OP-06

HIGH-GAIN INSTRUMENTATION OPERATIONAL AMPLIFIER

FEATURES

- **Very High Voltage Gain .... 1,000V/mV Minimum**
- **Low Offset Voltage and Offset Current**
- **Low Drift vs. Temperature (TCV_{OS}) .... 0.8μV/°C Maximum**
- **Low Input Voltage and Current Noise**
- **Low Offset Voltage Drift with Time**
- **High Common Mode Rejection .... 120dB Typical**
- **High Power Supply Rejection .... 2μV/V Maximum**
- **Wide Supply Range .... ±3.0V to ±22V**
- **±30V Input Overvoltage Protection**
- **MIL-STD-883 Processing Available**
- **Slew Rate to 100V/μs**

GENERAL DESCRIPTION

The OP-06 monolithic Instrumentation Operational Amplifier is specifically designed for accurate high-gain amplification of low level input signals in the presence of large common-mode voltages. Superior DC input characteristics include very low offset voltage and current, extremely high open-loop gain, low 1/f and wideband noise, and a minimum of "popcorn"noise. The extremely low offset voltage drift is further improved by an advanced nulling technique that provides optimum TCV_{OS} performance when V_{OS} has been nulled to zero. Very high common mode and power supply rejection enable accurate performance in the presence of large spurious signals.

Flexible external compensation provides wide bandwidth and high slew rate operation in high closed-loop gain applications. The superior long term stability, and compatibility with MIL-STD-883 processing, make the OP-06 an excellent choice for high reliability process control and aerospace applications; including strain gauge and thermocouple amplifiers, low noise audio amplifiers, and instrumentation amplifiers. The OP-06 is a direct replacement for all 725 types providing superior DC and noise performance plus the unique feature of **complete input differential voltage and output short circuit protection.**

See AN-25 for additional information.

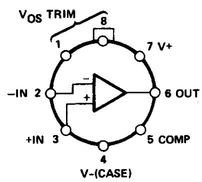
ORDERING INFORMATION†

$T_A = 25°C$ V_{OS} MAX (mV)	PACKAGE TO-99 8-PIN	PACKAGE HERMETIC DIP 8-PIN	PACKAGE HERMETIC DIP 14-PIN	OPERATING TEMPERATURE RANGE
0.2	OP06EJ	OP06EZ	OP06EY	COM
0.2	OP06AJ*	OP06AZ*	OP06AY*	MIL
0.5	OP06FJ	OP06FZ	OP06FY	COM
0.5	OP06BJ*	OP06BZ*	OP06BY*	MIL
1.3	OP06GJ	OP06GZ	OP06GY	COM
1.3	OP06CJ*	OP06CZ*	OP06CY*	MIL

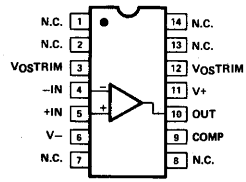
*Also available with MIl-STD-883B processing. To order add /883 as a suffix to the part number.

†All listed parts are available with 160 hour burn-in. See Ordering Information, Section 2.

PIN CONNECTIONS

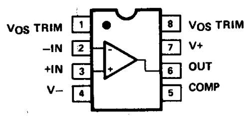


TO-99 (J-Suffix)



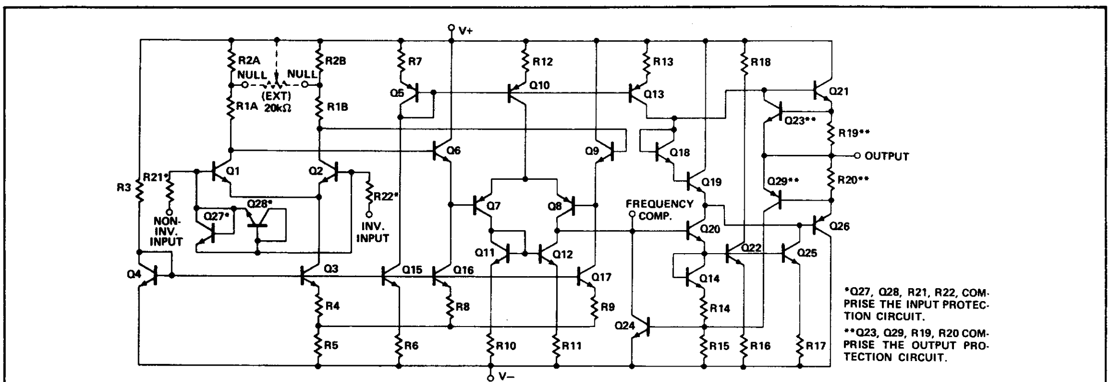
14-PIN DIP (Y-Suffix)*

*Not Recommended for New Designs



8-PIN DIP (Z-Suffix)

