NJM2352

The NJM2352 is the industry's first monolithic low power switching regulators available in an 8-lead mini-DIP, and designed specifically for battery operated instruments. They each contain a 1.3V temperature compensated bandgap reference, adjustable free running oscillator, voltage comparator, low battery detection circuitry, and a 200mA switch transistor with all of the functions required to make a complete low power switching regulator.

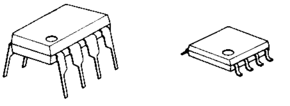
These regulators can achieve up to 80% efficiency in most applications while being able to operate over a wide input supply voltage range, 2.4V to 30V, at a very low quiescent drain of 280μA.

The NJM2352 can be used as a building block in three basic applications: step-up, step-down, and inverting.

■ Absolute Maximum Ratings (Ta=25°C)

Supply Voltage	V^+	24V
Power Dissipation	P_D (D-Type)	500mW
	(M-Type)	300mW
Operating Temperature Range	T_{opr}	−20~+75°C
Storage Temperature Range	T_{stg}	−40~+125°C

■ Package Outline



NJM2352D NJM2352M

■ Electrical Characteristics

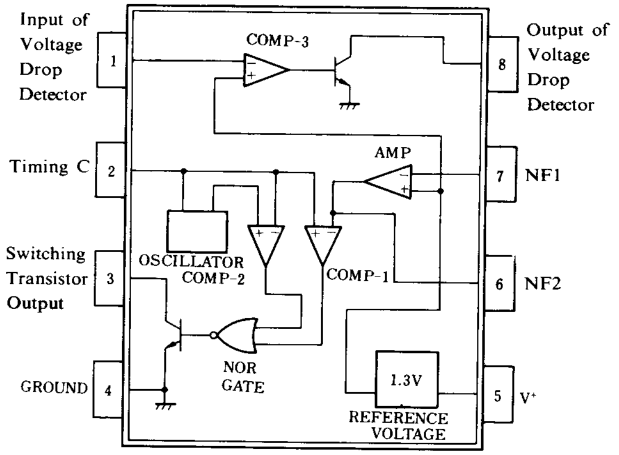
DC (V^+=6V, Ta=25°C)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Supply Current (1)	I_{cc} (1)		—	275	350	μA
Supply Current (2)	I_{cc} (2)	V^+=24V	—	400	550	μA
Reference Voltage	V_{REF}		1.24	1.31	1.38	V
Sw. Saturation Voltage	V_{SW}	I_{SW}=100mA	—	0.2	0.4	V
Sw. Current	I_{SW}	V_{SW}=0.4V	100	200	—	mA
Sw. Leakage Current	I_{SWO}	V③$_{PIN}$=24V	—	0.1	10	μA
Operating Frequency	F_O	C_X=50pF	40	50	60	kHz
Low Battery Output Current	I_{LED} (L)	V①$_{PIN}$=1.1V, V⑧$_{PIN}$=0.4V	300	800	—	μA
Low Battery Output Leakage Current	I_{LED} (H)	V①$_{PIN}$=1.4V, V⑧$_{PIN}$=6V	—	0.1	5	μA

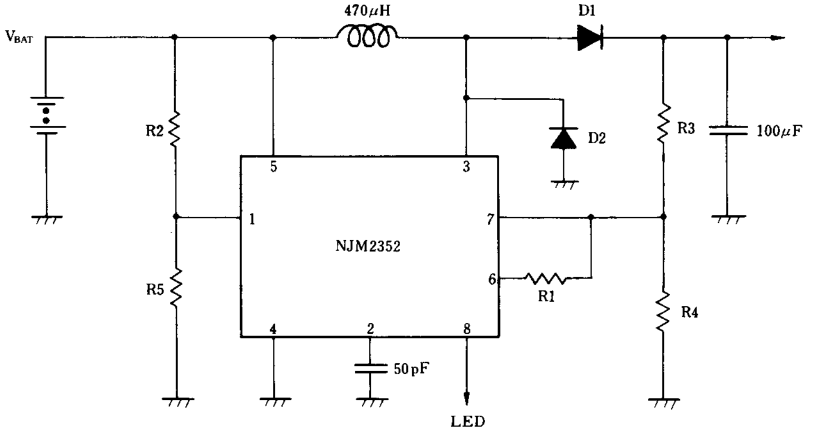
AC (STEP-UP, Ta=25°C)

