

Linear integrated-circuit arrays—building blocks for designers

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This paper describes some design guidelines which should be followed for most effective use of linear IC arrays, discusses some basic configurations that serve as "building blocks" in the design of complex monolithic circuits, and presents some typical circuits that illustrate the application of linear IC arrays.

RCA HAS DEVELOPED a number of linear integrated circuits consisting only of active devices, i.e., transistors and diodes. These arrays (Fig. 1) are extremely useful in circuit design because they provide the close electrical and thermal matching of device characteristics inherent in all monolithic integrated circuits, but are not limited by the restrictions applicable to passive elements (resistors, capacitors, and inductors) in the monolithic system. Besides making practical many circuits which cannot be constructed economically with discrete devices, these arrays may also be used for the "breadboarding" of complex monolithic circuits.

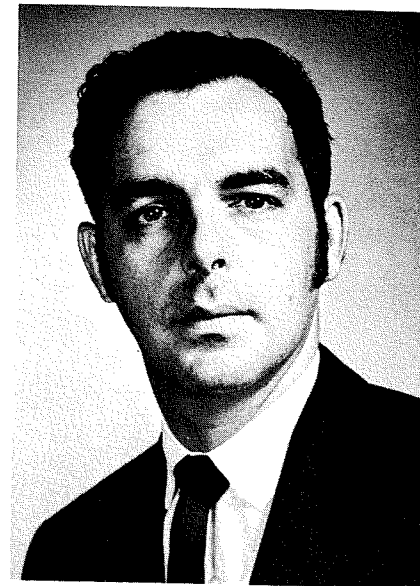
The simplest of these integrated-circuit arrays are finding wide commercial acceptance in a variety of fields because they provide the circuit designer with economical, easily handled packages of matched semiconductor devices. To date, high volume commercial usage has included audio amplifiers for automobile radios, sense amplifiers for small scale computer memories, balanced amplifiers for AC and DC instruments, relaxation, oscillators, for muscle stimulators, DC-operated audio attenuators, and waveshaping networks for function generators. The key to success is the ability of these IC's to provide matched components for prices very close to the cost of similar unmatched devices. The CA3046, for example, provides five transistors for 98 cents (in quantities of 1000 and up), or less than 20 cents per transistor. [Price based on the time that this article was written.]

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General design guidelines

If linear IC arrays are to be used to best advantage in circuit design, some basic rules must be observed to assure proper device operation and to avoid damage to the IC chip. Perhaps the most important rule is that the collector voltages of all array transistors must be kept positive with respect to the IC substrate. As shown in Fig. 2, the collector region of each N-P-N transistor is isolated from the P-type substrate material by an effective diode (N-P junction) which must always be reverse-biased for normal transistor operation. The emitter and base regions of the transistor may be negative with respect to the substrate, provided the collector-to-emitter and collector-to-base voltage ratings are not exceeded.

It is also important to prevent forward-biasing of the base-to-collector diode of a monolithic transistor to assure normal operation. The base-to-collector voltage should not be permitted to exceed 0.6 volt unless the current in the base lead is limited by a fairly large resistor (1000 ohms or more). As shown in Fig. 3, the fabrication of a monolithic N-P-N transistor in a P-type substrate produces the structure for an associated P-N-P transistor in which the collector is the substrate, the base is the collector of the N-P-N transistor, and the emitter is the base of the N-P-N transistor. If the base-to-collector junction of the N-P-N transistor becomes forward-biased, therefore, high currents can flow into the substrate unless limiting is provided in the base lead. Unwanted currents can also develop if the collector of the N-P-N transistor is left open because the P-N-P transistor then operates in the V_{CE0} mode.



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received the BSEE and MSEE from MIT. He joined RCA in 1957. He is presently responsible for evaluating devices, developing test equipment, establishing test specifications, and preparing technical data for commercial data sheets and application notes for both consumer and non-consumer linear integrated circuits. Mr. Kleinman has been granted three U.S. patents and has published several articles. He has received two RCA Engineering awards. The first was a divisional team award in 1963 for the development of devices and circuits which introduced the era of commercially practical solid-state audio amplifiers. The second was the 1966 David Sarnoff Team Award in Engineering for the development of the first commercial high voltage silicon power transistor.

Another important consideration in the use of linear IC arrays is the maximum dissipation rating for the integrated circuit. This rating is based on the sum of the dissipations of the individual devices in the array. Therefore, total dissipation must be calculated on the basis of all the devices operating in a given application.

A final point to be remembered is that the close electrical and thermal matching mentioned previously applies only to devices fabricated on the same IC chip. When several arrays are to be used in a circuit, the design should employ devices of a single array to provide matched characteristics when they are required.

In addition to these few general rules for proper device operation, some basic configurations should be recognized and used as "building blocks" in the design of complex monolithic circuits. Several of these configurations have been described in another paper.¹

