IC op amps have evolved from general-purpose differential-input amplifiers into many specialized types. Precision, high-speed, power and programmable versions abound.

Op amps have evolved from low-performance general-purpose devices to high-performance units, some highly specialized for specific needs. But no one type completely approaches all the properties of an ideal op amp.[1] These ideal properties include:

- Infinite voltage gain.
- Infinite input resistance.
- Zero output resistance.
- Infinite bandwidth.
- Zero offset voltage.

While these characteristics will never be completely attained by real op amps, continual improvements are bringing ideal performance closer and closer. As op amp prices come down, particularly in IC units, new applications crop up—from electrometers to audio amplifiers. And major advances—some by many orders of magnitude—have been made since the first widely used general-purpose 709 IC op amp.

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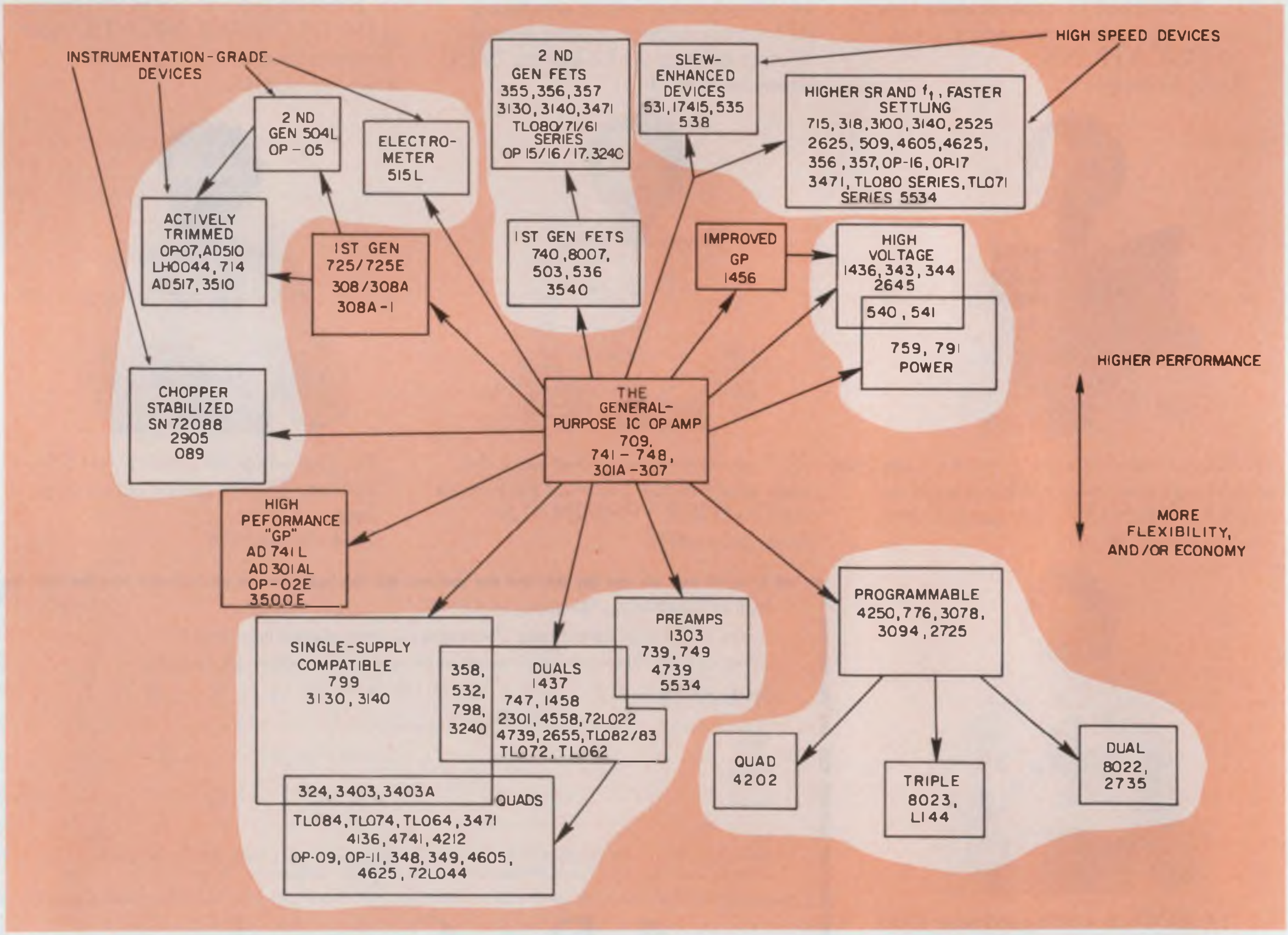
Right now, you can choose from thousands of IC op-amp types. However, certain units stand out, because either they have attracted a large market with their wide applicability, low price and multiple-source availability or because their performance capabilities are unique.

