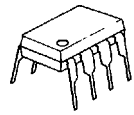
NJM2359

The NJM2359 is a low power switching regulator IC. Due to an internal current protection circuit, constant current limiting and foldback current limiting characteristics are set by external resistors.

The NJM2359 is well-suited for use in battery operated portable instruments (word processors, personal computers, etc.).

■ Package Outline



NJM2359D

■ Absolute Maximum Ratings (Ta=25℃)

Supply Voltage	V^+	24V
Power Dissipation	P_D (D-Type)	500mW
Operating Temperature Range	T_{opr}	−20~+75℃
Storage Temperature Range	T_{stg}	−40~+125℃

■ Electrical Characteristics

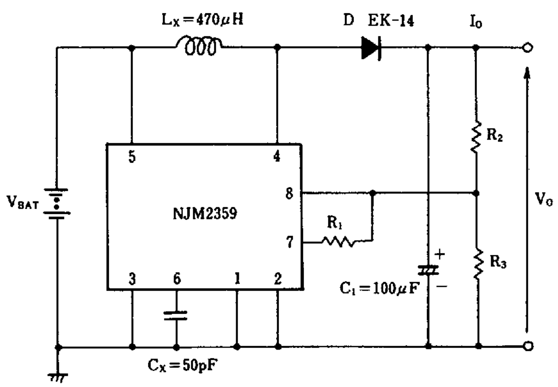
● DC Characteristics (V^+=6V, Ta=25℃)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Supply Current (1)	$I_{CC}(1)$		—	300	400	μA
Supply Current (2)	$I_{CC}(2)$	V^+=24V	—	450	600	μA
Reference Voltage	V_{REF}		1.24	1.31	1.38	V
Switch Saturation Voltage	V_{SW}	I_{SW}=100mA	—	0.2	0.4	V
Switch Current	I_{SW}	V_{SW}=0.4V	100	200	—	mA
Switch Leakage Current	I_{SWO}	V(4PIN)=24V	—	0.1	10	μA
Operating Frequency	Fo	C_X=50pF	40	50	60	kHz
Current Limit Sense Voltage (1)	$V_{CL}(1)$	V^+=6V	65	85	105	mV
Current Limit Sense Voltage (2)	$V_{CL}(2)$	V^+=24V	70	95	120	mV
Current Limit Input Voltage Range	V_{IB}		−0.3	–	V^+−2	V

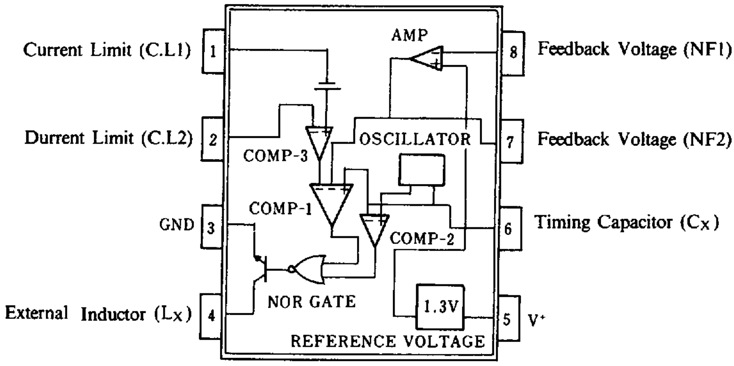
● AC Characteristics (Step-Up, Ta=25℃)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Output Voltage (9V Out)	$V_{O(9)}$	V^+=4.5V, I_O=10mA	8.51	9.00	9.49	V
Load Regulation (9V Out)	ΔV_O-$I_{O(9)}$	V^+=4.5V, I_O=2~17mA	—	100	200	mV
Line Regulation (9V Out)	ΔV_O-$I_{IN(9)}$	V^+=4.5~8.1V, I_O=10mA	—	50	200	mV
Output Voltage (5V Out)	$V_{O(5)}$	V^+=2.6V, I_O=10mA	4.72	5.00	5.28	V
Output Voltage (24V Out)	$V_{O(24)}$	V^+=12V, I_O=4mA	22.7	24.0	25.3	V

