

## Low Noise, Chopper Stabilized Operational Amplifier

### Features

- Low Offset Over Temperature Range: 10 $\mu$ V
- Ultra Low Long Term Drift: 150nV/Month
- Low Temperature Drift: 100nV/ $^{\circ}$ C
- Low DC Input Bias Current: 15pA
- High Gain, CMRR and PSRR: 110dB Min
- Low Input Noise Voltage: 0.2 $\mu$ V<sub>p-p</sub> (DC to 1Hz)
- Internally Compensated for Unity Gain Operation
- Clamp Circuit for Fast Overload Recovery

### Applications

- Instrumentation
- Medical Instrumentation
- Embedded Control
- Temperature Sensor Amplifier
- Strain Gage Amplifier

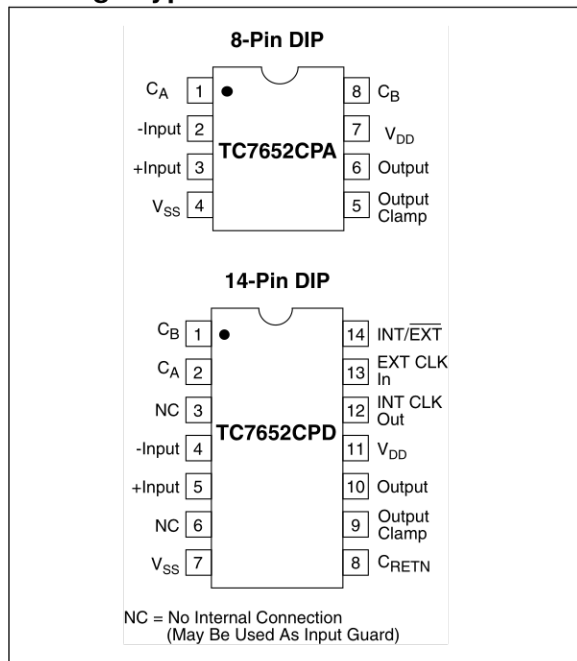
### General Description

The TC7652 is a lower noise version of the TC7650, sacrificing some input specifications (bias current and bandwidth) to achieve a 10x reduction in noise. All the other benefits of the chopper technique are present, (i.e, freedom from offset adjust, drift and reliability problems from external trim components). Like the TC7650, the TC7652 requires only two noncritical external caps for storing the chopped null potentials. There are no significant chopping spikes, internal effects or over-range lockup problems.

### Device Selection Table

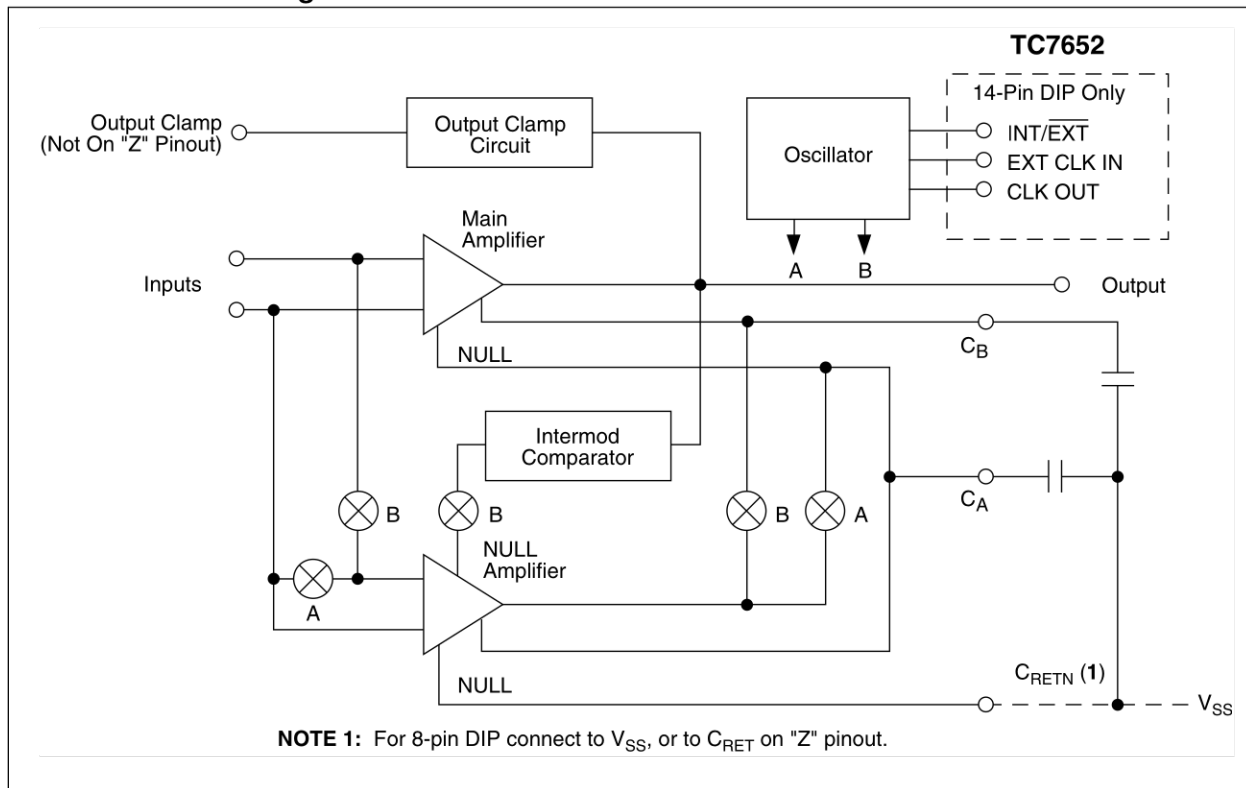
Part Number	Package	Temperature Range
TC7652CPA	8-Pin Plastic DIP	0 $^{\circ}$ C to +70 $^{\circ}$ C
TC7652CPD	14-Pin Plastic DIP	0 $^{\circ}$ C to +70 $^{\circ}$ C

