MINI ANALOG SERIES
CMOS SINGLE WIDE-BAND OPERATIONAL AMPLIFIER

S-89402A/89403A Series

The mini analog series is a group of ICs that incorporate a general-purpose analog circuit in an ultra-small package.
The S-89402A and S-89403A series are CMOS type wide-band operational amplifiers with a 10 MHz gain-bandwidth product (GBP) and can be used in a negative feedback circuit with five times or more gain. Since these products can be driven at a lower voltage with lower current consumption than existing bipolar operational amplifiers, they are ideal for use in small battery-powered portable equipment.

■ Features

- Gain-bandwidth product: 10 MHz (typ.)
- Bandwidth: 1 MHz (typ.) @ Gain = 10
- Used with a gain of five or more
- Can be driven at lower voltage than existing general-purpose operational amplifiers: V_{DD} = 2.7 to 5.5 V (S-89402A)
  V_{DD} = 1.2 to 3.3 V (S-89403A)
- Low current consumption: I_{DD} = 1.9 mA (typ.) @ 3.0 V
- Current consumption in shutdown mode: I_{DD} = 0.1 μA (typ.)
- Wide I/O voltage range: V_{CMR} = V_{SS} to V_{DD}
- Large output current
- Low input offset voltage (5.0 mV max.)
- Small package (SOT-23-6: 2.9 mm × 2.8 mm)

■ Applications

- Cellular phones
- PDAs
- Notebook PCs
- Digital cameras
- Digital video cameras

■ Package

- 6-Pin SOT-23-6 (package drawing code: MP006-A)

■ Selection Guide

Table 1

Recommended Operating Power Voltage	Product Name
2.7 to 5.5 V	S-89402ALMD-HNN-TF
1.2 to 3.3 V	S-89403ALMD-HOW-TF

■ Absolute Maximum Ratings

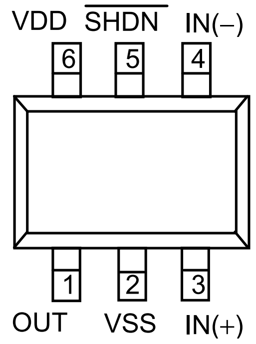
Table 2

Parameter	Symbol	Ratings	Unit
Power supply voltage	$V_{DD} - V_{SS}$	7.0	V
Input voltage	V_{IN}	V_{SS} to V_{DD}	V
Output voltage	V_{OUT}	V_{SS} to V_{DD}	V
Differential input voltage	V_{IND}	±5.5	V
Output pin current	I_{SOURCE}	30	mA
	I_{SINK}		
Power dissipation	P_D	250	mW
Operating temperature	T_{opr}	−40 to +85	°C
Storage temperature	T_{stg}	−55 to +125	°C

Caution The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

■ Pin Configuration

6-Pin SOT-23-6
Top View



(S-89402/89403ALMD)

Figure 1

Table 3

Pin No.	Symbol	Description	Internal Equivalent Circuit
1	OUT	Output pin	Figure 2
2	VSS	GND pin	—
3	IN(+)	Non-inverted input pin	Figure 3
4	IN(−)	Inverted input pin	Figure 3
5	$\overline{\mathrm{SHDN}}$	Shutdown pin	Figure 5
6	VDD	Positive power supply pin	Figure 4

[Internal equivalent circuit]

<1> Output pin

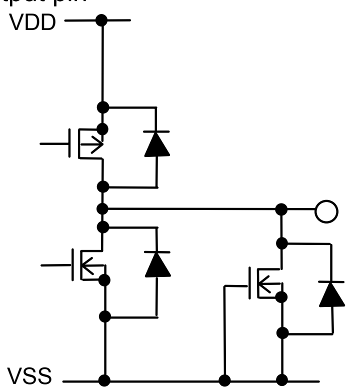


Figure 2

<2> Input pin

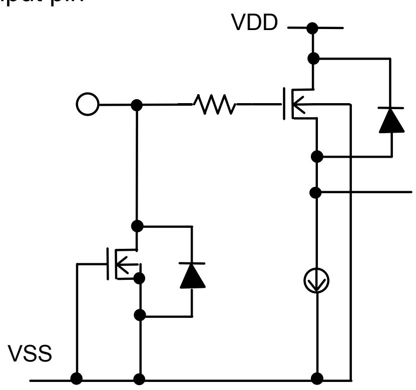


Figure 3

<3> VDD pin

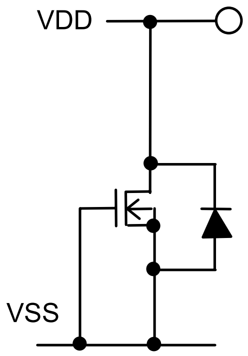


Figure 4

<4> $\overline{\mathrm{SHDN}}$ pin

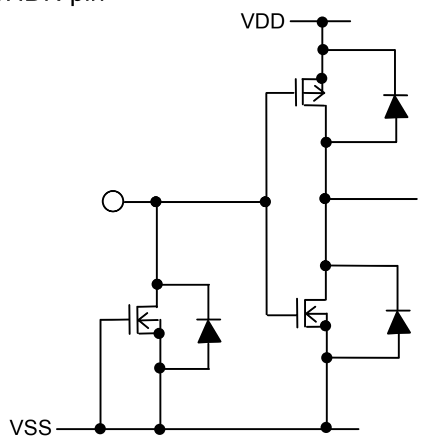


Figure 5

■ Electrical Characteristics (S-89402A)

