

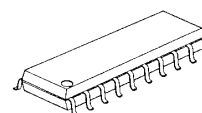
Lithium-ion Battery Charger Controller IC with Timer

■GENERAL DESCRIPTION

NJW4124 is a 1-cell and 2-cell lithium ion battery charge control IC with a built-in AC-DC secondary side control feature. Using a photocoupler to directly feed back optimum charging voltage and current information to the primary side, it increases energy efficiency, makes possible a smaller charger, and conserves energy. Charging current can be freely set and therefore it is possible to optimize charging according to battery capacity.

As safety features it has over voltage, over discharge, temperature detection, and a charge over timer. Also, the adaptor and the charge control circuit are mounted on one chip.

■PACKAGE OUTLINE

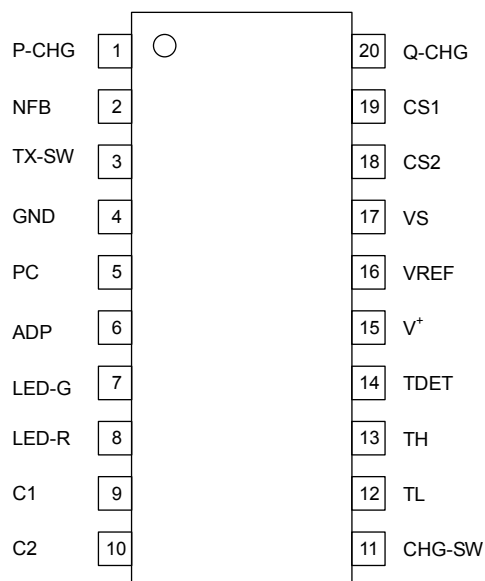


NJW4124M

■FEATURES

- Charge Control Feedback by Photocoupler
- Adjustable Charge Voltage
- Adjustable Pre-Charge and Full Charge Current
- Temperature Monitor
- Over Charge Timer
- Internal Re-Charge function
- Delay timers and Hysteresis inputs for high noise immunity
- Over Discharge Battery Detect
- Over Voltage Protection
- Bi-CMOS Technology
- Package Outline NJW4124M : DMP20

■PIN CONFIGURATION



NJW4124M

■ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

PARAMETER	SYMBOL	MAXIMUM RATINGS	UNIT
Operating Voltage	V^+	+15	V
C1 Pin Voltage	V_{C1}	+5	V
C2 Pin Voltage	V_{C2}	+5	V
TDET Pin Voltage	V_{TDET}	+5	V
TX-SW Pin Output Current	$I_{SINK-SW}$	50	mA
PC Pin Output Current	$I_{SINK-PC}$	50	mA
Power Dissipation	P_D	DMP20 :300	mW
Operating Temperature Range	T_{opr}	-20~+85	°C
Storage Temperature Range	T_{stg}	-40~+125	°C

■ELECTRICAL CHARACTERISTICS ($V^+=5V$, Ta=25°C)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
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General Characteristics

Operating Voltage	V_{OP}		2.7	—	14	V
Operating Current	I_{CC}	CHG-SW: OPEN	—	2	3	mA

Under Voltage Lockout Block

ON Threshold Voltage	V_{T-ON}		2.2	2.4	2.6	V
OFF Threshold Voltage	V_{T-OFF}		2.0	2.2	2.4	V
Hysteresis Voltage	V_{HYS}		100	200	300	mV

Reference Voltage Block

Reference Voltage	V_{REF}	$I_{REF}=0mA$	1.228	1.24	1.253	V
Load Regulation	ΔV_{REF}	$I_{REF}=0mA\sim 1mA$	—	—	10	mV

Voltage Detection Block

Quick Charge Detection Voltage	V_{Q-CHG}	VS: L→H	$V_{BAT} \times 0.71$	$V_{BAT} \times 0.73$	$V_{BAT} \times 0.75$	V
Re-Charge Detection Voltage	V_{R-CHG}	VS: H→L	$V_{BAT} \times 0.94$	$V_{BAT} \times 0.95$	$V_{BAT} \times 0.96$	V
Over Voltage Detection Voltage	V_{OV}	VS: L→H	$V_{BAT} \times 1.015$	$V_{BAT} \times 1.025$	$V_{BAT} \times 1.035$	V
Charge Control Block Reference Voltage	V_{REF-CV}	VS Pin	2.08	2.1	2.12	V
Adaptor Control Block Reference Voltage	$V_{REF-ADP}$		1.228	1.24	1.253	V
VS Pin Input Bias Current	I_{VS}	VS=2.1V	—	50	500	nA
Battery Connected Detection Voltage	V_{T-TDET}	TDET Pin	—	1.15	—	V

Low Voltage Detection (2mA Charge) Block

Charge Current	I_{CHG1}	VS=1V	1	2	3	mA
Low Voltage Detection Voltage	V_{LV}	VS: L→H	$V_{BAT} \times 0.505$	$V_{BAT} \times 0.525$	$V_{BAT} \times 0.545$	V

■ELECTRICAL CHARACTERISTICS ($V^+=5V$, $T_a=25^\circ C$)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
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Current Detection Block

