



Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!



## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: [info@chipsmall.com](mailto:info@chipsmall.com) Web: [www.chipsmall.com](http://www.chipsmall.com)

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



## Chopper Stabilized Operational Amplifier

### Features

- Low Input Offset Voltage: 0.7 $\mu$ V Typ
- Low Input Offset Voltage Drift: 0.05 $\mu$ V/ $^{\circ}$ C Max
- Low Input Bias Current: 10pA Max
- High Impedance Differential CMOS Inputs: 10<sup>12</sup> $\Omega$
- High Open Loop Voltage Gain: 120dB Min.
- Low Input Noise Voltage: 2.0 $\mu$ Vp-p
- High Slew Rate: 2.5V/ $\mu$ sec.
- Low Power Operation: 20mW
- Output Clamp Speeds Recovery Time
- Compensated Internally for Stable Unity Gain Operation
- Direct Replacement for ICL7650
- Available in 8-Pin Plastic DIP and 14-Pin Plastic DIP Packages

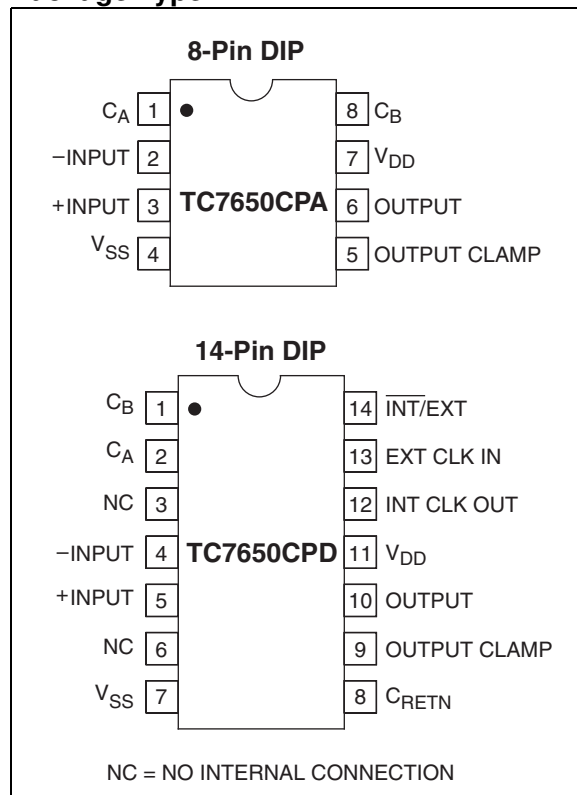
### Applications

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

### Device Selection Table

Part Number	Package	Temperature Range	Max V <sub>OS</sub>
TC7650CPA	8-Pin PDIP	0 $^{\circ}$ C to +70 $^{\circ}$ C	5 $\mu$ V
TC7650CPD	14-Pin PDIP	0 $^{\circ}$ C to +70 $^{\circ}$ C	5 $\mu$ V

### Package Type



# TC7650

## General Description

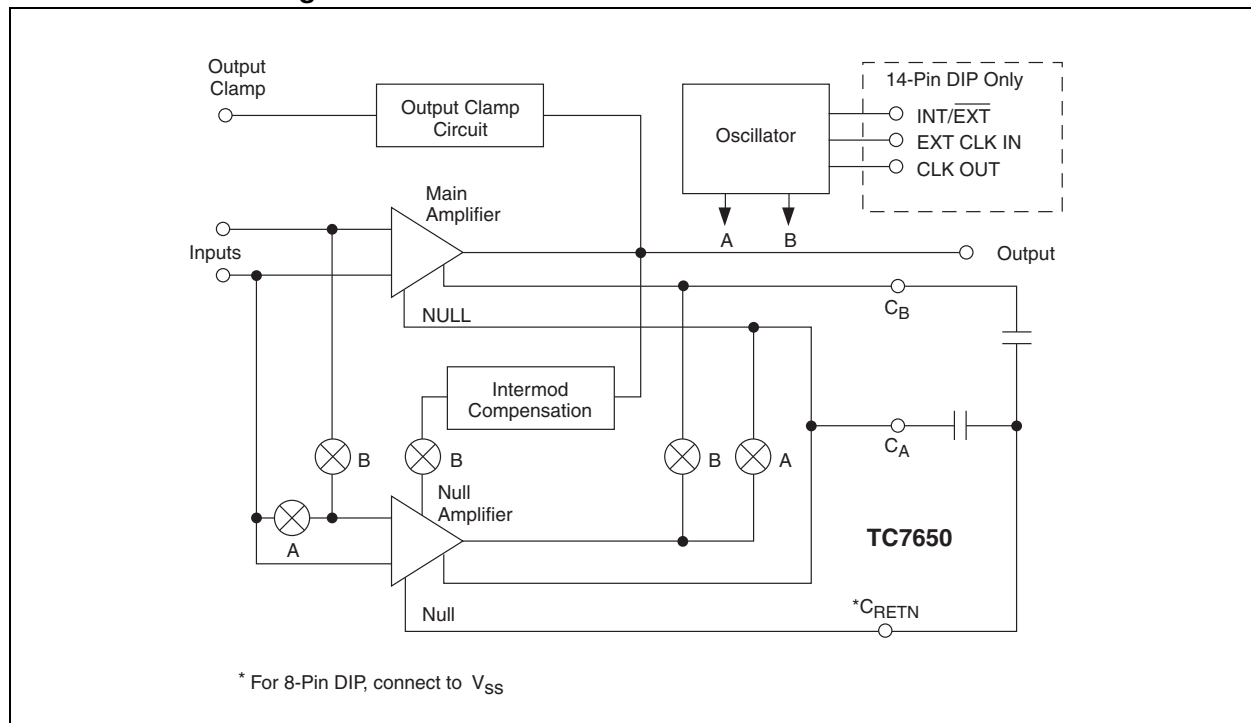
The TC7650 CMOS chopper stabilized operational amplifier practically removes offset voltage error terms from system error calculations. The  $5\mu\text{V}$  maximum  $V_{OS}$  specification, for example, represents a 15 times improvement over the industry standard OP07E. The  $50\text{nV}/^\circ\text{C}$  offset drift specification is over 25 times lower than the OP07E. The increased performance eliminates  $V_{OS}$  trim procedures, periodic potentiometer adjustment and the reliability problems caused by damaged trimmers.