1. V_{DD} = 5.0 V (S-89402A)

Table 4

DC Characteristics (V_{DD} = 5.0 V) ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Current consumption	I_{DD}	$V_{CMR} = V_{OUT} = 2.5$ V	—	2100	2500	μA	Figure 11
Current consumption in shutdown mode	I_{DD}shdn	$V_{\overline{SHDN}} = 0$ V	—	0.1	1	μA	Figure 12
Input offset voltage	V_{IO}	$V_{CMR} = 2.5$ V	—	±3	±5	mV	Figure 7
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	5	V	—
Voltage gain (open loop)	A_{VOL}	$V_{SS} + 0.1\text{ V} \le V_{OUT} \le V_{DD} - 0.1$ V $V_{CMR} = 2.5$ V, $R_L = 1$ MΩ	80	90	—	dB	Figure 16
Maximum output swing voltage	V_{OH}	$R_L = 100$ kΩ	4.99	—	—	V	Figure 9
	V_{OL}	$R_L = 100$ kΩ	—	—	0.01		Figure 10
Output voltage in shutdown mode	$V_O$shdn	$V_{\overline{SHDN}} = 0$ V, $R_L = 100$ kΩ	—	—	0.01	V	—
Common-mode input signal rejection ratio	CMRR	$V_{SS} \le V_{CMR} \le V_{DD}$	40	50	—	dB	Figure 8
Power supply voltage rejection ratio	PSRR	V_{DD} = 2.7 to 5.5 V	50	66	—	dB	Figure 6
Source current	I_{SOURCE}	$V_{OUT} = V_{DD} - 0.1$ V	6.7	7	—	mA	Figure 12
Sink current	I_{SINK}	$V_{OUT} = 0.1$ V	2.5	2.7	—	mA	Figure 13
Shutdown pin input voltage	$V_{\overline{SHDN}}$	During operation	2.2	—	5	V	—
		During shutdown	0	—	0.55		

Table 5

AC Characteristics (V_{DD} = 5.0 V)*1 ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Slew rate (Rise)	SR_R	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	25	—	V/μs	Figure 14
Slew rate (Fall)	SR_F	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	25	—	V/μs	Figure 14
Gain bandwidth	GBW	Gain = 10, C_L = 0 pF	—	1	—	MHz	—
Gain-bandwidth product	GBP	Gain = 10, C_L = 0 pF	—	10	—	MHz	—

***1.** Phase compensation is not applied when the gain is less than five. Use with a gain of five or more.

2. V_{DD} = 3.0 V (S-89402A)

Table 6

DC Characteristics (V_{DD} = 3.0 V) ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measure-ment Circuit
Current consumption	I_{DD}	$V_{CMR} = V_{OUT}$ = 1.5 V	—	1900	2300	μA	Figure 11
Current consumption in shutdown mode	I_{DD}shdn	$V_{\overline{SHDN}}$ = 0 V	—	0.1	1	μA	Figure 12
Input offset voltage	V_{IO}	V_{CMR} = 1.5 V	—	±3	±5	mV	Figure 7
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	3	V	—
Voltage gain (open loop)	A_{VOL}	V_{SS} + 0.1 V ≤ V_{OUT} ≤ V_{DD} − 0.1 V V_{CMR} = 1.5 V, R_L = 1 MΩ	80	90	—	dB	Figure 16
Maximum output swing voltage	V_{OH}	R_L = 100 kΩ	2.99	—	—	V	Figure 9
	V_{OL}	R_L = 100 kΩ	—	—	0.01		Figure 10
Output voltage in shutdown mode	$V_O$shdn	$V_{\overline{SHDN}}$ = 0 V, R_L = 100 kΩ	—	—	0.01	V	—
Common-mode input signal rejection ratio	CMRR	V_{SS} ≤ V_{CMR} ≤ V_{DD}	40	50	—	dB	Figure 8
Power supply voltage rejection ratio	PSRR	V_{DD} = 2.7 to 5.5 V	50	66	—	dB	Figure 6
Source current	I_{SOURCE}	$V_{OUT} = V_{DD}$ − 0.1 V	4.35	4.7	—	mA	Figure 13
Sink current	I_{SINK}	V_{OUT} = 0.1 V	1.6	1.7	—	mA	Figure 14
		$V_{OUT} = V_{DD}$	14.5	18	—		
Shutdown pin input voltage	$V_{\overline{SHDN}}$	During operation	1.8	—	3	V	—
		During shutdown	0	—	0.55		

Table 7

AC Characteristics (V_{DD} = 3.0 V)*1 ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measure-ment Circuit
Slew rate (Rise)	SR_R	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	20	—	V/μs	Figure 15
Slew rate (Fall)	SR_F	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	20	—	V/μs	Figure 15
Gain bandwidth	GBW	Gain = 10, C_L = 0 pF	—	1	—	MHz	—
Gain-bandwidth product	GBP	Gain = 10, C_L = 0 pF	—	10	—	MHz	—

***1.** Phase compensation is not applied when the gain is less than five. Use with a gain of five or more.

■ Electrical Characteristics (S-89403A)

1. V_{DD} = 1.8 V (S-89403A)

Table 8

DC Characteristics (V_{DD} = 1.8 V) ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measure-ment Circuit
Current consumption	I_{DD}	$V_{CMR} = V_{OUT}$ = 0.9 V	—	1700	2000	μA	Figure 11
Current consumption in shutdown mode	I_{DD}shdn	$V_{\overline{SHDN}}$ = 0 V	—	0.1	1	μA	Figure 12
Input offset voltage	V_{IO}	V_{CMR} = 0.9 V	—	±3	±5	mV	Figure 7
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	1.8	V	—
Voltage gain (open loop)	A_{VOL}	V_{SS} + 0.1 V ≤ V_{OUT} ≤ V_{DD} − 0.1 V V_{CMR} = 0.9 V, R_L = 1 MΩ	80	90	—	dB	Figure 17
Maximum output swing voltage	V_{OH}	R_L = 100 kΩ	1.79	—	—	V	Figure 9
	V_{OL}	R_L = 100 kΩ	—	—	0.01		Figure 10
Output voltage in shutdown mode	$V_O$shdn	$V_{\overline{SHDN}}$ = 0 V, R_L = 100 kΩ	—	—	0.01	V	—
Common-mode input signal rejection ratio	CMRR	$V_{SS} \le V_{CMR} \le V_{DD}$	30	40	—	dB	Figure 8
Power supply voltage rejection ratio	PSRR	V_{DD} = 1.2 to 3.3 V	50	66	—	dB	Figure 6
Source current	I_{SOURCE}	$V_{OUT} = V_{DD}$ − 0.1 V	2.2	2.55	—	mV	Figure 13
		$V_{OUT} = V_{SS}$	11.7	16	—		
Sink current	I_{SINK}	V_{OUT} = 0.1 V	0.85	1	—	mV	Figure 14
		$V_{OUT} = V_{DD}$	4.2	6	—		
Shutdown pin input voltage	$V_{\overline{SHDN}}$	During operation	1.5	—	1.8	V	—
		During shutdown	0	—	0.55		

