MOTOROLA

MC1776
MC1776C

Specifications and Applications Information

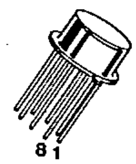
MONOLITHIC MICROPOWER PROGRAMMABLE OPERATIONAL AMPLIFIER

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.

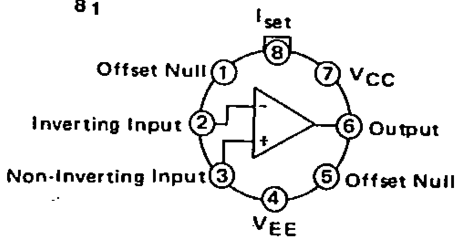
- ±1.2 V to ±18 V Operation
- Wide Programming Range
- Offset Null Capability
- No Frequency Compensation Required
- Low Input Bias Currents
- Short-Circuit Protection

PROGRAMMABLE OPERATIONAL AMPLIFIER

SILICON MONOLITHIC INTEGRATED CIRCUIT



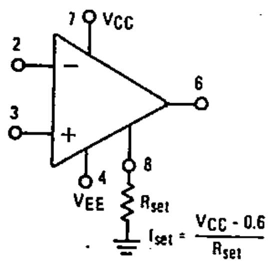
G SUFFIX
METAL PACKAGE
CASE 601-04



(Top View)

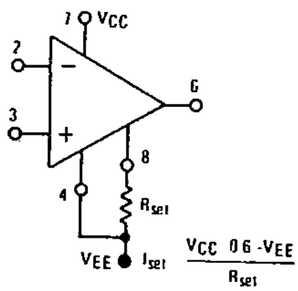
RESISTIVE PROGRAMMING (See Figure 1.)

R_{set} to GROUND



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

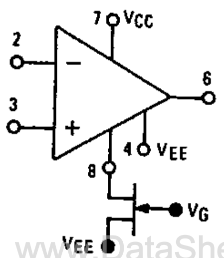
R_{set} to NEGATIVE SUPPLY
(Recommended for supply voltage less than ±6.0 V)



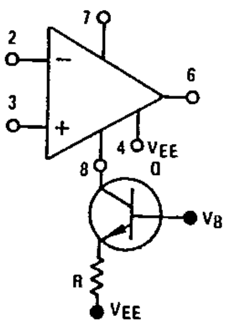
Typical R_{set} Values		
V_{CC}, V_{EE}	Iset = 1.5 μA	I_{set} = 15 μA
±1.5V	1.6 MΩ	160 kΩ
±3.0V	3.6 MΩ	360 kΩ
±6.0V	7.5 MΩ	750 kΩ
±15 V	20 MΩ	2.0 MΩ

ACTIVE PROGRAMMING

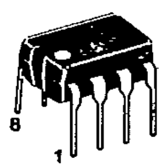
FET CURRENT SOURCE



BIPOLAR CURRENT SOURCE

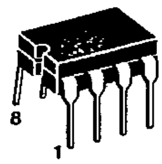


Pins not shown are not connected.

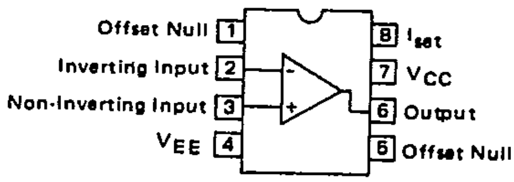


P1 SUFFIX
PLASTIC PACKAGE
CASE 626-05
(MC1776C Only)

U SUFFIX
CERAMIC PACKAGE
CASE 693-02



D SUFFIX
PLASTIC PACKAGE
CASE 751-02
SO-8



(Top View)

