MIC7300

High-Output Drive Rail-to-Rail Op Amp

General Description

The MIC7300 is a high-performance CMOS operational amplifier featuring rail-to-rail input and output with strong output drive capability. It is able to source and sink in excess of 80mA into large capacitive loads.

The input common-mode range extends beyond the rails by 300mV, and the output voltage typically swings to within 150µV of both rails when driving a 100kΩ load.

The amplifier operates from 2.2V to 10V and is fully specified at 2.2V, 3V, 5V, and 10V. Gain bandwidth and slew rate are 500kHz and 0.5V/µs, respectively.

The MIC7300 is available in Micrel's IttyBitty™ SOT-23-5 package for space-conscious circuits and in high-power MM8™ 8-lead MSOP for improved heat dissipation in higher power applications.

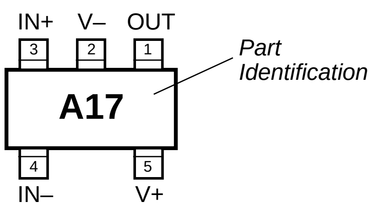
Features

- Small footprint SOT-23-5 and power MSOP-8 packages
- >80mA peak output sink and source with 5V supply
- Drives large capacitive loads (6000pF with 10V supply)
- Guaranteed 2.2V, 3V, 5V, and 10V performance
- 500kHz gain-bandwidth product
- 0.01% total harmonic distortion at 1kHz (10V, 2kΩ)
- 1mA typical power supply current at 5V

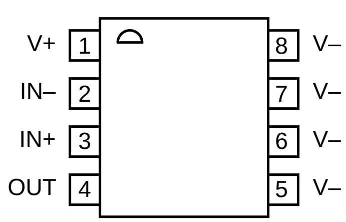
Applications

- Battery-powered instrumentation
- PCMCIA, USB peripherals
- Portable computers and PDAs

Pin Configurations



SOT-23-5 (M5)

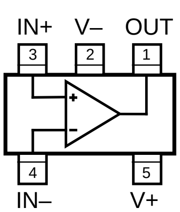


MSOP-8 (MM)

Ordering Information

Part Number			
Standard	**Pb-free**	**Temp. Range**	**Package**
MIC7300BM5	MIC7300YM5	–40°C to +85°C	SOT-23-5
MIC7300BMM	MIC7300YMM	–40°C to +85°C	MSOP-8

Functional Configuration



SOT-23-5 (M5)

Pin Description

Pin Number SOT-23-5	Pin Number MSOP-8	Pin Name	Pin Function
1	4	OUT	Amplifier Output
2	5–8	V–	Negative Supply: Negative supply for split supply application or ground for single supply application.
3	3	IN+	Noninverting Input
4	2	IN–	Inverting Input
5	1	V+	Positive Supply

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Absolute Maximum Ratings (Note 1)

Supply Voltage ($V_{V+} – V_{V–}$) 12V
Differential Input Voltage ($V_{IN+} – V_{IN–}$) .... ±12V
I/O Pin Voltage (V_{IN}, V_{OUT}), **Note 3**
.... V_{V+} + 0.3V to $V_{V–}$ – 0.3V
Junction Temperature (T_J) .... +150°C
Storage Temperature .... –65°C to +150°C
Lead Temperature (soldering, 10 sec.) .... 260°C
ESD, **Note 6**

Operating Ratings (Note 2)

Supply Voltage ($V_{V+} – V_{V–}$) .... 2.2V to 10V
Junction Temperature (T_J) .... –40°C to +85°C
Package Thermal Resistance, **Note 5**
SOT-23-5 (θ_{JA}) .... 260°C/W
MSOP-8 (θ_{JA}) .... 85°C/W
Max. Power Dissipation .... **Note 4**

DC Electrical Characteristics (2.2V)

