

CA3130A, CA3130

BiMOS Operational Amplifiers

With MOSFET Input/CMOS Output

Features:

- MOSFET input stage provides:
very high $Z_i=1.5\text{ T}\Omega$ ($1.5 \times 10^{12}\Omega$) typ.
very low $i_i=5\text{ pA}$ typ. at 15-V operation
 $=2\text{ pA}$ typ. at 5-V operation
 - Common-mode input-voltage range includes negative supply rail; input terminals can be swung 0.5 V below negative supply rail
 - CMOS output stage permits signal swing to either (or both) supply rails
- } Ideal for single-supply applications

RCA-CA3130A and CA3130 are integrated-circuit operational amplifiers that combine the advantages of both CMOS and bipolar transistors on a monolithic chip.

Gate-protected p-channel MOS/FET (PMOS) transistors are used in the input circuit to provide very-high-input impedance, very-low-input current, and exceptional speed performance. The use of PMOS field-effect transistors in the input stage results in common-mode input-voltage capability down to 0.5 volt below the negative-supply terminal, an important attribute in single-supply applications.

A complementary-symmetry MOS (CMOS) transistor-pair, capable of swinging the output voltage to within 10 millivolts of either supply-voltage terminal (at very high values of load impedance), is employed as the output circuit.

The CA3130 Series circuits operate at supply voltages ranging from 5 to 16 volts, or ± 2.5 to ± 8 volts when using split supplies. They can be phase compensated with a single external capacitor, and have terminals for adjustment of offset voltage for applications requiring offset-null capability. Terminal provisions are also made to permit strobing of the output stage.

The CA3130 Series is supplied in standard 8-lead TO-5 style packages (T suffix), 8-lead dual-in-line formed lead TO-5 style "DIL-CAN" packages (S suffix). The CA3130 is available in chip form (H suffix). The CA3130 and CA3130A are also available in the Mini-DIP 8-lead dual-in-line plastic package (E suffix). All types operate over the full military-temperature range of -55°C to $+125^\circ\text{C}$. The CA3130A offers superior input characteristics over those of the CA3130.

Applications:

- Ground-referenced single-supply amplifiers
- Fast sample-hold amplifiers
- Long-duration timers/monostables
- High-input-impedance comparators
(ideal interface with digital CMOS)
- High-input-impedance wideband amplifiers
- Voltage followers
(e.g., follower for single-supply D/A converter)
- Voltage regulators
(permits control of output voltage down to zero volts)
- Peak detectors
- Single-supply full-wave precision rectifiers
- Photo-diode sensor amplifiers

File Number 817

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ELECTRICAL CHARACTERISTICS at $T_A=25^\circ\text{C}$, $V^+=15\text{ V}$, $V^- = 0\text{ V}$ (Unless otherwise specified)

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| CHARACTERISTIC | LIMITS | | | | | | Units |
|--|-----------------|------------|------|----------------|------------|------|------------------------------|
| | CA3130A (T,S,E) | | | CA3130 (T,S,E) | | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Input Offset Voltage, $ V_{IO} $, $V^\pm = \pm 7.5\text{ V}$ | - | 2 | 5 | - | 8 | 15 | mV |
| Input Offset Current, $ I_{IO} $, $V^\pm = \pm 7.5\text{ V}$ | - | 0.5 | 20 | - | 0.5 | 30 | pA |
| Input Current, I_I , $V^\pm = \pm 7.5\text{ V}$ | - | 5 | 30 | - | 5 | 50 | pA |
| Large-Signal Voltage Gain, A_{OL} , $V_O = 10\text{ V}_{p-p}$, $R_L = 2\text{ k}\Omega$ | 50 k | 320 k | - | 50 k | 320 k | - | V/V |
| Common-Mode Rejection Ratio, CMRR | 80 | 90 | - | 70 | 90 | - | dB |
| Common-Mode Input-Voltage Range, V_{ICR} | 0 | -0.5 to 12 | 10 | 0 | -0.5 to 12 | 10 | V |
| Power-Supply Rejection Ratio, $\Delta V_{IO}/\Delta V^\pm$, $V^\pm = \pm 7.5\text{ V}$ | - | 32 | 150 | - | 32 | 320 | $\mu\text{V/V}$ |
| Maximum Output Voltage: | | | | | | | V |
| At $R_L = 2\text{ k}\Omega$ | | | | | | | |
| $\frac{V_{OM}^+}{V_{OM}^-}$ | 12 | 13.3 | - | 12 | 13.3 | - | |
| $\frac{V_{OM}^+}{V_{OM}^-}$ | - | 0.002 | 0.01 | - | 0.002 | 0.01 | |
| At $R_L = \infty$ | | | | | | | mA |
| $\frac{V_{OM}^+}{V_{OM}^-}$ | 14.99 | 15 | - | 14.99 | 15 | - | |
| $\frac{V_{OM}^+}{V_{OM}^-}$ | - | 0 | 0.01 | - | 0 | 0.01 | |
| Maximum Output Current: | | | | | | | mA |
| I_{OM}^+ (Source) @ $V_O = 0\text{ V}$ | 12 | 22 | 45 | 12 | 22 | 45 | |
| I_{OM}^- (Sink) @ $V_O = 15\text{ V}$ | 12 | 20 | 45 | 12 | 20 | 45 | |
| Supply Current, I^+ : | | | | | | | mA |
| $V_O = 7.5\text{ V}$, $R_L = \infty$ | - | 10 | 15 | - | 10 | 15 | |
| $V_O = 0\text{ V}$, $R_L = \infty$ | - | 2 | 3 | - | 2 | 3 | |
| Input Offset Voltage Temp. Drift, $\Delta V_{IO}/\Delta T^*$ | - | 10 | - | - | 10 | - | $\mu\text{V}/^\circ\text{C}$ |

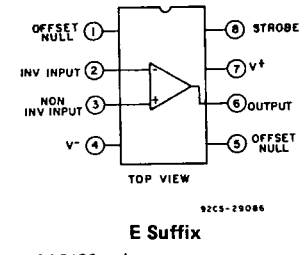
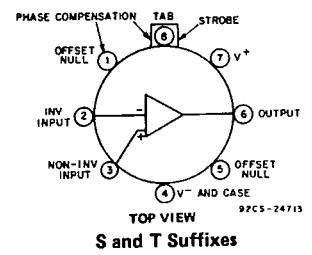


Fig.1 - Functional diagrams for the CA3130 series.

