



**THE DATASHEET OF
MC3303DR2**



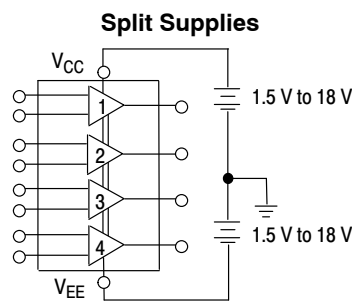
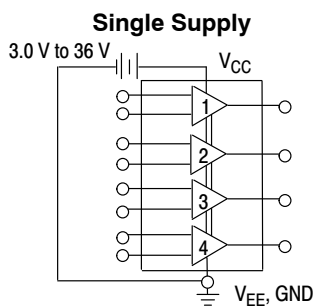
MC3403, MC3303

Single Supply Quad Operational Amplifiers

The MC3403 is a low cost, quad operational amplifier with true differential inputs. The device has electrical characteristics similar to the popular MC1741C. However, the MC3403 has several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 36 V with quiescent currents about one third of those associated with the MC1741C (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features

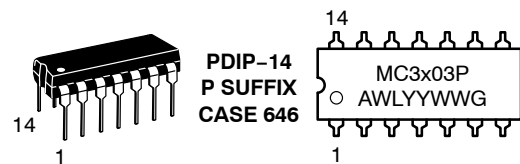
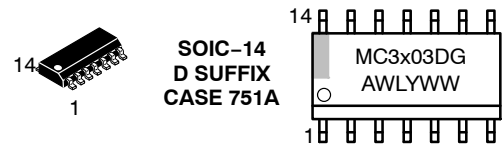
- Short Circuit Protected Outputs
- Class AB Output Stage for Minimal Crossover Distortion
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 36 V
- Split Supply Operation: ± 1.5 V to ± 18 V
- Low Input Bias Currents: 500 nA Max
- Four Amplifiers Per Package
- Internally Compensated
- Similar Performance to Popular MC1741C
- Industry Standard Pin-outs
- ESD Diodes Added for Increased Ruggedness
- Pb-Free Packages are Available



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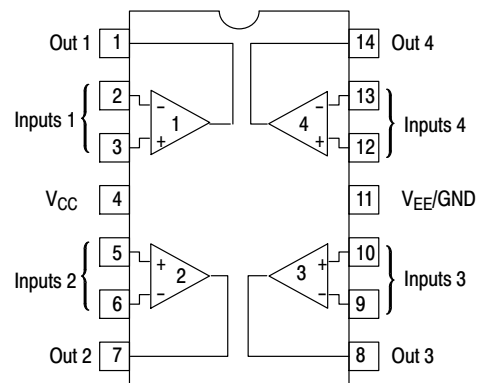
<http://onsemi.com>

MARKING DIAGRAMS



x = 3 or 4
 A = Assembly Location
 WL = Wafer Lot
 YY, Y = Year
 WW = Work Week
 G = Pb-Free Package

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 2 of this data sheet.

MC3403, MC3303

ORDERING INFORMATION

Device	Package	Shipping†
MC3303D	SOIC-14	55 Units / Rail
MC3303DG	SOIC-14 (Pb-Free)	
MC3303DR2	SOIC-14	2500 Tape & Reel
MC3303DR2G	SOIC-14 (Pb-Free)	
MC3303P	PDIP-14	25 Units / Rail
MC3303PG	PDIP-14 (Pb-Free)	
MC3403D	SOIC-14	55 Units / Rail
MC3403DG	SOIC-14 (Pb-Free)	
MC3403DR2	SOIC-14	2500 Tape & Reel
MC3403DR2G	SOIC-14 (Pb-Free)	
MC3403P	PDIP-14	25 Units / Rail
MC3403PG	PDIP-14 (Pb-Free)	

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Power Supply Voltages Single Supply Split Supplies	V_{CC} V_{CC}, V_{EE}	36 ± 18	Vdc
Input Differential Voltage Range (Note 1)	V_{IDR}	± 36	Vdc
Input Common Mode Voltage Range (Notes 1 and 2)	V_{ICR}	± 18	Vdc
Storage Temperature Range	T_{stg}	-55 to +125	°C
Operating Ambient Temperature Range	T_A	-40 to +85 0 to +70	°C
Junction Temperature	T_J	150	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Split power supplies.
2. For supply voltages less than ± 18 V, the absolute maximum input voltage is equal to the supply voltage.

MC3403, MC3303

ELECTRICAL CHARACTERISTICS

($V_{CC} = +15\text{ V}$, $V_{EE} = -15\text{ V}$ for MC3403; $V_{CC} = +14\text{ V}$, $V_{EE} = \text{GND}$ for MC3303 $T_A = 25^\circ\text{C}$, unless otherwise noted.)