Pre-Charge /Quick Charge Block Voltage Gain	A_{V1}	CS1=3.8V, CS2=3.6V	11.5	12	12.5	dB
Full Charge Detection Voltage	V_F	CS2=4.2V, VS=2.1V	8	12	16	mV
CS1 Pin Input Bias Current	I_{CS1}	CS1=4.2V	—	10	500	nA
CS2 Pin Input Bias Current	I_{CS2}	CS2=4.2V	—	10	500	nA

Photocoupler Out Block

Photocoupler Out Saturation Voltage	V_{OL-PC}	$I_{SINK}=20mA$	—	0.2	0.5	V
PC Pin Leak Current	$I_{LEAK-PC}$	$V^+=14V$	—	—	1	μA

TX-SW Out Block

TX-SW Out Saturation Voltage	V_{OL-SW}	$I_{SINK}=20mA$	—	0.2	0.5	V
TX-SW Pin Leak Current	$I_{LEAK-SW}$	$V^+=14V$	—	—	1	μA

LED Out Block

LED-G Output Voltage	V_{LED-G}		1.20	1.24	1.28	V
LED-R Output Voltage	V_{LED-R}		1.20	1.24	1.28	μA

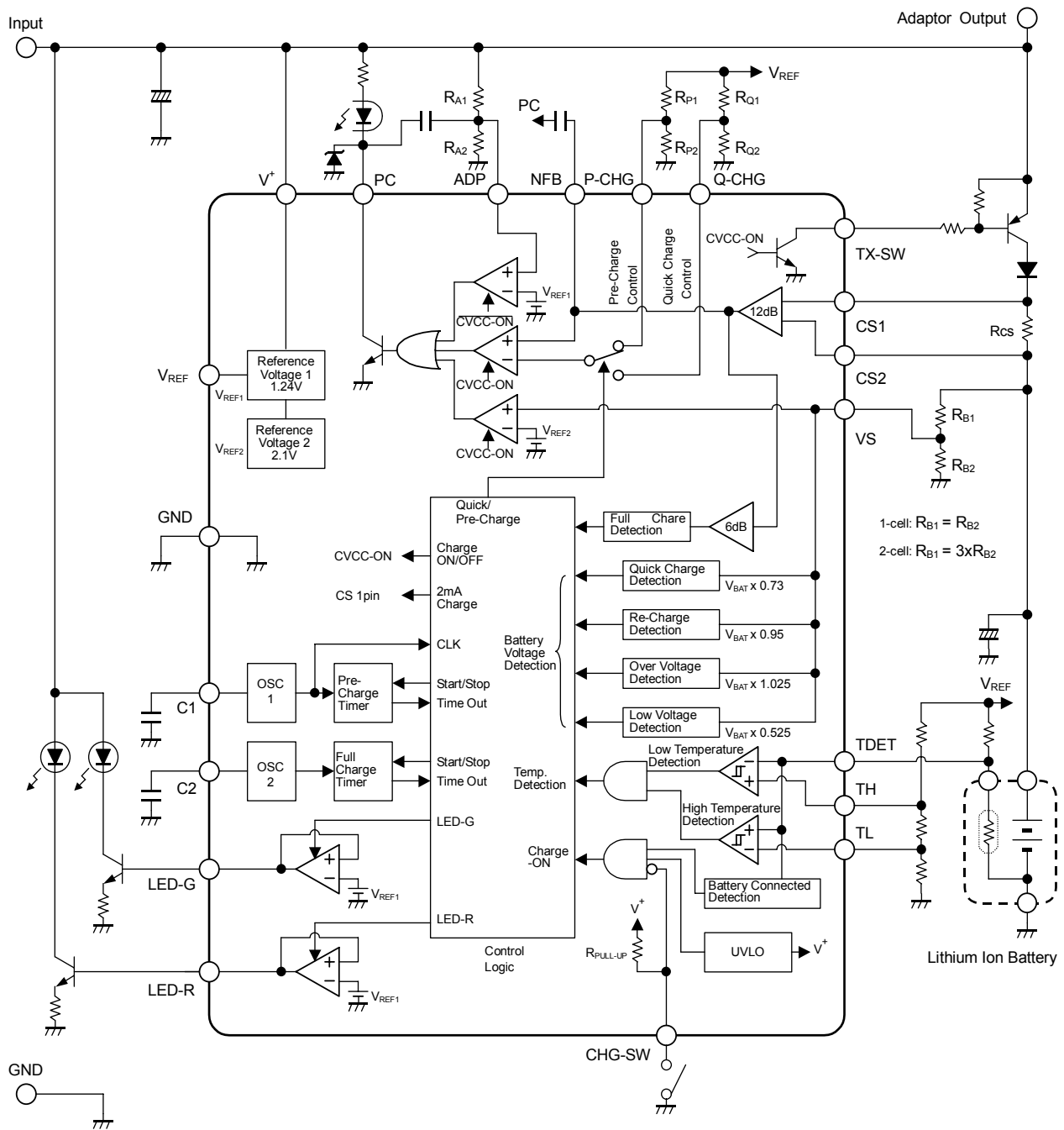
Timer Block

OSC1 Timer Error Time	$\Delta T1$	$C1=C2=0.01\mu F$ external	-10	—	+10	%
OSC2 Timer Error Time	$\Delta T2$	Not including external deviation	-10	—	+10	%