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TYPICAL VALUES INTENDED ONLY FOR DESIGN GUIDANCE

| CHARACTERISTIC | TEST CONDITIONS | CA3130A CA3130 (T,S,E) | UNITS |
|---|---|------------------------------|-------|
| | V ⁺ = +7.5 V V ⁻ = -7.5 V T _A = 25°C (Unless Otherwise Specified) | | |
| Input Offset Voltage Adjustment Range | 10 kΩ across Terms. 4 and 5 or 4 and 1 | ±22 | mV |
| Input Resistance, R _I | | 1.5 | TΩ |
| Input Capacitance, C _I | f = 1 MHz | 4.3 | pF |
| Equivalent Input Noise Voltage, e _n | BW = 0.2 MHz R _S = 1 MΩ* | 23 | μV |
| Unity Gain Crossover Frequency, f _T | C _C = 0 | 15 | MHz |
| | C _C = 47 pF | 4 | |
| Slew Rate, SR: | | | V/μs |
| Open Loop | C _C = 0 | 30 | |
| Closed Loop | C _C = 56 pF | 10 | |
| Transient Response: | C _C = 56 pF | 0.09 | μs |
| Rise Time, t _r | C _L = 25 pF | | |
| Overshoot | R _L = 2 kΩ (Voltage Follower) | 10 | % |
| Settling Time (4 V _{p-p} Input to <0.1%) | | 1.2 | μs |

* Although a 1-MΩ source is used for this test, the equivalent input noise remains constant for values of R_S up to 10 MΩ.

| CHARACTERISTIC | TEST CONDITIONS | CA3130A (T,S,E) | CA3130 (T,S,E) | UNITS |
|---|---|--------------------|-------------------|-------|
| | V ⁺ = 5 V V ⁻ = 0 V T _A = 25°C (Unless Otherwise Specified) | | | |
| Input Offset Voltage, V _{IO} | | 2 | 8 | mV |
| Input Offset Current, I _{IO} | | 0.1 | 0.1 | pA |
| Input Current, I _I | | 2 | 2 | pA |
| Common-Mode Rejection Ratio, CMRR | | 90 | 80 | dB |
| Large-Signal Voltage Gain, A _{OL} | V _O = 4 V _{p-p} R _L = 5 kΩ | 100 k | 100 k | V/V |
| Common-Mode Input Voltage Range, V _{ICR} | | 0 to 2.8 | 0 to 2.8 | V |
| Supply Current, I ⁺ | V _O = 5 V, R _L = ∞ | 300 | 300 | μA |
| | V _O = 2.5 V, R _L = ∞ | 500 | 500 | |
| Power Supply Rejection Ratio, ΔV _{IO} /ΔV ⁺ | | 200 | 200 | μV/V |

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MAXIMUM RATINGS, Absolute-Maximum Values

| | |
|--|--|
| DC SUPPLY VOLTAGE (Between V ⁺ and V ⁻ Terminals) | 16 V |
| DIFFERENTIAL-MODE INPUT VOLTAGE | ±8 V |
| COMMON-MODE DC INPUT VOLTAGE | (V ⁺ +8 V) to (V ⁻ -0.5 V) |
| INPUT-TERMINAL CURRENT | 1 mA |
| DEVICE DISSIPATION: WITHOUT HEAT SINK - | |
| UP TO 55°C | 630 mW |
| ABOVE 55°C | Derate linearly 6.67 mW/°C |
| WITH HEAT SINK - | |
| UP TO 90°C | 1 W |
| ABOVE 90°C | Derate linearly 16.7 mW/°C |

| | |
|--|---------------|
| TEMPERATURE RANGE: | |
| OPERATING (all types) | -55 to +125°C |
| STORAGE (all types) | -65 to +150°C |
| OUTPUT SHORT-CIRCUIT, DURATION | INDEFINITE |
| LEAD TEMPERATURE (DURING SOLDERING): | |
| AT DISTANCE 1/16 ± 1/32 INCH (1.59 ± 0.79 mm) FROM CASE | |
| FOR 10 SECONDS MAX. | +265°C |

*Short circuit may be applied to ground or to either supply.

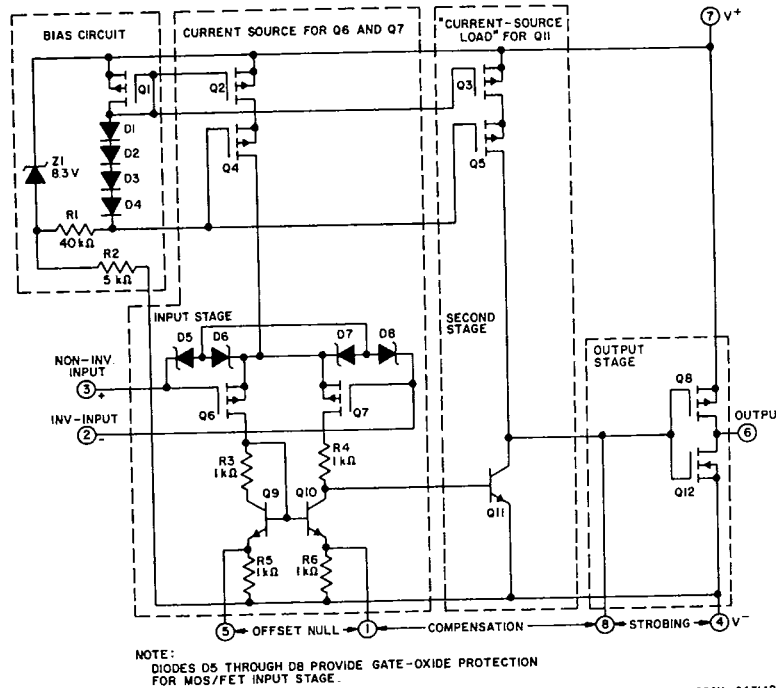


Fig. 2 - Schematic diagram of the CA3130 Series.

CIRCUIT DESCRIPTION

Fig. 3 is a block diagram of the CA3130 Series CMOS Operational Amplifiers. The input terminals may be operated down to 0.5 V below the negative supply rail, and the output can be swung very close to either supply rail in many applications. Consequently, the CA3130 Series circuits are ideal for single-supply operation. Three Class A amplifier stages, having the individual gain capability and current consumption shown in Fig. 3, provide the total gain of the CA3130. A biasing circuit provides two potentials for common use in the first and

second stages. Term. 8 can be used both for phase compensation and to strobe the output stage into quiescence. When Term. 8 is tied to the negative supply rail (Term. 4) by mechanical or electrical means, the output potential at Term. 6 essentially rises to the positive supply-rail potential at Term. 7. This condition of essentially zero current drain in the output stage under the strobed "OFF" condition can only be achieved when the ohmic load resistance presented to the amplifier is very high (e.g., when the amplifier output is used to drive CMOS digital circuits in comparator applications).

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Input Stages—The circuit of the CA3130 is shown in Fig. 2. It consists of a differential-input stage using PMOS field-effect transistors (Q6, Q7) working into a mirror-pair of bipolar transistors (Q9, Q10) functioning as load resistors together with resistors R3 through R6. The mirror-pair transistors also function as a differential-to-single-ended converter to provide base drive to the second-stage bipolar transistor (Q11). Offset nulling, when desired, can be effected by connecting a 100,000-ohm potentiometer across Terms. 1 and 5 and the potentiometer slider arm to Term. 4. Cascode-connected PMOS transistors Q2, Q4 are the constant-current source for the input stage. The biasing circuit for the constant-current source is subsequently described. The small diodes D5 through D8 provide gate-oxide protection against high-voltage transients, e.g., including static electricity during handling for Q6 and Q7.