Characteristic	Symbol	MC3403			MC3303			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage $T_A = T_{\text{high}}$ to T_{low} (Note 3)	V_{IO}	-	2.0	10	-	2.0	8.0	mV
		-	-	12	-	-	10	
Input Offset Current $T_A = T_{\text{high}}$ to T_{low}	I_{IO}	-	30	50	-	30	75	nA
		-	-	200	-	-	250	
Large Signal Open Loop Voltage Gain $V_O = \pm 10\text{ V}$, $R_L = 2.0\text{ k}\Omega$ $T_A = T_{\text{high}}$ to T_{low}	A_{VOL}	20	200	-	20	200	-	V/mV
		15	-	-	15	-	-	
Input Bias Current $T_A = T_{\text{high}}$ to T_{low}	I_{IB}	-	-200	-500	-	-200	-500	nA
		-	-	-800	-	-	-1000	
Output Impedance $f = 20\text{ Hz}$	z_o	-	75	-	-	75	-	Ω
Input Impedance $f = 20\text{ Hz}$	z_i	0.3	1.0	-	0.3	1.0	-	M Ω
Output Voltage Range $R_L = 10\text{ k}\Omega$ $R_L = 2.0\text{ k}\Omega$ $R_L = 2.0\text{ k}\Omega$, $T_A = T_{\text{high}}$ to T_{low}	V_O	± 12	± 13.5	-	12	12.5	-	V
		± 10	± 13	-	10	12	-	
		± 10	-	-	10	-	-	
Input Common Mode Voltage Range	V_{ICR}	+13 V - V_{EE}	+13 V - V_{EE}	-	+12 V - V_{EE}	+12.5 V - V_{EE}	-	V
Common Mode Rejection $R_S \leq 10\text{ k}\Omega$	CMR	70	90	-	70	90	-	dB
Power Supply Current ($V_O = 0$) $R_L = \infty$	I_{CC} , I_{EE}	-	2.8	7.0	-	2.8	7.0	mA
Individual Output Short-Circuit Current (Note 4)	I_{SC}	± 10	± 20	± 45	± 10	± 30	± 45	mA
Positive Power Supply Rejection Ratio	PSRR+	-	30	150	-	30	150	$\mu\text{V/V}$
Negative Power Supply Rejection Ratio	PSRR-	-	30	150	-	30	150	$\mu\text{V/V}$
Average Temperature Coefficient of Input Offset Current $T_A = T_{\text{high}}$ to T_{low}	$\Delta I_{IO}/\Delta T$	-	50	-	-	50	-	$\text{pA}/^\circ\text{C}$
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{\text{high}}$ to T_{low}	$\Delta V_{IO}/\Delta T$	-	10	-	-	10	-	$\mu\text{V}/^\circ\text{C}$
Power Bandwidth $A_V = 1$, $R_L = 10\text{ k}\Omega$, $V_O = 20\text{ V(p-p)}$, THD = 5%	BWp	-	9.0	-	-	9.0	-	kHz
Small-Signal Bandwidth $A_V = 1$, $R_L = 10\text{ k}\Omega$, $V_O = 50\text{ mV}$	BW	-	1.0	-	-	1.0	-	MHz
Slew Rate $A_V = 1$, $V_i = -10\text{ V}$ to $+10\text{ V}$	SR	-	0.6	-	-	0.6	-	V/ μs
Rise Time $A_V = 1$, $R_L = 10\text{ k}\Omega$, $V_O = 50\text{ mV}$	t_{TLH}	-	0.35	-	-	0.35	-	μs
Fall Time $A_V = 1$, $R_L = 10\text{ k}\Omega$, $V_O = 50\text{ mV}$	t_{TLH}	-	0.35	-	-	0.35	-	μs
Overshoot $A_V = 1$, $R_L = 10\text{ k}\Omega$, $V_O = 50\text{ mV}$	os	-	20	-	-	20	-	%
Phase Margin $A_V = 1$, $R_L = 2.0\text{ k}\Omega$, $V_O = 200\text{ pF}$	ϕ_m	-	60	-	-	60	-	$^\circ$
Crossover Distortion ($V_{in} = 30\text{ mVpp}$, $V_{out} = 2.0\text{ Vpp}$, $f = 10\text{ kHz}$)	-	-	1.0	-	-	1.0	-	%

3. MC3303: $T_{\text{low}} = -40^\circ\text{C}$, $T_{\text{high}} = +85^\circ\text{C}$, MC3403: $T_{\text{low}} = 0^\circ\text{C}$, $T_{\text{high}} = +70^\circ\text{C}$

4. Not to exceed maximum package power dissipation.

MC3403, MC3303

ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.0\text{ V}$, $V_{EE} = \text{GND}$, $T_A = 25^\circ\text{C}$, unless otherwise noted.)

Characteristic	Symbol	MC3403			MC3303			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{IO}	-	2.0	10	-	-	10	mV
Input Offset Current	I_{IO}	-	30	50	-	-	75	nA
Input Bias Current	I_{IB}	-	-200	-500	-	-	-500	nA
Large Signal Open Loop Voltage Gain $R_L = 2.0\text{ k}\Omega$	A_{VOL}	10	200	-	10	200	-	V/mV
Power Supply Rejection Ratio	PSRR	-	-	150	-	-	150	$\mu\text{V/V}$
Output Voltage Range (Note 5) $R_L = 10\text{ k}\Omega$, $V_{CC} = 5.0\text{ V}$ $R_L = 10\text{ k}\Omega$, $5.0 \leq V_{CC} \leq 30\text{ V}$	V_{OR}	3.3 $V_{CC}-2.0$	3.5 $V_{CC}-1.7$	- -	3.3 $V_{CC}-2.0$	3.5 $V_{CC}-1.7$	- -	V_{pp}
Power Supply Current	I_{CC}	-	2.5	7.0	-	2.5	7.0	mA
Channel Separation $f = 1.0\text{ kHz}$ to 20 kHz (Input Referenced)	CS	-	-120	-	-	-120	-	dB

