1. Protection Circuit

(1) Positive Voltage 3-Terminal Regulator (Fig.1)

(1-1) Thermal Shut Down Circuit

The thermal shut down circuit cuts off the output voltage to drop down the temperature to the safe level when the junction temperature in the chip goes up to extreme high (T_j=150~200°C).

The transistor Q_4 is biased off normally at room temperature. When the junction temperature in the chip goes high, the output pass transistor Q_6 and Q_7 become cut off because the decreased V_{BE} turns on the transistor Q_4 then the transistor Q_4 makes a bypass of the base current of the transistor Q_6.

(1-2) Overcurrent Protection Circuit

The overcurrent protection circuit limits the current to protect the output pass transistor against the overcurrent like as accidental short-circuit, current overload.

When the output current increases, the voltage drop of the R_{10} increases, the transistor Q_5 turns on because the V_{BE} increases. Then the base current of the transistor Q_6 and the collector current of the transistor Q_7 (output current) are limited.

(1-3) Safe Operating Area Control Circuit

The safe operating area control circuit to protect the output pass transistor operation within the safe operating area by decreasing the output current when the input-output differential voltage increases.

When the input-output differential voltage increases over the breakdown voltage (BV_Z) of zener diode D_2, the breakdown current flows from V_{IN} to V_{OUT} (V_{IN}→R_7→D_2→R_9→R_{10}→V_{OUT}).

As the input-output differential voltage increases, the V_{BE} of the transistor Q_5 increases and the base current of the transistor Q_6 and the collector current of the transistor Q_7 (output current) are decreased. Then the output pass transistor operates within the safe operating area because the power consumption of the transistor Q_7 is decreased.

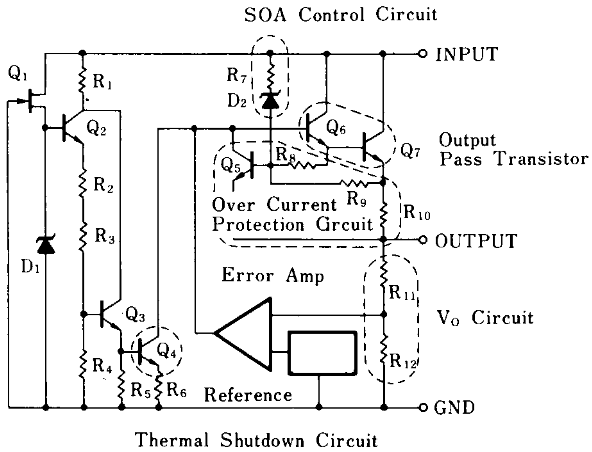


Fig. 1 NJM7800/78M00/78L00 Series Circuit Function

(2) Negative Voltage 3-Terminal Regulator (Fig. 2)

(2-1) Thermal Shut Down Circuit

The thermal shut down circuit cuts off the output voltage to drop down the temperature to the safe level when the junction temperature in the chip goes up to extreme high (Tj=150 to 200°C)

When the junction temperature in the chip goes high, the output pass transistor Q_9, Q_{11} and Q_{12} become cut off because the decreased V_{BE} of the transistor Q_3 turns on the transistor Q_5 then the transistor Q_5 makes a bypass of the base current of the transistor Q_9.

(2-2) Overcurrent Protection Circuit

The overcurrent protection circuit limits the current to protect the output pass transistor against the over current like as accidental short-circuit, current overload.

When the output current increases, the voltage drop of the R_{16} increases, the transistor Q_8 and Q_7 turn on because the V_{BE} of the transistor Q_8 increases.

Then the base current of the transistor Q_9 and the collector current of the transistor Q_{12} (output current) are limited.

(2-3) Safe Operating Area Control Circuit

The safe operating area control circuit to protect the output pass transistor operation within the safe operating area by decreasing the output current when the input-output differential voltage increases.