■ Test Circuit

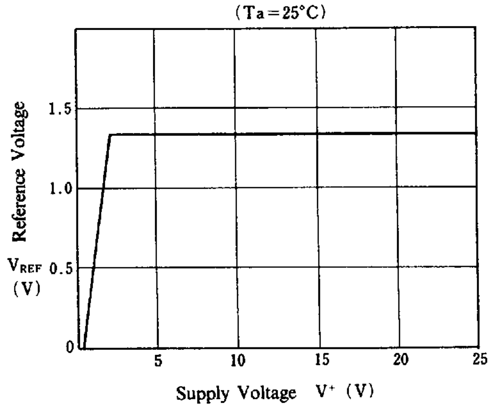


■ **Block Diagram**

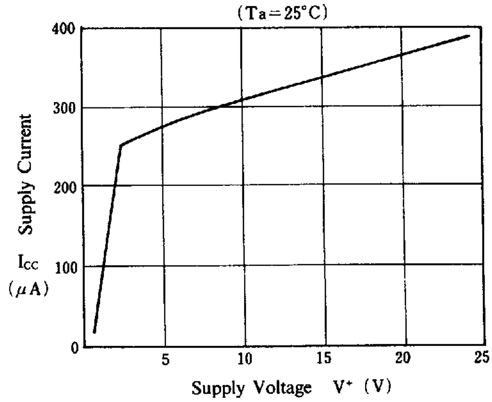


■ **Typical Characteristics**

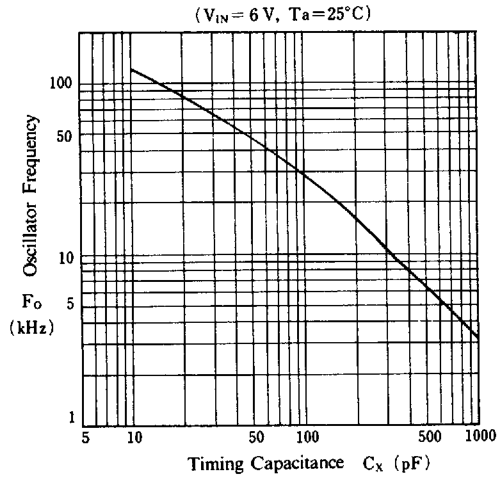
Reference Voltage vs. Supply Voltage



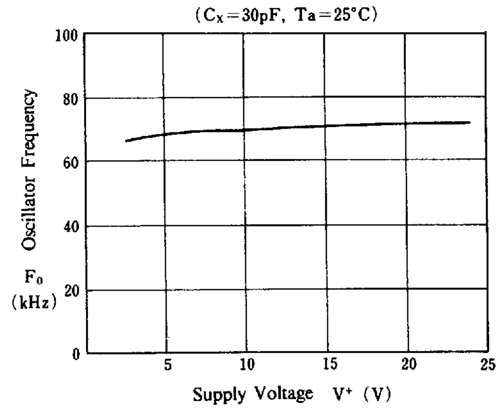
Supply Current vs. Supply Voltage



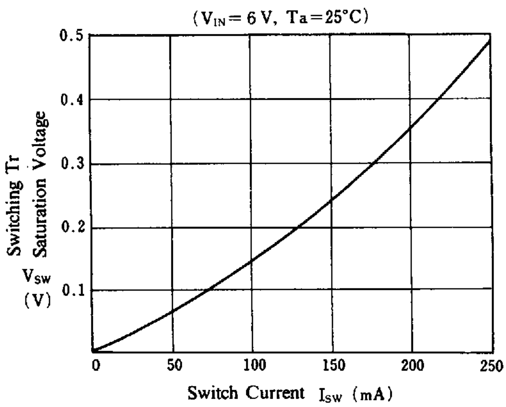
Oscilator Frequency vs. Timing Capacitance