CHG-SW Block

ON Threshold Voltage	V_{SW-ON}		—	—	0.25	V
OFF Threshold Voltage	V_{SW-OFF}		1	—	—	V
Pull-up Resistance	$R_{PULL-UP}$		300	500	700	k Ω

■TYPICAL APPLICATION



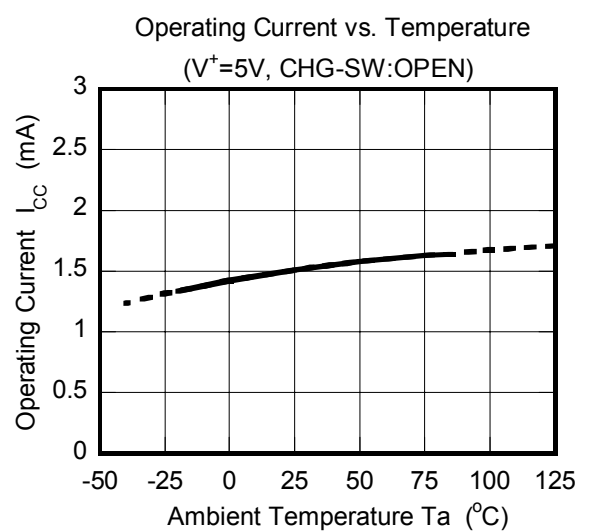
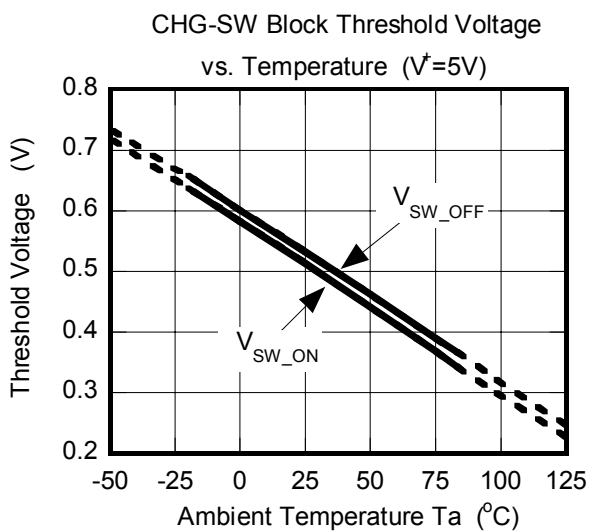
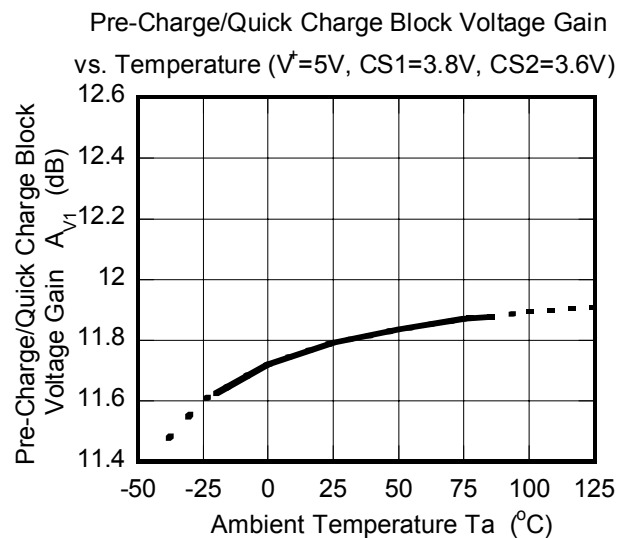
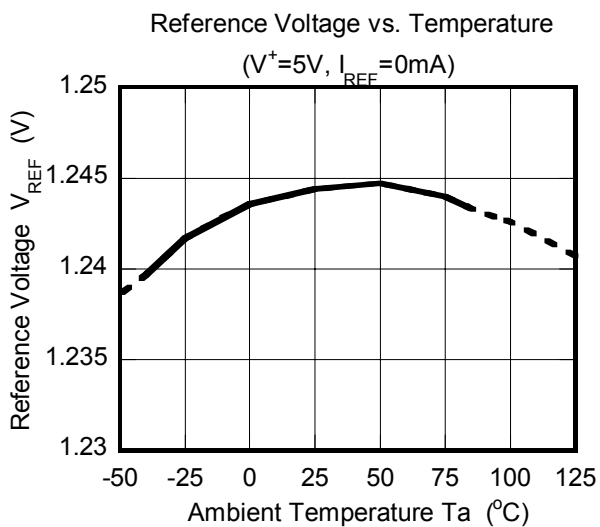
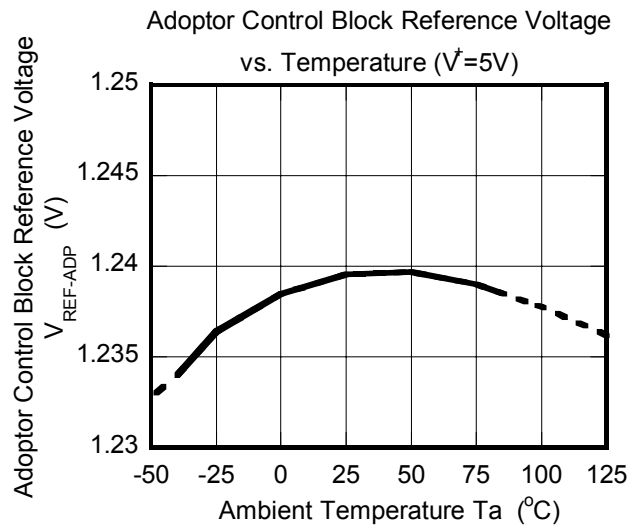
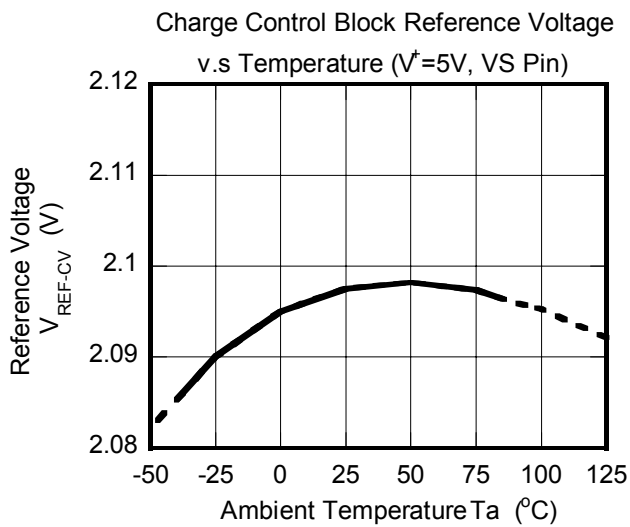
■PIN CONFIGURATION