When the input-output differential voltage increases over the breakdown voltage (BV_Z) of zener diode D_3, the breakdown current flows from COM to V_{IN} (COM→Q_{10}→D_3→R_{12}→R_{17}→R_{16}→V_{IN}).
As the input-output differential voltage increases, the V_{BE} of the transistor Q_8 increases and the base current of the transistor Q_9 and the collector current of the transistor Q_{12} (output current) are decreased. Then the output pass transistor operates within the safe operating area because the power consumption of the transistor Q_{12} is decreased.

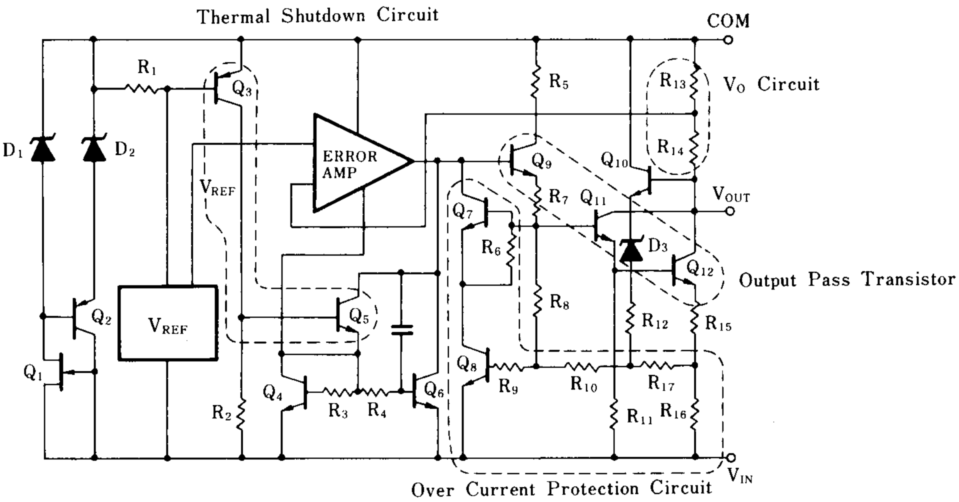


Fig. 2 NJM7900/79M00 Series Circuit Function

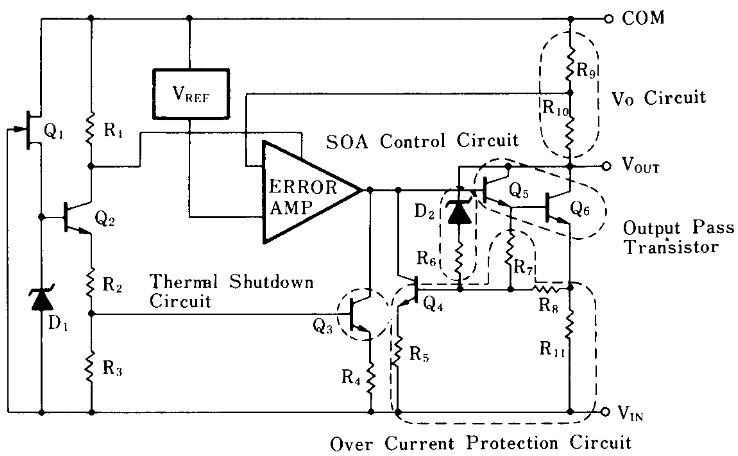
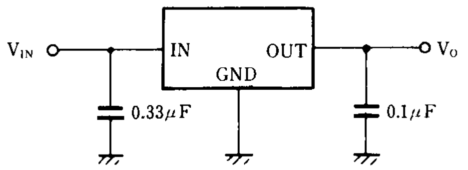


Fig. 3 NJM79L00 Series Circuit Function

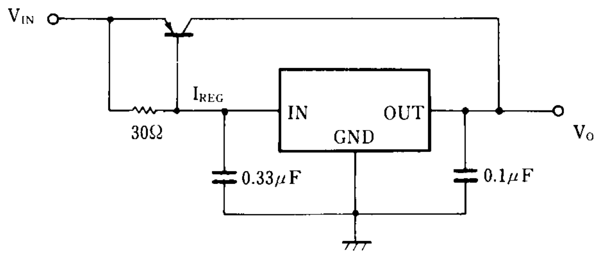
2. Application Circuit (78/78M/78L, 79/79M/79L)

In the following explain only the positive regulator unless otherwise specified. However they can apply to the negative voltage regulator by easy change.