ORDERING INFORMATION

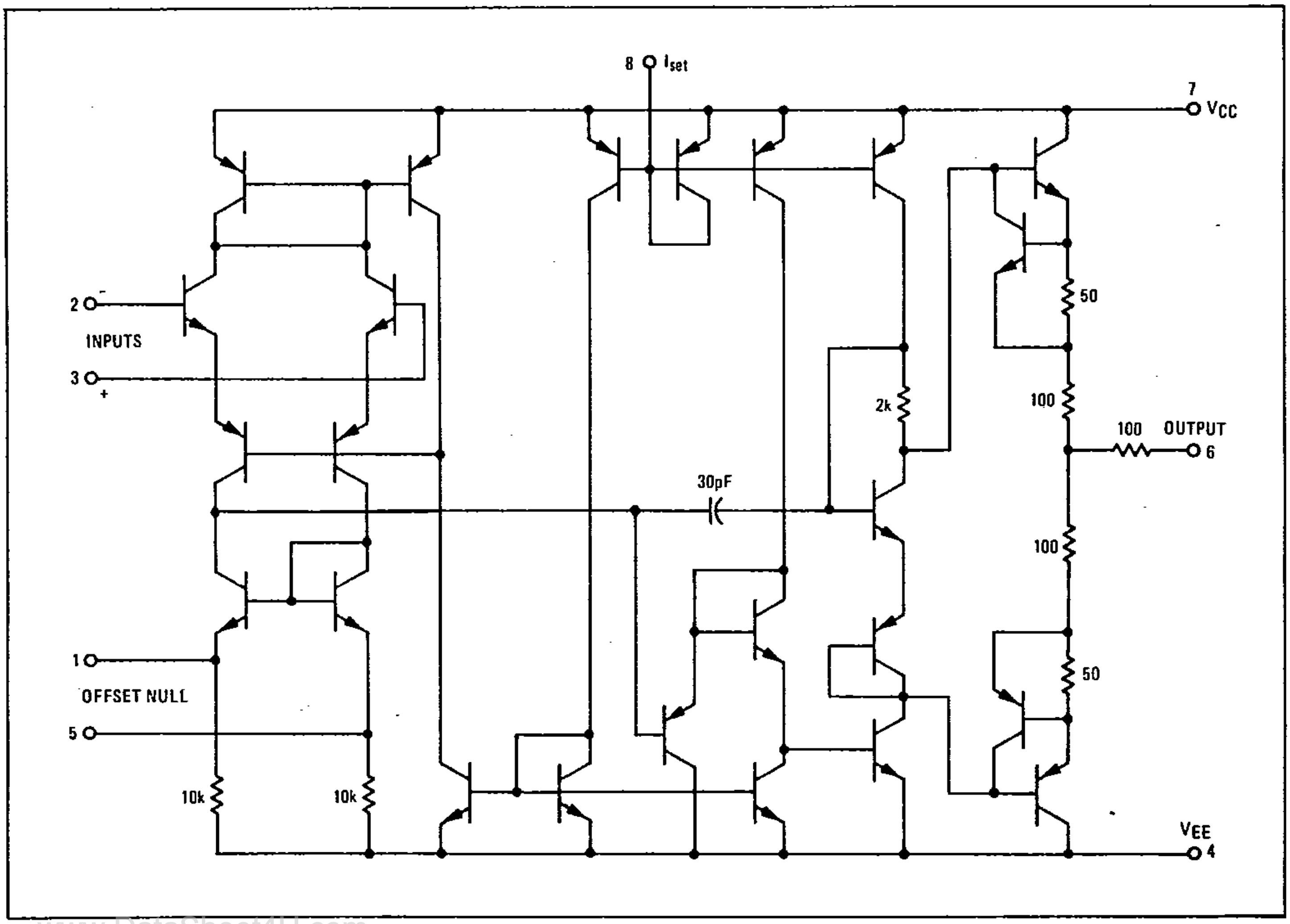
Device	Temperature Range	Package
MC1776G	−55 to +125°C	Metal Can
MC1776U		Ceramic DIP
MC1776CD	0 to +70°C	SO-8
MC1776CG		Metal Can
MC1776CP1		Plastic DIP
MC1776CU		Ceramic DIP

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*	t_s	Indefinite	s
Operating Temperature Range MC1776 MC1776C	T_A	 -55 to +125 0 to +70	°C
Storage Temperature Range Metal and Ceramic Packages Plastic Package	T_{stg}	 -65 to +150 -55 to +125	°C
Junction Temperature Metal and Ceramic Packages Plastic Package	T_J	 175 150	°C

*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.

SCHEMATIC DIAGRAM



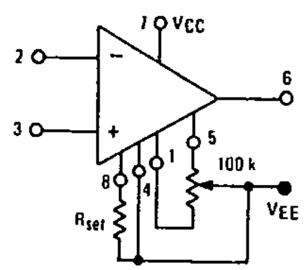
ELECTRICAL CHARACTERISTICS (V_{CC} = +3.0 V, V_{EE} = −3.0 V, I_{set} = 1.5 μA, T_A = +25°C unless otherwise noted.)

Characteristic	Symbol	MC1776			MC1776C			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage ($R_S \leq 10\ k\Omega$)	V_{IO}							mV
T_A = +25°C		–	2.0	5.0	–	2.0	6.0	
T_{low}* ≤ T_A ≤ T_{high}*		–	–	6.0	–	–	7.5	
Offset Voltage Adjustment Range	V_{IOR}	–	9.0	–	–	9.0	–	mV
Input Offset Current	I_{IO}							nA
T_A = +25°C		–	0.7	3.0	–	0.7	6.0	
T_A = T_{high}		–	–	5.0	–	–	6.0	
T_A = T_{low}		–	–	10	–	–	10	
Input Bias Current	I_{IB}							nA
T_A = +25°C		–	2.0	7.5	–	2.0	10	
