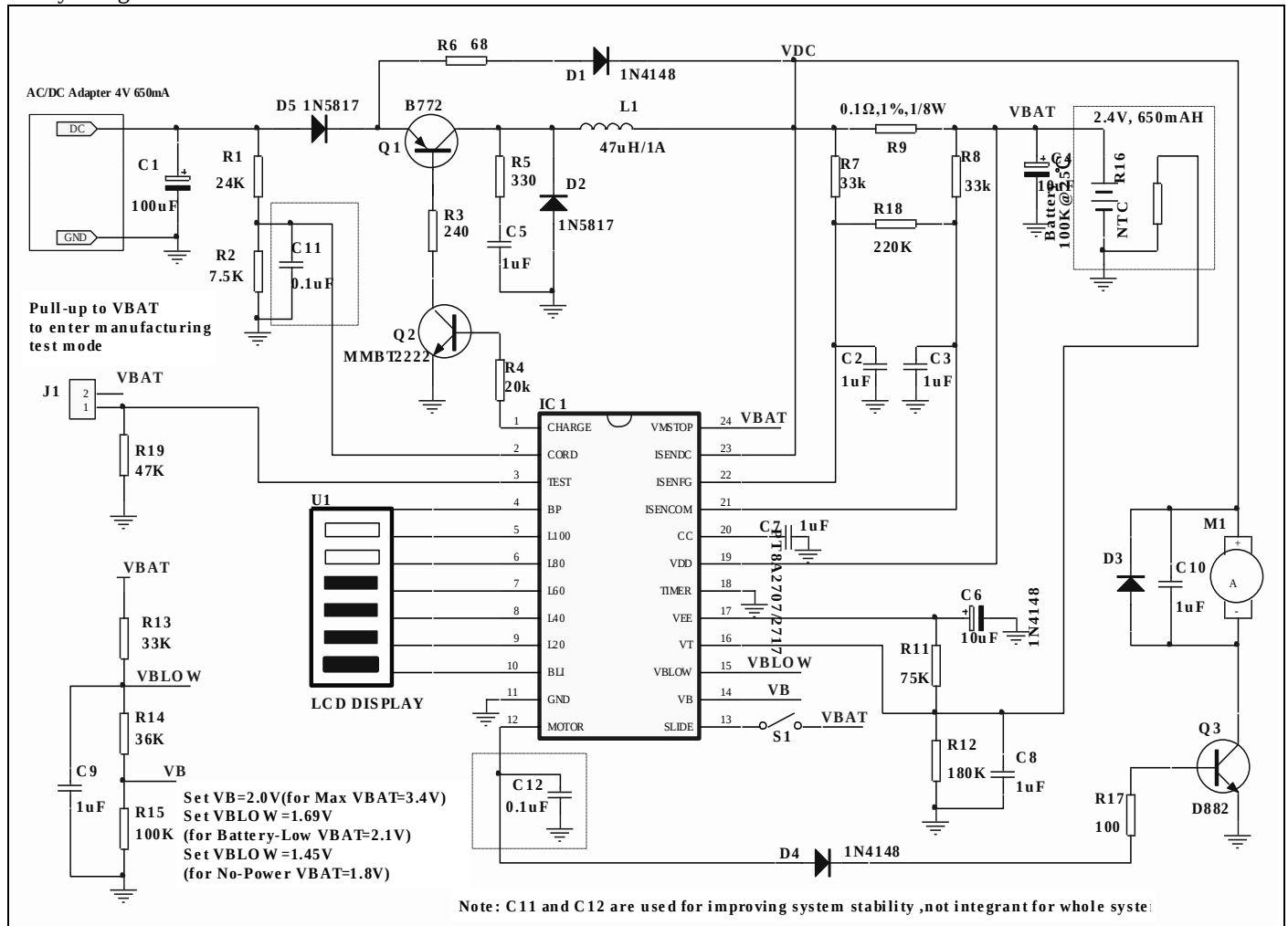


Figure 3: PT8A2707/17 LCD Display SLIDE Switch Application Circuit

2) Typical 2-Cell 1-hr Fast-Charge Application Circuit for PT8A2708/18

(DSTACT Switch Model with LCD display)