### Package Type



# TC7652

## Functional Block Diagram



## 1.0 ELECTRICAL CHARACTERISTICS

### ABSOLUTE MAXIMUM RATINGS\*

Total Supply Voltage ( $V_{DD}$ to $V_{SS}$ )	+18V
Input Voltage	( $V_{DD} + 0.3V$ ) to ( $V_{SS} - 0.3V$ )
Voltage on Oscillator Control Pins	$V_{DD}$ to $V_{SS}$
Duration of Output Short Circuit	Indefinite
Current Into Any Pin	10mA
While Operating ( <b>Note 1</b> )	100 $\mu$ A
Package Power Dissipation ( $T_A \leq 70^\circ\text{C}$ )	
8-Pin Plastic DIP	730mW
14-Pin Plastic DIP	800mW
Storage Temperature Range	-65 $^\circ\text{C}$ to +150 $^\circ\text{C}$
Operating Temperature Range	
C Device	0 $^\circ\text{C}$ to +70 $^\circ\text{C}$
I Device	-25 $^\circ\text{C}$ to +85 $^\circ\text{C}$

\*Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operation sections of the specifications is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

### TC7652 ELECTRICAL SPECIFICATIONS

Electrical Characteristics: $V_{DD} = +5V$ , $V_{SS} = -5V$ , $T_A = +25^\circ\text{C}$ , unless otherwise indicated.						
Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$V_{OS}$	Input Offset Voltage	—	$\pm 2$	$\pm 5$	$\mu\text{V}$	$T_A = +25^\circ\text{C}$
$TCV_{OS}$	Average Temperature Co-efficient of Input Offset Voltage	—	0.01	0.05	$\mu\text{V}/^\circ\text{C}$	$0^\circ\text{C} < T_A < +70^\circ\text{C}$
$V_{OS}/DT$	Offset Voltage vs Time	—	150	—	nV/mo	
$I_{BIAS}$	Input Bias Current (CLK On)	—	30 100 250	100 — 1000	pA	$T_A = +25^\circ\text{C}$ $0^\circ\text{C} < T_A < +70^\circ\text{C}$ $-25^\circ\text{C} < T_A < +85^\circ\text{C}$
$I_{BIAS}$	Input Bias Current (CLK Off)	—	15 35 100	30 — 1000	pA	$T_A = +25^\circ\text{C}$ $0^\circ\text{C} < T_A < +70^\circ\text{C}$ $-25^\circ\text{C} < T_A < +85^\circ\text{C}$
$I_{OS}$	Input Offset Current	—	25	150	pA	
$R_{IN}$	Input Resistance	—	$10^{12}$	—	$\Omega$	
OL	Large Signal Voltage Gain	120	150	—	dB	$R_L = 10k\Omega$ , $V_{OUT} = \pm 4V$
$V_{OUT}$	Output Voltage Swing ( <b>Note 2</b> )	$\pm 4.7$ —	$\pm 4.85$ $\pm 4.95$	— —	V	$R_L = 10k\Omega$ $R_L = 100k\Omega$
CMVR	Common Mode Voltage Range	-4.3	—	+3.5	V	
MRR	Common Mode Rejection Ratio	120	140	—	dB	CMVR = -4.3V to +3.5V
PSRR	Power Supply	120	140	—	dB	$\pm 3V$ to $\pm 8V$
$e_N$	Input Noise Voltage	—	0.2 0.7	1.5 5	$\mu\text{V}_{P-P}$ $\mu\text{V}_{P-P}$	$R_S = 100\Omega$ , DC to 1Hz DC to 10Hz
$I_N$	Input Noise Current	—	0.01	—	$\text{pA}/\sqrt{\text{Hz}}$	$f = 10\text{Hz}$
GBW	Unity Gain Bandwidth	—	0.4	—	MHz	
SR	Slew Rate	—	1	—	V/ $\mu\text{sec}$	$C_L = 50\text{pF}$ , $R_L = 10k\Omega$
	Overshoot	—	15	—	%	
$V_{DD}$ , $V_{SS}$	Operating Supply Range	5	—	16	V	

- Note 1:** Limiting input current to 100 $\mu\text{A}$  is recommended to avoid latch-up problems. Typically 1mA is safe however, this is not guaranteed.
- Note 2:** Output clamp not connected. See typical characteristics curves for output swing versus clamp current characteristics.
- Note 3:** See "Output Clamp" under detailed description.

# TC7652

## TC7652 ELECTRICAL SPECIFICATIONS (CONTINUED)

Electrical Characteristics: $V_{DD} = +5V$ , $V_{SS} = -5V$ , $T_A = +25^\circ C$ , unless otherwise indicated.						
Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
$I_S$	Supply Current	—	1	3	mA	No Load
$f_{CH}$	Internal Chopping Frequency	100	275	—	Hz	Pins 12 – 14 Open (DIP)
	Clamp ON Current ( <b>Note 3</b> )	25	100	—	$\mu A$	$R_L = 100k\Omega$
	Clamp OFF Current ( <b>Note 3</b> )	—	1	—	pA	$-4V \leq V_{OUT} < +10V$

- Note 1:** Limiting input current to  $100\mu A$  is recommended to avoid latch-up problems. Typically 1mA is safe however, this is not guaranteed.
- Note 2:** Output clamp not connected. See typical characteristics curves for output swing versus clamp current characteristics.
- Note 3:** See "Output Clamp" under detailed description.