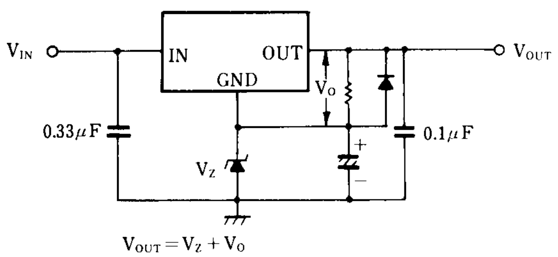
Typical Application



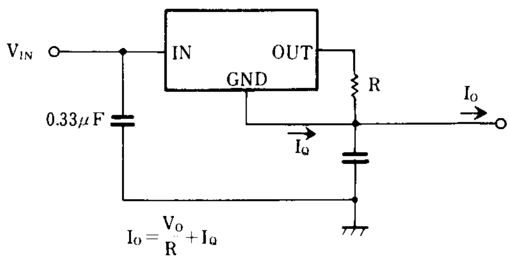
Current Boost Circuit (no short protection)



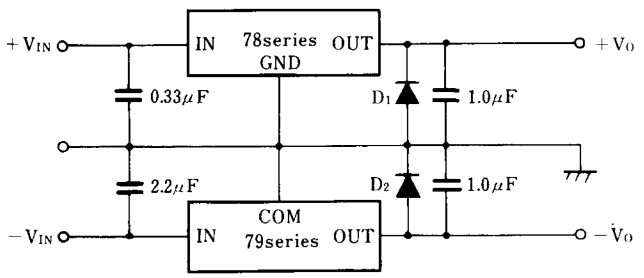
Output Voltage Boost Circuit



Constant Current Circuit



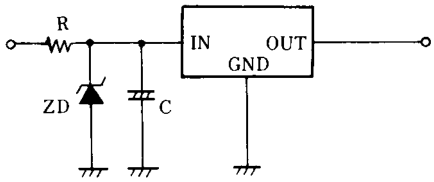
Positive/Negative Voltage Supply

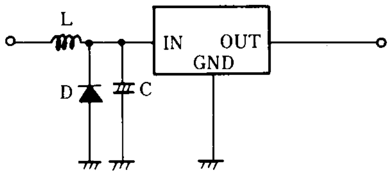


note) In the above positive and negative power supply application, D_1 and D_2 should be connected. If D_1 and D_2 are not connected, either of positive or negative power supply circuit may not turns on.

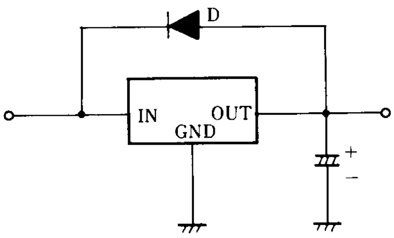
3. Note in Application Circuit

(1) If the higher voltage (above the rated value) or lower voltage (GND-0.5V) is supplied to the input terminals, the IC may be destroyed. To avoid such a case, a zener diode or other parts of the surge suppressor should be connected as shown below.





(2) If the higher voltage than the input terminal is supplied to the output terminal, the IC may be destroyed. To avoid input terminal short to the GND or the stored voltage in the capacitor back to the output terminal, by the large value capacitor connecting to the output terminal application, the SBD should be required as shown below;



* In case of negative voltage regulator, reverse the SBD and capacitor direction.

