

### NOW SERIES

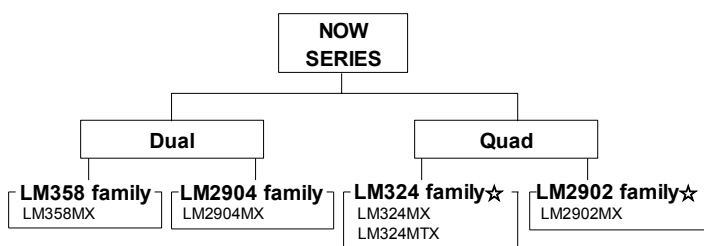


# Universal Standard Ground Sense Op-Amp.

LM358 family, LM324 family, LM2904 family, LM2902 family

#### ●Description

The Universal Standard family LM358/324, LM2904/2902 monolithic ICs integrate two independent op-amps and phase compensation capacitors on a single chip and feature high-gain, low power consumption, and an operating voltage range of 3[V] to 32[V] (single power supply.)

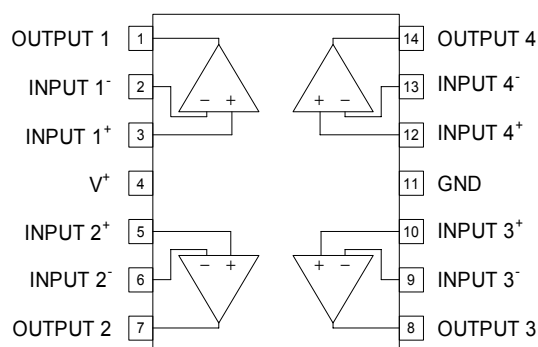
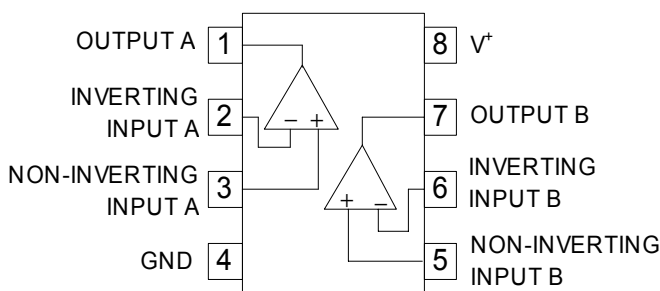


☆Under development

#### ●Characteristics

- 1) Operating temperature range  
Commercial Grade  
LM358/324 family: 0[°C] to +70[°C]  
Extended Industrial Grade  
LM2904/2902 family: -40[°C] to +125[°C]
- 2) Wide operating supply voltage  
+3[V] to +32[V] (single supply)  
± 1.5[V] to ± 16[V] (dual supply)
- 3) Low supply current
- 4) Common-mode input voltage range including ground
- 5) Differential input voltage range equal to maximum rated supply voltage
- 6) High large signal voltage gain
- 7) Wide output voltage range

#### ●Pin Assignment



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**SO package8**

LM358MX  
LM2904MX

**SO package 14**

LM324MX  
LM2902MX

**TSSOP14**

LM324MTX

## ● Absolute Maximum Ratings (Ta=25°C)

Parameter	Symbol	Rating				Unit
		LM358 family	LM324 family ☆	LM2904 family	LM2902 family ☆	
Supply Voltage	V <sup>+</sup>	+32		+26		V
Operating Temperature Range	Topr	0 to +70		-40 to +85		°C
Storage Temperature Range	Tstg	-65 to +150				°C
Storage Temperature Range	VICM	-0.3 to +32		-0.3 to +26		V
Maximum junction Temperature	Tjmax	+150				°C

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## ● Electric Characteristics

○ LM358, LM324 family (Unless otherwise specified, V<sup>+</sup> = +5[V])