Design ideas for RCA CA3018, CA3018A, CA3045, and CA3046 transistor arrays

The RCA CA3018, CA3018A, CA3045, and CA3046 transistor arrays

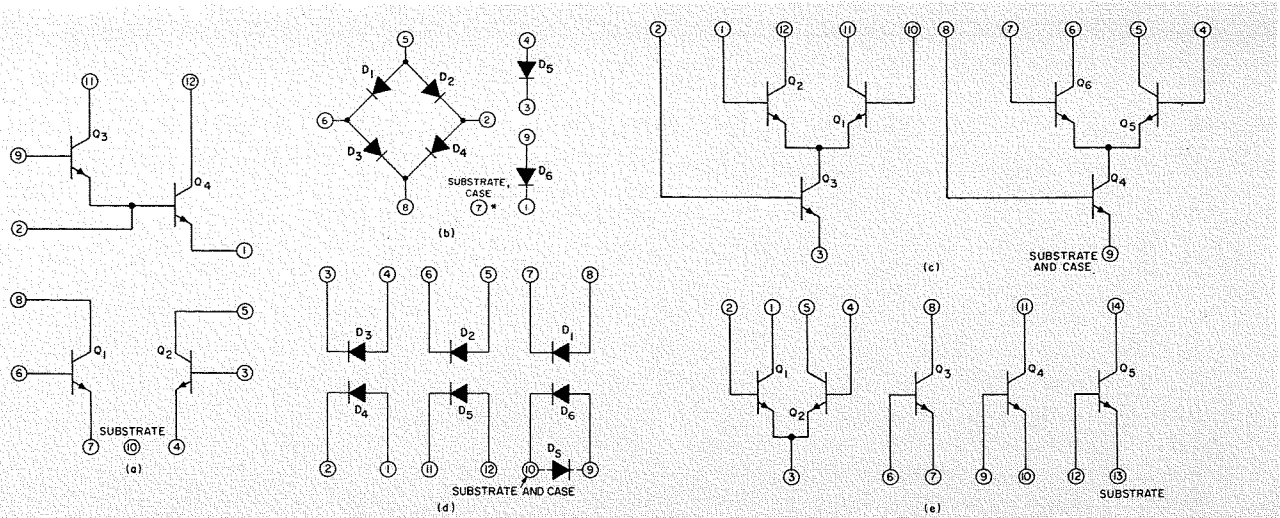


Fig. 1—Schematic diagrams of RCA linear IC arrays: (a) CA3018; (b) CA3019; (c) CA3026, CA3054; (d) CA3039; (e) CA3045, CA3046.

consist of closely matched general-purpose silicon N-P-N transistors on a common monolithic substrate; the schematic diagrams for these arrays are shown in Figs. 1a and 1e. Although the specification limits for the different types vary (as shown on the individual data sheets), the transistors in all these arrays have the following typical characteristics:

Collector-to-base voltage (V_{CB0})	60V
Collector-to-emitter voltage (V_{CE0})	24V
Emitter-to-base voltage (V_{EB0})	7V
Small-signal forward-current transfer ratio (h_{fe} at $I_C = 1$ mA)	100
Gain-bandwidth product (f_T)	550MHz

The CA3018 and CA3018A (Fig. 1a) consist of four transistors packaged in a 12-lead TO-5 can; the only difference between the two types consists of tighter control of some characteristics for the CA3018A. The CA3045 and CA3046 "handy pack" arrays (Fig. 1e) provide a more flexible arrangement of five transistors in 14-lead dual-in-line packages (ceramic and plastic, respectively).

The general-purpose transistors in these arrays are well suited to a wide variety of applications in low-power systems at frequencies from DC through the VHF range. They may be used as discrete devices in conventionally designed circuits to achieve the advantage of improved packing density. However, their full advantage will be realized only when the circuit design makes use of the close electrical and thermal matching of the devices on each IC chip.

Several possible applications for these arrays are presented in the following

paragraphs. For some of these circuits, performance is well documented;² others are design ideas which have not been proven out. Many circuits do not make use of all the devices on a chip; others require extra components. In general, these applications are presented to suggest the potential uses of these arrays of matched transistors; they should serve as a beginning to stimulate the thinking of circuit designers.

Differential amplifiers

The CA3018, CA3018A, CA3045, and CA3046 arrays are suitable for use in a wide range of differential-amplifier applications, particularly in tuned-amplifier, mixer, IF amplifier, and limiter service. Because the transistors in these arrays are similar to those used in the CA3004, CA3005, CA3006, CA3028A, and CA3028B RF-amplifier integrated circuits, the performance of the RF-amplifier types gives an excellent indication of the potential operation of the arrays.^{3,4,5} Some caution is required when the CA3045 and CA3046 dual-in-line circuits are used in high-frequency applications because capacitive coupling between the leads of these packages is greater than in the TO-5 packages. However, if care is taken to reduce capacitive coupling from input to output, these arrays are suitable for operation from DC to 100 MHz.

Fig. 4 shows the schematic diagram for the RCA-CA3028A and CA3028B integrated circuits. The operating point of the circuit is stabilized by a 500-ohm emitter resistor for transistor Q_3 . At the normal operating current of 6 mA, this resistor represents a voltage drop of about 3 V from the power supply.

Fig. 5a shows the CA3028A or CA3028B connected as a differential amplifier and limiter, and Fig. 5b shows an equivalent circuit that uses the transistors in a CA3046 array. It can be seen that fewer external components are required when the array is used. In addition, the CA3046 can provide as much dynamic range when operated from a 6-V supply as the CA3028A or CA3028B operated from a 9-V supply, and more gain and output power can be obtained from the CA3046 when a 9-V supply is used.

One disadvantage of the circuit shown in Fig. 5b is that the current drain is higher because the bias transistors draw the same current as the amplifier. This current can be reduced by use of two transistors in parallel for the constant-current source, as shown in Fig. 6. In this circuit, both Q_3 and Q_4 draw the same current as the bias transistor Q_5 ; as a result, the bias current may be reduced by 50%. It should be noted, however, that the base of transistor Q_2 must be bypassed

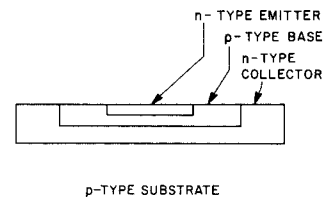


Fig. 2—Structure of an N-P-N monolithic transistor.