4. Package

(1) SOT-89 Package

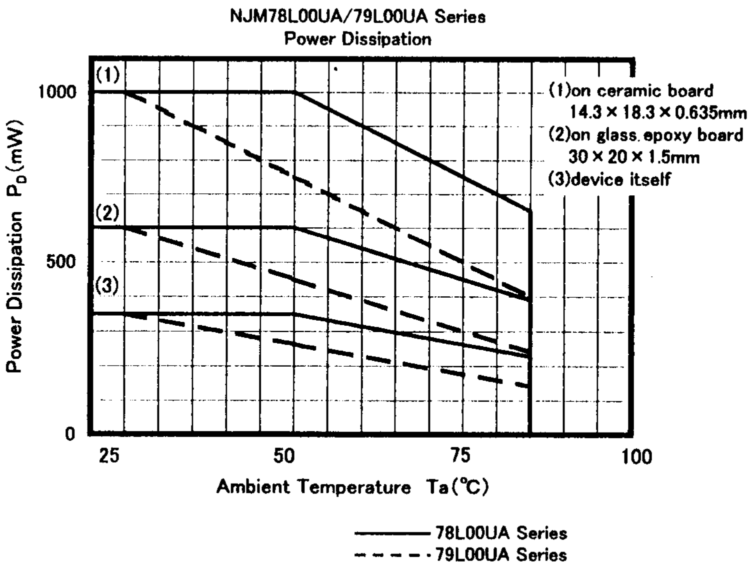
SOT-89 is a surface mount type package for low power 3-terminal voltage regulator.

(1-1) Features
1. Ultra miniature size
2. Surface mount type
3. Apply to the automatic mounter

(1-2) Structure

Refer to "IC PACKAGE DATA BOOK".

(1-3) Applied product Line up
1. NJM78L00UA/79L00UA
2. NJM431U
3. NJU7201U/7221U series
4. NJU7202U/7222U series
5. NJU7211U series
6. NJU7212U series



(2) TO-220F Package

TO-220F is fully covered plastic mold package of TO-220 for middle and high power 3-terminal voltage retulator, and is compatible with TO-220 package.

(2-1) Features

TO-220F has some features as follows, because of fully covering the own radiation fin by high thermal conductive epoxy resin.

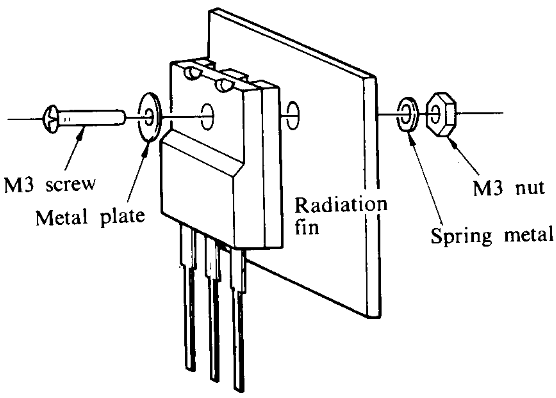
1. No Insulator between IC and heat sink is required.
2. Increase the power dissipation itself.
3. High density mounting.

(2-2) Structure

Refer to "IC PACKAGE DATA BOOK".

(2-3) Mounting Method

Refer to the following figure.



(2-4) Recommended Bolt Tighten Torque

recommended bolt tighten torque ≤ 0.6N·m

(3) Applied Product Line-up

Type No.	V_{OUT} [V]	Polarity	I_{OUT} [A]
NJM78M00FA Series	5, 6, 8, 9, 12 15, 18, 20, 24	Positive	0.5
NJM7800FA Series	5, 6, 8, 9, 12 15, 18, 20, 24	Positive	1.5
NJM79M00FA Series	5, 6, 8, 9, 12 15, 18, 24	Negative	0.5
NJM7900FA Series	5, 6, 8, 9, 12 15, 18, 24	Negative	1.5

5. Thermal Design

(1) Heat Producing

There are two kinds of heat producing (P_{LOSS-1}, P_{LOSS-2}) in three terminal regulator and the sum of them is total heat producing of the IC (P_{LOSS}).

