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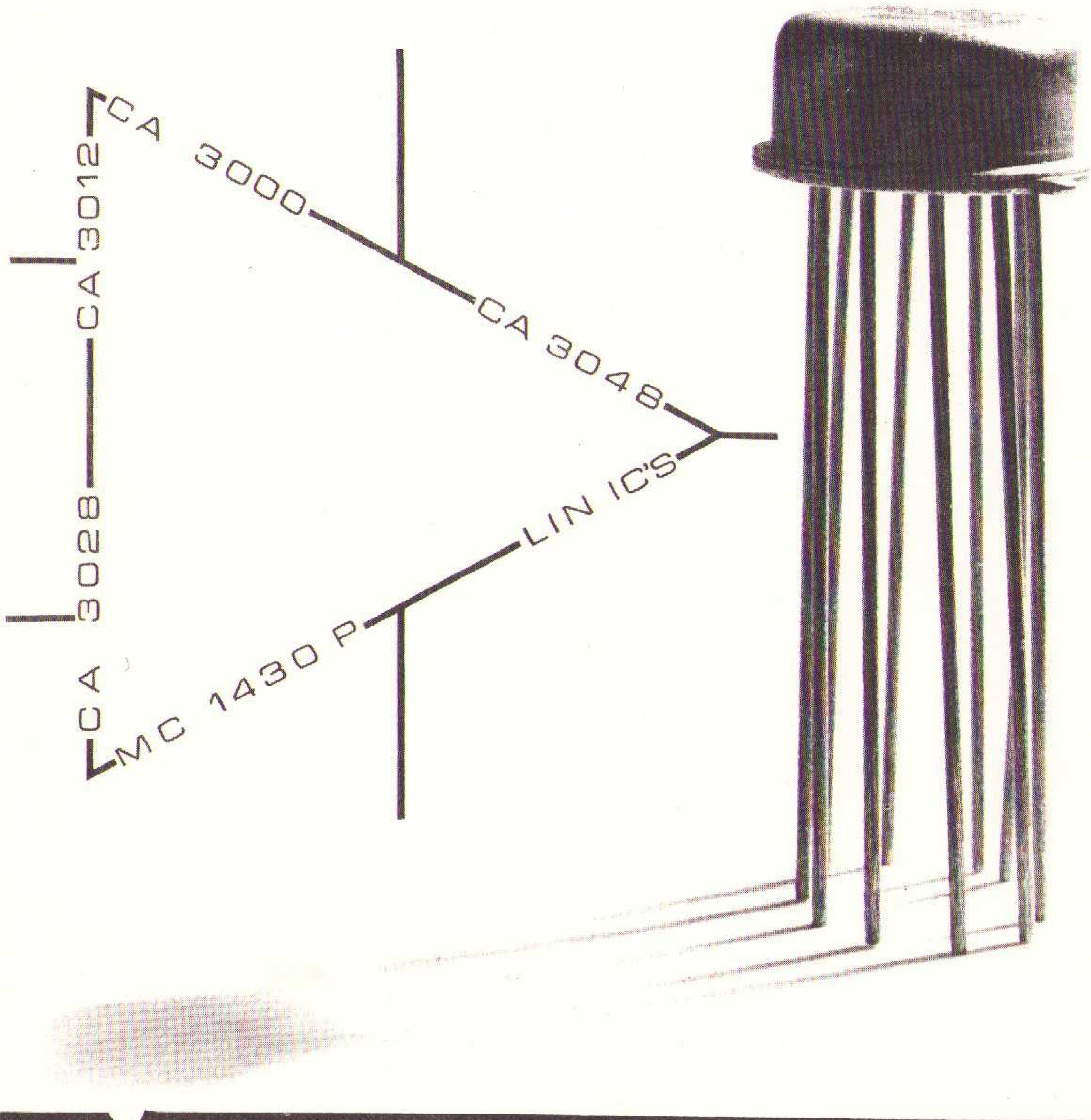

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Inleiding bij technische documentatie deel 10.
In deze uitgave wordt aandacht besteed aan het toepassen van verscheidene geïntegreerde versterkers, welke in voorgaande delen met het volledige datasheet waren opgenomen. De meeste toepassingen liggen in een frequentiegebied tussen 500 kHz en 100 MHz.