Parameter	Symbol	Temperature range	Limit						Unit	Conditions	Fig.No
			LM358 family			LM324 family ☆					
			Min.	Typ.	Max.	Min.	Typ.	Max.			
Input Offset Voltage (*1)	VIO	25°C	—	2	7	—	2	7	mV	RS=0[Ω] VO=1.4[V] V <sup>+</sup> =5[V] to 30[V]	2
		Full range	—	—	9	—	—	9			
Input Offset Voltage Drift	αVIO	—	—	7	—	—	7	—	μV/°C	RS=0[Ω]	—
Input Bias Current (*1)	IIB	25°C	—	45	250	—	45	250	nA	VO=1.4[V] IIN (+) or IIN (-) VCM=0[V]	2
		Full range	—	40	500	—	40	500			
Input Offset Current (*1)	IIO	25°C	—	5	50	—	5	50	nA	IIN (+)-IIN (-), VCM=0[V] IIN (+)-IIN (-)	2
		Full range	—	—	150	—	—	150			
Input Offset Current Drift	αIIO	—	—	10	—	—	10	—	pA/°C	RS=0[Ω]	—
Input Common-mode Voltage Range	VICR	25°C	—	—	V <sup>+</sup> -1.5	—	—	V <sup>+</sup> -1.5	V	V <sup>+</sup> =30[V] (*8)	2
		Full range	—	—	V <sup>+</sup> -2.0	—	—	V <sup>+</sup> -2.0			
Supply Current	ICC	Full range	—	0.5	1.2	—	0.7	1.2	mA	V <sup>+</sup> =5[V] RL=∞ All Op Amps V <sup>+</sup> =30[V] RL=∞ All Op Amps	3
			—	1	2	—	1.5	3			
Output Voltage Swing	VOH	Full range	27	28	—	27	28	—	V	V <sup>+</sup> =30[V], RL=10[kΩ]	3
	VOL		—	5	20	—	5	20	mV		
Large Signal Voltage Gain	AV	25°C	25	100	—	25	100	—	V/mV	V <sup>+</sup> =15[V] VO=1[V] to 11[V] RL ≥ 2[kΩ]	2
Common-mode Rejection ratio	CMRR	25°C	65	85	—	65	85	—	dB	VCM=0[V] to V <sup>+</sup> -1.5[V]	2
Power Supply Rejection Ratio	PSRR	25°C	65	100	—	65	100	—	dB	V <sup>+</sup> =5[V] to 30[V]	2
Amplifier-to-Amplifier Coupling	VO1/VO2	25°C	—	120	—	—	120	—	dB	f=1[kHz] to 20[kHz] input referred	5
Output Current (*2)	Source	25°C	20	40	—	20	40	—	mA	V <sup>+</sup> =15[V], VO=2[V] VIN+=1[V], VIN-=0[V]	3
		Full range	10	20	—	10	20	—			
	Sink	25°C	10	20	—	10	20	—	mA	V <sup>+</sup> =15[V], VO=2[V] VIN+=0[V], VIN-=1[V]	
		Full range	2	8	—	2	8	—			
Full range	12	50	—	12	40	—	μA				

(\*1) Absolute value

☆ Under development

(\*2) Under high temperatures, please consider the power dissipation when selecting the output current.

When output terminal is continuously shorted the output current reduces the internal temperature by flushing.

○LM2904,LM2902 family (Unless otherwise specified,  $V^+=+5[V]$ )