Pin No.	Pin Name	Function
1	P-CHG	Pre-Charge Current Setting
2	NFB	Current-Regulation-Loop Compensation
3	TX-SW	Switch Transistor connection
4	GND	GND
5	PC	Photocoupler connection for the first side feedback
6	ADP	Adaptor Control Voltage Setting
7	LED-G	LED Output
8	LED-R	LED Output
9	C1	Pre-Charge Timer, 2mA Charge Timer, LED Blinking Cycle, Delay Time Setting
10	C2	Quick Timer Setting
11	CHG-SW	Charge ON/OFF Control
12	TL	Batteries Thermal (High Temperature) Setting
13	TH	Batteries Thermal (Low Temperature) Setting
14	TDET	Battery Temperature Detection, Battery Connected Detection
15	V ⁺	Operating Voltage
16	VREF	Reference Voltage Output
17	VS	Battery Voltage Detection
18	CS2	Charge Current Detection 2
19	CS1	Charge Current Detection 1
20	Q-CHG	Quick Charge Current Setting

■CHARGE VOLTAGE / CURRENT for RESISTANCE SETTING

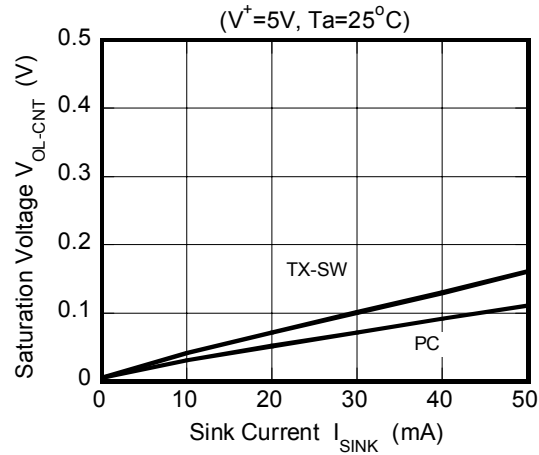
Parameter	Calculation formula	Examples of calculation	
Adaptor Output Voltage	$V_{ADP} = \frac{R_{A1} + R_{A2}}{R_{A2}} \times V_{REF-ADP(1.24V)}$	5.0V	10V
Charge Control Voltage	$V_{BAT} = \frac{R_{B1} + R_{B2}}{R_{B2}} \times V_{REF-CV(2.1V)}$	4.2V	8.4V
Low Voltage Detection Voltage	$V_{BAT} \times 0.525$	2.21V	4.41V
Quick Charge Start Voltage	$V_{BAT} \times 0.73$	3.07 V	6.13 V
Re-Charge Detection Voltage	$V_{BAT} \times 0.95$	3.99 V	7.98 V
Over Voltage Detection Voltage	$V_{BAT} \times 1.025$	4.305 V	8.61 V
Pre-Charge Current	$I_{P-CHG} = \left(\frac{R_{P2}}{R_{P1} + R_{P2}} \times V_{REF(1.24V)} / 4 \right) / R_{CS}$ (at. R_{P1} :232k Ω , R_{P2} :16k Ω , R_{CS} =0.2 Ω)	100mA	
Quick Charge Current	$I_{Q-CHG} = \left(\frac{R_{Q2}}{R_{Q1} + R_{Q2}} \times V_{REF(1.24V)} / 4 \right) / R_{CS}$ (at. R_{Q1} :128k Ω , R_{Q2} :120k Ω , R_{CS} =0.2 Ω)	750mA	
Full Charge Current	$I_{F-CHG} = (96mV / 8) / R_{CS}$ (at. R_{CS} =0.2 Ω)	60mA	