So-called general-purpose types are typified by 709,



1. **General-purpose IC op amps have evolved in numerous directions.** Many units now emphasize high speed, others are precision instrument-grade units, and some offer high voltage and power outputs. Dual and quad units save space and money in circuits that require several op amps, such as active filters and in data-gathering systems.

Table 1. General-purpose op amps

Typical specs

Input Characteristics									
Bias nA	Offset nA	Offset mV	Drift μV/°C	Common - mode RR dB	Power - supply RR dB	Gain dB	Slew rate V/μs	Unity - gain BW MHz
100	20	2	10	90	90	100	0.5	1

NOTE: Specs are for commercial units for operation in a 0-to-70-C ambient with ±5 to ±18-V supply voltage and 2-kΩ load. Standard supply is ±15 V. Premium versions of these op amps cover wider temperature ranges.

(a) Single unit devices

Internally compensated	Externally compensated
μA741 LM307	μA709 μA748 LM301A

(b) Dual devices

Moderate speed	Improved speed	High speed	Preamplifier
μA 747 MC 1458 (8) LM 358, LM 358 A (2) (3) (5) (8) NE 532 (2) (3) (5) (8) μA 798 (3) (8) SN 72L022 (5) (8) MC 1437 (7) LH 2301 (7)	RC 4558 (1) (8) RC 4739 (1) (8)	HA 2655 (8) TL 082 (8) TL 083 TL 072 (8) TL 062 (8) CA 3240 (3)	MC 1303 (1) (7) (15) μA 739 (1) (7) (15) μA 749 (1) (7) (15) RC 4739 (1) (8)

(c) Quad devices

Moderate speed	Improved speed	High speed
LM 324, LM 324A (2) (3) (5) MC 3403 (3) LM 348 (4) MC 4741 (4) SN 72L044 (5)	RC 4136 (1) HA 4741 (1) XR 4212 LM 349 (DEC) (4) RC 3403A (3) OP-09 (1) (10) OP-11 (1) (10) RC 4156 (1) TL 064	TL 084 MC 3471 HA 4605 (1) (9) HA 4625 (1) (DEC) TL 074 TL 075

(d) High-performance devices

Type	Input characteristics Bias nA	Offset nA	Offset mV	Drift μV/°C	Common - mode RR dB	Power - supply RR dB	Gain dB
OP-02E **	30	2	0.5	8	90	90	100
AD 741L	50	5	0.5	5	96	90	94
AD 301AL (7)	30	5	0.5	5	90	90	98
3500E **	50	30	0.5	1	88	100	100

Note: These specs are worst-case values at 25 C. **Available as matched pairs.

Notes applicable to all tables:

(DEC) Decompensated unit, not stable at unity gain
(1) Specified low input noise
(2) Class B output stage
(3) Input(s) (Output) will operate to V- (or ground)
(4) "True 741" inputs
(5) Low power operation
(6) Low supply voltage max limit
(7) External compensation (or components) required
(8) No offset null provision
(9) Specified for settling time
(10) Selections available, which improve parameter(s)
(11) Slew enhanced device
(12) Not specified as such, observed on typical samples
(13) Individual programming
(14) Common programming
(15) Single-ended output
(16) Limited common-mode

741 or 301A devices. Table 1 lists the popular units, including dual and quad versions, and some high-performance units. The typical specifications in Table 1 are composites of those for general-purpose op amps. Certain units may differ somewhat in one or two details, but these spec values are what experienced design engineers consider necessary for many of today's demanding applications.