SIMPLIFIED SCHEMATIC



ABSOLUTE MAXIMUM RATINGS (Note 3)

Supply Voltage .... ±22V
Internal Power Dissipation (Note 1) 500mW
Differential Input Voltage .... ±30V
Input Voltage (Note 2) .... ±22V
Output Short Circuit Duration .... Indefinite
Storage Temperature Range .... −65 °C to +150 °C
Operating Temperature Range
OP-06A, OP-06B, OP-06C .... −55 °C to +125 °C
OP-06E, OP-06F, OP-06G .... 0 °C to +70 °C
Lead Temperature Range (Soldering, 60 sec.) ..... 300 °C
DICE Junction Temperature .... −65° C to +150° C

NOTES:

1. See table for maximum ambient temperature rating and derating factor.

Package Type	Maximum Ambient Temperature for Rating	Derated Above Maximum Ambient Temperature
TO-99 (J)	80 °C	7.1mW/ °C
14-PIN HERMETIC DIP (Y)	100 °C	10.0mW/ °C
8-PIN HERMETIC DIP (Z)	75 °C	6.7mV/ °C

2. For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.
3. Absolute ratings apply to both DICE and packaged parts, unless otherwise noted.

ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $T_A = 25°C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	OP-06A/E MIN	OP-06A/E TYP	OP-06A/E MAX	OP-6B/F MIN	OP-6B/F TYP	OP-6B/F MAX	OP-6C/G MIN	OP-6C/G TYP	OP-6C/G MAX	UNITS
Input Offset Voltage	V_{OS}	$R_S \le 20k\Omega$ (Note 2)	—	0.06	0.2	—	0.2	0.5	—	0.4	1.3	mV
Input Offset Current	I_{OS}		—	0.3	2.0	—	0.75	5.0	—	2	13	nA
Input Bias Current	I_B		—	30	70	—	30	80	—	40	110	nA
Input Noise Voltage Density	e_n	$f_O = 10Hz$ (Note 1) $f_O = 100Hz$ $f_O = 1000Hz$	— — —	9.0 8.0 7.0	15.0 9.0 7.5	— — —	9.0 8.0 7.0	15.0 9.0 7.5	— — —	9.0 8.0 7.0	15.0 9.0 7.5	$nV/\sqrt{Hz}$
Input Noise Current Density	i_n	$f_O = 10Hz$ (Note 1) $f_O = 100Hz$ $f_O = 1000Hz$	— — —	0.5 0.25 0.15	1.2 0.6 0.25	— — —	0.5 0.25 0.15	1.2 0.6 0.25	— — —	0.6 0.3 0.2	1.4 0.7 0.3	$pA/\sqrt{Hz}$
Input Resistance	R_{IN}	(Note 3)	0.8	1.8	—	0.7	1.8	—	0.5	1.5	—	MΩ
Large Signal Voltage Gain	A_{VO}	$R_L \ge 2k\Omega$, $V_O = \pm 10V$	1,000,000	3,000,000	—	1,000,000	3,000,000	—	500,000	3,000,000	—	V/V
Output Voltage Swing	V_O	$R_L \ge 10k\Omega$ $R_L \ge 2k\Omega$ $R_L \ge 1k\Omega$	±12.5 ±12.0 ±11.0	±13.0 ±12.8 ±12.5	— — —	±12.5 ±12.0 ±11.0	±13.0 ±12.8 ±12.5	— — —	±12.0 ±11.5 —	±13.0 ±12.8 ±12.0	— — —	V
Input Voltage Range	IVR		±13.5	±14.0	—	±13.5	±14.0	—	±13.5	±14.0	—	V
Common Mode Rejection Ratio	CMRR	$V_{CM} = \pm 13.5V$ $R_S \le 20k\Omega$	114	120	—	114	120	—	110	115	—	dB
Power Supply Rejection Ratio	PSRR	$V_S = \pm 3V$ to $\pm 18V$ $R_S \le 20k\Omega$	—	0.5	2.0	—	1.0	5.0	—	2.0	10	μV/V
Power Consumption	P_d		—	90	120	—	90	120	—	110	150	mW
Large Signal Voltage Gain	A_{VO}	$R_L \ge 500\Omega$ (Note 3) $V_O = \pm 0.5V$ $V_S = \pm 3V$	100,000	600,000	—	100,000	600,000	—	60,000	600,000	—	V/V
Power Consumption	P_d	$V_S = \pm 3V$	—	4	6	—	4	6	—	4	8	mW