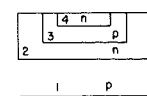


Fig. 3—Associated P-N-P transistor inherent in monolithic fabrication.

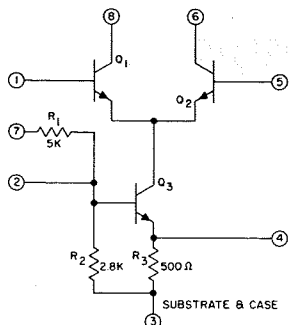


Fig. 4—Schematic diagram of CA3028A or CA3028B RF amplifier.

[no bypassing is required in the circuit of Fig. 5b because of the low-impedance connection through the diode-connected transistors to ground].

Automatic gain control (AGC) may be applied to the differential amplifiers shown in Figs. 5 and 6 by reduction of the current in the biasing device(s). However, the high current in the bias circuit makes it necessary to include DC amplification of the AGC signal. Fig. 7 illustrates the use of the fifth transistor of a CA3046 array as an AGC amplifier. Full AGC capability is realized with a positive-going AGC voltage.

Although the differential amplifiers shown have single-ended input and single-ended output and operate from a single power supply, the arrays shown in Figs. 1a and 1e can also be operated from dual supplies or with balanced inputs. In addition, the arrays provide better control for operation with DC loads than the RF-amplifier integrated circuits mentioned above.

Cascode amplifiers

Operation of the CA3045 or CA3046 array as a cascode amplifier is illustrated in Fig. 8. In this circuit, the diode-connected transistor Q_4 serves as a temperature-compensated base-bias supply for the input transistor Q_5 . The secondary winding of the input transformer T_1 is connected be-

tween Q_4 and Q_5 . The DC resistance of this connection should be less than 20 ohms to assure accurate control of the operating current. The AGC is applied to the circuit by means of a positive-going voltage at the base of Q_1 . Fig. 9 shows an adaptation of the cascode amplifier which permits the use of a grounded signal source. In this circuit, the DC resistance of the source must be less than 1 ohm for accurate control of bias. If the DC source impedance is greater than 1 ohm, a matching resistor should be inserted in the emitter circuit of Q_3 . Loss of gain can be kept to a minimum provided this resistor is smaller than 5 ohms. The cascode-amplifier techniques discussed can be readily applied to such applications as balanced mixers, product detectors, and other variations.³

Wideband video amplifiers

Fig. 10 illustrates the use of the CA3018 (or four transistors of the CA3045 or CA3046) to provide a wideband video amplifier with a gain of 49 dB and a bandwidth of 30 MHz.² This amplifier may be considered as a cascode of two direct-coupled stages. Gain of the amplifier is constant within 1 dB over the entire temperature range.

The adaptability of the devices in the CA3045 and CA3046 arrays is best illustrated by the tachometer circuit shown in Fig. 11. This circuit is designed to provide a full-scale current of 1 mA at an engine speed of 5,000 revolutions per minute (r/min) with an eight cylinder automobile engine. In this circuit, Q_5 acts as a switching transistor, Q_4 as a zener diode, Q_1 (used as a diode) and Q_2 form a current transfer circuit, and the collector-to-substrate diode of Q_1 (shown dotted) is used to provide a path to discharge the capacitor C . Calibration of the system may be changed, by changing the value of capacitor C :

$$C = \left(\frac{I}{V} \right) \left(\frac{\text{pulses}}{\text{revolution}} \right) \left(\frac{\text{revolutions}}{\text{minute}} \right) \left(\frac{1 \text{ minute}}{60 \text{ seconds}} \right)$$

where I and the number of revolutions per minute are full-scale values. The number of pulses per revolution is four for an eight cylinder engine and three for a six cylinder engine; V is approximately equal to zener volt-

age. For high-speed operation, it may be necessary to reduce the one kilohm-resistor in the collector of Q_5 to 470 ohms.

Operational amplifiers

Although integrated-circuit operational amplifiers have become widely used general-purpose devices, many applications require features which are not readily available in fully integrated form. The CA3045 and CA3046 arrays are especially suited to the construction of special-purpose operational amplifiers for battery-operated equipment in which low current drain and good performance at low supply voltage are extremely important.

Fig. 12 shows the schematic diagram of an "op-amp" meter amplifier using two CA3046 arrays. The circuit is designed to drive a 1-mA DC meter to full scale in the positive direction only. The open-loop voltage gain is 80 dB, and the input bias current is less than 20 nA.

The first CA3046 is connected to form a Darlington-connected differential amplifier similar to the first stage of a CA3033. This stage operates at a current level of less than 40 μ A. The Darlington-connected pairs have a composite beta in excess of 1000, and therefore provide an input bias current of less than 20 nA. Transistor Q_{4b} of the second CA3046 is used as an impedance-matching level shifter to drive the voltage amplifier Q_{1b} and Q_{2b} . Transistor Q_{3b} is an emitter-follower output. Transistor Q_{5b} is used to keep Q_{3b} from cutting off when the output is at zero volts. Capacitors C_1 and C_2 reduce the high-frequency gain to avoid the possibility of oscillation with feedback. Standby current drains are 500 μ A from the positive supply and 200 μ A from the negative supply, for a total dissipation of about 2mW. A total meter resistance (R_m) of 1000 ohms is recommended. Various feedback techniques can be used to tailor the amplifier to specific applications.

