MOTOROLA

MC1776C

Micropower Programmable Operational Amplifier

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

PROGRAMMABLE OPERATIONAL AMPLIFIER

SEMICONDUCTOR
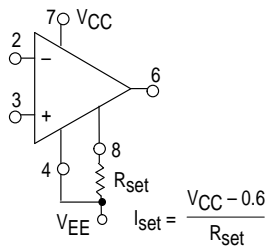TECHNICAL DATA
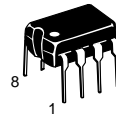
P1 SUFFIX
PLASTIC PACKAGE
CASE 626

D SUFFIX
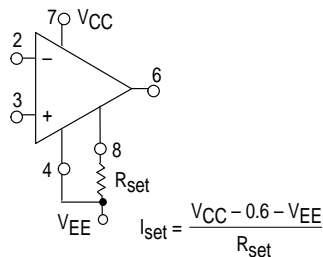PLASTIC PACKAGE
CASE 751
(SO–8)

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
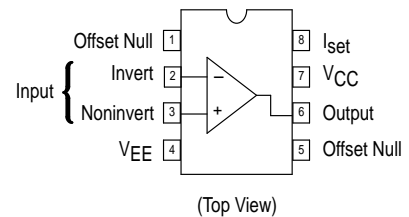
FET Current Source
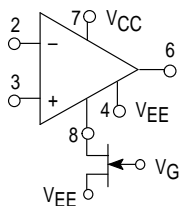
Bipolar Current Source
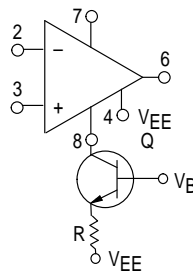
Pins not shown are not connected.

PIN CONNECTIONS

(Top View)

ORDERING INFORMATION

Device	Operating Temperature Range	Package
MC1776CD	$T_A = 0°$ to +70°C	SO–8
MC1776CP1		Plastic DIP

Rev 5

MC1776C

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
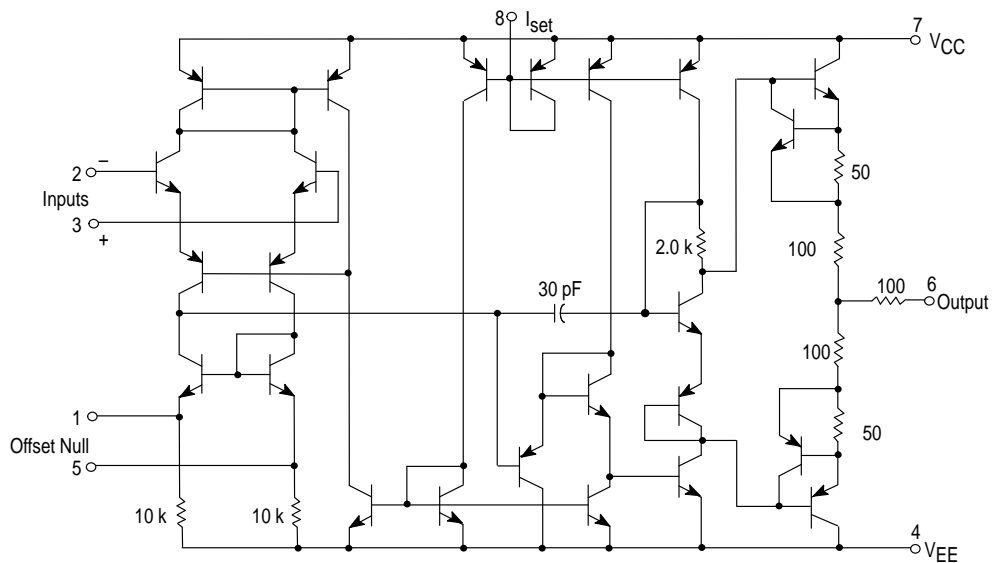
Voltage Offset Null Circuit
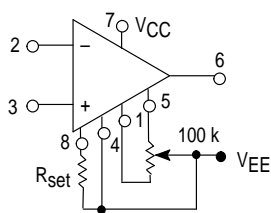
Transient Response Test Circuit

Pins not shown are not connected.

