Micropower Programmable Operator Amplifier
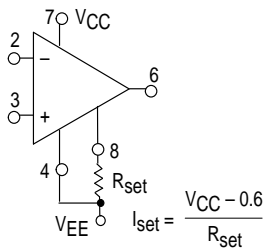
(compatible to TLC251&TLC271 (TI USA)

This extremely versatile operational amplifier features low power consumption and high input impedance. In addition, the quiescent currents within the device may be programmed by the choice of an external resistor value or current source applied to the I_{set} input. This allows the amplifier's characteristics to be optimized for input current and power consumption despite wide variations in operating power supply voltages.

- ±1.2 V to ±18 V Operation
- Wide Programming Range
- Offset Null Capability
- No Frequency Compensation Required
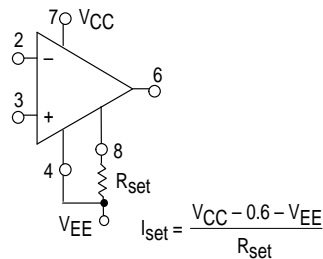- Low Input Bias Currents
- Short Circuit Protection

DIP8–8 N SUFFIX
HT8776BNZ

SOP–8 R SUFFIX
HT8776BRZ

MSOP–8 M SUFFIX
HT8776BRMZ

$T_A = 0°$ to $70°C$ for all packages.

NOTE: suffix B is version, suffix R is roll tape, suffix Z environmental protection.

Resistive Programming
(See Figure 1)

R_{set} to Ground

$$I_{set} = \frac{V_{CC} - 0.6}{R_{set}}$$

R_{set} to Negative Supply
(Recommended for supply voltage less than ±6.0 V)

$$I_{set} = \frac{V_{CC} - 0.6 - V_{EE}}{R_{set}}$$

Typical R_{set} Values		
V_{CC}, V_{EE}	I_{set} = 1.5 µA	I_{set} = 15 µA
±6.0 V	3.6 MΩ	360 kΩ
±10 V	6.2 MΩ	620 kΩ
±12 V	7.5 MΩ	750 kΩ
±15 V	10 MΩ	1.0 MΩ

Typical R_{set} Values		
V_{CC}, V_{EE}	I_{set} = 1.5 µA	I_{set} = 15 µA
±1.5 V	1.6 MΩ	160 kΩ
±3.0 V	3.6 MΩ	360 kΩ
±6.0 V	7.5 MΩ	750 kΩ
±15 V	20 MΩ	2.0 MΩ

Active Programming

FET Current Source
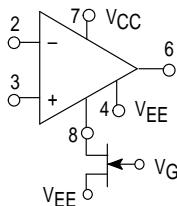
Bipolar Current Source

Pins not shown are not connected.

PIN CONNECTIONS

Offset Null	1	8	I_{set}
Invert	2	7	V_{CC}
Noninvert	3	6	Output
V_{EE}	4	5	Offset Null

Input {

(Top View)

MAXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltages	V_{CC}, V_{EE}	±18	Vdc
Differential Input Voltage	V_{ID}	±30	Vdc
Common Mode Input Voltage V_{CC} and $\|V_{EE}\| < 15$ V V_{CC} and $\|V_{EE}\| \geq 15$ V	V_{ICM}	V_{CC}, V_{EE} ±15	Vdc
Offset Null to V_{EE} Voltage	$V_{off}{-}V_{EE}$	±0.5	Vdc
Programming Current	I_{set}	500	μA
Programming Voltage (Voltage from I_{set} Terminal to Ground)	V_{set}	(V_{CC} −2.0 V) to V_{CC}	Vdc
Output Short Circuit Duration (Note 1)	t_{SC}	Indefinite	sec
Operating Temperature Range	T_A	0 to +70	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C
Junction Temperature	T_J	150	°C

NOTE 1. May be to ground or either supply voltage. Rating applies up to a case temperature of +125°C or ambient temperature of +70°C and $I_{set} \leq 30$ μA.