T_A = T_{high}		–	–	7.5	–	–	10	
T_A = T_{low}		–	–	20	–	–	20	
Input Resistance	r_i	–	50	–	–	50	–	MΩ
Input Capacitance	c_i	–	2.0	–	–	2.0	–	pF
Input Voltage Range T_{low} ≤ T_A ≤ T_{high}	V_{ID}	±1.0	–	–	±1.0	–	–	V
Large Signal Voltage Gain	A_{VOL}							V/V
$R_L \geq 75\ k\Omega$, V_O = ±1.0 V, T_A = +25°C		50 k	200 k	–	25 k	200 k	–	
$R_L \geq 75\ k\Omega$, V_O = ±1.0 V, T_{low} ≤ T_A ≤ T_{high}		25 k	–	–	25 k	–	–	
Output Voltage Swing $R_L \geq 75\ k\Omega$, T_{low} ≤ T_A ≤ T_{high}	V_O	±2.0	±2.4	–	±2.0	±2.4	–	V
Output Resistance	r_o	–	5.0	–	–	5.0	–	kΩ
Output Short-Circuit Current	I_{os}	–	3.0	–	–	3.0	–	mA
Common-Mode Rejection Ratio $R_S \leq 10\ k\Omega$, T_{low} ≤ T_A ≤ T_{high}	CMRR	70	86	–	70	86	–	dB
Supply Voltage Rejection Ratio $R_S \leq 10\ k\Omega$, T_{low} ≤ T_A ≤ T_{high}	PSRR	–	25	150	–	25	200	μV/V
Supply Current	I_{CC}, I_{EE}							μA
T_A = +25°C		–	13	20	–	13	20	
T_{low} ≤ T_A ≤ T_{high}		–	–	25	–	–	25	
Power Dissipation	P_D							μW
T_A = +25°C		–	78	120	–	78	120	
T_{low} ≤ T_A ≤ T_{high}		–	–	150	–	–	150	
Transient Response (Unity Gain) V_{in} = 20 mV, $R_L \geq 5.0\ k\Omega$, C_L = 100 pF								
Rise Time	t_{TLH}	–	3.0	–	–	3.0	–	μs
Overshoot	OS	–	0	–	–	0	–	%
Slew Rate ($R_L \geq 5.0\ k\Omega$)	S_R	–	0.03	–	–	0.03	–	V/μs