Parameter	Unit	Temperature range	Limit						Unit	Conditions	Fig.No
			LM2904 family			LM2902 family☆					
			Min.	Typ.	Max.	Min.	Typ.	Max.			
Input Offset Voltage (*3)	VIO	25°C	—	2	7	—	2	7	mV	RS=0[Ω] VO=1.4[V] V <sup>+</sup> =5[V] to 26[V]	2
		Full range	—	—	10	—	—	10			
Input Offset Voltage Drift	αVIO	—	—	7	—	—	7	—	μV/°C	RS=0[Ω]	-
Input Bias Current (*3)	IIB	25°C	—	45	250	—	45	250	nA	VO=1.4[V] IIN(+)-or-IIN(-) VCM=0[V]	2
		Full range	—	40	500	—	—	500			
Input Offset Current (*3)	IIO	25°C	—	5	50	—	5	50	nA	IIN(+)-IIN(-),VCM=0[V] IIN(+)-IIN(-)	2
		Full range	—	45	200	—	45	200			
Input Offset Current Drift	αIIO	—	—	10	—	—	10	—	pA/°C	RS=0[Ω]	-
Input Common-mode Voltage Range	VICR	25°C	—	—	V <sup>+</sup> -1.5	—	—	V <sup>+</sup> -1.5	V	V <sup>+</sup> =26[V] (*8)	2
		Full range	—	—	V <sup>+</sup> -2.0	—	—	V <sup>+</sup> -2.0			
Supply Current	ICC	Full range	—	0.5	1.2	—	0.7	1.2	mA	V <sup>+</sup> =5[V] RL=∞ All Op Amps V <sup>+</sup> =26[V], RL=∞ All Op Amps	3
			—	1	2	—	1.5	3			
Output Voltage Swing	VOH	Full range	23	24	—	23	24	—	V	V <sup>+</sup> =26[V], RL=10[kΩ]	3
	VOL		—	5	100	—	5	100	mV	RL=10[kΩ], V <sup>+</sup> =5[V]	
Large Signal Voltage Gain	AV	25°C	25	100	—	25	100	—	V/mV	V <sup>+</sup> =15[V] VO=1[V] to 11[V] RL≥2[kΩ]	2
Common-mode Rejection Ratio	CMRR	25°C	50	70	—	50	70	—	dB	VCM=0[V]to V <sup>+</sup> =-1.5[V]	2
Power Supply Rejection Ratio	PSRR	25°C	50	100	—	50	100	—	dB	V <sup>+</sup> =5[V] to 26[V]	2
Amplifier-to-Amplifier Coupling	VO1/VO2	25°C	—	120	—	—	120	—	dB	f=1[kHz] to 20[kHz] Input referred	5
Output Current (*4)	Source	25°C	20	40	—	20	40	—	mA	V <sup>+</sup> =15[V], VO=2[V] VIN+=1[V], VIN-=0[V]	3
		Full range	10	20	—	10	20	—			
	Sink	25°C	10	20	—	10	20	—	mA	V <sup>+</sup> =15[V], VO=2[V] VIN+=0[V], VIN-=1[V]	
		Full range	2	8	—	2	8	—			
Full range	12	50	—	12	50	—	μA				

(\*3) Absolute value

☆Under development

(\*4) Under high temperatures, please consider the power dissipation when selecting the output current.

When the output terminal is continuously shorted the output current reduces the internal temperature by flushing.

●Circuit Diagram

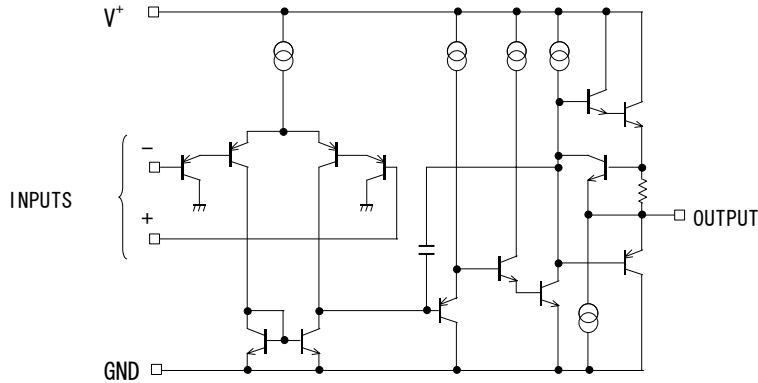


Fig.1 Circuit Diagram (each Op-Amp)

●Measurement circuit 1 NULL Method measurement condition

V<sup>+</sup>, GND, EK, VICR Unit : [V]