V_{V+} = +2.2V, $V_{V–}$ = 0V, V_{CM} = V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{OS}	Input Offset Voltage			1.0	9	mV
TCV_{OS}	Input Offset Voltage Average Drift			1.0		µV/°C
I_B	Input Bias Current			0.5		pA
I_{OS}	Input Offset Current			0.25		pA
R_{IN}	Input Resistance			>1		TΩ
CMRR	Common-Mode Rejection Ratio	0V ≤ V_{CM} ≤ 2.2V, **Note 9**	45	65		dB
V_{CM}	Input Common-Mode Voltage	input low, CMRR ≥ 45dB		–0.3	0.0	V
		input high, CMRR ≥ 45dB	2.2	2.5		V
±PSRR	Power Supply Rejection Ratio	$V_{V+} = \lvert V_{V–} \rvert$ = 1.1V to 2.5V, V_{CM} = 0	55	75		dB
C_{IN}	Common-Mode Input Capacitance			3		pF
V_O	Output Swing	output high, R_L = 100k, specified as $V_{V+} – V_{OUT}$		0.15	1 **1**	mV mV
		output low, R_L = 100k		0.15	1 **1**	mV mV
		output high, R_L = 2k specified as $V_{V+} – V_{OUT}$		10	33 **50**	mV mV
		output low, R_L = 2k		10	33 **50**	mV mV
		output high, R_L = 600Ω specified as $V_{V+} – V_{OUT}$		33	110 **165**	mV mV
		output low, R_L = 600Ω		33	110 **165**	mV mV
I_{SC}	Output Short Circuit Current	sinking or sourcing, **Note 8**	20	40		mA
I_S	Supply Current	V_{OUT} = V+/2		0.7	2.0	mA

AC Electrical Characteristics (2.2V)

V_{V+} = 2.2V, $V_{V–}$ = 0V, V_{CM} = V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
SR	Slew Rate			0.5		V/µs
GBW	Gain-Bandwidth Product			0.55		MHz
ϕ_m	Phase Margin	C_L = 0pF		80		°
		C_L = 2500pF		40		°
G_m	Gain Margin			10		dB

DC Electrical Characteristics (3.0V)

V_{V+} = +3.0V, V_{V-} = 0V, V_{CM} = V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{OS}	Input Offset Voltage			1.0	9	mV
TCV_{OS}	Input Offset Voltage Average Drift			1.0		µV/°C
I_B	Input Bias Current			0.5		pA
I_{OS}	Input Offset Current			0.25		pA
R_{IN}	Input Resistance			>1		TΩ
CMRR	Common-Mode Rejection Ratio	0V ≤ V_{CM} ≤ 3.0V, **Note 9**	50	70		dB
V_{CM}	Input Common-Mode Voltage	input low, CMRR ≥ 50dB		–0.3	0	V
		input high, CMRR ≥ 50dB	3.0	3.3		V
±PSRR	Power Supply Rejection Ratio	V_{V+} = $\lvert V_{V-} \rvert$ = 1.5V to 5.0V, V_{CM} = 0	55	75		dB
C_{IN}	Common-Mode Input Capacitance			3		pF
V_{OUT}	Output Swing	output high, R_L = 100k specified as $V_{V+} - V_{OUT}$		0.2	1 **1**	mV mV
		output low, R_L = 100k		0.2	1 **1**	mV mV
		output high, R_L = 2k specified as $V_{V+} - V_{OUT}$		10	33 **50**	mV mV
		output low, R_L = 2k		10	33 **50**	mV mV
		output high, R_L = 600Ω specified as $V_{V+} - V_{OUT}$		33	110 **165**	mV mV
		output low, R_L = 600Ω		33	110 **165**	mV mV
I_{SC}	Output Short Circuit Current	sinking or sourcing, **Note 8**	60	95		mA
I_S	Supply Current			0.8	2.2	mA

AC Electrical Characteristics (3V)

V_{V+} = 3V, V_{V-} = 0V, V_{CM} = 1.5V, V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
SR	Slew Rate			0.5		V/µs
GBW	Gain-Bandwidth Product			0.45		MHz
ϕ_m	Phase Margin	C_L = 0pF		85		°
		C_L = 3500pF		40		°
G_m	Gain Margin			10		dB