Representative Schematic Diagram
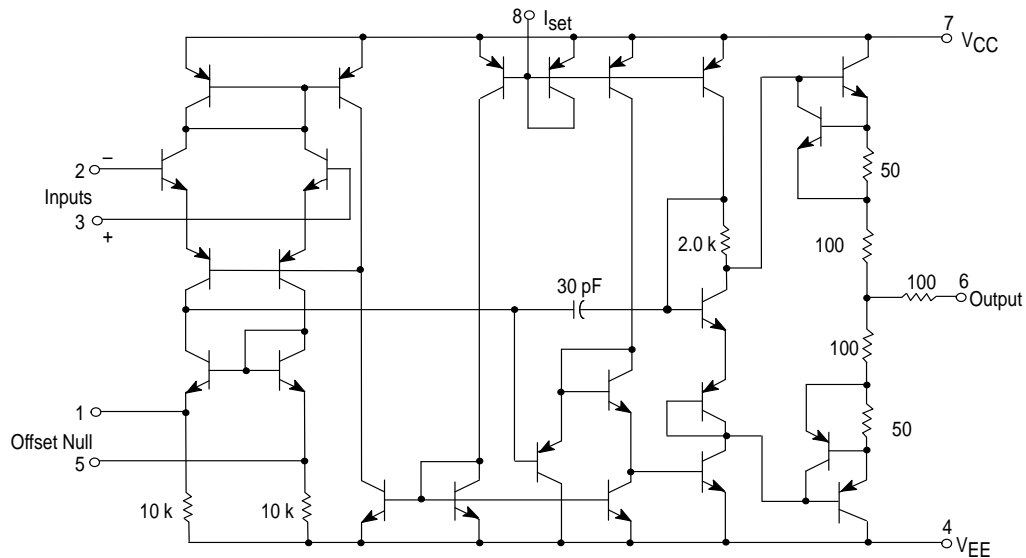
Voltage Offset Null Circuit
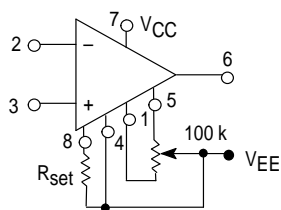
Transient Response Test Circuit

Pins not shown are not connected.

ELECTRICAL CHARACTERISTICS (V_{CC} = +3.0 V, V_{EE} = −3.0 V, I_{set} = 1.5 µA, T_A = +25°C, unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Input Offset Voltage ($R_S \leq 10$ kΩ) $\quad T_A$ = +25°C $\quad T_{low}^* \leq T_A \leq T_{high}^*$	V_{IO}	 − −	 2.0 −	 6.0 7.5	mV
Offset Voltage Adjustment Range	V_{IOR}	−	9.0	−	mV
Input Offset Current $\quad T_A$ = +25°C $\quad T_A = T_{high}$ $\quad T_A = T_{low}$	I_{IO}	 − − −	 0.7 − −	 6.0 6.0 10	nA
Input Bias Current $\quad T_A$ = +25°C $\quad T_A = T_{high}$ $\quad T_A = T_{low}$	I_{IB}	 − − −	 2.0 − −	 10 10 20	nA
Input Resistance	r_i	−	50	−	MΩ
Input Capacitance	c_i	−	2.0	−	pF
Input Voltage Range $\quad T_{low} \leq T_A \leq T_{high}$	V_{ID}	 +1.0	 −	 −	V
Large Signal Voltage Gain $\quad R_L \geq 75$ kΩ, $V_O = \pm1.0$ V, T_A = +25°C $\quad R_L \geq 75$ kΩ, $V_O = \pm1.0$ V, $T_{low} \leq T_A \leq T_{high}$	A_{VOL}	 25 k 25 k	 200 k −	 − −	V/V
Output Voltage Swing $\quad R_L \geq 75$ kΩ, $T_{low} \leq T_A \leq T_{high}$	V_O	 ±2.0	 ±2.4	 −	V
Output Resistance	r_o	−	5.0	−	kΩ
Output Short Circuit Current	I_{SC}	−	3.0	−	mA
Common Mode Rejection $\quad R_S \leq 10$ kΩ, $T_{low} \leq T_A \leq T_{high}$	CMR	 70	 86	 −	dB
Supply Voltage Rejection Ratio $\quad R_S \leq 10$ kΩ, $T_{low} \leq T_A \leq T_{high}$	PSRR	 −	 25	 200	µV/V
Supply Current $\quad T_A$ = +25°C $\quad T_{low} \leq T_A \leq T_{high}$	I_{CC}, I_{EE}	 − −	 13 −	 20 25	µA
Power Dissipation $\quad T_A$ = +25°C $\quad T_{low} \leq T_A \leq T_{high}$	P_D	 − −	 78 −	 120 150	µW
Transient Response (Unity Gain) $\quad V_{in}$ = 20 mV, $R_L \geq 5.0$ kΩ, C_L = 100 pF $\quad\quad$ Rise Time $\quad\quad$ Overshoot	 t_{TLH} os	 − −	 3.0 0	 − −	 µs %
Slew Rate ($R_L \geq 5.0$ kΩ)	S_R	−	0.03	−	V/µs

