

LOW NOISE, CHOPPER-STABILIZED OPERATIONAL AMPLIFIER

FEATURES

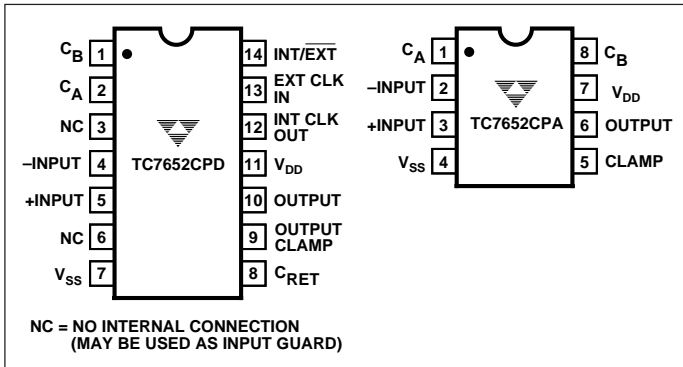
- Low Offset Over Temperature Range 10 μ V
- Ultra-Low Long-Term Drift 150nV/Month
- Low Temperature Drift 100nV/ $^{\circ}$ C
- Low DC Input Bias Current 15pA
- High Gain, CMRR and PSRR 110dB Min
- Low Input Noise Voltage 0.2 μ V_{P-P}; DC to 1Hz
- Internally-Compensated for Unity-Gain Operation
- Clamp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

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 overrange lockup problems.

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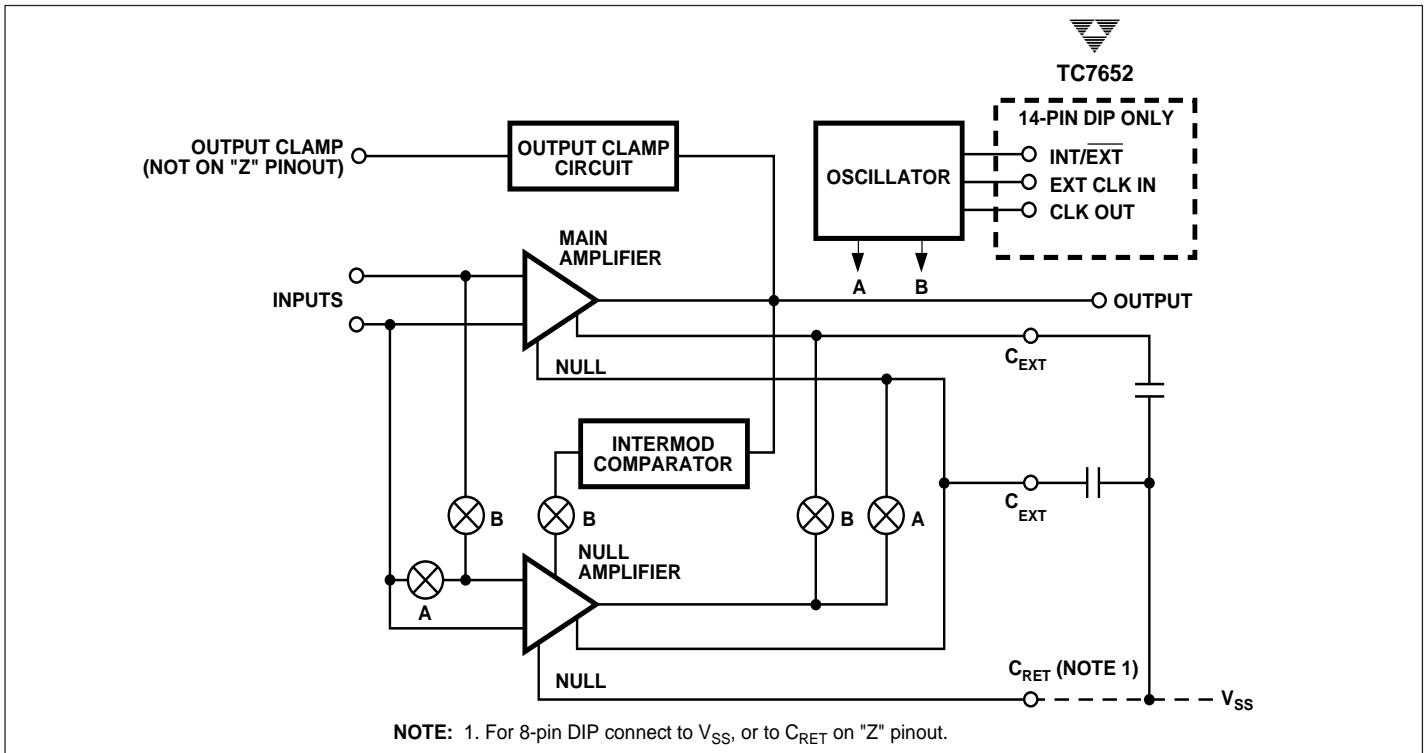
PIN CONFIGURATIONS