The evolutionary route

Advanced op amps have evolved from the single-unit general-purpose types (Table 1a) to meet specific needs (Fig. 1). One path in the figure has led simply to multiple-unit packages that save money and space. For example, the 1437 and 2301 dual op amps are merely two units of types 709 and 301As, respectively, in a single package (Table 1b). And the very popular 741 boasts of many versions in both dual and quad packages, for example, the 747 is a dual and 348 a quad version (Table 1c).

Eight-pin mini-DIP configurations are almost universally used for dual units and 14-pin DIPs for quads (Fig. 2). Consequently, duals and quads usually lack an offset-null capability because of pin limiting.

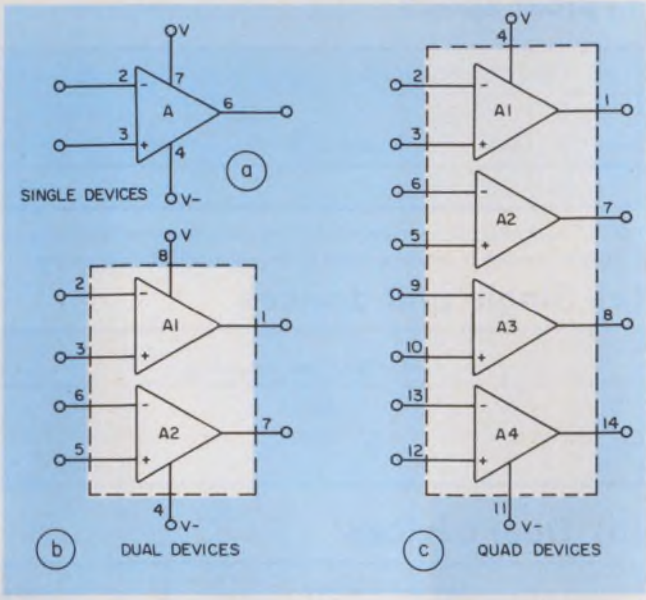
Other evolutionary paths have led to moderately over-all improved performance units, such as the "high-performance" general-purpose devices listed in Table 1d. Some paths led to specialized new designs whose performance in specific areas is vastly improved over general-purpose types (Tables 2 to 6).

Not only do dual and quad-packaged op amps save space and money, but many of them are improved-performance versions. In fact, manufacturers have increased the speed of some dual general-purpose op amps without major design changes.

Moderate-speed general-purpose op amps have a typical slew rate of 0.5 V/μs and f_t of 1 MHz. But in improved-speed types, the slew rate doubles to 1 V/μs and f_t triples to 3 MHz. Such improvements sometimes can change a marginally satisfactory circuit to one that performs brilliantly. Units with improved speed include the dual 4558, which is a pin-for-pin version of the moderate-speed 1458—another dual version of the 741.

To get speeds much higher than provided by the improved-speed, general-purpose devices, you must use a more specialized unit such as the 2655, whose slew rate is 5 V/μs and unity-gain bandwidth, 8 MHz. Instead of the common-junction isolation usually used in general-purpose op amps, the 2655 features dielectric isolation, which accounts for most of the speed improvement. Performance details of other fast op amps are covered in Table 4.

A number of dual op amps, though they have general-purpose operational specs, have specialized features such as single-power-supply compatibility and class-B outputs. Types 358 and 532 operate satisfactorily on single supplies, because their input and output voltage ranges can include their negative-



2. **Many single-unit op amps packaged in DIPs are pin-standardized** (a). Unfortunately, the limitations of 8-pin mini-DIP and 14-pin DIP packages for dual (b) and quad (c) devices don't allow for a nulling capability.

supply rail, even when grounded. Furthermore, these op amps provide class-B outputs, which allow low-power consumption when quiescent and efficient performance when operating.

While the 798 has characteristics similar to the 358 and 532, it has a class-AB output stage, which reduces class-B crossover distortion, but consumes higher quiescent power. For exceptionally low quiescent power, however, you should consider the 72L022—the lowest powered among the units listed (Table 1b).

Although specialized for preamplifier applications and in a strict sense not true op amps, the 1303, 739 and 749 devices are included in the dual-device Table 1b, because of their design similarity to op amps. These three preamplifiers feature common pinouts and are generally similar to each other. But the 4739, though listed as a preamplifier, can be used also as an improved-speed, general-purpose op amp. Originally designed as a replacement for the 1303, 739 and 749 units, the 4739 features something the others don't have—internal compensation.