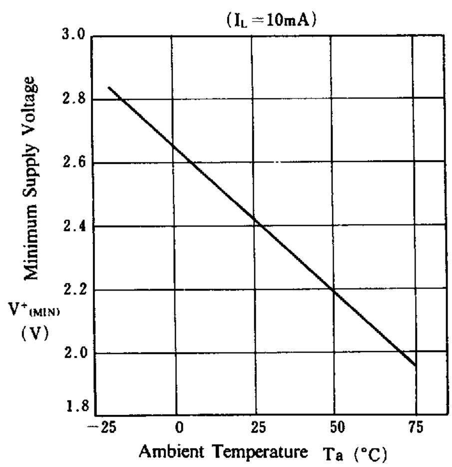
Oscillator Frequency vs. Supply Voltage



Switching Tr Saturation Voltage vs. Switch Current

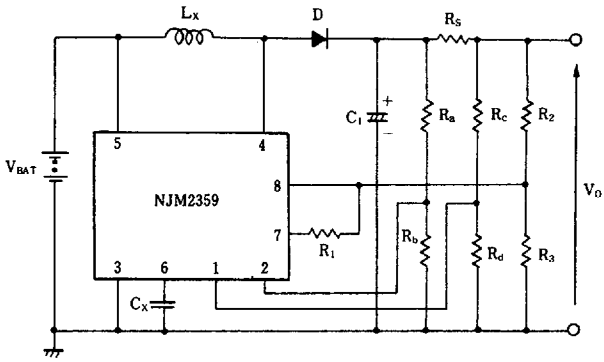


Minimum supply Voltage vs. Temperature



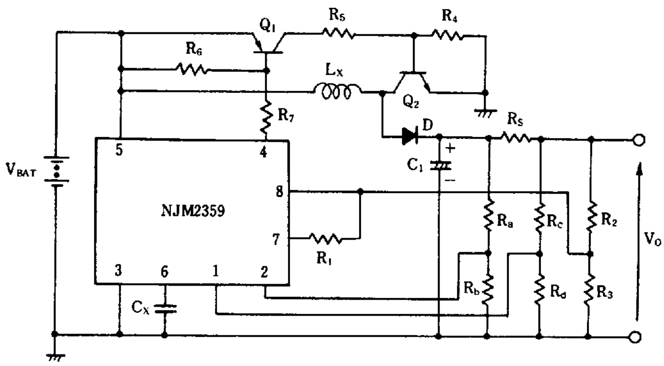
■ Typical Applications

1) Step-Up Switching Regurator (Low Current)



$$V_O = \frac{R_2 + R_3}{R_3} \cdot V_{REF}$$

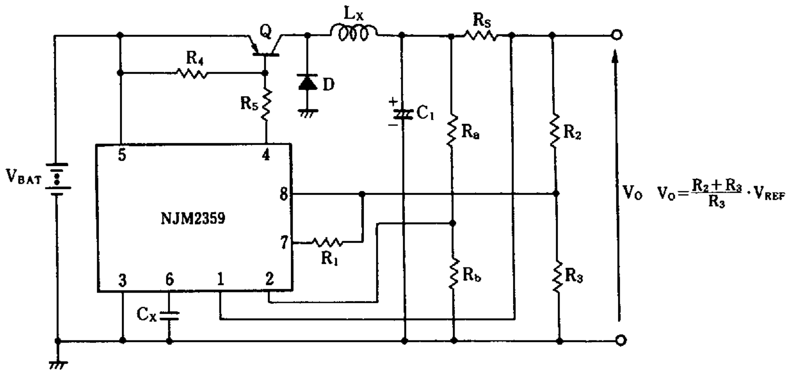
2) Step-Up Switching Regurator (High Current)



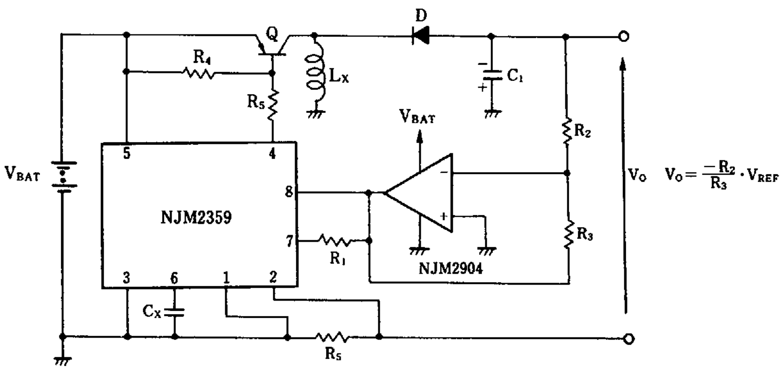
$$V_O = \frac{R_2 + R_3}{R_3} \cdot V_{REF}$$