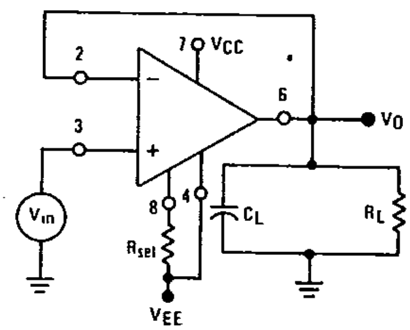
*T_{low} = −55°C for MC1776
0°C for MC1776C

T_{high} = +125°C for MC1776
+70°C for MC1776C

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} = 15 μA, T_A = +25°C unless otherwise noted.)

Characteristic	Symbol	MC1776			MC1776C			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage ($R_S \leq$ 10 kΩ)	V_{IO}							mV
T_A = +25°C		–	2.0	5.0	–	2.0	6.0	
T_{low}* ≤ T_A ≤ T_{high}*		–	–	6.0	–	–	7.5	
Offset Voltage Adjustment Range	V_{IOR}	–	18	–	–	18	–	mV
Input Offset Current	I_{IO}							nA
T_A = +25°C		–	2.0	15	–	2.0	25	
T_A = T_{high}		–	–	15	–	–	25	
T_A = T_{low}		–	–	40	–	–	40	
Input Bias Current	I_{IB}							nA
T_A = +25°C		–	15	50	–	15	50	
T_A = T_{high}		–	–	50	–	–	50	
T_A = T_{low}		–	–	120	–	–	100	
Input Resistance	r_i	–	5.0	–	–	5.0	–	MΩ
Input Capacitance	c_i	–	2.0	–	–	2.0	–	pF
Input Voltage Range	V_{ID}							V
T_{low} ≤ T_A ≤ T_{high}		±1.0	–	–	±1.0	–	–	
Large Signal Voltage Gain	A_{VOL}							V/V
R_L ≥ 5.0 kΩ, V_O = ±1.0 V, T_A = +25°C		50 k	200 k	–	25 k	200 k	–	
R_L ≥ 5.0 kΩ, V_O = ±1.0 V, T_{low} ≤ T_A ≤ T_{high}		25 k	–	–	25k	–	–	
Output Voltage Swing	V_O							V
R_L ≥ 5.0 kΩ, T_{low} ≤ T_A ≤ T_{high}		±1.9	±2.1	–	±2.0	±2.1	–	
Output Resistance	r_o	–	1.0	–	–	1.0	–	kΩ
Output Short-Circuit Current	I_{os}	–	5.0	–	–	5.0	–	mA
Common-Mode Rejection Ratio	CMRR							dB
R_S ≤ 10 kΩ, T_{low} ≤ T_A ≤ T_{high}		70	86	–	70	86	–	
Supply Voltage Rejection Ratio	PSRR							μV/V
R_S ≤ 10 kΩ, T_{low} ≤ T_A ≤ T_{high}		–	25	150	–	25	200	
Supply Current	I_{CC}, I_{EE}							μA
T_A = +25°C		–	130	160	–	130	170	
T_{low} ≤ T_A ≤ T_{high}		–	–	180	–	–	180	
Power Dissipation	P_D							μW
T_A = +25°C		–	780	960	–	780	1020	
T_{low} ≤ T_A ≤ T_{high}		–	–	1080	–	–	1080	
Transient Response (Unity Gain)								
V_{in} = 20 mV, R_L ≥ 5.0 kΩ, C_L = 100 pF								
Rise Time	t_{TLH}	–	0.6	–	–	0.6	–	μs
Overshoot	OS	–	5.0	–	–	5.0	–	%
Slew Rate (R_L ≥ 5.0 kΩ)	S_R	–	0.35	–	–	0.35	–	V/μs