## 2.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 2-1.

**TABLE 2-1: PIN FUNCTION TABLE**

Pin Number		Symbol	Description
8-pin DIP	14-pin DIP		
1,8	2,1	$C_A, C_B$	Nulling capacitor pins
2	4	-INPUT	Inverting Input
3	5	+INPUT	Non-inverting Input
4	7	$V_{SS}$	Negative Power Supply
5	9	OUTPUT CLAMP	Output Voltage Clamp
6	10	OUTPUT	Output
7	11	$V_{DD}$	Positive Power Supply
—	3,6	NC	No internal connection
—	8	$C_{RETN}$	Capacitor current return pin
—	12	INT CLK OUT	Internal Clock Output
—	13	EXT CLK IN	External Clock Input
—	14	INT/EXT	Select Internal or External Clock

## 3.0 DETAILED DESCRIPTION

### 3.1 Capacitor Connection

Connect the null storage capacitors to the  $C_A$  and  $C_B$  pins with a common connection to the  $C_{RET}$  pin (14-pin TC7652) or to  $V_{SS}$  (8-pin TC7652). When connecting to  $V_{SS}$ , avoid injecting load current IR drops into the capacitive circuitry by making this connection directly via a separate wire or PC trace.

### 3.2 Output Clamp

In chopper stabilized amplifiers, the output clamp pin reduces overload recovery time. When a connection is made to the inverting input pin (summing junction), a current path is created between that point and the output pin, just before the device output saturates. This prevents uncontrolled differential input voltages and charge build-up on correction storage capacitors. Output swing is reduced.

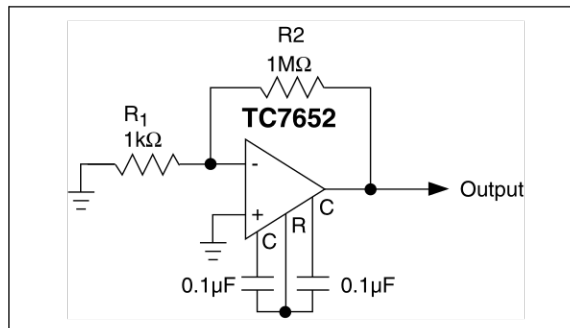
### 3.3 Clock

The TC7652 has a 550Hz internal oscillator, which is divided by two before clocking the input chopper switches. The 275Hz chopping frequency is available at INT CLK OUT (Pin 12) on 14-pin devices. In normal operation, INT/EXT (Pin 14), which has an internal pull-up, can be left open.

An external clock can also be used. To disable the internal clock and use an external one, the INT/EXT pin must be tied to  $V_{SS}$ . The external clock signal is then applied to the EXT CLK IN input (Pin 13). An internal divide-by-two provides a 50% switching duty cycle. The capacitors are only charged when EXT CLK IN is high, so a 50% to 80% positive duty cycle is recommended for higher clock frequencies. The external clock can swing between  $V_{DD}$  and  $V_{SS}$ , with the logic threshold about 2.5V below  $V_{DD}$ .

The output of the internal oscillator, before the divide-by-two circuit, is available at EXT CLK IN when INT/EXT is high or unconnected. This output can serve as the clock input for a second TC7652 (operating in a master/slave mode), so that both op amps will clock at the same frequency. This prevents clock intermodulation effects when two TC7652's are used in a differential amplifier configuration.

FIGURE 3-1: TEST CIRCUIT



If the TC7652's output saturates, error voltages on the external capacitors will slow overload recovery. This condition can be avoided if a strobe signal is available. The strobe signal is applied to EXT CLK IN and the overload signal is applied to the amplifier while the strobe is LOW. In this case, neither capacitor will be charged. The low leakage of the capacitor pins allow long measurements to be made within eligible errors (typical capacitor drift is 10 $\mu$ V/sec).

## 4.0 TYPICAL APPLICATIONS

### 4.1 Component Selection

$C_A$  and  $C_B$  (external capacitors) should be in the 0.1 $\mu$ F to 1 $\mu$ F range. For minimum clock ripple noise, use a 1 $\mu$ F capacitor in broad bandwidth circuits. For limited bandwidth applications where clock ripple is filtered out, use a 0.1 $\mu$ F capacitor for slightly lower offset voltage. High quality, film type capacitors (polyester or polypropylene) are recommended, although a lower grade ceramic may work in some applications. For quickest settling after initial turn-on, use low dielectric absorption capacitors (e.g., polypropylene). With ceramic capacitors, settling to 1 $\mu$ V takes several seconds.

### 4.2 Static Protection

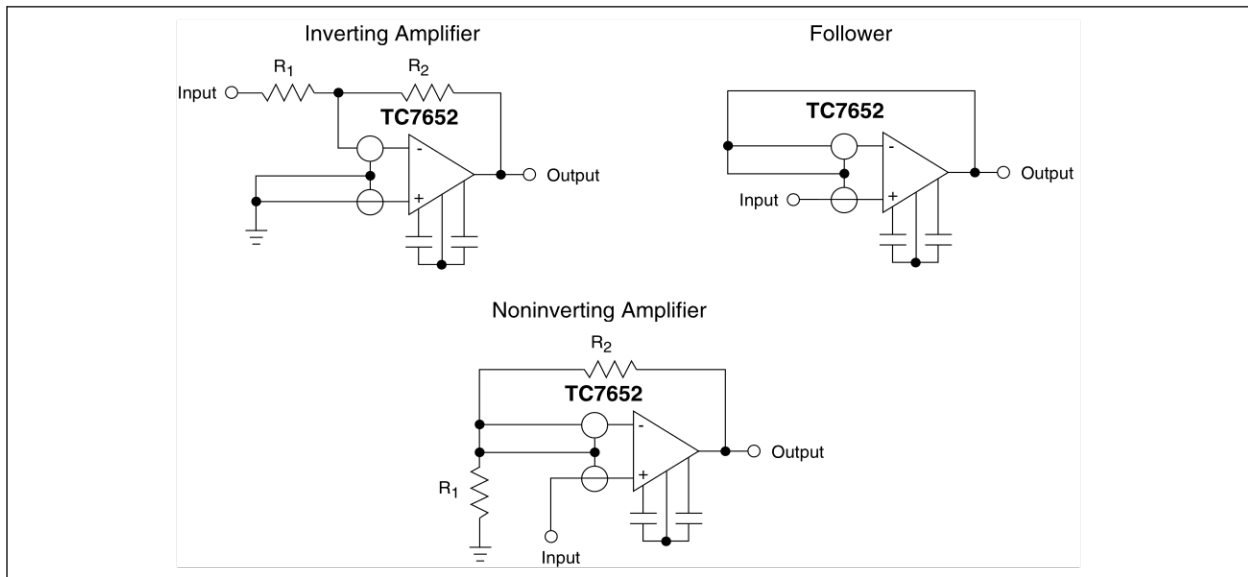
Although input diodes static protect all device pins, avoid strong electrostatic fields and discharges that can cause degraded diode junction characteristics and produce increased input-leakage currents.