NOTES:

1. Sample tested.
2. Thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can prevent the realization of the performance indicated if both sides of the contacts are not kept at approximately the same temperature. Temperature gradients should therefore be minimized.
3. Guaranteed by design.

ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $-55°C \leq T_A \leq +125°C$, unless otherwise noted.

			OP-06A			OP-06B			OP-06C			
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
Input Offset Voltage (Without external trim)	V_{OS}	$R_S \leq 20k\Omega$ (Note 2)	—	0.08	0.28	—	0.3	0.7	—	0.5	1.6	mV
Average Input Offset Voltage Drift (Without external trim)	TCV_{OS}	$R_S = 50\Omega$ (Notes 1,2)	—	0.3	0.8	—	0.7	2.0	—	1.4	4.5	μV/°C
Average Input Offset Voltage Drift (With external trim)	TCV_{OSn}	$R_S = 50\Omega$ (Notes 1,2) $R_P = 20k\Omega$	—	0.2	0.6	—	0.28	1.0	—	0.5	1.5	μV/°C
Input Offset Current	I_{OS}	T_AMAX T_AMIN	— —	0.25 0.8	1.0 4.0	— —	0.6 2.0	4.0 18.0	— —	2.0 3.0	15 25	nA
Average Input Offset Current Drift	TCI_{OS}	(Note 1)	—	3	20	—	8	90	—	14	150	pA/°C
Input Bias Current	I_B	T_AMAX T_AMIN	— —	22 40	60 120	— —	25 45	70 180	— —	35 45	110 180	nA
Common Mode Rejection Ratio	CMRR	$V_{CM} = \pm 13.5V$ $R_S \leq 20k\Omega$	109	112	—	109	112	—	95	110	—	dB
Power Supply Rejection Ratio	PSRR	$V_S = \pm 3V$ to $\pm 18V$ $R_S \leq 20k\Omega$	—	1.0	5.0	—	2.0	8.0	—	3.0	15	μV/V
Large Signal Voltage Gain	A_{VO}	$V_O = \pm 10V$; $R_L \geq 2k\Omega$ T_AMAX T_AMIN	1,000,000 700,000	3,500,000 2,000,000	— —	1,000,000 700,000	3,500,000 1,800,000	— —	400,000 300,000	3,200,000 1,700,000	— —	V/V
Output Voltage Swing	V_O	$R_L \geq 2k\Omega$	±12.0	±12.6	—	±12.0	±12.6	—	±11.0	±12.6	—	V

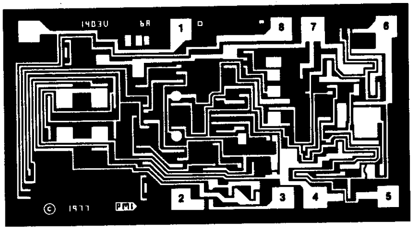
ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $0°C \leq T_A \leq 70°C$, unless otherwise noted.