5. Output will swing to ground with a 10 k Ω pull down resistor.

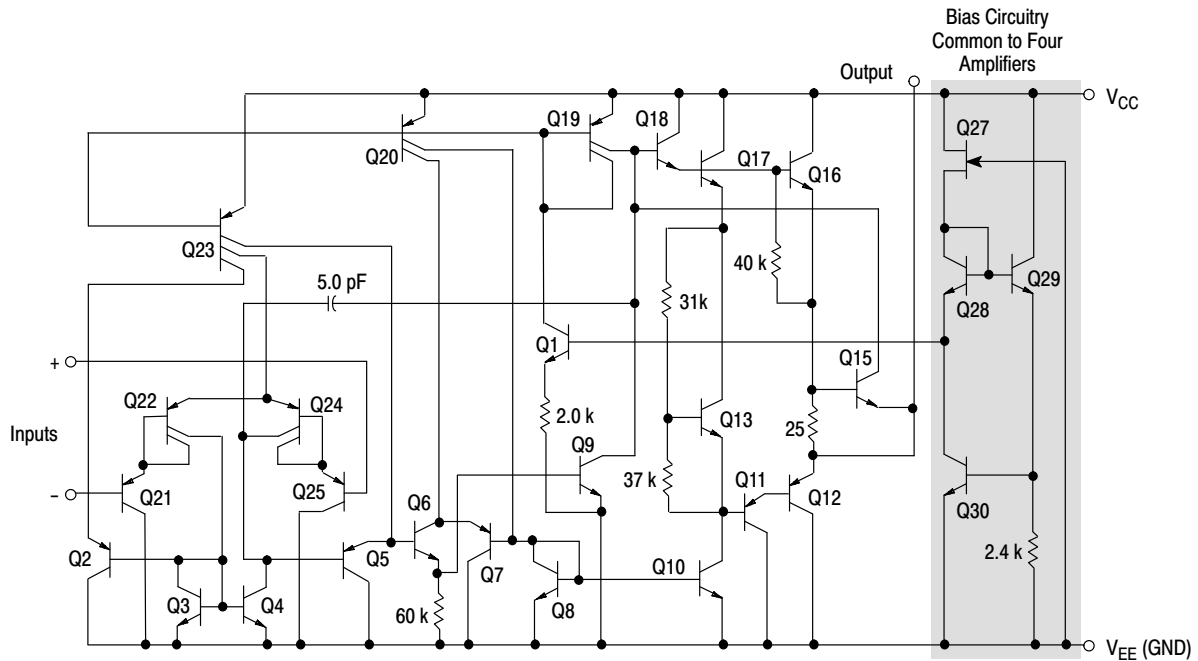


Figure 1. Representative Schematic Diagram
(1/4 of Circuit Shown)

CIRCUIT DESCRIPTION

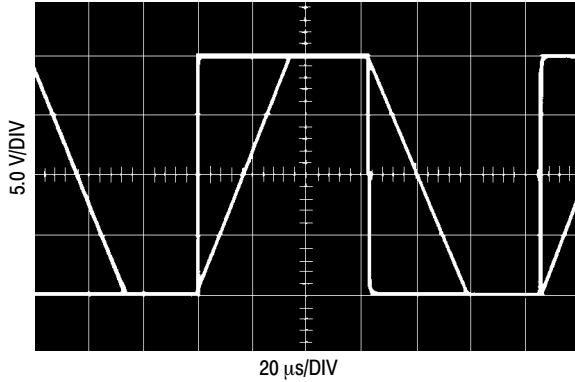


Figure 2. Inverter Pulse Response

The MC3403/3303 is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input device Q24 and Q22 with input buffer transistors Q25 and Q21 and the differential to single ended converter Q3 and Q4. The first

stage performs not only the first stage gain function but also performs the level shifting and Transconductance reduction functions. By reducing the Transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The Transconductance reduction is accomplished by splitting the collectors of Q24 and Q22. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single-ended converter. The second stage consists of a standard current source load amplifier stage.

The output stage is unique because it allows the output to swing to ground in single supply operation and yet does not exhibit any crossover distortion in split supply operation. This is possible because Class AB operation is utilized.

Each amplifier is biased from an internal voltage regulator which has a low temperature coefficient, thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.

