NCP1800

Single-Cell Lithium Ion Battery Charge Controller

The NCP1800 is a constant current, constant voltage (CCCV) lithium ion battery charge controller. The external sense resistor sets the full charging current, and the termination current is 10% of the full charge current (0.1 C). The voltage is regulated at ±1% during the final charge stage. There is virtually zero drain on the battery when the input power is removed.

Features

- Integrated Voltage and Programmable Current Regulation
- Integrated Cell Conditioning for Deeply Discharged Cell
- Integrated End of Charge Detection
- Better than 1% Voltage Regulation
- Charger Status Output for LED or Host Processor Interface
- Charge Interrupt Input
- Safety Shutoff for Removal of Battery
- Blocking Diode Not Required with PNP Transistor
- Adjustable Charge Current Limit
- Input Over and Under Voltage Lockout
- Micro8 Package

Applications

- Cellular Phones, PDAs
- Handheld Equipments
- Battery Operated Portable Devices

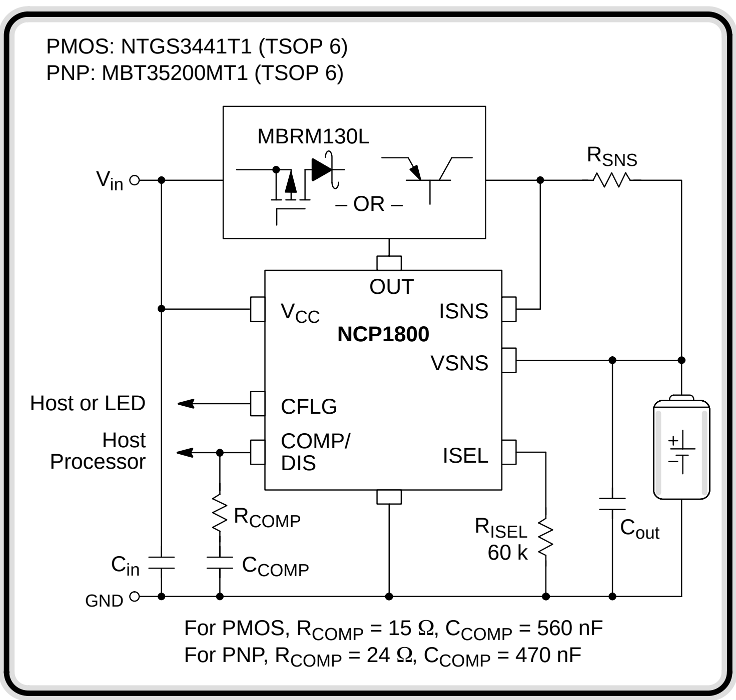

Figure 1. Typical Application

This device contains 1015 transistors.

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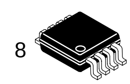
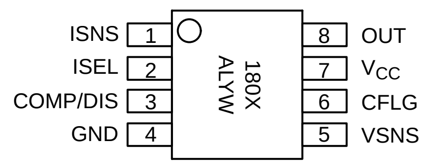


Micro8™
CASE 846A
DM SUFFIX

PIN CONNECTIONS AND MARKING DIAGRAM



X = A for 41 Device
B for 42 Device
A = Assembly Location
L = Wafer Lot
Y = Year
W = Work Week

ORDERING INFORMATION

Device	Package	Shipping
NCP1800DM41R2	Micro8	4000 Units/Reel
NCP1800DM42R2	Micro8	4000 Units/Reel