			OP-06E			OP-06F			OP-06G			
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
Input Offset Voltage (Without external trim)	V_{OS}	$R_S \leq 20k\Omega$ (Note 2)	—	0.08	0.28	—	0.25	0.6	—	0.5	1.6	mV
Average Input Offset Voltage Drift (Without external trim)	TCV_{OS}	$R_S = 50\Omega$ (Notes 1,2)	—	0.3	0.8	—	0.7	2.0	—	1.4	4.5	μV/°C
Average Input Offset Voltage Drift (With external trim)	TCV_{OSn}	$R_S = 50\Omega$ (Notes 1,2) $R_P = 20k\Omega$	—	0.2	0.6	—	0.28	1.0	—	0.5	1.5	μV/°C
Input Offset Current	I_{OS}	T_AMAX T_AMIN	— —	0.25 0.8	1.0 4.0	— —	0.65 2.0	5.0 18.0	— —	2.0 3.0	15 25	nA
Average Input Offset Current Drift	TCI_{OS}	(Note 1)	—	3	20	—	8	90	—	14	150	pA/°C
Input Bias Current	I_B	T_AMAX T_AMIN	— —	22 40	60 120	— —	30 45	80 180	— —	35 45	110 180	nA
Common Mode Rejection Ratio	CMRR	$V_{CM} = \pm 13.5V$ $R_S \leq 20k\Omega$	109	112	—	109	112	—	95	110	—	dB
Power Supply Rejection Ratio	PSRR	$V_S = \pm 3V$ to $\pm 18V$ $R_S \leq 20k\Omega$	—	1.0	5.0	—	1.5	7.0	—	3.0	15	μV/V
Large Signal Voltage Gain	A_{VO}	$V_O = \pm 10V$; $R_L \geq 2k\Omega$ T_AMAX T_AMIN	1,000,000 800,000	3,500,000 2,000,000	— —	1,000,000 800,000	3,500,000 1,800,000	— —	400,000 300,000	3,200,000 1,700,000	— —	V/V
Output Voltage Swing	V_O	$R_L \geq 2k\Omega$	±12.0	±12.6	—	±12.0	±12.6	—	±11.0	±12.6	—	V

NOTES:

1. Sample tested.
2. Thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can prevent the realization of the performance indicated if both sides of the contacts are not kept at approximately the same temperature. Temperature gradients should therefore be minimized.

DICE CHARACTERISTICS



DIE SIZE 0.094 × 0.050 inch

1. NULL
2. INVERTING INPUT
3. NON-INVERTING INPUT
4. V−
5. COMPENSATION
6. OUTPUT
7. V+
8. NULL

Refer to Section 2 for additional DICE information.

ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $T_A = +25°C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	OP-06N LIMIT	OP-06G LIMIT	OP-06GR LIMIT	UNITS
Input Offset Voltage	V_{OS}	$R_S \leq 20k\Omega$	0.2	0.5	1.3	mV MAX
Input Offset Current	I_{OS}		2	5	13	nA MAX
Input Bias Current	I_B		70	80	110	nA MAX
Input Resistance Differential Mode	R_{IN}	(Note 1)	0.8	0.7	0.5	MΩ MIN
Input Voltage Range	IVR		±13.5	±13.5	±13.5	V MIN
Common Mode Rejection Ratio	CMRR	$V_{CM} = \pm 13.5V$ $R_S \leq 20k\Omega$	114	114	110	dB MIN
Power Supply Rejection Ratio	PSRR	$V_S = \pm 3V$ to $\pm 18V$ $R_S \leq 20k\Omega$	2	5	10	μV/V MAX
Output Voltage Swing	V_O	$R_L \geq 10k\Omega$ $R_L \geq 2k\Omega$ $R_L \geq 1k\Omega$	±12.5 ±12.0 ±11.0	± 12.5 ± 12.0 ±11.0	±12.0 ± 11.5 —	V MIN
Large Signal Voltage Gain	A_{VO}	$R_L \geq 2k\Omega$ $V_O = \pm 10V$	1000	1000	500	V/mV MIN
Differential Input Voltage			±30	±30	±30	V MAX
Power Consumption ($V_{OUT} = 0V$)	P_d		120	120	150	mW MAX

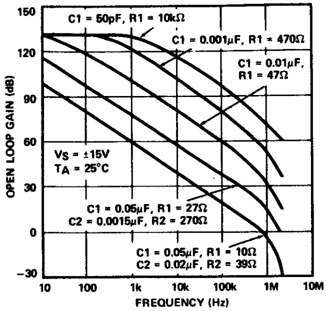
TYPICAL ELECTRICAL CHARACTERISTICS at $V_S = \pm 15V$, $T_A = +25°C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	OP-06N TYPICAL	OP-06G TYPICAL	OP-06GR TYPICAL	UNITS
Average Input Offset Voltage Drift	TCV_{OS}	$R_S \leq 50\Omega$	0.3	0.7	1.4	μV/°C
Nulled Input Offset Voltage Drift	TCV_{OSn}	$R_S \leq 50k\Omega$ $R_P = 20k\Omega$	0.2	0.28	0.5	μV/°C
Average Input Offset Current Drift	TCI_{OS}		3	8	14	pA/°C

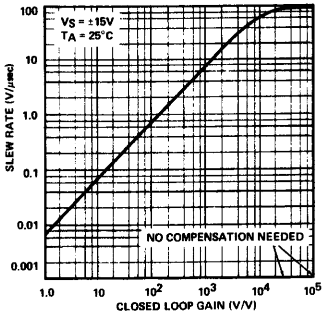
NOTE:
1. Guaranteed by design.

