ANALOG DEVICES DATA FROM 1972.

The following pages from my catalog(ue) of 1972 gives a comparison of some 50+ amplifiers then available.

Detailed data are included for the following models:-

40

41

43

44

45

46

48

118

119

120

146

201A

208

507

741

AD503

AD505

AD511

AD513

I shall add further data later or on request

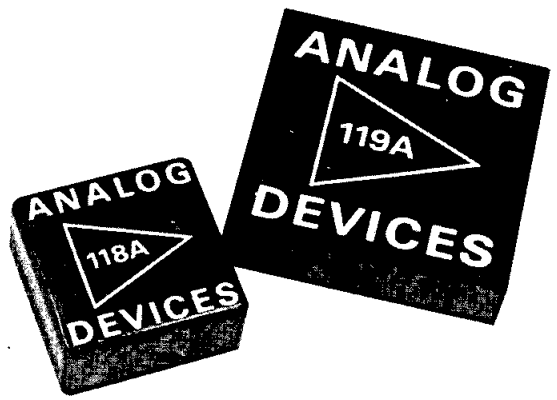
## CAPSULE SELECTION TABLE AMPLIFIER PRODUCTS

| Description | Model | Open Loop Gain | Rated Output | | Frequency Response | | |
|---|---|---|---|---|---|---|---|
| | | V/V | V | mA | Unity Gain MHz | Full Power kHz | Slew Rate V/μs |
| General Purpose – Bipolar | | | | | | | |
| Moderate Performance Op Amps | | | | | | | |
| Good Performance Economy | 118 A/K | 250k | ±10 | ±5 | 1.5 | 100 | 6.0 |
| Low Cost, 20mA Output | 119 A/K | 500k | ±10 | ±20 | 1.5 | 100 | 6.0 |
| Slew Rate, High Gain, IC | AD507 J/K | 80k | ±10 | ±10 | 35 | 320 | 20 |
| Economy, Speed, IC | AD201A | 50k | ±10 | ±5 | 1.0 | 10 | 0.5 |
| Lowest Cost, General Purpose, IC | AD741 K/L | 50k | ±10 | ±5 | 1.0 | 10 | 0.5 |
| Super Beta-Low 2nA $I_{bias}$, IC | AD208/A | 50k/80k | ±13 | ±1.3 | 1.0 | 10 | 0.3 |
| General Purpose FET – | | | | | | | |
| Low Bias Current, High $Z_{in}$ Op Amps | | | | | | | |
| Lowest Cost Discrete | 40 J/K | 50k | ±10 | ±5 | 4.0 | 100 | 6.0 |
| Guaranteed CMR – Low Bias | 43J | 50k | ±10 | ±5 | 4.0 | 100 | 6.0 |
| Lowest Bias – High CMR | 41 J/K/L | 100k | ±10 | ±5 | 1.0 | 50 | 3.0 |
| Lowest Drift – 20mA Output | 146 J/K | 100k | ±10 | ±20 | 5.0 | 150 | 10 |
| Best Choice – Economy IC | AD503 J/K | 20k/50k | ±10 | ±5 | 1.0 | — | 6.0 |
| Hybrid – Lowest Offset & Bias, IC | AD511 A/B | 25k | ±10 | ±5 | 1.0 | 70 | 5.0 |
| High GBW, Slew Rate, IC | AD513 J/K | 20k/50k | ±10 | ±5 | 1.0 | — | 20 |
| Wide Bandwidth – | | | | | | | |
| Fast Settling Op Amps | | | | | | | |
| 1000V/μs Slew, 100ns Settling, 100mA | 46 J/K | 25k | ±10 | ±100 | 40 | 10MHz | 1000 |
| 125V/μs, 250ns Settling to 0.1% | 48 J/K | 100k | ±10 | ±20 | 15 | 1.5MHz(inv.) | 125 (inv.) |
| Lowest Cost –1μs Settling to 0.01% | 45 J/K | 50k | ±10 | ±20 | 10 | 1MHz | 75 |
| 0.01% Buffer, 1μs to 0.01% | 44 J/K | 100k | ±10 | ±20 | 10 | 1MHz | 75 |
| 100MHz GBW, Lowest Drift | 120 A/B | 500k | ±10 | ±25 | 10-100 | 4MHz | 250 |
| Wideband, 130V/μs, IC | AD505 J/K | 100k/250k | ±10 | ±5 | 10 | 2MHz | 120 |
| Low Voltage Drift – | | | | | | | |
| Chopper Stabilized Op Amps | | | | | | | |
| 0.1μV/°C Drift – Lowest Noise | 234 J/K/L | 10M | ±10 | ±5 | 2.5 | 500 | 30 |
| Lowest Cost – General Purpose | 233 J/K/L | 10M | ±10 | ±5 | 0.5 | 4.0 | 0.25 |
| Low Cost, Non-Inverting, High $Z_{in}$ | 260 J/K | 5M | ±10 | ±5 | 100Hz | 2-50Hz | 100V/sec |
| General Purpose – 25mA Output | 231 J/K | 10M | ±10 | ±25 | 0.5 | 3.0 | 0.2 |
| High Bandwidth – 20mA Output | 210/211 | 100M | ±10 | ±20 | 20 | 500 | 100 |
| Low Voltage Drift – | | | | | | | |
| Differential Input, High CMR Op Amps | | | | | | | |
| Lowest Cost – 0.25μV/°C | 184 J/K/L | 300k | ±10 | ±5 | 1.0 | 5.0 | 0.3 |
| Battery Powered – Gen. Purpose | 153 J/K | 50k | ±1.0 | ±1.0 | 0.15 | 5.0 | 0.02 |
| Lowest Bias, 4nA, 0.5μV/°C | 180 J/K | 300k | ±10 | ±2.5 | 1.0 | 10 | 0.6 |
| Super Beta, 1μV/°C, 20nA, IC | AD508 J/K/L | 250k/500k/1M | ±10 | ±5 | 0.3 | 1.5 | 0.12 |
| Highest CMR, Low Offset and Drift, IC | AD504 J/K/L | 250k/500k/1M | ±10 | ±5 | 0.3 | 1.5 | 0.12 |
| Electrometers – | | | | | | | |
| Ultra Low Bias Current | | | | | | | |
| Varactor, Inverting | 310 J/K | 100k | ±10 | ±5 | 2kHz | 7Hz | 0.4V/ms |
| Varactor, Non-Inverting | 311 J/K | 100k | ±10 | ±5 | 2kHz | 7Hz | 0.4V/ms |
| Lowest Cost – High Gain FET | 42 J/K/L | 300k | ±10 | ±5 | 1.0 | 4.0 | 0.25 |
| High CMR, Wideband | 41 J/K/L | 100k | ±10 | ±5 | 1.0 | 50 | 3.0 |
| FET, Input, IC | AD523 J/K/L | 75k | ±10 | ±5 | 0.5 | 70 | 5.0 |
| High Output Voltage or Current Op Amps | | | | | | | |
| 100mA Booster – Lowest Cost | B100 | 0.85 | ±10 | ±100 | — | 1MHz | — |
| 20V, 20mA Output – High CMR | 163 A/K | 500k | ±20 | ±20 | 1.5 | 50 | 6.0 |
| 20μV, 5mA Output – Economy | 165 A/K | 250k | ±20 | ±5 | 1.5 | 50 | 6.0 |
| 100mA Output – 10MHz fp – Diff Input | 46 J/K | 25k | ±10 | ±100 | 40 | 10MHz | 1000 |
| Guaranteed 10mA vs. Temp, IC | AD512 K/S | 50k | ±12/±10 | ±12/±10 | 1.0 | 10 | 0.5 |
| Instrumentation Amplifiers | | | | | | | |
| Wide Band, Low Drift, 25μs to 0.01% | 604 J/K/L | 1-1000 | ±10 | ±10 | 50kHz | 50 | 3.0 |
| Low Drift – High CMR | 605 J/K/L | 1-1000 | ±10 | ±5 | 0.3 | 1.5 | 0.1 |
| Low Cost, General Purpose | 603 J/K/L | 1-2000 | ±10 | ±5 | 1.0 | 10 | 2.0 |
| Low Drift – Fixed Gains | 602 J10/ J100/K100 | 10/100/100 | ±10 | ±4 | 75kHz | -1%@1kHz | — |
| Low Cost, General Purpose, IC | AD520J | 1-1000 | ±10 | ±5 | 0.3 | 60 | 4.0 |
| Isolation Amplifiers, | | | | | | | |
| Medical, Industrial | | | | | | | |
| EEG/ECG Inputs, Adjust Gain | 274 J | 1-100 | ±10 | 1.0 | 3.0kHz | 200Hz | — |
| ECG Input, 5kV Safety | 273K | 1.0 | ±3 | 0.5 | 4kHz | 200Hz | — |
| Low Noise Buffer | 273J | 1.0 | ±3 | 0.5 | 4kHz | 200Hz | — |
| ECG Input, 5kV Safety | 272J | 1.0 | ±3 | 0.5 | 2kHz | 200Hz | — |