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

■ **Block Diagram**



■ **Test Circuit**

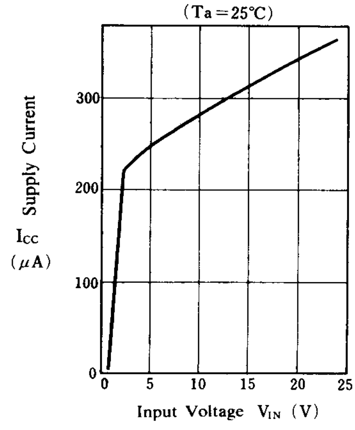


D2: SBD (EK-14)

■ Typical Characteristics

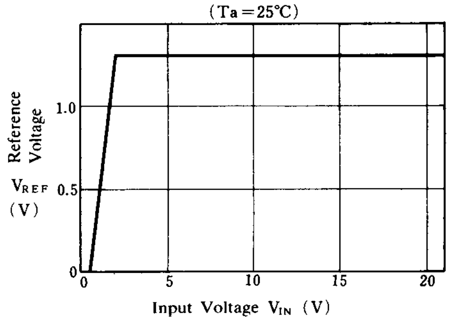
Supply Current

(Ta=25°C)



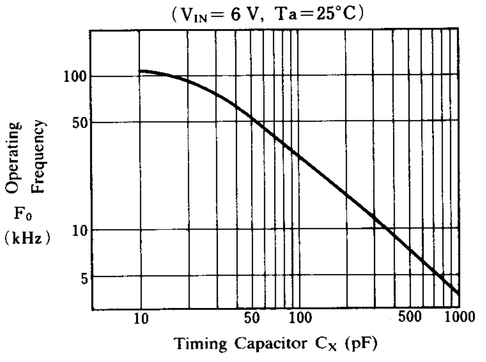
Reference Voltage

(Ta=25°C)



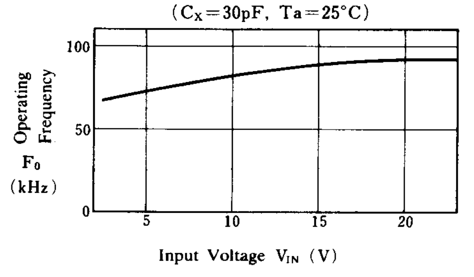
Operating Frequency

(VIN= 6 V, Ta=25°C)



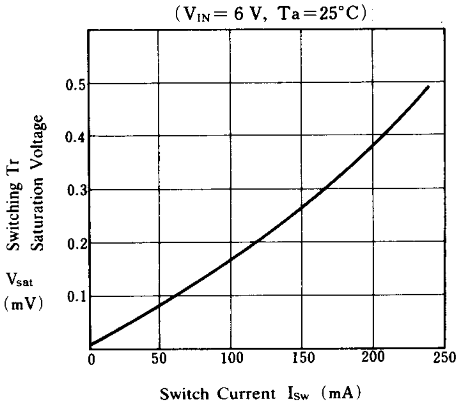
Operating Frequency

(CX=30pF, Ta=25°C)



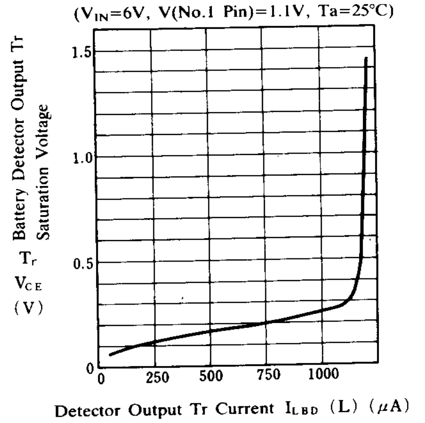
Switching Tr Saturation Voltage

(VIN= 6 V, Ta=25°C)



VCE (No. 8 Pin)

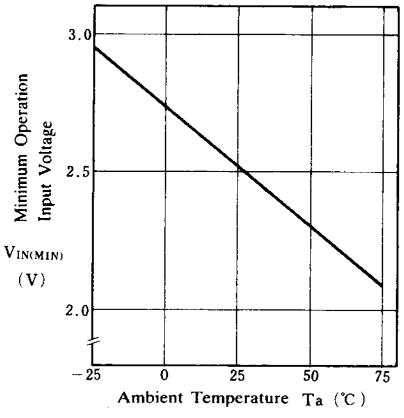
(VIN=6V, V(No.1 Pin)=1.1V, Ta=25°C)



■ **Typical Characteristics**

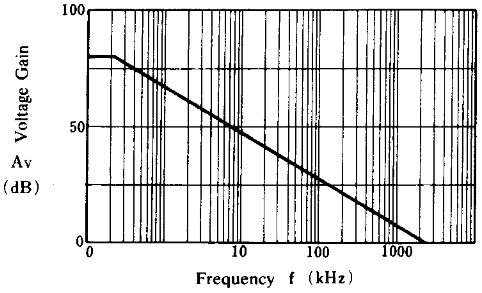
Minimum Operation Input Voltage

(Ta=25℃)