■ Typical Applications

3) Step-Down Switching Regurator



4) Inverting Switching Regurator



(note) The operating voltage of the NJM2904 is 3.0V to 32V. Use a low operating volgtage operational amplifier instead of the NJM2904 when V_{BAT} is used at 3V or less (2.6V to 3.0V). In this case,operatiomal amplifier output Voltage should be greater than V_{REF}.

■ Design Equations

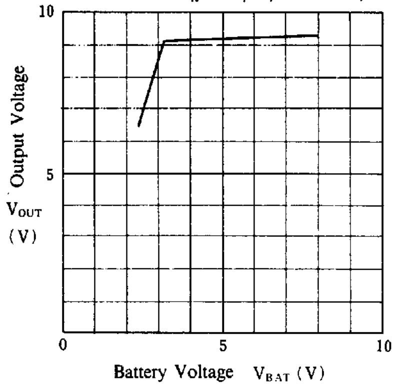
Component	Step-UP	Step-Down	Inverting
R_1	$R_1=R_3\times10$	$R_1=R_3\times10$	$R_1=R_3\times10$
R_2	$\frac{V_{OUT}-V_{REF}}{I_1}$	$\frac{V_{OUT}-V_{REF}}{I_1}$	$\frac{V_{OUT}}{I_1}$
R_3	$\frac{V_{REF}}{I_1}$	$\frac{V_{REF}}{I_1}$	$\frac{V_{REF}}{I_1}$
Cx(pF)	$\frac{2.5\times10^6}{Fo(Hz)}$	$\frac{2.5\times10^6}{Fo(Hz)}$	$\frac{2.5\times10^6}{Fo(Hz)}$
Lx	$\frac{0.3(V_{BAT})(V_{OUT}-V_{BAT})}{Fo(I_{LOAD})(V_{OUT})}$	$\frac{0.3(V_{OUT})}{Fo(I_{LOAD})}$	$\frac{0.3(V_{BAT})(\lvert V_{OUT}\rvert)}{Fo(I_{LOAD})(V_{BAT}+\lvert V_{OUT}\rvert)}$
C_1	$\frac{2(V_{OUT})-(V_{BAT})}{4Fo(V_{OUT})V_R}$	$\frac{I_{LOAD}}{4Fo(V_R)}$	$\frac{0.15(I_{LOAD})(V_{BAT}+2\lvert V_{OUT}\rvert)^2}{Fo(V_{BAT})(V_{BAT}+\lvert V_{OUT}\rvert)V_R}$
R_4	$\frac{35(V_{BAT})}{(I_{LOAD})(V_{OUT})}$	$\frac{35}{I_{LOAD}}$	$\frac{35(V_{BAT})}{(I_{LOAD})(V_{BAT}+\lvert V_{OUT}\rvert)}$
R_5	$\frac{5(V_{BAT})^2}{(I_{LOAD})(V_{OUT})}$	$\frac{5(V_{BAT})}{I_{LOAD}}$	$\frac{5(V_{BAT})^2}{(I_{LOAD})(V_{BAT}+\lvert V_{OUT}\rvert)}$
R_6	$\frac{350(V_{BAT})}{(I_{LOAD})(V_{OUT})}$		
R_7	$\frac{50(V_{BAT})^2}{(I_{LOAD})(V_{OUT})}$		

$I_1=100\mu A$
V_{BAT} : Battery Voltage
V_{OUT} : Output Voltage
V_{REF} : Reference Voltage
V_R : Ripple Voltage
I_{LOAD} : Load Current
Fo : Oscillator Frequency

■ Typical Characteristics (Application)