AC/DC Adapter: 4V 650mA,

Battery Capacity: 650-730mAh,

Safety charge timer: 1.5hrs

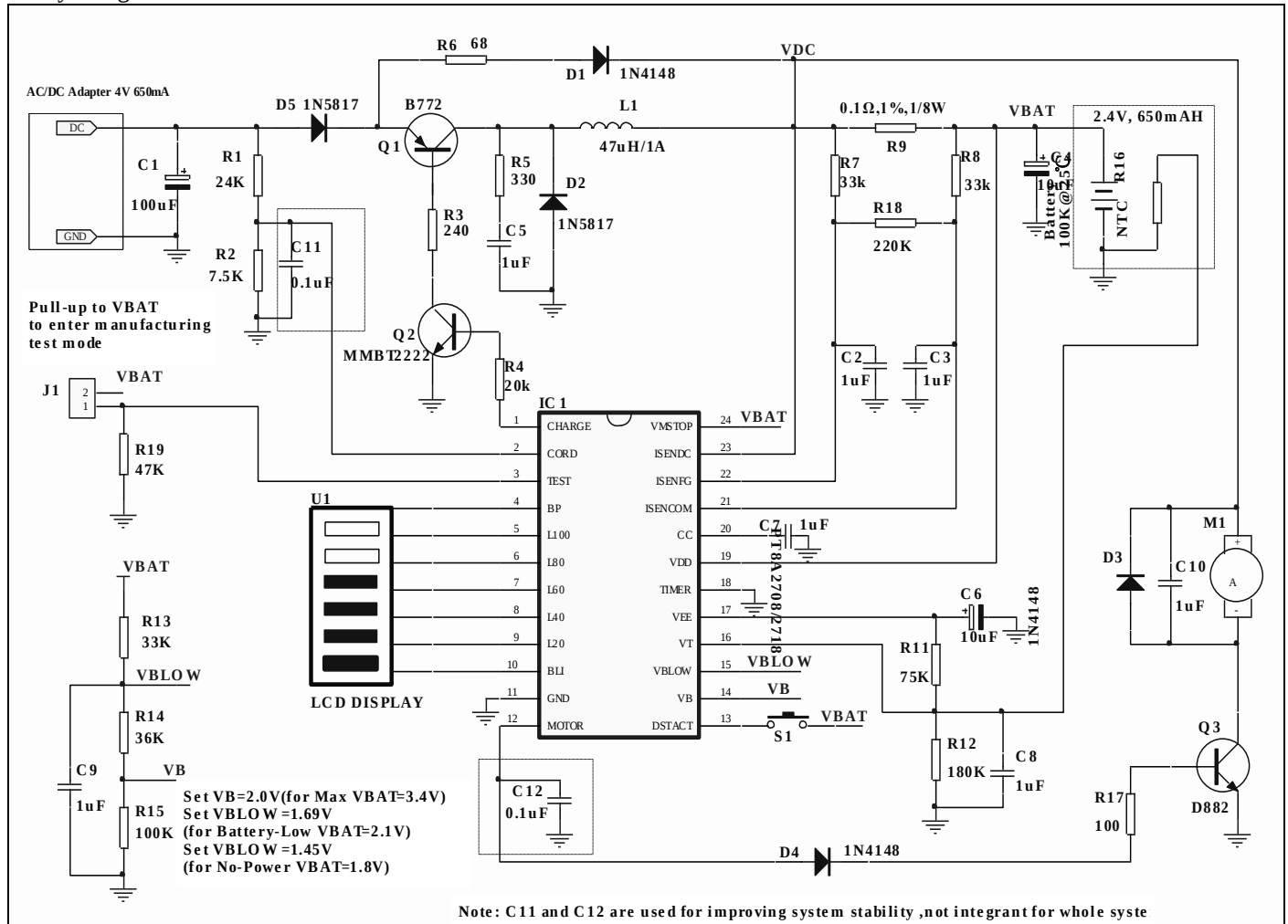


Figure 4: PT8A2708/18 LCD Display Dual-speed DSTACT Switch Application Circuit

3) Typical 2-Cell 1-hr Fast-Charge Application Circuit for PT8A2709/19
 (TACT Switch Model with LCD display)
 AC/DC Adapter: 4V 650mA,
 Battery Capacity: 650-730mAh,
 Safety charge timer: 1.5hrs