■TYPICAL CHARACTERISTICS

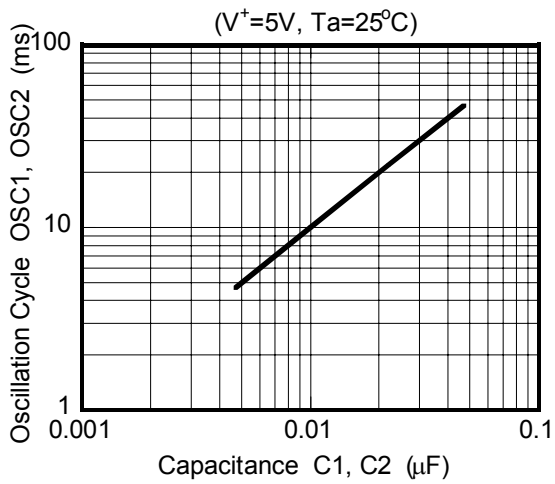


■ TYPICAL CHARACTERISTICS

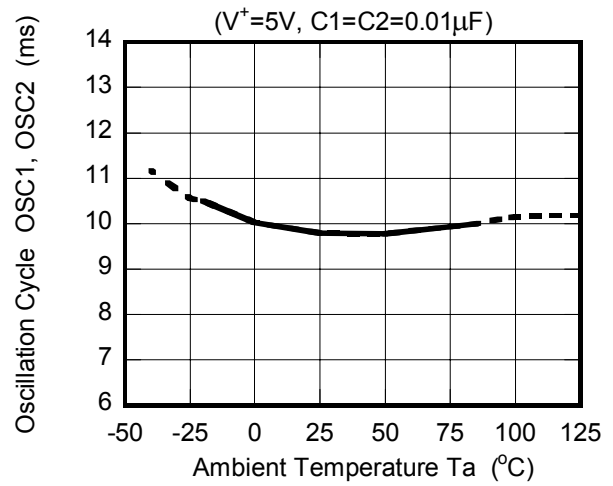
TX-SW, PC Pin Saturation Voltage vs. Sink Current



Oscillation Cycle vs. Capacitance



Oscillation Cycle vs. Temperature



■Feature Description

1. Photocoupler Feedback Unit (PC pin, CHG-SW pin, TX-SW pin)

NJW4124 feeds back voltage and current information that are required for battery charging via a photocoupler to the primary side of the AC/DC converter, and controls AC/DC converter output. No special method is required if the primary side of the AC/DC converter that is being controlled (whether self excited or externally excited) has circuitry that takes into account the range of output voltage and current that is required for charge control.

It also incorporates an adaptor output mode, and extraction of any constant voltage output is possible. The following will switch between charge control and adaptor output.

CHG-SW pin, and TDET pin battery set detection are both on: Charge control mode

Either CHG-SW pin, or TDET pin battery set detection is off: Adaptor output mode

However, if charging is prohibited due to over voltage detection, temperature detection, or the charge over timer, or when there is 2mA of charge, the system will move to adaptor mode.

The unit that controls feedback to the photocoupler consists of the ADP voltage control, charge voltage control, and charge current control amps. Each amp controls the photocoupler drive transistor via an OR circuit (Figure 1).

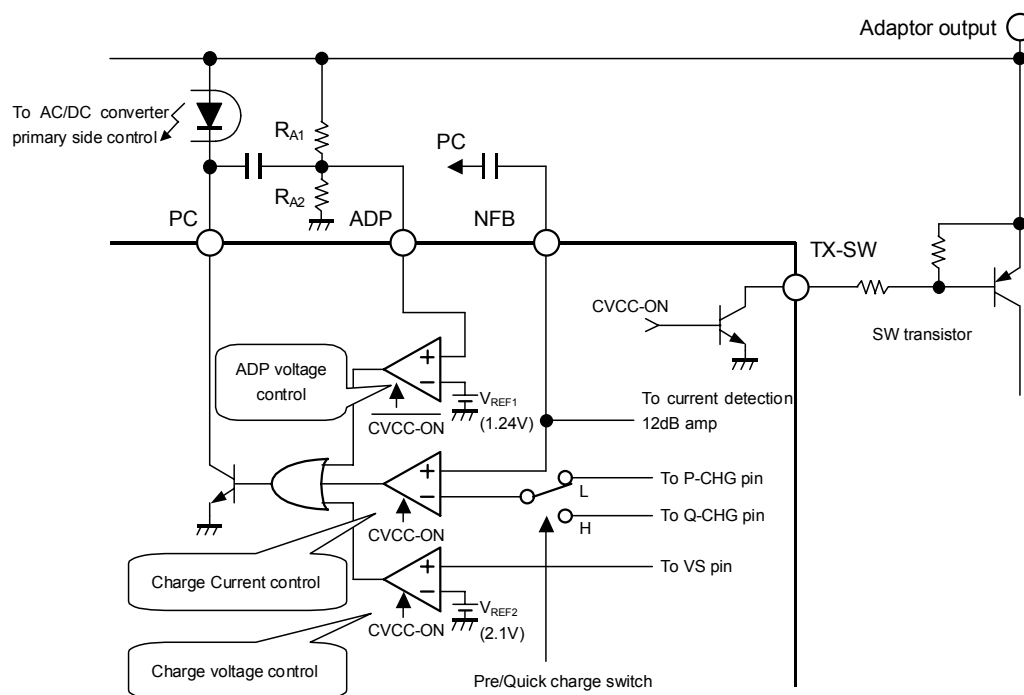


Figure 1 : Photocoupler Feedback Unit and SW Transistor

■Feature Description (Continued)

Amp control and control of the SW transistor connected to the TX-SW pin are not the same in adapter output mode and charge control mode.