Parameter	VF	S1	S2	S3	LM358/LM324 family				LM2904/LM2902 family				Calculation
					V <sup>+</sup>	GND	EK	VICR	V <sup>+</sup>	GND	EK	VICR	
Input Offset Voltage	VF1	ON	ON	OFF	5 to 30	0	-1.4	0	5 to 30	0	-1.4	0	1
Input Offset Current	VF2	OFF	OFF	OFF	5	0	-1.4	0	5	0	-1.4	0	2
Input Bias Current	VF3	OFF	ON	OFF	5	0	-1.4	0	5	0	-1.4	0	3
	VF4	ON	OFF		5	0	-1.4	0	5	0	-1.4	0	
Large Signal Voltage Gain	VF5	ON	ON	ON	15	0	-1.4	0	15	0	-1.4	0	4
	VF6				15	0	-11.4	0	15	0	-11.4	0	
Common-mode Rejection Ratio	VF7	ON	ON	OFF	5	0	-1.4	0	5	0	-1.4	0	5
	VF8				5	0	-1.4	3.5	5	0	-1.4	3.5	
Power supply Rejection Ratio	VF9	ON	ON	OFF	5	0	-1.4	0	5	0	-1.4	0	6
	VF10				30	0	-1.4	0	30	0	-1.4	0	

— Calculation —

1. Input Offset Voltage (V<sub>IO</sub>)

$$V_{IO} = \frac{|VF1|}{1 + R_f/R_s} \text{ [V]}$$

2. Input Offset Current (I<sub>IO</sub>)

$$I_{IO} = \frac{|VF2 - VF1|}{R_i(1 + R_f/R_s)} \text{ [A]}$$

3. Input Bias Current (I<sub>IB</sub>)

$$I_{IB} = \frac{|VF4 - VF3|}{2 \times R_i(1 + R_f/R_s)} \text{ [A]}$$

4. Large Signal Voltage Gain (A<sub>v</sub>)

$$A_v = 20 \times \text{Log} \frac{10 \times (1 + R_f/R_s)}{|VF6 - VF5|} \text{ [dB]}$$

5. Common-mode Rejection Ratio (CMRR)

$$CMRR = 20 \times \text{Log} \frac{3.5 \times (1 + R_f/R_s)}{|VF8 - VF7|} \text{ [dB]}$$

6. Power supply rejection ratio (PSRR)

$$PSRR = 20 \times \text{Log} \frac{\Delta V^+ \times (1 + R_f/R_s)}{VF10 - VF9} \text{ [dB]}$$

ΔV<sup>+</sup>=25V

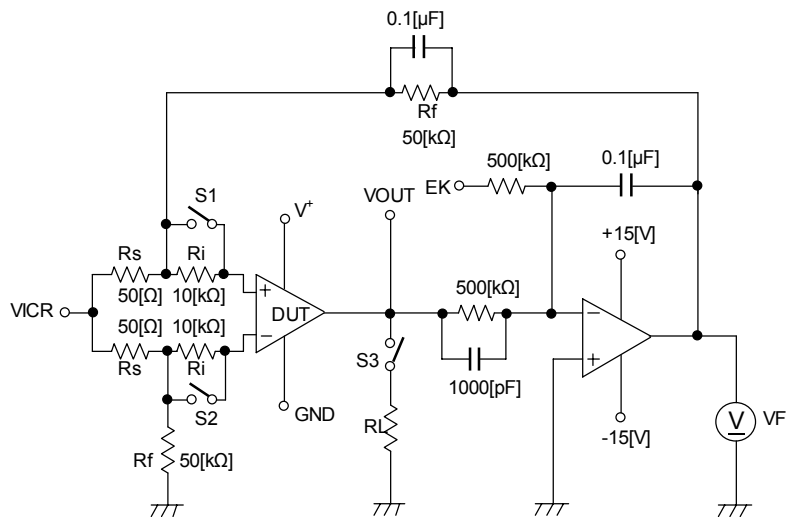


Fig.2 Measurement circuit1 (Each Op Amps)