## 4.3 Output Stage/Load Driving

The output circuit is high impedance (about 18k $\Omega$ ). With lesser loads, the chopper amplifier behaves somewhat like a transconductance amplifier with an open-loop gain proportional to load resistance. (For example, the open-loop gain is 17dB lower with a 1k $\Omega$  load than with a 10k $\Omega$  load.) If the amp is used only for DC, the DC gain is typically greater than 120dB (even

with a 1k $\Omega$  load), and this lower gain is inconsequential. For wide band, the best frequency response occurs with a load resistor of at least 10k $\Omega$ . This produces a 6dB/octave response from 0.1Hz to 2MHz, with phase shifts of less than 2 degrees in the transition region, where the main amplifier takes over from the null amplifier.

**FIGURE 4-1: CONNECTION OF INPUT GUARDS**



## 4.4 Thermoelectric Effects

The thermoelectric (Seebeck) effects in thermocouple junctions of dissimilar metals, alloys, silicon, etc. limit ultra high precision DC amplifiers. Unless all junctions are at the same temperature, thermoelectric voltages around 0.1 $\mu$ V/ $^{\circ}$ C (up to tens of  $\mu$ V/ $^{\circ}$ C for some materials) are generated. To realize the low offset voltages of the chopper, avoid temperature gradients. Enclose components to eliminate air movement, especially from power dissipating elements in the system. Where possible, use low thermoelectric co-efficient connections. Keep power supply voltages and power dissipation to a minimum. Use high impedance loads and seek maximum separation from surrounding heat dissipating elements.

## 4.5 Guarding

To benefit from TC7652 low input currents, take care assembling printed circuit boards. Clean boards with alcohol or TCE and blow dry with compressed air. To prevent contamination, coat boards with epoxy or silicone rubber.

Even if boards are cleaned and coated, leakage currents may occur because input pins are next to pins at supply potentials. To reduce this leakage, use guarding to lower the voltage difference between the inputs and adjacent metal runs. The guard (a conductive ring surrounding inputs) is connected to a low impedance point at about the same voltage as inputs. The guard absorbs leakage currents from high voltage pins.

The 14-pin dual-in-line arrangement simplifies guarding. Like the LM108 pin configuration (but unlike the 101A and 741), pins next to inputs are not used.

## 4.6 Pin Compatibility

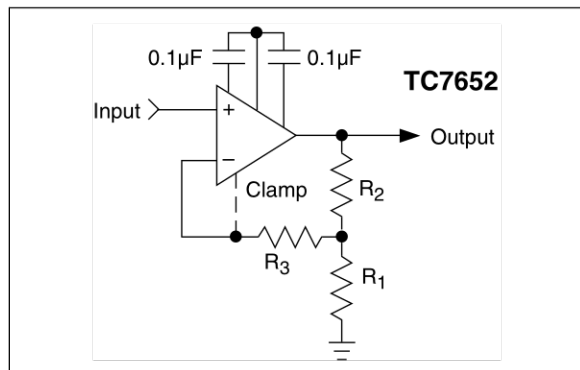
Where possible, the 8-pin device pinout conforms to such industry standards as the LM101 and LM741. Null storing external capacitors connect to Pins 1 and 8, which are usually for offset null or compensation capacitors. Output clamp (Pin 5) is similarly used. For OP05 and OP07 devices, replacement of the offset null potentiometer (connected between Pins 1 and 8 and  $V_{DD}$  by two capacitors from those pins to  $V_{SS}$ ) provides compatibility. Replacing the compensation capacitor between Pins 1 and 8 by two capacitors to  $V_{SS}$  is required. The same operation (with the removal of any connection to Pin 5) works for LM101,  $\mu A748$  and similar parts.

Because NC pins provide guarding between input and other pins, the 14-pin device pinout conforms closely to the LM108. Because this device does not use any extra pins and does not provide offset nulling (but requires a compensation capacitor), some layout changes are necessary to convert to the TC7652.

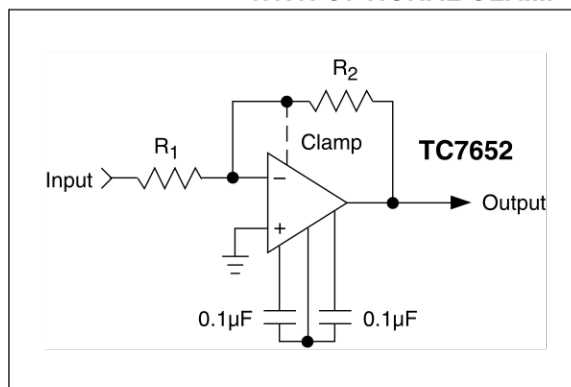
## 4.7 Some Applications

Figures 4-2 and 4-3 show basic inverting and noninverting amplifier circuits using the output clamping circuit to enhance overload recovery performance. The only limitations on replacing other op amps with the TC7652 are supply voltage ( $\pm 8V$  maximum) and output drive capability (10k $\Omega$  load for full swing). Overcome these limitations with a booster circuit (Figure 4-4) to combine output capabilities of the LM741 (or other standard device) with input capabilities of the TC7652. These two form a composite device, therefore, when adding the feedback network, the monitor loop gains stability.