1-1. Adapter output mode (ADP pin)

In adapter output mode, each of the circuits in the control unit will be in the following state.

- ADP voltage control amp → ON
- Charge voltage control amp → OFF
- Charge current control amp → OFF
- SW transistor → OFF

To set the adapter output voltage, use the ADP pin's external resistors R_{A1} , and R_{A2} and the following formula.

$$V_{ADP} = \frac{R_{A1} + R_{A2}}{R_{A2}} \times V_{REF-ADP (1.24V)}$$

In adapter output mode the SW transistor connected to the TX-SW pin will turn OFF, and charge to the battery will be cut off. For this reason, take adapter output voltage from a power supply line that comes before the SW transistor.

1-2. Charge control mode

In the case of pre-charge and quick charge each of the circuits in the control unit will be in the following state.

- ADP voltage control amp → OFF
- Charge voltage control amp → ON
- Charge current control amp → ON
- SW transistor → ON

However, when there is 2mA of charge, the system will operate in adapter output mode (SW transistor → OFF).

The SW transistor turns ON, and battery charging will be performed.

Charge voltage and charge current operations are described in "2. Voltage Detection Block", and "3. Current Detection Block".

2. Voltage Detection Block (VS pin)

The VS pin determines charge voltage, low voltage, over voltage, and re-charge voltage. Battery voltage conditions are constantly monitored. (Figure 2)

2-1. Charge Voltage (VS pin)

Charge voltage V_{BAT} is set using the VS pin external resistors R_{B1} and R_{B2} and the following equation:

$$V_{BAT} = \frac{R_{B1} + R_{B2}}{R_{B2}} \times V_{REF-CV} (2.1V)$$

Using the following settings makes it easy to support applications for one or two cells: for one cell, $R_{B1} = R_{B2}$; for two cells, $R_{B1} = 3 \times R_{B2}$.

If you use a high resistance, the VS pin's bias current will cause incorrect values. Use as low a resistance as possible.

2-2. Overcharge Detection Block (VS pin)

The overcharge detection block stops charging when a high voltage is detected at the VS pin.

The overcharge detection voltage is obtained with the following equation:

$$V_{OV} = V_{BAT} \times 1.025 \text{ (typ.)}$$

When overcharge is detected, charging is prohibited and LED-R blinks. After that, charge will continue to be prohibited, even after battery voltage drops to a normal value. Turning the power off to release UVLO, battery connection detection, or CHG-SW switching will enable the charge sequence to restart.

2-3. Low Voltage Detection (2mA charge) Block (VS pin, CS1 pin)

The low voltage detection block detects an over-discharged battery, or an open battery caused by the battery protection circuit or the like. This will determine a 2mA charge prior to pre-charging.

The low voltage detection voltage is obtained with the following equation:

$$V_{LV} = V_{BAT} \times 0.525 \text{ (typ.)}$$

During a 2mA charge, the block monitors battery voltage recovery while a steady 2mA current is output from the CS1 pin. (Figure 3)

If voltage does not recover within a prescribed time, the timer will prohibit 2mA charging. Turning the power off to release UVLO, battery connection detection, or CHG-SW switching will enable the charge sequence to restart.

2-4. Re-Charge Detection (VS pin)

When a fully charged battery is left for a long period of time, voltage will drop due to self-discharge. The re-charge detection block detects a drop in voltage and re-charges the battery.

The re-charge detection voltage is obtained with the following equation.