(Specifications typical @ +25°C and ±15VDC power supply unless otherwise noted.)

| Offset Voltage vs. Temperature | Input Bias Current @25°C | Input Bias Current vs. Temperature | Input Impedance | | Input Noise Voltage | |
|---|---|---|---|---|---|---|
| μV/°C max | pA | pA/°C | Differential Ω | Common Mode Ω | 0.01-1Hz μV,p-p | 5-50kHz μV,rms |
| ±20/±5 | 0,+35nA | ±0.6/±0.5nA/°C | $10^6$ | $10^9$ | 1.0 | 3.0 |
| ±20/±5 | 0,+35nA | ±0.6/±0.5nA/°C | $10^6$ | $10^9$ | 1.0 | 3.0 |
| ±15/±15 max | ±25nA | — | $40 \times 10^6$ | — | — | 7.0(1 to 100kHz) |
| ±15 | ±75nA | — | $4 \times 10^6$ | — | 4.0 | 5.0(10Hz to 10kHz) |
| ±15/±5 | ±75nA | — | $5 \times 10^6$ | — | 2.0 | 4.0(10Hz to 10kHz) |
| ±15/±5 | ±2.0nA | — | $10 \times 10^6$ | — | — | — |
| ±50/±20 | 0,-50/-20 | 2x/10°C | $10^{11}$ | $10^{11}$ | 6.0 | 3.0 |
| ±30 | 0,-10 | 2x/10°C | $10^{11}$ | $10^{11}$ | 6.0 | 3.0 |
| ±25/±10/±25 | 0,-0.5/-0.25/-0.15 | 2x/10°C | $10^{13}$ | $10^{13}$ | 8.0 | 10 |
| ±7/±2 | 0,-30/-20 | 2x/10°C | $10^{11}$ | $10^{11}$ | 6.0 | 16 |
| ±75/±25 | 0,-15/-10 | 2x/10°C | $10^{11}$ | $10^{12}$ | 30 | 15 |
| ±75/±25 | 0,-25/-10 | 2x/10°C | $10^{11}$ | $10^{12}$ | 30 | 15 |
| ±75/±25 | 0,-30/-20 | 2x/10°C | $10^{11}$ | $10^{12}$ | 30 | 15 |
| ±75/±25 | 0,-100 | 2x/10°C | $10^{11}$ | $10^{11}$ | 10 | 5.0 |
| ±50/±15 | 0,-50/-25 | 2x/10°C | $10^{11}$ | $10^{11}$ | 2.0 | 3.0 |
| ±50/±15 | 0,-50/-25 | 2x/10°C | $10^{11}$ | $10^{11}$ | 5.0 | 3.0 |
| ±50/±15 | 0,-50/-25 | 2x/10°C | $10^{11}$ | $10^{11}$ | 2.0 | 3.0 |
| ±15/±8 | 0,+55nA | 0.9/0.7nA/°C | $2 \times 10^5$ | — | 0.5 | 3.0 |
| ±15/±8 typ | ±75/±25nA | — | $2 \times 10^6$ | — | 8(0.01 to 10Hz) | 20 |
| ±1.0/±0.3/±0.1 | ±100 | ±4/±2/±2 | $3 \times 10^5$ | NA | 1.0 | 2.0 |
| ±1.0/±0.3/±0.1 | ±50 | ±2/±1/±0.5 | $6 \times 10^5$ | NA | 1.0 | 3.0 |
| ±0.3/±0.1 | ±300 | ±10 | $8 \times 10^4$//0.01μF | $10^9$//0.02μF | 0.4 | — |
| ±0.25/±0.1 | ±100/±50 | ±1/±0.5 | $3 \times 10^5$ | NA | 1.5 | 5.0 |
| ±0.5/±1.0 | ±100/±150 | ±1/±3 | $5 \times 10^5$ | NA | 5/10 | 10 |
| ±1.5/±0.5/±0.25 | 0,+25nA | ±0.25nA/°C | $4 \times 10^6$ | $2 \times 10^9$ | 1.0 | 4.0 |
| ±5.0/±2.0 | ±3nA | ±0.1nA/°C | $10^6$ | $2 \times 10^8$ | 1.0 | 4.0 |
| ±1.5/±0.5 | ±4nA | ±0.1/±0.05nA/°C | $2 \times 10^6$ | $10^9$ | 1.0 | 4.0 |
| ±5.0/±3.0/±1.0 | ±50/±20/±20 | — | $4 \times 10^6$ | — | 1.0 | 2.0 |
| ±5.0/±3.0/±1.0 | ±200/±100/±80 | — | $10^6$ | — | 1.0 | 2.0 |
| ±30/±10 | ±10fA | ±1fA/°C | $3 \times 10^{11}$ | — | 10 | 10(1 to 100Hz) |
| ±30/±10 | ±10fA | ±1fA/°C | $3 \times 10^{11}$ | — | 10 | 10(1 to 100Hz) |
| ±75/±25/±75 | 0,-0.5/-0.25/-0.15 | 4(0 to +70°C) | $10^{13}$ | $10^{13}$ | 6.0 | 8.0 |
| ±25/±10/±25 | 0,-0.5/-0.25/-0.15 | 4(0 to +70°C) | $10^{13}$ | $10^{13}$ | 8.0 | 10 |
| ±90/±30/±60 | -1.0/-0.5/-0.25 | 2x/10°C | $10^{12}$ | $10^{13}$ | 20 | — |
| ±1.0mV/°C | ±500μA | — | $9 \times 10^3$ | NA | — | — |
| ±20/±5 | 0,+35nA | ±0.6/±0.5nA/°C | $10^6$ | $10^9$ | 1.0 | 4.0 |