The TC7650 performance advantages are achieved without the additional manufacturing complexity and cost incurred with laser or "zener zap"  $V_{OS}$  trim techniques.

The TC7650 nulling scheme corrects both DC  $V_{OS}$  errors and  $V_{OS}$  drift errors with temperature. A nulling amplifier alternately corrects its own  $V_{OS}$  errors and the main amplifier  $V_{OS}$  error. Offset nulling voltages are stored on two user supplied external capacitors. The capacitors connect to the internal amplifier  $V_{OS}$  null points. The main amplifier input signal is never switched. Switching spikes are not present at the TC7650 output.

The 14-pin dual-in-line package (DIP) has an external oscillator input to drive the nulling circuitry for optimum noise performance. Both the 8 and 14-pin DIPs have an output voltage clamp circuit to minimize overload recovery time.

## 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 ( $V_{SS} - 0.3V$ )
Storage Temperature Range .....	-65°C to +150°C
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 3</b> ) .....	100μA
Package Power Dissipation ( $T_A \leq 70^\circ\text{C}$ )	
8-Pin Plastic DIP .....	730mW
14-Pin Plastic DIP .....	800mW
Operating Temperature Range	
C Device .....	0°C to +70°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: $V_{DD} = +5V$ , $V_{SS} = -5V$ , $C_A = C_B = 0.1\mu F$ , $T_A = +25^\circ\text{C}$ , unless otherwise indicated.						
Symbol	Parameter	Min.	Typ	Max	Units	Test Conditions
<b>Input</b>						
$V_{OS}$	Input Offset Voltage	—	$\pm 0.7$ $\pm 1.0$	$\pm 5$ —	— μV	$T_A = +25^\circ\text{C}$ Over Operating Temp Range
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Average Temperature Coefficient	—	0.01	0.05	μV/°C	Operating Temperature Range
	Offset Voltage vs. Time	—	100	—	nV/ month	
$I_{BIAS}$	Input Bias Current	—	1.5	10	pA	$T_A = +25^\circ\text{C}$
		—	35	150	pA	$0^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$
		—	100	400	pA	$-25^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$
$I_{OS}$	Input Offset Current	—	0.5	—	pA	
$e_{NP-P}$	Input Noise Voltage	—	2	—	μV <sub>P-P</sub>	$R_S = 100\Omega$ , 0 to 10Hz
$I_N$	Input Noise Current	—	0.01	—	pA/√Hz	f = 10Hz
$R_{IN}$	Input Resistance	—	$10^{12}$	—	Ω	
CMVR	Common Mode Voltage Range	-5	-5.2 to +2	+1.6	V	
CMRR	Common Mode Rejection Ratio	120	130	—	dB	CMVR = -5V to +1.5V
<b>Output</b>						
A	Large Signal Voltage Gain	120	130	—	dB	$R_L = 10k\Omega$
$V_{OUT}$	Output Voltage Swing ( <b>Note 2</b> )	$\pm 4.7$ —	$\pm 4.85$ $\pm 4.95$	— —	v v	$R_L = 10k\Omega$ $R_L = 100k\Omega$
	Clamp ON Current	25	70	200	μA	$R_L = 100k\Omega$ ( <b>Note 1</b> )
	Clamp OFF Current	—	1	—	pA	-4V < $V_{OUT}$ < +4V ( <b>Note 1</b> )
<b>Dynamic</b>						
$B_W$	Unity Gain Bandwidth	—	2.0	—	MHz	Unity Gain (+1)
$S_R$	Slew Rate	—	2.5	—	V/μsec	$C_L = 50pF$ , $R_L = 10k\Omega$
$t_R$	Rise Time	—	0.2	—	μsec	
	Overshoot	—	20	—	%	
$f_{CH}$	Internal Chopping Frequency	120	200	375	Hz	Pins 12–14 Open (DIP)
<b>Supply</b>						
$V_{DD}, V_{SS}$	Operating Supply Range	4.5	—	16	V	
$I_S$	Supply Current	—	2	3.5	mA	No Load
PSRR	Power Supply Rejection Ratio	120	130	—	dB	$V_S = \pm 3V$ to $\pm 8V$