Second-Stage—Most of the voltage gain in the CA3130 is provided by the second amplifier stage, consisting of bipolar transistor Q11 and its cascode-connected load resistance provided by PMOS transistors Q3 and Q5. The source of bias potentials for these PMOS transistors is subsequently described. Miller-Effect compensation (roll-off) is accomplished by simply connecting a small capacitor between Terms. 1 and 8. A 47-picofarad capacitor provides sufficient compensation for stable unity-gain operation in most applications.

Bias-Source Circuit—At total supply voltages, somewhat above 8.3 volts, resistor R2 and zener diode Z1 serve to establish a voltage of 8.3 volts across the series-connected circuit, consisting of resistor R1, diodes D1 through D4, and PMOS transistor Q1. A tap at the junction of resistor R1 and diode D4 provides a gate-bias potential of about 4.5 volts for PMOS transistors Q4 and Q5 with respect to Term. 7. A potential of about 2.2 volts is developed across diode-connected PMOS transistor Q1 with respect to Term. 7 to provide gate bias for PMOS transistors Q2 and Q3. It

should be noted that Q1 is "mirror-connected"† to both Q2 and Q3. Since transistors Q1, Q2, Q3 are designed to be identical, the approximately 200-microampere current in Q1 establishes a similar current in Q2 and Q3 as constant-current sources for both the first and second amplifier stages, respectively.

At total supply voltages somewhat less than 8.3 volts, zener diode Z1 becomes non-conductive and the potential, developed across series-connected R1, D1-D4, and Q1, varies directly with variations in supply voltage. Consequently, the gate bias for Q4, Q5 and Q2, Q3 varies in accordance with supply-voltage variations. This variation results in deterioration of the power-supply-rejection ratio (PSRR) at total supply voltages below 8.3 volts. Operation at total supply voltages below about 4.5 volts results in seriously degraded performance.

Output Stage—The output stage consists of a drain-loaded inverting amplifier using CMOS transistors operating in the Class A mode. When operating into very high resistance loads, the output can be swung within millivolts of either supply rail. Because the output stage is a drain-loaded amplifier, its gain is dependent upon the load impedance. The transfer characteristics of the output stage for a load returned to the negative supply rail are shown in Fig. 6. Typical op-amp loads are readily driven by the output stage. Because large-signal excursions are non-linear, requiring feedback for good waveform reproduction, transient delays may be encountered. As a voltage follower, the amplifier can achieve 0.01 per cent accuracy levels, including the negative supply rail.

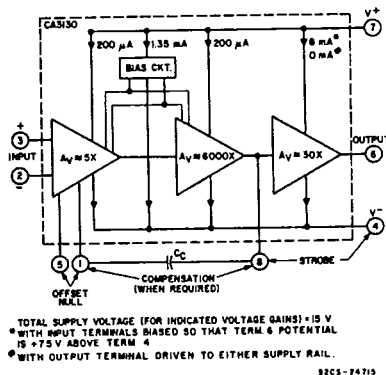


Fig. 3 — Block diagram of the CA3130 Series.

†For general information on the characteristics of CMOS transistor-pairs in linear-circuit applications, see File No. 619, data bulletin on CA3600E "CMOS Transistor Array".

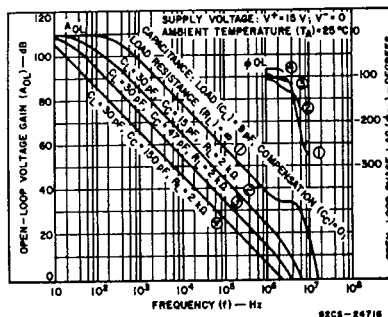


Fig. 4 — Open-loop voltage gain and phase shift vs. frequency for various values of R_L , C_C and R_L .

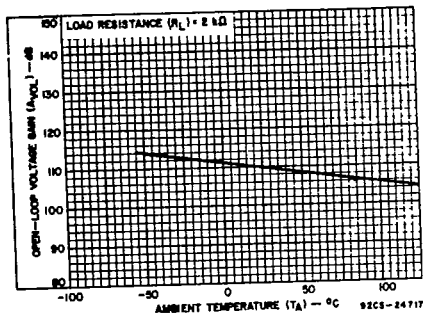


Fig. 5 - Open-loop gain vs. temperature.

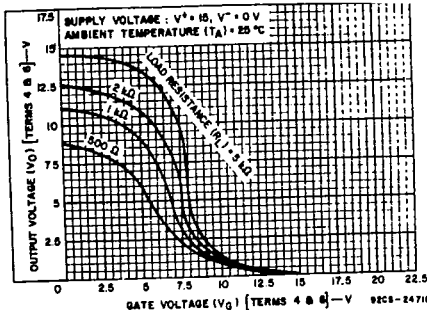


Fig. 6 - Voltage transfer characteristics of COS/MOS output stage.

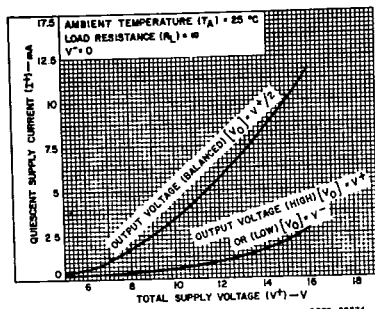


Fig. 7 - Quiescent supply current vs. supply voltage.

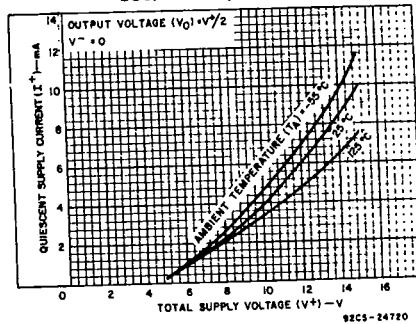


Fig. 8 - Quiescent supply current vs. supply voltage at several temperatures.

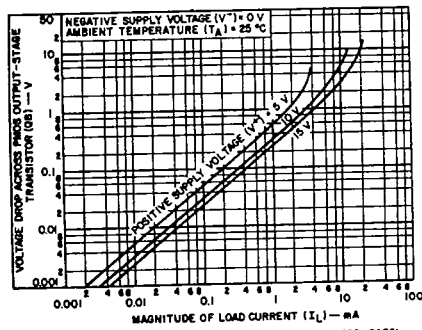


Fig. 9 - Voltage across PMOS output transistor (Q8) vs. load current.

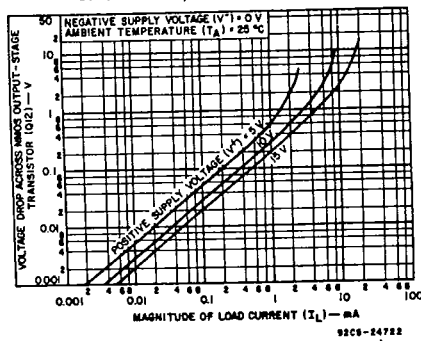


Fig. 10 - Voltage across NMOS output transistor (Q12) vs. load current.