● Measurement Circuit2 Switch condition

SW No.	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	SW 11	SW 12	SW 13	SW 14	SW 15
Supply Current	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
High Level Output Voltage	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF
Low Level Output Voltage	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
Output Source Current	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
Output Sink Current	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
Slew Rate	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
Gain Bandwidth Product	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF
Equivalent Input Noise Voltage	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF

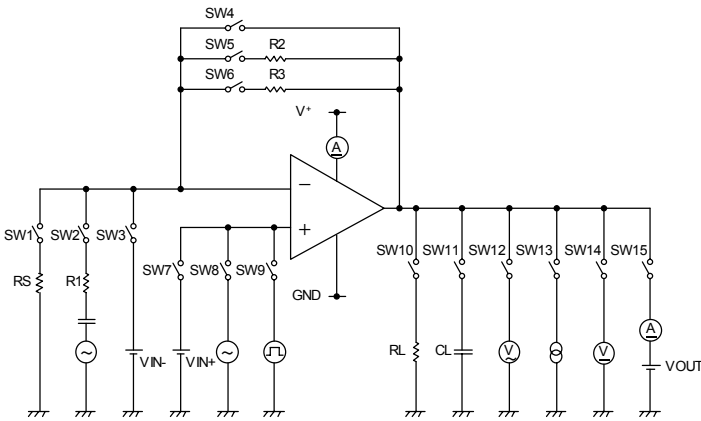


Fig.3 Measurement Circuit2 (each Op-Amp)