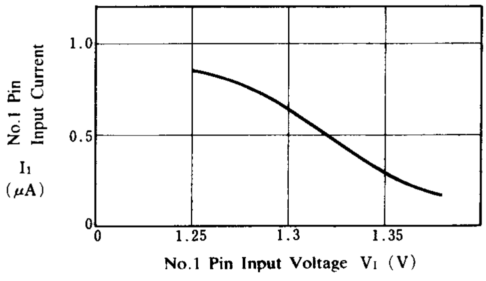
Voltage Gain

(VIN= 6 V, Ta=25℃)



No. 1 Pin Input Current

(VIN= 6 V, Ta=25℃)



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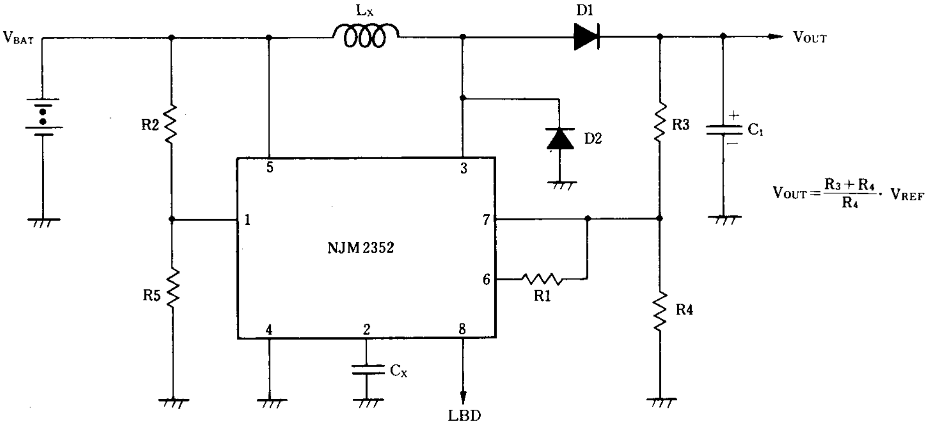
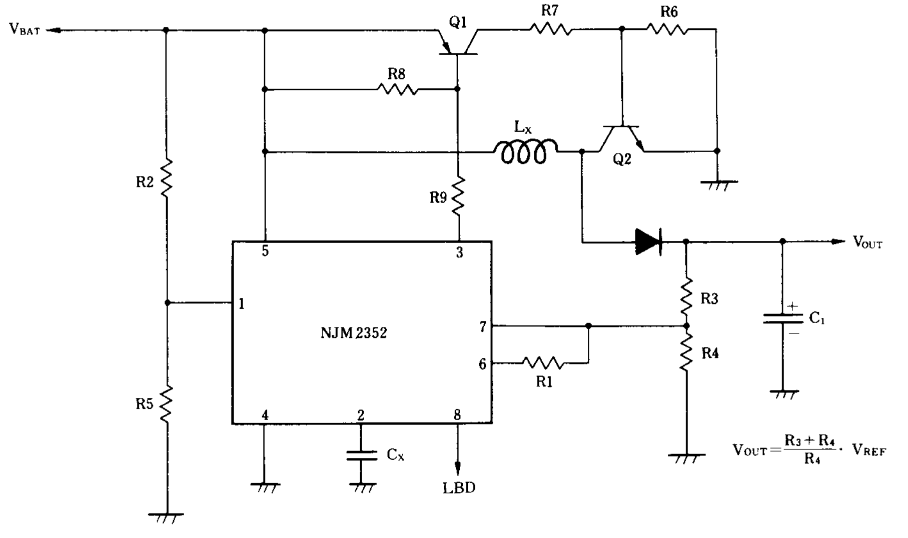
■ **Typical Application**