Other uses

The ability to use the matched device characteristics of IC arrays to replace bulky bypass elements is illustrated in Fig. 13 if R_{C2} is selected for maximum output-voltage swing and R_B is

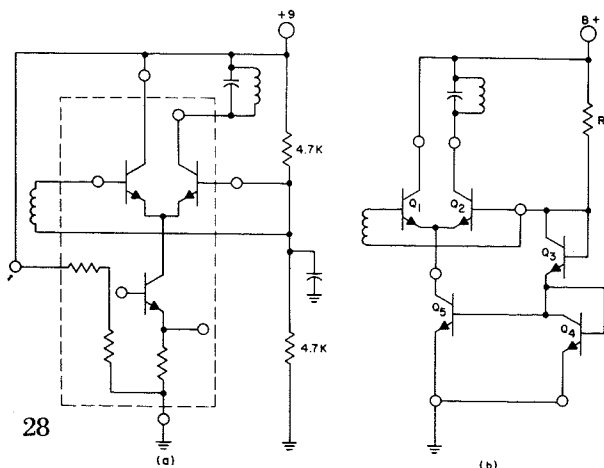


Fig. 5—Differential-amplifier/limiter circuits (a) for the CA3028A or CA3028B and (b) the CA3046.

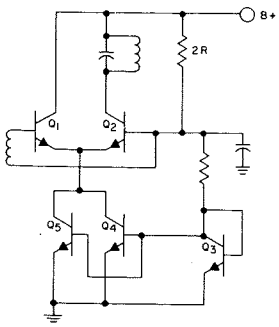


Fig. 6—CA3046 differential amplifier/limiter circuit with reduced current drain.

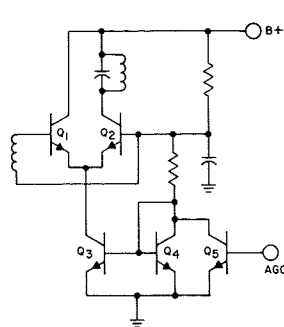


Fig. 7—CA3046 differential amplifier using Q_5 for AGC amplification.

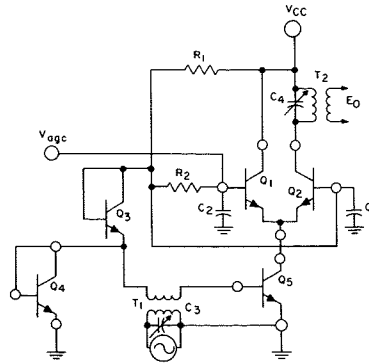


Fig. 8—Cascode-amplifier circuit using CA3045 or CA3046 array.

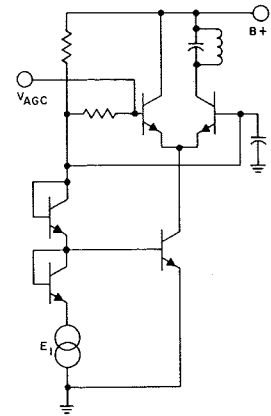


Fig. 9—Cascode amplifier with grounded input.

selected so that I_{c2} does not change more than $\pm 10\%$ from its center value as the beta of Q_1 changes from minimum to maximum, the circuit of Fig. 13a has the characteristics and typical performance shown in Table I. (However, the circuit is easily tailored to different requirements.) If it is desired to maintain the input impedance and gain of the circuit within 3% of the midband values at a low frequency of 20 Hz, C must have a value approaching 3000 μF . Although C is a low-voltage capacitor, for this requirement it becomes a large and expensive component.

The circuit of Fig. 13b shows how the matched characteristics of the CA3046 may be used to eliminate this large capacitor. In this circuit, Q_2 and Q_3 are connected in the same manner as in the circuit of Fig. 13a, except that no AC signals are applied to these transistors. Provided all the resistors are matched within 1 or 2%, the current in Q_1 is the same as that in Q_2 . The voltage drop across the diode-connected transistor Q_2 then exactly compensates for the drop across R_E in the circuit of Fig. 13a. The operating points of Q_1 and Q_3 are at the levels desired, and the dynamic performance is the same as that of the discrete-component circuit.

Design ideas for the RCA-CA3026 and CA3054 dual-differential-amplifier array

The CA3026 integrated-circuit transistor array consists of two independent differential amplifiers with associated constant-current transistors on a common monolithic substrate. The six N-P-N transistors which comprise the amplifiers are general-purpose devices similar to those in the arrays and IC's described previously. These transistors exhibit low $1/f$ noise and a value of f_T in excess of 300 MHz; these features make the CA3026 useful from

DC to 120 MHz. Bias and load resistors are omitted in the array to provide maximum application flexibility.

The schematic diagram of the CA3026 is shown in Fig. 1c. The most obvious advantage of the array is an improvement in packaging density; the circuit provides two differential amplifiers in one package instead of one differential amplifier per package as in the case of the popular CA3028A and CA3028B. This more compact packaging of differential amplifiers results in simultaneous economic advantages. However, the two matched amplifiers of the CA3026 provide other advantages which transcend anything previously available in either tubes or solid-state devices.

Although doubly balanced circuits are not new, they have not been commonly used because of the difficulties encountered in obtaining components which are truly matched and which maintain their match despite variations in temperature and the passage of time. While the procurement of matched passive components (e.g., center-tapped coils, matched resistors, and the like) has been merely tedious, provision of matched active components (e.g., tubes and transistors) has been both difficult and costly. However, the CA3026 provides matched active components in the proper configuration for the design of customized doubly balanced circuits. Some typical doubly balanced circuit configurations are described in the following paragraphs.