Table 9

AC Characteristics (V_{DD} = 1.8 V)*1 ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measure-ment Circuit
Slew rate (Rise)	SR_R	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	15	—	V/μs	Figure 15
Slew rate (Fall)	SR_F	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	15	—	V/μs	Figure 15
Gain bandwidth	GBW	Gain = 10, C_L = 0 pF	—	1	—	MHz	—
Gain-bandwidth product	GBP	Gain = 10, C_L = 0 pF	—	10	—	MHz	—

***1.** Phase compensation is not applied when the gain is less than five. Use with a gain of five or more.

2. V_{DD} = 1.2 V (S-89403A)

Table 10

DC Characteristics (V_{DD} = 1.2 V) ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Current consumption	I_{DD}	$V_{CMR} = V_{OUT}$ = 0.6 V	—	1400	1700	μA	Figure 11
Current consumption in shutdown mode	I_{DD}shdn	$V_{\overline{SHDN}}$ = 0 V	—	0.1	1	μA	Figure 12
Input offset voltage	V_{IO}	V_{CMR} = 0.6 V	—	±3	±5	mV	Figure 7
Input offset current	I_{IO}	—	—	1	—	pA	—
Input bias current	I_{BIAS}	—	—	1	—	pA	—
Common-mode input voltage	V_{CMR}	—	0	—	1.2	V	—
Voltage gain (open loop)	A_{VOL}	V_{SS} + 0.1 V ≤ V_{OUT} ≤ V_{DD} − 0.1 V V_{CMR} = 0.6 V, R_L = 1 MΩ	70	80	—	dB	Figure 17
Maximum output swing voltage	V_{OH}	R_L = 100 kΩ	1.19	—	—	V	Figure 9
	V_{OL}	R_L = 100 kΩ	—	—	0.01		Figure 10
Output voltage in shutdown mode	$V_O$shdn	$V_{\overline{SHDN}}$ = 0 V, R_L = 100 kΩ	—	—	0.01	V	—
Common-mode input signal rejection ratio	CMRR	V_{SS} ≤ V_{CMR} ≤ V_{DD}	20	34	—	dB	Figure 8
		V_{SS} ≤ V_{CMR} ≤ V_{DD} − 0.3 V	34	50	—		
Power supply voltage rejection ratio	PSRR	V_{DD} = 1.2 to 3.3 V	50	66	—	dB	Figure 6
Source current	I_{SOURCE}	$V_{OUT} = V_{DD}$ − 0.1 V	0.8	1.2	—	mV	Figure 13
		$V_{OUT} = V_{SS}$	1.7	4	—		
Sink current	I_{SINK}	V_{OUT} = 0.1 V	0.4	0.55	—	mV	Figure 14
		$V_{OUT} = V_{DD}$	1	1.8	—		
Shutdown pin input voltage	$V_{\overline{SHDN}}$	During operation	1.14	—	1.2	V	—
		During shutdown	0	—	0.3		

Table 11

AC Characteristics (V_{DD} = 1.2 V)*1 ($V_{\overline{SHDN}} = V_{DD}$, Ta = 25°C unless otherwise specified)

Parameter	Symbol	Measurement Conditions	Min.	Typ.	Max.	Unit	Measurement Circuit
Slew rate (rise)	SR_R	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	10	—	V/μs	Figure 15
Slew rate (fall)	SR_F	R1 = 5 kΩ, R2 = 20 kΩ, C_L = 15 pF	—	10	—	V/μs	Figure 15
Gain bandwidth	GBW	Gain = 10, C_L = 0 pF	—	1	—	MHz	—
Gain-bandwidth product	GBP	Gain = 10, C_L = 0 pF	—	10	—	MHz	—

***1.** Phase compensation is not applied when the gain is less than five. Use with a gain of five or more.

■ Measurement Circuits

1. Power supply voltage rejection ratio

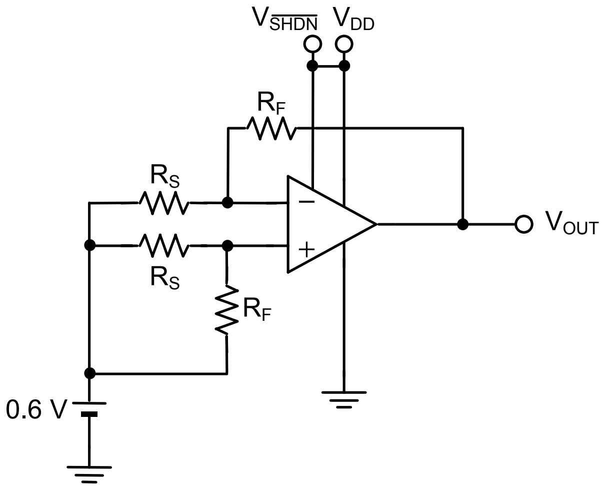


Figure 6

- Power supply voltage rejection ratio (PSRR)
  The power supply voltage rejection ratio (PSRR) can be calculated by the following formula, with the value of V_{OUT} measured at each V_{DD}.