1. Step-Up Switching Regulator (Low Current)

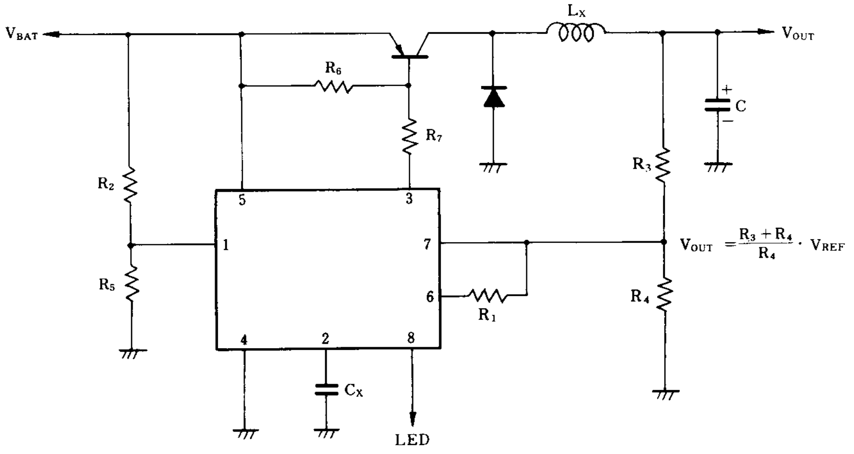


2. Step-Up Switching Regulator (High Current)

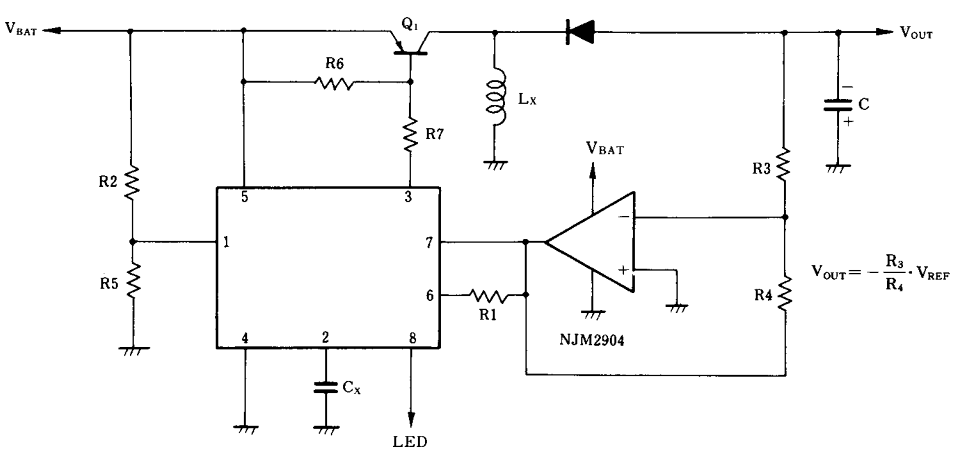


■ **Typical Application**

3. Step-Down Switching Regulator



4. Inverting Switching Regulator



■ 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	$\frac{V_{TH}-V_{REF}}{5\mu A}$	$\frac{V_{TH}-V_{REF}}{5\mu A}$	$\frac{V_{TH}-V_{REF}}{5\mu A}$
R_3	$\frac{V_{OUT}-V_{REF}}{I_1}$	$\frac{V_{OUT}-V_{REF}}{I_1}$	$\frac{V_{OUT}}{I_1}$
R_4	$\frac{V_{REF}}{I_1}$	$\frac{V_{REF}}{I_1}$	$\frac{V_{REF}}{I_1}$
R_5	261kΩ	261kΩ	261kΩ
C_x (pF)	$\frac{2.14\times10^6}{F_O\ (Hz)}$	$\frac{2.14\times10^6}{F_O\ (Hz)}$	$\frac{2.14\times10^6}{F_O\ (Hz)}$
L_X	$\frac{0.3\ (V_{BAT})\ (V_{OUT}-V_{BAT})}{F_O\ (I_{LOAD})\ (V_{OUT})}$	$\frac{0.3\ (V_{OUT})}{F_O\ (I_{LOAD})}$	$\frac{0.3\ (V_{BAT})\ (\lvert V_{OUT}\rvert)}{F_O\ (I_{LOAD})\ (V_{BAT}+\lvert V_{OUT}\rvert)}$
C_1	$\frac{0.15(I_{LOAD})(2V_{OUT}-V_{BAT})^2}{F_O\cdot V_{OUT}\cdot V_R\cdot V_{BAT}}$	$\frac{I_{LOAD}}{4F_O\ (V_R)}$	$\frac{0.15I_{LOAD}\ (V_{BAT}+2\lvert V_{OUT}\rvert)^2}{F_O\ (V_{BAT})\ (V_{BAT}+\lvert V_{OUT}\rvert)\ V_R}$
R_6	$\frac{35V_{BAT}}{(I_{LOAD})\ (V_{OUT})}$	$\frac{35}{I_{LOAD}}$	$\frac{35\ (V_{BAT})}{(I_{LOAD})\ (V_{BAT}+\lvert V_{OUT}\rvert)}$
R_7	$\frac{5\ (V_{BAT})^2}{(I_{LOAD})\ (V_{OUT})}$	$\frac{5\ V_{BAT}}{I_{LOAD}}$	$\frac{5\ (V_{BAT})^2}{(I_{LOAD})\ (V_{BAT}+\lvert V_{OUT}\rvert)}$
R_8	$\frac{350\ (V_{BAT})}{(I_{LOAD})\ (V_{OUT})}$		
R_9	$\frac{50\ (V_{BAT})^2}{(I_{LOAD})\ (V_{OUT})}$		

$I_1=100\mu A$
V_{TH}: Detection voltage of input voltage by design.
Ripple Voltage at V_R : $I_1=50\sim100\mu A$.