November, 2001 – Rev. 1

Publication Order Number:
NCP1800/D

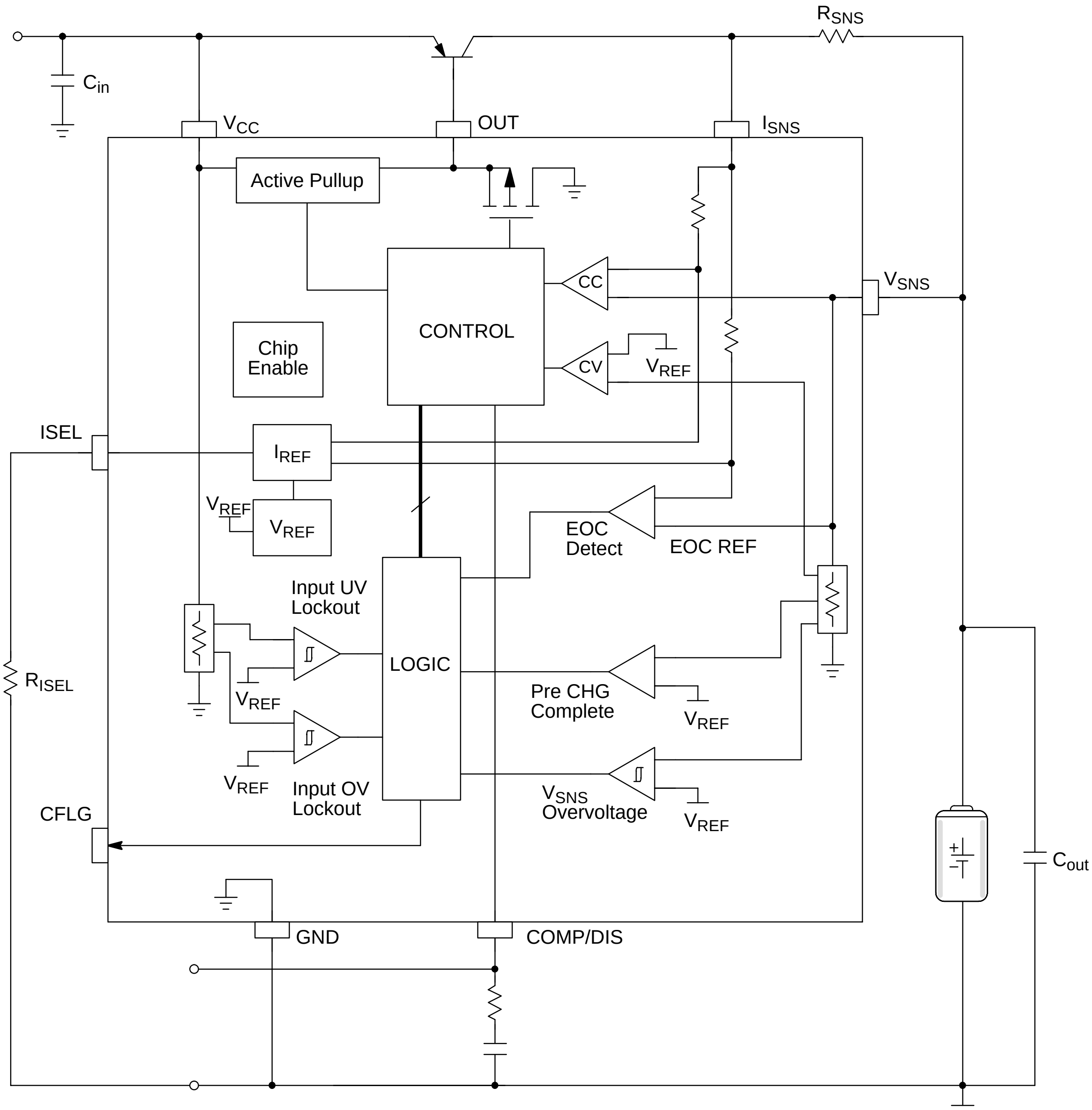


Figure 2. NCP1800 Internal Block Diagram

PIN FUNCTION DESCRIPTIONS

Pin	Symbol	Description
1	ISNS	This is one of the inputs to the current regulator and the end–of–charge comparator.
2	ISEL	A resistor from this pin to ground pin sets the full charging current regulation level.
3	COMP/DIS	This is a multifunction pin that is used for compensation and can be used to interrupt charge with an open drain/collector output from a microcontroller. When this pin is pulled to ground, the charge current is interrupted.
4	GND	This is the ground pin of the IC.
5	VSNS	This is an input that is used to sense battery voltage and is the other input to the current regulator. It also serves as the input to the battery overvoltage comparator.
6	CFLG	An open drain output that indicates the battery charging status.
7	V_{CC}	This is a multifunction pin that powers the device and senses for over and undervoltage conditions.
8	OUT	This is a current source driver for the pass transistor.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage	V_{CC}	16	V
Voltage Range for: VSNS Input ISNS Input COMP/DIS Input ISEL Input CFLG Output Out Output	–	 –0.3 to 6.0 –0.3 to 6.0 –0.3 to 6.0 –0.3 to 6.0 –0.3 to 6.0 –0.3 to V_{CC}	V
OUT Sink Current	Io	20	mA
Thermal Resistance, Junction to Air	$R_{\theta JA}$	240	°C/W
Operating Ambient Temperature	T_A	–20 to +85	°C
Operating Junction Temperature	T_J	–20 to +150	°C
Storage Temperature	T_{stg}	–55 to +150	°C

1. This device series contains ESD protection and exceeds the following tests:
   Human Body Model (HBM) ≤ 2.0 kV per JEDEC standard: JESD22–A114.
   Machine Model (MM) ≤ 200 V per JEDEC standard: JESD22–A115.
2. Latch–up Current Maximum Rating: ≤ 150 mA per JEDEC standard: JESD78.

ELECTRICAL CHARACTERISTICS (T_A = 25°C for typical values, –20°C < T_A < 85 °C for min/max values, unless otherwise noted.)

Characteristic		Symbol	Min	Typ	Max	Unit
Input Supply Voltage (Note 3)		V_{CC}	2.5	–	16	V
Input Supply Current		I_{CC}	–	140	250	µA
Regulated Output Voltage	NCP1800DM41 NCP1800DM42	V_{REG}	4.059 4.158	4.1 4.2	4.141 4.242	V
Full–Charge Current Reference Voltage V_{CC} = 6.0 V, 3.0 V < V_{SNS} < 4.2 V, R_{ISEL} = 60 KΩ, T_A = 25°C		V_{FCHG}	220	240	260	mV
Full–Charge Current Reference Voltage Temperature Coefficient V_{CC} = 6.0 V, 3.0 V < V_{SNS} < 4.2 V, R_{ISEL} = 60 KΩ		TCV_{FCHG}	–	–0.163	–	%/°C
Pre–Charge Current Reference Voltage V_{CC} = 6.0 V, V_{SNS} < 3.0 V, R_{ISEL} = 60 KΩ, T_A = 25°C		V_{PCHG}	13.2	24	34.8	mV
Pre– Charge Current Reference Voltage Temperature Coefficient V_{CC} = 6.0 V, V_{SNS} < 3.0 V, R_{ISEL} = 60 KΩ		TCV_{PCHG}	–	–0.180	–	%/°C
Pre–Charge Threshold Voltage	NCP1800DM41 NCP1800DM42	V_{PCTH}	2.78 2.85	2.93 3.0	3.08 3.15	V
V_{CC} Under Voltage Lockout Voltage		V_{UVLO}	3.43	3.56	3.69	V
Hysteresis of V_{CC} Under Voltage Lockout (V_{UVLO}), T_A = 25°C		–	90	150	195	mV
Hysteresis of V_{CC} Under Voltage Lockout Voltage (V_{UVLO}) Temperature Coefficient		–	–	0.261	–	%/°C
End–of–Charge Voltage Reference V_{CC} = 6.0 V, V_{SNS} > 4.2 V, R_{ISEL} = 60 KΩ		V_{EOC}	20	24	28	mV
End–of–Charge Voltage Reference Temperature Coefficient V_{CC} = 6.0 V, V_{SNS} > 4.2 V, R_{ISEL} = 60 KΩ		TCV_{EOC}	–	–0.160	–	%/°C
Charge Disable Threshold Voltage (I_{COMP} = 100 µA min.)		V_{CDIS}	–	–	0.08	V
V_{CC} Over Voltage Lockout		V_{OVLO}	6.95	7.20	7.45	V
Hysteresis of V_{CC} Over Voltage Lockout (V_{OVLO}),T_A = 25°C		–	90	150	180	mV
Hysteresis of V_{CC} Over Voltage Lockout (V_{OVLO}) Temperature Coefficient		–	–	0.39	–	%/°C
V_{SNS} Over Voltage Lockout	NCP1800DM41 NCP1800DM42	V_{SOVLO}	4.3 4.4	4.4 4.5	4.5 4.6	V

3. See the “External Adaptor Power Supply Voltage Selection” section of the application note to determine the minimum voltage of the charger power supplies.