Quad-packaged op amps, a logical extension of dual units, give further savings in cost and space—and some have even had their performance boosted (Table 1c). The 348 and MC4741, closest to quad versions of a 741, all have similar npn input stages—the other bipolar quads have pnp inputs. And the 4136, one of the first available quads, is equivalent to two dual improved-speed general-purpose 4558s.

Send in the quads

Another early quad, the 324, is single-supply compatible for low-power operation and works like two dual 358s. The 3403, also single-supply compatible, features a class-AB output stage for low crossover

Table 2. Instrument-grade op amps

	Type	Input characteristics: Bias nA	Offset nA	Offset mV	Drift $\mu V/^\circ C$ unnulled	Drift $\mu V/^\circ C$ nulled	Common-mode RR dB	Power-supply RR dB	Gain dB
1st gen.	μA 725E (1) (7)	75	5	0.5	2	1	120	106	120
	LM 308 A-1 (5) (7) (8)	7	1	0.5	1	—	96	96	98 (R_L=10 k)
2nd gen.	AD 504 L (1) (7)	80	10	0.5	2	1	110	100	120
	OP-05E (1)	4	3.8	0.5	2	0.6	110	94	106
Actively trimmed	OP-07E (1)	4	3.8	0.075	1.3	1.3	106	94	106
	AD510L (1)	10	2.5	0.025	2	0.5	110	100	120
	LH0044AC (1) (8)	15	2.5	0.05	0.5	0.5	120	120	120 (R_L=10 k)
	3510CM (1) (7)	15	10	0.06	0.7	0.5	110	110	120
	OP-12E	2	0.2	0.15	2.5	2.5	104	104	94
	AD517L ** (1)	1	0.25	0.025	0.5	0.5	110	110	120
	μA714E **	4	3.8	0.075	1.3	1.3	106	94	106
Chopper stabilized	SN72088 (7) (16)	10	0.6	0.15	1 (typ)	—	80 (typ)	70 (typ)	100
	HA2905 (7)	0.15 (typ)	0.05 (typ)	0.02 (typ)	0.2 (typ)	—	120 (16)	120	174 (typ)
	TL089 (7)	1	0.6	0.1	0.2 (typ)	—	100	100	100
Electrometer	AD515L (1) (5)	75 fA	—	1	25	—	70	74	88

NOTE: Specs are worst-case values at 25C. **Newly introduced — final specs not available.

distortion, like the dual 798. And quad unit 72L044, a dual 72L022 in quad form features very low-power operation, lower than the 324.

Of course, speed-improved devices also have their quad counterparts: the speed-improved quad 4136, HA4741, 4156, 4212 and 3403A units are similar to each other and have pinouts like the moderate-speed quad 324 (Fig. 2c). But the 349 is a decompensated unit, which means that it is unstable at unity gain, unlike most other op amps, but stable above some higher specified gain.

The high-speed quad devices in Table 1c are aimed mainly at active-filter applications, where speed and the availability of several devices in a single package are great assets. The 084, 074, 075 and 3471 FET units are particularly suitable for active-filter circuits, because they offer very low input-bias currents and high-input impedances, so they don't load tuning networks and reduce the circuit's Q. And their high slew rates and wide bandwidths provide low distortion and high accuracy at high frequencies.

High-performers swing with singles

Nevertheless, to improve the over-all performance of general-purpose op amps substantially, manufacturers are forced to stay with single-amplifier units. Table 1d lists key worst-case performance specs of high-performance op amps. Note the across-the-board tightening of all dc parameters, when compared with the Table 1a specs and worst-case limits. The OP02E, AD741L and 3500E are upgraded "pin-for-pin replacements" for the 741. And the AD-301AL is an improved 301A that features not only improved dc accuracy, but also the external-compensation flexibility of the basic 301A.

Even better accuracy can be achieved, by using some units in matched pairs. For instance, matched pairs of OP02Es, designated OP04E, and 3500Es, designated 3500MP, are often used as instrumentation amplifiers.

But for the highest precision, special instrument-grade amplifiers go past general-purpose units with vastly improved input dc characteristics along with higher open-loop gain (Table 2). Such op amps are used in very accurate dc and low-frequency measurement, control and analog-computing systems.