| ±20/±5 | 0,+35nA | ±0.6/±0.5nA/°C | $10^6$ | $10^9$ | 1.0 | 4.0 |
| ±75/±25 | 0,-100 | 2x/10°C | $10^{11}$ | $10^{11}$ | 10 | 8.0 |
| ±20/±25 | ±200nA | — | $2 \times 10^6$ | — | 4.0 | 5.0(10Hz to 10kHz) |
| ±3/±1/±0.5(G=1000) | 0,+50nA | -1.0nA/°C | $10^{11}$/G | $10^{11}$ | 1(G=1000) | 1.5(G=1000) |
| ±3/±1/±0.5(G=1000) | 0,+100nA | -1.0nA/°C | $10^9$ | $10^9$ | 1.5(G=1000) | 5(G=1) |
| ±50/±15/±5(G=1000) | 0,-50/-20/-20 | 2x/10°C | $10^{12}$ | $10^{12}$ | 2(G=1000) | 80(G=1) |
| ±10/±1000/±200 | ±50nA | ±1.0nA/°C | $10^9$ | — | — | — |
| ±5(G=1000) | ±100nA | — | $2 \times 10^9$ | — | 1mV | — |
| ±100 RTI,G=100 typ | 0,-50 | 2x/10°C | $10^{12}$ | $10^{11}$ | 3 | 5 |
| 100 typ | 0,-50 | 2x/10°C | $10^{12}$ | $10^{11}$ | 3 | 5 |
| ±100 typ | 0,-50 | 2x/10°C | $10^{12}$ | $10^{11}$ | 3 | 5 |
| ±125 typ | 0,-50 | 2x/10°C | $10^{12}$ | $10^{11}$ | 6 | 15 |

# GENERAL PURPOSE-MODERATE PERFORMANCE
## MODELS 118, 119, 201A, 507, 741, 208




### GENERAL DESCRIPTION

Amplifiers in this group include Analog's lowest cost devices. They are best suited for general purpose designs with moderate drift requirements in the range from 5 to 40$\mu$V/°C, unity gain bandwidths to 1MHz, and full power response to 100kHz. Using silicon bipolar transistors as the differential input stage, bias currents range from 2 to 75nA placing upper limits of 10k to 100k ohms on circuit impedances for best performance. Typical applications include linear designs for summing, inverting, impedance buffering (followers) and active filtering. They are also useful for developing non-linear transfer functions.

### MODEL 118 A/K: LOWEST COST

The first op amp to consider for general purpose applications is model 118, a discrete component amplifier which surpasses the performance of lower cost IC's. It has high open loop gain and good slew rate with drifts of 20$\mu$V/°C (118A) and 5$\mu$V/°C (118K). Careful component selection and advanced design techniques yield low bias current and low thermal overshoots for improved performance over earlier discrete op amp designs.

Model 119 A(K) is identical to 118 A(K) except for its higher 20mA output current at ±10V. For ±20 volt output voltage requirements, select model 163 to replace model 118, and model 165 for model 119 replacement. (See page 48, "High Output-Voltage, Current.")

### AD201/AD201A: ADJUSTABLE BANDWIDTH

The low cost AD201 series combines the dynamic response flexibility, afforded by external frequency compensation, with good DC performance. Because frequency compensation is performed externally, the AD201 provides a greater degree of design control, and permits the dynamic operating characteristics to be fitted to the specific system application. Other models to consider in this series are AD101A (military grade) and AD301A (industrial grade). The device offers full short circuit protection, external offset voltage nulling, and the absence of latch-up. (See also Linear IC Section.)