ELECTRICAL CHARACTERISTICS (continued)
(T_A = 25°C for typical values, –20°C < T_A < 85 °C for min/max values, unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Hysteresis of V_{SNS} Over Voltage Lockout (V_{SOVLO}), T_A = 25°C	–	40	70	100	mV
Hysteresis of V_{SNS} Over Voltage Lockout (V_{SOVLO}) Temperature Coefficient T_A = 25°C	–	–	0.52	–	%/°C
Full Charge Current Range with R_{SNS} = 0.4 Ω	I_{REG1}	600	–	1000	mA
Full Charge Current Range with R_{SNS} = 0.8 Ω	I_{REG2}	300	–	600	mA
Battery Drain Current (V_{SNS} + I_{SNS}) V_{CC} = Ground, V_{SNS} = 4.2 V	I_{BDRN}	–	–	0.5	µA
CFLG Pin Output Low Voltage (CFLG = LOW, I_{CFLG} = 5.0 mA)	V_{CFLGL}	–	–	0.35	V
CFLG Pin Leakage Current (CFLG = HIGH)	I_{CFLGH}	–	–	0.1	µA

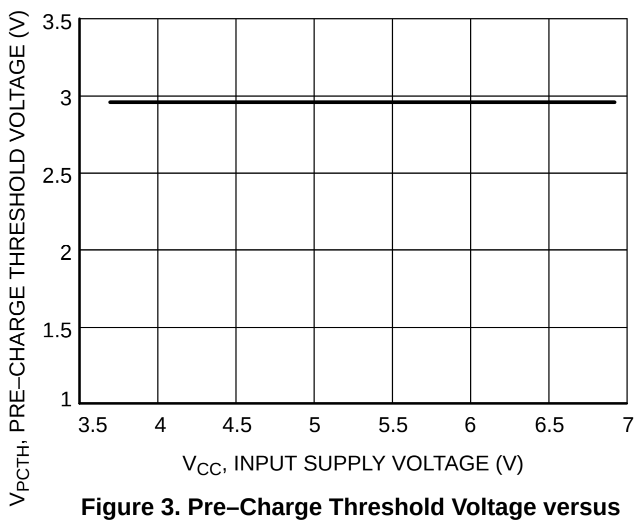


Figure 3. Pre–Charge Threshold Voltage versus Input Supply Voltage

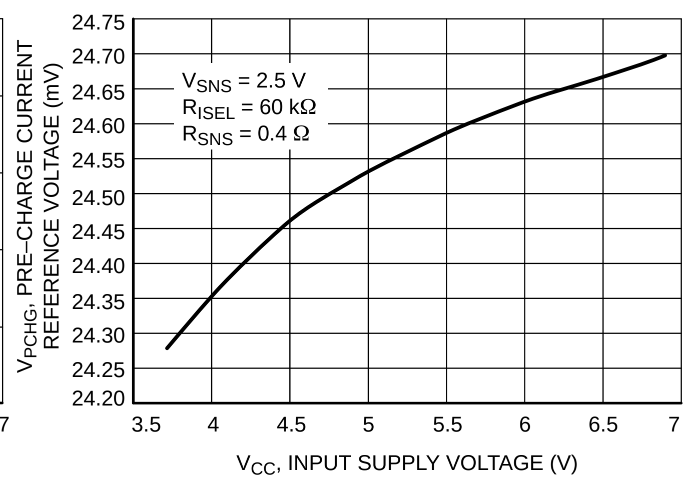


Figure 4. Pre–Charge Current Reference Voltage versus Input Supply Voltage

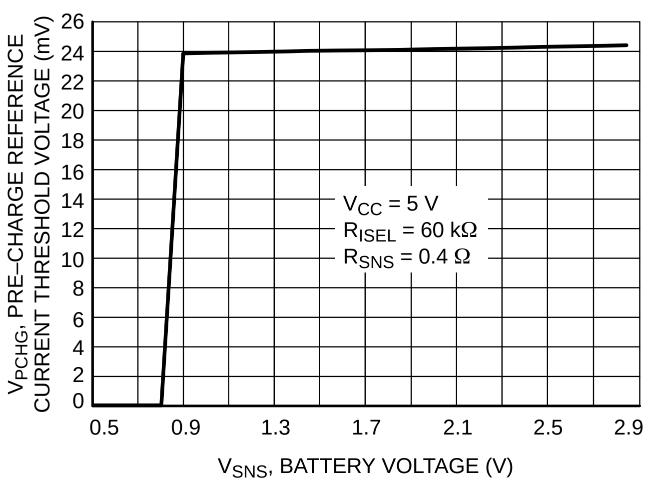


Figure 5. Pre–Charge Current Reference Voltage versus Battery Voltage

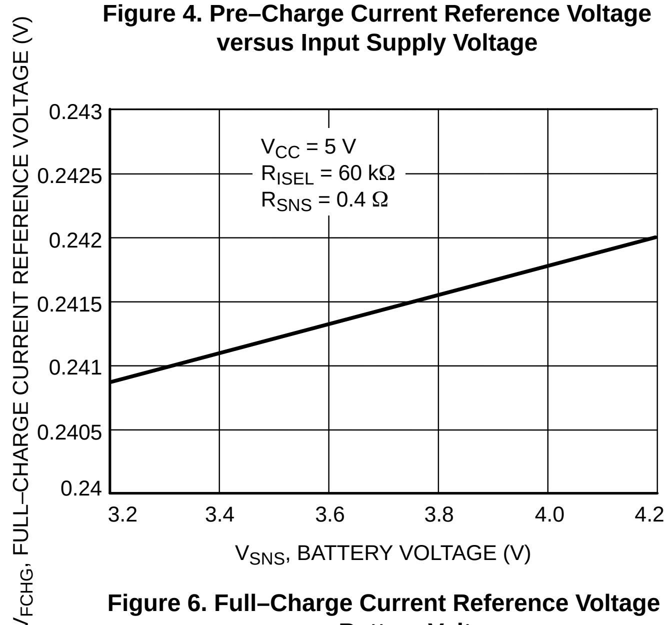


Figure 6. Full–Charge Current Reference Voltage versus Battery Voltage

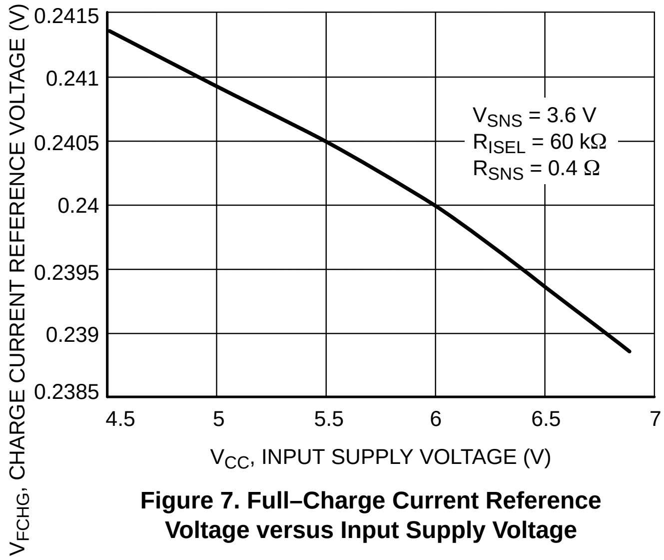


Figure 7. Full–Charge Current Reference Voltage versus Input Supply Voltage