DC Electrical Characteristics (5V)

V_{V+} = +5.0V, V_{V-} = 0V, V_{CM} = 1.5V, V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{OS}	Input Offset Voltage			1.0	9	mV
TCV_{OS}	Input Offset Voltage Average Drift			1.0		µV/°C
I_B	Input Bias Current			0.5		pA
I_{OS}	Input Offset Current			0.25		pA
R_{IN}	Input Resistance			>1		TΩ
CMRR	Common-Mode Rejection Ratio	0V ≤ V_{CM} ≤ 5V, **Note 9**	55	80		dB
V_{CM}	Input Common-Mode Voltage	input low, CMRR ≥ 55dB		–0.3	–0.0	V
		input high, CMRR ≥ 55dB	5.0	5.3		V
±PSRR	Power Supply Rejection Ratio	V_{V+} = $\lvert V_{V-} \rvert$ = 2.5V to 5.0V, V_{CM} = 0	55	75		dB
C_{IN}	Common-Mode Input Capacitance			3		pF
V_{OUT}	Output Swing	output high, R_L = 100k specified as $V_{V+} - V_{OUT}$		0.3	1.0 **1.5**	mV mV
		output low, R_L = 100k		0.3	1.0 **1.5**	mV mV
		output high, R_L = 2k specified as $V_{V+} - V_{OUT}$		15	50 **75**	mV mV
		output low, R_L = 2k		15	50 **75**	mV mV
		output high, R_L = 600Ω specified as $V_{V+} - V_{OUT}$		50	165 **250**	mV mV
		output low, R_L = 600Ω		50	165 **250**	mV mV
I_{SC}	Output Short Circuit Current	sinking or sourcing, **Note 8**	85	105		mA
I_S	Supply Current	V_{OUT} = V+/2		1.0	2.8	mA

AC Electrical Characteristics (5V)

V_{V+} = 5V, V_{V-} = 0V, V_{CM} = 1.5V, V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
THD	Total Harmonic Distortion	f = 1kHz, A_V = –2, R_L = 2kΩ, V_{OUT} = 4.0 V_{PP}		0.05		%
SR	Slew Rate			0.5		V/µs
GBW	Gain-Bandwidth Product			0.4		MHz
ϕ_m	Phase Margin	C_L = 0pF		85		°
		C_L = 4500pF		40		°
G_m	Gain Margin			10		dB

DC Electrical Characteristics (10V)

V_{V+} = +10V, V_{V-} = 0V, V_{CM} = 1.5V, V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{OS}	Input Offset Voltage			1.0	9	mV
TCV_{OS}	Input Offset Voltage Average Drift			1.0		µV/°C
I_B	Input Bias Current			0.5		pA
I_{OS}	Input Offset Current			0.25		pA
R_{IN}	Input Resistance			>1		TΩ
CMRR	Common-Mode Rejection Ratio	0V ≤ V_{CM} ≤ 10V, **Note 9**	60	85		dB
V_{CM}	Input Common-Mode Voltage	input low, V+ = 10V, CMRR ≥ 60dB		–0.3	–0.0	V
		input high, V+ = 10V, CMRR ≥ 60dB	10.0	10.3		V
±PSRR	Power Supply Rejection Ratio	V_{V+} = $\lvert V_{V-} \rvert$ = 2.5V to 5.0V, V_{CM} = 0	55	75		dB
A_V	Large Signal Voltage Gain	sourcing or sinking, R_L = 2k, **Note 10**	80	340		V/mV
		sourcing or sinking, R_L = 600Ω, **Note 10**	15	300		V/mV
C_{IN}	Common-Mode Input Capacitance			3		pF
V_{OUT}	Output Swing	output high, R_L = 100k specified as $V_{V+} - V_{OUT}$		0.5	1.5 **2.5**	mV mV
		output low, R_L = 100k		0.5	1.5 **2.5**	mV mV
		output high, R_L = 2k specified as $V_{V+} - V_{OUT}$		24	80 **120**	mV mV
		output low, R_L = 2k		24	80 **120**	mV mV
		output high, R_L = 600Ω specified as $V_{V+} - V_{OUT}$		80	270 **400**	mV mV
		output low, R_L = 600Ω		80	270 **400**	mV mV
I_{SC}	Output Short Circuit Current	sinking or sourcing, **Notes 8**	90	115		mA
I_S	Supply Current	V_{OUT} = V+/2		1.5	4.0	mA