### AD507 J/K: 35V/$\mu$sec SLEWING

The AD507 at economical prices has improved frequency and gain characteristics over other general purpose monolithic designs. Typical specifications include 35V/$\mu$sec slew rate, 100MHz gain bandwidth, 150,000 V/V gain and low 5nA bias current. Available with external offset trim and

| (Specifications typical @ +25°C and ±15VDC power supply unless otherwise noted.) | Discrete: Good Performance, Economy 118 |
|---|---|
| Model | A / K |
| Open Loop Gain | |
| DC Rated Load, V/V min | 250,000 |
| Rated Output, min | ±10V@5mA |
| Frequency Response | |
| Unity Gain, Small Signal | 1.5MHz |
| Full Power Response, min | 100kHz |
| Slewing Rate, min | 6V/$\mu$s[1] |
| Overload Recovery | 0.5ms |
| Input Offset Voltage | |
| Initial, 25°C, (adj. to zero) max | ±5mV |
| Avg. vs. Temp, max | ±20 / ±5$\mu$V/°C |
| vs. Supply Voltage | ±10$\mu$V/% |
| vs. Time | ±200$\mu$V/mo. |
| Input Bias Current | |
| Initial, 25°C, max | ±35nA |
| Avg. vs. Temp, max | ±0.6 / ±0.5nA/°C |
| Input Difference Current | |
| Initial, 25°C, max | ±3nA |
| Avg. vs. Temp, max | ±0.1 / ±0.05nA/°C |
| Input Impedance | |
| Differential | $10^6\ \Omega$ |
| Common Mode | $10^9\ \Omega$ |
| Input Noise | |
| Voltage, 0.01 to 1Hz, p-p | 1$\mu$V |
| 10Hz to 10kHz, rms | 2$\mu$V |
| Current, 0.01 to 1Hz, p-p | 20pA |
| Input Voltage Range | |
| Common Mode Voltage, min | ±10V |
| Common Mode Rejection | 86dB |
| Max Safe Differential Voltage | ±15V |
| Power Supply Range (VDC) | ±(12 to 18)V |
| Rated Specification (VDC) | ±15V@4mA |
| Temperature Range | |
| Operating, Rated Specification | -25 to +85°C 0 to +70°C |
| Package Outline | M-1 |
| Case Dimensions | 1" x 1" x 0.5" |
| Price | ↑ |

(1)20kHz and 1.2V/$\mu$s for non-inverting operation.
(2)Compensated gain of 20dB.

frequency adjustment terminals, this device may be designed to meet a wide range of applications. (See also Linear IC Section.)

### AD741 K/L: LOWEST COST

These low cost devices are general purpose op amps with internal frequency compensation and improved 741 specifications. As members of the 741 class of amplifiers, their tighter specifications allow present designs using 741 socket, to be upgraded with devices having guaranteed limits on offset voltage and current drift. (See also Linear IC Section.)

### AD208/208A: LOW BIAS CURRENT

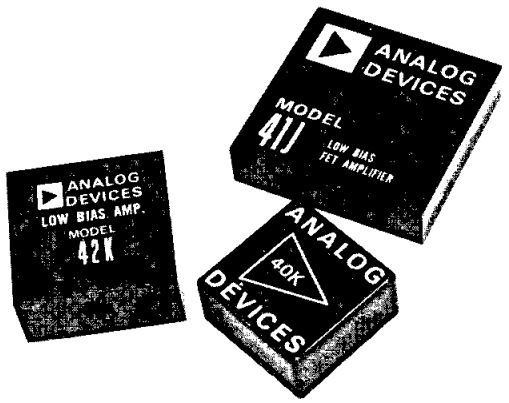
Using a superbeta input device, AD208A offers low bias current, to 2nA, for use with higher circuit impedances or for lower current drift. The "A" selection has lower offset voltage and drift with specified minimum gain and CMRR ratings. Included in this series are models AD108/AD108A (military grade) and AD301/AD301A (industrial grade) with varying specifications for temperature operating range and input characteristics. (See also Linear IC Section.)

| | Microcircuit | | | |
|---|---|---|---|---|
| Low Cost, 20mA Output 119<br>A K | Economy, Speed AD201A | Low Cost General Purpose AD741<br>K L | Super Beta Low 2nA Bias AD208<br>AD208 AD208A | Highest Performance General Purpose AD507<br>J K |
| 500,000 | 50,000 | 50,000 | 50,000 \| 80,000 | 80,000 |
| ±10V@5mA | ±10V@5mA | ±10V@5mA | ±13V@1.3mA | ±10V@10mA |
| 1.5MHz<br>100kHz<br>6V/μs[1]<br>0.5ms | 1MHz<br>10kHz typ<br>0.5V/μs typ<br>--- | 1MHz<br>10kHz typ<br>0.5V/μs typ<br>--- | 1MHz<br>10kHz typ[2]<br>0.3V/μs typ<br>--- | 35MHz<br>320kHz<br>20V/μs<br>--- |
| ±5mV<br>±20 \| ±5μV/°C<br>±10μV/%<br>±200μV/mo. | ±2mV<br>±15μV/°C<br>15μV/% max<br>--- | ±2mV \| ±0.5mV<br>±15 \| ±5μV/°C<br>2μV/% max<br>--- | ±2mV[3] \| ±0.5mV<br>±15 \| ±5μV/°C<br>15μV/% max<br>--- | 5mV \| 3mV<br>15 typ \| 15μV/°C max<br>30 \| 15μV/% max<br>--- |
| ±35nA<br>±0.6 \| ±0.5nA/°C | ±75nA<br>--- | ±75nA<br>--- | ±2nA<br>--- | 25nA \| 15nA<br>--- |
| ±3nA<br>±0.1 \| ±0.05nA/°C | ±10nA<br>±0.2nA/°C | ±10nA<br>±0.2nA/°C | ±0.2nA<br>±2.5pA/°C | 25nA \| 15nA<br>--- |
| $10^6$ Ω<br>$10^9$ Ω | 4 x $10^6$ Ω<br>--- | 5 x $10^6$ Ω<br>--- | 70 x $10^6$ Ω<br>--- | 300 x $10^6$ Ω<br>--- |
| 1μV<br>2μV<br>20pA | 2μV<br>4μV<br>--- | 4μV<br>5μV<br>--- | ---<br>---<br>--- | ---<br>7μV(1 to 100kHz)<br>--- |
| ±10V<br>86dB<br>±15V | ±12V<br>96dB<br>±30V | ±12V<br>100dB<br>±30V | ±14V<br>100dB<br>Note[4] | ±11V<br>100dB<br>±12V |
| ±(12 to 18)V<br>±15V@2mA | ±(3 to 22)V<br>±15V@3mA | ±(3 to 22)V<br>±15V@2.8mA | ±(2 to 20)V<br>±15V@0.6mA | ±(5 to 20)V<br>±15V@4mA max |
| -25 to +85°C \| 0 to +70°C | -25 to +85°C | 0 to +70°C | -25 to +85°C | 0 to +70°C |
| F-1<br>1.5" x 1.5" x 0.4" | TO-99<br>--- | TO-99<br>--- | TO-99<br>--- | TO-99<br>--- |

(3)No provision for external $V_{os}$ null.
(4)Shunt-diode input protection. Current must be limited to ±10mA.