TYPICAL DYNAMIC PERFORMANCE CURVES

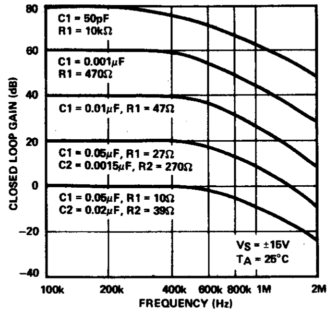
OPEN LOOP RESPONSE FOR VALUES OF COMPENSATION



SLEW RATE USING RECOMMENDED COMPENSATION NETWORKS



CLOSED LOOP FREQUENCY RESPONSE FOR VALUES OF COMPENSATION

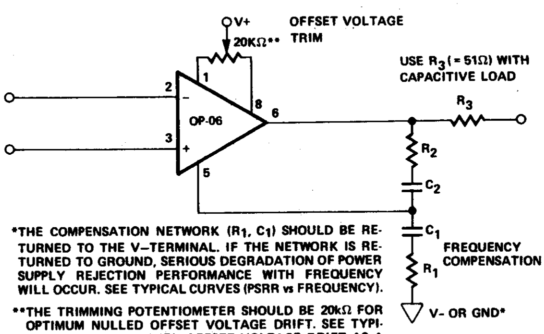


FREQUENCY COMPENSATION

COMPENSATION VALUES

Avcl	R_1 (Ω)	C_1 (μF)	R_2 (Ω)	C_2 (μF)
10000	10k	50pF	—	—
1000	470	0.001	—	—
100	47	0.01	—	—
10	27	0.05	270	0.0015
1	10	0.05	39	0.02

COMPENSATION CIRCUIT (J or Z PACKAGE)

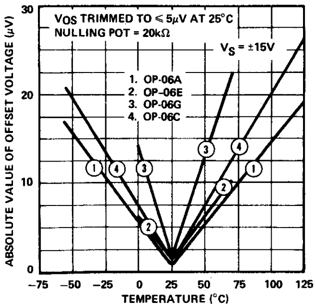


*THE COMPENSATION NETWORK (R_1, C_1) SHOULD BE RETURNED TO THE V− TERMINAL. IF THE NETWORK IS RETURNED TO GROUND, SERIOUS DEGRADATION OF POWER SUPPLY REJECTION PERFORMANCE WITH FREQUENCY WILL OCCUR. SEE TYPICAL CURVES (PSRR vs FREQUENCY).

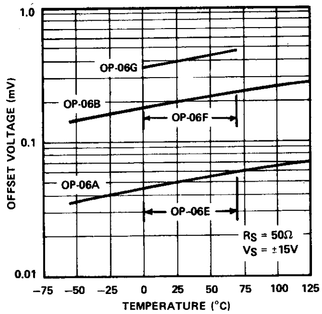
**THE TRIMMING POTENTIOMETER SHOULD BE 20kΩ FOR OPTIMUM NULLED OFFSET VOLTAGE DRIFT. SEE TYPICAL CURVES (TRIMMED OFFSET VOLTAGE DRIFT AS A FUNCTION OF TRIMMING POTENTIOMETER).