AC Electrical Characteristics (10V)

V_{V+} = 10V, V_{V-} = 0V, V_{CM} = 1.5V, V_{OUT} = V_{V+}/2; R_L = 1MΩ; T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C; **Note 7**; unless noted

Symbol	Parameter	Condition	Min	Typ	Max	Units
THD	Total Harmonic Distortion	f = 1kHz, A_V = –2, R_L = 2k, V_{OUT} = 8.5 V_{PP}		0.01		%
SR	Slew Rate	V+ = 10V, **Note 11**		0.5		V/µs V/µs
GBW	Gain-Bandwidth Product			0.37		MHz
ϕ_m	Phase Margin	C_L = 0pF		85		°
		C_L = 6000pF		40		°
G_m	Gain Margin			10		dB
e_n	Input-Referred Voltage Noise	f = 1kHz, V_{CM} = 1V		37		nV/$\sqrt{Hz}$
i_n	Input-Referred Current Noise	f = 1kHz		1.5		fA/$\sqrt{Hz}$

Note 1. Exceeding the absolute maximum rating may damage the device.

Note 2. The device is not guaranteed to function outside its operating rating.

Note 3. I/O Pin Voltage is any external voltage to which an input or output is referenced.

Note 4. The maximum allowable power dissipation is a function of the maximum junction temperature, $T_{J(max)}$; the junction-to-ambient thermal resistance, θ_{JA}; and the ambient temperature, T_A. The maximum allowable power dissipation at any ambient temperature is calculated using: $P_D = (T_{J(max)} - T_A) \div \theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature.

Note 5. Thermal resistance, θ_{JA}, applies to a part soldered on a printed-circuit board.

Note 6. Devices are ESD protected; however, handling precautions are recommended.

Note 7. All limits guaranteed by testing or statistical analysis.

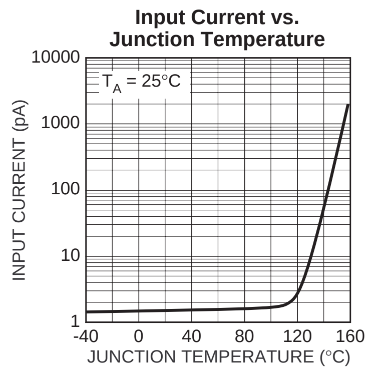
Note 8. Continuous short circuit may exceed absolute maximum T_J under some conditions.

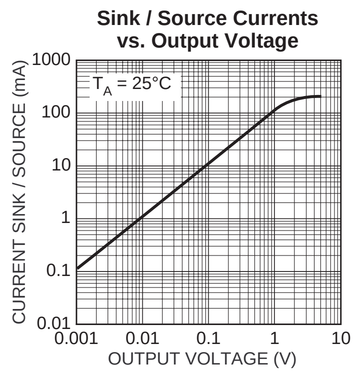
Note 9. CMRR is determined as follows: The maximum ΔV_{OS} over the V_{CM} range is divided by the magnitude of the V_{CM} range. The measurement points are: V_{V-}, $(V_{V+} - V_{V-})/2$, and V_{V+}.

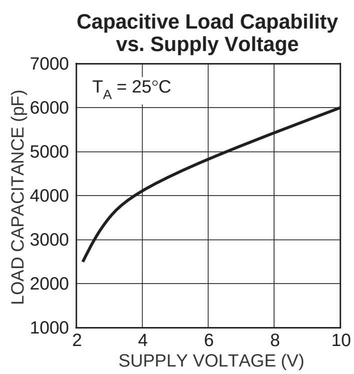
Note 10. R_L connected to 5V. Sourcing: $5V \leq V_{OUT} \leq 10V$. Sinking: $2.5V \leq V_{OUT} \leq 5V$.