ELECTRICAL CHARACTERISTICS (V_{CC} = +3.0 V, V_{EE} = −3.0 V, I_{set} = 15 µA, T_A = +25°C, unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit
Input Offset Voltage ($R_S \leq$ 10 kΩ) T_A = +25°C $T_{low}^* \leq T_A \leq T_{high}^*$	V_{IO}	– –	2.0 –	6.0 7.5	mV
Offset Voltage Adjustment Range	V_{IOR}	–	18	–	mV
Input Offset Current T_A = +25°C $T_A = T_{high}$ $T_A = T_{low}$	I_{IO}	– – –	2.0 – –	25 25 40	nA
Input Bias Current T_A = +25°C $T_A = T_{high}$ $T_A = T_{low}$	I_{IB}	– – –	15 – –	50 50 100	nA
Input Resistance	r_i	–	5.0	–	MΩ
Input Capacitance	c_i	–	2.0	–	pF
Input Voltage Range $T_{low} \leq T_A \leq T_{high}$	V_{ID}	±1.0	–	–	V
Large Signal Voltage Gain $R_L \geq$ 5.0 kΩ, V_O = ±1.0 V, T_A = +25°C $R_L \geq$ 5.0 kΩ, V_O = ±1.0 V, $T_{low} \leq T_A \leq T_{high}$	A_{VOL}	25 k 25 k	200 k –	– –	V/V
Output Voltage Swing $R_L \geq$ 5.0 kΩ, $T_{low} \leq T_A \leq T_{high}$	V_O	±2.0	±2.1	–	V
Output Resistance	r_o	–	1.0	–	kΩ
Output Short Circuit Current	I_{SC}	–	5.0	–	mA
Common Mode Rejection $R_S \leq$ 10 kΩ, $T_{low} \leq T_A \leq T_{high}$	CMR	70	86	–	dB
Supply Voltage Rejection Ratio $R_S \leq$ 10 kΩ, $T_{low} \leq T_A \leq T_{high}$	PSRR	–	25	200	µV/V
Supply Current T_A = +25°C $T_{low} \leq T_A \leq T_{high}$	I_{CC}, I_{EE}	– –	130 –	170 180	µA
Power Dissipation T_A = +25°C $T_{low} \leq T_A \leq T_{high}$	P_D	– –	780 –	1020 1080	µW

Transient Response (Unity Gain)
V_{in} = 20 mV, $R_L \geq$ 5.0 kΩ, C_L = 100 pF
    Rise Time
    Overshoot
	
	t_{TLH}
	os
		
		–
		–
			
			0.6
			5.0
				
				–
				–
					
					µs
					%

Slew Rate ($R_L \geq$ 5.0 kΩ)	S_R	–	0.35	–	V/µs

ELECTRICAL CHARACTERISTICS (V_{CC} = +15 V, V_{EE} = −15 V, I_{set} = 1.5 μA, T_A = +25°C, unless otherwise noted.*)

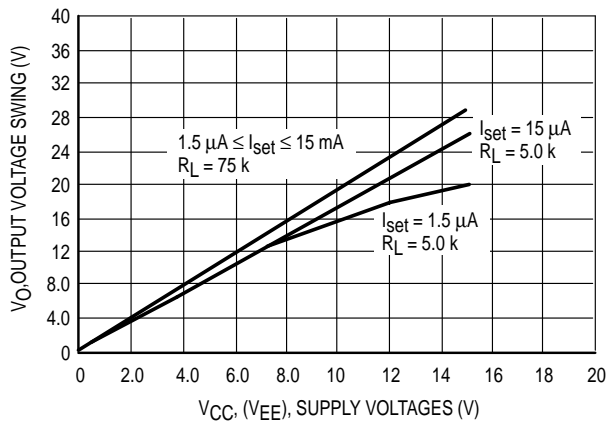| Characteristic	Symbol	Min	Typ	Max	Unit
Input Offset Voltage ($R_S \leq$ 10 kΩ) T_A = +25°C $T_{low}^* \leq T_A \leq T_{high}^*$	V_{IO}	– –	2.0 –	6.0 7.5	mV
Offset Voltage Adjustment Range	V_{IOR}	–	9.0	–	mV
Input Offset Current T_A = +25°C T_A = T_{high} T_A = T_{low}	I_{IO}	– – –	0.7 – –	6.0 6.0 10	nA
Input Bias Current T_A = +25°C T_A = T_{high} T_A = T_{low}	I_{IB}	– – –	2.0 – –	10 10 20	nA
Input Resistance	r_i	–	50	–	MΩ
Input Capacitance	c_i	–	2.0	–	pF
Input Voltage Range $T_{low} \leq T_A \leq T_{high}$	V_{ID}	±10	–	–	V
Large Signal Voltage Gain $R_L \geq$ 75 kΩ, V_O = ±10 V, T_A = +25°C $R_L \geq$ 75 kΩ, V_O = ±10 V, $T_{low} \leq T_A \leq T_{high}$	A_{VOL}	50 k 50 k	400 k –	– –	V/V
Output Voltage Swing $R_L \geq$ 75 kΩ, T_A = +25°C $R_L \geq$ 75 kΩ, $T_{low} \leq T_A \leq T_{high}$	V_O	±12 ±10	±14 –	– –	V
Output Resistance	r_o	–	5.0	–	kΩ
Output Short Circuit Current	I_{SC}	–	3.0	–	mA
Common Mode Rejection $R_S \leq$ 10 kΩ, $T_{low} \leq T_A \leq T_{high}$	CMR	70	90	–	dB
Supply Voltage Rejection Ratio $R_S \leq$ 10 kΩ, $T_{low} \leq T_A \leq T_{high}$	PSRR	–	25	200	μV/V
Supply Current T_A = +25°C $T_{low} \leq T_A \leq T_{high}$	I_{CC}, I_{EE}	– –	20 –	30 35	μA
Power Dissipation T_A = +25°C $T_{low} \leq T_A \leq T_{high}$	P_D	– –	780 –	0.9 1.05	mW
Transient Response (Unity Gain) V_{in} = 20 mV, $R_L \geq$ 5.0 kΩ, C_L = 100 pF Rise Time Overshoot	 t_{TLH} os	 – –	 1.6 0	 – –	 μs %
Slew Rate ($R_L \geq$ 5.0 kΩ)	S_R	–	0.1	–	V/μs