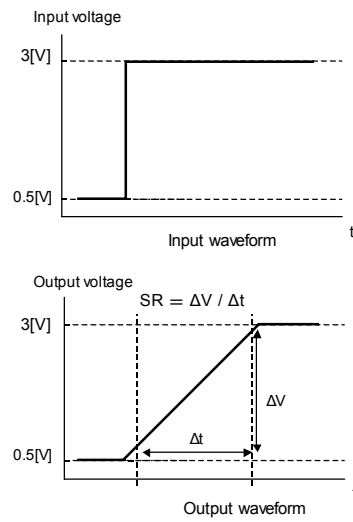


Fig.4 Slew Rate Input Waveform

● Measurement Circuit3 Amplifier To Amplifier Coupling

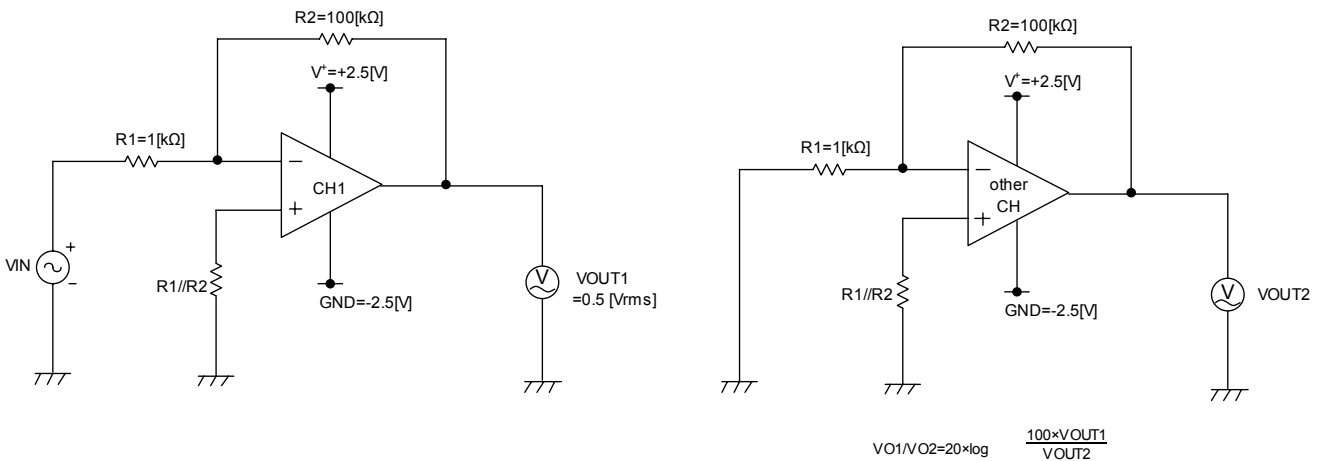


Fig.5 Measurement Circuit3

## ● Description of Electrical Characteristics

Described below are descriptions of the relevant electrical terms

Please note that item names, symbols and their meanings may differ from those on another manufacturer's documents.

### 1. Absolute maximum ratings

The absolute maximum ratings are values that should never be exceeded, since doing so may result in deterioration of electrical characteristics or damage to the part itself as well as peripheral components.

#### 1.1 Power supply voltage ( $V^*/GND$ )

Expresses the maximum voltage that can be supplied between the positive and negative supply terminals without causing deterioration of the electrical characteristics or destruction of the internal circuitry.

#### 1.2 Differential input voltage (VID)

Indicates the maximum voltage that can be supplied between the non-inverting and inverting terminals without damaging the IC.

#### 1.3 Input common-mode voltage range (VICR)

Signifies the maximum voltage that can be supplied to non-inverting and inverting terminals without causing deterioration of the characteristics or damage to the IC itself. Normal operation is not guaranteed within the common-mode voltage range of the maximum ratings – use within the input common-mode voltage range of the electric characteristics instead.

#### 1.4 Operating and storage temperature ranges ( $T_{opr}, T_{stg}$ )

The operating temperature range indicates the temperature range within which the IC can operate. The higher the ambient temperature, the lower the power consumption of the IC. The storage temperature range denotes the range of temperatures the IC can be stored under without causing excessive deterioration of the electrical characteristics.

#### 1.5 Power dissipation ( $P_d$ )

Indicates the power that can be consumed by a particular mounted board at ambient temperature (25°C). For packaged products,  $P_d$  is determined by the maximum junction temperature and the thermal resistance.

### 2. Electrical characteristics

#### 2.1 Input offset voltage (VIO)

Signifies the voltage difference between the non-inverting and inverting terminals. It can be thought of as the input voltage difference required for setting the output voltage to 0 V.

#### 2.2 Input offset voltage drift ( $\Delta V_{IO}/\Delta T$ )

Denotes the ratio of the input offset voltage fluctuation to the ambient temperature fluctuation.

#### 2.3 Input offset current (IIO)

Indicates the difference of input bias current between the non-inverting and inverting terminals.

#### 2.4 Input offset current drift ( $\Delta I_{IO}/\Delta T$ )

Signifies the ratio of the input offset current fluctuation to the ambient temperature fluctuation.

#### 2.5 Input bias current (IIB)

Denotes the current that flows into or out of the input terminal, it is defined by the average of the input bias current at the non-inverting terminal and the input bias current at the inverting terminal.

#### 2.6 Circuit current (ICC)

Indicates the current of the IC itself that flows under specified conditions and during no-load steady state.

#### 2.7 High level output voltage/low level output voltage (VOH/VOL)

Signifying the voltage range that can be output under specified load conditions, it is in general divided into high level output voltage and low level output voltage. High level output voltage indicates the upper limit of the output voltage, while low level output voltage the lower limit.

#### 2.8 Large signal voltage gain (AV)

The amplifying rate (gain) of the output voltage against the voltage difference between non-inverting and inverting terminals, it is (normally) the amplifying rate (gain) with respect to DC voltage.

$AV = (\text{output voltage fluctuation}) / (\text{input offset fluctuation})$

#### 2.9 Input common-mode voltage range (VICR)

Indicates the input voltage range under which the IC operates normally.