**FIGURE 4-2: NONINVERTING AMPLIFIER WITH OPTIONAL CLAMP**



**FIGURE 4-3: INVERTING AMPLIFIER WITH OPTIONAL CLAMP**



**FIGURE 4-4: USING 741 TO BOOST OUTPUT DRIVE CAPABILITY**

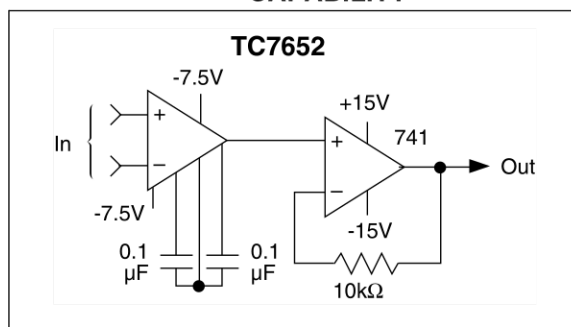
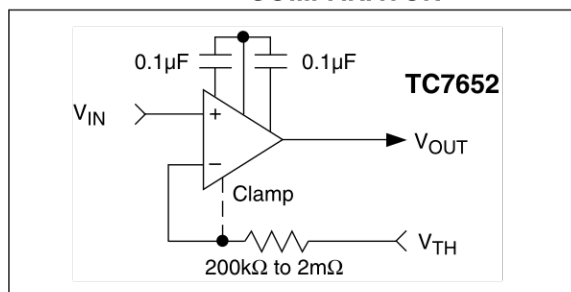


Figure 4-5 shows the clamp circuit of a zero offset comparator. Because the clamp circuit requires the inverting input to follow the input signal, problems with a chopper stabilized op amp are avoided. The threshold input must tolerate the output clamp current  $\approx V_{IN}/R$  without disrupting other parts of the system.

Figure 4-6 shows how the TC7652 can offset null high slew rate and wideband amplifiers.

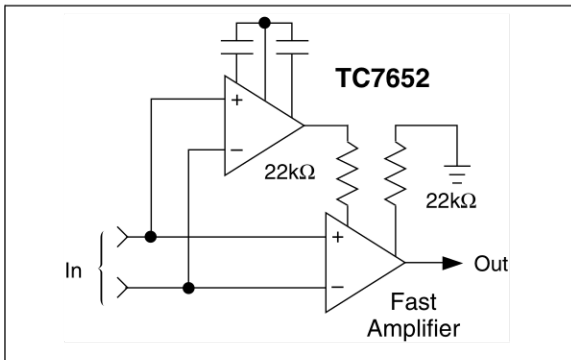
Mixing the TC7652 with circuits operating at  $\pm 15V$  requires a lower supply voltage divider with the TC7660 voltage converter circuit operated "backwards." Figure 4-7 shows an approximate connection.