ELECTRICAL CHARACTERISTICS $(V_{CC} = +15$ V, $V_{EE} = -15$ V, $I_{set} = 15$ μA, $T_A = +25°C$, unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit

Input Offset Voltage ($R_S \leq 10$ kΩ)
  $T_A = +25°C$
  $T_{low}* \leq T_A \leq T_{high}*$
	V_{IO}	–
		–
			2.0
			–
				6.0
				7.5
					mV

Offset Voltage Adjustment Range	V_{IOR}	–	18	–	mV

Input Offset Current
  $T_A = +25°C$
  $T_A = T_{high}$
  $T_A = T_{low}$
	I_{IO}	–
		–
		–
			2.0
			–
			–
				25
				25
				40
					nA

Input Bias Current
  $T_A = +25°C$
  $T_A = T_{high}$
  $T_A = T_{low}$
	I_{IB}	–
		–
		–
			15
			–
			–
				50
				50
				100
					nA

Input Resistance	r_i	–	5.0	–	MΩ
Input Capacitance	c_i	–	2.0	–	pF
Input Voltage Range $T_{low} \leq T_A \leq T_{high}$	V_{ID}	± 10	–	–	V

Large Signal Voltage Gain
  $R_L \geq 5.0$ kΩ, $V_O = \pm 10$ V, $T_A = +25°C$
  $R_L \geq 75$ kΩ, $V_O = \pm 10$ V, $T_{low} \leq T_A \leq T_{high}$
	A_{VOL}	50 k
		50 k
			400 k
			–
				–
				–
					V/V

Output Voltage Swing
  $R_L \geq 5.0$ kΩ, $T_A = +25°C$
  $R_L \geq 75$ kΩ, $T_{low} \leq T_A \leq T_{high}$
	V_O	± 10
		± 10
			± 13
			–
				–
				–
					V

Output Resistance	r_o	–	1.0	–	kΩ
Output Short Circuit Current	I_{SC}	–	12	–	mA
Common Mode Rejection $R_S \leq 10$ kΩ, $T_{low} \leq T_A \leq T_{high}$	CMR	70	90	–	dB
Supply Voltage Rejection Ratio $R_S \leq 10$ kΩ, $T_{low} \leq T_A \leq T_{high}$	PSRR	–	25	200	μV/V

Supply Current
  $T_A = +25°C$
  $T_{low} \leq T_A \leq T_{high}$
	I_{CC}, I_{EE}	–
		–
			160
			–
				190
				200
					μA

Power Dissipation
  $T_A = +25°C$
  $T_{low} \leq T_A \leq T_{high}$
	P_D	–
		–
			–
			–
				5.7
				6.0
					μW

Transient Response (Unity Gain)
  $V_{in} = 20$ mV, $R_L \geq 5.0$ kΩ, $C_L = 100$ pF
    Rise Time
    Overshoot
	