- Note**
- 1: See "Output Clamp" discussion.
  - 2: Output clamp not connected. See typical characteristics curves for output swing versus clamp current characteristics.
  - 3: Limiting input current to 100μA is recommended to avoid latch-up problems.

## 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 Theory of Operation

Figure 3-1 shows the major elements of the TC7650. There are two amplifiers (the main amplifier and the nulling amplifier), and both have offset null capability. The main amplifier is connected full-time from the input to the output. The nulling amplifier, under the control of the chopping frequency oscillator and clock circuit, alternately nulls itself and the main amplifier. Two external capacitors provide the required storage of the nulling potentials and the necessary nulling loop time constants. The nulling arrangement operates over the full common mode and power supply ranges, and is also independent of the output level, thus giving exceptionally high CMRR, PSRR and  $A_{VOL}$ .

Careful balancing of the input switches minimizes chopper frequency charge injection at the input terminals, and the feed forward type injection into the compensation capacitor that can cause output spikes in this type of circuit.

The circuit's offset voltage compensation is easily shown. With the nulling inputs shorted, a voltage almost identical to the nulling amplifier offset voltage is stored on  $C_A$ . The effective offset voltage at the null amplifier input is:

**EQUATION 3-1:**

$$V_{OSE} = \frac{1}{A_N + 1} V_{OSN}$$

After the nulling amplifier is zeroed, the main amplifier is zeroed; the A switches open and B switches close.

The output voltage equation is:

**EQUATION 3-2:**

$$V_{OUT} = A_M[V_{OSM} + (V^+ - V^-) + A_N(V^+ - V^-) + A_N V_{OSE}]$$

**EQUATION 3-3:**

$$V_{OUT} = A_M A_N \left[ (V^+ - V^-) + \frac{V_{OSM} + V_{OSN}}{A_N} \right]$$

As desired, the device offset voltages are reduced by the high open loop gain of the nulling amplifier.

### 3.2 Output Stage/Loading

The output circuit is a high impedance stage (approximately 18k $\Omega$ ). With loads less than this, the chopper amplifier behaves in some ways like a trans-conductance amplifier whose open-loop gain is proportional to load resistance. For example, the open loop gain will be 17dB lower with a 1k $\Omega$  load than with a 10k $\Omega$  load. If the amplifier is used strictly for DC, the lower gain is of little consequence, since the DC gain is typically greater than 120dB, even with a 1k $\Omega$  load. In wideband applications, the best frequency response will be achieved with a load resistor of 10k $\Omega$  or higher. This results in a smooth 6dB/octave response from 0.1Hz to 2MHz, with phase shifts of less than 10° in the transi-



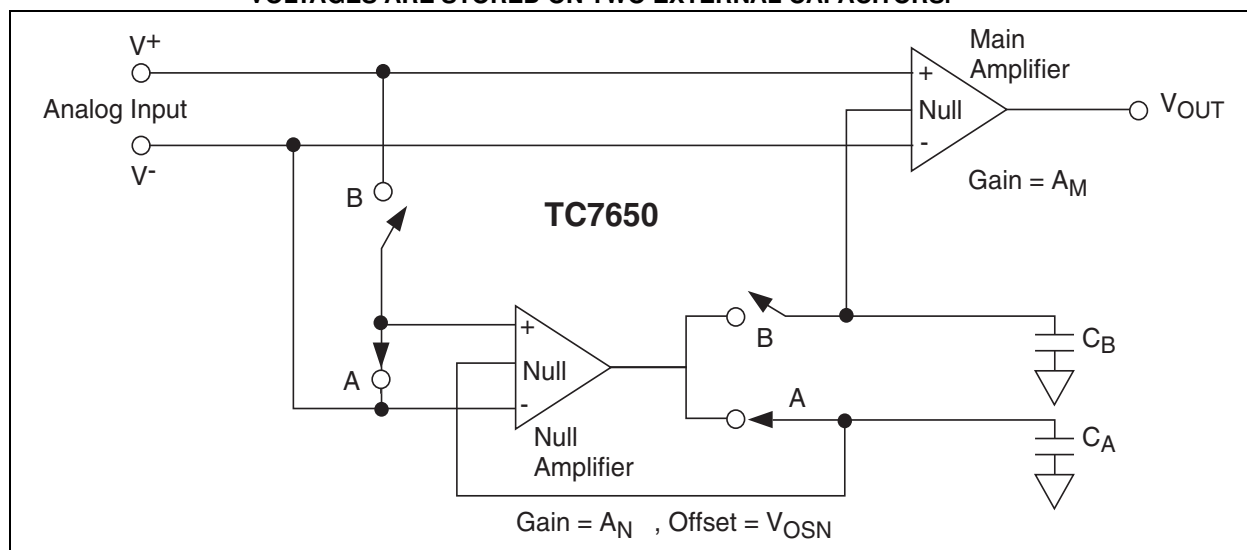
tion region, where the main amplifier takes over from the null amplifier. The clock frequency sets the transition region.