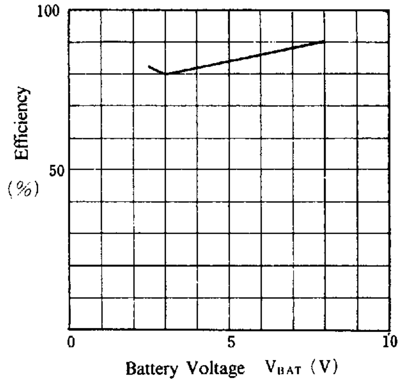
Step-Up Output Voltage vs. Battery Voltage

(I_L=10mA, C_X=50pF, C_I=100μF, L_X=470μH, Ta=25°C)



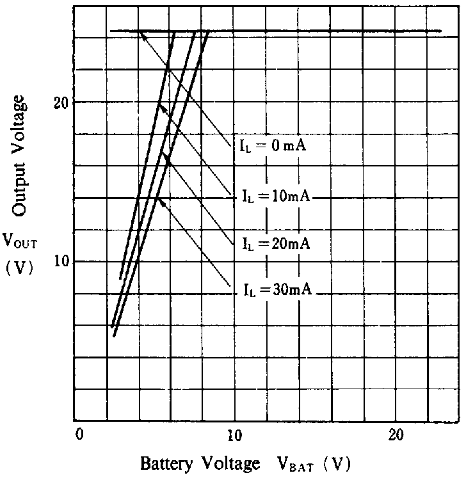
Step-Up Efficiency vs. Battery Voltage

(I_L=10mA, C_X=50pF, C_I=100μF, L_X=470μH, Ta=25°C)



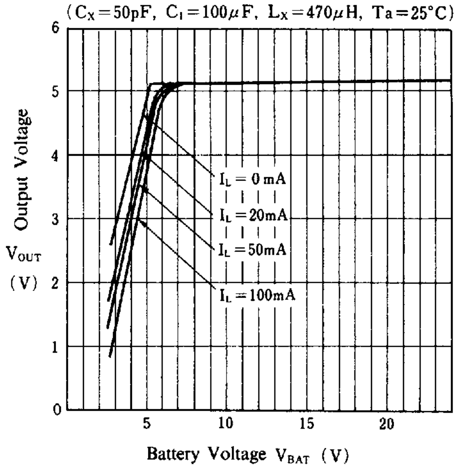
Step-Up Output Voltage vs. Battery Voltage

(C_X=20pF, C_I=100μF, L_X=470μH, Ta=25°C)



Step-Down Output Voltage vs. Battery Voltage

(C_X=50pF, C_I=100μF, L_X=470μH, Ta=25°C)



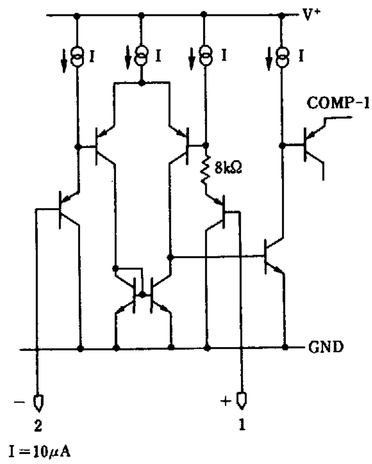
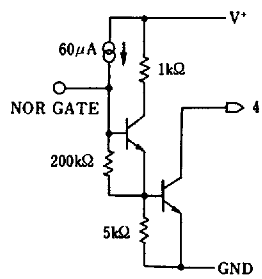
Detailed Description

The NJM2359 is a low power switching regulator IC containing a current protection circuit which may be used as a step-up, step-down and inverting regulator.

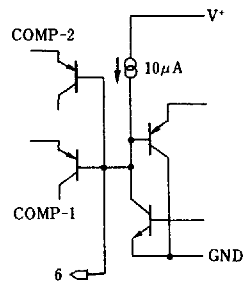
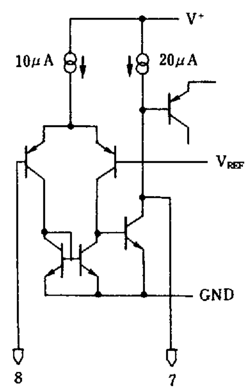
The NJM2359 consists of a reference, oscillator, amplifier comparator, and switching transistor. Output voltage is controlled using the PWM method.