MC1776C

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) 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}	 +1.0	 −	 −	V
Large Signal Voltage Gain $R_L \geq 75$ kΩ, $V_O = \pm1.0$ V, T_A = +25°C $R_L \geq 75$ 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 $R_L \geq 75$ 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 $R_S \leq 10$ 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}	 − −	 13 −	 20 25	μA
Power Dissipation T_A = +25°C $T_{low} \leq T_A \leq T_{high}$	P_D	 − −	 78 −	 120 150	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	 − −	 3.0 0	 − −	 μs %
Slew Rate ($R_L \geq 5.0$ kΩ)	S_R	−	0.03	−	V/μs

*T_{low} = 0°C T_{high} = +70°C

MC1776C

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 ≤ 10 kΩ) T_A = +25°C T_{low}* ≤ T_A ≤ 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} ≤ T_A ≤ T_{high}	V_{ID}	 ±1.0	 −	 −	V
Large Signal Voltage Gain R_L ≥ 5.0 kΩ, V_O = ±1.0 V, T_A = +25°C R_L ≥ 5.0 kΩ, V_O = ±1.0 V, T_{low} ≤ T_A ≤ T_{high}	A_{VOL}	 25 k 25 k	 200 k −	 − −	V/V
Output Voltage Swing R_L ≥ 5.0 kΩ, T_{low} ≤ T_A ≤ 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 ≤ 10 kΩ, T_{low} ≤ T_A ≤ T_{high}	CMR	 70	 86	 −	dB
Supply Voltage Rejection Ratio R_S ≤ 10 kΩ, T_{low} ≤ T_A ≤ T_{high}	PSRR	 −	 25	 200	μV/V
Supply Current T_A = +25°C T_{low} ≤ T_A ≤ T_{high}	I_{CC}, I_{EE}	 − −	 130 −	 170 180	μA
Power Dissipation T_A = +25°C T_{low} ≤ T_A ≤ T_{high}	P_D	 − −	 780 −	 1020 1080	μW
Transient Response (Unity Gain) V_{in} = 20 mV, R_L ≥ 5.0 kΩ, C_L = 100 pF Rise Time Overshoot	 t_{TLH} os	 − −	 0.6 5.0	 − −	 μs %
Slew Rate (R_L ≥ 5.0 kΩ)	S_R	−	0.35	−	V/μs

*T_{low} = 0°C T_{high} = +70°C

MC1776C

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

*T_{low} = 0°C T_{high} = +70°C

MC1776C

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 = ±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 $R_L \geq$ 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

*T_{low} = 0°C T_{high} = +70°C

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Figure 1. Set Current versus Set Resistor

R_{set}, SET RESISTOR (Ω) vs I_{set}, SET CURRENT (μA)

V_{CC} = +15 V
V_{EE} = −15 V
R_{set} to V_{EE}

V_{CC} = +15 V
V_{EE} = −15 V
R_{set} to GND

V_{CC} = +3.0 V
V_{EE} = −3.0 V
R_{set} to V_{EE}

V_{CC} = +3.0 V
V_{EE} = −3.0 V
R_{set} to GND
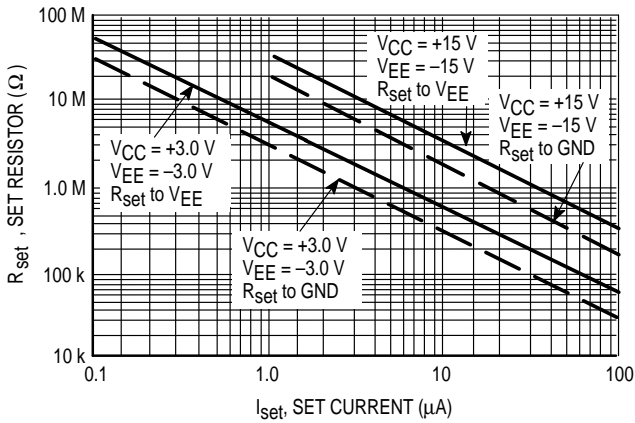
Figure 2. Positive Standby Supply Current versus Set Current