Four quadrant multiplier modulator

The matched differential amplifiers of the CA3054 (Fig. 1c) are ideal elements for the construction of a so called "doubly balanced circuit." This configuration is the basis for many multiplier, modulator, and demodulator circuits. A typical circuit of this type is shown in Fig. 14. The doubly

balanced designation is justified because the circuit is balanced for both inputs. When the 100-ohm balancing potentiometers are properly adjusted, neither input signal appears at the output. The waveform photos of Figs. 15a through 15d show the squaring of a 200-Hz sine wave, a 500-Hz triangular wave, a 1-MHz sine wave, and a 5-MHz sine wave, respectively. Note that the response at 5 MHz is about 3 dB below that at low frequency. Fig. 15e illustrates double-sideband suppressed-carrier modulation of a 5-KHz sine wave by a 100 Hz triangular wave with the modulation wave superimposed to indicate the linearity. The phase reversal of the carrier as the modulation changes polarity is easily seen.

A CA3018 is used to complete the circuit. Transistors Q_1 and Q_2 form the constant current source for the multiplier, while Q_3 and Q_4 provide a high impedance load for the modulator and a low output impedance.

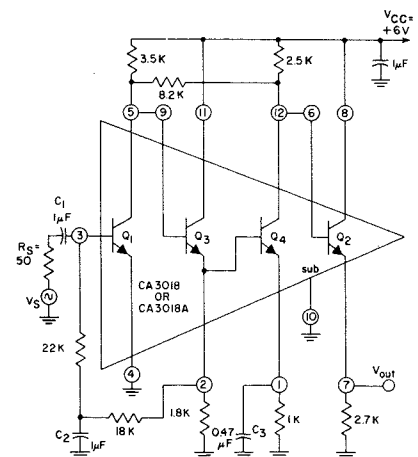


Fig. 10—Wide-band video amplifier using the CA3018.

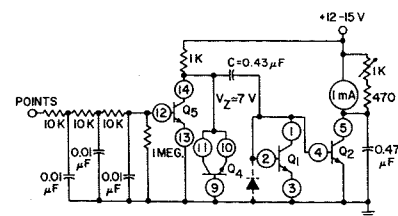
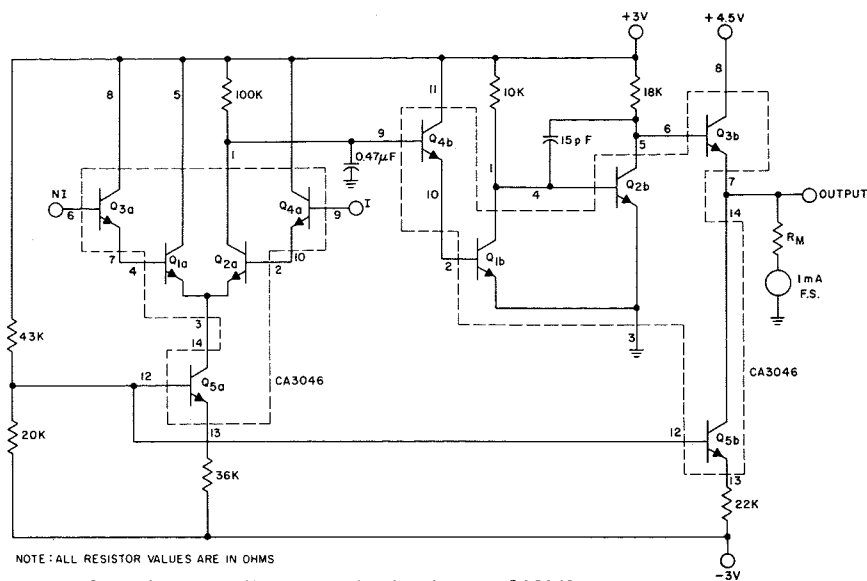


Fig. 11—Tachometer circuit showing a wide variety of uses for the devices, e.g. zener operation, diodes, switches, and substrate diodes.



NOTE: ALL RESISTOR VALUES ARE IN OHMS

Fig. 12—Operational-amplifier meter circuit using two CA3046 arrays.

Table I—Approximate characteristics for the circuit of Fig. 13. -

$$\text{Voltage gain} = \frac{(V^+ - 2V_{BE})^2}{2(0.026)^2} \left[1 + \frac{(V^+ - 2V_{BE})}{0.026\beta_2} \left(\frac{I_{C1}}{I_{C2}} \right) \right]^{-1}$$

$$R_{in} (\text{min}) = \frac{0.022\beta_1 (\text{min})}{I_{C2}} ; R_B = \frac{0.140\beta (\text{min})}{I_{C1}} ; R_{C1} = \frac{V^+ - 2V_{BE}}{I_{C1}}$$

$$R_{out} = R_{C2} ; R_E = \frac{V_{BE}}{I_{C2}} ; R_{C2} = \frac{V^+ - V_{BE}}{2I_{C2}}$$

Example

$V^+ = 12V$	$R_{C1} = 0.1 \text{ megohm}$
$V_{BE} \cong 700mV$	$R_{C2} = 5600 \text{ ohms}$
$I_{C2} = 1mA$	$R_B = 42,000 \text{ ohms}$
$\beta_2 = 100$	$R_E = 700 \text{ ohms}$
$\beta_1 (\text{min}) = 30$	

$$\text{Voltage gain} = 2.12 \times 10^3 \cong 67dB$$

$$R_{in} (\text{min}) = 6600 \text{ ohms}$$

$$R_{out} = 5600 \text{ ohms}$$

Synchronous detector

A synchronous detector is another example of a doubly balanced circuit. Fig. 16 shows a simplified synchronous detector using the CA3026 which can be used to detect both the phase and the amplitude of a TV chroma signal. In this circuit, the reference signal is fixed in both phase and amplitude at 3.58 MHz. The chroma input signal varies in both phase and amplitude in accordance with the hue and saturation information, respectively. The tv detector must compare

the steady reference signal and the varying chroma input signal without causing interaction between the two signals, and must cancel the reference signal without resorting to elaborate filtering systems in the output. A doubly balanced demodulator is an ideal means of accomplishing this objective. Although a rigorous analysis of this circuit is beyond the scope of this paper, a brief description of the circuit configuration is given below.