**FIGURE 4-5: LOW OFFSET COMPARATOR**

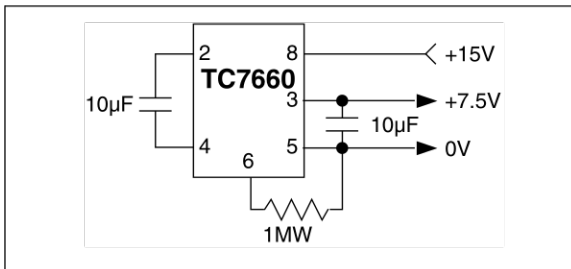




**FIGURE 4-6: 1437 OFFSET NULLED BY TC7652**



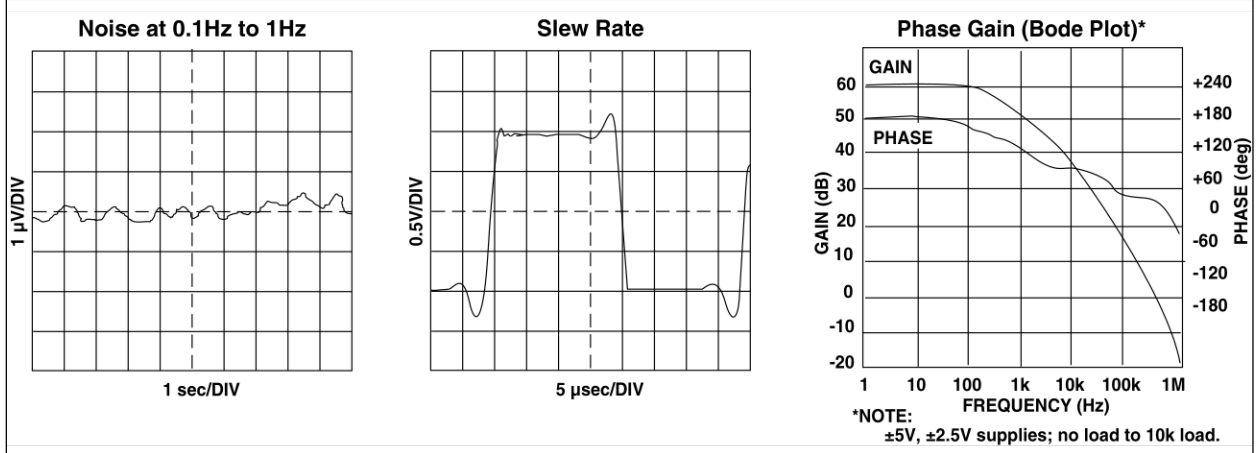
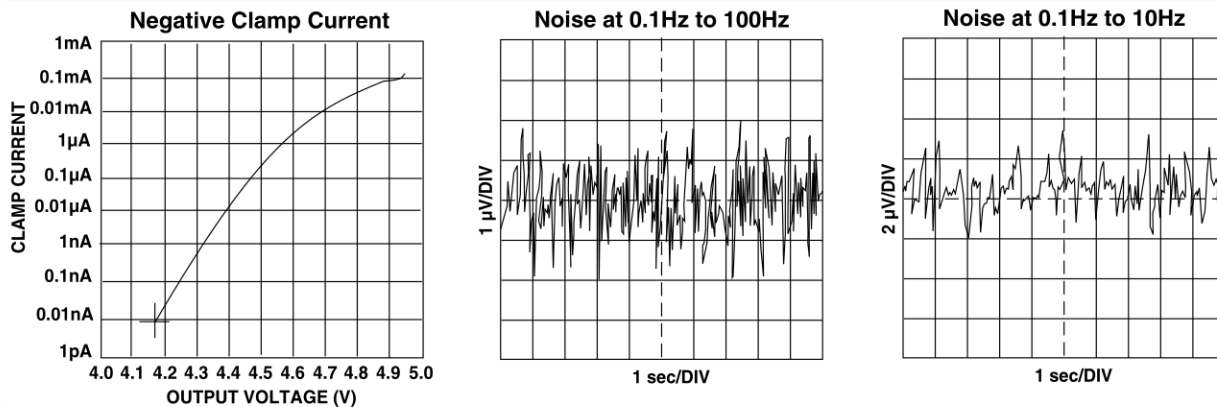
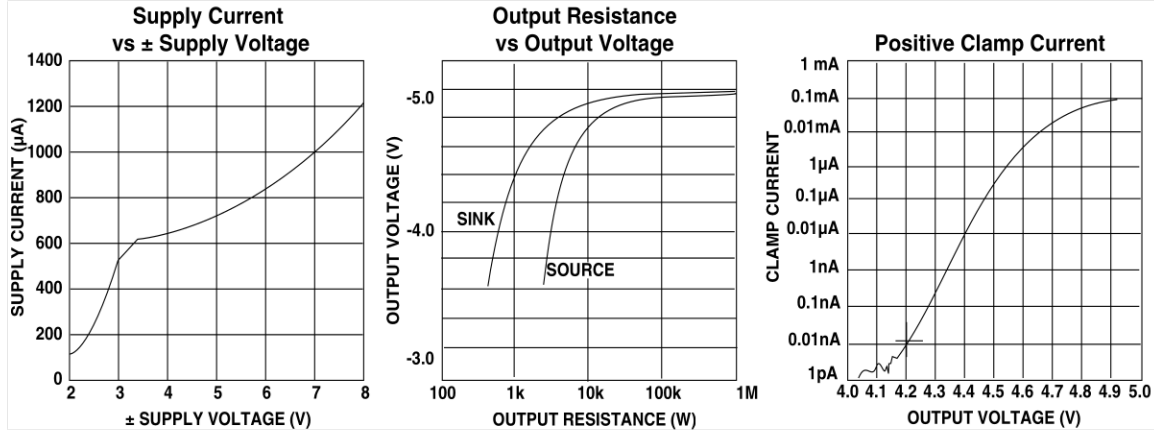
**FIGURE 4-7: SPLITTING +15V WITH THE 7660 AT >95% EFFICIENCY**

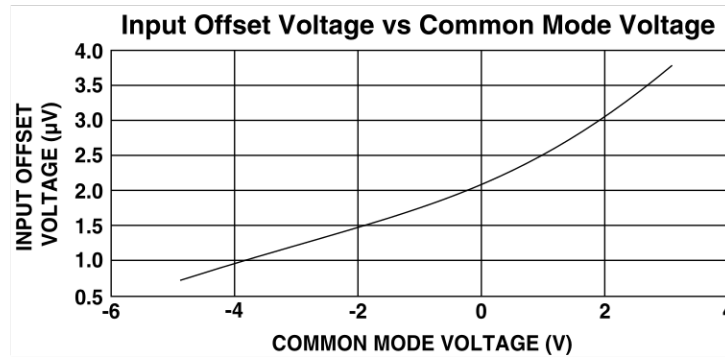


# TC7652

## 5.0 TYPICAL CHARACTERISTICS

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.