ORDERING INFORMATION

Part No.	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

FUNCTIONAL BLOCK DIAGRAM



LOW NOISE, CHOPPER-STABILIZED OPERATIONAL AMPLIFIER

TC7652

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 (Note 1)	100 μ 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 $^\circ\text{C}$
Lead Temperature (Soldering, 10 sec)	+300 $^\circ\text{C}$

*Static-sensitive device. Unused devices must be stored in conductive material. Protect devices from static discharge and static fields. 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 operational sections of the specifications is not implied. Exposure to Absolute Maximum Rating Conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS: $V_{DD} = +5V$, $V_{SS} = -5V$, $T_A = +25^\circ\text{C}$, unless otherwise indicated.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
V_{OS}	Input Offset Voltage	$T_A = +25^\circ\text{C}$ $0^\circ\text{C} < T_A < +70^\circ\text{C}$	—	± 2 ± 10	± 5 —	μV
TCV_{OS}	Average Temperature Coefficient of Input Offset Voltage	$0^\circ\text{C} < T_A < +70^\circ\text{C}$	—	0.01	0.05	$\mu\text{V}/^\circ\text{C}$
V_{OS}/DT	Offset Voltage vs Time		—	150	—	nV/mo
I_{BIAS}	Input Bias Current (CLK On)	$T_A = +25^\circ\text{C}$ $0^\circ\text{C} < T_A < +70^\circ\text{C}$ $-25^\circ\text{C} < T_A < +85^\circ\text{C}$	—	30 100 250	100 — 1000	pA
I_{BIAS}	Input Bias Current (CLK Off)	$T_A = +25^\circ\text{C}$ $0^\circ\text{C} < T_A < +70^\circ\text{C}$ $-25^\circ\text{C} < T_A < +85^\circ\text{C}$	—	15 35 100	30 — —	pA
I_{OS}	Input Offset Current		—	25	150	pA
R_{IN}	Input Resistance		—	10^{12}	—	Ω
OL	Large Signal Voltage Gain	$R_L = 10\text{k}\Omega$, $V_{OUT} = \pm 4V$	120	150	—	dB
V_{OUT}	Output Voltage Swing (Note 2)	$R_L = 10\text{k}\Omega$ $R_L = 100\text{k}\Omega$	± 4.7 —	± 4.85 ± 4.95	— —	V
CMVR	Common-Mode Voltage Range		-4.3	—	+3.5	V
MRR	Common-Mode Rejection Ratio	CMVR = -4.3V to +3.5V	120	140	—	dB
PSRR	Power Supply Rejection Ratio	$\pm 3V$ to $\pm 8V$	120	140	—	dB
e_N	Input Noise Voltage	$R_S = 100\Omega$, DC to 1Hz DC to 10Hz	—	0.2 0.7	1.5 5	μV_{P-P} μV_{P-P}
I_N	Input Noise Current	$f = 10\text{Hz}$	—	0.01	—	$\text{pA}/\sqrt{\text{Hz}}$
GBW	Unity-Gain Bandwidth		—	0.4	—	MHz
SR	Slew Rate	$C_L = 50\text{ pF}$, $R_L = 10\text{k}\Omega$	—	1	—	V/ μsec
	Overshoot		—	15	—	%
V_{DD} , V_{SS}	Operating Supply Range		5	—	16	V
I_S	Supply Current	No Load	—	1	3	mA
f_{CH}	Internal Chopping Frequency	Pins 12 – 14 Open (DIP)	100	275	—	Hz
	Clamp ON Current (Note 3)	$R_L = 100\text{k}\Omega$	25	100	—	μA
	Clamp OFF Current (Note 3)	$-4V \leq V_{OUT} < +10V$	—	1	—	pA