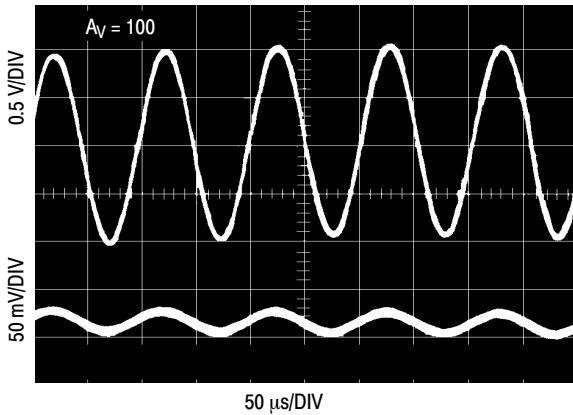


Figure 3. Sine Wave Response

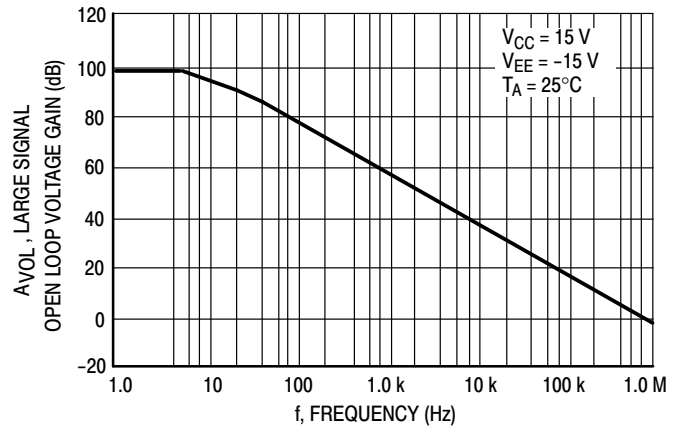


Figure 4. Open Loop Frequency Response

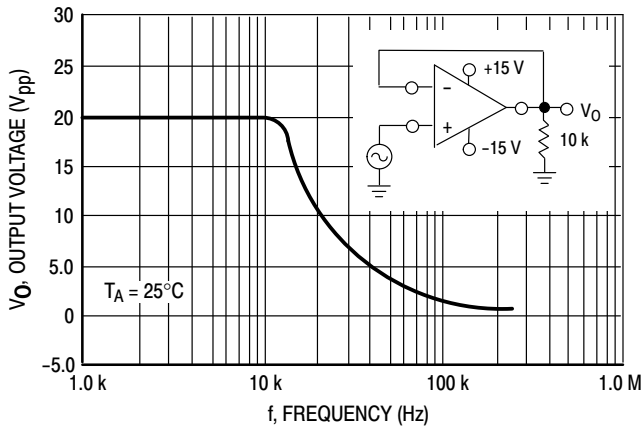


Figure 5. Power Bandwidth

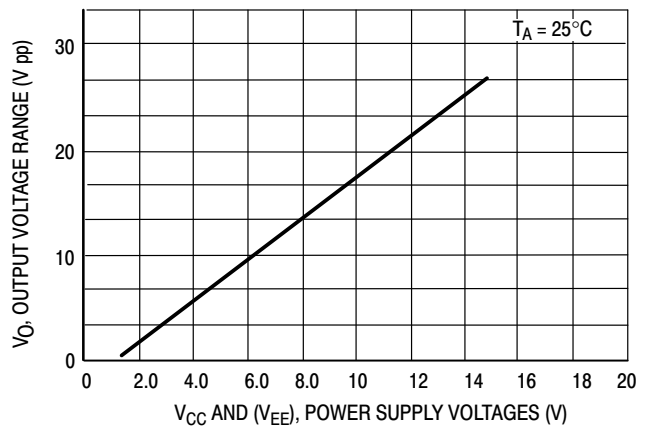


Figure 6. Output Swing versus Supply Voltage

MC3403, MC3303

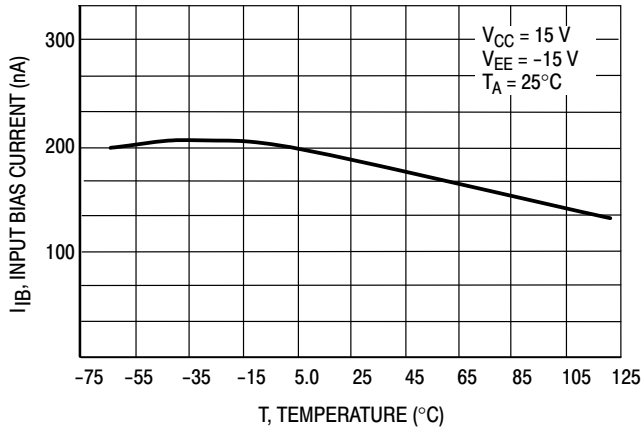


Figure 7. Input Bias Current versus Temperature

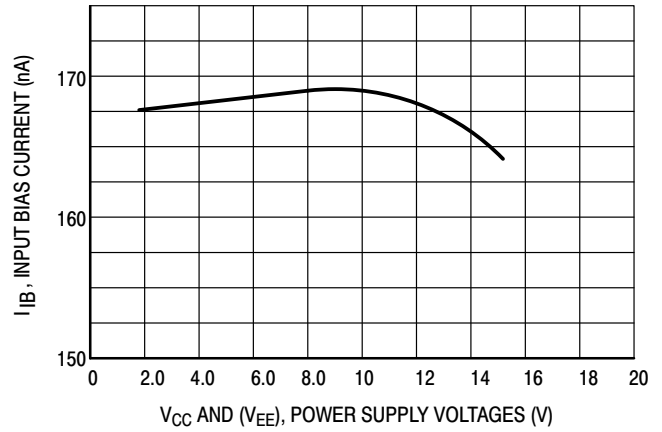


Figure 8. Input Bias Current versus Supply Voltage

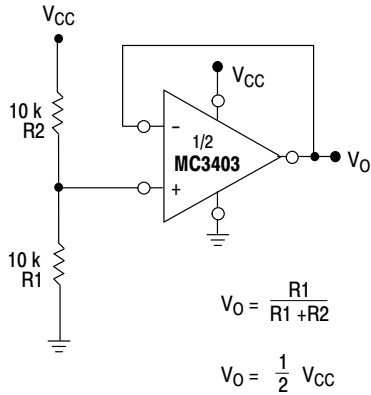


Figure 9. Voltage Reference

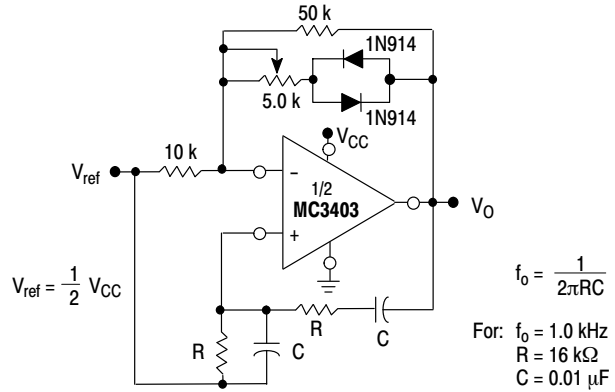


Figure 10. Wien Bridge Oscillator

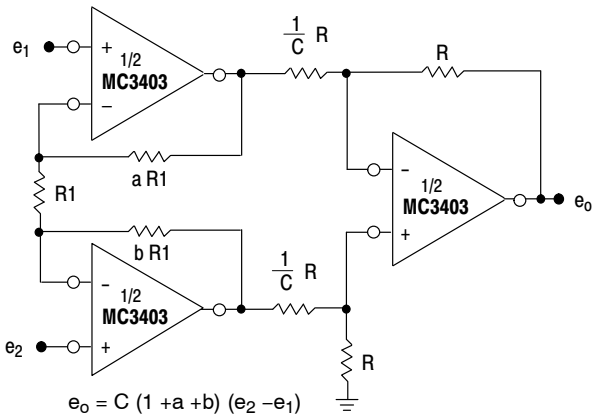


Figure 11. High Impedance Differential Amplifier

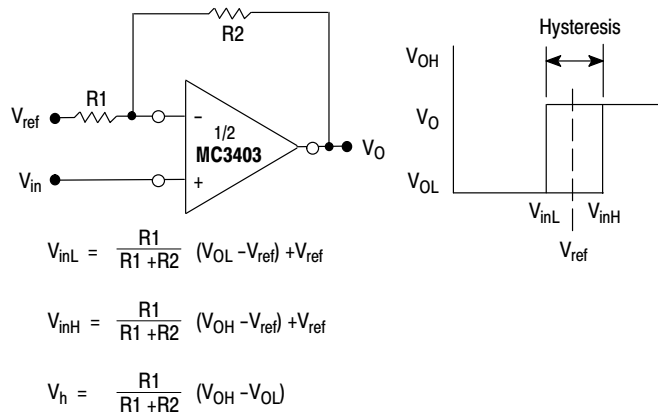


Figure 12. Comparator with Hysteresis

MC3403, MC3303

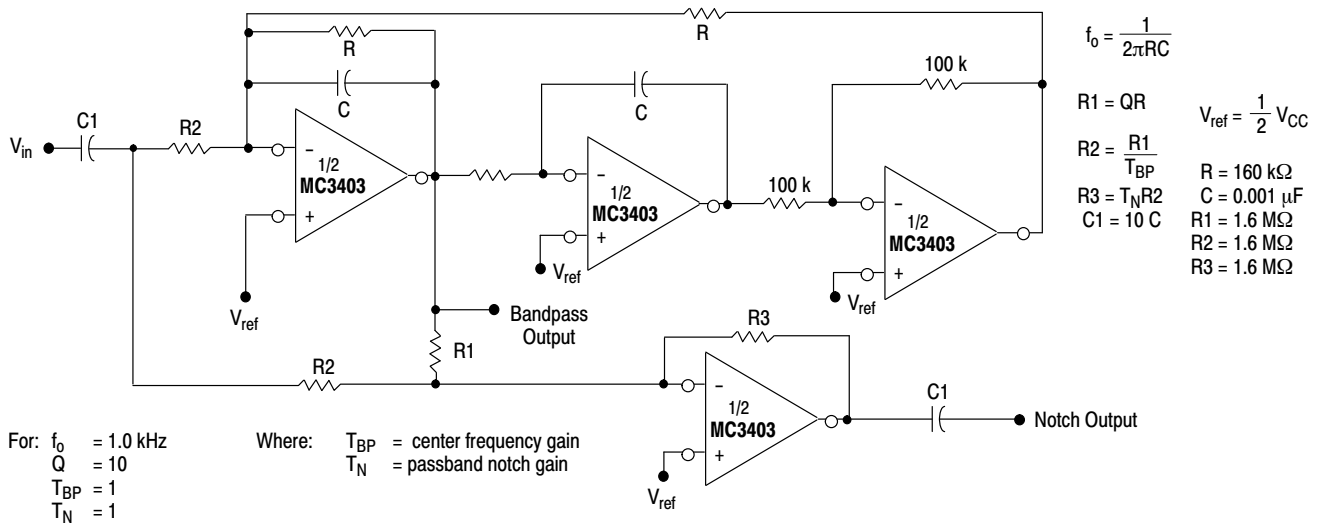


Figure 13. Bi-Quad Filter

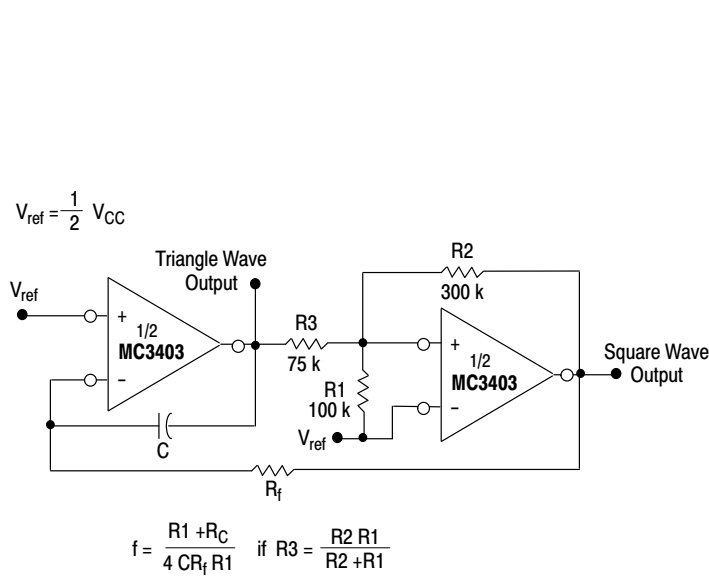