  Measurement conditions:
  When $V_{DD} = V_{DD}$ (max.): $V_{DD} = V_{DD1}$, $V_{OUT} = V_{OUT1}$
  When $V_{DD} = V_{DD}$ (min.): $V_{DD} = V_{DD2}$, $V_{OUT} = V_{OUT2}$

$$PSRR = 20\log\left(\left|\frac{V_{DD1} - V_{DD2}}{V_{OUT1} - V_{OUT2}}\right| \times \frac{R_F + R_S}{R_S}\right)$$

2. Input offset voltage

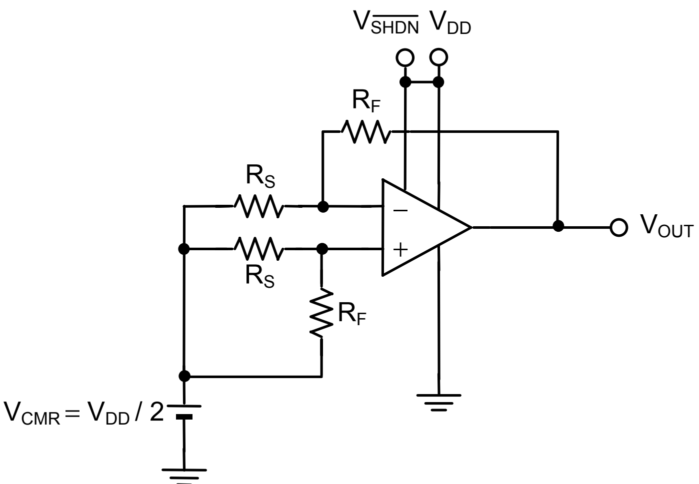


Figure 7

- Input offset voltage (V_{IO})

$$V_{IO} = \left(V_{OUT} - \frac{V_{DD}}{2}\right) \times \frac{R_S}{R_F + R_S}$$

3. Common-mode input signal rejection ratio, common-mode input voltage

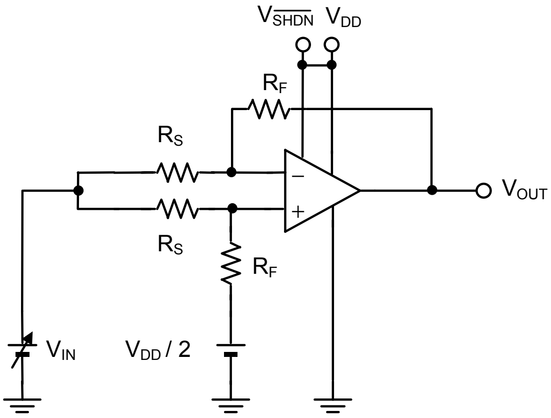


Figure 8

- Common-mode input signal rejection ratio (CMRR)
  The common-mode input signal rejection ratio (CMRR) can be calculated by the following formula, with the value of V_{OUT} measured at each V_{IN}.

  Measurement conditions:
  When $V_{IN} = V_{CMR}$ (max.): $V_{IN} = V_{IN1}$, $V_{OUT} = V_{OUT1}$
  When $V_{IN} = V_{CMR}$ (min.): $V_{IN} = V_{IN2}$, $V_{OUT} = V_{OUT2}$

$$\mathrm{CMRR} = 20\log\left(\left|\frac{V_{IN1} - V_{IN2}}{V_{OUT1} - V_{OUT2}}\right| \times \frac{(R_F + R_S)}{R_S}\right)$$

- Common-mode input voltage (V_{CMR})
  The common-mode input voltage is the range of input voltage within which V_{OUT} satisfies the common-mode input signal rejection ratio specification when V_{IN} is varied.

4. Maximum output swing voltage

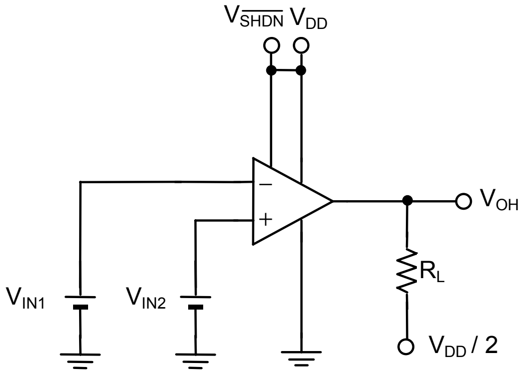


Figure 9

- Maximum output swing voltage (V_{OH})

  Measurement conditions:

$$V_{IN1} = \frac{V_{DD}}{2} - 0.1\ \mathrm{V}$$

$$V_{IN2} = \frac{V_{DD}}{2} + 0.1\ \mathrm{V}$$

  $R_L = 100\ \mathrm{k\Omega}$

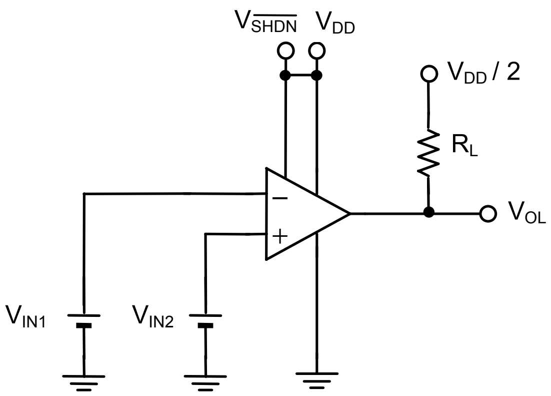


Figure 10

- Maximum output swing voltage (V_{OL})

  Measurement conditions:

$$V_{IN1} = \frac{V_{DD}}{2} + 0.1\mathrm{V}$$

$$V_{IN2} = \frac{V_{DD}}{2} - 0.1\mathrm{V}$$

  $R_L = 100\ \mathrm{k\Omega}$

5. Power supply current

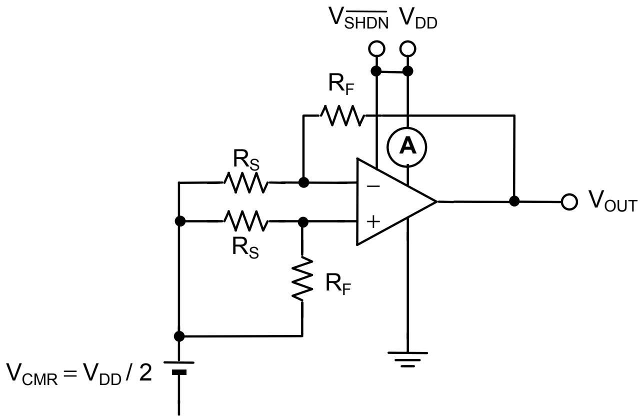


Figure 11

- Power supply current (I_{DD})