Note 11. Device connected as a voltage follower with a 10V step input. The value is the positive or negative slew rate, whichever is slower.

Typical Characteristics







Application Information

Input Common-Mode Voltage

The MIC7300 tolerates input overdrive by at least 300mV beyond either rail without producing phase inversion.

If the absolute maximum input voltage is exceeded, the input current should be limited to ±5mA maximum to prevent reducing reliability. A 10kΩ series input resistor, used as a current limiter, will protect the input structure from voltages as large as 50V above the supply or below ground. See Figure 1.

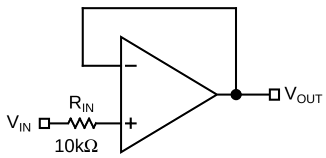


Figure 1. Input Current-Limit Protection

Output Voltage Swing

Sink and source output resistances of the MIC7300 are equal. Maximum output voltage swing is determined by the load and the approximate output resistance. The output resistance is:

$$R_{OUT} = \frac{V_{DROP}}{I_{LOAD}}$$

V_{DROP} is the voltage dropped within the amplifier output stage. V_{DROP} and I_{LOAD} can be determined from the V_O (output swing) portion of the appropriate Electrical Characteristics table. I_{LOAD} is equal to the typical output high voltage minus V+/2 and divided by R_{LOAD}. For example, using the Electrical Characteristics DC (5V) table, the typical output high voltage using a 2kΩ load (connected to V+/2) is 4.985V, which produces an I_{LOAD} of:

$$\left(\frac{4.985V - 2.5V}{2k\Omega}\right) = 1.243mA.$$

Voltage drop in the amplifier output stage is:

$$V_{DROP} = 5.0V - 4.985V$$

$$V_{DROP} = 0.015V$$

Because of output stage symmetry, the corresponding typical output low voltage (0.015V) also equals V_{DROP}. Then:

$$R_{OUT} = \frac{0.015V}{0.001243A} = 12\Omega$$

Power Dissipation

The MIC7300 output drive capability requires considering power dissipation. If the load impedance is low, it is possible to damage the device by exceeding the 125°C junction temperature rating.

On-chip power consists of two components: supply power and output stage power. Supply power (P_S) is the product of the supply voltage ($V_S = V_{V+} - V_{V-}$) and supply current (I_S). Output stage power (P_O) is the product of the output stage voltage drop (V_{DROP}) and the output (load) current (I_{OUT}). Total on-chip power dissipation is:

$$P_D = P_S + P_O$$

$$P_D = V_S I_S + V_{DROP} I_{OUT}$$

where:

P_D = total on-chip power

P_S = supply power dissipation

P_O = output power dissipation

$V_S = V_{V+} - V_{V-}$

I_S = power supply current

$V_{DROP} = V_{V+} - V_{OUT}$ *(sourcing current)*

$V_{DROP} = V_{OUT} - V_{V-}$ *(sinking current)*

The above addresses only steady state (dc) conditions. For non-dc conditions the user must estimate power dissipation based on rms value of the signal.

The task is one of determining the allowable on-chip power dissipation for operation at a given ambient temperature and power supply voltage. From this determination, one may calculate the maximum allowable power dissipation and, after subtracting P_S, determine the maximum allowable load current, which in turn can be used to determine the miniumum load impedance that may safely be driven. The calculation is summarized below.

$$P_{D(max)} = \frac{T_{J(max)} - T_A}{\theta_{JA}}$$

$\theta_{JA(SOT\text{-}23\text{-}5)} = 260°C/W$

$\theta_{JA(MSOP\text{-}8)} = 85°C/W$

Driving Capacitive Loads

Driving a capacitive load introduces phase-lag into the output signal, and this in turn reduces op-amp system phase margin. The application that is least forgiving of reduced phase margin is a unity gain amplifier. The MIC7300 can typically drive a 2500pF capacitive load connected directly to the output when configured as a unity-gain amplifier and powered with a 2.2V supply. At 10V operation the circuit typically drives 6000pF. Phase margin is typically 40°.