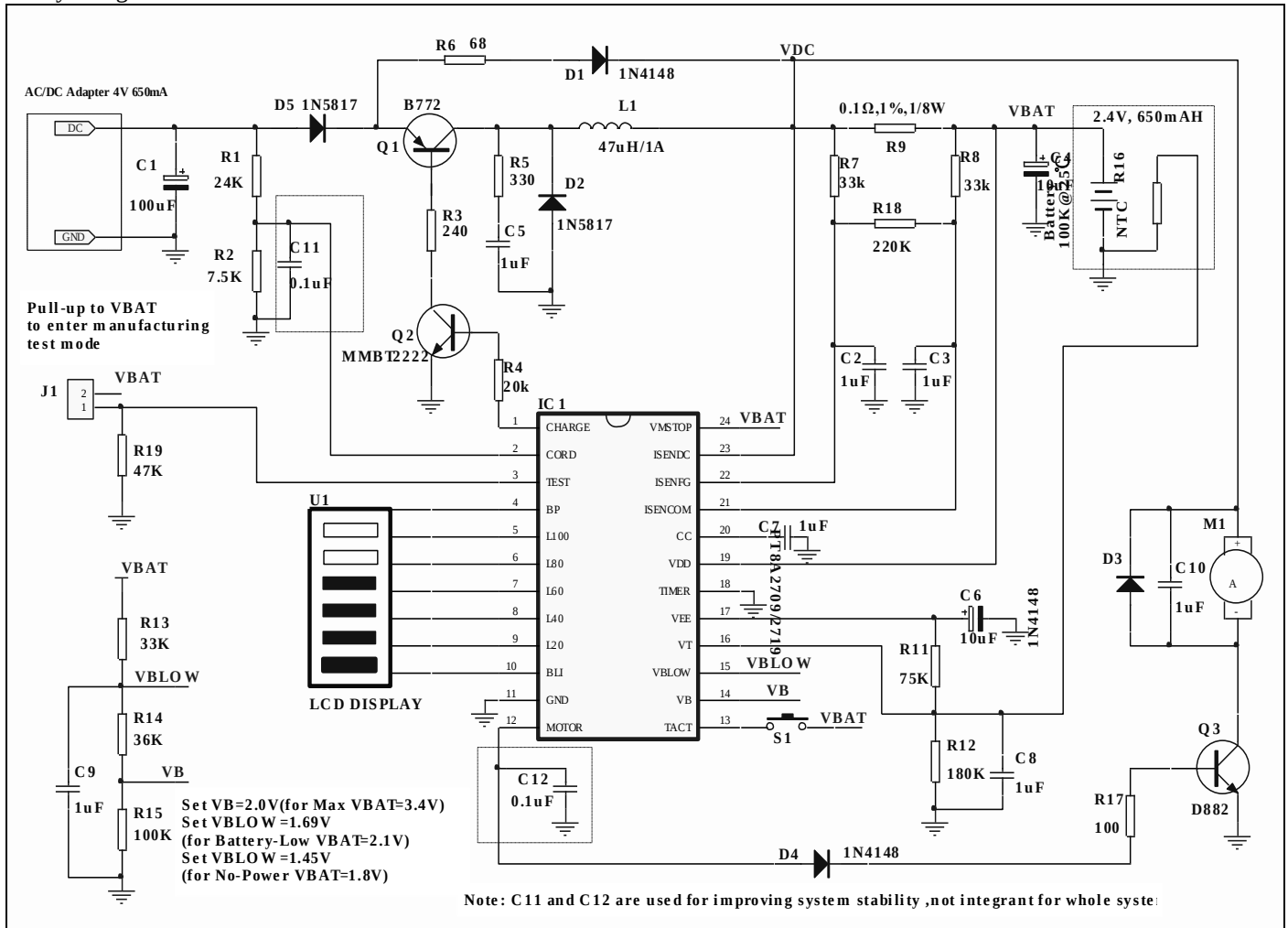
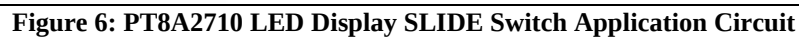


Figure 5: PT8A2709/19 LCD Display TACT Switch Application Circuit

AC/DC Adapter: 4V 650mA,
Battery Capacity: 650-730mAh,
Safety charge timer: 1.5hrs



5) Typical 2-Cell 1-hr Fast-Charge Application Circuit for PT8A2711

(DSTACT Switch Model LED display)