*T_{low} = −55°C for MC1776
0°C for MC1776C

T_{high} = +125°C for MC1776
+70°C for 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	MC1776			MC1776C			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage ($R_S \le 10$ kΩ)	V_{IO}							mV
T_A = +25°C		–	2.0	5.0	–	2.0	6.0	
T_{low}* ≤ T_A ≤ T_{high}*		–	–	6.0	–	–	7.5	
Offset Voltage Adjustment Range	V_{IOR}	–	9.0	–	–	9.0	–	mV
Input Offset Current	I_{IO}							nA
T_A = +25°C		–	0.7	3.0	–	0.7	6.0	
$T_A = T_{high}$		–	–	5.0	–	–	6.0	
$T_A = T_{low}$		–	–	10	–	–	10	
Input Bias Current	I_{IB}							nA
T_A = +25°C		–	2.0	7.5	–	2.0	10	
$T_A = T_{high}$		–	–	7.5	–	–	10	
$T_A = T_{low}$		–	–	20	–	–	20	
Input Resistance	r_i	–	50	–	–	50	–	MΩ
Input Capacitance	c_i	–	2.0	–	–	2.0	–	pF
Input Voltage Range	V_{ID}							V
$T_{low} \le T_A \le T_{high}$		±10	–	–	±10	–	–	
Large Signal Voltage Gain	A_{VOL}							V/V
$R_L \ge 75$ kΩ, V_O = ±10 V, T_A = +25°C		200 k	400 k	–	50 k	400 k	–	
$R_L \ge 75$ kΩ, V_O = ±10 V, $T_{low} \le T_A \le T_{high}$		100 k	–	–	50 k	–	–	
Output Voltage Swing	V_O							V
$R_L \ge 75$ kΩ, T_A = +25°C		±12	±14	–	±12	±14	–	
$R_L \ge 75$ kΩ, $T_{low} \le T_A \le T_{high}$		±10	–	–	±10	–	–	
Output Resistance	r_o	–	5.0	–	–	5.0	–	kΩ
Output Short-Circuit Current	I_{os}	–	3.0	–	–	3.0	–	mA
Common-Mode Rejection Ratio	CMRR							dB
$R_S \le 10$ kΩ, $T_{low} \le T_A \le T_{high}$		70	90	–	70	90	–	
Supply Voltage Rejection Ratio	PSRR							μV/V
$R_S \le 10$ kΩ, $T_{low} \le T_A \le T_{high}$		–	25	150	–	25	200	
Supply Current	I_{CC}, I_{EE}							μA
T_A = +25°C		–	20	25	–	20	30	
$T_{low} \le T_A \le T_{high}$		–	–	30	–	–	35	
Power Dissipation	P_D							mW
T_A = +25°C		–	–	0.75	–	–	0.9	
$T_{low} \le T_A \le T_{high}$		–	–	0.9	–	–	1.05	
Transient Response (Unity Gain)								
V_{in} = 20 mV, $R_L \ge 5.0$ kΩ, C_L = 100 pF								
Rise Time	t_{TLH}	–	1.6	–	–	1.6	–	μs
Overshoot	OS	–	0	–	–	0	–	%
Slew Rate ($R_L \ge 5.0$ kΩ)	S_R	–	0.1	–	–	0.1	–	V/μs

*T_{low} = −55°C for MC1776
0°C for MC1776C

T_{high} = +125°C for MC1776
+70°C for MC1776C

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

Characteristic	Symbol	MC1776			MC1776C			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage ($R_S \leq 10$ kΩ)	V_{IO}							mV
T_A = +25°C		–	2.0	5.0	–	2.0	6.0	
T_{low}* ≤ T_A ≤ T_{high}*		–	–	6.0	–	–	7.5	
Offset Voltage Adjustment Range	V_{IOR}	–	18	–	–	18	–	mV
Input Offset Current	I_{IO}							nA
T_A = +25°C		–	2.0	15	–	2.0	25	
T_A = T_{high}		–	–	15	–	–	25	
T_A = T_{low}		–	–	40	–	–	40	
Input Bias Current	I_{IB}							nA
T_A = +25°C		–	15	50	–	15	50	
T_A = T_{high}		–	–	50	–	–	50	
T_A = T_{low}		–	–	120	–	–	100	
Input Resistance	r_i	–	5.0	–	–	5.0	–	MΩ
Input Capacitance	c_i	–	2.0	–	–	2.0	–	pF
Input Voltage Range	V_{ID}							V
T_{low} ≤ T_A ≤ T_{high}		±10	–	–	±10	–	–	
Large Signal Voltage Gain	A_{VOL}							V/V
R_L ≥ 5.0 kΩ, V_O = ±10 V, T_A = +25°C		100 k	400 k	–	50 k	400 k	–	
R_L ≥ 75 kΩ, V_O = ±10 V, T_{low} ≤ T_A ≤ T_{high}		75 k	–	–	50 k	–	–	
Output Voltage Swing	V_O							V
R_L ≥ 5.0 kΩ, T_A = +25°C		±10	±13	–	±10	±13	–	
R_L ≥ 75 kΩ, T_{low} ≤ T_A ≤ T_{high}		±10	–	–	±10	–	–	
Output Resistance	r_o	–	1.0	–	–	1.0	–	kΩ
Output Short-Circuit Current	I_{os}	–	12	–	–	12	–	mA
Common-Mode Rejection Ratio	CMRR							dB
R_S ≤ 10 kΩ, T_{low} ≤ T_A ≤ T_{high}		70	90	–	70	90	–	
Supply Voltage Rejection Ratio	PSRR							μV/V
R_S ≤ 10 kΩ, T_{low} ≤ T_A ≤ T_{high}		–	25	150	–	25	200	
Supply Current	I_{CC}, I_{EE}							μA
T_A = +25°C		–	160	180	–	160	190	
T_{low} ≤ T_A ≤ T_{high}		–	–	200	–	–	200	
Power Dissipation	P_D							mW
T_A = +25°C		–	–	5.4	–	–	5.7	
T_{low} ≤ T_A ≤ T_{high}		–	–	6.0	–	–	6.0	
Transient Response (Unity Gain)								
V_{in} = 20 mV, R_L ≥ 5.0 kΩ, C_L = 100 pF								
Rise Time	t_{TLH}	–	0.35	–	–	0.35	–	μs
Overshoot	OS	–	10	–	–	10	–	%
Slew Rate (R_L ≥ 5.0 kΩ)	S_R	–	0.8	–	–	0.8	–	V/μs