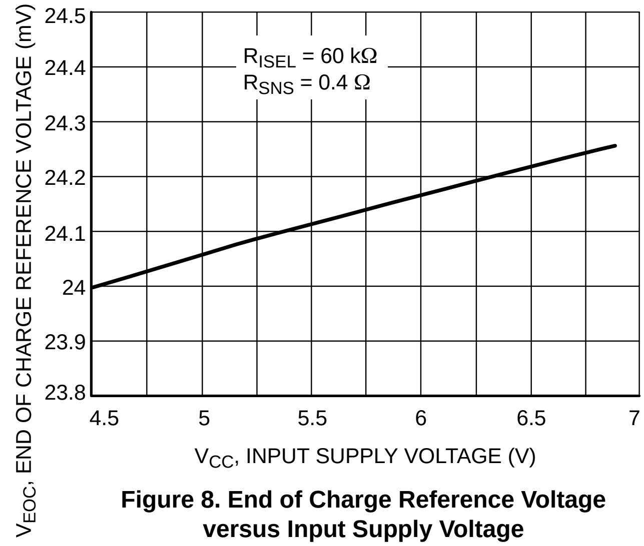


Figure 8. End of Charge Reference Voltage versus Input Supply Voltage

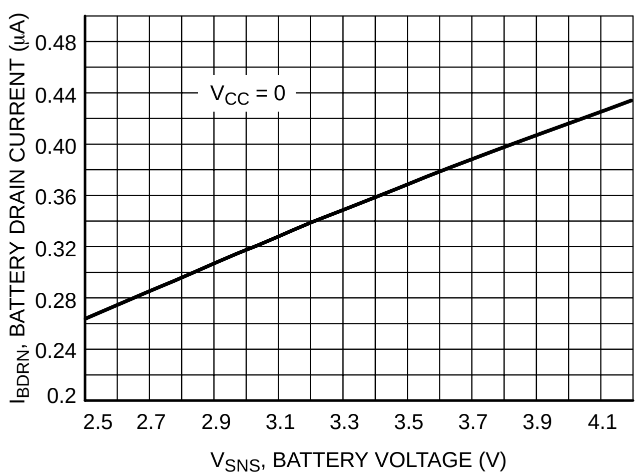


Figure 9. Battery Drain Current versus Battery Voltage

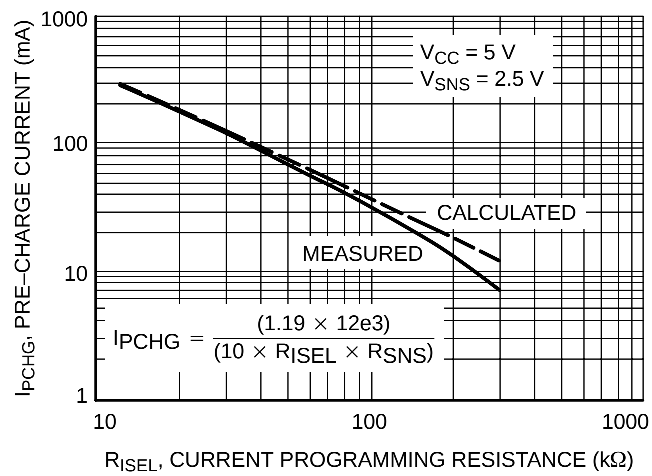


Figure 10. Pre–Charge Current versus Current Programming Resistor

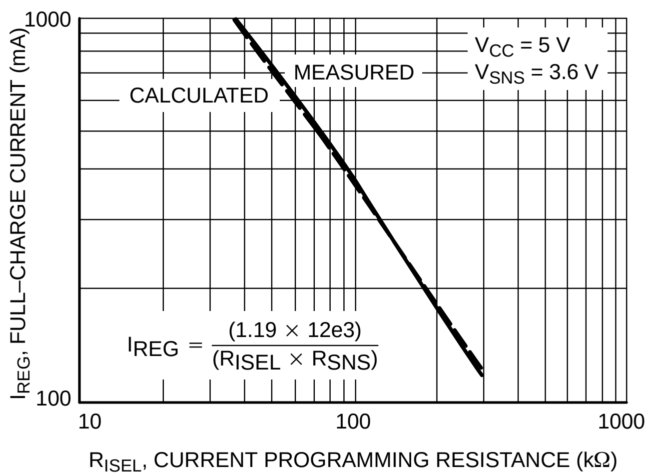


Figure 11. Full–Charge Current versus Current Programming Resistor

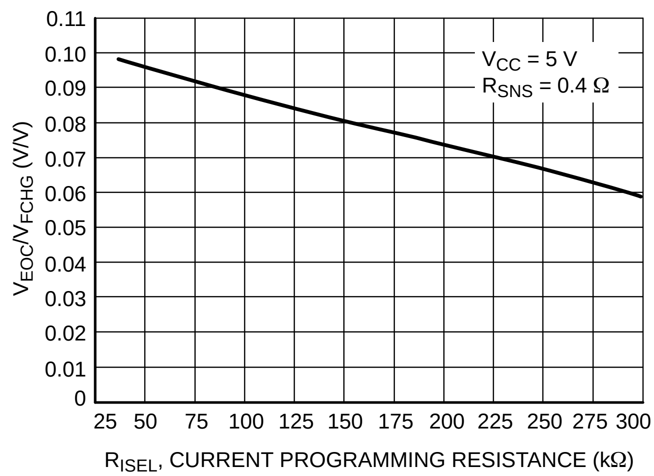


Figure 12. V_{EOC}/V_{FCHG} versus Current Programming Resistor

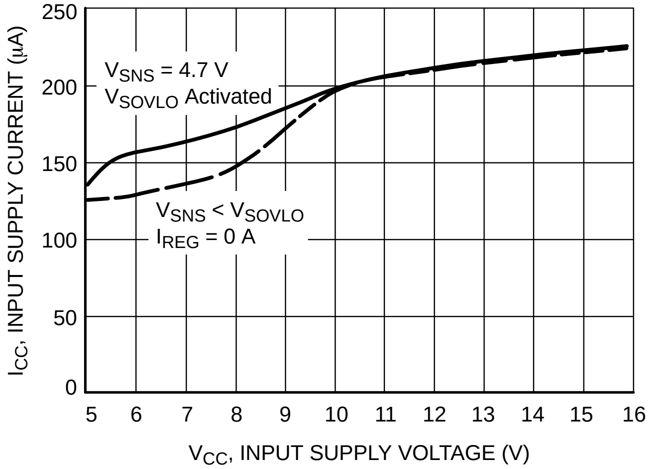


Figure 13. Input Supply Current versus Input Supply Voltage