NOTES: 1. Limiting input current to 100 μ A is recommended to avoid latch-up problems. Typically, 1mA is safe; however, this is not guaranteed.
2. Output clamp not connected. See typical characteristics curves for output swing versus clamp current characteristics.

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.

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 buildup on correction-storage capacitors. Output swing is reduced.

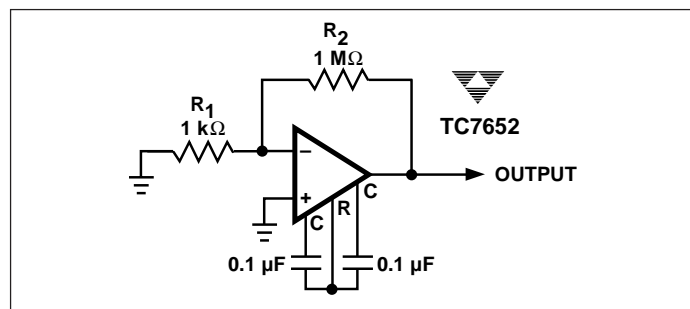
Clock

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.

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 with negligible errors (typical capacitor drift is 10μV/sec).

APPLICATION NOTES

Component Selection

C_A and C_B (external capacitors) should be in the 0.1μF to 1μF range. For minimum clock ripple noise, use a 1μF capacitor in broad bandwidth circuits. For limited bandwidth applications where clock ripple is filtered out, use a 0.1μF 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 1μV takes several seconds.

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.

Latch-Up

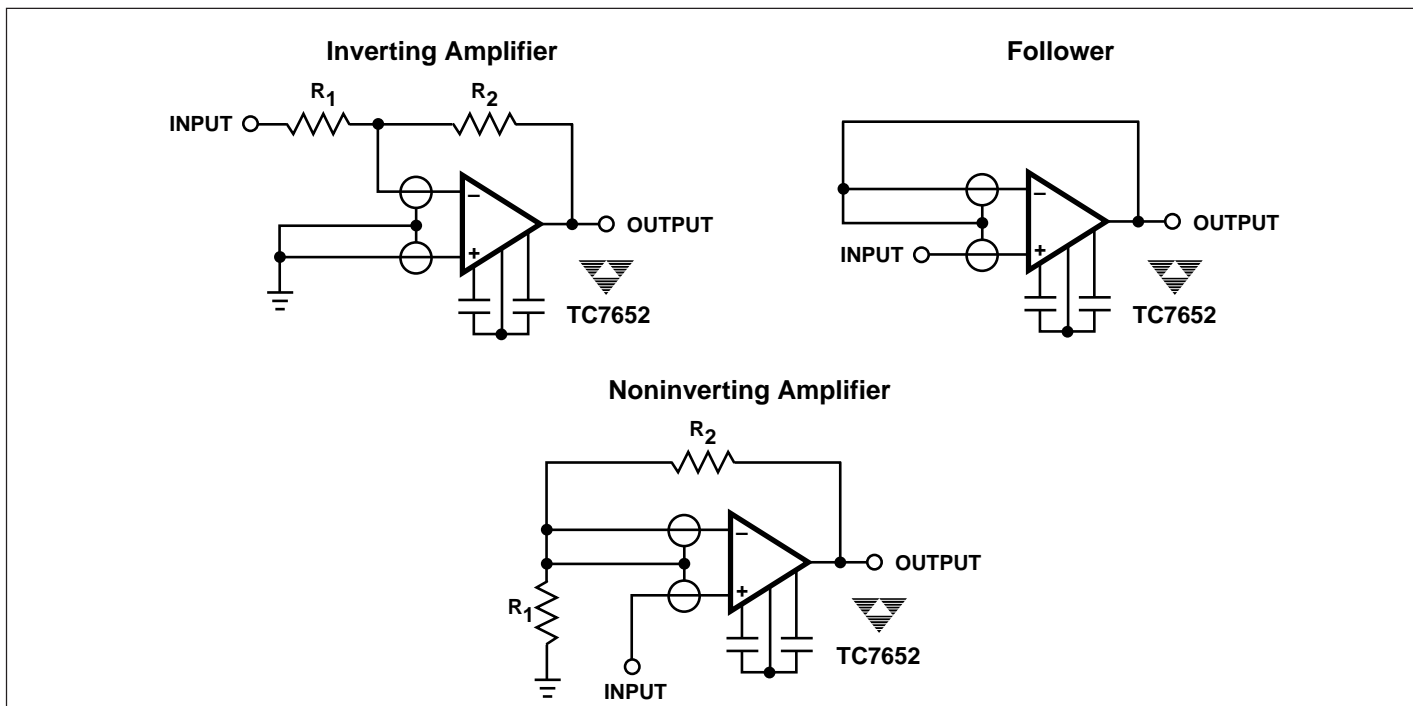
Junction-isolated CMOS circuits have a 4-layer (p-n-p-n) structure similar to an SCR. Sometimes this junction can be triggered into a low-impedance state and produce excessive supply current. Therefore, avoid applying voltage greater than 0.3V beyond the supply rails to any pin. Establish the amplifier supplies at the same time or before any input signals are applied. If this is not possible, drive circuits must limit input current flow to under 1mA to avoid latch-up, even under fault conditions.