#### 2.10 Common-mode rejection ratio (CMRR)

Signifies the ratio of fluctuation of the input offset voltage when the in-phase input voltage is changed (DC fluctuation).

$CMRR = (\text{change in input common-mode voltage}) / (\text{input offset fluctuation})$

#### 2.11 Power supply rejection ratio (PSRR)

Denotes the ratio of fluctuation of the input offset voltage when supply voltage is changed (DC fluctuation).

$PSRR = (\text{change in power supply voltage}) / (\text{input offset fluctuation})$

#### 2.12 Output source current/ output sink current (IOH/IOL)

The maximum current that can be output under specific output conditions, it is divided into output source current and output sink current. The output source current indicates the current flowing out of the IC, and the output sink current the current flowing into the IC.

#### 2.13 Channel separation (CS)

Expresses the amount of fluctuation of the input offset voltage or output voltage with respect to the change in the output voltage of a driven channel.

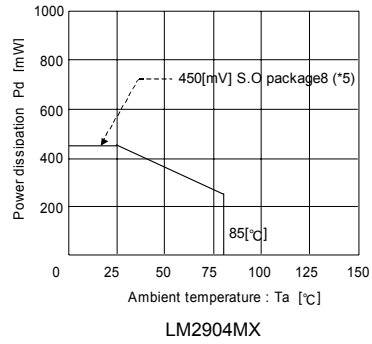
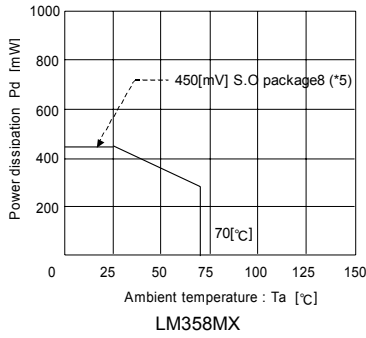
#### 2.14 Slew rate (SR)

Indicates the time fluctuation ratio of the output voltage when an input step signal is supplied.

#### 2.15 Gain bandwidth product (GBW)

The product of the specified signal frequency and the gain of the op-amp at such frequency, it gives the approximate value of the frequency where the gain of the op-amp is 1 (maximum frequency, and unity gain frequency).

● Derating curves



Power Dissipation

Package	Pd[W]	$\theta_{ja}$ [°C/W]
S.O Package8 (*5)	450	3.6

$$\theta_{ja} = (T_j - T_a) / P_d [°C/W]$$

Fig.6 Derating Curves

● Precautions

1) Unused circuits

When there are unused circuits, it is recommended that they be connected as in Fig.7, setting the non-inverting input terminal to a potential within the in-phase input voltage range (VICR).

2) Input terminal voltage

Applying GND + 32V to the input terminal is possible without causing deterioration of the electrical characteristics or destruction, irrespective of the supply voltage. However, this does not ensure normal circuit operation. Please note that the circuit operates normally only when the input voltage is within the common mode input voltage range of the electric characteristics.

3) Power supply (single / dual)

The op-amp operates when the voltage supplied is between  $V^+$  and GND. Therefore, the single supply op-mp can be used as a dual supply op-amp as well.

4) Power dissipation (Pd)

Using the unit in excess of the rated power dissipation may cause deterioration in electrical characteristics due to the rise in chip temperature, including reduced current capability. Therefore, please take into consideration the power dissipation (Pd) under actual operating conditions and apply a sufficient margin in thermal design. Refer to the thermal derating curves for more information.

5) Short-circuit between pins and erroneous mounting

Incorrect mounting may damage the IC. In addition, the presence of foreign substances between the outputs, the output and the power supply, or the output and GND may result in IC destruction.

6) Operation in a strong electromagnetic field

Operation in a strong electromagnetic field may cause malfunctions.

7) Radiation

This IC is not designed to withstand radiation.

8) IC handling

Applying mechanical stress to the IC by deflecting or bending the board may cause fluctuation of the electrical characteristics due to piezoelectric (piezo) effects.