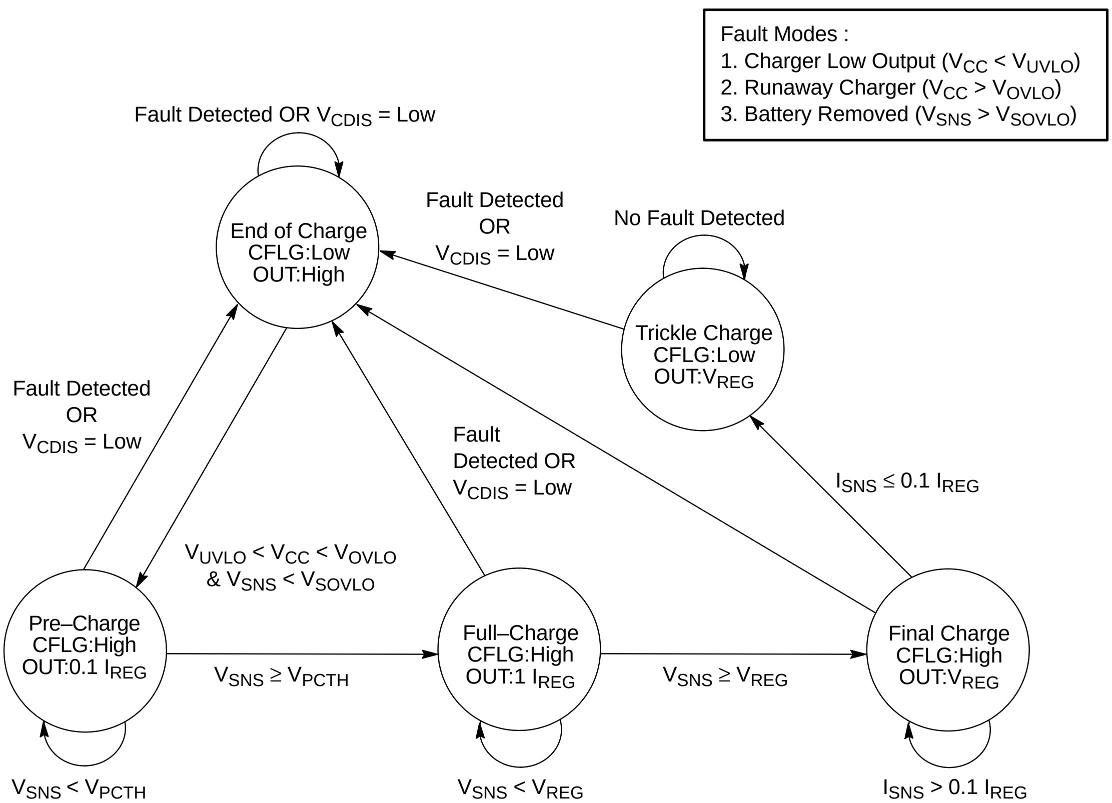


Figure 14. NCP1800 State Machine Diagram

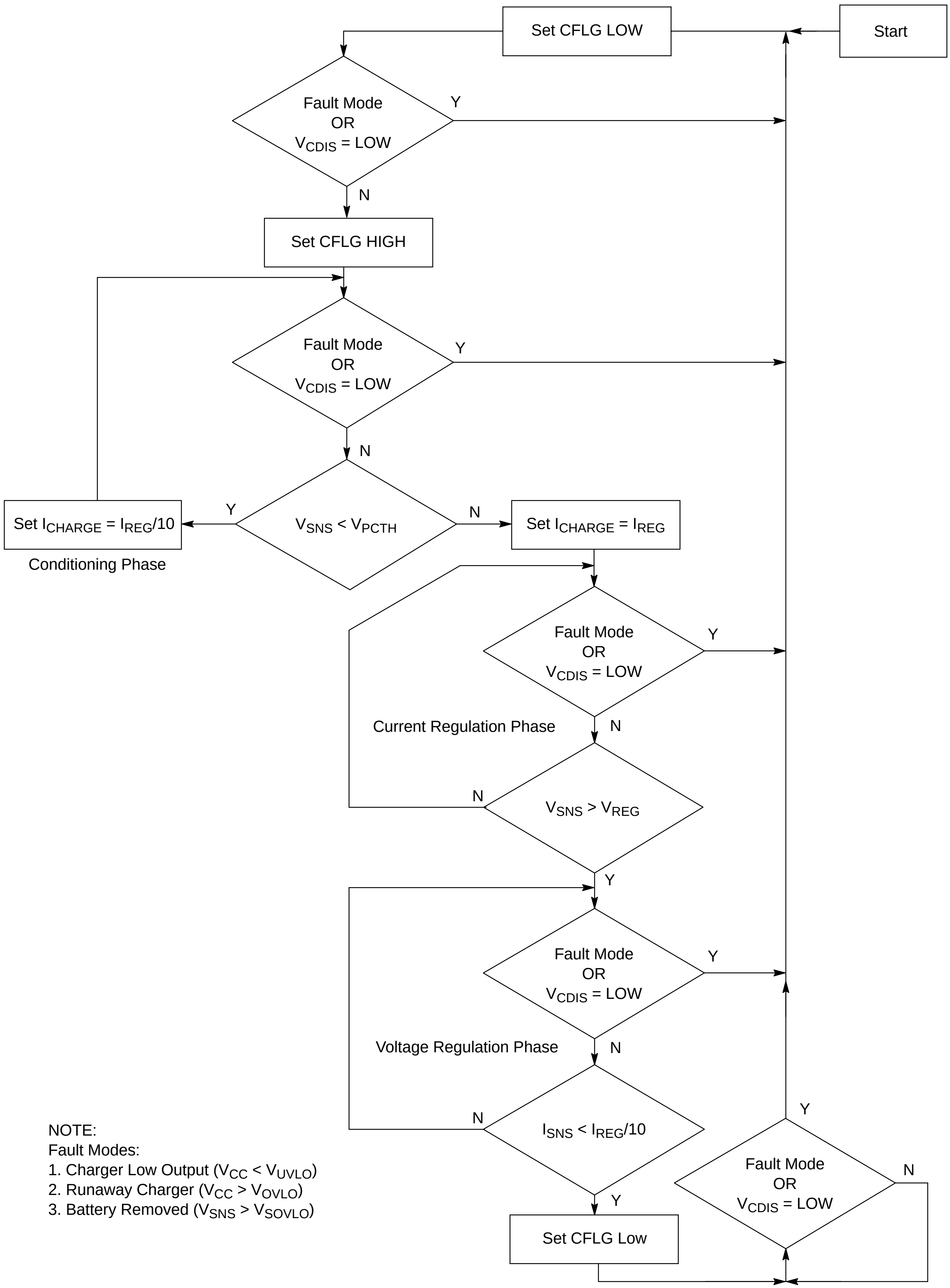


Figure 15. NCP1800 Charging Operational Flow Chart

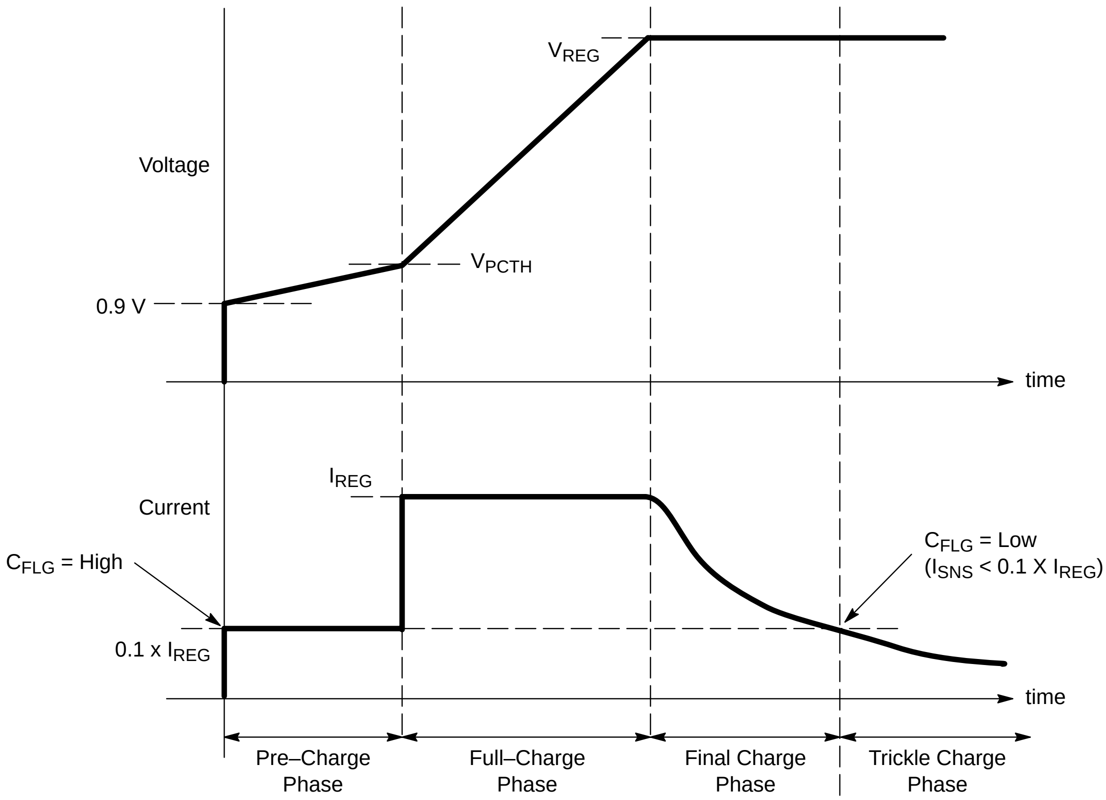


Figure 16. Typical Charging Algorithm

Charge Status

Conditions	CFLG Pin
Pre–Charge, Full–Charge and Final Charge	High–Z
End–of–Charge, Trickle Charge and Faults	Low

Operation Descriptions

The NCP1800 is a linear lithium ion (Li–ion) battery charge controller and provides the necessary control functions for charging Li–ion batteries precisely and safely. It features the constant current and constant voltage method (CCCV) of charging.