Transistors Q_3 and Q_4 are connected as a differential amplifier for the chroma signal input, and supply opposite-phase chroma signals to the transistor switches Q_1, Q_2 and Q_5, Q_6 . The chroma-signal currents flow from Q_3 and Q_4 into either of the output leads in accordance with the instantaneous state of each transistor switch. The state of the switch is entirely dependent upon the reference signal applied to its base. In essence, the reference signal performs synchronous switching at its frequency of

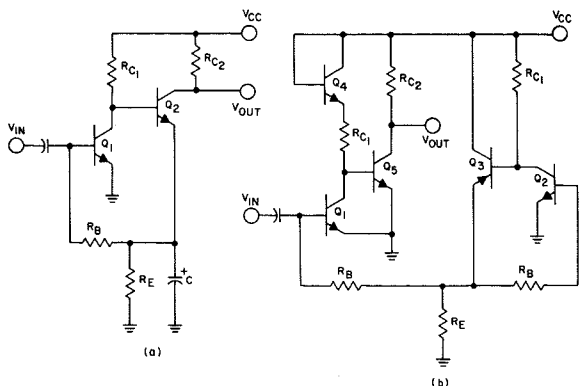


Fig. 13—Circuits illustrating the use of a CA3046 array to eliminate a bulky capacitor.

repetition. By the synchronous comparison process, it is possible to produce an output signal which is a function of the instantaneous phase difference between the chroma and reference signals. Because both the chroma and the reference signals enter into balanced-differential networks, the circuit is doubly balanced. It can also be shown that amplitude variation in the chroma input (with fixed-amplitude reference input) produces corresponding amplitude variations in the chroma video output.

Although the doubly balanced circuit of Fig. 16 could be built with matched discrete transistors, the need for multiple matched devices would make it expensive. Furthermore, matching would deteriorate as a result of temperature variations and there would be a serious degradation in performance. The circuit could also be built with two single-stage differential amplifiers, such as a pair of CA3028A or CA3028B devices, with Q_1 through Q_3 in one package and Q_4 through Q_6 in another package. Even if selected pairs of CA3028A or CA3028B packages were used, however, serious mismatching could still occur with temperature variations. Because the CA3026 contains the required six transistors on the same chip, it has excellent pair-matching characteristics; in addition, tracking of characteristics is maintained with variations in temperature.

Design ideas for the CA3019 and CA3039 diode arrays

The CA3019 and CA3039 arrays (Figs. 1b and 1d) consist of six ultra-fast, low-capacitance diodes on a common monolithic substrate. Integrated-circuit construction assures excellent static and dynamic matching

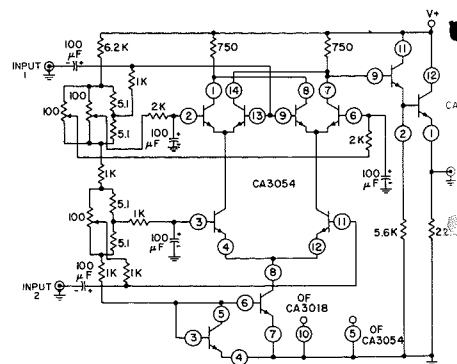


Fig. 14—High-frequency four-quadrant multiplier/modulator with provision for adjustment of all parameters 200Hz to 5MHz.

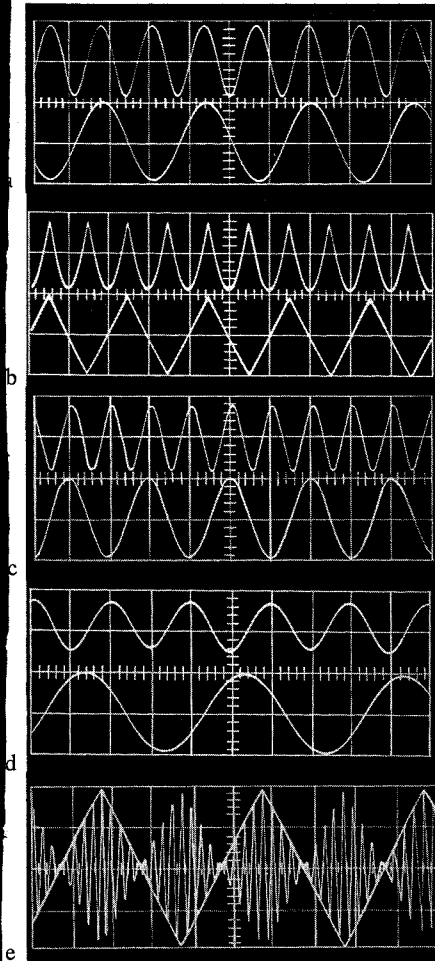


Fig. 15—Input and output waveforms for the multiplier/modulator in Fig. 14 operating from 200Hz to 5MHz.

of the diodes and makes the arrays extremely useful in a wide variety of applications in communications and switching systems. In the CA3019, four diodes are internally connected on a diode-quad arrangement; the other two diodes are independent. In the CA3039, five of the diodes are independently accessible; the sixth shares a common terminal with the substrate.