## 3.3 Intermodulation

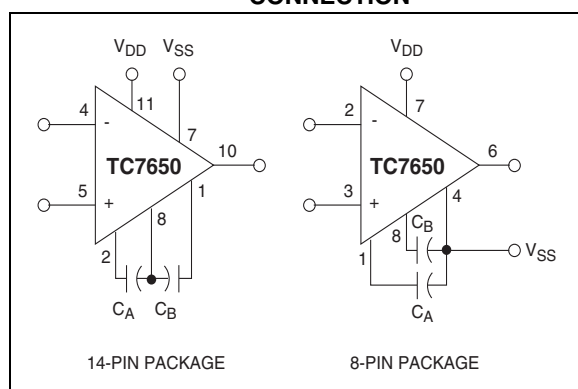
Previous chopper stabilized amplifiers have suffered from intermodulation effects between the chopper frequency and input signals. These arise because the finite AC gain of the amplifier results in a small AC signal at the input. This is seen by the zeroing circuit as an error signal, which is chopped and fed back, thus inject-

ing sum and difference frequencies, and causing disturbances to the gain and phase versus frequency characteristics near the chopping frequency. These effects are substantially reduced in the TC7650 by feeding the nulling circuit with a dynamic current corresponding to the compensation capacitor current in such a way as to cancel that portion of the input signal due to a finite AC gain. The intermodulation and gain/phase disturbances are held to very low values, and can generally be ignored.

**FIGURE 3-1: TC7650 CONTAINS A NULLING AND MAIN AMPLIFIER. OFFSET CORRECTION VOLTAGES ARE STORED ON TWO EXTERNAL CAPACITORS.**



**FIGURE 3-2: NULLING CAPACITOR CONNECTION**



## 3.4 Nulling Capacitor Connection

The offset voltage correction capacitors are connected to  $C_A$  and  $C_B$ . The common capacitor connection is made to  $V_{SS}$  (Pin 4) on the 8-pin packages and to capacitor return ( $C_{RET}$ , Pin 8) on the 14-pin packages. The common connection should be made through a separate PC trace or wire to avoid voltage drops. The capacitors outside foil, if possible, should be connected to  $C_{RET}$  or  $V_{SS}$ .

## 3.5 Clock Operation

The internal oscillator is set for a 200Hz nominal chopping frequency on both the 8- and 14-pin DIPs. With the 14-pin DIP TC7650, the 200 Hz internal chopping frequency is available at the internal clock output (Pin 12). A 400Hz nominal signal will be present at the external clock input pin (Pin 13) with INT/EXT high or open. This is the internal clock signal before a divide-by-two operation.

The 14-pin DIP device can be driven by an external clock. The INT/EXT input (Pin 14) has an internal pull-up and may be left open for internal clock operation. If an external clock is used, INT/EXT must be tied to  $V_{SS}$  (Pin 7) to disable the internal clock. The external clock signal is applied to the external clock input (Pin 13).

The external clock amplitude should swing between  $V_{DD}$  and ground for power supplies up to  $\pm 6V$  and between  $V^+$  and  $V^+ - 6V$  for higher supply voltages.

At low frequencies the external clock duty cycle is not critical, since an internal divide-by-two gives the desired 50% switching duty cycle. The offset storage correction capacitors are charged only when the external clock input is high. A 50% to 80% external clock

# TC7650

positive duty cycle is desired for frequencies above 500Hz to ensure transients settle before the internal switches open.

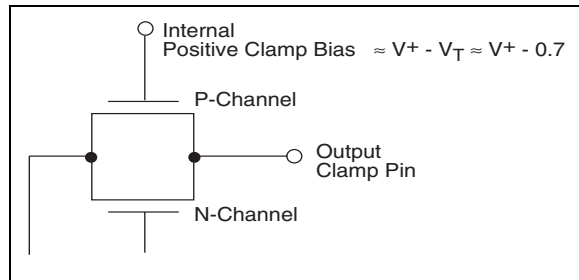
The external clock input can also be used as a strobe input. If a strobe signal is connected at the external clock input so that it is LOW during the time an overload signal is applied, neither capacitor will be charged. The leakage currents at the capacitors pins are very low. At 25°C a typical TC7650 will drift less than 10μV/sec.