(1-1) P_{LOSS-1} : heat producing by own operation

Input voltage (V_{IN}) and quiescent current (I_Q) produce the heat mentioned below equation.

$$P_{LOSS-1} = V_{IN} \times I_Q \text{ (W)}$$

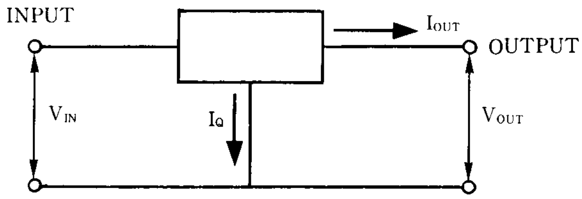


Fig. 1

(1-2) P_{LOSS-2} : heat producing by output current and the input-output differential voltage Internal power transistor produces the heat mentioned following equation.

$$P_{LOSS-2} = (V_{IN}-V_{OUT}) \times I_{OUT} \qquad \text{(W)}$$

Therefore, the total heat producing P_{LOSS} is :

$$P_{LOSS} = P_{LOSS-1} + P_{LOSS-2}$$
$$= V_{IN} \times I_Q + (V_{IN}-V_{OUT}) \times I_{OUT} \qquad \text{(W)}$$

(2) Thermal Resistance

(2-1) Definition of Thermal Resistance : θ

Thermal resistance (θ) is a degree of heat radiation mentioned following equation.

$\theta = (T_1-T_2)/P$ (°C/W) Heat Producing Quantity : P (W)
Ambient Temperature : T_2 (°C)
Heat Source Temperature : T_1 (°C)

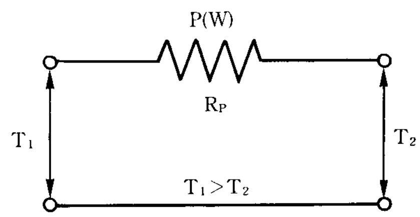


Fig. 2

(2-2) Thermal resistance of TO-220

There are two kinds of thermal resistance of TO-220. One is "θ jc" for the application with the heat sink, the other is "θja" for the application without the heat sink.

"θ jc": thermal resistance between IC chip (junction point) and the package back side contacting with the heat sink

"θ ja": thermal resistance between IC chip (junction point) and ambience

(2-3) Thermal resistance of TO-92

Thermal resistance of TO-92 is only θja because of the no heat sink required.

There are two measurement methods of θja mentioned following equation.

1. Calculation by the data of ambient temperature vs. power consumption

θ ja is calculated by the ratio of changes of ambient temperature ΔTa and the changes of power consumption ΔP_D, which called temperature decrease curve, in the ambient temperature (Ta) vs. power dissipation (P_D) figure.

The start temperature of temperature decrease curve is 25°C normally, but some of them start from 50°C.

$$\theta ja = \Delta Ta/\Delta P_D \qquad \text{(°C/W)}$$

2. Calculation by the absolute maximum ratings
θ ja is calculated by the maximum power dissipation ($P_D$max at Ta=25°C) and the maximum junction temperature (Tj max : apply the maximum strage temperature, 125°C) as mentioned below.

θ ja= (Tj max-Ta)/PD (°C/W) Ta=25°C

Note) (2-3) 2. is applied only for the device which specified the temperature decrease curve starting from 25°C

Typical Thermal Resistance Value

Thermal Resistance	TO-220	TO-220F	TO-92	UNIT
θ ja	70	60	200	°C/W
θ jc	5	5	—	°C/W

(3) Heat Radiation Balance
The heat produced in the IC is radiated to ambience through the package and the heat sink.
The quantity of the heat radiation depends on the heat source temperature, ambient temperature and the thermal resistance of the package.
(3-1) TO-220 with heat sink
Heat radiation balance model of the TO-220 with heat sink is shown as below.

Heat Radiation Quantity

Heat Source (junction) Temperature

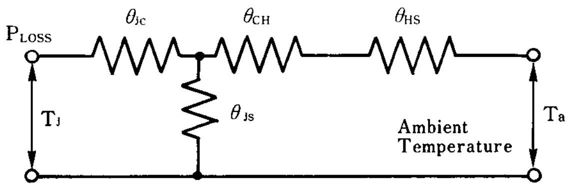
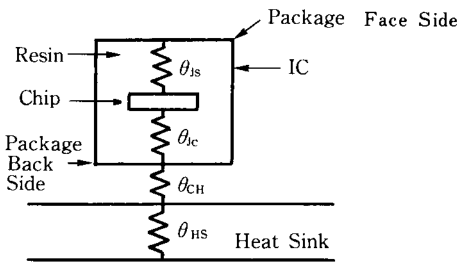