*T_{low} = −55°C for MC1776 T_{high} = +125°C for MC1776
0°C for MC1776C   +70°C for MC1776C

TYPICAL CHARACTERISTICS

(T_A = +25°C unless otherwise noted.)

FIGURE 1 – SET CURRENT versus SET RESISTOR

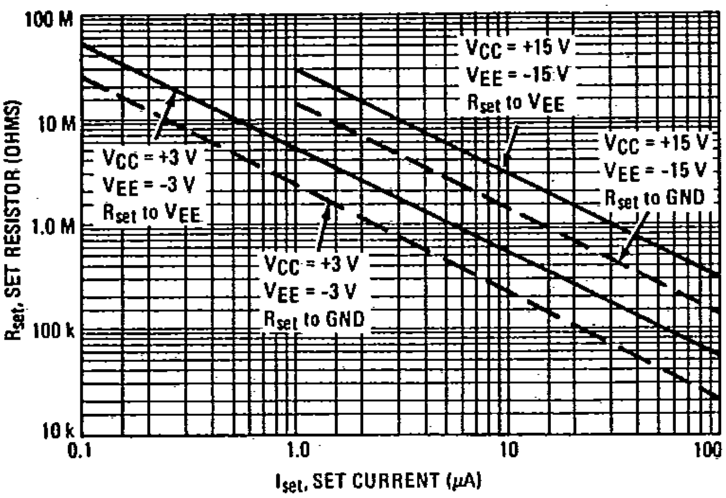


FIGURE 2 – POSITIVE STANDBY SUPPLY CURRENT versus SET CURRENT

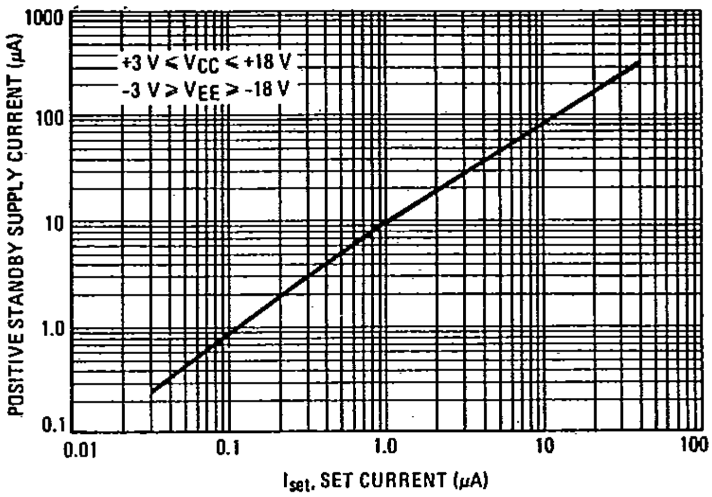


FIGURE 3 – OPEN-LOOP GAIN versus SET CURRENT

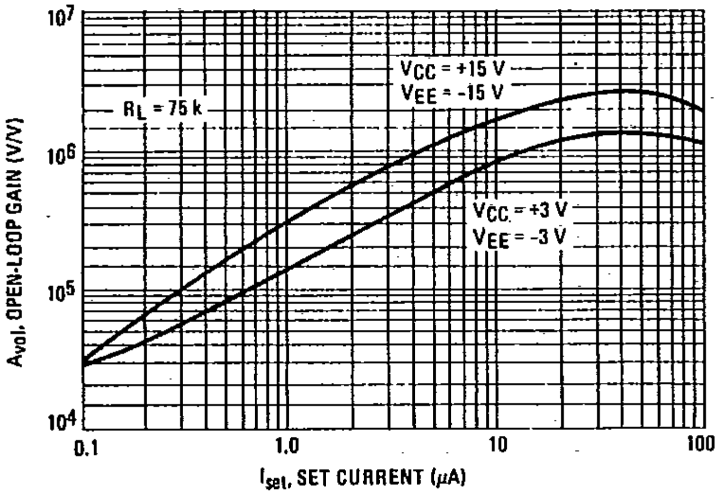


FIGURE 4 – INPUT BIAS CURRENT versus SET CURRENT

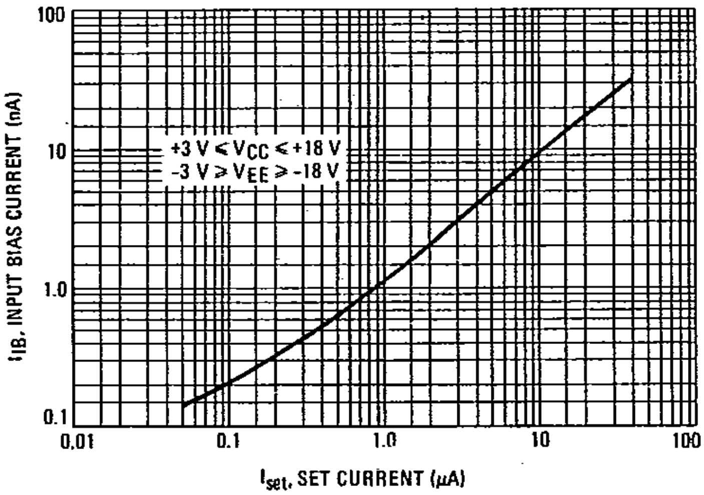


FIGURE 5 – INPUT BIAS CURRENT versus AMBIENT TEMPERATURE

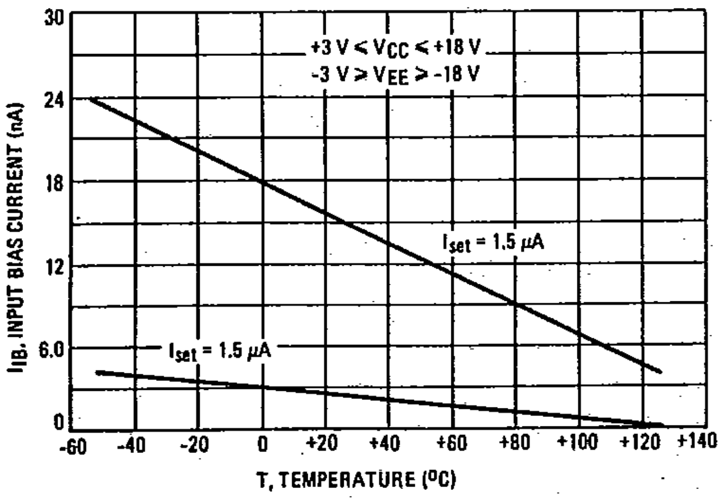
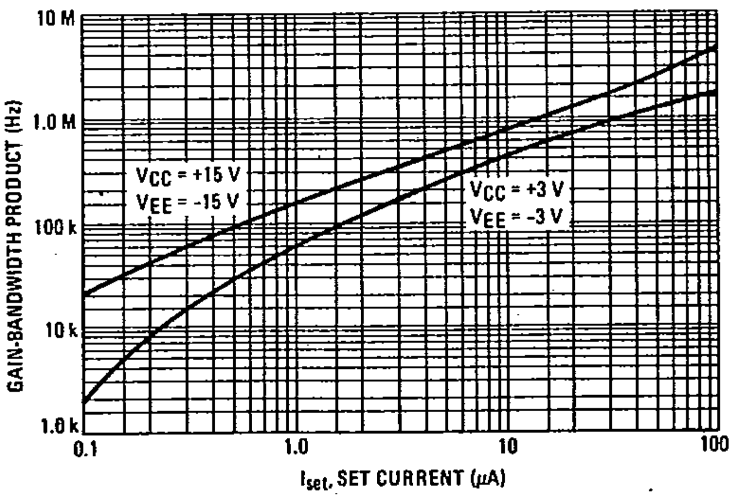


FIGURE 6 – GAIN-BANDWIDTH PRODUCT (GBW) versus SET CURRENT



TYPICAL CHARACTERISTICS (continued)

(T_A = +25°C unless otherwise noted.)