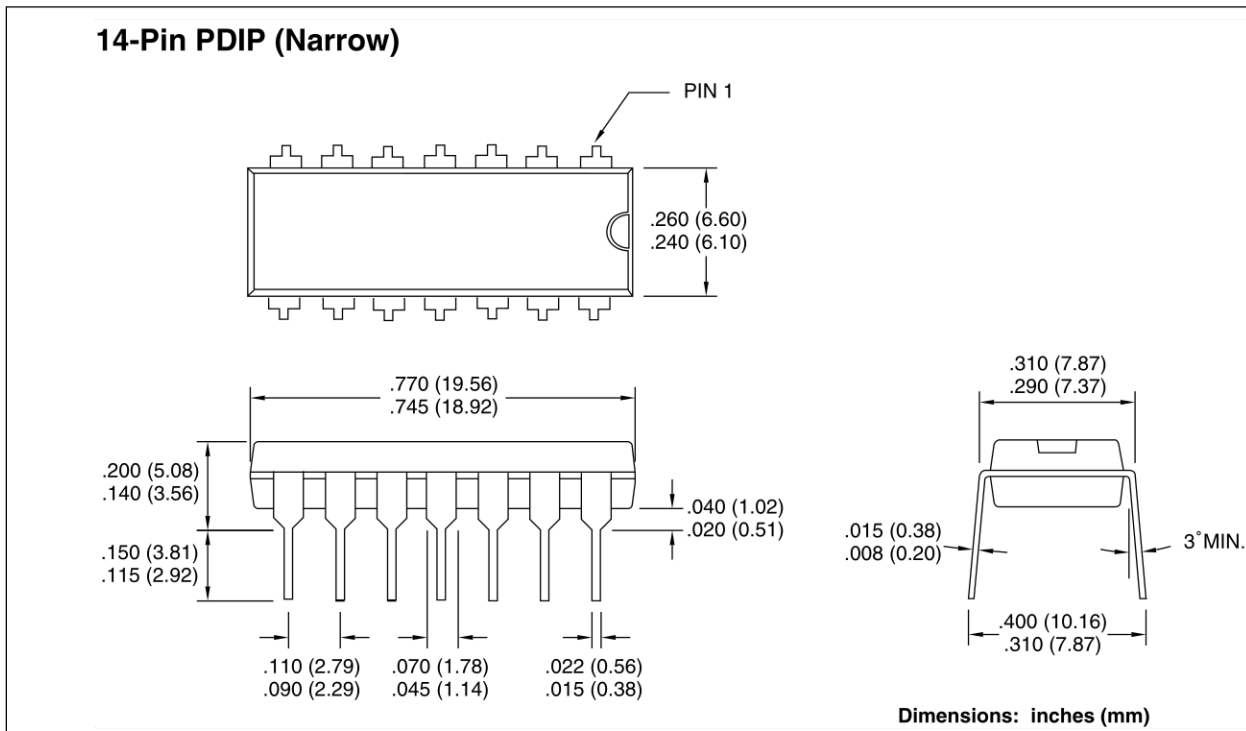
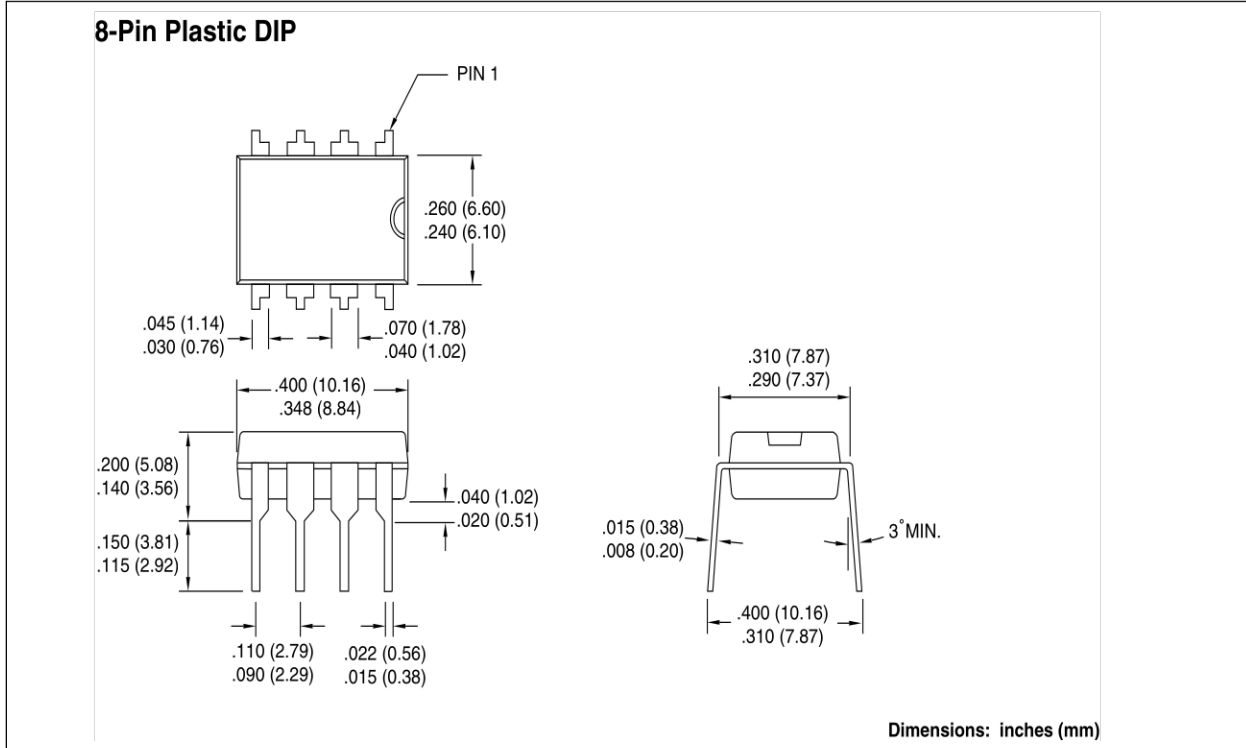
# TC7652

## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

Package marking information not available at this time.

### 6.2 Package Dimensions



## SALES AND SUPPORT

### **Data Sheets**

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
3. The Microchip Worldwide Site ([www.microchip.com](http://www.microchip.com))

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

### **New Customer Notification System**

Register on our web site ([www.microchip.com/cn](http://www.microchip.com/cn)) to receive the most current information on our products.

# TC7652

---

NOTES:

---

---

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip's products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

#### Trademarks


The Microchip name and logo, the Microchip logo, FilterLab, KEELOQ, microID, MPLAB, PIC, PICmicro, PICMASTER, PICSTART, PRO MATE, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

dsPIC, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, MXDEV, PICC, PICDEM, PICDEM.net, rPIC, Select Mode and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A.

Serialized Quick Turn Programming (SQTP) is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.

© 2002, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

 Printed on recycled paper.



*Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999 and Mountain View, California in March 2002. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, non-volatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001 certified.*



# MICROCHIP

## WORLDWIDE SALES AND SERVICE

### AMERICAS

#### Corporate Office

2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7200 Fax: 480-792-7277  
Technical Support: 480-792-7627  
Web Address: <http://www.microchip.com>

#### Rocky Mountain

2355 West Chandler Blvd.  
Chandler, AZ 85224-6199  
Tel: 480-792-7966 Fax: 480-792-7456

#### Atlanta

500 Sugar Mill Road, Suite 200B  
Atlanta, GA 30350  
Tel: 770-640-0034 Fax: 770-640-0307

#### Boston

2 Lan Drive, Suite 120  
Westford, MA 01886  
Tel: 978-692-3848 Fax: 978-692-3821

#### Chicago

333 Pierce Road, Suite 180  
Itasca, IL 60143  
Tel: 630-285-0071 Fax: 630-285-0075

#### Dallas

4570 Westgrove Drive, Suite 160  
Addison, TX 75001  
Tel: 972-818-7423 Fax: 972-818-2924

#### Detroit

Tri-Atria Office Building  
32255 Northwestern Highway, Suite 190  
Farmington Hills, MI 48334  
Tel: 248-538-2250 Fax: 248-538-2260

#### Kokomo

2767 S. Albright Road  
Kokomo, Indiana 46902  
Tel: 765-864-8360 Fax: 765-864-8387

#### Los Angeles

18201 Von Karman, Suite 1090  
Irvine, CA 92612  
Tel: 949-263-1888 Fax: 949-263-1338

#### New York

150 Motor Parkway, Suite 202  
Hauppauge, NY 11788  
Tel: 631-273-5305 Fax: 631-273-5335

#### San Jose

Microchip Technology Inc.  
2107 North First Street, Suite 590  
San Jose, CA 95131  
Tel: 408-436-7950 Fax: 408-436-7955

#### Toronto

6285 Northam Drive, Suite 108  
Mississauga, Ontario L4V 1X5, Canada  
Tel: 905-673-0699 Fax: 905-673-6509

### ASIA/PACIFIC

#### Australia

Microchip Technology Australia Pty Ltd  
Suite 22, 41 Rawson Street  
Epping 2121, NSW  
Australia  
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

#### China - Beijing

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Beijing Liaison Office  
Unit 915  
Bei Hai Wan Tai Bldg.  
No. 6 Chaoyangmen Beidajie  
Beijing, 100027, No. China  
Tel: 86-10-85282100 Fax: 86-10-85282104

#### China - Chengdu

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Chengdu Liaison Office  
Rm. 2401, 24th Floor,  
Ming Xing Financial Tower  
No. 88 TIDU Street  
Chengdu 610016, China  
Tel: 86-28-6766200 Fax: 86-28-6766599

#### China - Fuzhou

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Fuzhou Liaison Office  
Unit 28F, World Trade Plaza  
No. 71 Wusi Road  
Fuzhou 350001, China  
Tel: 86-591-7503506 Fax: 86-591-7503521

#### China - Shanghai

Microchip Technology Consulting (Shanghai)  
Co., Ltd.  
Room 701, Bldg. B  
Far East International Plaza  
No. 317 Xian Xia Road  
Shanghai, 200051  
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

#### China - Shenzhen

Microchip Technology Consulting (Shanghai)  
Co., Ltd., Shenzhen Liaison Office  
Rm. 1315, 13/F, Shenzhen Kerry Centre,  
Renminnan Lu  
Shenzhen 518001, China  
Tel: 86-755-2350361 Fax: 86-755-2366086

#### Hong Kong

Microchip Technology Hongkong Ltd.  
Unit 901-6, Tower 2, Metroplaza  
223 Hing Fong Road  
Kwai Fong, N.T., Hong Kong  
Tel: 852-2401-1200 Fax: 852-2401-3431

#### India

Microchip Technology Inc.  
India Liaison Office  
Divyasree Chambers  
1 Floor, Wing A (A3/A4)  
No. 11, O'Shaugnessey Road  
Bangalore, 560 025, India  
Tel: 91-80-2290061 Fax: 91-80-2290062

### Japan

Microchip Technology Japan K.K.  
Benex S-1 6F  
3-18-20, Shinyokohama  
Kohoku-Ku, Yokohama-shi  
Kanagawa, 222-0033, Japan  
Tel: 81-45-471-6166 Fax: 81-45-471-6122

### Korea

Microchip Technology Korea  
168-1, Youngbo Bldg. 3 Floor  
Samsung-Dong, Kangnam-Ku  
Seoul, Korea 135-882  
Tel: 82-2-554-7200 Fax: 82-2-558-5934

### Singapore

Microchip Technology Singapore Pte Ltd.  
200 Middle Road  
#07-02 Prime Centre  
Singapore, 188980  
Tel: 65-6334-8870 Fax: 65-6334-8850

### Taiwan

Microchip Technology Taiwan  
11F-3, No. 207  
Tung Hua North Road  
Taipei, 105, Taiwan  
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

### EUROPE

#### Denmark

Microchip Technology Nordic ApS  
Regus Business Centre  
Lautrup høj 1-3  
Ballerup DK-2750 Denmark  
Tel: 45 4420 9895 Fax: 45 4420 9910

#### France

Microchip Technology SARL  
Parc d'Activite du Moulin de Massy  
43 Rue du Saule Trapu  
Batiment A - 1er Etage  
91300 Massy, France  
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

#### Germany

Microchip Technology GmbH  
Gustav-Heinemann Ring 125  
D-81739 Munich, Germany  
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

#### Italy

Microchip Technology SRL  
Centro Direzionale Colleoni  
Palazzo Taurus 1 V. Le Colleoni 1  
20041 Agrate Brianza  
Milan, Italy  
Tel: 39-039-65791-1 Fax: 39-039-6899883

#### United Kingdom

Arizona Microchip Technology Ltd.  
505 Eskdale Road  
Winnersh Triangle  
Wokingham  
Berkshire, England RG41 5TU  
Tel: 44 118 921 5869 Fax: 44-118 921-5820

03/01/02