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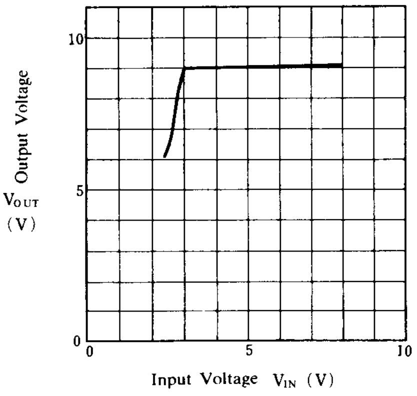
■ **Typical Characteristics (Application)**

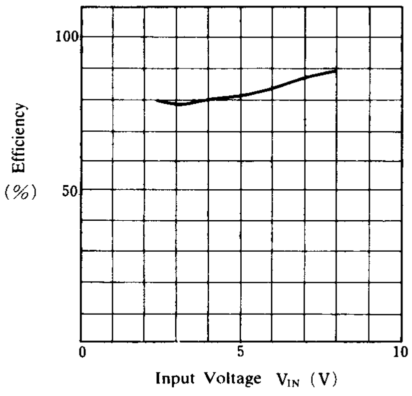
Output Voltage

(IL=10mA, Vo=9 V, Lx=470μH, Cx=50pF, CI=100μF, Ta=25℃)



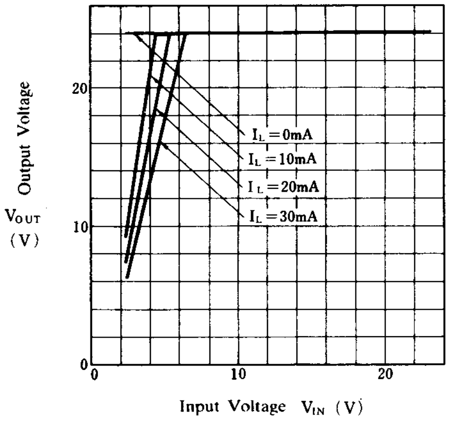
Efficiency

(IL=10mA, Vo=9 V, Lx=470μH, Cx=50pF, CI=100μF, Ta=25℃)



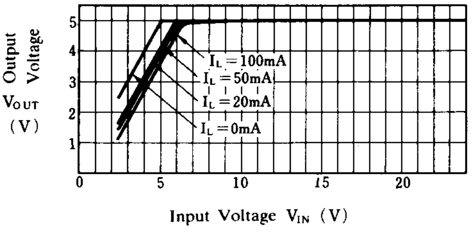
Output Voltage

(Lx=470μH, Cx=20pF, CI=100μF, Vo =24V, Ta=25℃)



Output Voltage

(Lx=470μH, Cx=50pF, CI=100μF, Vo=5 V, Ta=25℃)



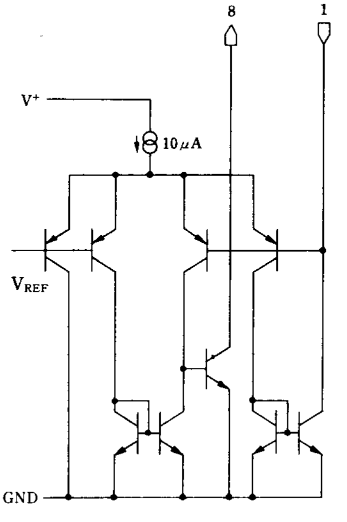
■ Description

The NJM2352 is a micro-power switching regulator control IC suitable for a equipment of battery operation and may be used as step-up, step-down and inverting regulators.

The NJM2352 contains a reference, oscillator, amplifier, comparator, indicator of input voltage drop and switching transistor. The output voltage is controled by PWM method.

The NJM2352 applies a bandgap as a reference voltage. The oscillator is composed of putting one capacitance (C_X) to the pin 2. The amplifier is 80dB open-loop voltage gain and 1MHz band width. By adding adequate resistors to the pin 1, the indicating signal comes when the input voltage drops more than designed input voltage. Switching transistor is open collector.