$$V_{R-CHG} = V_{BAT} \times 0.95 \text{ (typ.)}$$

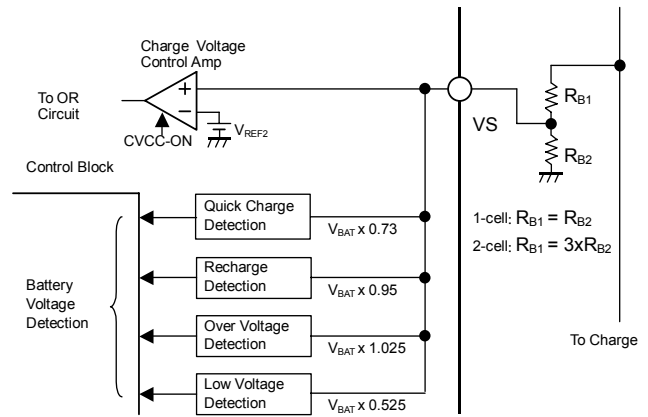


Figure 2. Voltage Detection Block Configuration

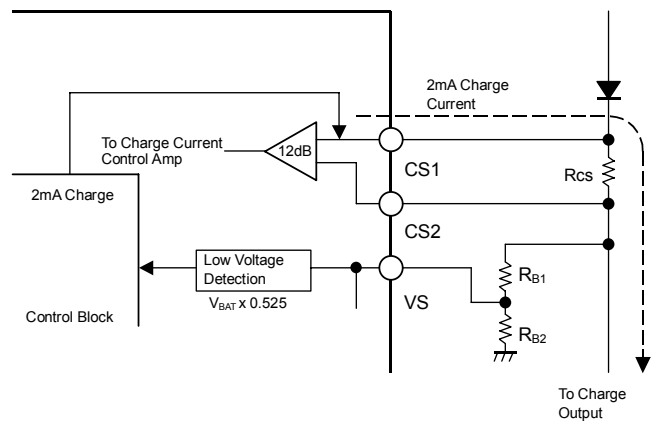


Figure 3. 2mA Charging Block

3. Current Detection Block (CS1 pin, CS2 pin)

The input voltage between pin CS1 and pin CS2 is amplified by the 12dB current detection amp and fed back to the charge current control amp. (Figure 4)

This will switch between charging with pre-charge current or quick charge current according to the level of the battery voltage V_{BAT} that is input from the VS pin.

$V_{BAT} \times 0.525$ to $V_{BAT} \times 0.73$	Pre-charge control
$V_{BAT} \times 0.73$ to V_{BAT}	Quick charge control

Pre-charge and quick charge current values are determined by the P-CHG pin and the Q-CHG pin voltage settings. Settings are made according to the following formulae.

Pre-Charge Current Value

$$I_{P-CHG} = \left(\frac{R_{P2}}{R_{P1} + R_{P2}} \times V_{REF(1.24V)} / 4 \right) / R_{CS}$$

Quick Charge Current Value

$$I_{Q-CHG} = (\frac{R_{Q2}}{R_{Q1} + R_{Q2}} \times V_{REF(1.24V)} / 4) / R_{CS}$$

Charge termination is determined by a set full charge current I_{F-CHG} , which is determined by a voltage setting on the F-CHG pin.

$$I_{F-CHG} = (96\text{mV} / 8) / R_{CS}$$

When charging is terminated, LED-G turns on, and the sequence moves to the re-charge detection operation.

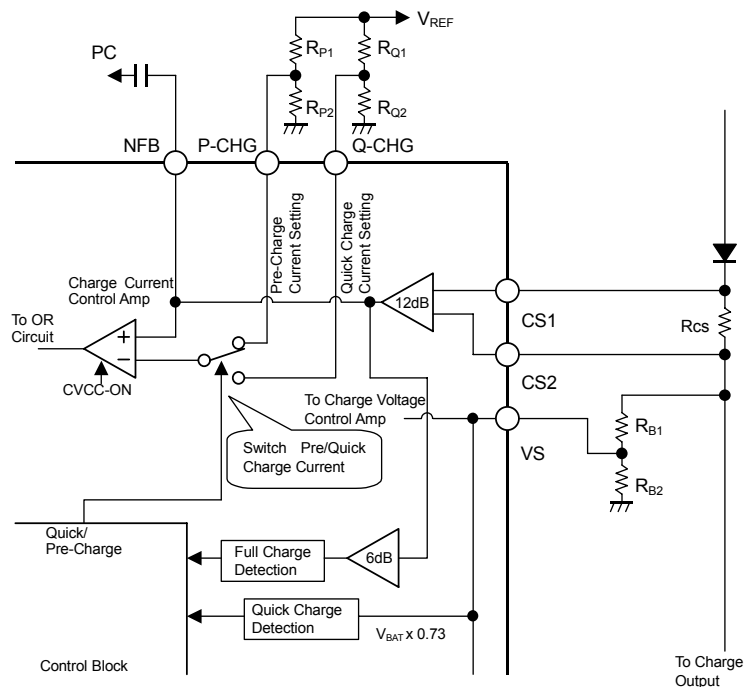


Figure 4. Block for Controlling Pre-Charge, Quick Charge, and Block for Detecting Full Charge.

■FEATURE DESCRIPTION (CONTINUED)

4. Temperature Detection Block, Battery Connected Detection Block (TDET pin, TH pin, TL pin)

The charge temperature range is set with the TL pin (high temperature) and the TH pin (low temperature).

The threshold voltage for the temperature detection comparator is set with the external resistors R_{THL} , R_{TH} , R_{TL} . Therefore, you can select any type of thermistor (NTC) and any charge temperature range (Figure 5).

The TL pin and the TH pin are set to go to the potential states shown below for fluctuations in TDET voltage.

V_{TL} (high temperature) < V_{TDET} (charge Temperature) < V_{TH} (low temperature)

Pin voltages are obtained from the following formulae.