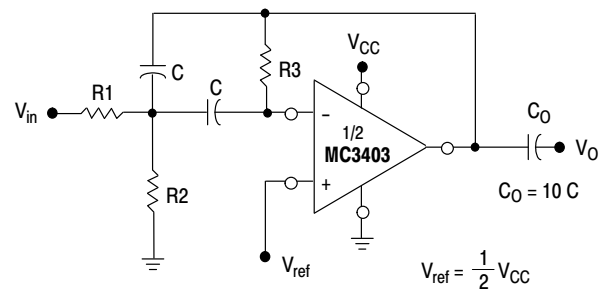


Figure 14. Function Generator



Given: f_o = center frequency
 $A(f_o)$ = gain at center frequency

Choose value f_o, C

$$\text{Then: } R3 = \frac{Q}{\pi f_o C} \quad R1 = \frac{R3}{2 A(f_o)} \quad R2 = \frac{R1 R5}{4Q^2 R1 - R5}$$

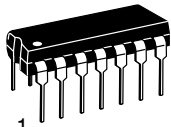
For less than 10% error from operational amplifier $\frac{Q_o f_o}{BW} < 0.1$
 where f_o and BW are expressed in Hz.

If source impedance varies, filter may be preceded by voltage follower buffer to stabilize filter parameters.

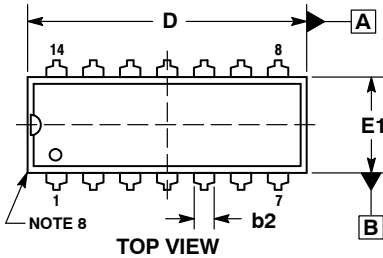
Figure 15. Multiple Feedback Bandpass Filter

MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS

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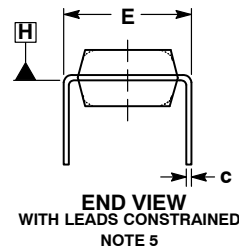


SCALE 1:1



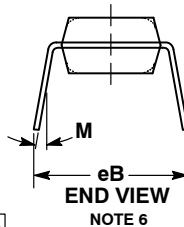
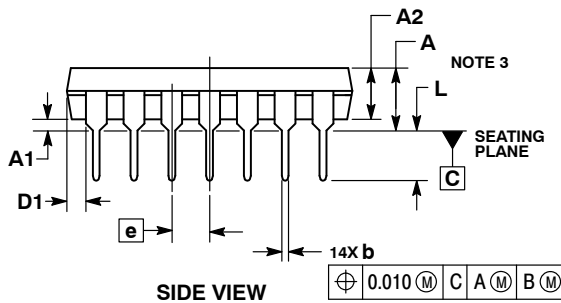
PDIP-14
CASE 646-06
ISSUE S

DATE 22 APR 2015



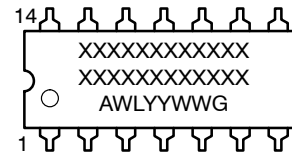
NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACKAGE SEATED IN JEDEC SEATING PLANE GAUGE GS-3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE NOT TO EXCEED 0.10 INCH.
5. DIMENSION E IS MEASURED AT A POINT 0.015 BELOW DATUM PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR TO DATUM C.
6. DIMENSION eB IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE CORNERS).



DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	----	0.210	----	5.33
A1	0.015	----	0.38	----
A2	0.115	0.195	2.92	4.95
b	0.014	0.022	0.35	0.56
b2	0.060 TYP		1.52 TYP	
C	0.008	0.014	0.20	0.36
D	0.735	0.775	18.67	19.69
D1	0.005	----	0.13	----
E	0.300	0.325	7.62	8.26
E1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
eB	----	0.430	----	10.92
L	0.115	0.150	2.92	3.81
M	----	10°	----	10°

GENERIC
MARKING DIAGRAM*



- XXXXX = Specific Device Code
- A = Assembly Location
- WL = Wafer Lot
- YY = Year
- WW = Work Week
- G = Pb-Free Package

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present.