FIGURE 7 – OUTPUT VOLTAGE SWING versus LOAD RESISTANCE

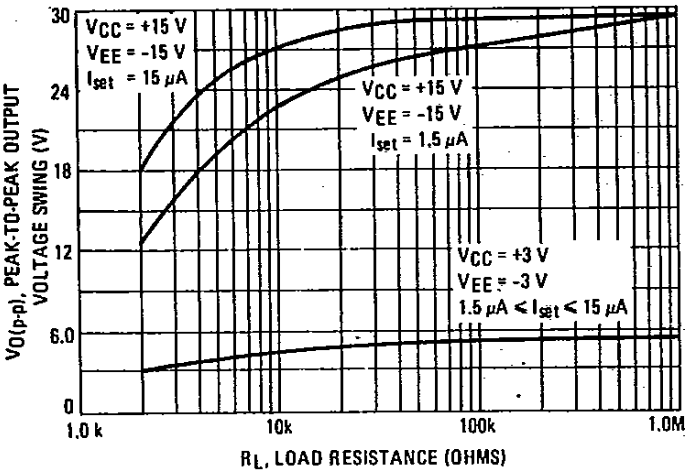


FIGURE 8 – SUPPLY CURRENT versus AMBIENT TEMPERATURE

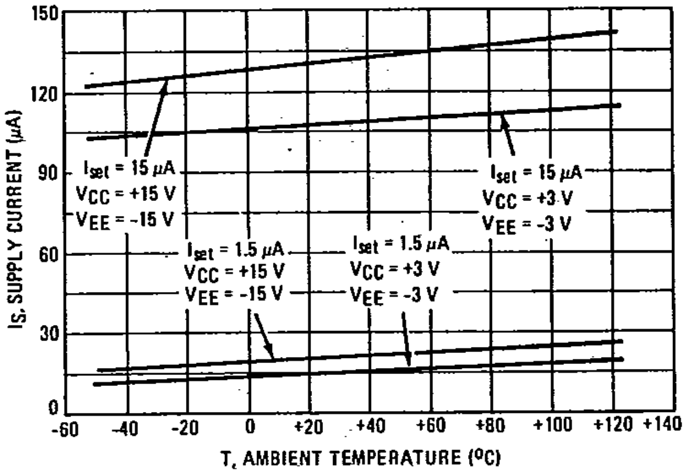


FIGURE 9 – OUTPUT SWING versus SUPPLY VOLTAGE

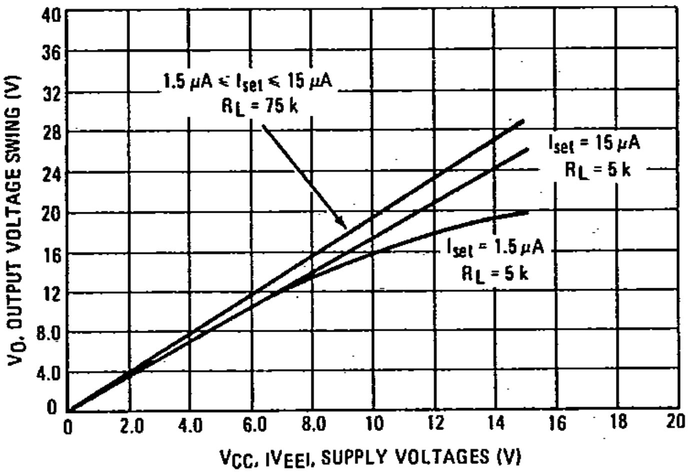


FIGURE 10 – SLEW RATE versus SET CURRENT

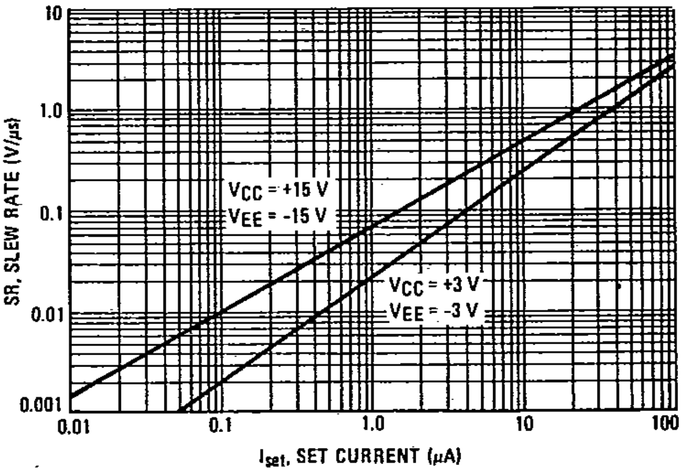


FIGURE 11 – INPUT NOISE VOLTAGE versus SET CURRENT

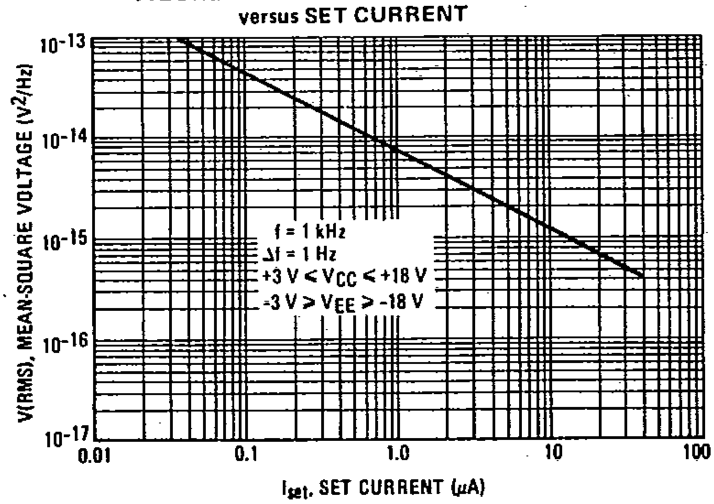


FIGURE 12 – OPTIMUM SOURCE RESISTANCE FOR MINIMUM NOISE versus SET CURRENT

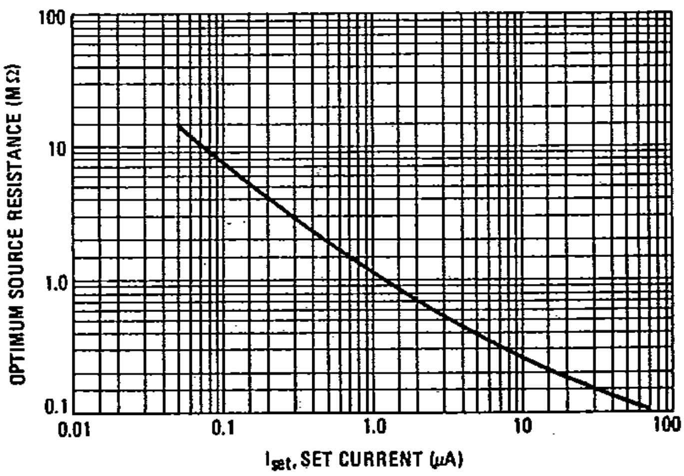
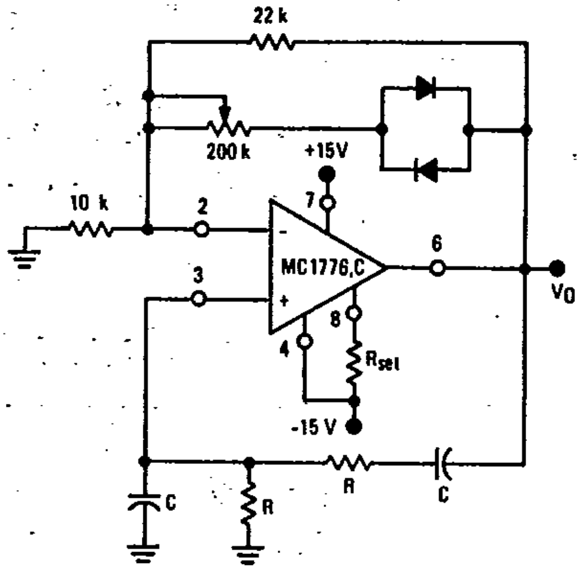


FIGURE 13 – WIEN BRIDGE OSCILLATOR