POSITIVE STANDBY SUPPLY CURRENT (μA) vs I_{set}, SET CURRENT (μA)

+3.0 V ≤ V_{CC} ≤ +18 V
−3.0 V ≥ V_{EE} ≥ −18 V
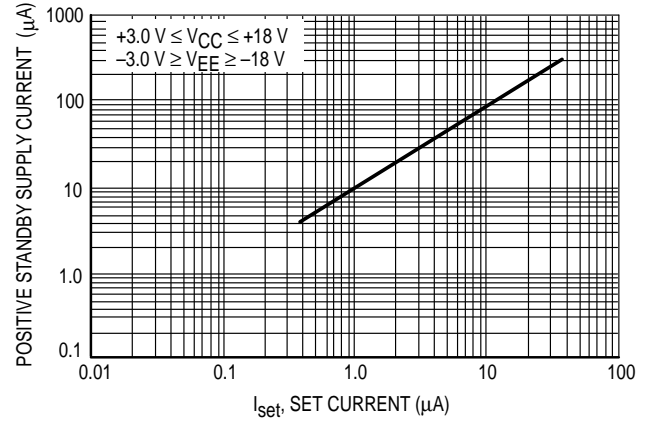
Figure 3. Open Loop Gain versus Set Current

A_{VOL}, OPEN LOOP GAIN (V/M) vs I_{set}, SET CURRENT (μA)

R_L = 75 k

V_{CC} = +15 V
V_{EE} = −15 V

V_{CC} = +3.0 V
V_{EE} = −3.0 V
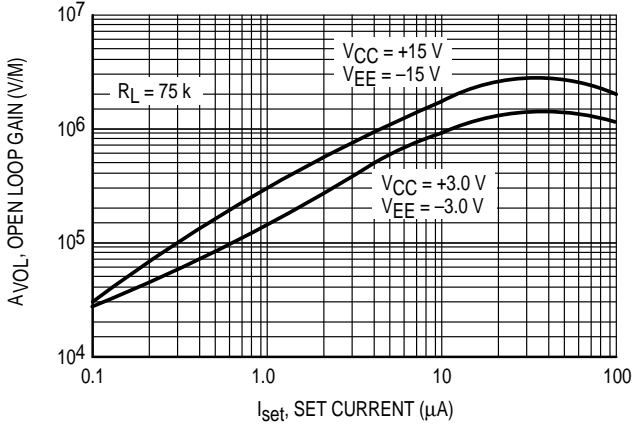
Figure 4. Input Bias Current versus Set Current

I_{IB}, INPUT BIAS CURRENT (nA) vs I_{set}, SET CURRENT (μA)

+3.0 V ≤ V_{CC} ≤ +18 V
−3.0 V ≥ V_{EE} ≥ −18 V
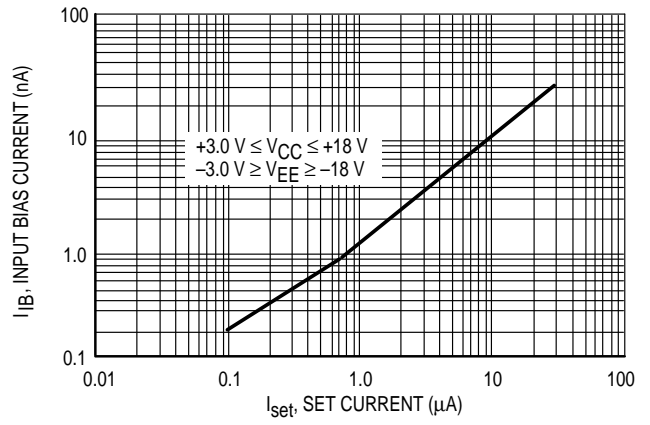
Figure 5. Input Bias Current versus Ambient Temperature

I_{IB}, INPUT BIAS CURRENT (nA) vs T, TEMPERATURE (°C)