Using Large-Value Feedback Resistors

A large-value feedback resistor (> 500kΩ) can reduce the phase margin of a system. This occurs when the feedback resistor acts in conjunction with input capacitance to create phase lag in the feedback signal. Input capacitance is usually a combination of input circuit components and other parasitic capacitance, such as amplifier input capacitance and stray printed circuit board capacitance.

Figure 2 illustrates a method of compensating phase lag caused by using a large-value feedback resistor. Feedback capacitor C_{FB} introduces sufficient phase lead to overcome the phase lag caused by feedback resistor R_{FB} and input capacitance C_{IN}. The value of C_{FB} is determined by first estimating C_{IN} and then applying the following formula:

$$R_{IN} \times C_{IN} \leq R_{FB} \times C_{FB}$$

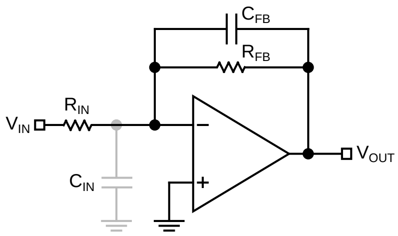


Figure 2. Cancelling Feedback Phase Lag

Since a significant percentage of C_{IN} may be caused by board layout, it is important to note that the correct value of C_{FB} may change when changing from a breadboard to the final circuit layout.

Typical Circuits

Some single-supply, rail-to-rail applications for which the MIC7300 is well suited are shown in the circuit diagrams of Figures 3 through 7.