TYPICAL PERFORMANCE CURVES

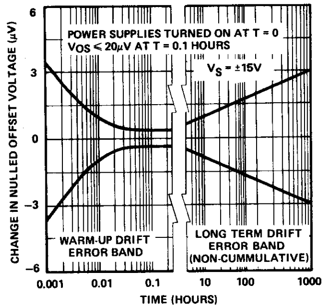
TRIMMED OFFSET VOLTAGE vs TEMPERATURE



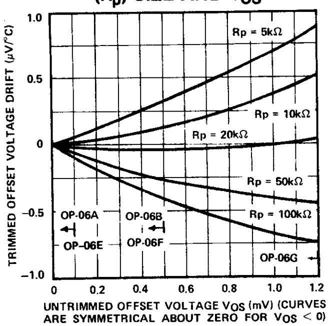
OFFSET VOLTAGE vs TEMPERATURE



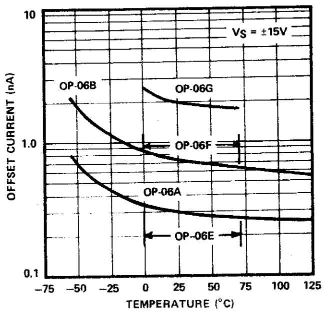
OFFSET VOLTAGE DRIFT WITH TIME



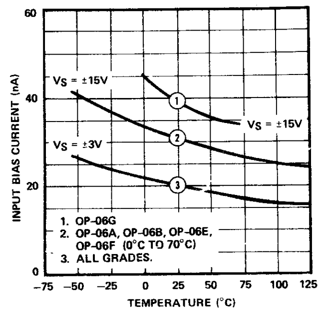
TRIMMED OFFSET VOLTAGE DRIFT AS A FUNCTION OF TRIMMING POTENTIOMETER (R_p) SIZE AND V_{OS}



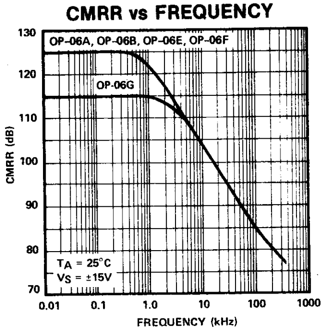
OFFSET CURRENT vs TEMPERATURE



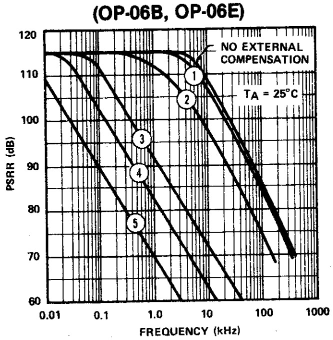
INPUT BIAS CURRENT vs TEMPERATURE



CMRR vs FREQUENCY

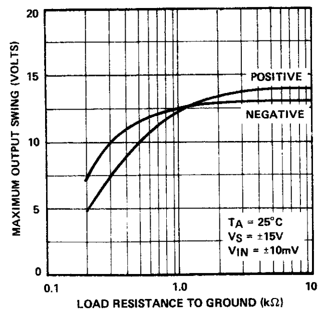


PSRR vs FREQUENCY (OP-06B, OP-06E)



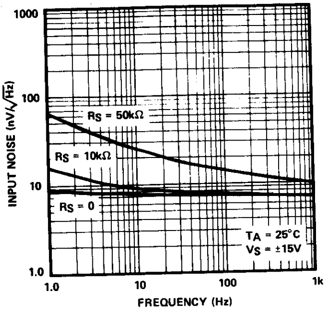
1. C1 = 0.001μF, R1 = 470Ω FROM PIN 5 TO V–
2. C1 = 0.1μF, R1 = 5Ω TO V–
3. C1 = 0.001μF, R1 = 470Ω FROM PIN 5 TO GND
4. C1 = 0.05μF, R1 = 10Ω, C2 = 0.02μF, R2 = 39Ω TO V–
5. C1 = 0.05μF, R1 = 10Ω, C2 = 0.02μF, R2 = 39Ω TO GND