Conditioning and Pre–charge Phase

The NCP1800 initiates a charging cycle upon toggling the COMP/DIS to LOW or application of the valid external power source (i.e. $V_{UVLO} < V_{CC} < V_{OVLO}$) with the Li–ion battery present or when the Li–ion battery is inserted. Before a charge cycle can begin, the battery conditions are verified to be within safe limits. The battery will not be charged when its voltage is less than 0.9 V or higher than V_{SOVLO}.

Li–ion batteries can be easily damaged when fast charged from a completely discharged state. Also, a fully discharged Li–ion battery may indicate an abnormal battery condition. With the built–in safety features of the NCP1800, the Li–ion battery pre–charges (Pre–Charge Phase) at 10% of the full rated charging current (I_{REG}) when the battery voltage is lower than V_{PCTH} and the CFLG pin is HIGH. Typically, the battery voltage reaches V_{PCTH} in a few minutes and then the Full Charge phase begins.

Full Charge (Current Regulation) Phase

When the battery voltage reaches V_{PCTH}, the NCP1800 begins fast charging the battery with full rate charging current I_{REG}. The NCP1800 monitors the charging current at the I_{SNS} input pin by the voltage drop across a current sense resistor, R_{SNS}, and the charging current is maintained at I_{REG} by the pass transistor throughout the full charge phase.

I_{REG} is determined by R_{SNS} and R_{ISEL} with the following formula:

$$I_{REG} = \frac{(1.19 \times 12\ k)}{(R_{ISEL} \times R_{SNS})}$$

And with R_{ISEL} = 60 k and R_{SNS} = 0.4 Ω, I_{REG} = 0.6 A.

Since the external P channel MOSFET or PNP transistor is used to regulate the current to charge the battery and operates in linear mode as a linear regulator, power is dissipated in the pass transistor. Designing with a very well regulated external adaptor (e.g. 5.1 V ±1%) can help to minimize the heat dissipation in the pass transistor. Care must be taken in heat sink designing in enclosed environments such as inside the battery operated portables or cellular phones.

The Full Charge phase continues until the battery voltage reaches V_{REG}. The NCP1800 comes in two options with V_{REG} thresholds of 4.1 and 4.2 V.

Final Charge (Voltage Regulation) Phase

Once the battery voltage reaches V_{REG}, the pass transistor is controlled to regulate the voltage across the battery and the Final Charge phase (constant voltage mode) begins. Once the charger is in the Final Charge phase, the charger maintains a regulated voltage and the charging current will begin to decrease and is dependent on the state of the charge of the battery. As the battery approaches a fully charged condition, the charge current falls to a very low value.

Trickle Charge Phase

During the Final Charge phase, the charging current continues to decrease and the NCP1800 monitors the charging current through the current sense resistor R_{SNS}. When the charging current decreases to such a level that $I_{SNS} < 0.1 \times I_{REG}$, the CFLG pin is set to LOW and the Trickle Charge phase begins. The charger stays in the Trickle Charge phase until any fault modes are detected or the COMP/DIS pin is pulled low to start over the charging cycle.