6. Power supply current in shutdown mode

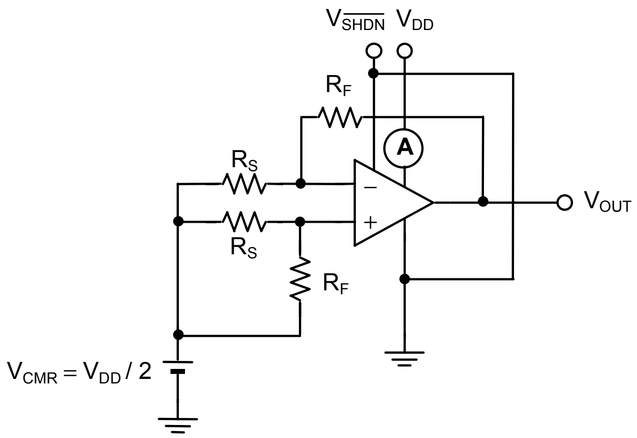


Figure 12

- Power supply current (I_{DD})

7. Source current

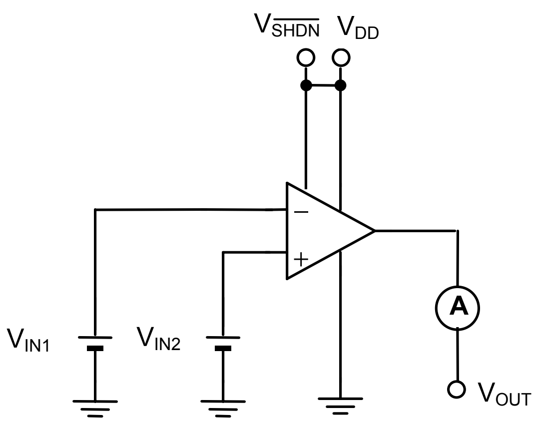


Figure 13

- Source current (I_{SOURCE})

Measurement conditions:

$V_{OUT} = V_{DD} - 0.1\text{ V}$ or $V_{OUT} = 0\text{ V}$

$$V_{IN1} = \frac{V_{DD}}{2} - 0.1\text{V}$$

$$V_{IN2} = \frac{V_{DD}}{2} + 0.1\text{V}$$

8. Sink current

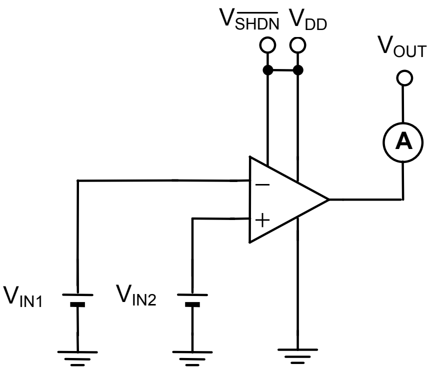


Figure 14

- Sink current (I_{SINK})

  Measurement conditions:

  V_{OUT} = 0.1 V or V_{OUT} = V_{DD}

  $$V_{IN1} = \frac{V_{DD}}{2} + 0.1\,V$$

  $$V_{IN2} = \frac{V_{DD}}{2} - 0.1\,V$$

9. Slew rate (SR)

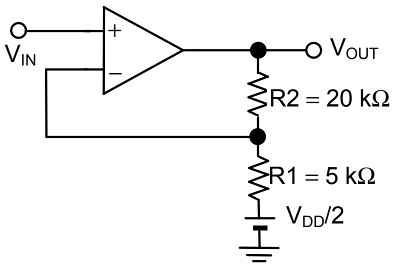
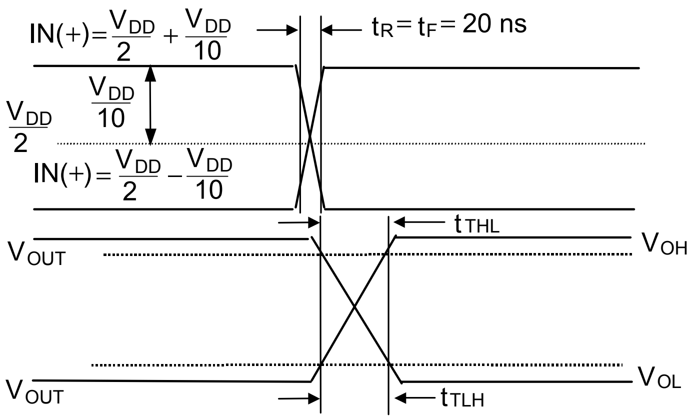


Figure 15



When falling

$$SR = \frac{V_{OH} - V_{OL}}{t_{THL}}$$

When rising

$$SR = \frac{V_{OH} - V_{OL}}{t_{TLH}}$$

Figure 16

V_{OH} = 2.7 V (when V_{DD} = 3.0 V), 1.62 V (when V_{DD} = 1.8 V), 1.08 V (when V_{DD} = 1.2 V)
V_{OL} = 0.3 V (when V_{DD} = 3.0 V), 0.18 V (when V_{DD} = 1.8 V), 0.12 V (when V_{DD} = 1.2 V)

10. Voltage gain (open loop)

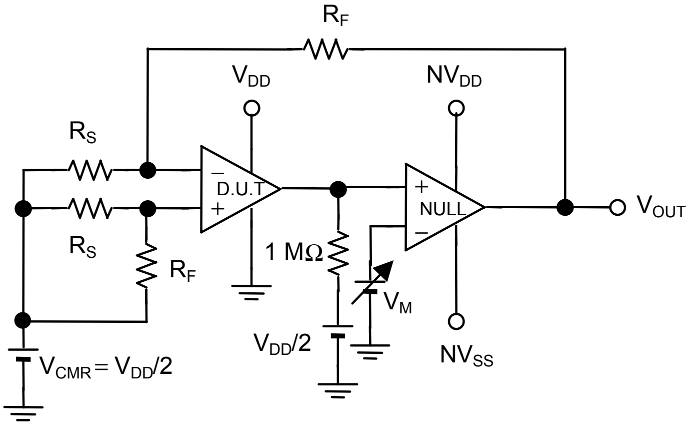


Figure 17

- Voltage gain (open loop) (A_{VOL})
  The voltage gain (open loop) (A_{VOL}) can be calculated by the following formula, with the value of V_{OUT} measured at each V_M.