AC/DC Adapter: 4V 650mA,

Battery Capacity: 650-730mAh,

Safety charge timer: 1.5hrs

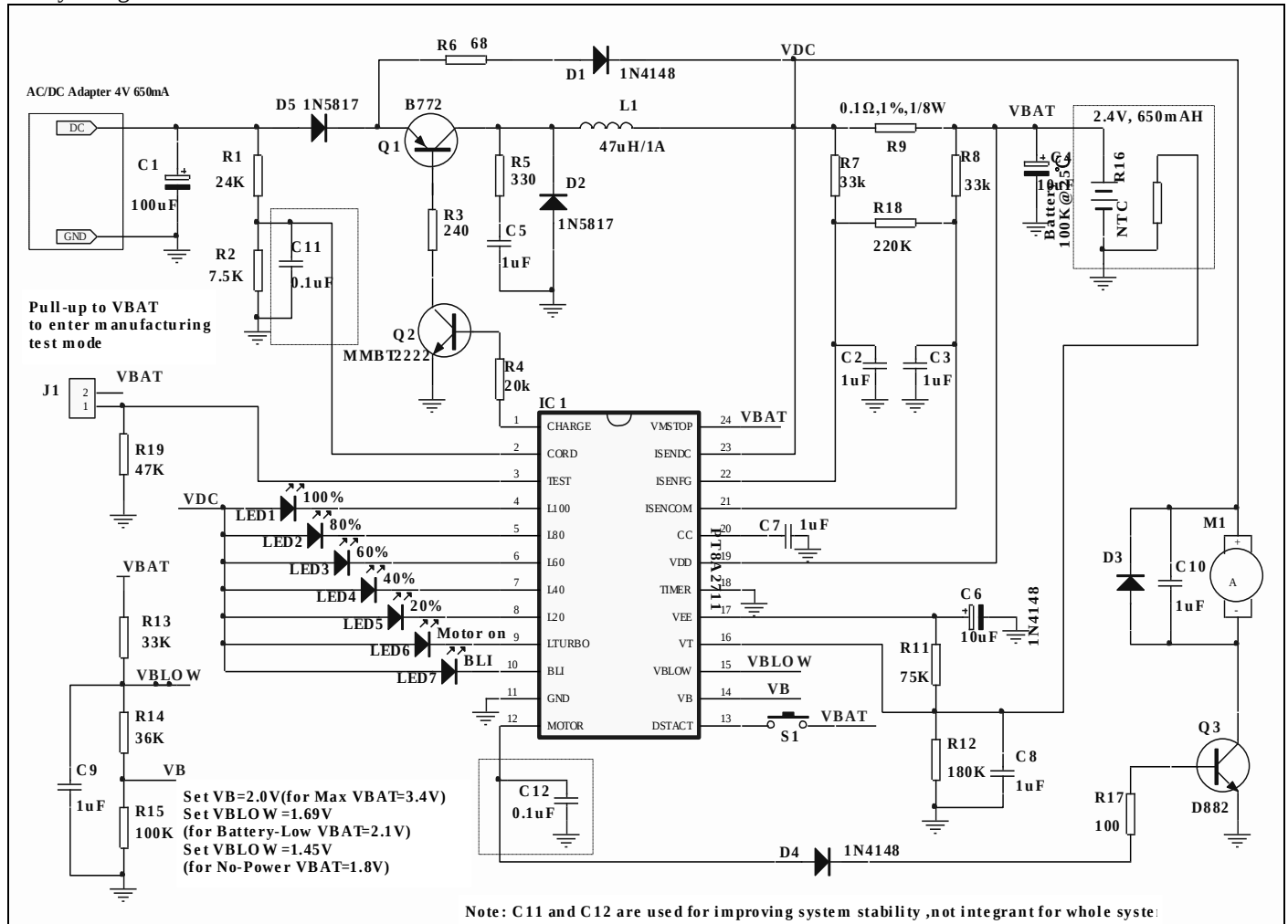


Figure 7: PT8A2711 LED Display Dual-speed DSTACT Switch Application Circuit

6) Typical 2-Cell 1-hr Fast-Charge Application Circuit for PT8A2712

(TACT Switch Model with LED display)

AC/DC Adapter: 4V 650mA,

Battery Capacity: 650-730mAh,

Safety charge timer: 1.5hrs

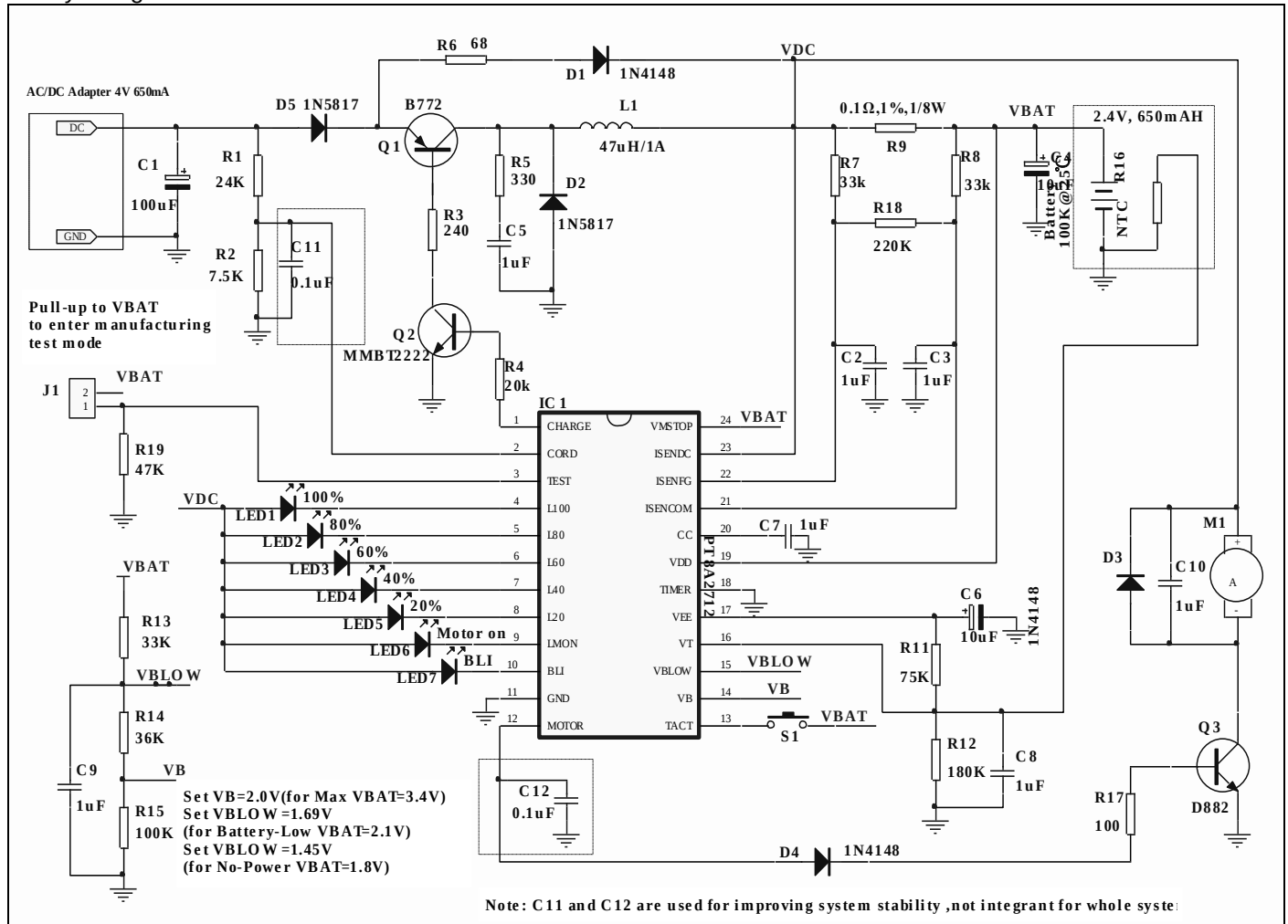


Figure 8: PT8A2712 LED Display TACT Switch Application Circuit

(DSTACT Switch Model LED display)