■ Terminal Description

Terminal No.	Terminal Items	Function	Inside Equivalent Circuits
1	Input of Voltage Drop Detector	Inverting input Terminal of comparator-3. When input voltage drops than non-inverting input voltage, comparator drives indicator output transistor.	
8	Output of Voltage Drop Detector	Open collector output transistor for driving LED, LCD etc.	

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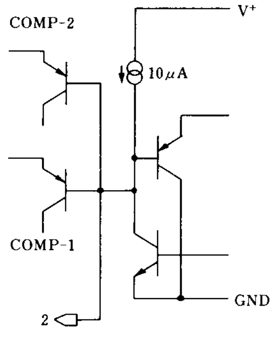
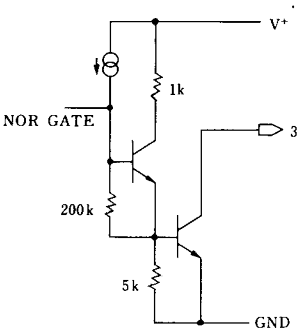
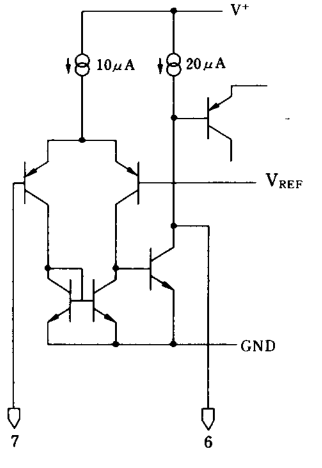
■ **Terminal Description**

Terminal No.	Terminal Items	Function	Inside Equivalent Circuits
2	Timing C	Connecting timing for deciding oscillator frequency.	
3	Switching Transistor Output	Open collector Output of switching transistor.	
4	GROUND	Ground	
5	V+	Supply voltage terminal.	

■ Terminal Description

Terminal No.	Terminal Items	Function	Inside Equivalent Circuits
6	NF2	Terminal from connecting point of AMP output and COMP-1 inverting input.	
7	NF1	Inverting input of amplifier.	

■ Principle of Operation

The NJM2352 circuit block is shown on Fig. 1 and timing chart on Fig. 2. Function of COMP-2 is setting dead-time. At point Ⓐ is the square wave and at point B is the triangular wave. By putting two input signals (Ⓐ, Ⓑ) into COMP-2, output (point Ⓒ) voltage is held high level during rising period of triangular wave and the switching transistor is kept in the off condition regardless the COMP-1 output level. So the maximum duty cycle of the NJM2352 is 50%.

The COMP-1 makes on-time of switching transistor longer when the output voltage is high and shorter when it is low. Thus function of the COMP-1 is pulse wide modulation. When the AMP's output waveform is Ⓓ, COMP-1 output is like Ⓔ, and NOR GATE output becomes high level only when both inputs, Ⓒ, Ⓔ, are low, and so the falling period of triangular wave is the range of pulse width control.

Fig. 1

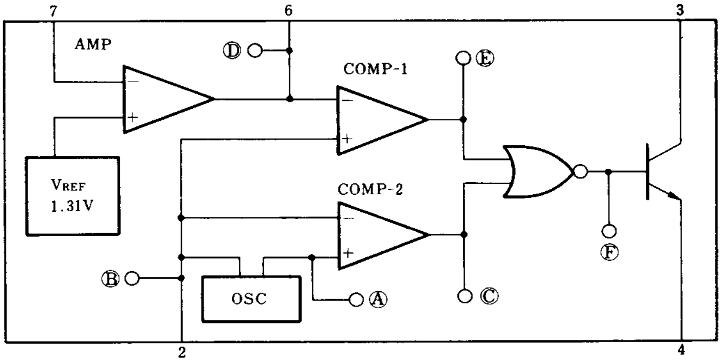
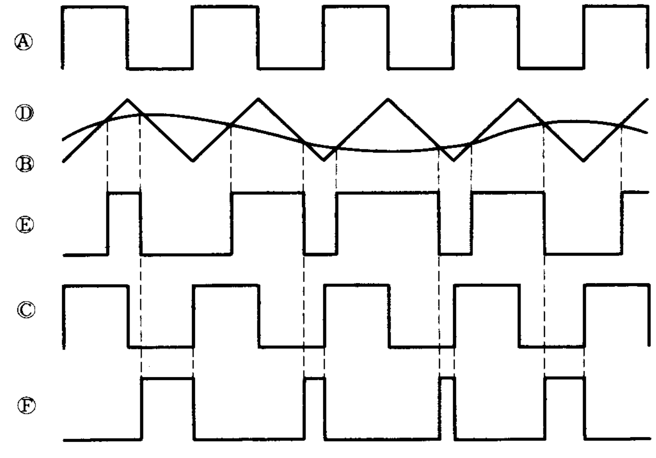


Fig. 2



■ Minimum Operating Voltage

Minimum operating voltage is $V^+ \geqq 2.6V$ at 25°C and its temperature coefficient is negative. Be careful when you design. Less than this minimum operating voltage, internal switching transistor becomes on, and the surge-like high current flows into it especially in Step-Up or Inverting application.