  Measurement conditions:
  When $V_M = V_{DD} - 0.1$ V: $V_M = V_{M1}$, $V_{OUT} = V_{OUT1}$
  When $V_M = 0.1$ V: $V_M = V_{M2}$, $V_{OUT} = V_{OUT2}$

$$A_{VOL} = 20\log\left(\left|\frac{V_{M1} - V_{M2}}{V_{OUT1} - V_{OUT2}}\right| \times \frac{(R_F + R_S)}{R_S}\right)$$

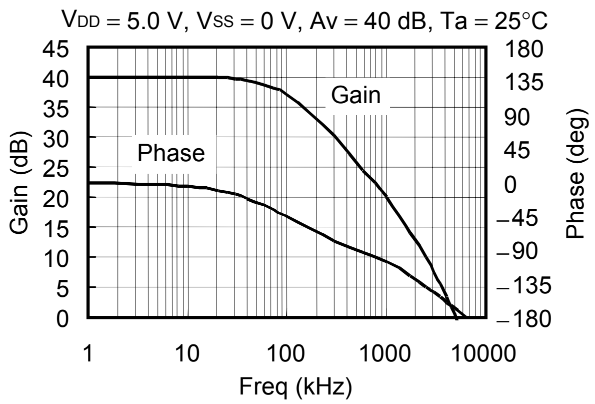
■ Cautions

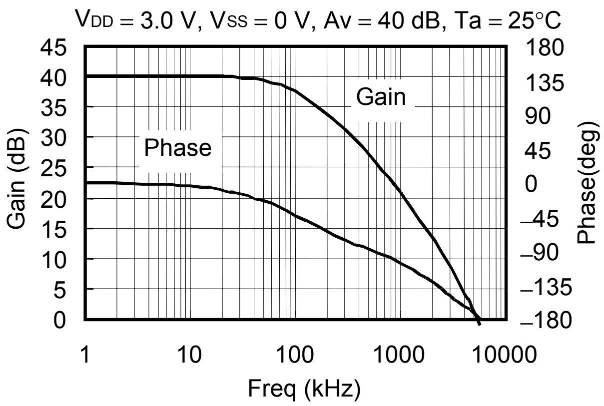
- Phase compensation is not applied when the gain is less than five times. Use a gain of five times or more. Be aware that, as in the majority of other operational amplifiers, the capacitative load reduces the phase margin, which may cause ringing, overshoot, or inadvertent oscillation even if the gain is five times or more.
- Be sure to use the product with an output current of no more than 30 mA.

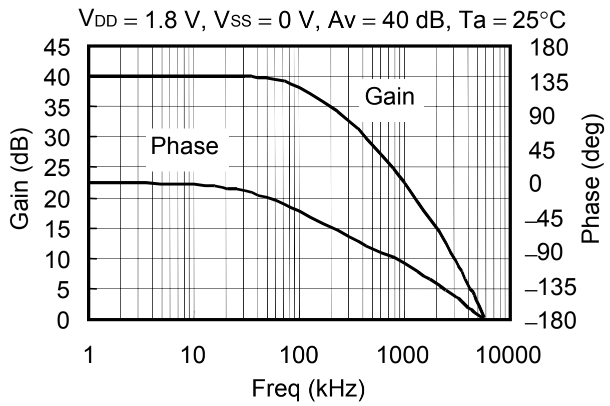
■ Operational Amplifier Characteristics

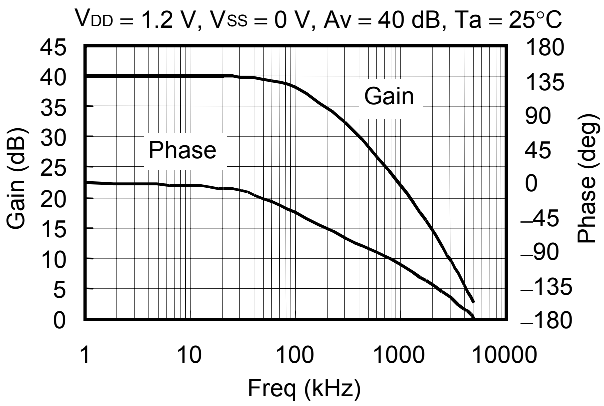
(All Data Indicates Typical Values for One Circuit, $V_{\overline{SHDN}} = V_{DD}$)

(1) Voltage gain vs. Frequency

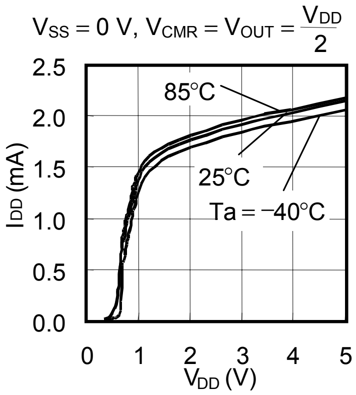








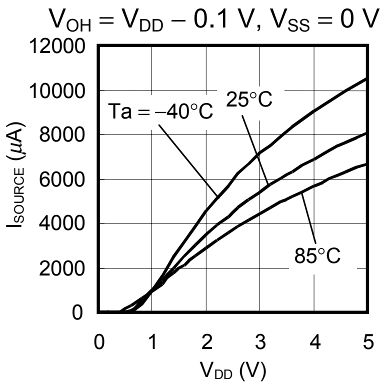
(2) Power supply current vs. Power supply voltage