## 3.6 Output Clamp

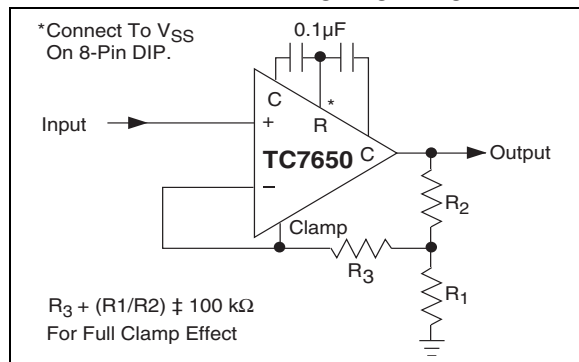
Chopper-stabilized systems can show long recovery times from overloads. If the output is driven to either supply rail, output saturation occurs. The inputs are no longer held at a "virtual ground." The  $V_{OS}$  null circuit treats the differential signal as an offset and tries to correct it by charging the external capacitors. The nulling circuit also saturates. Once the input signal returns to normal, the response time is lengthened by the long recovery time of the nulling amplifier and external capacitors.

Through an external clamp connection, the TC7650 eliminates the overload recovery problem by reducing the feedback network gain before the output voltage reaches either supply rail.

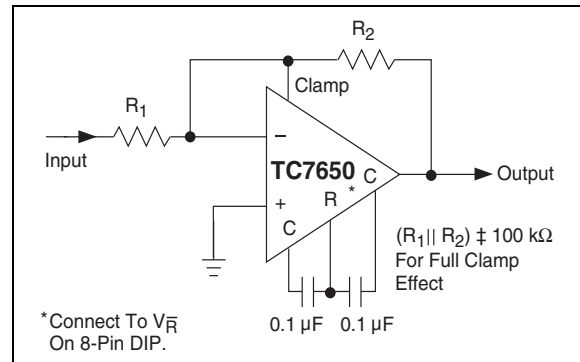
**FIGURE 3-3: INTERNAL CLAMP CIRCUIT**



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



**FIGURE 3-5: INVERTING AMPLIFIER WITH OPTIONAL CLAMP**



The output clamp circuit is shown in Figure 3-3, with typical inverting and non-inverting circuit connections shown in Figures 3-4 and 3-5. Output voltage versus clamp circuit current characteristics are shown in the typical operating curves. For the clamp to be fully effective, the impedance across the clamp output should be greater than 100kΩ.

## 3.7 Latch-Up Avoidance

Junction-isolated CMOS circuits inherently include a parasitic 4-layer (p-n-p-n) structure which has characteristics similar to an SCR. Under certain circumstances this junction may be triggered into a low-impedance state, resulting in excessive supply current. To avoid this condition, no voltage greater than 0.3V beyond the supply rails should be applied to any pin. In general, the amplifier supplies must be established either at the same time or before any input signals are applied. If this is not possible, the drive circuits must limit input current flow to under 0.1mA to avoid latch-up.

## 3.8 Thermoelectric Potentials

Precision DC measurements are ultimately limited by thermoelectric potentials developed in thermocouple junctions of dissimilar metals, alloys, silicon, etc. Unless all junctions are at the same temperature, thermoelectric voltages, typically around 0.1μV/°C, but up to tens of μV/°C for some materials, will be generated. In order to realize the benefits extremely-low offset voltages provide, it is essential to take special precautions to avoid temperature gradients. All components should be enclosed to eliminate air movement, especially those caused by power dissipating elements in the system. Low thermoelectric co-efficient connections should be used where possible and power supply voltages and power dissipation should be kept to a minimum. High impedance loads are preferable, and separation from surrounding heat dissipating elements is advised.

## 3.9 Pin Compatibility

On the 8-pin mini-DIP TC7650, the external null storage capacitors are connected to pins 1 and 8. On most other operational amplifiers these are left open or are used for offset potentiometer or compensation capacitor connections.

For OP05 and OP07 operational amplifiers, the replacement of the offset null potentiometer between pins 1 and 8 by two capacitors from the pins to  $V_{SS}$  will convert the OP05/07 pin configurations for TC7650 operation. For LM108 devices, the compensation capacitor is replaced by the external nulling capacitors. The LM101/748/709 pinouts are modified similarly by removing any circuit connections to Pin 5. On the TC7650, Pin 5 is the output clamp connection.

Other operational amplifiers may use this pin as an offset or compensation point.

The minor modifications needed to retrofit a TC7650 into existing sockets operating at reduced power supply voltages make prototyping and circuit verification straightforward.