Battery Capacity: 1300mAh,

Safety charge timer: 1.5hrs

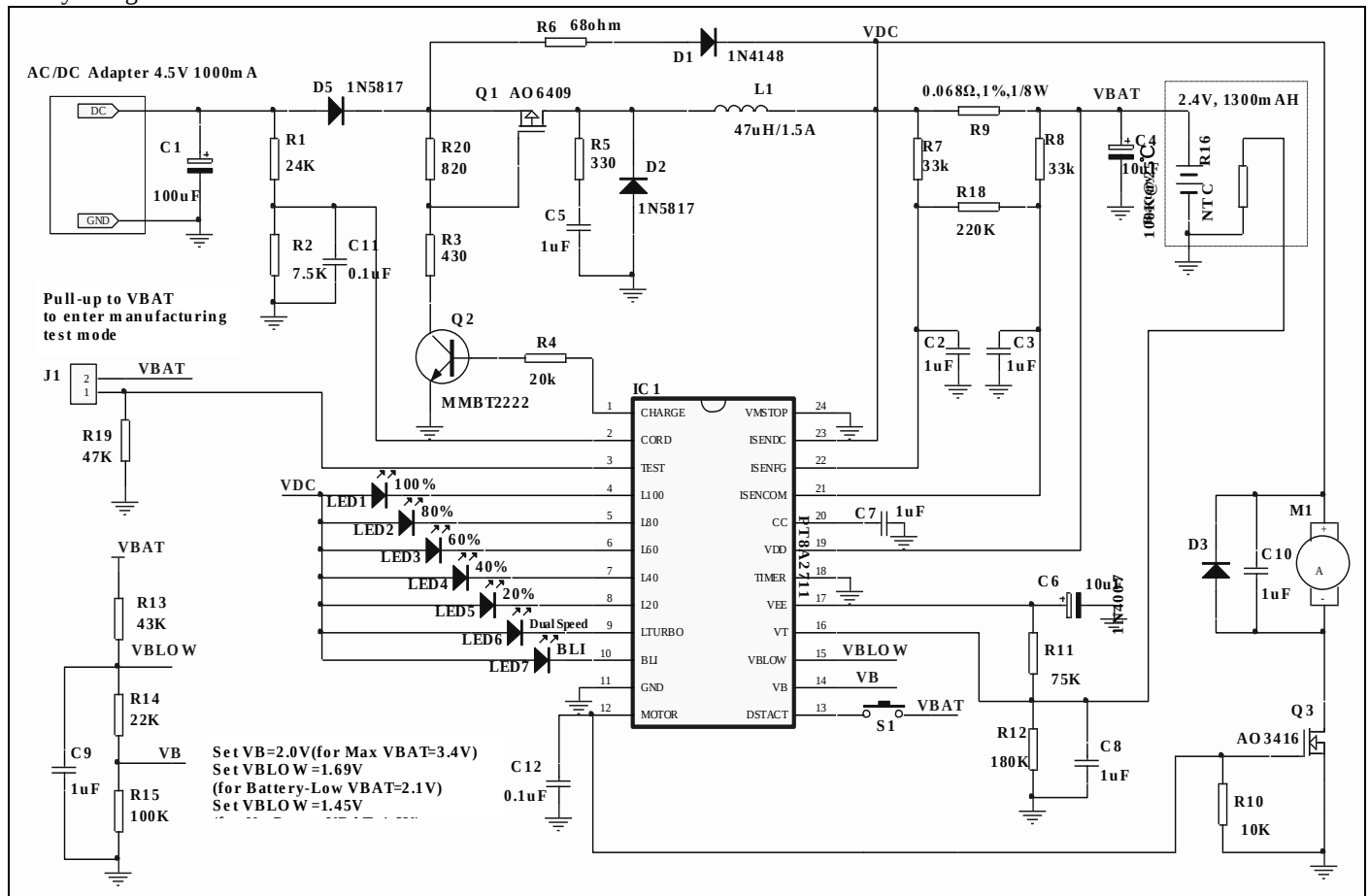


Figure 9: PT8A2711 1.4A fast-charge Application Circuit

Application instruction

1. Self-Discharge Calibration

During the idle state, the self-discharge rate of batteries is calibrated in the fuel-gauge counter. The self-discharge calibration rate is fixed at 1/128C per day, which corresponds to the NiMH battery characteristics at which the battery pack will be completely self-charged to zero in about 4 months in a storage temperature of about 20-35°C.