+3.0 V ≤ V_{CC} ≤ +18 V
−3.0 V ≥ V_{EE} ≥ −18 V

I_{set} = 1.5 μA

I_{set} = 1.5 μA
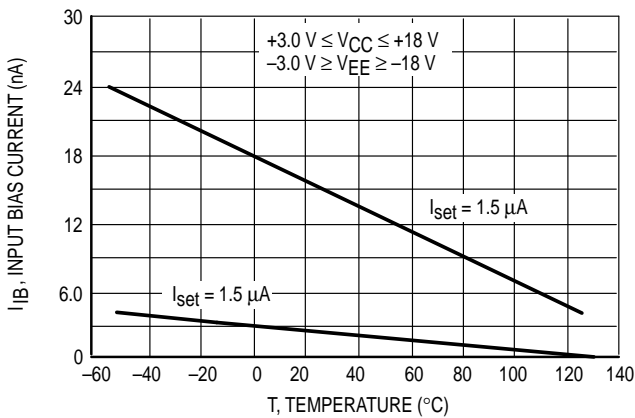
Figure 6. Gain Bandwidth Product versus Set Current

GBW, GAIN BANDWIDTH PRODUCT (Hz) vs I_{set}, SET CURRENT (μA)

V_{CC} = +15 V
V_{EE} = −15 V

V_{CC} = +3.0 V
V_{EE} = −3.0 V
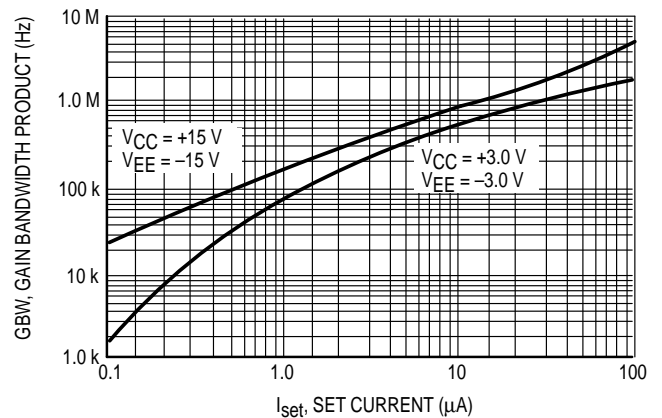
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Figure 7. Output Voltage Swing versus Load Resistance

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

R_L, LOAD RESISTANCE (Ω)

$V_{CC} = +15$ 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
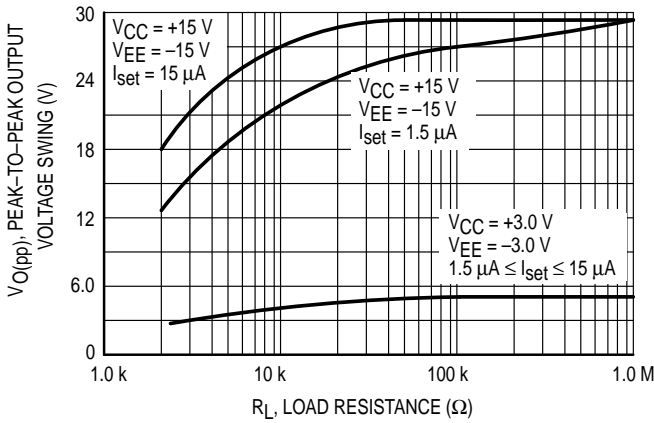
Figure 8. Supply Current versus Ambient Temperature

I_S, SUPPLY CURRENT (µA)

T, AMBIENT TEMPERATURE (°C)

$I_{set} = 1.5$ 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
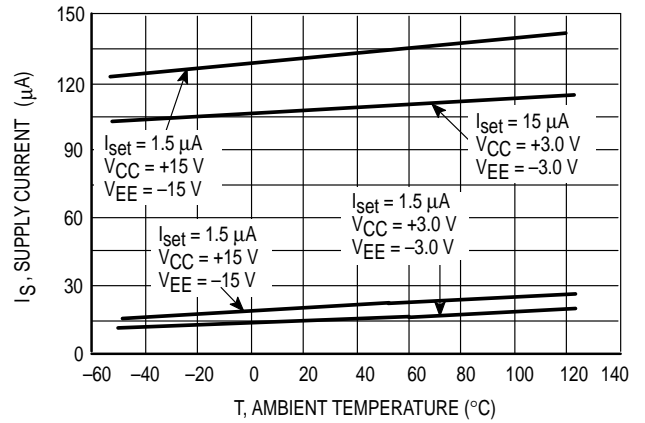
Figure 9. Output Voltage Swing versus Supply Voltage