## 3.10 Input Guarding

High impedance, low leakage CMOS inputs allow the TC7650 to make measurements of high-impedance sources. Stray leakage paths can increase input currents and decrease input resistance unless inputs are guarded. A guard is a conductive PC trace surrounding the input terminals. The ring connects to a low impedance point at the same potential as the inputs. Stray leakages are absorbed by the low impedance ring. The equal potential between ring and inputs prevents input leakage currents. Typical guard connections are shown in Figure 3-6.

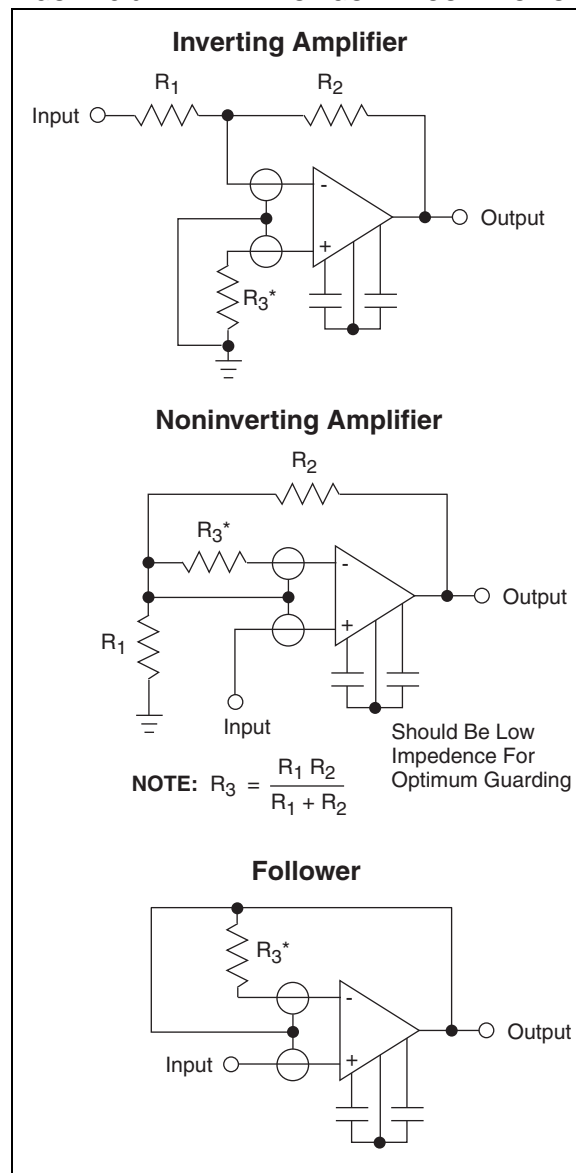
The 14-pin DIP configuration has been specifically designed to ease input guarding. The pins adjacent to the inputs are unused.

In applications requiring low leakage currents, boards should be cleaned thoroughly and blown dry after soldering. Protective coatings will prevent future board contamination.

## 3.11 Component Selection

The two required capacitors,  $C_A$  and  $C_B$ , have optimum values, depending on the clock or chopping frequency. For the preset internal clock, the correct value is  $0.1\mu\text{F}$ . To maintain the same relationship between the chopping frequency and the nulling time constant, the capacitor values should be scaled in proportion to the external clock, if used. High quality film type capacitors (such as Mylar) are preferred; ceramic or other lower grade capacitors may be suitable in some applications. For fast settling on initial turn-on, low dielectric absorption capacitors (such as polypropylene) should be used. With ceramic capacitors, several seconds may be required to settle to  $1\mu\text{V}$ .