2. Setting Battery Temperature Measurement

The PT8A2707-12/2717-19 employs a thermistor with negative temperature coefficient to measure the battery's temperature. Since most thermistors are inherently nonlinear with respect to temperature, in order to reduce the effect of nonlinearity, a resistor-divider network in parallel with the thermistor is recommended. A typical application circuit is shown on the right side. The resistor-divider consists of RX and RY, which can be selected to adjust the peak temperature threshold (e.g. 55°C) as well as dT/dt slope according to the characteristics of the employed thermistors. (The calculation methods will be provided in datasheet later)

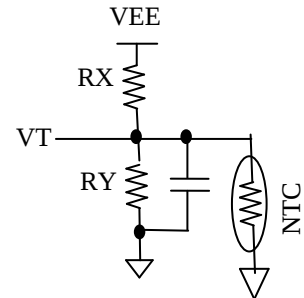


Figure 10

3. Setting Charging Current

The PT8A2707-12/2717-19 employs two internal references for DC/DC bulk converter to achieve constant current charging disregards to the input power supply voltages. For fast-charging, an internal reference voltage of 70mV is employed to compare with the voltage drop across the sensing resistor. For pre-charging or maintenance trickle-charging, an internal reference voltage of 7mV is employed to compare the voltage drop across the sensing resistor to achieve 1/10 of the fast-charging current. For example, when controlling a 700mA charging control, a 0.10Ω 1/8W sensing resistor is required. When it is in the pre-charging or trickle-charge status, the current is controlled at 70mA (This is already excluding the additional current that may flow from the adapter to LCD screen or LEDs or even to the motor when loaded unless motor is drawing all current from adapter). When a higher charging current would be used for 1-hr charging for a higher capacity battery, the sensing resistor should be scaled proportionally to maintain the same reference voltages. For examples:

Table 9: Charge Sensing Resistor Selection

Charging Current	Pre-Charging & Maintenance Current	Sensing Resistor
700mA	70mA	0.10Ω, 1/8W
1.03A	100mA	0.068Ω, 1/8W
1.3A	130mA	0.054Ω, 1/8W
1.6A	160mA	0.044Ω, 1/8W

Basically, the sense resistor is inversely proportional to the charging current. The power dissipation is maintained at about 0.07W.

4. Setting dT/dt value to stop fast-charge

The PT8A2707-12/2717-19 employs thermistor (NTC) as battery temperature sensor. When the rate of temperature change (dT/dt) reaches certain value, fast-charge is terminated. When design external NTC sampling circuit, user should consider that appropriate dT/dt value is depended on fast charge time and battery type. Table 16 shows the dT/dt value for different fast charge time. Suggested NTC sampling circuit is based on this table and dT/dt characteristics of the devices.

Table 10: Rate of Temperature Change (dT/dt) to Terminate Fast-Charge

Fast charge time and measure time	dT/dt
T _{FCMAX} =90mins, Measure 90s	0.9°C/min
T _{FCMAX} =60mins, Measure 60s	1.38°C/min
T _{FCMAX} =30mins, Measure 30s	2.76°C/min
T _{FCMAX} =150mins, Measure 150s	0.54°C/min

5. Setting Motor-Over-Current Protection Threshold

By setting the VMSTOP pin, three motor-over-current voltage thresholds can be selected as follows:

Table 11: Motor-Over-Current Setting

VMSTOP	Over-Current Reference Voltage
GND	300mV across sensing resistor
0.6-1.0V	350mV across sensing resistor
VDD	210mV across sensing resistor

Table 12: Design Reference for Current Limit

Charging Current	Sensing Resistor	VMSTOP Setting	Motor-over-current limit
700mA	0.10Ω, 1/8W	GND	3.0A (300mV/0.1Ω)
		0.6-1.0V	3.5A (350mV/0.1Ω)
		VDD	2.1A (210mV/0.1Ω)
1A	68mΩ, 1/8W	GND	4.4A (300mV/0.068Ω)
		0.6-1.0V	5A (350mV/0.068Ω)
		VDD	3A (210mV/0.068Ω)
1.6A	44mΩ, 1/8W	GND	6.8A (300mV/0.044Ω)
		0.6-1.0V	8A (350mV/0.044Ω)
		VDD	4.8A (210mV/0.044Ω)

6. Setting Maximum Battery Protection and Low-Battery Detection Thresholds

The ratio of RA: (RB+RC) sets the maximum battery detection and $-\Delta V$ detection window ($\pm 0.3V$).

The ratio of (RA+RB): RC sets the Battery-Low detection threshold.

VB and VBLOW contain individual comparators with fixed internal reference.

VB internal comparator reference voltage 2.0V (V_{MB} comparator works when VBAT is above 2.4V)

VBLOW internal comparator reference voltage 1.45V (No-Power threshold)

VBLOW internal comparator second reference voltage 1.65V (Battery-Low threshold)

$-\Delta V$ detection reference voltage range at VB = 1.5V to 2.1V

$$1.45V = V_{BL} \cdot \left(\frac{R_B + R_C}{R_A + R_B + R_C} \right)$$

$$2.0V = V_{MB} \cdot \left(\frac{R_C}{R_A + R_B + R_C} \right)$$

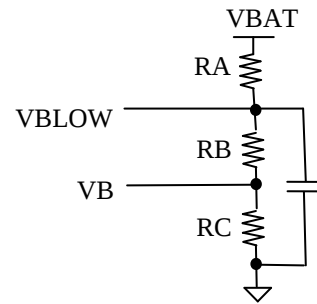


Figure 11

Example #1:

No-Power threshold = VBL=1.8V, Maximum Battery Voltage=VMB=3.4V

Assuming RC=100kΩ, RA and RB can be calculated as follows:

RB= 36kΩ, RA=33kΩ

In this setting, $-\Delta V$ is measured for battery voltage from 2.55V to 3.58V. (The internal ADC measures -8mV such that at the 2-cell battery pack the actual $-\Delta V$ is 10mV (i.e. -5mV/cell). For the Battery-Low threshold, it will be about 2.0V