OUTPUT SWING vs LOAD RESISTANCE

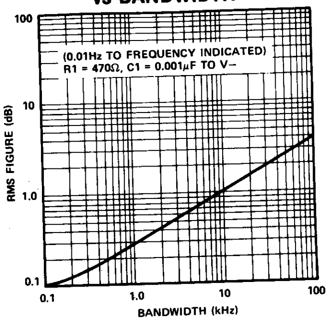


TYPICAL PERFORMANCE CURVES

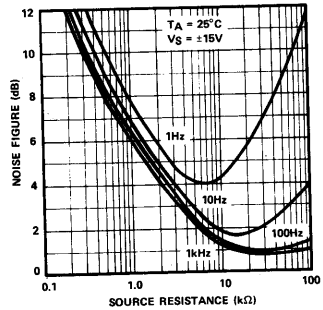
TYPICAL INPUT NOISE VOLTAGE



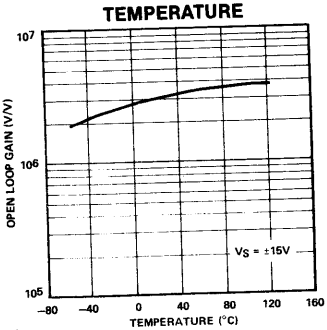
INPUT WIDEBAND NOISE vs BANDWIDTH



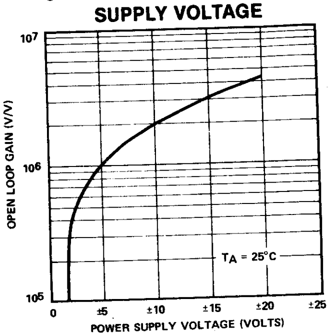
NOISE FIGURE vs SOURCE RESISTANCE



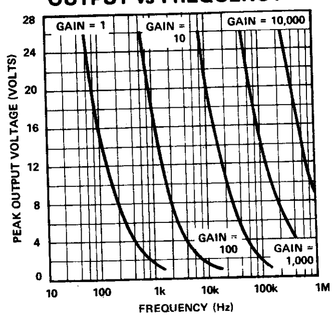
OPEN LOOP GAIN vs TEMPERATURE



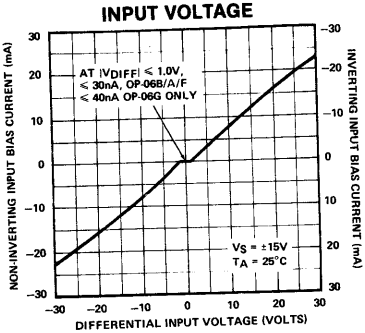
OPEN LOOP GAIN vs POWER SUPPLY VOLTAGE



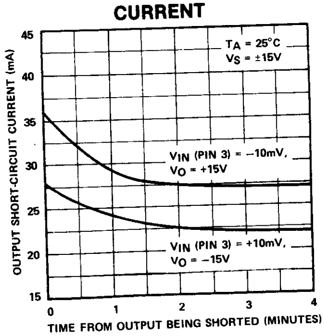
MAXIMUM UNDISTORTED OUTPUT vs FREQUENCY



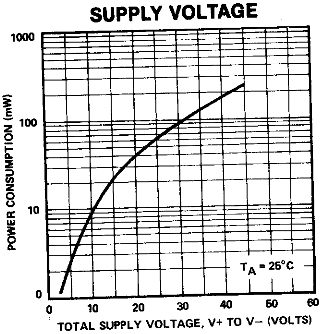
INPUT BIAS CURRENT vs DIFFERENTIAL INPUT VOLTAGE



OUTPUT SHORT-CIRCUIT CURRENT

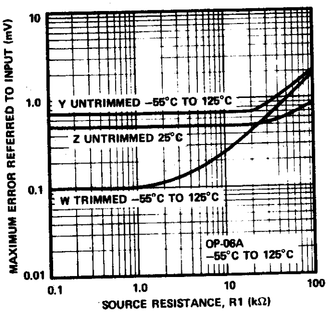


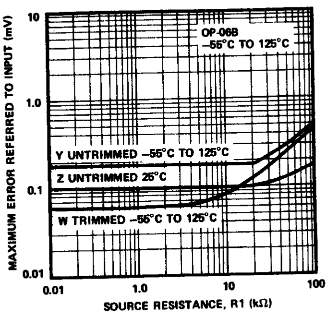
POWER CONSUMPTION vs SUPPLY VOLTAGE

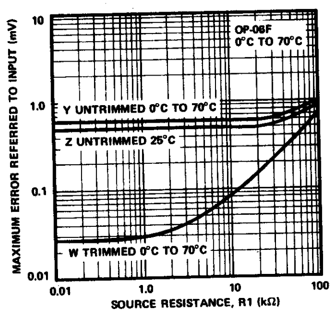


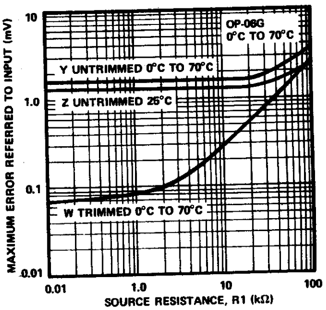
Note: For further information refer to AN-15, "Minimization of Noise in Operational Amplifier Applications".

GUARANTEED PERFORMANCE CURVES









These graphs depict maximum error referred to the input as a function of source resistance (R_1). Curves W are shown with V_{OS} trimmed at +25°C and include errors due to V_{OS} and I_{OS} over the indicated temperature range. Curves Y and Z plot maximum errors with V_{OS} not trimmed.