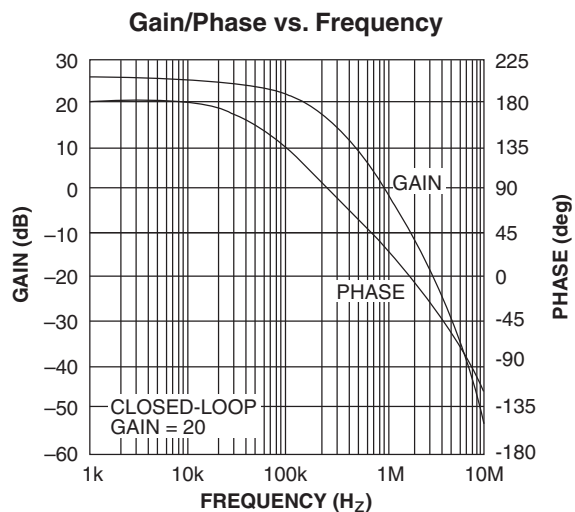
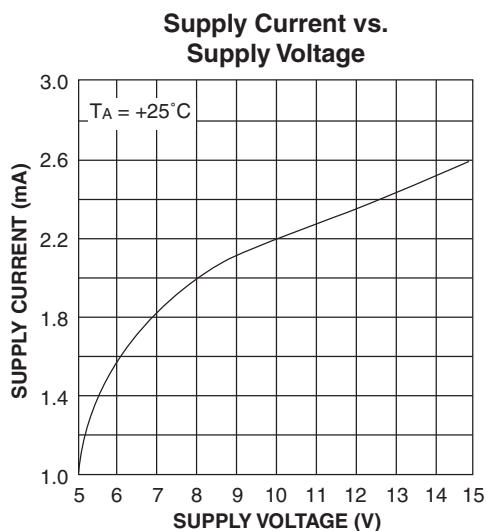
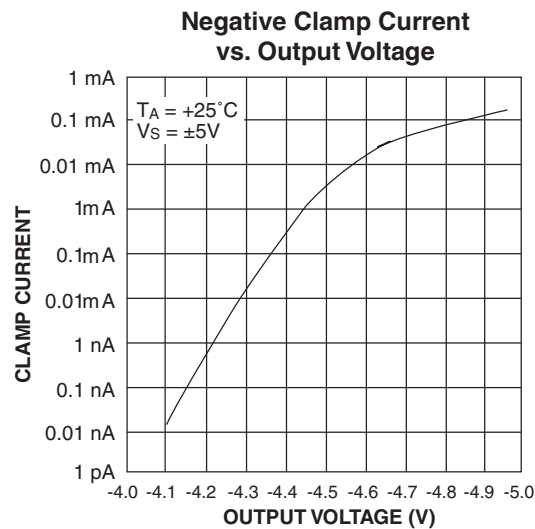
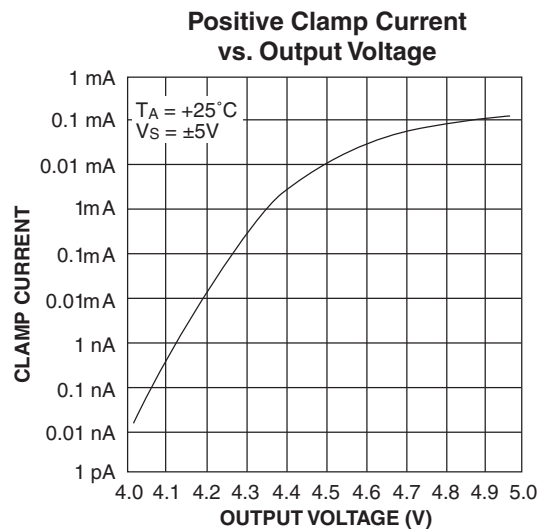
FIGURE 3-6: INPUT GUARD CONNECTION





## 4.0 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.





## 6.0 REVISION HISTORY

### Revision C (December 2012)

Added a note to each package outline drawing.

## 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 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.

# TC7650

---

NOTES:



---

**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

---

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights.

#### Trademarks

The Microchip name and logo, the Microchip logo, dsPIC, FlashFlex, KEELOQ, KEELOQ logo, MPLAB, PIC, PICmicro, PICSTART, PIC<sup>32</sup> logo, rPIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

FilterLab, Hampshire, HI-TECH C, Linear Active Thermistor, MTP, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

Analog-for-the-Digital Age, Application Maestro, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, dsSPEAK, ECAN, ECONOMONITOR, FanSense, HI-TIDE, In-Circuit Serial Programming, ICSP, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, mTouch, Omniscent Code Generation, PICC, PICC-18, PICDEM, PICDEM.net, PICkit, PICTail, REAL ICE, rLAB, Select Mode, SQL, Serial Quad I/O, Total Endurance, TSHARC, UniWinDriver, WiperLock, ZENA and Z-Scale are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

GestIC and ULPP are registered trademarks of Microchip Technology Germany II GmbH & Co. & KG, a subsidiary of Microchip Technology Inc., in other countries.

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

© 2001-2012, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.



Printed on recycled paper.

ISBN: 9781620768402

**QUALITY MANAGEMENT SYSTEM**  
**CERTIFIED BY DNV**  
**= ISO/TS 16949 =**

*Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.*



## 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:  
<http://www.microchip.com/support>  
Web Address:  
[www.microchip.com](http://www.microchip.com)