Instrument op amps drift less

The first widely used IC instrumentation op amp, the 725, provided substantially lower offset voltage and drift, and higher power-supply rejection ratio (PSRR), common-mode rejection ratio (CMRR) and gain over then existing devices. However, it didn't dramatically improve input-current requirements. This problem was taken care of by the super-beta 308 series, whose 308A-1 provides general-instrumentation quality, but at somewhat lower PSRR, CMRR and gain.

A second-generation instrumentation op amp, the 504L, comparable to the 725 in dc specs, features external single-component compensation and more predictable drift characteristics. The OP05E, however, is internally compensated, needs much lower bias current, and exhibits slightly less drift than the externally compensated 504L.

But active-circuit trimming techniques with lasers and other methods now make possible nearly the ultimate in "as-delivered" input-offset voltage specs —about 50 μV—and also reduced drift rates, typically less than 0.5 $\mu V/^\circ C$. Active-circuit trimmed op amps such as the OP07E, 510L and 0044AC compare favorably with the more complex chopper-stabilized amplifiers in both offset voltage and drift.

Table 2 lists some chopper-stabilized IC op amps, the 72088, 2905 and 089, which have FET inputs for low bias current. The oldest IC chopper amp, the 72088, possesses relatively poor specs. The newer 2905 has a good all-around collection of specs, and the 089, the most recently announced device, is similar, pin-for-pin, to the 2905.

Finally, electrometer-instrumentation op amps must operate with ultra-low input bias currents—less than 1 pA. Few amplifiers of any kind, let alone ICs, are suitable for such use. Nevertheless, the 515L IC op amp, which has a maximum input-bias current of 75×10^{-15} A, amply fills this requirement. The 515L represents the state of the art for low input-bias current. Fortunately, the device's remaining specifications are still reasonably good, although short of other instrumentation units.

FETs solve input-current problem

But not all applications require the extremely low input-current characteristic of an electrometer. Many uses merely need a reduction from the 10 to 100 nA of general-purpose op amps to, say, 10 to 100 pA. Unfortunately, the first monolithic FET-input op amps had notably poor dc characteristics (Table 3), although their input currents were less than 100 pA. Matching FETs in the op-amp differential inputs was difficult, so offsets and drift were high, and CMRR and PSRR were low. Nevertheless, these early units had slew rates over 10 times better than general-purpose 741s.

Second-generation units, however, offer low input current together with high slew rate and bandwidth without severe penalties in drift and other dc specs. For example, 3130s and 3140s with MOSFET inputs combine very low input current—5 to 10 pA—with reasonably low offset voltages and drifts, comparable to general-purpose units. Note: The 3140 is similar to the 741, but with FET-input characteristics, and the new 3240 is a dual 3140.

Ion-implanted JFETs in IC op amps, moreover, can be matched extremely well—like bipolar devices. The specs in Table 3 of the 355, 356 and 357 devices with ion-implanted JFETs clearly show the drift and offset improvements. The "A" versions have especially low offset voltages and drifts. Although not quite at the level of instrumentation-quality op amps, these devices are decidedly better than general-purpose units. Further details on the ac performance of FET units are included in Table 4.

The best over-all performance combination for FET-input op amps is provided by OP15/16/17 units, where well known current-mirror cancellation techniques keep bias currents low even at elevated temperatures. They are patterned after the 355/356/357 units, but offer greater speed and much lower dc errors, in many ways comparable to instrumentation-quality amplifiers.

Two of the newest FET op-amp types, the TL series and the 3471, are multi-unit devices. The 3471 is quad-packaged, has a particularly good slew rate—a minimum of 20 V/μs—and a 10-MHz unity-gain bandwidth. Both types are well suited to active-filter design. The TL080 is available in singles, duals and quads, and internally and externally compensated.