	t_{TLH}
	os
		
		–
		–
			
			0.35
			10
				
				–
				–
					
					μs
					%

Slew Rate ($R_L \geq 5.0$ kΩ)	S_R	–	0.8	–	V/μs

Figure 1. Set Current versus Set Resistor
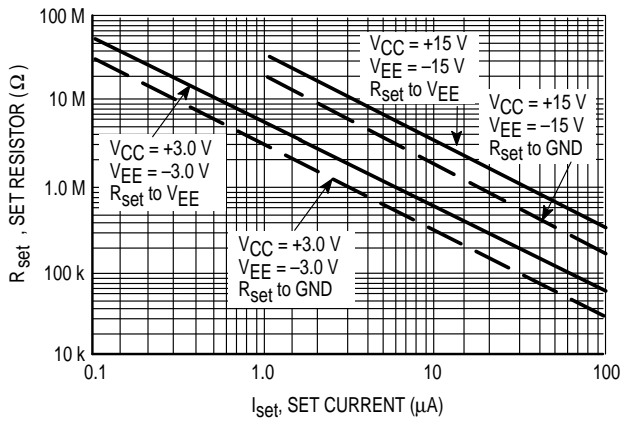
Figure 2. Positive Standby Supply Current versus Set Current
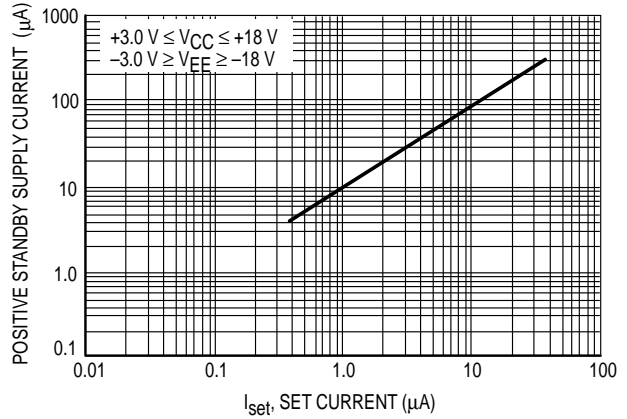
Figure 3. Open Loop Gain versus Set Current
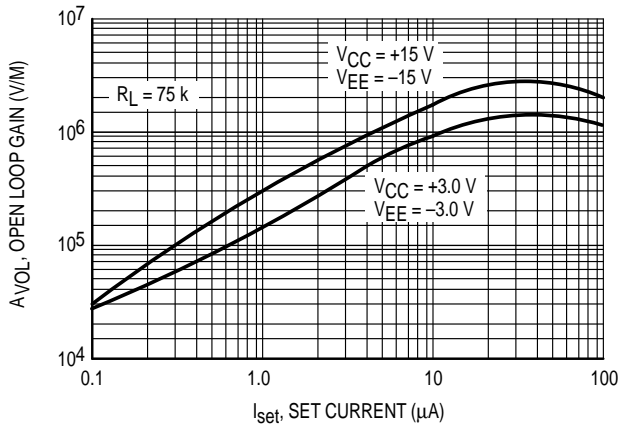
Figure 4. Input Bias Current versus Set Current
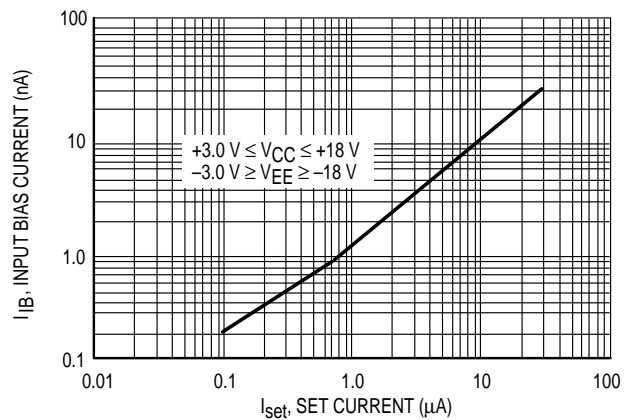
Figure 5. Input Bias Current versus Ambient Temperature
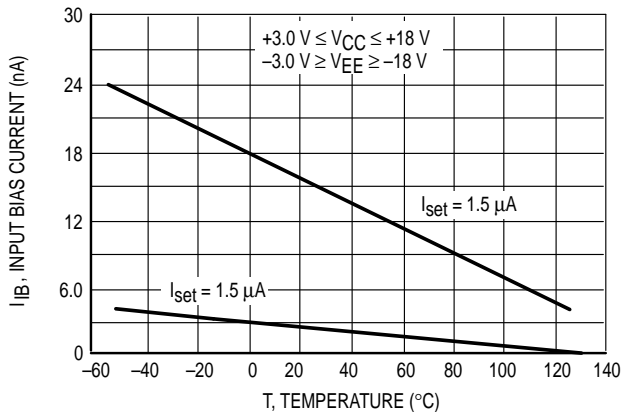
Figure 6. Gain Bandwidth Product versus Set Current
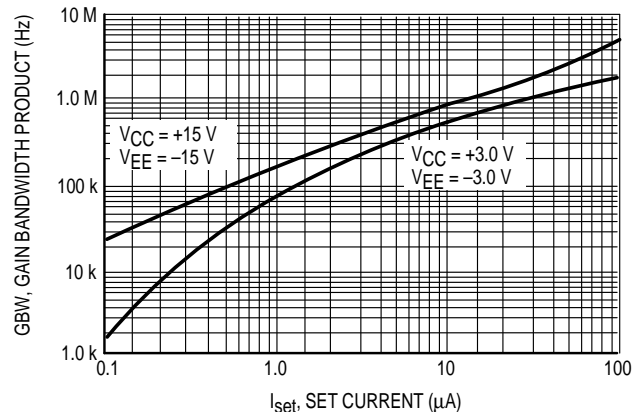
Figure 7. Output Voltage Swing versus Load Resistance

$V_{CC} = +15$ V
$V_{EE} = -15$ V
$I_{set} = 15$ μA

$V_{CC} = +15$ V
$V_{EE} = -15$ V
$I_{set} = 1.5$ μA

$V_{CC} = +3.0$ V
$V_{EE} = -3.0$ V
1.5 μA $\leq I_{set} \leq 15$ μA

$V_{O(pp)}$, PEAK-TO-PEAK OUTPUT VOLTAGE SWING (V)