V_O, OUTPUT VOLTAGE SWING (V)

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

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
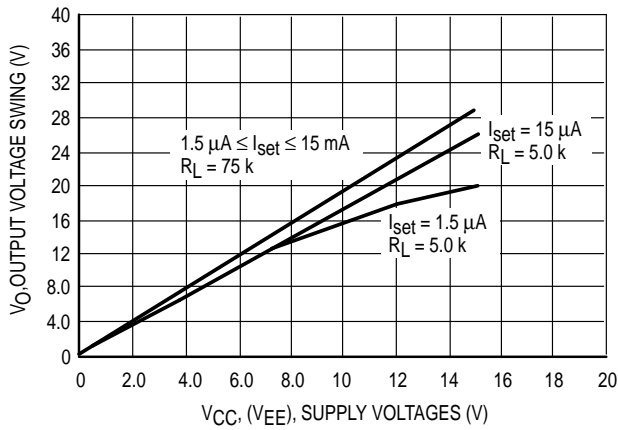
Figure 10. Slew Rate versus Set Current

SR, SLEW RATE (V/µ s)

I_{set}, SET CURRENT (µA)

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

$V_{CC} = +3.0$ V
$V_{EE} = -3.0$ V
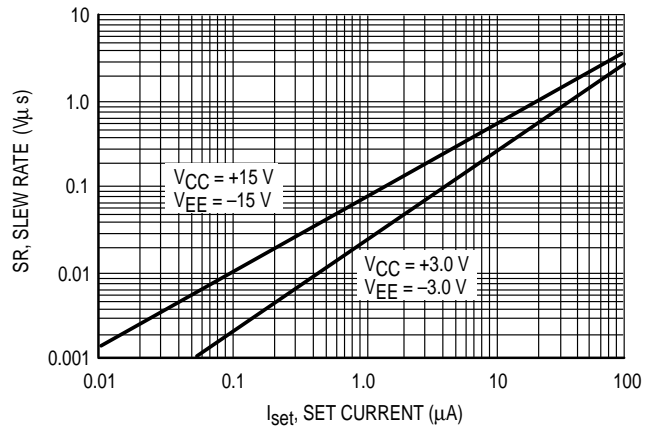
Figure 11. Input Noise Voltage versus Set Current

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

I_{set}, SET CURRENT (µA)

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
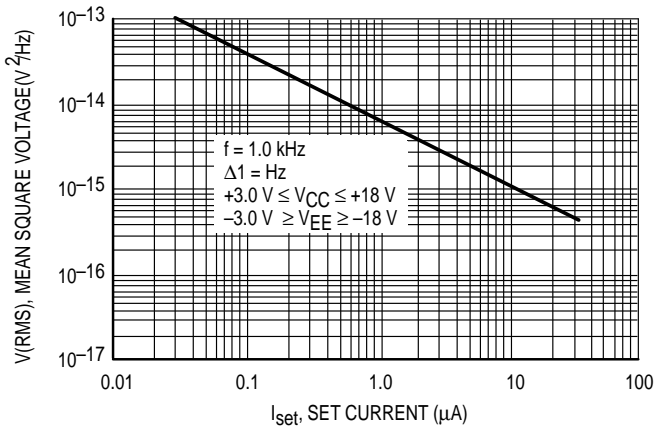
Figure 12. Optimum Source Resistance for Minimum Noise versus Set Current

OPTIMUM SOURCE RESISTANCE (MΩ)