Input Current Variation with Common-Mode Input Voltage

As shown in the Table of Electrical Characteristics, the input current for the CA3130 Series Op-Amps is typically 5 pA at $T_A = 25^\circ\text{C}$ when terminals 2 and 3 are at a common-mode potential of +7.5 volts with respect to negative supply Terminal 4. Fig.11 contains data showing the variation of input current as a function of common-mode input voltage at $T_A = 25^\circ\text{C}$. These data show that circuit designers can advantageously exploit these characteristics to design circuits which typically require an input current of less than 1 pA, provided the common-mode input voltage does not exceed 2 volts. As previously noted, the input current is essentially the result of the leakage current through the

gate-protection diodes in the input circuit and, therefore, a function of the applied

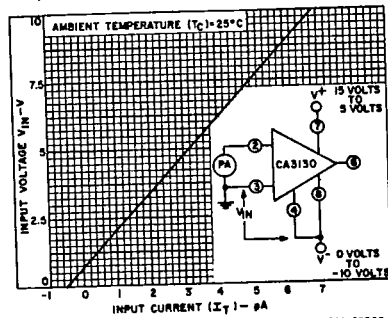


Fig. 11 - Input current vs. common-mode voltage.

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voltage. Although the finite resistance of the glass terminal-to-case insulator of the TO-5 package also contributes an increment of leakage current, there are useful compensating factors. Because the gate-protection network functions as if it is connected to Terminal 4 potential, and the TO-5 case of the CA3130 is also internally tied to Terminal 4, input terminal 3 is essentially "guarded" from spurious leakage currents.

Offset Nulling

Offset-voltage nulling is usually accomplished with a 100,000-ohm potentiometer connected across Terms. 1 and 5 and with the potentiometer slider arm connected to Term. 4. A fine offset-null adjustment usually can be effected with the slider arm positioned in the mid-point of the potentiometer's total range.

Input-Current Variation with Temperature

The input current of the CA3130 Series circuits is typically 5 pA at 25°C. The major portion of this input current is due to leakage current through the gate-protective diodes in the input circuit. As with any semiconductor-junction device, including op amps with a junction-FET input stage, the leakage current approximately doubles for every 10°C increase in temperature. Fig.12 provides data on the typical variation of input bias current as a function of temperature in the CA3130.

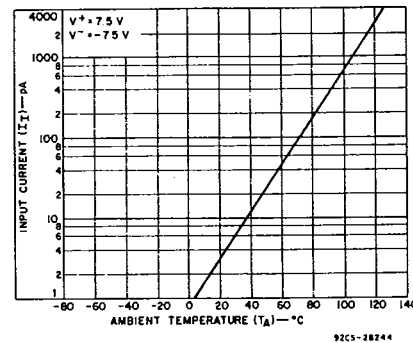


Fig.12 - Input current vs. ambient temperature.

In applications requiring the lowest practical input current and incremental increases in current because of "warm-up" effects, it is suggested that an appropriate heat sink be used with the CA3130. In addition, when "sinking" or "sourcing" significant output current the chip temperature increases, causing an increase in the input current. In such cases, heat-sinking can also very markedly reduce and stabilize input current variations.

Input-Offset-Voltage (V_{IO}) Variation with DC Bias vs. Device Operating Life

It is well known that the characteristics of a MOS/FET device can change slightly when a dc gate-source bias potential is applied to the device for extended time periods. The magni-

tude of the change is increased at high temperatures. Users of the CA3130 should be alert to the possible impacts of this effect if the application of the device involves extended operation at high temperatures with a significant differential dc bias voltage applied across Terms. 2 and 3. Fig.13 shows typical data pertinent to shifts in offset voltage encountered with CA3130 devices (TO-5 package) during life testing. At lower temperatures (TO-5 and plastic), for example at 85°C, this change in voltage is considerably less. In typical linear applications where the differential voltage is small and symmetrical, these incremental changes are of about the same magnitude as those encountered in an operational amplifier employing a bipolar transistor input stage. The two-volt dc differential voltage example represents conditions when the amplifier output stage is "toggled", e.g., as in comparator applications.

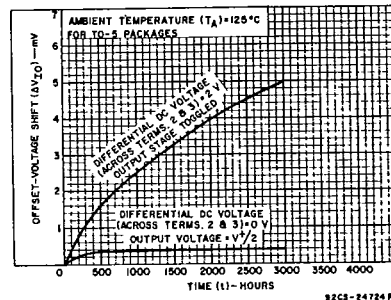


Fig.13 - Typical incremental offset-voltage shift vs. operating life.

Power-Supply Considerations

Because the CA3130 is very useful in single-supply applications, it is pertinent to review some considerations relating to power-supply current consumption under both single- and dual-supply service. Figs. 14a and 14b show the CA3130 connected for both dual- and single-supply operation.

Dual-supply operation: When the output voltage at Term. 6 is zero-volts, the currents supplied by the two power supplies are equal. When the gate terminals of Q8 and Q12 are driven increasingly positive with respect to ground, current flow through Q12 (from the negative supply) to the load is increased and current flow through Q8 (from the positive supply) decreases correspondingly. When the gate terminals of Q8 and Q12 are driven increasingly negative with respect to ground, current flow through Q8 is increased and current flow through Q12 is decreased accordingly.

Single-supply operation: Initially, let it be assumed that the value of R_L is very high (or disconnected), and that the input-terminal bias (Terms. 2 and 3) is such that the output terminal (No. 6) voltage is at $V^+/2$, i.e.,

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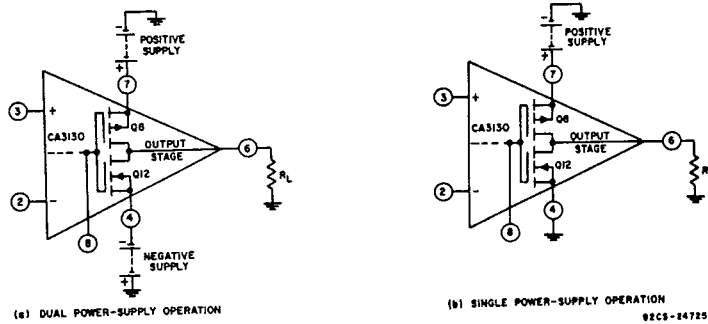


Fig. 14 - CA3130 output stage in dual and single power-supply operation.

the voltage-drops across Q8 and Q12 are of equal magnitude. Fig. 7 shows typical quiescent supply-current vs. supply-voltage for the CA3130 operated under these conditions. Since the output stage is operating as a Class A amplifier, the supply-current will remain constant under dynamic operating conditions as long as the transistors are operated in the linear portion of their voltage-transfer characteristics (see Fig. 6). If either Q8 or Q12 are swung out of their linear regions toward cut-off (a non-linear region), there will be a corresponding reduction in supply-current. In the extreme case, e.g., with Term. 8 swung down to ground potential (or tied to ground), NMOS transistor Q12 is completely cut off and the supply-current to series-connected transistors Q8, Q12 goes essentially to zero. The two preceding stages in the CA3130, however, continue to draw modest supply-current (see the lower curve in Fig. 7) even though the output stage is strobed off. Fig. 14a shows a dual-supply arrangement for the output stage that can also be strobed off, assuming $R_L = \infty$, by pulling the potential of Term. 8 down to that of Term. 4.