# GENERAL PURPOSE FET-LOW BIAS, HIGH $Z_{IN}$
## MODELS 40, 43, 41, 146, AD503, AD511, AD513

### GENERAL DESCRIPTION
General purpose FET amplifiers should be considered for moderate performance designs requiring high input impedance, low bias currents and bandwidths to 1MHz. These models should meet most design requirements, especially those which cannot be satisfied by bipolar input designs because of excessive bias currents or too low input impedance. The lower bias currents (1 to 100pA) and higher input impedances ($10^{11}$ ohms) of FETS make them a natural choice when amplifier gain networks exceed 100k ohms and it is necessary to minimize input loading and current offset errors for improved accuracy. Significant applications include integrators, sample and hold amplifiers, current to voltage converters and low bias current log circuits.




### MODEL 40 J/K: ECONOMY, LOW BIAS
The popular model 40J is a best choice for OEM designs and for the general class of applications requiring low bias current (50pA), moderate offset drift (50μV/°C), and high input impedance ($10^{11}\Omega$). Designed with minimum performance tradeoffs, it has high gain, for improved closed loop accuracy, and 5MHz bandwidth with stable 6dB roll-off. Select model 40K for a lower 20μV/°C offset drift and a bias current of 20pA.

### MODEL 43J: GUARANTEED 80dB CMR
Closely resembling model 40J in performance, model 43J has improved bias currents of 10pA and offset drift of 30μV/°C. It is especially noted for its guaranteed CMR of 80dB at ±11 volts for accurate noninverting buffer or differential applications. Its 10pA bias and high input impedance are desirable for accurately amplifying small current or voltage signals approaching those levels requiring electrometer designs.

### MODEL 41 J/K/L: HIGH CMR, 0.5pA DIFFERENTIAL FET
Model 41 has guaranteed bias currents from 0.5pA to 0.15pA max, typical CMR of 94dB, and a 1MHz bandwidth. It was specifically designed for low level current measurements demanding minimal errors when used with high impedance sources such as pH transducers, photomultipliers and long term integrators. Its speed, high CMR and low input capacitance also make it useful for medium speed automated test systems.

### MODEL 42 J/K/L: 110dB GAIN, SUB-PICOAMP ECONOMY
Undoubtedly one of the best values for OEM designs, the model 42 is an ultra low bias current FET useful for measuring low level currents or voltages from high source impedance such as photo/ion detectors and pH transducers. Typical specifications include 110dB open loop gain, 1 MHz bandwidth and CMR of 66dB at ±1V for differential designs. Models are available with 0.5pA bias, 75μV/°C (42J), 0.25pA and 25μV/°C (42K) and 0.15pA and 75μV/°C (42L). Refer to Electrometer Amplifier product group for further information.

### MODEL 146 J/K: LOWEST VOLTAGE DRIFT
Model 146 features low voltage and current drift for use with high impedance sources. High CMR performance make this differential FET amplifier especially useful for bridge circuits and buffer designs where good CMR performance

| (Specifications typical @ +25°C and ±15VDC power supply unless otherwise noted.) | Lowest Cost Discrete—$12 40 | |
|---|---|---|
| **Model** | **J** | **K** |
| Open Loop Gain<br>DC Rated Load, V/V min | 50,000 | |
| Rated Output, min | ±10V@5mA | |
| Frequency Response<br>Unity Gain, Small Signal<br>Full Power Response, min<br>Slewing Rate, min<br>Overload Recovery | 4MHz<br>100kHz<br>6V/μs<br>4μs | |
| Input Offset Voltage<br>Initial, 25°C, (adj. to zero) max<br>Avg. vs. Temp, max<br>vs. Supply Voltage<br>vs. Time | ±2mV[1]<br>±50 | ±20μV/°C<br>±50μV/%<br>±250μV/mo. |
| Input Bias Current<br>Initial, 25°C, max<br>(Doubles every +10°C) | 0, -50pA | 0, -20pA |
| Input Difference Current<br>Initial, 25°C<br>(Doubles every +10°C) | ±25pA | ±10pA |
| Input Impedance<br>Differential<br>Common Mode | $10^{11}\Omega$//3.5pF<br>$10^{11}\Omega$//3.5pF | |
| Input Noise<br>Voltage, 0.01 to 1Hz, p-p<br>5Hz to 50kHz, rms<br>Current, 0.01 to 1Hz, p-p | 6μV<br>3μV<br>0.1pA | |
| Input Voltage Range<br>Common Mode Voltage, min<br>Common Mode Rejection<br>Max Safe Differential Voltage | +8, -10V<br>80dB(+8, -10V)<br>±15V | |
| Power Supply Range, $\pm V_S$ (VDC)<br>Rated Specification (VDC) | ±(12 to 18)V<br>±15V@5.5mA | |
| Temperature Range<br>Operating, Rated Specifications | 0 to +70°C | |
| Package Outline [2]<br>Case Dimensions | M-2<br>1" x 1" x 0.5" | |
| Price | | |

(1)With external 499k trim
(2)With trim terminals open

is required for accuracy. For source impedances below 100kΩ, the 184 series low drift amplifiers are a good alternative to model 146. The models 146J and 146K have 7μV/°C and 2μV/°C voltage drift respectively, with 80dB CMR and 20mA output. Other specifications include $10^{11}\Omega$ input impedance, 5MHz bandwidth, 10V/μsec slew rates, bias currents to 20pA and 100dB gain for use with high speed integrators, current to voltage converters, accurate buffer designs and, in general, where speed and FET characteristics must be combined with good drift performance.