**Atlanta**  
Duluth, GA  
Tel: 678-957-9614  
Fax: 678-957-1455

**Boston**  
Westborough, MA  
Tel: 774-760-0087  
Fax: 774-760-0088

**Chicago**  
Itasca, IL  
Tel: 630-285-0071  
Fax: 630-285-0075

**Cleveland**  
Independence, OH  
Tel: 216-447-0464  
Fax: 216-447-0643

**Dallas**  
Addison, TX  
Tel: 972-818-7423  
Fax: 972-818-2924

**Detroit**  
Farmington Hills, MI  
Tel: 248-538-2250  
Fax: 248-538-2260

**Indianapolis**  
Noblesville, IN  
Tel: 317-773-8323  
Fax: 317-773-5453

**Los Angeles**  
Mission Viejo, CA  
Tel: 949-462-9523  
Fax: 949-462-9608

**Santa Clara**  
Santa Clara, CA  
Tel: 408-961-6444  
Fax: 408-961-6445

**Toronto**  
Mississauga, Ontario,  
Canada  
Tel: 905-673-0699  
Fax: 905-673-6509

### ASIA/PACIFIC

**Asia Pacific Office**  
Suites 3707-14, 37th Floor  
Tower 6, The Gateway  
Harbour City, Kowloon  
Hong Kong  
Tel: 852-2401-1200  
Fax: 852-2401-3431

**Australia - Sydney**  
Tel: 61-2-9868-6733  
Fax: 61-2-9868-6755

**China - Beijing**  
Tel: 86-10-8569-7000  
Fax: 86-10-8528-2104

**China - Chengdu**  
Tel: 86-28-8665-5511  
Fax: 86-28-8665-7889

**China - Chongqing**  
Tel: 86-23-8980-9588  
Fax: 86-23-8980-9500

**China - Hangzhou**  
Tel: 86-571-2819-3187  
Fax: 86-571-2819-3189

**China - Hong Kong SAR**  
Tel: 852-2943-5100  
Fax: 852-2401-3431

**China - Nanjing**  
Tel: 86-25-8473-2460  
Fax: 86-25-8473-2470

**China - Qingdao**  
Tel: 86-532-8502-7355  
Fax: 86-532-8502-7205

**China - Shanghai**  
Tel: 86-21-5407-5533  
Fax: 86-21-5407-5066

**China - Shenyang**  
Tel: 86-24-2334-2829  
Fax: 86-24-2334-2393

**China - Shenzhen**  
Tel: 86-755-8864-2200  
Fax: 86-755-8203-1760

**China - Wuhan**  
Tel: 86-27-5980-5300  
Fax: 86-27-5980-5118

**China - Xian**  
Tel: 86-29-8833-7252  
Fax: 86-29-8833-7256

**China - Xiamen**  
Tel: 86-592-2388138  
Fax: 86-592-2388130

**China - Zhuhai**  
Tel: 86-756-3210040  
Fax: 86-756-3210049

### ASIA/PACIFIC

**India - Bangalore**  
Tel: 91-80-3090-4444  
Fax: 91-80-3090-4123

**India - New Delhi**  
Tel: 91-11-4160-8631  
Fax: 91-11-4160-8632

**India - Pune**  
Tel: 91-20-2566-1512  
Fax: 91-20-2566-1513

**Japan - Osaka**  
Tel: 81-6-6152-7160  
Fax: 81-6-6152-9310

**Japan - Tokyo**  
Tel: 81-3-6880-3770  
Fax: 81-3-6880-3771

**Korea - Daegu**  
Tel: 82-53-744-4301  
Fax: 82-53-744-4302

**Korea - Seoul**  
Tel: 82-2-554-7200  
Fax: 82-2-558-5932 or  
82-2-558-5934

**Malaysia - Kuala Lumpur**  
Tel: 60-3-6201-9857  
Fax: 60-3-6201-9859

**Malaysia - Penang**  
Tel: 60-4-227-8870  
Fax: 60-4-227-4068

**Philippines - Manila**  
Tel: 63-2-634-9065  
Fax: 63-2-634-9069

**Singapore**  
Tel: 65-6334-8870  
Fax: 65-6334-8850

**Taiwan - Hsin Chu**  
Tel: 886-3-5778-366  
Fax: 886-3-5770-955

**Taiwan - Kaohsiung**  
Tel: 886-7-213-7828  
Fax: 886-7-330-9305

**Taiwan - Taipei**  
Tel: 886-2-2508-8600  
Fax: 886-2-2508-0102

**Thailand - Bangkok**  
Tel: 66-2-694-1351  
Fax: 66-2-694-1350

### EUROPE

**Austria - Wels**  
Tel: 43-7242-2244-39  
Fax: 43-7242-2244-393

**Denmark - Copenhagen**  
Tel: 45-4450-2828  
Fax: 45-4485-2829

**France - Paris**  
Tel: 33-1-69-53-63-20  
Fax: 33-1-69-30-90-79

**Germany - Munich**  
Tel: 49-89-627-144-0  
Fax: 49-89-627-144-44

**Italy - Milan**  
Tel: 39-0331-742611  
Fax: 39-0331-466781

**Netherlands - Drunen**  
Tel: 31-416-690399  
Fax: 31-416-690340

**Spain - Madrid**  
Tel: 34-91-708-08-90  
Fax: 34-91-708-08-91

**UK - Wokingham**  
Tel: 44-118-921-5869  
Fax: 44-118-921-5820

11/29/12