Let it now be assumed that a load-resistance of nominal value (e.g., 2 kilohms) is connected between Term. 6 and ground in the circuit of Fig. 14b. Let it further be assumed again that the input-terminal bias (Terms. 2 and 3) is such that the output terminal (No. 6) voltage is a $V^+/2$. Since PMOS transistor Q8 must now supply quiescent current to both R_L and transistor Q12, it should be apparent that under these conditions the supply-current must increase as an inverse function of the R_L magnitude. Fig. 9 shows the voltage-drop across PMOS transistor Q8 as a function of load current at several supply-voltages. Fig. 6 shows the voltage-transfer characteristics of the output stage for several values of load resistance.

Wideband Noise

From the standpoint of low-noise performance considerations, the use of the CA3130 is most advantageous in applications where in the source resistance of the input signal is

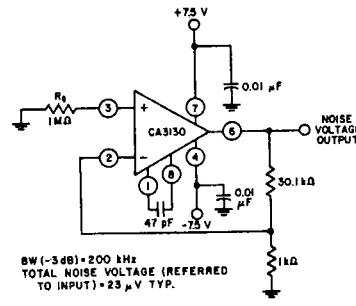
in the order of 1 megohm or more. In this case, the total input-referred noise voltage is typically only $23 \mu V$ when the test-circuit amplifier of Fig. 15 is operated at a total supply voltage of 15 volts. This value of total input-referred noise remains essentially constant, even though the value of source resistance is raised by an order of magnitude. This characteristic is due to the fact that reactance of the input capacitance becomes a significant factor in shunting the source resistance. It should be noted, however, that for values of source resistance very much greater than 1 megohm, the total noise voltage generated can be dominated by the thermal noise contributions of both the feedback and source resistors.

TYPICAL APPLICATIONS

Voltage Followers

Operational amplifiers with very high input resistances, like the CA3130, are particularly suited to service as voltage followers. Fig. 16 shows the circuit of a classical voltage follower, together with pertinent waveforms using the CA3130 in a split-supply configuration.

A voltage follower, operated from a single supply, is shown in Fig. 17, together with related waveforms. This follower circuit is

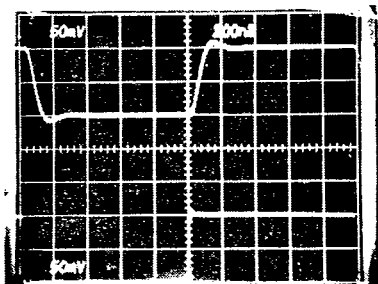
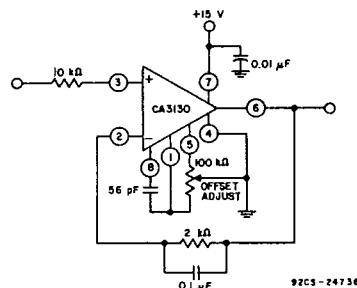
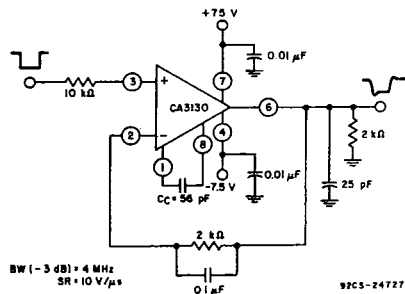


BW 1-3 kHz - 200 kHz
TOTAL NOISE VOLTAGE (REFERRED TO INPUT) = $23 \mu V$ TYP.

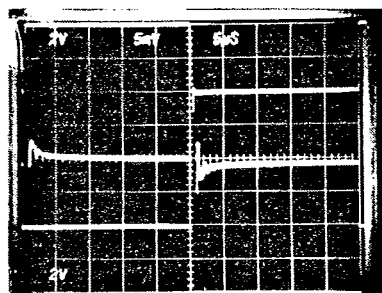
Fig. 15 - Test-circuit amplifier (30-dB gain) used for wideband noise measurements.

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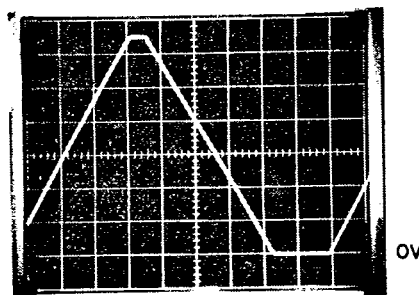
Top Trace: Output
Bottom Trace: Input
(a) Small-signal response (50 mV/div. and 200 ns/div.)



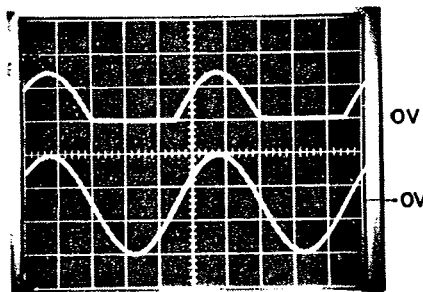
Top Trace: Output signal (2 V/div. and 5 μs/div.)
Center Trace: Difference signal (5 mV/div. and 5 μs/div.)
Bottom Trace: Input signal (2 V/div. and 5 μs/div.)
(b) Input-output difference signal showing settling time (Measurement made with Tektronix 7A13 differential amplifier)

Fig. 16 - Split-supply voltage follower with associated waveforms.

linear over a wide dynamic range, as illustrated by the reproduction of the output waveform in Fig. 17a with input-signal ramping. The waveforms in Fig. 17b show that the follower does not lose its input-to-output phase-sense, even though the input is



(a) Output-waveform with input-signal ramping (2 V/div. and 500 μs/div.)



Top Trace: Output (5 V/div. and 200 μs/div.)
Bottom Trace: Input (5 V/div. and 200 μs/div.)
(b) Output-waveform with ground-reference sine-wave input

Fig. 17 - Single-supply voltage-follower with associated waveforms. (e.g., for use in single-supply D/A converter; see Fig. 9 in ICAN-6080).

being swung 7.5 volts below ground potential. This unique characteristic is an important attribute in both operational amplifier and comparator applications. Fig. 17b also shows the manner in which the CMOS output stage permits the output signal to swing down to the negative supply-rail potential (i.e., ground in the case shown). The digital-to-analog converter (DAC) circuit, described in the following section, illustrates the practical use of the CA3130 in a single-supply voltage-follower application.