The NJM 2359 employs band gap as a reference voltage. The oscillator frequency is set by the value of the capacitor connected to pin 6. The amplifier has an open-loop gain of 80dB and 1MHz bandwidth. The converted voltage of the output current of the external resistors is sent to pins 1 and 2 of the over current protection circuit. Over current protection characteristics are determined by the value of the external resistors.

Terminal Explanation

Pin NO.	Symbol	Function	Inside Equivalent Circuit
1	C.L 1	Non-inverting input with offset voltage of comparator 3 of the over current protection circuit.	
2	C.L 2	Inverting input of comparator 3 of the over current protection circuit.	
3	GND	Ground	
4	Lx	Switching transistor open collector output	

■ Terminal Explanation

Pin NO.	Symbol	Function	Inside Equivalent Circuit
5	V^+	Supply Voltage	
6	Cx	Sets oscillator frequency by connecting capacitor	
7	NF 2	Amplifier Output Comparator 1 inverting input	
8	NF 1	Amplifier inverting input	

■ Operation Description

The internal block diagram is shown in Fig.1 and the waveform is shown in Fig.2. The oscillator OSC charges and discharges the capacitor attached to pin 6 between the lower limit one V_{BE} and the upper limit three V_{BE}. there is a square waveform at point a, a triangular waveform at point b. By putting two input signals (a, b) into COMP-2, output (point c) voltage is held at high level during the rising period of the triangular waveform and the switching transistor is kept off regardless of the COMP-1 and COMP-3 output levels. Accordingly, the maximum duty ratio is 50 percent.

When COMP-2 output level is low, the switching transistor with high COMP-1 output is turned off and the switching transistor with low COMP-1 output is turned on. The function of COMP-1 is thus pulse width modulation. When the AMP output waveform is d, the COMP-1 output waveform is like e. NOR GATE output goes high only when two input signals (c, e) are low. The falling period of the triangular waveform is like e. NOR GATE output goes high only when two input signals (c,e) are low. The falling period of the triangular waveform is thus the pulse width control range.

When the differential voltage which arises at the over current detection resistor exceeds the COMP-3 offset voltage, the COMP-3 output is low and the switching transistor turned off.

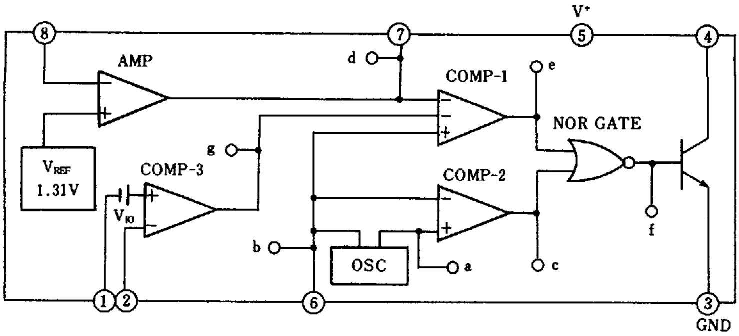


Fig.1 Bolck Diagram

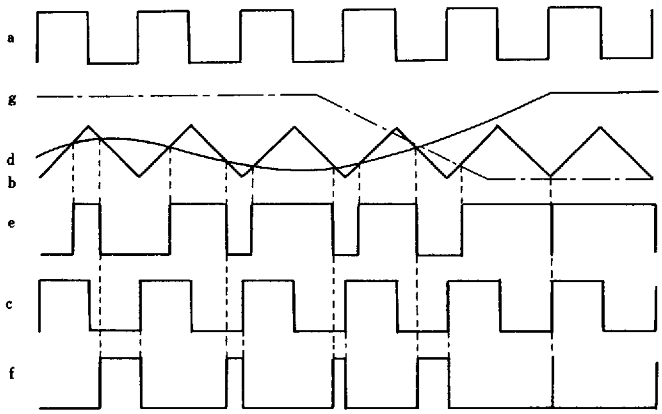


Fig.2 Timing Chart

■ Notes

1. Minimum Operating Voltage

   Minimum operating voltage is $V^+=2.6V$ at 25℃ and the temperature coefficient is negative. Please take this into account during designing.