Because all the diodes are fabricated simultaneously on a single silicon chip, they have nearly identical characteristics, and their parameters track each other with temperature variations as a result of their close proximity and the good thermal conductivity of silicon. Consequently, these arrays are particularly useful in circuit configurations which require either a balanced diode bridge or identical diodes.

Applications of the CA3019 have been described previously.⁵ The six diodes in the CA3039 can be connected in a number of ways for use in voltage-regulator circuits, bias and current-limiting circuits for constant-

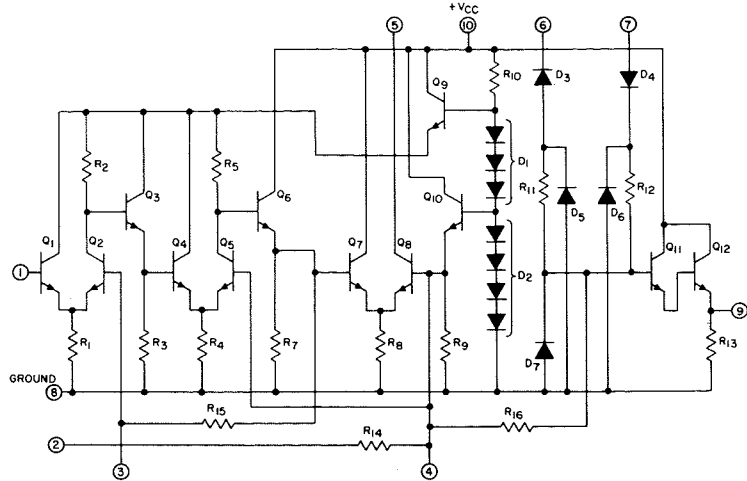


Fig. 18—Schematic diagram of the CA3014 IF amplifier/discriminator/AF amplifier for FM.

current sources and SCR triggering circuits, direct-coupled transistor amplifiers, signal limiting and clamping circuits, logic gates, level-shifting circuits in DTL (diode-transistor-logic) circuits, and varistor circuits. The following paragraphs describe a few practical circuits to stimulate the thinking of potential users.

Low-voltage regulator circuit

The six diodes in the CA3039 may be connected in series, as shown in Fig. 17, to protect against voltage changes in a voltage source. Thus, the CA3039 is able to provide a regulated voltage output of approximately 4.5 V. Higher voltages may be regulated by connection of an appropriate number of CA3039 arrays in series. The type of regulator shown in Fig. 17, when coupled with the package flexibility offered by the CA3039, can also supply intermediate values of voltage in applications requiring base-biasing. The schematic diagram of the CA3014 FM IF amplifier/discriminator/AF amplifier, shown in Fig. 18 illustrates the manner in

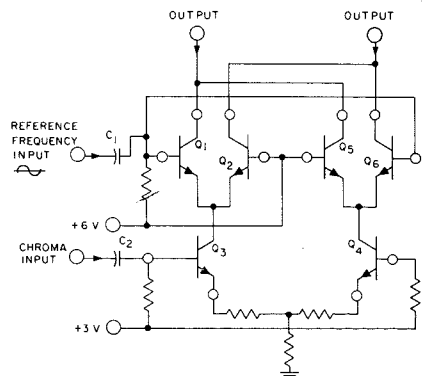


Fig. 16—Synchronous detector using a doubly balanced circuit.

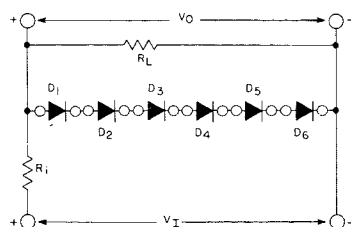


Fig 17—Low-voltage regulator circuit.

which supply potentials for a complex solid-state circuit can be regulated by a diode-connected series-string configuration similar to that of the CA3039. A monolithic series-string regulator can also provide base and collector potentials which track in the face of temperature variations.

Biasing and current limiting for push-pull amplifiers

The amplifier shown in Fig. 19 is a complementary push-pull configuration driven by a class-A driver-amplifier device. Resistor R_2 serves as a common path for AC and DC feedback. The diode pair D_1, D_2 biases the output stage in such a way that crossover distortion is minimized while temperature compensation is provided to keep the idling current stable. The other two diode pairs— D_3, D_4 and D_5, D_6 —are connected in such a manner that they limit the emitter current in the output transistors and thereby protect them. This emitter-current limiting technique is also applicable to single transistors, as shown in Fig. 20. The maximum emitter current is equal to $(V_{cc} - V_{be})/R_E$, and is relatively independent of load, base drive, and the power supply. This configuration can be used for current-limiting service in amplifiers, switching circuits, and voltage and current regulators.

Signal limiting and clamping circuits

Four diodes of the CA3039 may be connected as shown in Fig. 21 to provide limiting or clamping and a choice of two voltage levels, approximately 3 V or 1.5 V peak to peak.

Logic circuits

The diodes of the CA3039 can be connected to form either passive or active logic gates. Fig. 22 shows five-input OR and NOR gates using five of

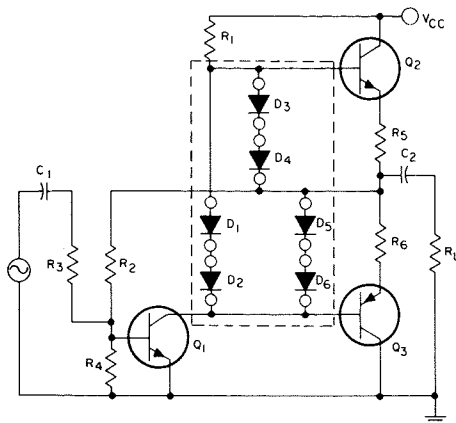


Fig. 19—Complementary push-pull amplifier driven by class-A drive-amplifier device.