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9-Bit COS/MOS DAC

A typical circuit of a 9-bit Digital-to-Analog Converter (DAC)* is shown in Fig.18 This system combines the concepts of multiple-switch CMOS IC's, a low-cost ladder network of discrete metal-oxide-film resistors, a CA3130 op amp connected as a follower, and an inexpensive monolithic regulator in a simple single power-supply arrangement. An additional feature of the DAC is that it is readily interfaced with CMOS input logic, e.g., 10-volt logic levels are used in the circuit of Fig. 18.

of one per cent tolerance metal-oxide film resistors. The five arms requiring the highest accuracy are assembled with series and parallel combinations of 806,000-ohm resistors from the same manufacturing lot.

A single 15-volt supply provides a positive bus for the CA3130 follower amplifier and feeds the CA3085 voltage regulator. A "scale-adjust" function is provided by the regulator output control, set to a nominal 10-volt level in this system. The line-voltage regulation (approximately 0.2%) permits a 9-bit accuracy to be maintained with varia-

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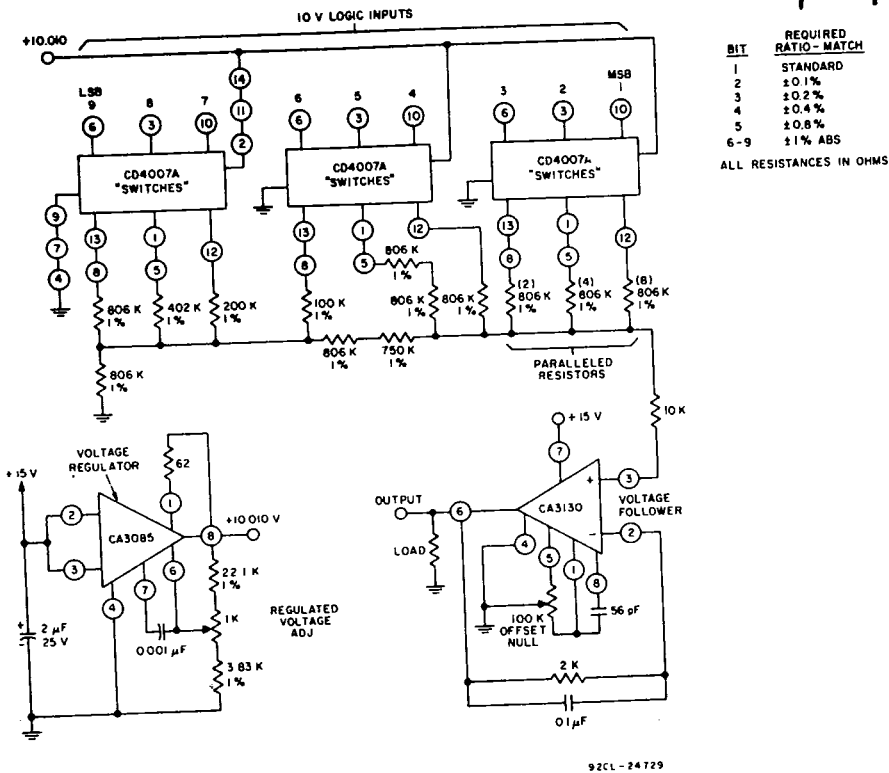


Fig. 18-9-bit DAC using CMOS digital switches and CA3130.

The circuit uses an R/2R voltage-ladder network, with the output potential obtained directly by terminating the ladder arms at either the positive or the negative power-supply terminal. Each CD4007A contains three "inverters", each "inverter" functioning as a single-pole double-throw switch to terminate an arm of the R/2R network at either the positive or negative power-supply terminal. The resistor ladder is an assembly

tions of several volts in the supply. The flexibility afforded by the COS/MOS building blocks simplifies the design of DAC systems tailored to particular needs.

Single-Supply, Absolute-Value, Ideal Full-Wave Rectifier

The absolute-value circuit using the CA3130 is shown in Fig. 19. During positive excursions, the input signal is fed through the feedback network directly to the output. Simultaneously, the positive excursion of the input signal also drives the output terminal (No. 6) of the inverting amplifier in a

*"Digital-to-Analog Conversion Using the RCA-CD4007A COS/MOS IC", Application Note ICAN-6080.

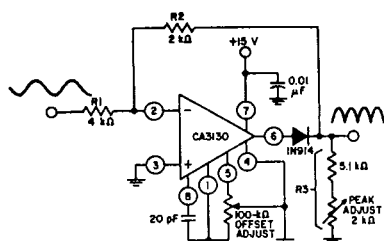
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negative-going excursion such that the 1N914 diode effectively disconnects the amplifier from the signal path. During a negative-going excursion of the input signal, the CA3130 functions as a normal inverting amplifier with a gain equal to $-R2/R1$. When the equality of the two equations shown in Fig. 19 is satisfied, the full-wave output is symmetrical.

Error-Amplifier in Regulated-Power Supplies

The CA3130 is an ideal choice for error-amplifier service in regulated power supplies since it can function as an error-amplifier when the regulated output voltage is required to approach zero. Fig. 21 shows the schematic diagram of a 40-mA power supply capable of providing regulated output volt-

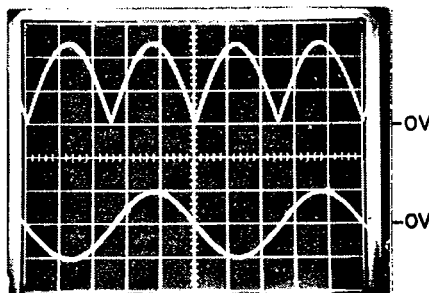


$$GAIN = \frac{R2}{R1} + X + \frac{R3}{R1 + R2 + R3}$$

$$R3 = R1 \left(\frac{X + \frac{R2}{R1}}{1 - X} \right)$$

FOR $X = 0.5$: $\frac{2k\Omega}{4k\Omega} = \frac{R2}{R1}$
 $R3 = 4k\Omega \left(\frac{0.75}{0.5} \right) = 6k\Omega$

20 V p-p INPUT: BW(-3dB) = 230 kHz, DC OUTPUT (AVG.) = 3.2 V
 1 VOLT p-p INPUT: BW(-3dB) = 130 kHz, DC OUTPUT (AVG.) = 160 mV
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Top Trace: Output signal (2 V/div.)
 Bottom Trace: Input signal (10 V/div.)
 Time base on both traces: 0.2 ms/div.

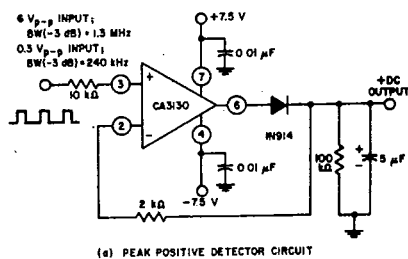
Fig. 19 — Single-supply, absolute-value, ideal full-wave rectifier with associated waveforms.