Output Stage/Load Driving

The output circuit is high impedance (about 18kΩ). 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 1kΩ load than with a 10kΩ load.) If the amp is used only for DC, the DC gain is typically greater than 120dB (even with a 1kΩ load), and this lower gain is inconsequential. For wideband, the best frequency response occurs with a load resistor of at least 10kΩ. This produces

TC7652

CONNECTION OF INPUT GUARDS



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.

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 μ V/ $^{\circ}$ C (up to tens of μ 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-coefficient connections. Keep power supply voltages and power dissipation to a minimum. Use high-impedance loads and seek maximum separation from surrounding heat-dissipating elements.

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.

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, μ 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.

Some Applications

Figures 1 and 2 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 3) 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, monitor loop gain stability.

Figure 4 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 5 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 6 shows an approximate connection.

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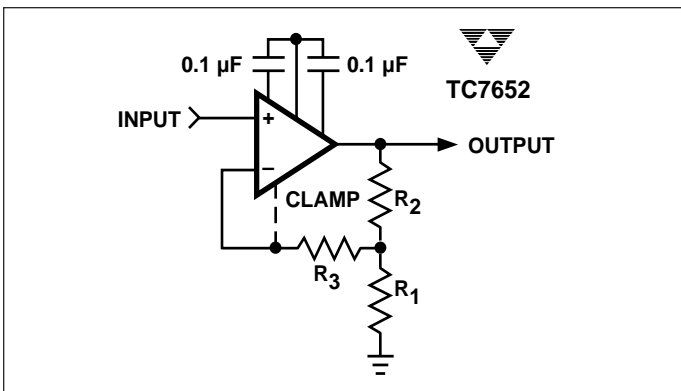