R_L, LOAD RESISTANCE (Ω)
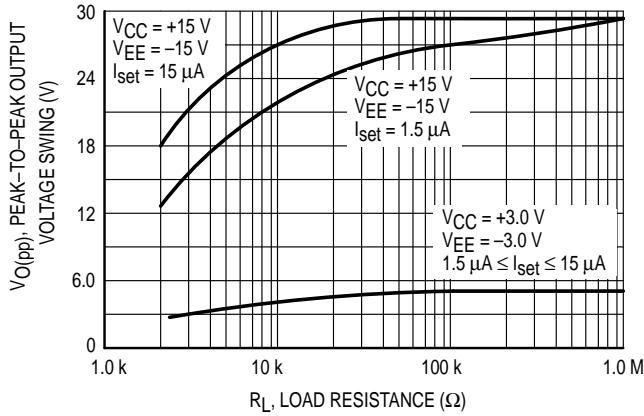
Figure 8. Supply Current versus Ambient Temperature

$I_{set} = 1.5$ μA
$V_{CC} = +15$ V
$V_{EE} = -15$ V

$I_{set} = 15$ μA
$V_{CC} = +3.0$ V
$V_{EE} = -3.0$ V

$I_{set} = 1.5$ μA
$V_{CC} = +3.0$ V
$V_{EE} = -3.0$ V

$I_{set} = 1.5$ μA
$V_{CC} = +15$ V
$V_{EE} = -15$ V

I_S, SUPPLY CURRENT (μA)

T, AMBIENT TEMPERATURE (°C)
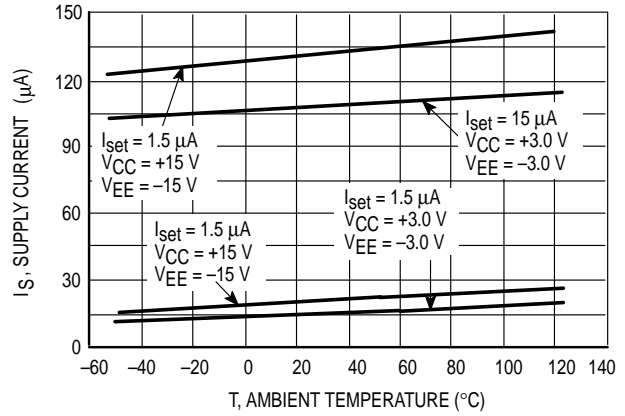
Figure 9. Output Voltage Swing versus Supply Voltage

1.5 μA $\leq I_{set} \leq 15$ mA
$R_L = 75$ k

$I_{set} = 15$ μA
$R_L = 5.0$ k

$I_{set} = 1.5$ μA
$R_L = 5.0$ k

V_O, OUTPUT VOLTAGE SWING (V)

V_{CC}, (V_{EE}), SUPPLY VOLTAGES (V)

Figure 10. Slew Rate versus Set Current

$V_{CC} = +15$ V
$V_{EE} = -15$ V

$V_{CC} = +3.0$ V
$V_{EE} = -3.0$ V

SR, SLEW RATE (Vμs)

I_{set}, SET CURRENT (μA)
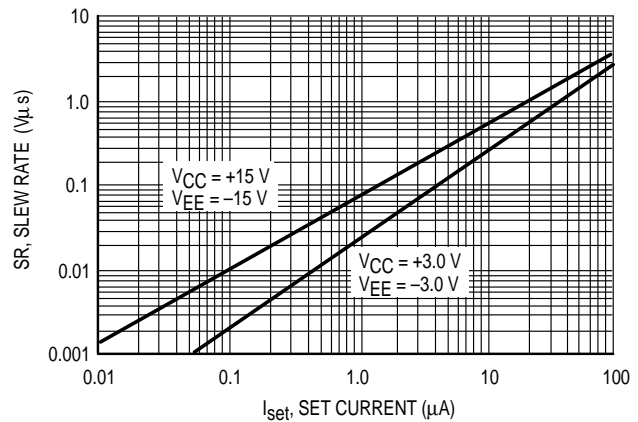
Figure 11. Input Noise Voltage versus Set Current

$f = 1.0$ kHz
$\Delta 1 = $ Hz
$+3.0$ V $\leq V_{CC} \leq +18$ V
-3.0 V $\geq V_{EE} \geq -18$ V

V(RMS), MEAN SQUARE VOLTAGE(V^2/Hz)

I_{set}, SET CURRENT (μA)
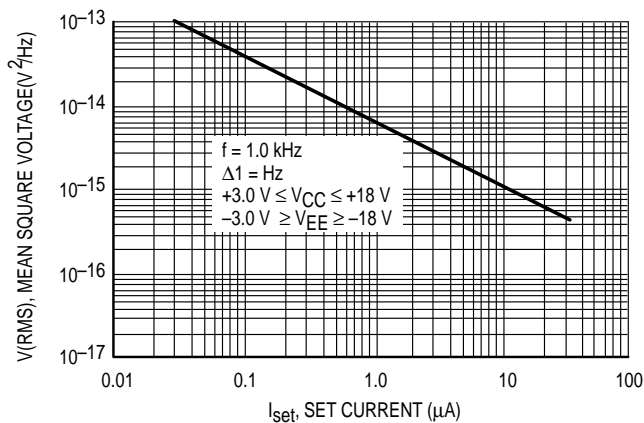
Figure 12. Optimum Source Resistance for Minimum Noise versus Set Current