Table 3. FET - input op amps

Type		Input bias pA	Input offset mV	Input drift μV/°C	Common - mode RR dB	Power - supply RR dB	Slew rate V/μs	Unity - gain BW MHz
	μA 740	100	30	N.S.	80	83	6	1
1st	AD 503 (10)	15	20	30	90	74	6	1
gen	ICL 8007 (10)	3	20	N.S.	95	83	6	1
	NE 536	30	30	N.S.	80	80	6	1
	3540	50	50 (max)	75 (max)	90	64 (min)	6	1
	CA 3130 (3) (6) (7) (9)	5	8	10	90	90	10	4
	CA 3140 (3) (9)	10	5	N.S.	90	80	9	4.5
	LF 355, 355A (5) (9)	30	3, 1	5, 3	100	100	5	2.5
	LF356, 356A (1) (9)	30	3, 1	5, 3	100	100	12	5
2nd	LF 357, 357A (DEC) (1) (9)	30	3, 1	5, 3	100	100	50	20
gen	LF 351, 353, 347 (1) (9) (10)	50	10	10	100	100	13	4
	OP-15G, OP-15E (9) (10)	15	3, 0.5 (max)	15, 5 (max)	100	100	15, 17	5.4, 6
	OP-16G, OP-16E (9) (10)	15	3, 0.5 (max)	15,5 (max)	100	100	23, 25	7.2, 8
	OP-17G, OP-17E (DEC) (9) (10)	15	3, 0.5 (max)	15, 5 (max)	100	100	62, 7	26, 30
	TL 080 series (10)	30	15-3 (max)	10	86	86	12	3
	TL 071 series (10)	30	10-3 (max)	10	86	86	12	3
	TL 061 series (10)	30	15-3 (max)	10	86	95	3.5	1
	MC 3471 (8)	20	6 (max)	N.S.	80 (min)	70 (min)	20 (min)	10

NOTE: Specs are typical except as noted. Recently introduced FET op amps whose data were not available — CA 3240 (dual 3140), μAF 771, 772, 774 (single, dual, quad), LFT 356A (trimmed LF 356).

The LF 351/353/347 units also come in singles, duals and quads. Other TL versions, such as the TL071, feature low noise; the TL061 offers low power.

For high speed—specialized op amps

But if it's fast response you're mainly interested in, concentrate on selections from Table 4. These op amps emphasize one or all of the three major speed-related specs: slew rate, unity-gain bandwidth and settling time. Slew rate and bandwidth are closely related and well understood, but since settling time depends on many factors, it's difficult to pin down specific performance effects. Furthermore, settling time isn't always specified by the manufacturer. And when it is specified, seldom do the specs include your particular conditions.

The 3100 high-speed op amp combines bipolar and MOS techniques. External compensation helps to optimize its speed. The somewhat slower 3140, another combination device, has a MOSFET input and is internally compensated.

But the fastest device listed, the 2525, is a dielectrically isolated unit. It slews at 100 V/μs, has a correspondingly wide 20-MHz unity-gain bandwidth, and settles quickly, within 0.2 μs. These values are state of the art—the best combination of speed specs in an amplifier for both the inverting and noninverting operating modes.

However, another dielectrically isolated unit, the 2625, can be specially compensated to a bandwidth as high as 100 MHz. And the 715, one of the first high-speed IC op amps, is notable for very wide bandwidth. When compensated at high gain, its bandwidth can reach 3000 MHz.

For more of a compromise between slew rate and bandwidth, look to the 4625, a decompensated 4605 with a 70-MHz bandwidth and a 25-V/μs slew rate. (Note: bandwidth and slew rate in op amps usually increase with reduced compensation.)

For primarily improved slew rates regardless of bandwidth, a slew-enhanced device such as the 531 slews at 30 V/μs, but it's bandwidth is only 1 MHz. More recent units include the internally compensated 1741S and 535 devices; also the 538, a decompensated version of the 535.

If settling time is your concern, the 356 and 357 FET units stand out—only 1.5 μs with an error band of 0.01%—which can provide the high precision needed for such applications as d/a and a/d converters. The OP16 and OP17 offer the same general features as the 356 and 357 plus somewhat better dc properties, but the OPs' listed faster settle times—0.8 and 0.5 μs —have a wider error band, 0.1%, compared with 0.01% for the 356 and 357 FET units.