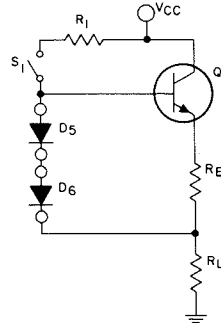


Fig. 20—Emitter-current limiting circuit for single transistors.

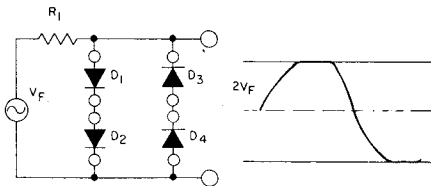


Fig. 21—Use of four diodes of the CA3039 to form a limiting or clamping circuit.

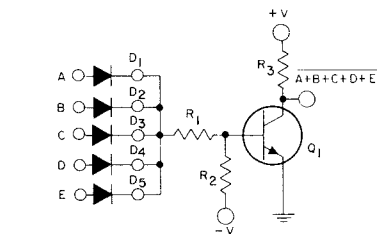
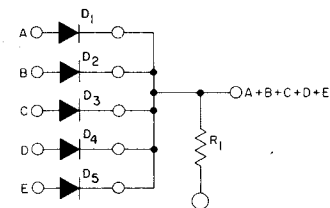


Fig. 22—Five-input "OR" and "NOR" gates.

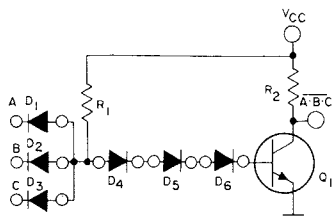


Fig. 23—Use of CA3039 diodes in a NAND gate to provide level shifting.

the CA3039 diodes. The diodes can be connected to provide for level shifting in a NAND gate (Fig. 23) so that only one power supply is required.

Varistor circuits

A varistor is a device consisting of two matched junctions of opposite polarity connected in parallel; it is used primarily for direct conversion of AC and DC information into logarithmic information over several decades. The transfer characteristics of the CA3039 (Fig. 24) illustrate the suitability of this array for such use. Three matched varistors can be provided by proper interconnection of diode pairs in the CA3039, as shown in Fig. 25. Varistors are applicable to fractional voltage regulators, meter protectors, telephone circuits, and negative-temperature-coefficient resistors.

Temperature compensation in SCR triggering circuits

Fig. 26 shows a schematic diagram for a circuit that translates a low-level output signal from a thermistor temperature-sensing element into an on-off control output capable of directly driving high-level loads, such as indicator lamps, resistance heaters, power-control relays, or solenoids. When R_A becomes smaller than R_B , sufficient positive gate current is provided to trigger the SCR on. When R_A is a thermistor and R_B an adjustable reference resistor, the SCR turns on when the thermistor temperature rises above the set value. If the thermistor and the reference resistor are interchanged, the SCR operates when the thermistor temperature decreases.

Without the use of the temperature-compensation diodes D_1 , D_2 and D_3 , the SCR gate trigger voltage would vary as a result of changes in junction temperature. This temperature-sensing error is of the order of 5°C for an ambient temperature change from -55 to 125°C . The use of CA3039 diodes D_1 through D_3 , or D_4 through D_6 can reduce this temperature-sensing error to a value in the order of 0.5°C over the same temperature range. When R_A in Fig. 26 is precisely equal to R_B , zero potential exists at a virtual ground point "B" midway between points "A" and "C". With "B" as an imaginary small point, there are effectively 1.5 diodes in the upper leg

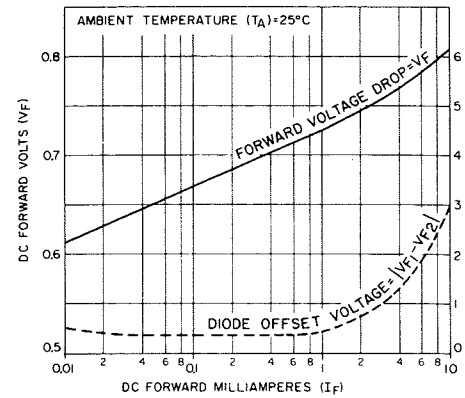


Fig. 24—Transfer characteristics of a CA3039 diode.

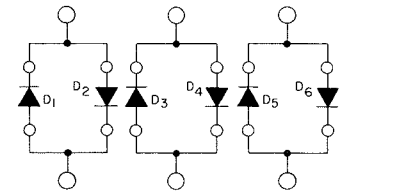


Fig. 25—Three matched varistors composed of CA3039 diodes.

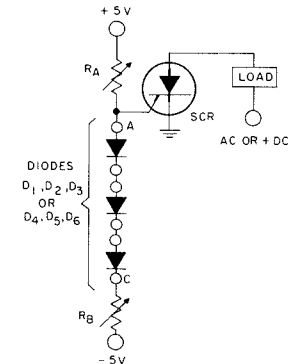


Fig. 26—An SCR triggering circuit with temperature compensation.

of the input circuit and 1.5 diodes in the lower leg; each diode has a temperature coefficient of about $-2\text{mV}/^\circ\text{C}$. Thus, if R_A and R_B are kept equal and ambient temperature is changed, the voltage at "A" changes about $-3\text{mV}/^\circ\text{C}$ (1.5 diodes at $-2\text{mV}/^\circ\text{C}$ each). Compensation is then achieved because the temperature coefficient of the SCR gate trigger voltage is also of the order of $-3\text{mV}/^\circ\text{C}$.

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