Peak Detectors

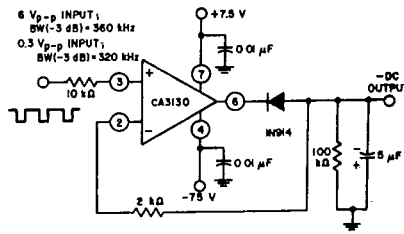
Peak-detector circuits are easily implemented with the CA3130, as illustrated in Fig. 20 for both the peak-positive and the peak-negative circuit. It should be noted that with large-signal inputs, the bandwidth of the peak-negative circuit is much less than that of the peak-positive circuit. The second stage of the CA3130 limits the bandwidth in this case. Negative-going output-signal excursion requires a positive-going signal excursion at the collector of transistor Q11, which is loaded by the intrinsic capacitance of the associated circuitry in this mode. On the other hand, during a negative-going signal excursion at the collector of Q11, the transistor functions in an active "pull-down" mode so that the intrinsic capacitance can be discharged more expeditiously.

age by continuous adjustment over the range from 0 to 13 volts. Q3 and Q4 in IC2 (a CA3086 transistor-array IC) function as zeners to provide supply-voltage for the CA3130 comparator (IC1). Q1, Q2, and Q5 in IC2 are configured as a low impedance, temperature-compensated source of adjustable reference voltage for the error amplifier. Transistors Q1, Q2, Q3, and Q4 in IC3 (another CA3086 transistor-array IC) are connected in parallel as the series-pass element. Transistor Q5 in IC3 functions as a current-limiting device by diverting base drive from the series-pass transistors, in accordance with the adjustment of resistor R2.

Fig. 22 contains the schematic diagram of a regulated power-supply capable of providing regulated output voltage by continuous ad-



(a) PEAK POSITIVE DETECTOR CIRCUIT



(b) PEAK NEGATIVE DETECTOR CIRCUIT

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Fig. 20 — Peak-detector circuits.

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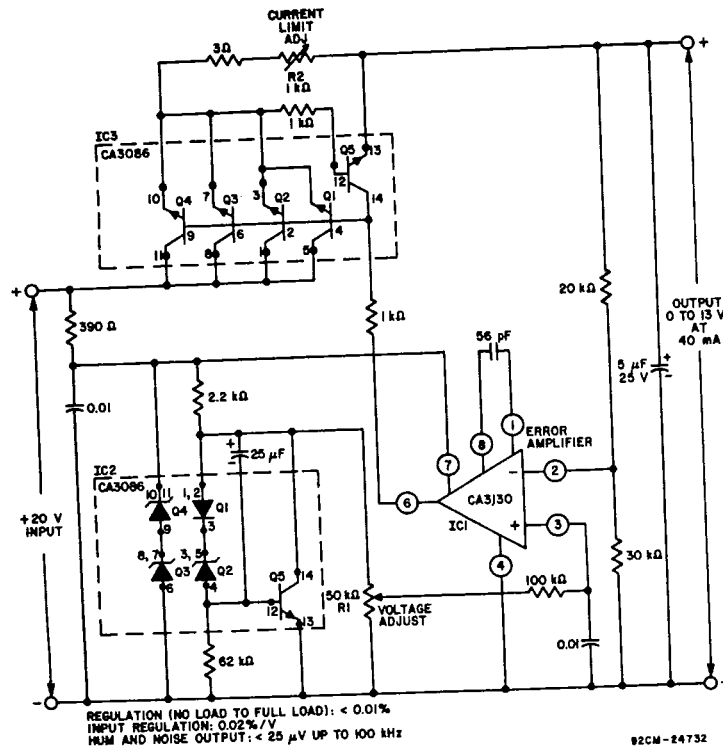


Fig. 21 - Voltage regulator circuit (0 to 13 V at 40 mA).

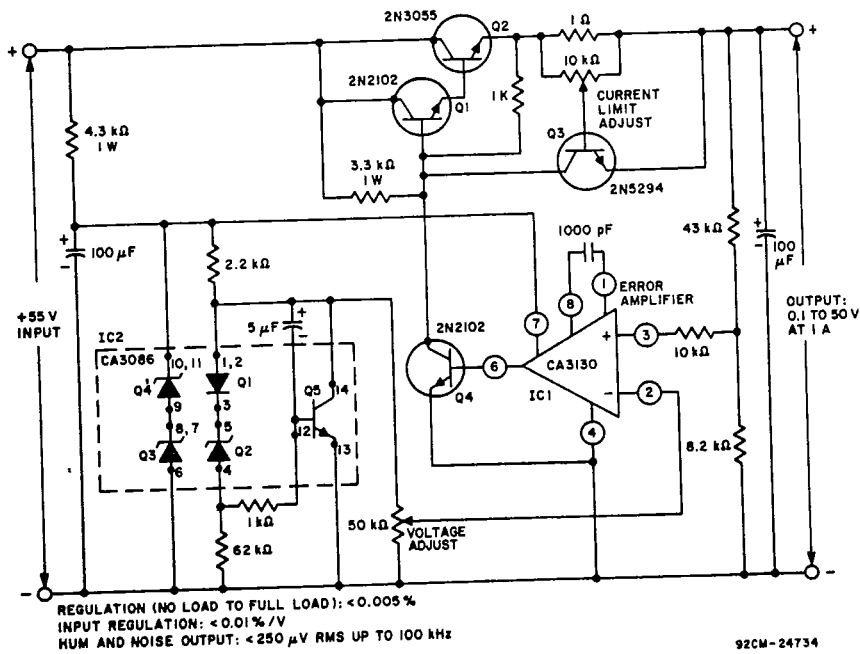


Fig. 22 - Voltage regulator circuit (0.1 to 50 V at 1 A).

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justment over the range from 0.1 to 50 volts and currents up to 1 ampere. The error amplifier (IC1) and circuitry associated with IC2 function as previously described, although the output of IC1 is boosted by a discrete transistor (Q4) to provide adequate base drive for the Darlington-connected series-pass transistors Q1, Q2. Transistor Q3 functions in the previously described current-limiting circuit.

Multivibrators

The exceptionally high input resistance presented by the CA3130 is an attractive feature for multivibrator circuit design because it permits the use of timing circuits with high R/C ratios. The circuit diagram of a pulse generator (astable multivibrator), with provisions for independent control of the "on" and "off" periods, is shown in Fig. 23. Resistors R1 and R2 are used to bias the CA3130 to the mid-point of the supply-voltage and R3 is the feedback resistor. The pulse repetition rate is selected by positioning S1 to the desired position and the rate remains essentially constant when the resistors which determine "on-period" and "off-period" are adjusted.

Function Generator

Fig. 24 contains a schematic diagram of a function generator using the CA3130 in the integrator and threshold detector functions. This circuit generates a triangular or square-

wave output that can be swept over a 1,000,000:1 range (0.1 Hz to 100 kHz) by means of a single control, R1. A voltage-control input is also available for remote sweep-control.

The heart of the frequency-determining system is an operational-transconductance-amplifier (OTA)*, IC1, operated as a voltage-controlled current-source. The output, I_O , is a current applied directly to the integrating capacitor, C1, in the feedback loop of the integrator IC2, using a CA3130, to provide the triangular-wave output. Potentiometer R2 is used to adjust the circuit for slope symmetry of positive-going and negative-going signal excursions.