Figure 1. Noninverting Amplifier With Optional Clamp

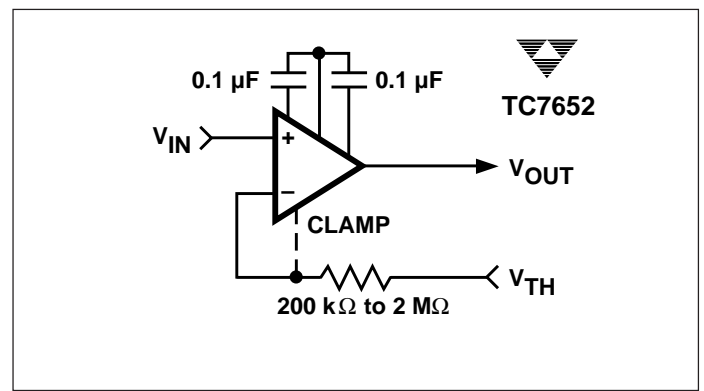


Figure 4. Low Offset Comparator

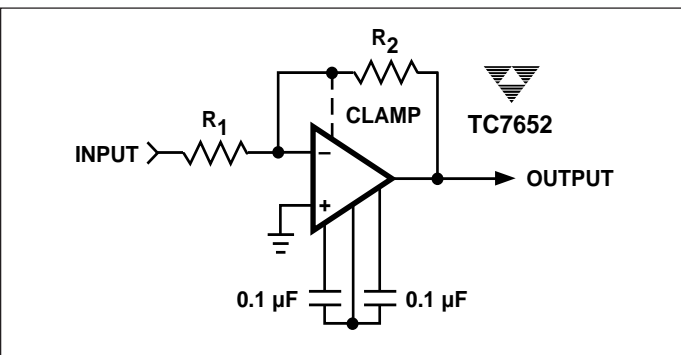


Figure 2. Inverting Amplifier With Optional Clamp

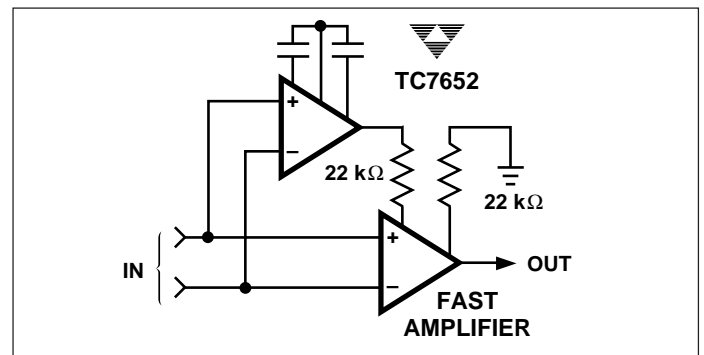


Figure 5. 1437 Offset-Nullled by TC7652

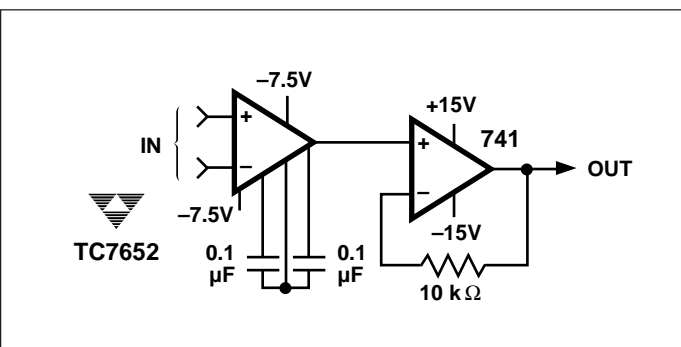


Figure 3. Using 741 to Boost Output Drive Capability

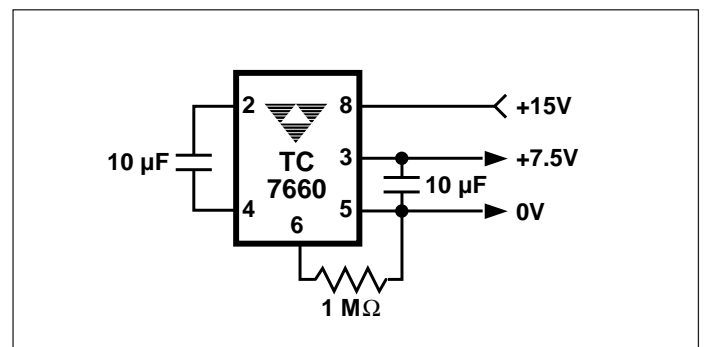


Figure 6. Splitting +15V With the 7660 at >95% Efficiency

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TC7652

TYPICAL CHARACTERISTICS