You can even get power op amps

Some general-purpose op amps have evolved into power-output devices (Table 5). For instance, the general-purpose 1456, which features super-beta input transistors for low bias current, has evolved into the

Table 4. High-speed op amps

Type	Slew rate* V/μs	Unity-gain bandwidth MHz	Settling time** μs	Input offset mV	Input bias nA
CA 3100 (7)	≥ 25	≥ 30	0.6 (0.5%)	1	700
CA 3140 (3)	9	4.5	1.4	5	0.01
HA 2525 (7)	100	20	0.2 (Av = 3)	5	125
HA 2625 (7)	≥ 7	≥ 12	N.S.	3	5
HA 4605 (1) (8) (quad)	4	8	4.2 (0.01%)	0.5	130
HA 4625 (1) (8) DEC (quad)	25	70	N.S.	0.5	130
AD 509 (7)	120	20	0.2	5	125
LF 356 (1)	12	5	1.5 (Av = −1, 0.01%)	3	0.03
LF 357 (DEC) (1)	50	20	1.5 (Av = −5, 0.01%)	3	0.03
OP-16 (1)	23	7.2	0.8 (Av = −1) 1.8 (Av = −1, 0.01%)	3	0.015
OP-17 (DEC) (1)	62	26	0.5 (Av = −5) 1.6 (Av = −5, 0.01%)	3	0.015
LM 318	≥ 70	≥ 15	0.8	4	150
MC 1741S (11)	12	1	3	2	200
MC 3471 (8) (quad)	20 (min)	10	N.S.	6 (max)	0.02
NE 531 (7) (11)	≥ 30	≥ 1	2.5 (0.01%)	2	300
NE 535 (11)	15	1	3	2	65
NE 538 (DEC) (11)	60	6	1.2	2	65
NE 5534 (1) (7) (10)	≥ 7	≥ 10	N.S.	0.5	500
TL 080 (7) (10)	≥ 12	≥ 3	N.S.	15-3 (max)	
TL 071 (10)	13	3	N.S.	10-3 (max)	0.03
μA 715 (7)	≥ 18	≥ 15	0.8 (Av = −1, 5 V)	2	400

NOTE: Specs are typical except where noted. *Unity gain, except for variable-compensation units that can reach high speeds indicated by ≥ symbol.
** With 0.1% error band for a ± 10-V step into a unity-gain follower, except as noted.

Table 5. High-voltage and power-output op amps

	Type	Supply voltage V (max)	Output voltage V (min), RL = 5 kΩ	Slew rate V/μs*	Gain dB	Input offset mV	Input bias nA
High voltage	MC 1436G	± 34	40 V p-p @ V_S = ± 28 V	2	114 (R_L = 100 kΩ)	5	15
	LM 343	± 34	40 V p-p @ V_S = ± 28 V	2.5	105 (R_L = 100 kΩ)	2	8
	LM 344 (7)	± 34	40 V p-p @ V_S = ± 28 V	≥ 2.5	105 (R_L = 100 kΩ)	2	8
	HA 2645	± 40	70 V p-p @ V_S = ± 40 V	5	106 (R_L = 100 kΩ)	2	12

	Type	Supply voltage V (max)	Output current mA	Output power W at 25 C	Slew rate V/μs	Gain dB	Input offset mV	Input bias nA
High power	NE 540 (DEC) (1) (7) (8)	± 20	± 100	1	≥ 4 (x 10 comp) (12)	(90,R_L ≥ 10 k) (12)	7	2000
	NE 541 (DEC) (1) (7) (8)	± 42	± 65	1	≥ 4 (x 10 comp) (12)	(90,R_L ≥ 10 k) (12)	7	2000
	μA 759 (3)	± 18	± 350	Int. limit	0.5	106, R_L ≥ 50 Ω	1	50
	μA 791 (7)	± 18	± 1000	Int. limit	≥ 0.5	86 min, R_L = 10 Ω	2	80

NOTE: Specs are typical except as noted. *Unity gain, except for variable-compensation units that can reach high speed indicated by a ≥ symbol.

Table 6. Programmable op amps.

Single		Dual		Triple	Quad
Moderate speed	High speed	Moderate speed	High speed		
4250 ICL 8021 μA 776 MC 3476 CA 3078 (7) (8) (10) CA 3094 (7) (8) (15)	HA 2725	ICL 8022 (13)	HA 2735 (13)	ICL 8023 (8) (13) L 144 (8) (14)	XR 4202 (8) (14)

1436, the first IC op amp to handle "high" voltages —a ±34-V maximum supply voltage. And it can supply a ±20-V output with a ±28-V supply and 5-kΩ resistive load.