**AD503 J/K: ECONOMY, MONOLITHIC FET**

These internally compensated FET op amps, with stable 6dB roll-off provide a good combination of economy and performance for most FET applications. In addition to their high CMRR, slew rate and low bias current, the nulling technique for trimming offset voltage results in only minor changes in drift performance – unlike other comparable IC FET designs.

Offered in an AD741 pin configuration, other models in this series include AD506 J/K/S with less than 1mV of offset voltage. Refer to linear IC section for more information.

**AD511 A/B: HYBRID, LOWEST BIAS AND OFFSET**

These devices are low cost replacements for AD501 and ADP501 type hybrid amplifiers and are manufactured by combining FET input chips with a monolithic bipolar op amp on a laser trimmed substrate. Offsets are held below 1mV while drift and bias currents are less than 25μV/°C and 5pA respectively. See linear IC section for more information.

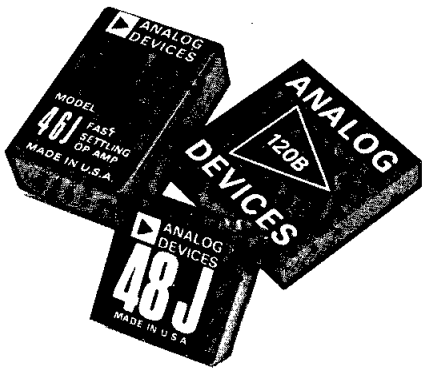
**AD513 J/K: ADJUSTABLE GAIN BANDWIDTH**

Useful for high speed comparators, integrators, sample/hold or peak detectors, the AD513 offers external frequency compensation for adjusting gain bandwidth and slew rate performance. Using either simple lag or feedforward compensation, GBW products and slew rates of 30MHz and 50V/μsec may be achieved with ease. AD513J has offsets of 50mV, bias currents of 30pA and drifts to 28μV/°C. For comparable performance with lower offsets to 3mV, select the AD516 series with laser trimmed offsets. See Linear IC section also.

| Discrete | | | | | Microcircuit | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Economy Guaranteed CMR Low Bias 43 | High Performance Lowest Bias Wideband, High CMR 41 | | | Lowest Drift 20mA Output 146 | | Best Choice Economy (Low Offset) AD503 (AD506) | | Low Cost Minipackage Replacement AD511 | | High GBW, Slew Rate (Low Offset) AD513 (AD516) | |
| J * | J | K | L | J | K | J | K | A | B | J | K |
| 50,000 | 100,000 | | | 100,000 | | 20,000 | 50,000 | 25,000 | | 20,000 | 50,000 |
| ±10V@5mA | ±10V@5mA | | | ±10V@20mA | | ±10V@5mA | | ±10V@5mA | | ±10V@5mA | |
| 4MHz<br>100kHz<br>6V/μs<br>4μs | 1MHz<br>50kHz<br>3V/μs<br>2μs | | | 5MHz<br>150kHz<br>10V/μs<br>1.5ms | | 1MHz<br>100kHz typ<br>5V/μs typ | | 1MHz<br>70kHz<br>5V/μs<br>6μs | | 1MHz<br>100kHz typ<br>20V/μs typ | |
| ±2mV[1]<br>±30μV/°C<br>±50μV/%<br>±250mV/mo. | ±2mV[2]<br>±25 | ±10<br>±10μV/%<br>±250μV/mo. | ±25μV/°C | ±0.7mV[3]<br>±7 | ±2μV/°C<br>±15μV/%<br>±100μV/mo. | ±50(3.0)mV<br>±75<br>±12 | ±20(1.5)mV<br>±25μV/°C<br>±6μV/% | ±2mV<br>±75<br>±15μV/% | ±1mV<br>±25μV/°C | ±50mV<br>±75<br>±50 | ±20mV<br>±25μV/°C<br>±15μV/% |
| 0, -10pA | 0, -0.5pA | -0.25pA | -0.15pA | 0, -30pA | -20pA | -15pA | -10pA | -25pA | -10pA | -30pA | -20pA |
| ±3pA | ±0.2pA | ±0.1pA | ±0.1pA | ±10pA | | ±10pA | ±5pA | — | | ±20pA | ±10pA |
| $10^{11}\Omega$//3.5pF<br>$10^{11}\Omega$//3.5pF | $10^{13}\Omega$//3.5pF<br>$10^{13}\Omega$//3.5pF | | | $10^{11}\Omega$//3.5pF<br>$10^{11}\Omega$//3.5pF | | $10^{11}\Omega$<br>$10^{12}\Omega$ | | $10^{11}\Omega$<br>$10^{12}\Omega$ | | $10^{11}\Omega$<br>$10^{12}\Omega$ | |
| 6μV<br>3μV<br>0.1pA | 8μV<br>10μV<br>— | | | 6μV<br>16μV<br>0.1pA | | 30μV<br>15μV<br>— | | 30μV<br>15μV<br>— | | 30μV<br>15μV<br>— | |
| ±11V<br>80dB min@±10V<br>±15V | ±10V<br>94dB[4]<br>±15V | | | ±10V<br>80dB(+5, -10V)<br>±15V | | ±10V<br>70dB | 80dB<br>±4V(for Ib level) | ±10V<br>86dB<br>— | | ±10V<br>70dB | 80dB<br>±$V_S$ |
| ±(12 to 18)V<br>±15V@5.5mA | ±(12 to 18)V<br>±15V@8mA | | | ±(12 to 18)V<br>±15V@5mA | | ±(5 to 18)V<br>±15V@4mA | | ±(5 to 18)V<br>±15V@4mA | | ±(5 to 18)V<br>±15V@4mA | |
| 0 to +70°C | 0 to +70°C | | | 0 to +70°C | | 0 to +70°C | | -25 to +85°C | | 0 to +70°C | |
| M–2<br>1" x 1" x 0.5" | F–1<br>1.5" x 1.5" x 0.4" | | | F–1<br>1.5" x 1.5" x 0.4" | | TO–99<br>— | | FP-1<br>0.6" x 0.6" x 0.25" | | TO–99<br>— | |