I_{set}, SET CURRENT (µA)
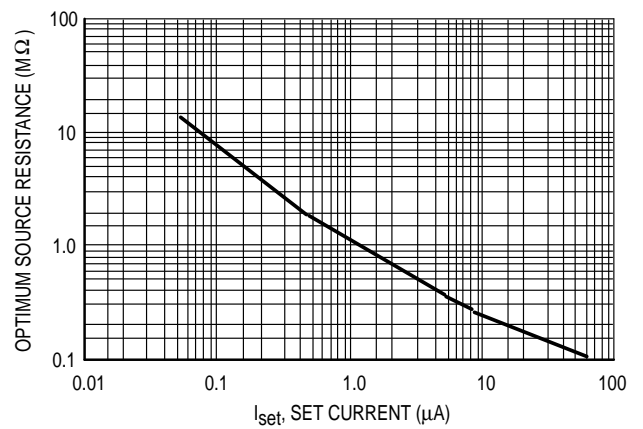
MC1776C

Figure 13. Wien Bridge Oscillator

$$f_O = \frac{1}{2\pi \, RC} \quad \text{(for } f_O = 1.0 \text{ kHz)}$$
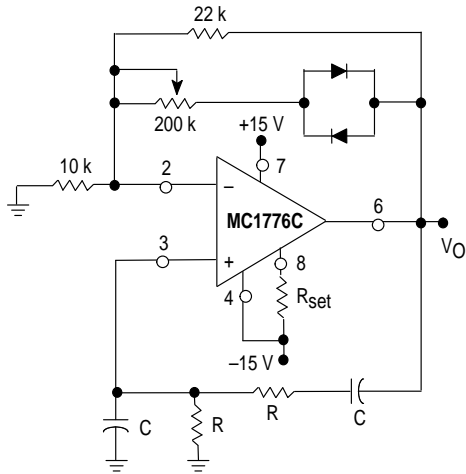
R= 16 kΩ
C = 0.01 μF

Figure 14. Multiple Feedback Bandpass Filter
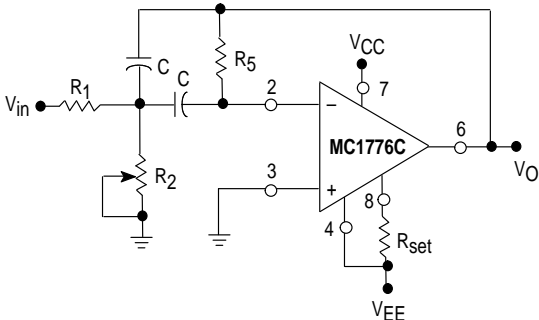
For a given:
  fo = center frequency
  A (fo) = Gain at center frequency
  Q = quality factor

Choose a value for C, then

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

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

$$R_2 = \frac{R1,R5}{4Q^2 \, R1 - R5}$$
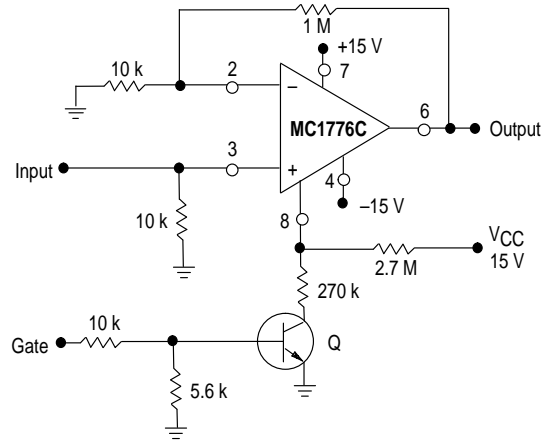
To obtain less than 10% error from the operational amplifier:

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

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)

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
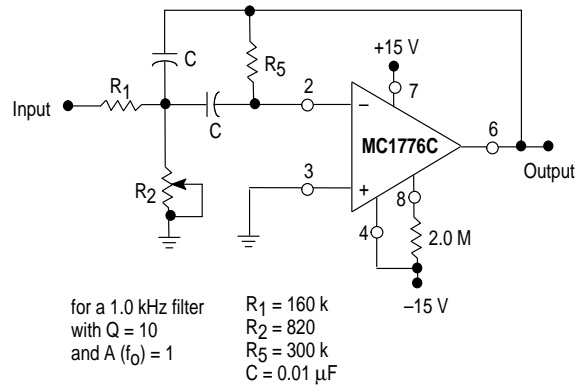
Figure 16. Gated Amplifier