Like most high-voltage op amps, however, the 1436 can't supply load currents much greater than a typical general-purpose unit. Still, even with its high-voltage capability, the 1436's remaining specs remain quite reasonable—better in fact than many general-purpose devices. Like the 1456, its bias current is low and its slew rate is high. But the LM 343/344 and HA 2645 have still lower offsets and input-bias currents.

Still you can get both high voltage and current (high power) in some op amps. Four high-power units are listed in Table 4. The 540 and 541 give you a choice of lower voltage and higher current, or the converse. The 540 provides ±20 V at ±100 mA and the 541, ±42 V—the highest voltage output on the list—at ±65 mA. However, both the 540 and 541 are decompensated and have no offset-null provisions, and thus, may not be flexible in use. The 540 can be compensated externally to a minimum gain of 10, with a resulting respectably high slew rate of 4 V/μs.

The 759 offers a conventional supply-voltage rating, but a high output current, 350 mA. And it can operate on a single supply with inputs whose difference can swing to ground.

The highest output current on the list, 1 A max, is supplied by the 791. Furthermore, the 791 is externally compensated so speed can be optimized—and its dc specs are similar to those listed for general-purpose operational amplifiers.

Program your own performance

Perhaps the most interesting of the IC op amps are some so-called specialized types that are programmable—which, ironically, makes them rather *un*specialized. The operating characteristic of programmable IC op amps can be adjusted with a control current, I_{set}, so that a single device can assume the operating characteristics of many devices. Input currents, bandwidth, slew rate and power dissipation are some of the key parameters directly adjustable by I_{set}. Also, programmable op amps can be used in micropower modes and in switched, on/off modes.

Programmable devices can be single, dual, triple or quad units (Table 6). The most popular single units include the 4250, 776, 8021 and 3476, which are internally compensated and pinned like a 741 (Fig. 2a), but with an extra pin (pin 8) for programming. The 3078 and 3094 are externally compensated and feature unusual capabilities, such as very low voltage (the 3078) and very high output current (the 3094).

Some IC op-amp manufacturers

Manufacturer	Typical op-amp number	Circle No.
Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086.	Second sourcing	**501**
Analog Devices, P.O. Box 280, Route 1 Industrial Park, Norwood, MA 02062.	AD504L, AD741L	**502**
Burr-Brown Research Corp., Int'l Airport Industrial Park, Tucson, AZ 85734.	3500E	**503**
Exar, 750 Palomar Ave., Sunnyvale, CA 94086.	XR4202	**504**
Fairchild Semiconductor, 464 Ellis St., Mountain View, CA 94040.	MA741, MA725E	**505**
Harris Semiconductor, Inc., P.O. Box 883, Melbourne, FL 32901.	HA2525, HA4741	**506**
Intersil, 10710 N. Tantau Ave., Cupertino, CA 95014.	ICL8007	**507**
Motorola Semiconductor, Box 20924, Phoenix, AZ 85036.	MC1456, MC4741	**508**
National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051.	LM301A, LF356, LH0044	**509**
Precision Monolithics, 1500 Space Park Dr., Santa Clara, CA 95050.	OP-05, OP-15, 16, 17, OP-09, OP-11	**510**
Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040.	RC4558, RC4156	**511**
RCA Solid State Div., Route 202, Somerville, NJ 08876.	CA3140, CA3240, CA3130, CA3160	**512**
Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086.	NE531, NE535, NE538, NE5534	**513**
Siliconix, 2201 Laurelwood Rd., Santa Clara, CA 95054.	L144	**514**
Solitron Devices, Semiconductor Div., 8808 Balboa Ave., San Diego, CA 92123.	UC4250	**515**
Texas Instruments, Dallas, TX 75222.	SN72088, TL081, TL071, TL061	**516**

For high speed, the 2725 is about 10 times faster than the moderate-speed programmable units, because of its dielectric-isolation construction.

The duals, 8022 and 2735, are versions of their single counterparts, the 8021 and 2725. And the 8023 is a triple 8021, with individually adjustable programming in each section. But the L144 triple has common programming for its sections. So does the 4202, the only programmable quad—it's like four 4250s. ■■

Reference

1. Jung, W.G., *IC Op Amp Cook Book*, Howard W. Sams, Indianapolis, IN, 1974.