OPTIMUM SOURCE RESISTANCE (MΩ)

I_{set}, SET CURRENT (μA)
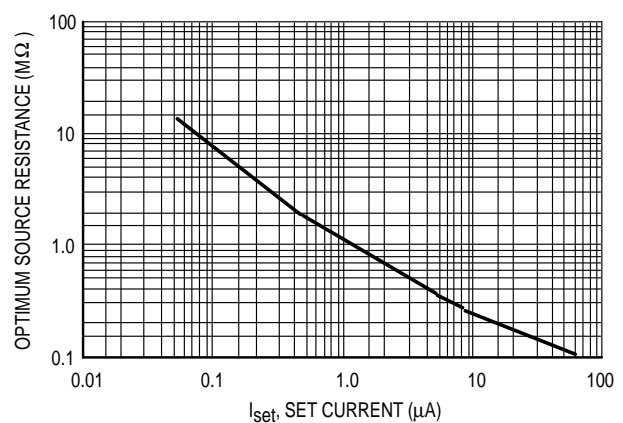
Figure 13. Wien Bridge Oscillator

22 k

200 k

+15 V

10 k

2

7

−

HT8776

6

V_O

3

+

8

4

R_{set}

−15 V

C   R   R   C
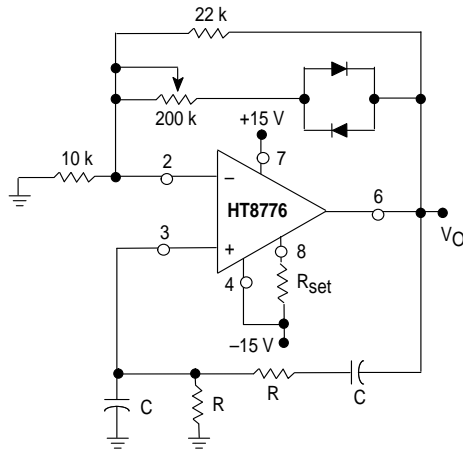
$$f_O = \frac{1}{2\pi\,RC} \quad \text{(for } f_O = 1.0 \text{ kHz)}$$

R = 16 kΩ
C = 0.01 μF

Figure 14. Multiple Feedback Bandpass Filter

V_{CC}

C   C

R_5

V_{in} R_1

2

7

−

R_2

HT8776

6

V_O

3

+

8

4

R_{set}

V_{EE}
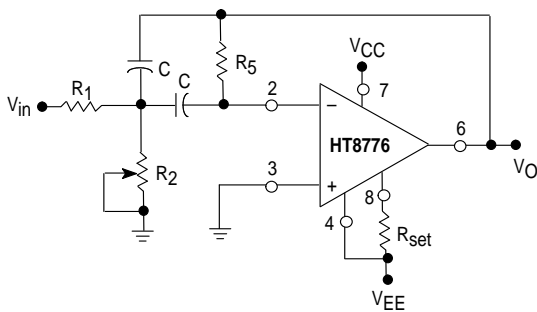
For a given:
  fo = center frequency
  A (fo) = Gain at center frequency
  Q = quality factor
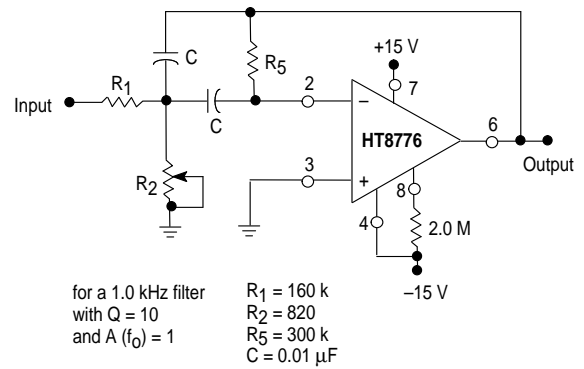
Choose a value for C, then

$$R_5 = \frac{Q}{\pi f_O C}$$

$$R_1 = \frac{R5}{2A\,(f_O)}$$

$$R_2 = \frac{R1,R5}{4Q^2\,R1{-}R5}$$

To obtain less than 10% error from the operational amplifier:

$$\frac{Q_O\,f_O}{GBW} \leq 0.1$$

where f_O and GBW are expressed in Hz. GBW is available from Figure 6 as a function of Set Current, I_{set}.
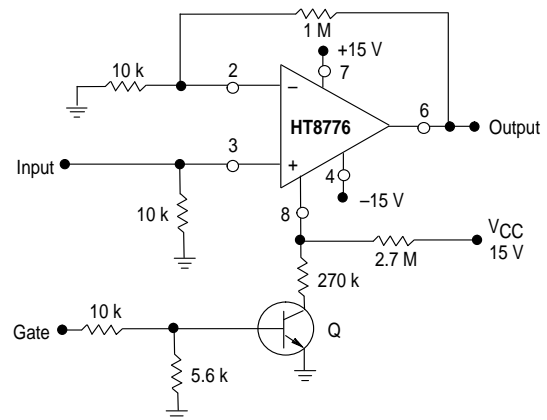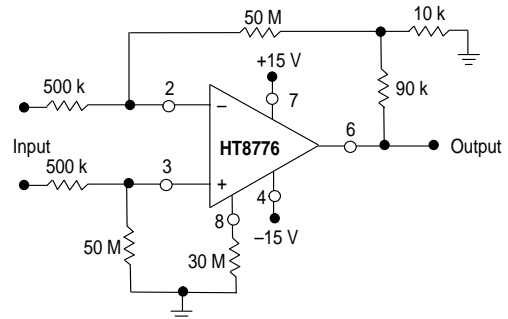
Figure 15. Multiple Feedback Bandpass Filter (1.0 kHz)

C R_5

+15 V

Input R_1

2

7

−

C

R_2

HT8776

6

Output
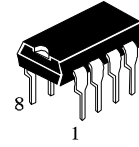
3

+

8

4

2.0 M

−15 V

for a 1.0 kHz filter
with Q = 10
and A (f_O) = 1

R_1 = 160 k
R_2 = 820
R_5 = 300 k
C = 0.01 μF

Figure 16. Gated Amplifier

1 M

10 k

+15 V

2

7

−

HT8776

6

Output

Input

3

+

4

−15 V

10 k

8

V_{CC}
15 V

2.7 M

270 k

Gate   10 k

Q

5.6 k

Figure 17. High Input Impedance Amplifier

50 M

10 k

+15 V

500 k

2

7

−

90 k

Input

500 k

HT8776

6

Output

3

+

4

8

−15 V

50 M

30 M

(DIP8)

	Dimension, mm	
Symbol	**MIN**	**MAX**
A	8.51	10.16
B	6.1	7.11
C		5.33
D	0.36	0.56
F	1.14	1.78
G	2.54	
H	7.62	
J	0°	10°
K	2.92	3.81
L	7.62	8.26
M	0.2	0.36
N	0.38	
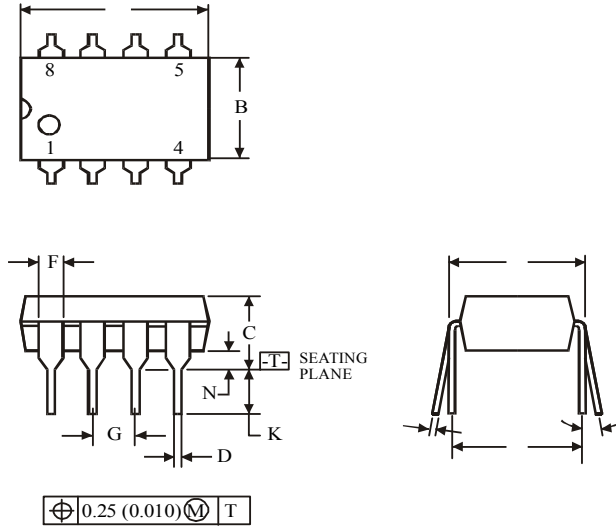
NOTES:

1. Dimensions "A", "B" do not include mold flash or protrusions.

   Maximum mold flash or protrusions 0.25 mm (0.010) per side.

(SOP8)

	Dimension, mm	
Symbol	**MIN**	**MAX**
A	4.8	5
B	3.8	4
C	1.35	1.75
D	0.33	0.51
F	0.4	1.27
G	1.27	
H	5.72	
J	0°	8°
K	0.1	0.25
M	0.19	0.25
P	5.8	6.2
R	0.25	0.5
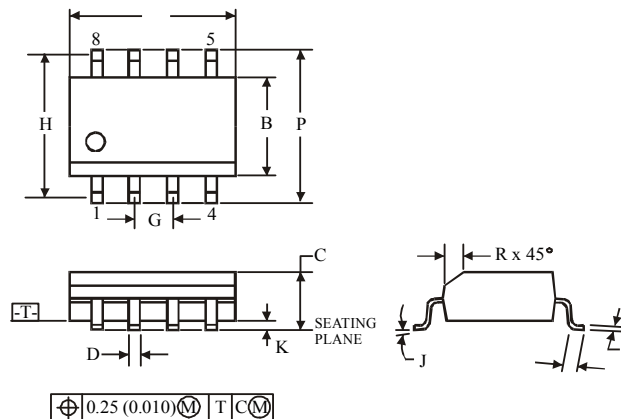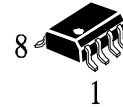
NOTES:

1. Dimensions A and B do not include mold flash or protrusion.

2. Maximum mold flash or protrusion 0.15 mm (0.006) per side
   for A; for B‑0.25 mm (0.010) per side.

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