9) IC operation

The output stage of the IC is configured using Class C push-pull circuits. Therefore, when the load resistor is connected to the middle potential of  $V^+$  and GND, crossover distortion occurs at the changeover between discharging and charging of the output current. Connecting a resistor between the output terminal and GND, and increasing the bias current for Class A operation will suppress crossover distortion.

10) Board inspection

Connecting a capacitor to a pin with low impedance may stress the IC. Therefore, discharging the capacitor after every process is recommended. In addition, when attaching and detaching the jig during the inspection phase, ensure that the power is turned OFF before inspection and removal. Furthermore, please take measures against ESD in the assembly process as well as during transportation and storage.

11) Output capacitor

Discharge of the external output capacitor to  $V^+$  is possible via internal parasitic elements when  $V^+$  is shorted to GND, causing damage to the internal circuitry due to thermal stress. Therefore, when using this IC in circuits where oscillation due to output capacitive load does not occur, such as in voltage comparators, use an output capacitor with a capacitance less than 0.1  $\mu$ F.

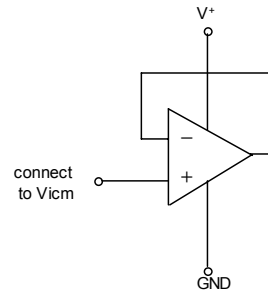
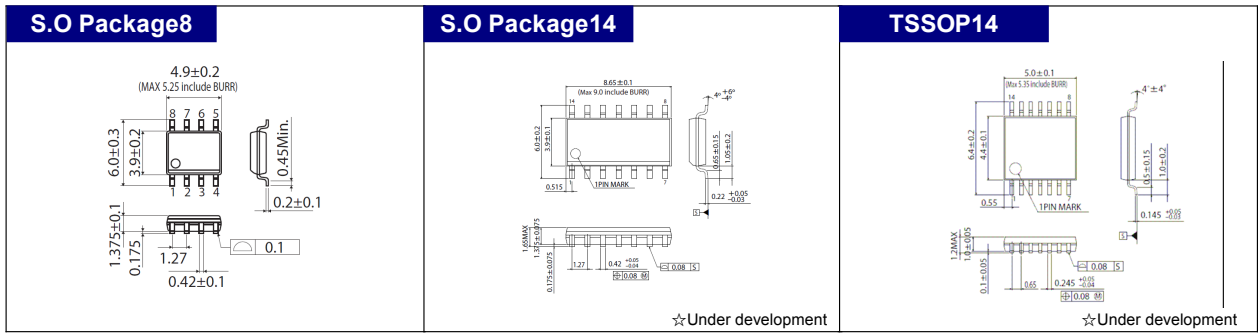


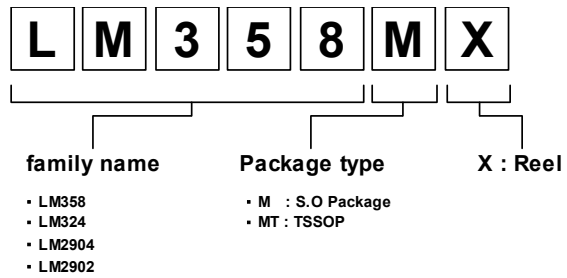
Fig.7 Disable circuit example

● External Dimensions

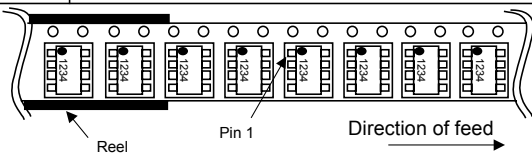


● Part Number Explanation

- Specify the product by the part number when placing orders.
- Verify that the entire part number is correct.
- Start with the leftmost space without leaving any empty space between characters.



Tape	Embossed carrier tape
Quantity	2500pcs
Direction of feed	Pin 1 is at the upper left holding the reel with the left hand while pulling the tape out with the right



※Please order in multiples of the minimum package quantity.