■ Oscillator

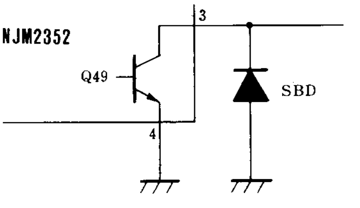
Oscillator frequency is decided by putting a capacitor into PIN 2. The amplitude of both square wave Ⓐ and triangular wave Ⓑ is between 1 V_{BE} and 3 V_{BE}.

■ Amplifier

AMP source current it 20μA max.and so the feedback resistor R_1 to be connected to PIN 6 and PIN 7 are recommended more than 100kΩ.

■ Switching Transistor

When the negative voltage more than 0.5V absolute value based on ground level is applied, the NJM2352 may operate unordinary by reason of parasitic effect in it. And so put SBD in between PIN 3 and ground when you drive directory coil with internal switching transistor.



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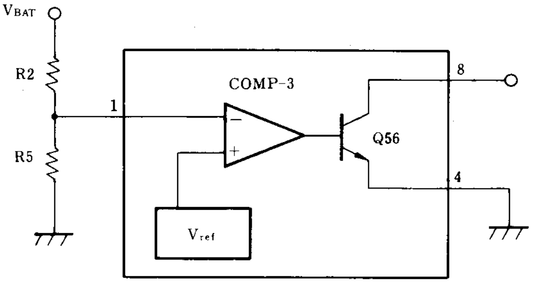
■ Detection Circuit of Input Voltage Drop

When input voltage becomes lower than specified voltage, transistor Q_{56} switches on and indicative device like LED turns on. The specified voltage is decided by internal reference voltage and outer resistors ratio.

$$V_{TH}=V_{REF}(1+R2/R5)+R2\times 0.5\mu A$$

When ⊖ input voltage becomes lower than ⊕ input voltage, PIN 1 of COMP-3 sinks about 1μA and thus prevents chattering. Transistor Q_{56} becomes off condition when PIN 1 voltage is lower than about 0.2V. It is recommendable to put about 1μF to PIN 1 in actual application to avoid switching noise.



■ Efficiency

Efficiency is shown below.

$$\text{Step Up} = \frac{V_{IN}-V_S}{V_{IN}} \times \frac{V_{OUT}}{V_{OUT}+V_D-V_S}$$

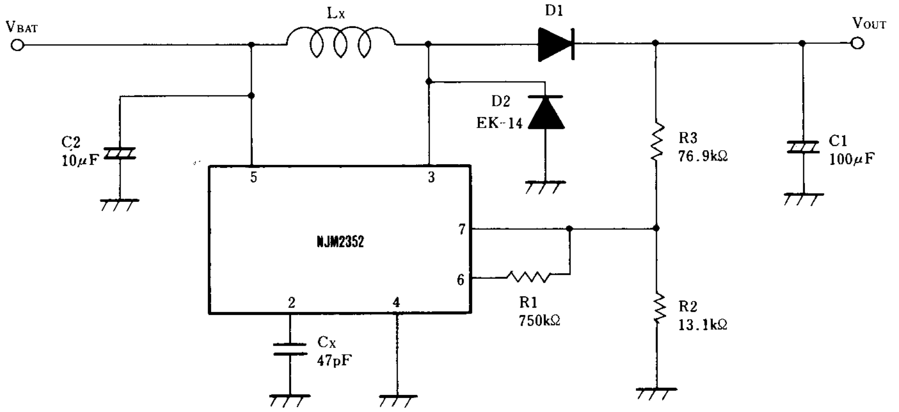
$$\text{Step Down} = \frac{V_{IN}-V_S+V_D}{V_{IN}} \times \frac{V_{OUT}}{V_{OUT}+V_D}$$

$$\text{Inverting} = \frac{V_{IN}-V_S}{V_{IN}} \times \frac{|V_{OUT}|}{|V_{OUT}|+V_D}$$

V_S : Voltage Drop based on Switching Transistor On-Resistance.
V_D : Diode Forward Voltage Drop.