Fig. 3

where θ jc : thermal resistance between IC chip (junction point) and the package backside connecting to the heat sink
θ js : thermal resistance between IC chip (junction point) and package surface
θ_{CH} : thermal resistance between package backside and the heat sink including the condition of insulator, silicon grease and bolt tighten torque
θ_{HS} :: thermal resistance of the heat sink



If the θ js is large enough compare with other thermal resistance, the θ js can be neglected and the heat radiation model can be mentioned as below.

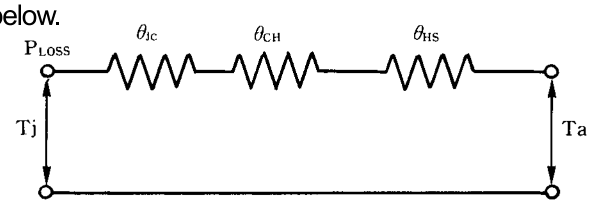


Fig. 4

The relation between temperature and heat radiation quantity is shown below.

$T_j = P_{LOSS} \times (\theta_{jc} + \theta_{CH} + \theta_{HS}) + T_a$ (°C)

(3-2) TO-92

Heat radiation balance model of the To-92 is shown as follows.

The relation between temperatures and heat radiation quantity is mentioned below.

$T_j = P_{LOSS} \times \theta_{ja} + T_a$ (°C)

Heat Source (junction)

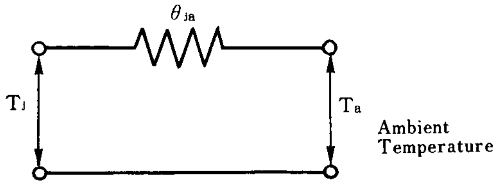


Fig. 5

(4) Thermal Design

The heat radiation balance model of the TO-220 with the heat sink is shown as follows.

Heat radiation balance

$T_j = P_{LOSS} \times (\theta_{jc} + \theta_{CH} + \theta_{HS}) + T_a$ (°C) (4-1)

$P_{LOSS} = V_{IN} \times I_Q + (V_{IN} - V_{OUT}) \times I_{OUT}$ (W) (4-2)

Substituting "Eq. (4-2)" into "Eq. (4-1)" obtains

$T_j = [V_{IN} \times I_Q + (V_{IN} - V_{OUT}) \times I_{OUT}] \times (\theta_{jc} + \theta_{CH} + \theta_{HS}) + T_a$ (°C) (4-3)

In Eq. (4-3)

V_{IN}, I_{OUT}, θ_{CH}, θ_{HS}, Ta depend on using condition.

Tj, I_Q, V_{OUT}, θ jc depend on IC specification.

When θ_{CH}, I_Q and Tj are assumed the following values,

Eq. (4-3) becomes Eq. (4-4).

θ_{CH} = 0.3 to 0.4(°C/W) Insert the mica paper (0.1t) and thermal conduction silicon grease between the IC and heat sink and tighten them with the bolt by 4Kg·cm-min.

I_Q = 5 to 6mA (max)

Tj =125°C (max)

$T_j(max) = 125 = [5 \times V_{IN} + (V_{IN} - V_{OUT}) \times I_{OUT}] \times (5 + 0.3 + \theta_{HS}) + T_a$ (°C) (4-4)

When fix the V_{OUT}, Tj depends on the V_{IN}, I_{OUT}, θ_{HS} and T_a.

It means :

Lower V_{IN} and/or I_{OUT} are required to limit the temperature rise.

Smaller θ_{HS} is required for the effective heat reduce (i. e. using the large heat sink).

In the termal design, when fix the V_{IN}, I_{OUT} and Ta, select the heat sink which θ_{HS} is smaller than the result of Eq. (4-4).

For more detail, please refer the heat resistance value mentioned in the specification of the heat sink supplier.