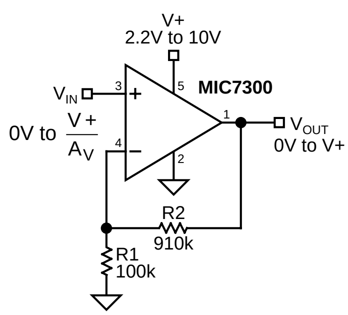


Figure 3a. Noninverting Amplifier

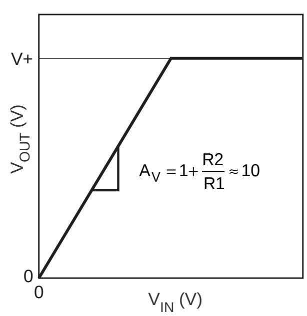


Figure 3b. Noninverting Amplifier Behavior

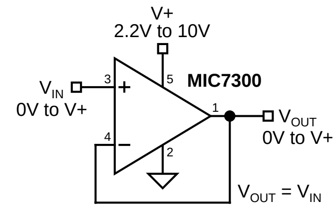


Figure 4. Voltage Follower/Buffer

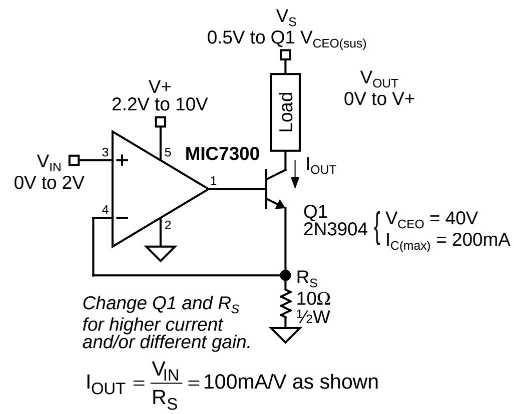


Figure 5. Voltage-Controlled Current Sink

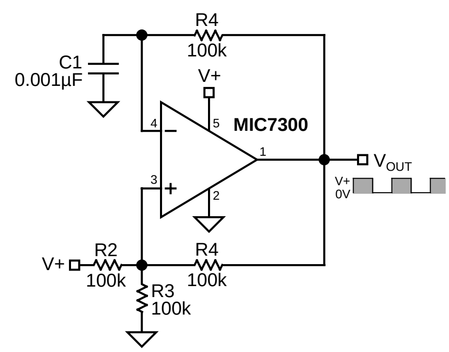


Figure 6. Square Wave Oscillator

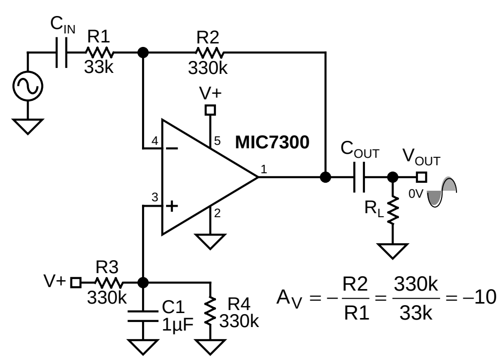
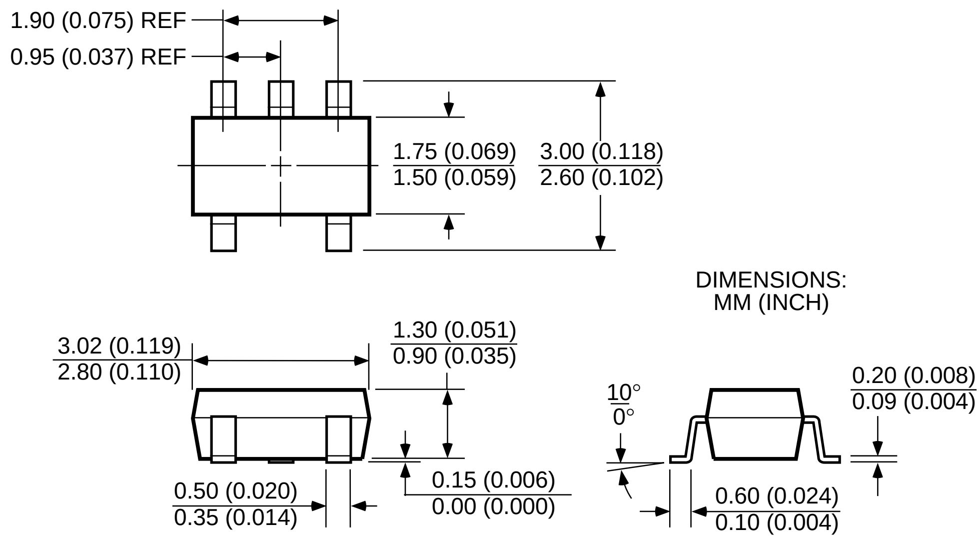
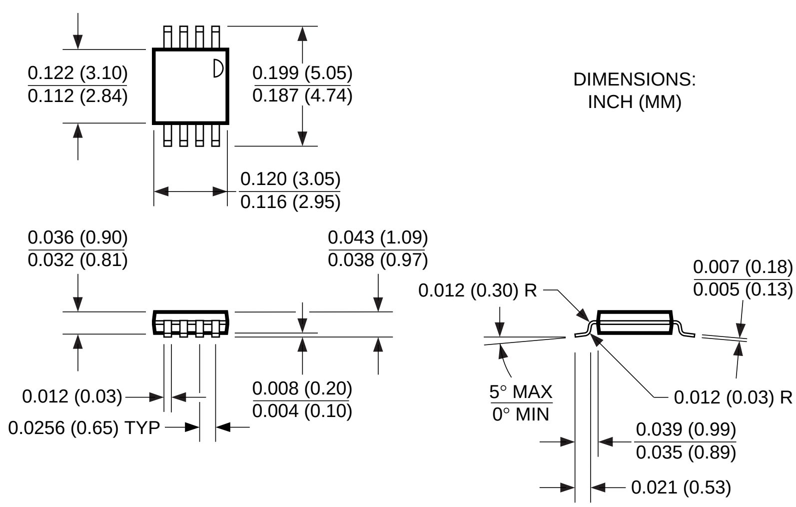


Figure 7. AC-Coupled Inverting Amplifier

Package Information



SOT-23-5 (M5)



8-Pin MSOP (MM)

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