If V_S and V_D are low, efficiency increase. Also speed of switching transistor and diode, series resistance of L will affect to it. Example is shown on typical characteristic graph.

■ Test Circuits 2 (V_{OUT}: 9V)



■ Parameter

- D1
  - EK-14
  - IS1588
- L_X=470µH
  - L1 : Internal Resistance = 0.2Ω
  - L2 : Internal Resistance = 2Ω
  - L3 : Internal Resistance = 7Ω

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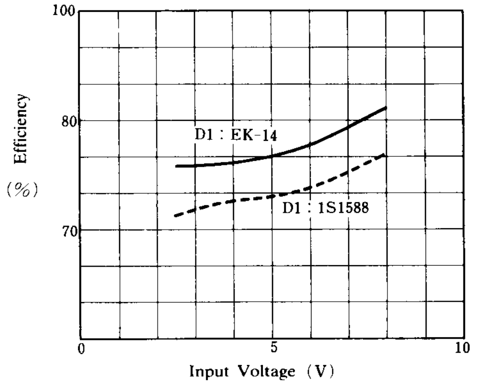
■ Typcial Characteristics
(Test Circuits 2)

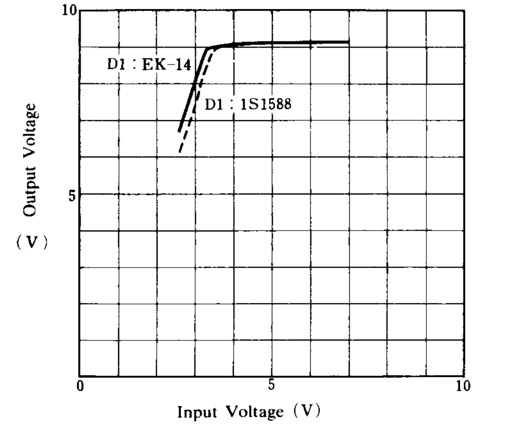
Efficiency

(L_X : L1, γ=0.2Ω, Load Current=10mA, Ta=25°C)



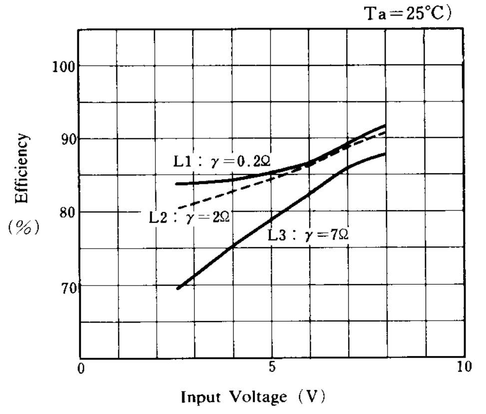
Output Voltage

(L_X : L1, γ=0.2Ω, Load Current=10mA, Ta=25°C)



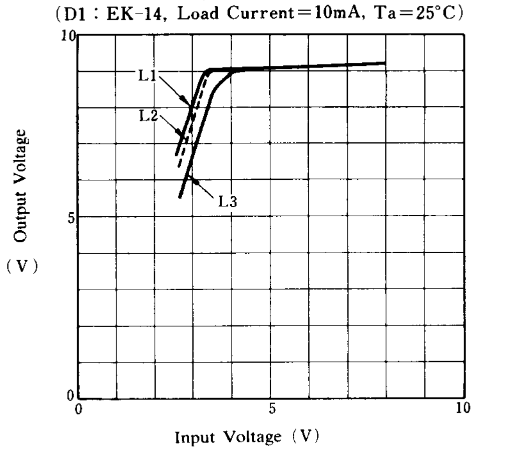
Efficiency

(D1 : EK-14, Load Current=10mA, Ta=25°C)



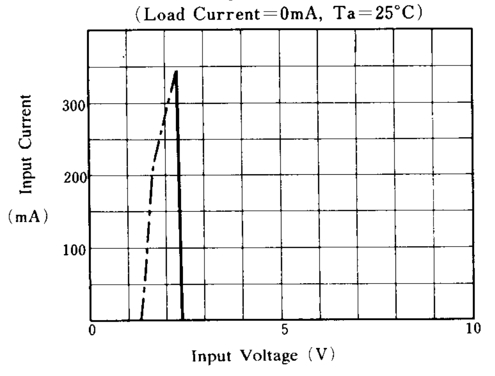
Output Voltage

(D1 : EK-14, Load Current=10mA, Ta=25°C)



Input Current

(Load Current=0mA, Ta=25°C)



Output Voltage

(Load Current=0mA, Ta=25°C)