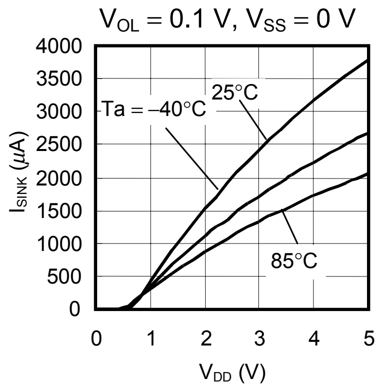
(3) Output current characteristics

3-1. Power supply voltage

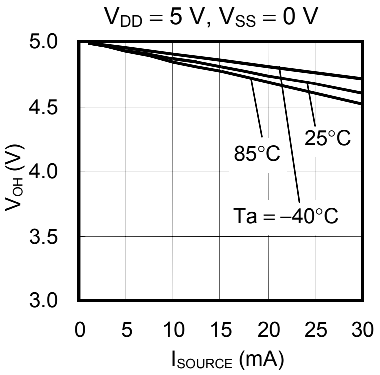
I_{SOURCE} vs. Power supply voltage

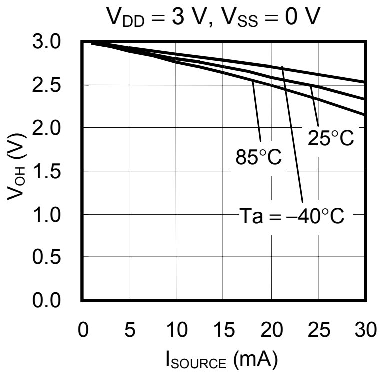


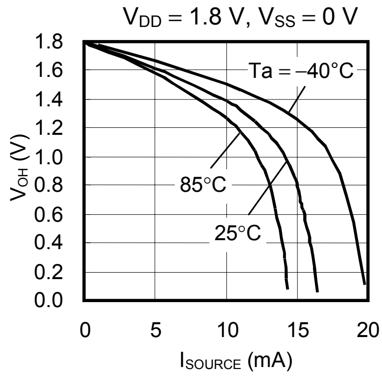
I_{SINK} vs. Power supply voltage

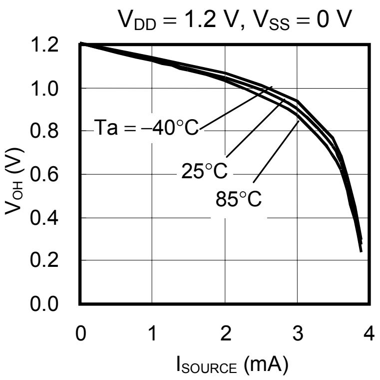


3-2. Output voltage (V_{OH}) vs. I_{SOURCE}



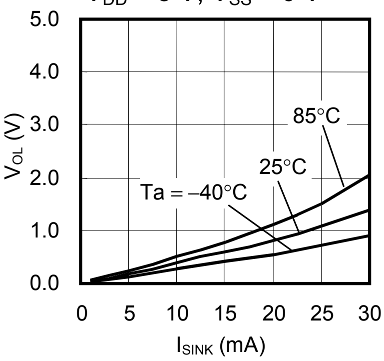




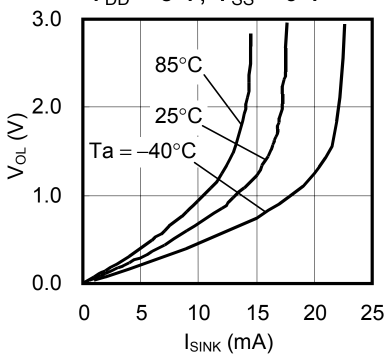


3-3. Output voltage (V_{OL}) vs. I_{SINK}

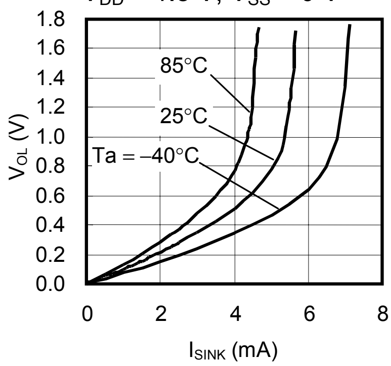
V_{DD} = 5 V, V_{SS} = 0 V



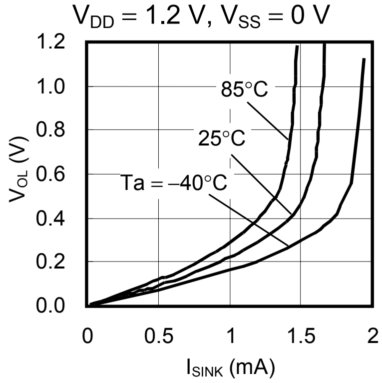
V_{DD} = 3 V, V_{SS} = 0 V



V_{DD} = 1.8 V, V_{SS} = 0 V