(3)With external trim resistor supplied
(4)CMR @ ±5V. Option 'V' provides 80dB CMR @ ±10V

# WIDE BANDWIDTH-FAST SETTLING
## MODELS 45, 46, 48, 44, 120, AD505




### GENERAL DESCRIPTION

Amplifiers in this group feature both FET and bipolar designs with differential and single ended input stages to provide a wide choice of drift and bias current specifications. They emphasize exceptionally fast response and wide bandwidths for applications in data acquisition and pulse data transmission systems. Critical specifications are step response settling time, full power response and stable 6dB roll-off. Low output impedance and output current capability also become important for line driving applications and immunity from capacitive loads or oscillations. Typical performance numbers are unity-gain bandwidths to 40MHz, 0.1% settling times to 100ns, 1000V/μs slew rates, and 10MHz full power response.

These amplifiers are useful for sample and hold circuits, A/D converters, or as high speed buffers and integrators. Offering high output current capability, they should be considered for video or line driver circuits, D to A output amplifiers or as deflection control amplifiers.

### MODEL 46 J/K: 1000V/μs DIFFERENTIAL, 100ns SETTLING FET

The model 46, an extremely fast amplifier, should be considered if settling time, slew rate or bandwidth are critical requirements for digital and linear signals in the 100ns and 10MHz region. It is an exceptionally stable FET amplifier offering guaranteed 1000V/μs slew rate, 100ns settling time to 0.1% and 40MHz bandwidth with −6dB per octave roll off.

### MODEL 45 J/K: ECONOMY, 1μsec SETTLING FET

Designed for use with A to D, D to A and multiplexer circuits, the model 45 FET amplifier is the best choice for most inverting and noninverting applications. It offers a good balance between cost and performance with 75V/μsec slew rate, 10MHz unity gain bandwidth and 20mA output for driving up to 700pF of capacitance. Models 45J (50μV/°C, 25pA bias) and 45K (15μV/°C, 10pA bias) settle to 0.01% in 1 μsec (max) inverting; CMR capability is 74dB at +5V, −10V CMV making it useful as a follower at minimum gains of 2V/V, noninverting.

Unlike most available high speed amplifiers, model 46 uniquely combines the above specifications with a 100mA output capability and will operate as an inverting or non-inverting amplifier. The CMR is 4000 min (15,000 typical) at a full ±10V. Maximum offset drifts of 75μV/°C (46J) and 25μV/°C (46K) complete the performance profile which suits this amplifier well for both digital signal conversion and wideband linear applications which include A/D, D/A converters, video and booster circuits and multipliers.

To satisfy OEM requirements for low cost, the model 46 uses the latest design techniques and components to achieve guaranteed performance at very competitive prices.

### MODEL 48 J/K: 300ns SETTLING, 80dB CMR

Model 48 is an ultra fast differential amplifier, optimized for D/A and A/D converter applications demanding excellent slew rate, settling time and DC characteristics. When used with these high speed circuits, its smooth settling response and wideband CMR capability are particularly useful for resolving small bit increments and for rejecting logic ground noise.

| (Specifications typical @ +25°C and ±15VDC power supply unless otherwise noted.) | Lowest Cost 1μs to 0.01% 45 |
|---|---|
| Model | J K |
| Open Loop Gain | |
| DC Rated Load, V/V min | 50,000 |
| Rated Output, min | ±10V@20mA |
| Frequency Response | |
| Unity Gain, Small Signal | 10MHz |
| Full Power Response, min | 1MHz |
| Slewing Rate, min | 75V/μs |
| Overload Recovery | 0.5μs |
| Settling Time to 0.01% | 1.0μs, max |
| Settling Time to 0.1% | 500ns |
| Input Offset Voltage | |
| Initial, 25°C, (Adj. to zero) | ±2mV[4] |
| Avg. vs. Temp, max | ±50 \| ±15μV/°C |
| vs. Supply Voltage | ±50μV/% |
| vs. Time | ±250μV/mo. |
| Input Bias Current | |
| Initial, 25°C, max | 0, -50pA \| 0, -25pA |
| Avg. vs. Temp, max | 2x/10°C |
| Input Impedance | |
| Differential | $10^{11}$ Ω//3.5pF |
| Common Mode | $10^{11}$ Ω//3.5pF |
| Input Noise | |
| Voltage, 0.01 to 1Hz, p-p | 5μV |
| 50Hz to 50kHz, rms | 3μV |
| Current, 0.01 to 1Hz, p-p | 0.1pA |
| Input Voltage Range | |
| Common Mode Voltage, min | — |
| Common Mode Rejection @ ±10V | 74dB (+5, -10V)[8] |
| Max. Safe Differential Voltage | ±15V |
| Power Supply Range (VDC) | ±(12 to 18)V |
| Rated Specification (VDC) | ±15V@7mA |
| Temperature Range | |
| Operating, Rated Specifications | 0 to +70°C |
| Package Outline | QC−1 |
| Case Dimensions | 1.125" x 1.125" x 0.4" |
| Price | \| |

(1)External trim adjustment
(2)Model 48 non-inverting slew rate-90μs
(3)Model 44 non-inverting slew rate-50V/μs

Typical specifications for this FET design include 300ns settling to 0.01% (inverting or noninverting), CMR of 80dB at ±10V, open loop gain of 100dB and 125V/μsec slew rate (inverting). Extremely stable at 15MHz bandwidths, model 48 has good immunity to oscillations under heavy load capacitance, to 750pF. This device is available in two drift selections, 50μV/°C (48 J) and 15μV/°C (48K), and uses monolithic input stages to minimize thermal feedback affects for improved small signal resolution.

**MODEL 44 J/K: 0.01% BUFFER, 1 μsec SETTLING FET**
Model 44 is a fast differential amplifier with guaranteed CMR of 80dB at ±10V for high speed non-inverting buffer applications requiring high open loop gain and 0.01% full scale accuracy with 1μsec settling times. Capable of driving 1000pF capacitive load, its smooth settling characteristics make it a good choice for 12-bit D/A, A/D circuits, multiplexers, peak detectors, and sample/hold circuits where overall speed is affected by this cascaded circuit element. Other specifications include 100dB open loop gain, 10MHz bandwidth, 50V/μsec slew rate, 20mA output. Model 44J is available with 50μV/°C drift and model 44K with 15μV/°C drift.