Example #2:

No-Power threshold = VBL=2.0V, Maximum Battery Voltage=VMB=3.5V

Assuming RC=100kΩ, RA and RB can be calculated as follows:

RB= 27kΩ, RA=48kΩ

In this setting, $-\Delta V$ is measured for battery voltage from 2.625V to 3.675V. (The internal ADC measures -8mV such that at the 2-cell battery pack the actual $-\Delta V$ is 10mV (i.e. -5mV/cell). For the Battery-Low threshold, it will be about 2.25V

Example #3:

No-power threshold=VBL=2.7V (0.9V/cell), Maximum Battery Voltage=VMB=5.1V (1.7V/cell)

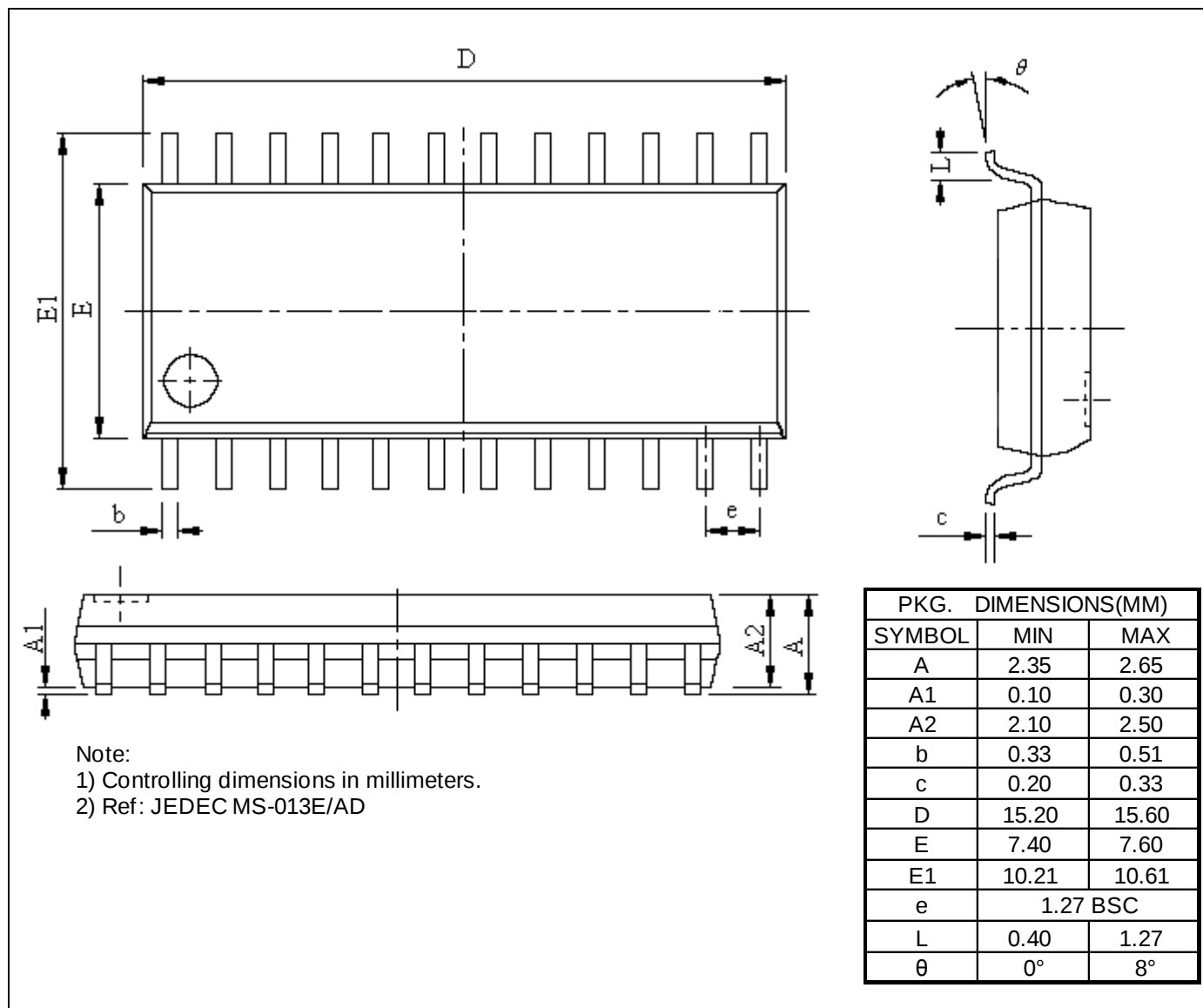
Assuming RC=100kΩ, RA and RB can be calculated as follows:

RB= 36kΩ, RA=118kΩ

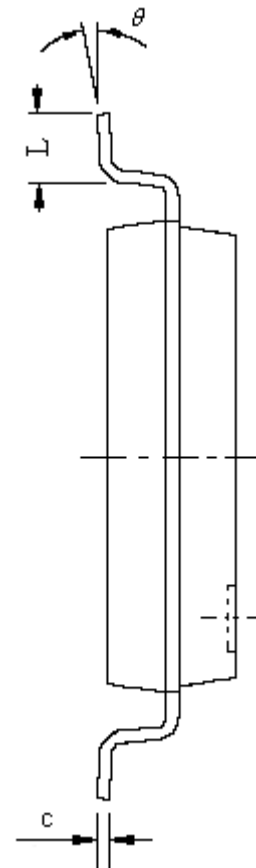
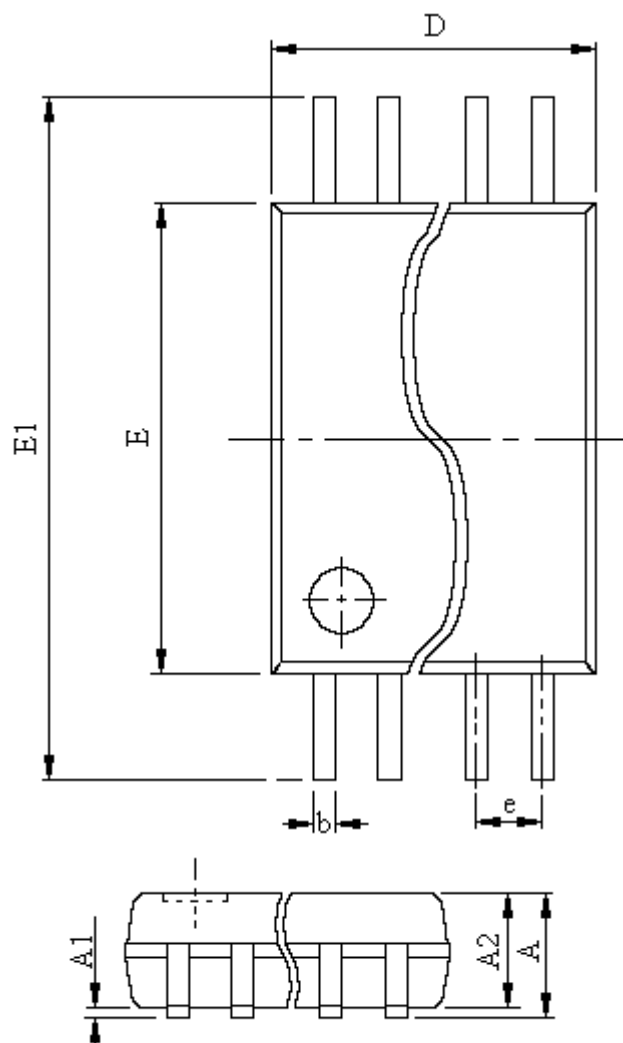
In this setting, $-\Delta V$ is measured for battery voltage from 3.85V to 5.35V. (The internal ADC measures -8mV such that at the 3-cell battery pack the actual $-\Delta V$ is 15mV (i.e. -5mV/cell). For the Battery-Low threshold, it will be about 3.3V

Mechanical Information

SE (Lead free SOIC-24)



HE (Lead free SSOP-24)



Note:
 1) Ref: JEDEC MO-150B/AG
 2) N=Number of pins

PKG. DIMENSIONS(MM)		
SYMBOL	MIN	MAX
A		1.73
A1	0.05	0.23
A2	1.40	1.60
b	0.22	0.38
c	0.09	0.25
D	8.00	8.40
E	5.10	5.50
E1	7.60	8.00
e	0.65 BSC	
L	0.55	0.95
θ	0°	8°
N	24	

Ordering Information

Part No.	Package Code	Package
PT8A2707SE*	S	Lead free and Green 24-pin SOIC
PT8A2708SE*	S	Lead free and Green 24-pin SOIC
PT8A2709SE*	S	Lead free and Green 24-pin SOIC
PT8A2710SE*	S	Lead free and Green 24-pin SOIC
PT8A2711SE*	S	Lead free and Green 24-pin SOIC
PT8A2712SE	S	Lead free and Green 24-pin SOIC
PT8A2717SE*	S	Lead free and Green 24-pin SOIC
PT8A2718SE*	S	Lead free and Green 24-pin SOIC
PT8A2719SE*	S	Lead free and Green 24-pin SOIC
PT8A2707HE*	H	Lead free and Green 24-pin SSOP
PT8A2708HE*	H	Lead free and Green 24-pin SSOP
PT8A2709HE*	H	Lead free and Green 24-pin SSOP
PT8A2710HE*	H	Lead free and Green 24-pin SSOP
PT8A2711HE*	H	Lead free and Green 24-pin SSOP
PT8A2712HE	H	Lead free and Green 24-pin SSOP
PT8A2717HE*	H	Lead free and Green 24-pin SSOP
PT8A2718HE*	H	Lead free and Green 24-pin SSOP
PT8A2719HE	H	Lead free and Green 24-pin SSOP

Note:

- E = Pb-free and Green
- Adding X Suffix= Tape/Reel
- *Contact Pericom for availability.

Pericom Semiconductor Corporation • 1-800-435-2336 • www.pericom.com

Pericom reserves the right to make changes to its products or specifications at any time, without notice, in order to improve design or performance and to supply the best possible product. Pericom does not assume any responsibility for use of any circuitry described other than the circuitry embodied in Pericom product. The company makes no representations that circuitry described herein is free from patent infringement or other rights, of Pericom.