Figure 17. High Input Impedance Amplifier
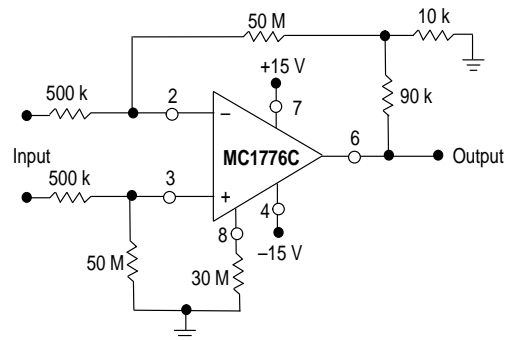
MC1776C

OUTLINE DIMENSIONS

P1 SUFFIX
PLASTIC PACKAGE
CASE 626–05
ISSUE K

NOTE 2

–T–
SEATING PLANE

⊕ | ⌀ 0.13 (0.005) Ⓜ | T | A Ⓜ | B Ⓜ |
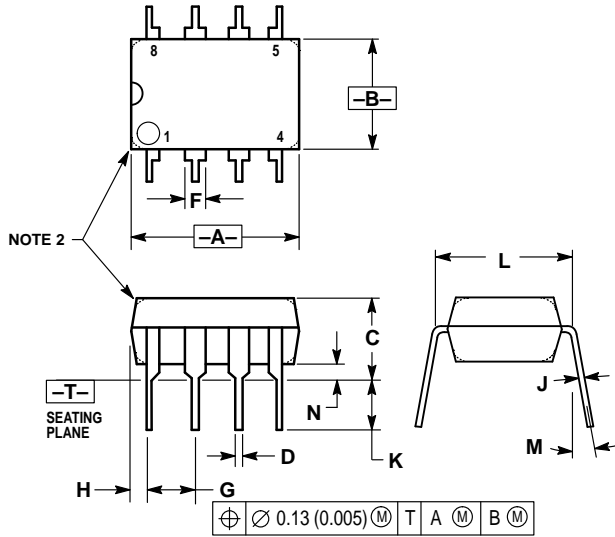
NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	—	10°	—	10°
N	0.76	1.01	0.030	0.040

D SUFFIX
PLASTIC PACKAGE
CASE 751–05
(SO–8)
ISSUE R

⊕ | 0.25 Ⓜ | B Ⓜ |

SEATING PLANE

⌓ | 0.10 |

⊕ | 0.25 Ⓜ | C | B Ⓢ | A Ⓢ |

h X 45°
θ
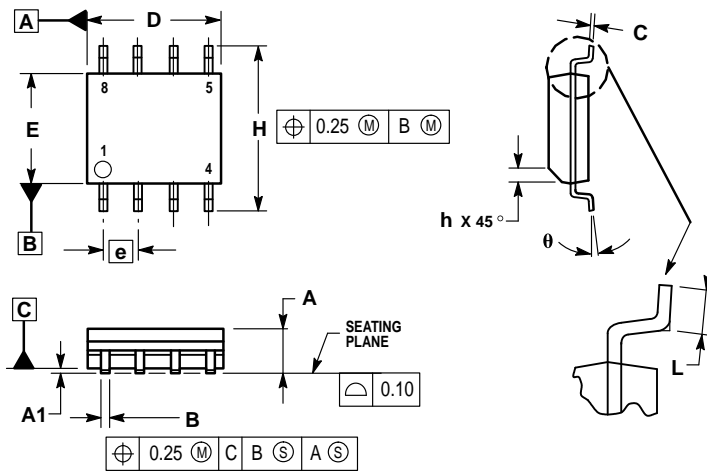
NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. DIMENSIONS ARE IN MILLIMETERS.
3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

DIM	MILLIMETERS	
	MIN	MAX
A	1.35	1.75
A1	0.10	0.25
B	0.35	0.49
C	0.18	0.25
D	4.80	5.00
E	3.80	4.00
e	1.27 BSC	
H	5.80	6.20
h	0.25	0.50
L	0.40	1.25
θ	0°	7°

MC1776C

MOTOROLA

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