Model 47 A/B (not tabulated), with all hermetically sealed devices, is recommended to upgrade models 44 and 45 for wider temperature range applications as required in military grade circuits. Settling time is 1μs to 0.01% (inverting and noninverting) and CMR is 86dB at ±10V. Other specifications parallel those of model 44 J/K.

**MODEL 120 A/B: 100MHz BANDWIDTH, 1 μsec SETTLING**
The model 120 offers design flexibility in an inverting amplifier with bipolar input stage and externally adjustable gain-bandwidth product from 10MHz to 100MHz. Requiring only a single resistor for frequency response shaping, it is very useful for providing large gains at wide bandwidth, as used in video circuits, radar signal processing, fast Fourier Transformer or, in general, whenever fast low level signals must be amplified accurately. At lower gains, it achieves 250V/μsec slew rates and 1μsec settling with 0.01% error for use in comparators, D/A converters or in other high speed circuits.

Optimized for use with circuit impedances below 10kΩ, the model 120 will deliver 25mA and is available in two versions: 120A (15μV/°C) and 120B (8μV/°C).

**AD505 J/K: WIDEBAND, FAST SETTLING MONOLITHIC**
Model 505, with bipolar input, features high gain, low voltage drift and wide bandwidth when operated in the inverting mode. Using external frequency compensation, these devices should be considered for high speed applications requiring fast slew rates and settling times or whenever high loop gain is required at wideband frequencies. Typical applications include active filters, sample/hold circuits, D/A and A/D converters.

Specifications include high open loop gain, 130V/μsec slew rate and 100nA bias current. It is available in two drift selections, 25μV/°C (J) and 10μV/°C (K).

| Discrete | | | | | | | Microcircuit | | |
|---|---|---|---|---|---|---|---|---|---|
| 100ns Settling to 0.1%<br>1000V/μs, Differential<br>100mA Driver<br>46 | | 300ns to 0.01%<br>Smooth Settling<br>48* | | Accurate Buffer<br>1μs to 0.01%<br>44 | | Wideband 100MHz<br>250V/μs<br>120 | Wideband<br>120V/μs Inverter<br>AD505 | | |
| J | K | J | K | J | K | A B | J | K | S |
| 25,000 | | 100,000 | | 100,000 | | 500,000 | 100,000 | 250,000 | 250,000 |
| ±10V@100mA | | ±10V@20mA | | ±10V@20mA | | ±10V@25mA | ±10V@5mA | | |
| 40MHz<br>10MHz<br>1000V/μs<br>0.2μs<br>300ns, max<br>100ns max | | 15MHz<br>1.5MHz inv 1MHz noninv<br>125V/μs[2]<br>0.5μs<br>300ns<br>250ns | | 10MHz<br>1MHz<br>75V/μs[3]<br>0.5μs<br>1.0μs, max<br>500ns | | 10 to 100MHz[1]<br>4MHz<br>250V/μs<br>10μs<br>1.0μs<br>--- | 10MHz<br>2MHz typ<br>120V/μs typ<br>---<br>2μs<br>800ns | | |
| ±3mV<br>±75<br>±30μV/%<br>±500μV/mo. | ±25μV/°C | ±2mV[4]<br>±50<br>---<br>±250μV/mo. | ±15μV/°C | ±2mV[4]<br>±50<br>---<br>±250μV/mo. | ±15μV/°C | Adjust to 0<br>±15<br>20μV/%<br>50μV/mo. | ±5.0mV<br>±15<br>±45μV/% | ±2.5mV<br>±8 | ±2.5mV max<br>±10μV/°C typ |
| 0, -100pA<br>2x/10 °C | | 0, -50pA<br>2x/10 °C | 0, -25pA | 0, -50pA<br>2x/10 °C | 0, -25pA | 0, +55nA<br>0.9 | 75nA | 25nA | 25nA |
| $10^{11}$ Ω//3.5pF<br>$10^{11}$ Ω//3.5pF | | $10^{11}$ Ω//3.5pF<br>$10^{11}$ Ω//3.5pF | | $10^{11}$ Ω//3.5pF<br>$10^{11}$ Ω//3.5pF | | Note[5] | Note[6] | | |
| 10μV<br>Note[7]<br>0.1pA | | 2μV<br>3μV<br>0.1pA | | 2μV<br>3μV<br>0.1pA | | 0.5μV<br>3μV<br>100pA | 8μV(0.01Hz to 10Hz)<br>20μV(10Hz to 1MHz)<br>200pA(0.01Hz to 10Hz) | | |
| ±10V<br>72dB min<br>±15V | | ±11V<br>80dB min<br>±15V | | ±11V<br>80dB, min<br>±15V | | NA<br>NA<br>±15V | NA<br>NA<br>±10V | | |
| ±(12 to 18)V<br>±15V@55mA | | ±(12 to 18)V<br>±15V@9mA | | ±(12 to 18)V<br>±15V@9mA | | ±(13 to 18)V<br>±15V@20mA | ±(5 to 18)V<br>±15V@6mA | | |
| 0 to +70°C | | 0 to +70 °C | | 0 to +70 °C | | -25 to +85 °C | 0 to +70°C | 0 to +70°C | -55 to +125°C |
| M-1<br>1.22" x 1.88" x 0.6" | | QC-1<br>1.125" x 1.125" x 0.4" | | QC-1<br>1.125" x 1.125" x 0.4" | | F-3<br>1.5" x 1.5" x 0.4" | TO-100<br>--- | | |

(4)With fixed 499Ω external trim
(5)200KΩ at DC; 10k//3pf above 10Hz
(6)2MΩ at DC; 20k above 10Hz
(7)3μV rms 5Hz to 16kHz; 25μV 5Hz to 2MHz
(8)CMR specified at +5V, −10V. Option 'V' provides CMR of 74dB min at ±10V.
*Model 48 is a new product. Available: May, 1972.