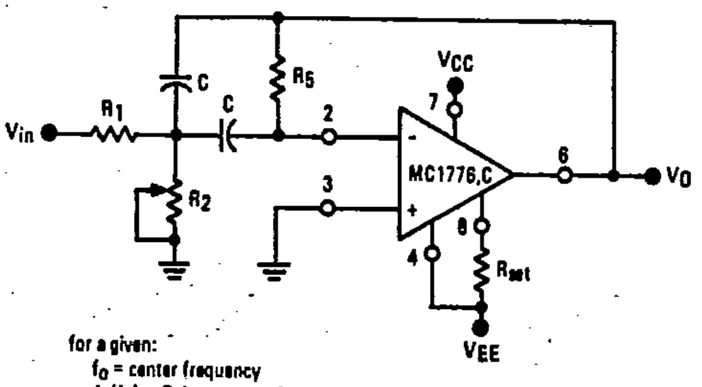


$$f_o = \frac{1}{2\pi RC}$$

(for f_o = 1.0 kHz)

R = 16 kΩ
C = 0.01 μF

FIGURE 14 – MULTIPLE FEEDBACK BANDPASS FILTER



for a given:
f_o = center frequency
A (f_o) = Gain at center frequency
Q = quality factor
Choose a value for C, then

$$R5 = \frac{Q}{\pi f_o C}$$

$$R1 = \frac{R5}{2A(f_o)}$$

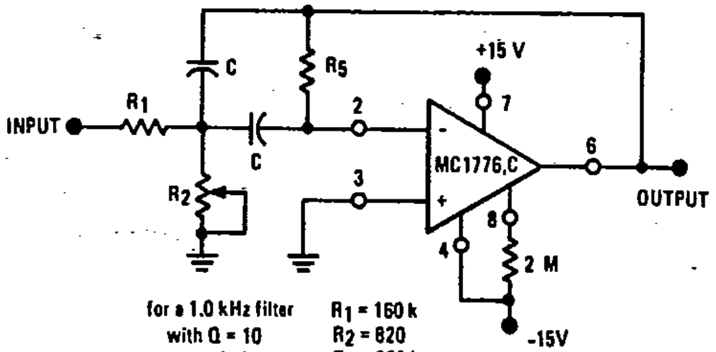
$$R2 = \frac{R1 R5}{4Q^2 R1 - R5}$$

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

$$\frac{Q_o f_o}{GBW} < 0.1$$

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

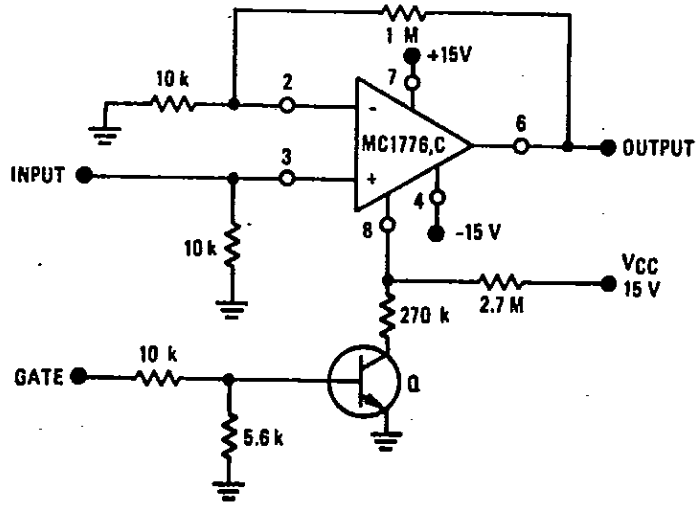


FIGURE 17 – HIGH INPUT IMPEDANCE AMPLIFIER