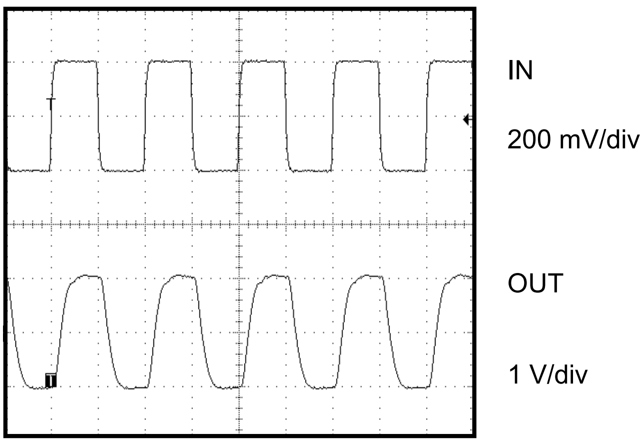
V_{DD} = 1.2 V, V_{SS} = 0 V



(4) Transient response

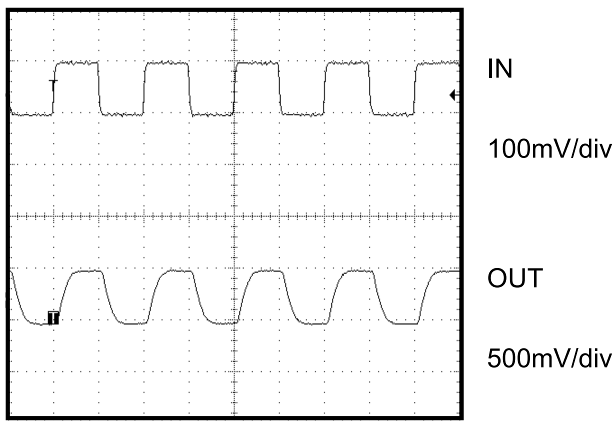
4-1. Large signal transient response

V_{DD} = $-V_{SS}$ = 1.5 V, Gain = +5, C_L = 15 pF
500 ns/div



4-2. Small signal transient response

V_{DD} = $-V_{SS}$ = 1.5 V, Gain = +5, C_L = 15 pF
500 ns/div



■ SOT-23-6

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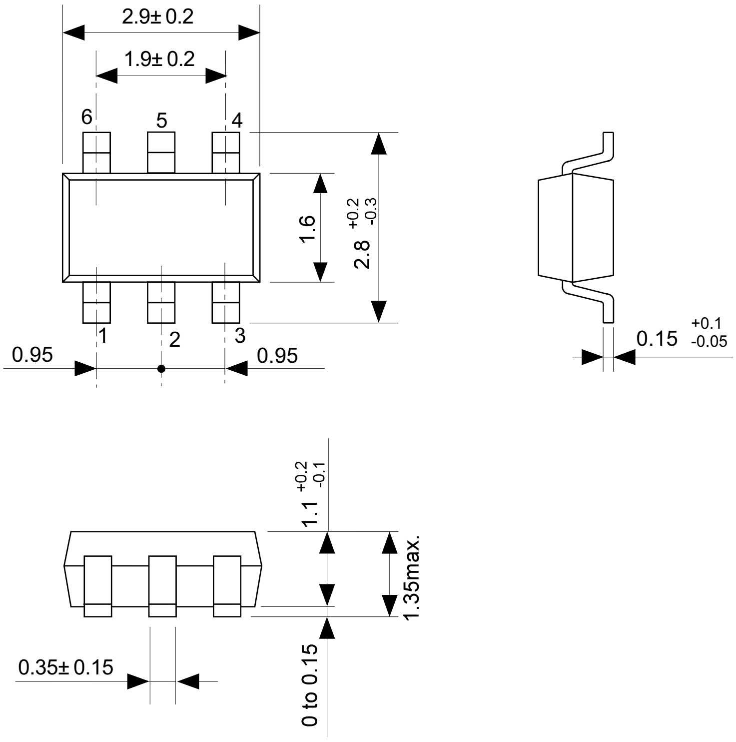
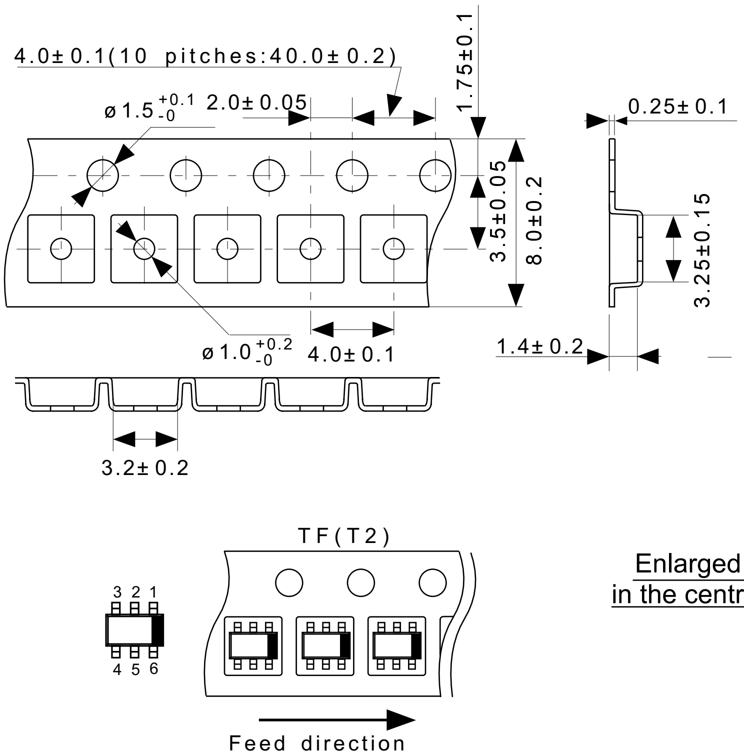
● Dimensions

Unit : mm



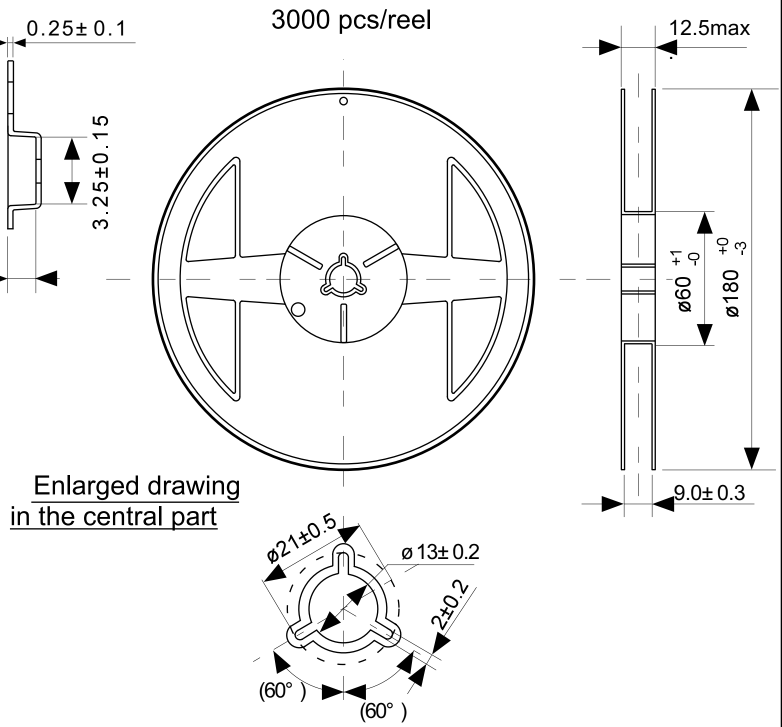
No. MP006-A-P-SD-1.1

● Taping Specifications



No. MP006-A-C-SD-3.1

● Reel Specifications



No. MP006-A-R-SD-2.1