TDET pin (thermistor setting)

$$V_{TDET} = \frac{R_T}{R_{TDET} + R_T} \times V_{REF(1.24V)}$$

TH pin (low temperature setting)

$$V_{TH} = \frac{R_{TH} + R_{TL}}{R_{THL} + R_{TH} + R_{TL}} \times V_{REF(1.24V)}$$

TL pin (high temperature setting)

$$V_{TL} = \frac{R_{TL}}{R_{THL} + R_{TH} + R_{TL}} \times V_{REF(1.24V)}$$

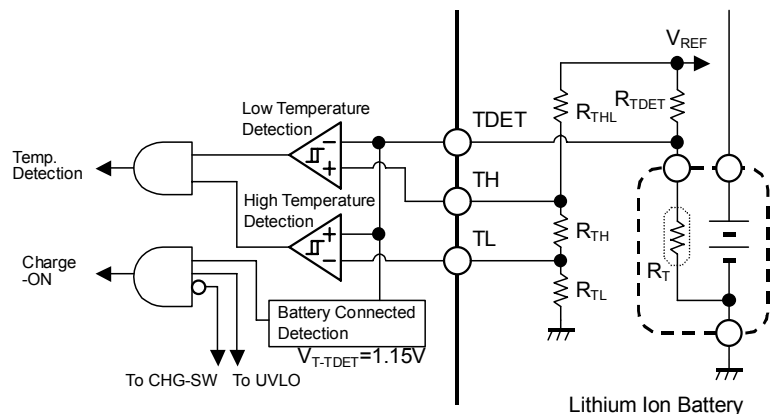


Figure 5 Temperature Detection Block

When the detected temperature goes out of the range of the set values, charging stops, and LED-R is blinks. After temperature is restored, charging recommences in line with battery voltage status.

The TDET pin is also used for the battery-connected detection feature.

The battery-connected detection feature determines that a battery is connected if TDET pin voltage is no greater than 1.15V(typ.), and commences charging.

■FEATURE DESCRIPTION (CONTINUED)

5. Delay Circuits (each detection block)

Each detection block has a delay circuit and extra features for preventing malfunction due to noise or excess signals.

Table 1 Delay Circuits and Extra Features.

Detection Block	Delay Circuit	Extra Feature
Low Voltage Malfunction Prevention Circuit	Delay I	Hysteresis
CHG-SW		Hysteresis
Battery Connected Detection		Hysteresis
Temperature Detection		Hysteresis
Full Charge Detection		—
Re-Charge Detection		—
Low Voltage Detection		Hysteresis
Over Voltage Detection		Latch
Quick Charge Detection	Delay II	Hysteresis

The delay circuit block receives a signal from the timer circuit to fix a delay time.

For details on the relationship between the delay time and capacitors see “6. Timer Circuit Block”.

6. Timer Circuit Block (C1 pin, C2 pin)

OSC1 is used for the timer that is used for pre-charge, 2mA charge and the like. OSC2 is used for the quick charge timer.

You can change the time of the timers with external capacitors. Tables 2, 3 show the relationship between capacitance and time.

Table 2 C1, C2 Oscillation Cycle t

Capacitance (C1, C2)	Oscillation Cycle (OSC1, OSC2)
4700pF	t = 4.7ms
0.01μF	t = 10ms
0.022μF	t = 22ms
0.047μF	t = 47ms

Table 3 Timer Time

Block Name	Parameter	Calculation Formula	Examples	
Pre-Charge Timer	2mA Charge Timer	$t \times 2^{10}$	10.2s	C1=0.01μF
	Pre-Charge Timer	$t \times 2^{17}$	22min.	
	LED R Blinking Cycle	$t \times 2^7$	1.28s	
	Delay I	$t \times 2^5$	0.32s	
	Delay II	$t \times 2^4$	0.16s	
Quick Charge Timer	Quick Charge Timer	$t \times 2^{20}$	2hours 55 min.	C2=0.01μF

Use capacitors the have good temperature characteristics in the OSC block.

Capacitor deviation will cause timer errors.

■FEATURE DESCRIPTION (CONTINUED)

In each charge mode if time-over occurs charging is prohibited and LED-R blinks. Turning the power off to release UVLO, battery connection detection, or CHG-SW switching will enable the charge sequence to restart.

NJW4120 incorporates a test mode that shortens the timer block function's test time by 1/150,000.

To operate in test mode set the TH pin voltage to a value no greater than that of the TL pin. In test mode, regardless of the external timing capacitors C1, C2, the internal timer clock frequency will operate in a range of approximately 200kHz to 300kHz. The following shows calculation values when the oscillating frequency is 250kHz (4μs cycle).

Table 4. Timer Times in Test Mode.

Block Name	Parameter	Calculation Formula	Example (t = Appx. 4μs)
Pre-Charge Timer	2mA Charge Timer	$t \times 2^{10}$	Appx. 4ms
	Pre-Charge Timer	$t \times 2^{17}$	Appx. 0.5s
	LED R Blinking Cycle	$t \times 2^7$	Appx. 0.5ms
	Delay I	$t \times 2^5$	Appx. 0.13ms
	Delay II	$t \times 2^4$	Appx. 64μs
Quick Charge Timer	Quick Charge Timer	$t \times 2^{20}$	Appx. 4.2s

When the TDET pin voltage is approximately 1.2V or greater, the pre-charge / quick charge timers operate normally.

If you want to further reduce the test time, setting TDET pin voltage makes it possible to run each of the timer counters divided in half. When the TDET pin is approximately 0.3V or less, the first half of the counter is bypassed. When the voltage is approximately greater than 0.4V and less than 1.1V, the second half of the counter is bypassed.

Table 5. Reduced Test Time Mode

Parameter	Calculation Formula	Example (t = Appx. 4μs)
Pre-Charge Timer	$t \times 2^8$, $t \times 2^8$	Appx. 1ms, Appx. 1ms
Quick Charge Timer	$t \times 2^9$, $t \times 2^{10}$	Appx. 2ms, Appx. 4ms