2. Oscillator

   The oscillator frequency is set by a capacitor attached to pin 6.

3. Amplifier

   Since the AMP source current is 20μA maximum, the feedback resistor connected between pins 7 and 8 should be over 100kΩ.

4. Switching Transistor

   Due to the fact that the switching transistor is protected from malfunction by parasitic effect, the NJM2359 does not have to be clamped by external components.

5. Over Current Protection

   Connect to ground pins 1 and 2 when not using over current protection.

   In Fig.5-1, the input voltage of E_1 and E_2 of COMP-3 is

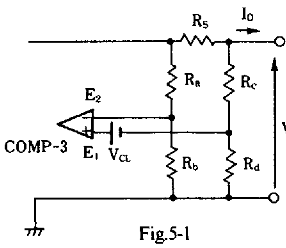


Fig.5-1

$$E_1=V_O\frac{R_d}{R_c+R_d}+V_{CL} \quad \cdots\cdots(1)$$

$$E_2=(V_O+I_OR_S)\frac{R_b}{R_a+R_b} \cdots\cdots(2)$$

If the COMP-3 input voltage is taken to be $E_1=E_2$, the output current I_O which is detected as the over current is

$$V_O\frac{R_d}{R_c+R_d}+V_{CL}=(V_O+I_OR_S)\frac{R_b}{R_a+R_b}$$

$$I_OR_S=\frac{R_a+R_b}{R_b}(V_O\frac{R_d}{R_c+R_d}+V_{CL})-V_O$$

$$=\frac{R_a+R_b}{R_b}\{V_O(\frac{R_d}{R_c+R_d}-\frac{R_b}{R_a+R_b})+V_{CL}\}$$

$$I_O=\frac{1}{R_S}\frac{R_a+R_b}{R_b}\{V_O(\frac{R_d}{R_c+R_d}-\frac{R_b}{R_a+R_b})+V_{CL}\} \quad \cdots\cdots(3)$$

6. Constant Current Limiting

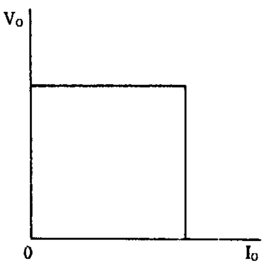


Fig.6-1

R_a to R_b are the comparator input voltage range adjustment resistors. In order to make constant current limiting, design with conditions $R_a=R_c$, $R_b=R_d$. The comparator input voltage range is −0.3V to V^+-2V. If the output voltage V_O is within this range, R_a to R_d are unnecessary (Fig. 6-2). When V_O < 0V, R_s should be inserted into the GND side (Fig.6-3).

$R_a=R_c$, $R_b=R_d$ are substituted into formula (3).

$$I_O=\frac{1}{R_s}\frac{R_a+R_b}{R_b}\{V_O(\frac{R_b}{R_a+R_b}-\frac{R_b}{R_a+R_b})+V_{CL}\}$$

$$=\frac{1}{R_s}\frac{R_a+R_b}{R_b}V_{CL} \cdots\cdots(4)$$

$R_a=0$, $R_b=$infinity are substituted into formula (4).

$$I_O=\frac{1}{R_s}V_{CL} \cdots\cdots(5)$$

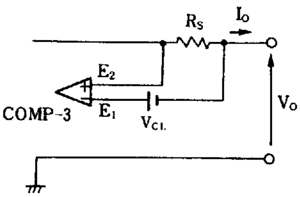


Fig.6-2

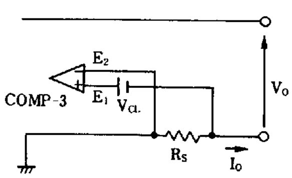


Fig.6-3

7. Foldback Current Limiting

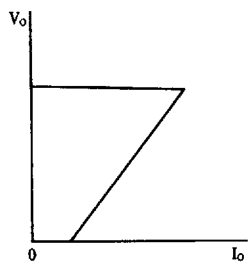


Fig.7-1

R_a to R_d are set as desired. If the output voltage V_O is within the comparator input voltage range, R_C and R_d are unneccesary.