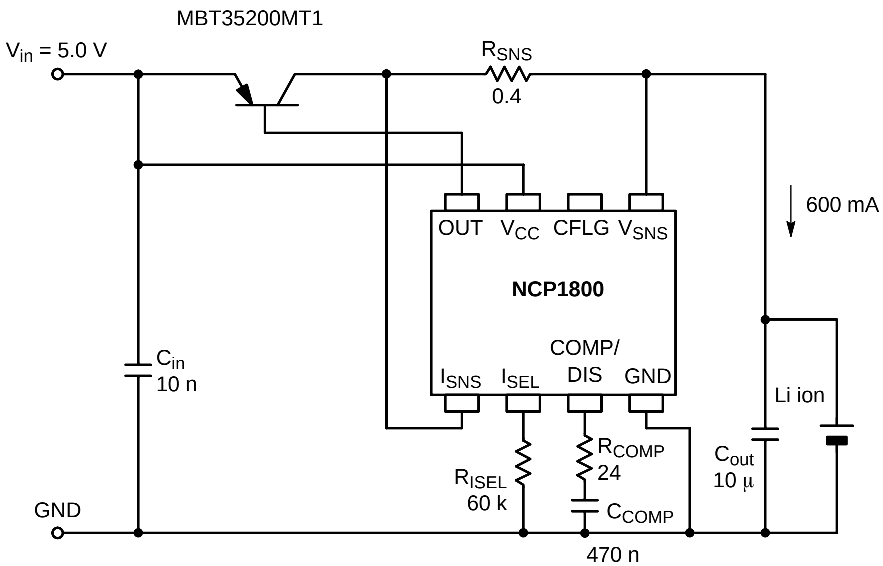


Figure 17. Typical Application Circuit with PNP Transistor

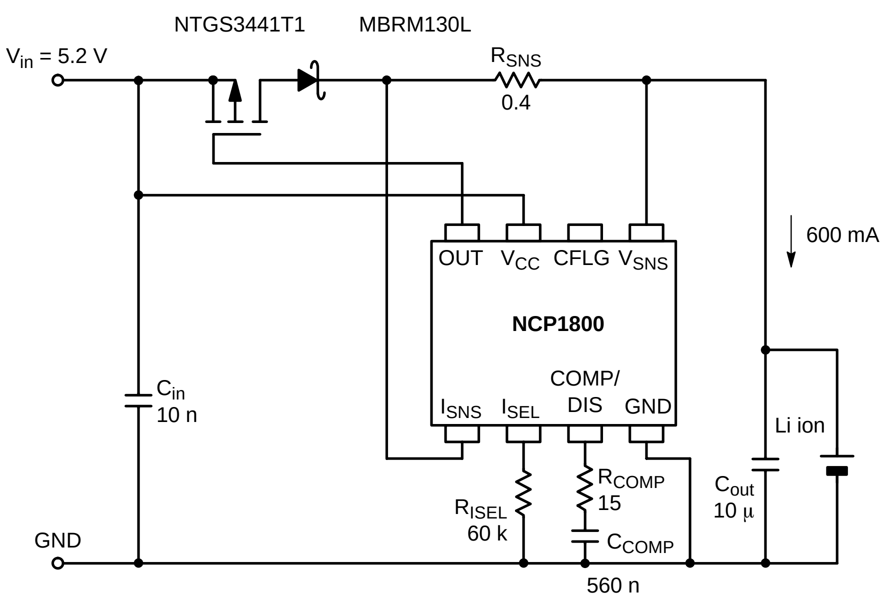


Figure 18. Typical Application Circuit with P Channel MOSFET

Selecting External Components

External Adaptor Power Supply Voltage Selection

Since the NCP1800 is using a linear, charging algorithm, the efficiency is lower. Adapter voltage selection must be done carefully in order to minimize the heat dissipation. In general, the power supply input voltage should be around 5.0 to 6.0 V. The minimum input voltage should be chosen to minimize the heat dissipation in the system. Excessively high input voltages can cause too much heat dissipation and will complicate the thermal design in applications like cellular phones. With the overvoltage protection feature of the NCP1800, input voltages higher than 7.0 V will activate the overvoltage protection circuit and disconnect the power supply input to the battery and other circuitry.

For applications with the MBT35200,

$$V_{IN(min)} > \text{Li–ion regulated voltage, } V_{REG} + \max V_{CE(sat)} + \text{voltage drop of } R_{SNS}$$

$$> 4.2\text{ V} + 0.15\text{ V} + (0.6\text{ A})(0.4\ \Omega)$$

$$= 4.59\text{ V} \simeq 4.6\text{ V},$$

(there is no blocking diode required with PNP)

For applications with the NTGS3441T1,

$$V_{IN(min)} > \text{Li–ion regulated voltage, } V_{REG} + (0.6\text{ A})(R_{DS(ON)}) + V_F \text{ of Schottky Diode } + \text{voltage drop of } R_{SNS}$$

$$> 4.2\text{ V} + (0.6\text{ A})\ (100\text{ m}\Omega) + 0.38\text{ V} + (0.6\text{ A})\ (0.4\ \Omega) = 4.88\text{ V} \simeq 4.9\text{ V}$$

Therefore, with the PMOS application, if the output voltage accuracy is 5%, then a typ. 5.2 V ±5% output voltage adaptor must be used.

And for a very good regulated adaptor of accuracy 1%, 5.0 V ±1% output voltage adaptor can then be used. It is obvious that if tighter tolerance adaptors are used, heat dissipation can be minimized by using lower nominal voltage adaptors.

Pass Element Selection

The pass element used with the NCP1800 can either be a PNP transistor or a P channel MOSFET. The type and size of the pass transistor is determined by input–output differential voltage, charging current, current sense resistor and the type of blocking diode used.

The selected pass element must satisfy the following criteria:

Drop across pass element =

$$V_{IN(min)} - \text{Li–ion regulated voltage} - V_F - I_{REG} \times R_{SNS}$$

With:

$$V_{IN(min)} = 5.0\text{ V}$$
$$V_{REG} = 4.2\text{ V}$$
$$I_{REG} = 0.6\text{ A}$$
$$R_{SNS} = 0.4\ \Omega$$

Dropout across pass element =

$$5.0\text{ V} - 4.2\text{ V} - 0.38\text{ V} - (0.6\text{ A})\ (0.4\ \Omega) = 0.18\text{ V}$$

When using p–channel MOSFET's, max. $R_{DS(on)}$ should be less than (0.18 V)/(0.6 A) = 0.3 Ω at 0.6 A. And in PNP applications, as the blocking diode is not required, the blocking diode forward voltage drop must be neglected in the calculation.

External Output Capacitor

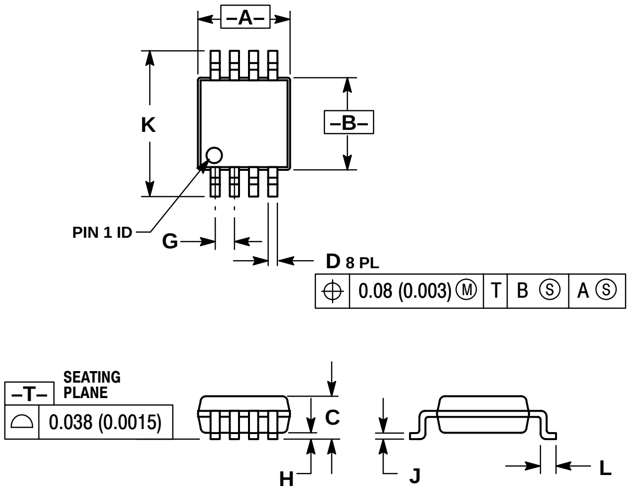
Any good quality output filter can be used, independent of the capacitor's minimum ESR. However, a 10 μF tantalum capacitor or electrolytic capacitor is recommended at the output to suppress fast ramping spikes at the V_{SNS} input and to ensure stability for 1.0 A at full range. The capacitor should be mounted with the shortest possible lead or track length to the VSNS and GND pins.

Current Sense Resistor

The charging current can be set by the value of the current sense resistor as in the previous formula. Proper de–rating is advised when selecting the power dissipation rating of the resistor. If necessary, R_{ISEL} can also be changed for proper selection of the R_{SNS} values. Take note of the recommended full–charge current ranges specified in the electrical characteristics section. Also notice the effect of RISEL on the accuracy of pre–charge current and end–of–charge detection as noted in Figures 10 and 12, respectively.

PACKAGE DIMENSIONS

Micro8
DM SUFFIX
CASE 846A–02
ISSUE E



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	2.90	3.10	0.114	0.122
B	2.90	3.10	0.114	0.122
C	---	1.10	---	0.043
D	0.25	0.40	0.010	0.016
G	0.65 BSC		0.026 BSC	
H	0.05	0.15	0.002	0.006
J	0.13	0.23	0.005	0.009
K	4.75	5.05	0.187	0.199
L	0.40	0.70	0.016	0.028

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