STYLES ON PAGE 2

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DESCRIPTION:	PDIP-14	PAGE 1 OF 2

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PDIP-14
CASE 646-06
ISSUE S

DATE 22 APR 2015

STYLE 1:
 PIN 1. COLLECTOR
 2. BASE
 3. EMITTER
 4. NO
 CONNECTION
 5. EMITTER
 6. BASE
 7. COLLECTOR
 8. COLLECTOR
 9. BASE
 10. EMITTER
 11. NO
 CONNECTION
 12. EMITTER
 13. BASE
 14. COLLECTOR

STYLE 2:
 CANCELLED

STYLE 3:
 CANCELLED

STYLE 4:
 PIN 1. DRAIN
 2. SOURCE
 3. GATE
 4. NO
 CONNECTION
 5. GATE
 6. SOURCE
 7. DRAIN
 8. DRAIN
 9. SOURCE
 10. GATE
 11. NO
 CONNECTION
 12. GATE
 13. SOURCE
 14. DRAIN

STYLE 5:
 PIN 1. GATE
 2. DRAIN
 3. SOURCE
 4. NO CONNECTION
 5. SOURCE
 6. DRAIN
 7. GATE
 8. GATE
 9. DRAIN
 10. SOURCE
 11. NO CONNECTION
 12. SOURCE
 13. DRAIN
 14. GATE

STYLE 6:
 PIN 1. COMMON CATHODE
 2. ANODE/CATHODE
 3. ANODE/CATHODE
 4. NO CONNECTION
 5. ANODE/CATHODE
 6. NO CONNECTION
 7. ANODE/CATHODE
 8. ANODE/CATHODE
 9. ANODE/CATHODE
 10. NO CONNECTION
 11. ANODE/CATHODE
 12. ANODE/CATHODE
 13. NO CONNECTION
 14. COMMON ANODE

STYLE 7:
 PIN 1. NO CONNECTION
 2. ANODE
 3. ANODE
 4. NO CONNECTION
 5. ANODE
 6. NO CONNECTION
 7. ANODE
 8. ANODE
 9. ANODE
 10. NO CONNECTION
 11. ANODE
 12. ANODE
 13. NO CONNECTION
 14. COMMON
 CATHODE

STYLE 8:
 PIN 1. NO CONNECTION
 2. CATHODE
 3. CATHODE
 4. NO CONNECTION
 5. CATHODE
 6. NO CONNECTION
 7. CATHODE
 8. CATHODE
 9. CATHODE
 10. NO CONNECTION
 11. CATHODE
 12. CATHODE
 13. NO CONNECTION
 14. COMMON ANODE


STYLE 9:
 PIN 1. COMMON CATHODE
 2. ANODE/CATHODE
 3. ANODE/CATHODE
 4. NO CONNECTION
 5. ANODE/CATHODE
 6. ANODE/CATHODE
 7. COMMON ANODE
 8. COMMON ANODE
 9. ANODE/CATHODE
 10. ANODE/CATHODE
 11. NO CONNECTION
 12. ANODE/CATHODE
 13. ANODE/CATHODE
 14. COMMON CATHODE

STYLE 10:
 PIN 1. COMMON
 CATHODE
 2. ANODE/CATHODE
 3. ANODE/CATHODE
 4. ANODE/CATHODE
 5. ANODE/CATHODE
 6. NO CONNECTION
 7. COMMON ANODE
 8. COMMON
 CATHODE
 9. ANODE/CATHODE
 10. ANODE/CATHODE
 11. ANODE/CATHODE
 12. ANODE/CATHODE
 13. NO CONNECTION
 14. COMMON ANODE

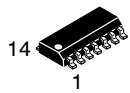
STYLE 11:
 PIN 1. CATHODE
 2. CATHODE
 3. CATHODE
 4. CATHODE
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 7. CATHODE
 8. ANODE
 9. ANODE
 10. ANODE
 11. ANODE
 12. ANODE
 13. ANODE
 14. ANODE

STYLE 12:
 PIN 1. COMMON CATHODE
 2. COMMON ANODE
 3. ANODE/CATHODE
 4. ANODE/CATHODE
 5. ANODE/CATHODE
 6. COMMON ANODE
 7. COMMON CATHODE
 8. ANODE/CATHODE
 9. ANODE/CATHODE
 10. ANODE/CATHODE
 11. ANODE/CATHODE
 12. ANODE/CATHODE
 13. ANODE/CATHODE
 14. ANODE/CATHODE

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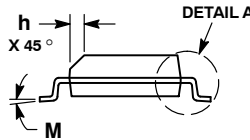
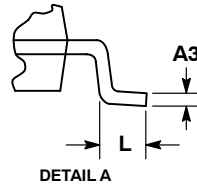
MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS



SCALE 1:1

SOIC-14 NB
CASE 751A-03
ISSUE L

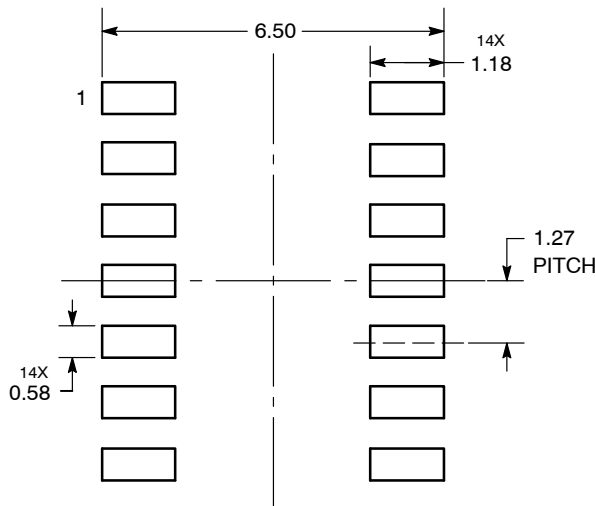
DATE 03 FEB 2016



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
 2. CONTROLLING DIMENSION: MILLIMETERS.
 3. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF AT MAXIMUM MATERIAL CONDITION.
 4. DIMENSIONS D AND E DO NOT INCLUDE MOLD PROTRUSIONS.
 5. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.35	1.75	0.054	0.068
A1	0.10	0.25	0.004	0.010
A3	0.19	0.25	0.008	0.010
b	0.35	0.49	0.014	0.019
D	8.55	8.75	0.337	0.344
E	3.80	4.00	0.150	0.157
e	1.27 BSC		0.050 BSC	
H	5.80	6.20	0.228	0.244
h	0.25	0.50	0.010	0.019
L	0.40	1.25	0.016	0.049
M	0°	7°	0°	7°

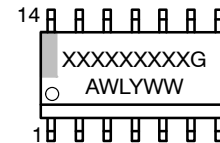
SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

GENERIC MARKING DIAGRAM*



- XXXXXX = Specific Device Code
- A = Assembly Location
- WL = Wafer Lot
- Y = Year
- WW = Work Week
- G = Pb-Free Package

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present. Some products may not follow the Generic Marking.

STYLES ON PAGE 2

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CASE 751A-03
ISSUE L

DATE 03 FEB 2016

STYLE 1:
 PIN 1. COMMON CATHODE
 2. ANODE/CATHODE
 3. ANODE/CATHODE
 4. NO CONNECTION
 5. ANODE/CATHODE
 6. NO CONNECTION
 7. ANODE/CATHODE
 8. ANODE/CATHODE
 9. ANODE/CATHODE
 10. NO CONNECTION
 11. ANODE/CATHODE
 12. ANODE/CATHODE
 13. NO CONNECTION
 14. COMMON ANODE

STYLE 2:
 CANCELLED

STYLE 3:
 PIN 1. NO CONNECTION
 2. ANODE
 3. ANODE
 4. NO CONNECTION
 5. ANODE
 6. NO CONNECTION
 7. ANODE
 8. ANODE
 9. ANODE
 10. NO CONNECTION
 11. ANODE
 12. ANODE
 13. NO CONNECTION
 14. COMMON CATHODE

STYLE 4:
 PIN 1. NO CONNECTION
 2. CATHODE
 3. CATHODE
 4. NO CONNECTION
 5. CATHODE
 6. NO CONNECTION
 7. CATHODE
 8. CATHODE
 9. CATHODE
 10. NO CONNECTION
 11. CATHODE
 12. CATHODE
 13. NO CONNECTION
 14. COMMON ANODE

STYLE 5:
 PIN 1. COMMON CATHODE
 2. ANODE/CATHODE
 3. ANODE/CATHODE
 4. ANODE/CATHODE
 5. ANODE/CATHODE
 6. NO CONNECTION
 7. COMMON ANODE
 8. COMMON CATHODE
 9. ANODE/CATHODE
 10. ANODE/CATHODE
 11. ANODE/CATHODE
 12. ANODE/CATHODE
 13. NO CONNECTION
 14. COMMON ANODE

STYLE 6:
 PIN 1. CATHODE
 2. CATHODE
 3. CATHODE
 4. CATHODE
 5. CATHODE
 6. CATHODE
 7. CATHODE
 8. ANODE
 9. ANODE
 10. ANODE
 11. ANODE
 12. ANODE
 13. ANODE
 14. ANODE

STYLE 7:
 PIN 1. ANODE/CATHODE
 2. COMMON ANODE
 3. COMMON CATHODE
 4. ANODE/CATHODE
 5. ANODE/CATHODE
 6. ANODE/CATHODE
 7. ANODE/CATHODE
 8. ANODE/CATHODE
 9. ANODE/CATHODE
 10. ANODE/CATHODE
 11. COMMON CATHODE
 12. COMMON ANODE
 13. ANODE/CATHODE
 14. ANODE/CATHODE

STYLE 8:
 PIN 1. COMMON CATHODE
 2. ANODE/CATHODE
 3. ANODE/CATHODE
 4. NO CONNECTION
 5. ANODE/CATHODE
 6. ANODE/CATHODE
 7. COMMON ANODE
 8. COMMON ANODE
 9. ANODE/CATHODE
 10. ANODE/CATHODE
 11. NO CONNECTION
 12. ANODE/CATHODE
 13. ANODE/CATHODE
 14. COMMON CATHODE

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