Formula (3) can be applied as the design formula without any changes.

$$I_O=\frac{1}{R_s}\,\frac{R_a+R_b}{R_b}\left\{V_O\left(\frac{R_d}{R_c+R_d}-\frac{R_b}{R_a+R_b}\right)+V_{CL}\right\}$$

$R_c=0$, $R_d=$infinity are substituted into formula (3).

$$I_O=\frac{1}{R_s}\,\frac{R_a+R_b}{R_b}\left\{V_O\left(1-\frac{R_b}{R_a+R_b}\right)+V_{CL}\right\}$$

$$=\frac{1}{R_s}\,\frac{R_a+R_b}{R_b}\left(V_O\,\frac{R_a}{R_a+R_b}+V_{CL}\right)\quad\cdots\cdots(6)$$

note 1: When shorted, $I_O \fallingdotseq V_{CL}/R_S$ current flows.

note 2: If the over current protection is applied with the chopper method Step-up, the output current rises quickly when V_{IN} exceeds V_O. This is because, circuitwise, the input and output are shorted even though the switching transistor is turned off.

note 3: The noise portion of the output voltage increases due to over current protection. In order to restrain this noise, either increase the capacitance of an output capacitor or insert an RC filter as shown in Fig.7-3.

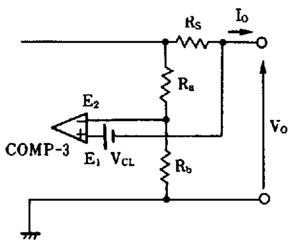


Fig.7-2

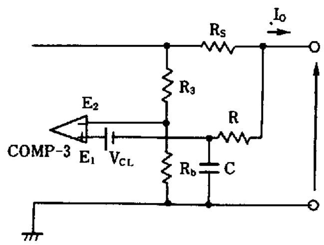
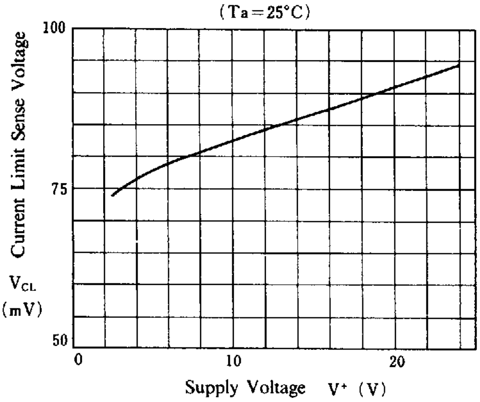


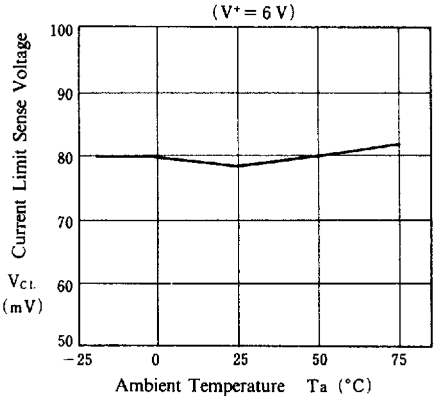
Fig.7-3

■ **Typical Characteristics**

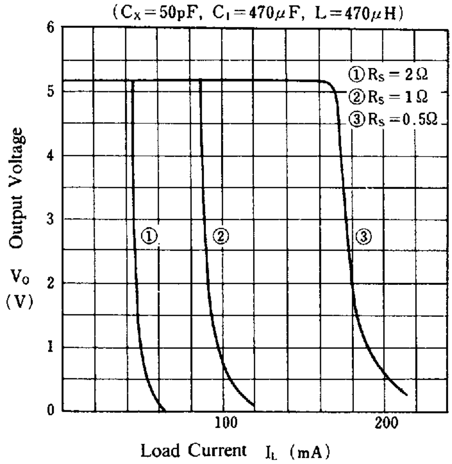
Current Limit Sense Voltage vs. Supply Voltage



Current Limit Sense Voltage vs. Temperature



Step-Down (V_{IN}=24V) Constant Current Limiting



Step-Down (V_{IN}=24V) Foldback Current Limiting