Another CA3130, IC3, is used as a controlled switch to set the excursion limits of the triangular output from the integrator circuit. Capacitor C2 is a "peaking adjustment" to optimize the high-frequency square-wave performance of the circuit.

Potentiometer R3 is adjustable to perfect the "amplitude symmetry" of the square-wave output signals. Output from the threshold detector is fed back via resistor R4 to the input of IC1 so as to toggle the current source from plus to minus in generating the linear triangular wave.

*See File No. 475 and ICAN-6668.

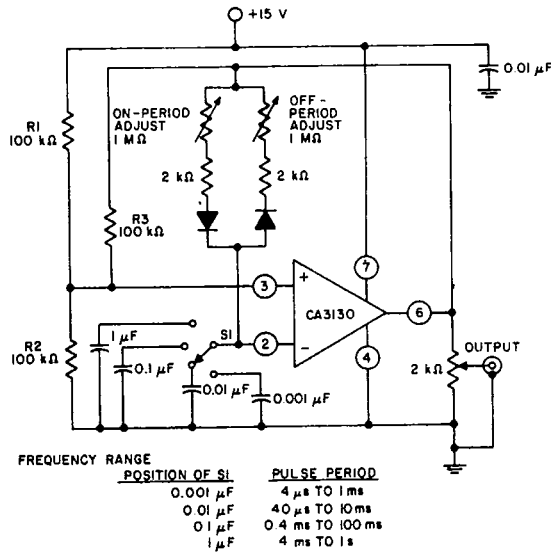
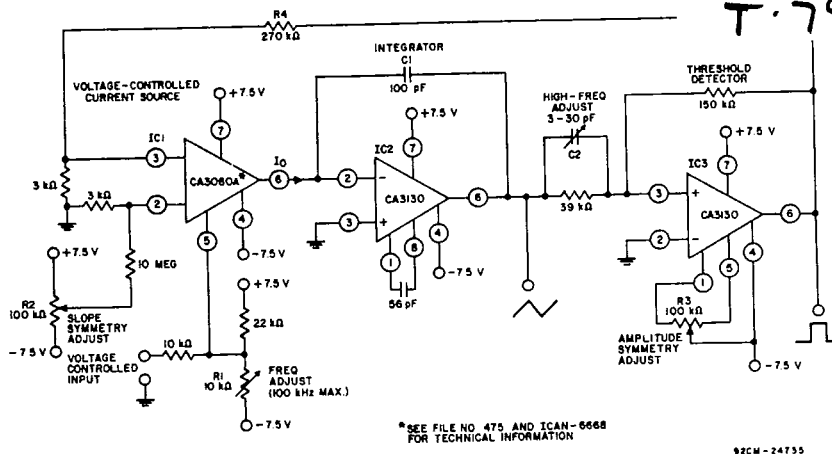


Fig.23 - Pulse generator (astable multivibrator) with provisions for independent control of "ON" and "OFF" periods.

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*SEE FILE NO. 475 AND ICAN-6668 FOR TECHNICAL INFORMATION

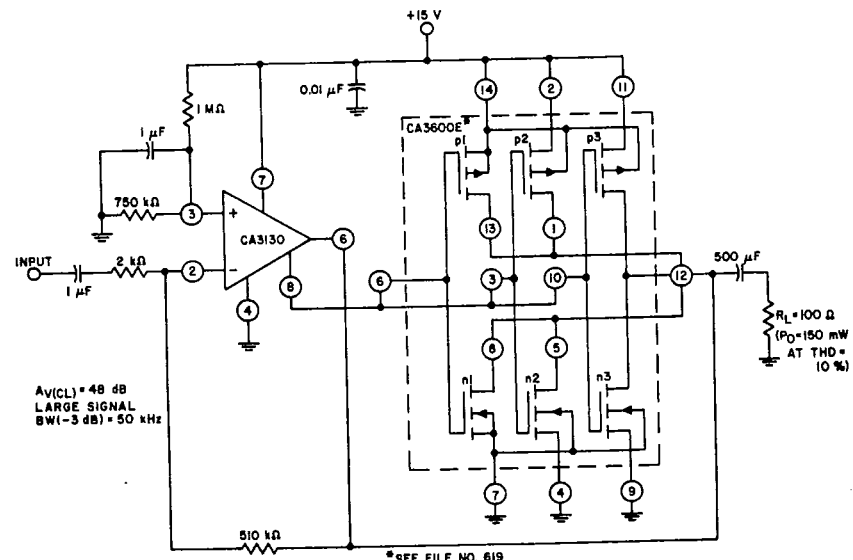
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Fig. 24 - Function generator (frequency can be varied 1,000,000/1 with a single control).

Operation with Output-Stage Power-Booster
 The current-sourcing and -sinking capability of the CA3130 output stage is easily supplemented to provide power-boost capability. In the circuit of Fig. 25, three CMOS transistor-pairs in a single CA3600E IC array are shown parallel connected with the output stage in the CA3130. In the Class A mode of CA3600E shown, a typical device consumes 20 mA of supply current at 15-V

operation. This arrangement boosts the current-handling capability of the CA3130 output stage by about 2.5X. The amplifier circuit in Fig. 25 employs feedback to establish a closed-loop gain of 48 dB. The typical large-signal bandwidth (-3 dB) is 50 kHz.

*See File No. 619 for technical information.



$A_v(CL) = 48 \text{ dB}$
 LARGE SIGNAL
 $BW(-3 \text{ dB}) = 50 \text{ kHz}$

NOTE:
 TRANSISTORS p1, p2, p3 AND n1, n2, n3 ARE PARALLEL-CONNECTED WITH Q8 AND Q12, RESPECTIVELY, OF THE CA3130

*SEE FILE NO. 619

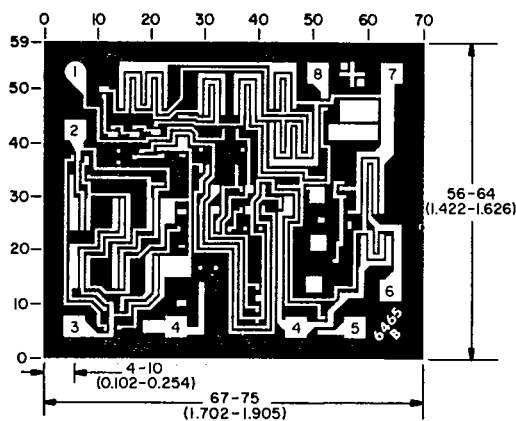
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Fig. 25 - CMOS transistor array (CA3600E) connected as power-booster in the output stage of the CA3130.

Operational Amplifiers

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Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated. Grid graduations are in mils (10^{-3} inch).

The photographs and dimensions represent a chip when it is part of the wafer. When the wafer is cut into chips, the cleavage angles are 57° instead of 90° with respect to the face of the chip. Therefore, the isolated chip is actually 7 mils (0.17 mm) larger in both dimensions.

Dimensions and Pad Layout for CA3130H.

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