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USEFUL FREQUENCY RANGE EXTENSION FOR MC1530 OPERATIONAL AMPLIFIERS

INTRODUCTION

"Those 'blankety-blank' devices are no good. They oscillate all over the place." This could well be a typical remark of many would-be I/C customers. A common misconception in the usage and testing of Integrated Circuit Amplifiers at DC and audio frequencies is that these amplifiers may be connected as casually to external circuitry as is customary with their equivalent discrete circuits. Today's integrated circuits are capable of outperforming their discrete counterparts in many way; however, the design techniques required to build I/C's and the inherent properties of monolithic circuits require that the user follow certain additional precautions to assure reliable circuit operation.

MAJOR DIFFERENCE BETWEEN DISCRETE AND INTEGRATED CIRCUIT LAYOUT

To the economy-minded circuit designer accustomed to constructing DC and audio amplifiers with inexpensive, low frequency transistors and using as few transistors as possible, modern I/C amplifiers may appear unnecessarily complex and "over-spec'd." Space savings, construction materials and labor required, reliability, and temperature stability are some of the reasons that may decide in favor of I/C's.

Consider that a monolithic circuit must be made as physically small as possible and that the use of a large number of direct coupled monolithic transistors and diodes with minimal associated resistors is the approach used for integration. It is more common than not, because of their small physical size, to find monolithic transistors with exceptionally high f_t's considering the circuit applications. This parameter may be found to measure upwards to 400 megaHertz. Consequently, an amplifier designed to be used in the audio range, and up to several megaHertz, with large open-loop gain (for the addition of negative feedback for gain stability and low distortion) may oscillate at some higher frequency, unless proper precautions are taken. This oscillation is, of course, enhanced by the direct-coupled nature of the monolithic circuit. The oscillations generally are at frequencies between 1 and 10 megaHertz, depending upon external configurations.

Care must be exercised in interconnecting these amplifiers with input, output, power supply and any other circuitry which may be required. The user should remember that the monolithic circuit with which he is dealing is a potential RF amplifier, and therefore should be handled according to good RF practice.

The actual techniques of good installation are not much more difficult than the construction of ordinary audio frequency breadboards, except that the user must think in terms of good low resistance and inductance ground and power supply leads. Bypass and/or frequency rolloff capacitors, when called for, should be selected for proper value and should be connected directly at, or as near as possible, the device socket. Inductive leads forming resonant circuits with such capacitors at frequencies within the amplifying capability of the device generate unwanted oscillations. This resonance can also be formed in careless grounding or ground loops in general.

A point of merit for I/C circuits in this regard is due to the consistency or uniformity from one unit to another, in that once proper configurations are realized, they will not vary with the devices.

Constructive suggestions include: proper R. F. bypassing of all power supplies to ground, keep the leads between the power supply bypass and the device short, keep input and output leads short and shielded if required, use one common tie point for all grounds near the device, and use proper frequency rolloff capacitors when called for or found necessary.

An answer to most of the inductive lead problems is the use of copper clad boards or printed circuit techniques. In all cases, the device output and power supply terminals should be monitored with an oscilloscope to verify the circuit's operations.

EXAMPLE

Figure 1 illustrates a typical operational amplifier used in a Wien Bridge Oscillator configuration. The breadboard used was copper clad epoxy glass. Power supply leads were one foot in length and twisted pair.

Figure 2 shows the output signal of the Wien Bridge Oscillator without power supply bypassing or frequency rolloff capacitor.

Figure 3 shows the output signal with power supply bypassing only. Notice the improvement already present in the waveform.

Figure 4 shows the expanded signal superimposed on the output signal of Figure 3. The frequency of oscillation is approximately 6.2 megaHertz.

Figure 5 shows the output signal desired. This resulted by using a 51pF from pin 2 to ground, a 0.1μF from each of pins 4 and 6 to ground, and a 0.01μF between pins 9 and 10 (frequency rolloff).

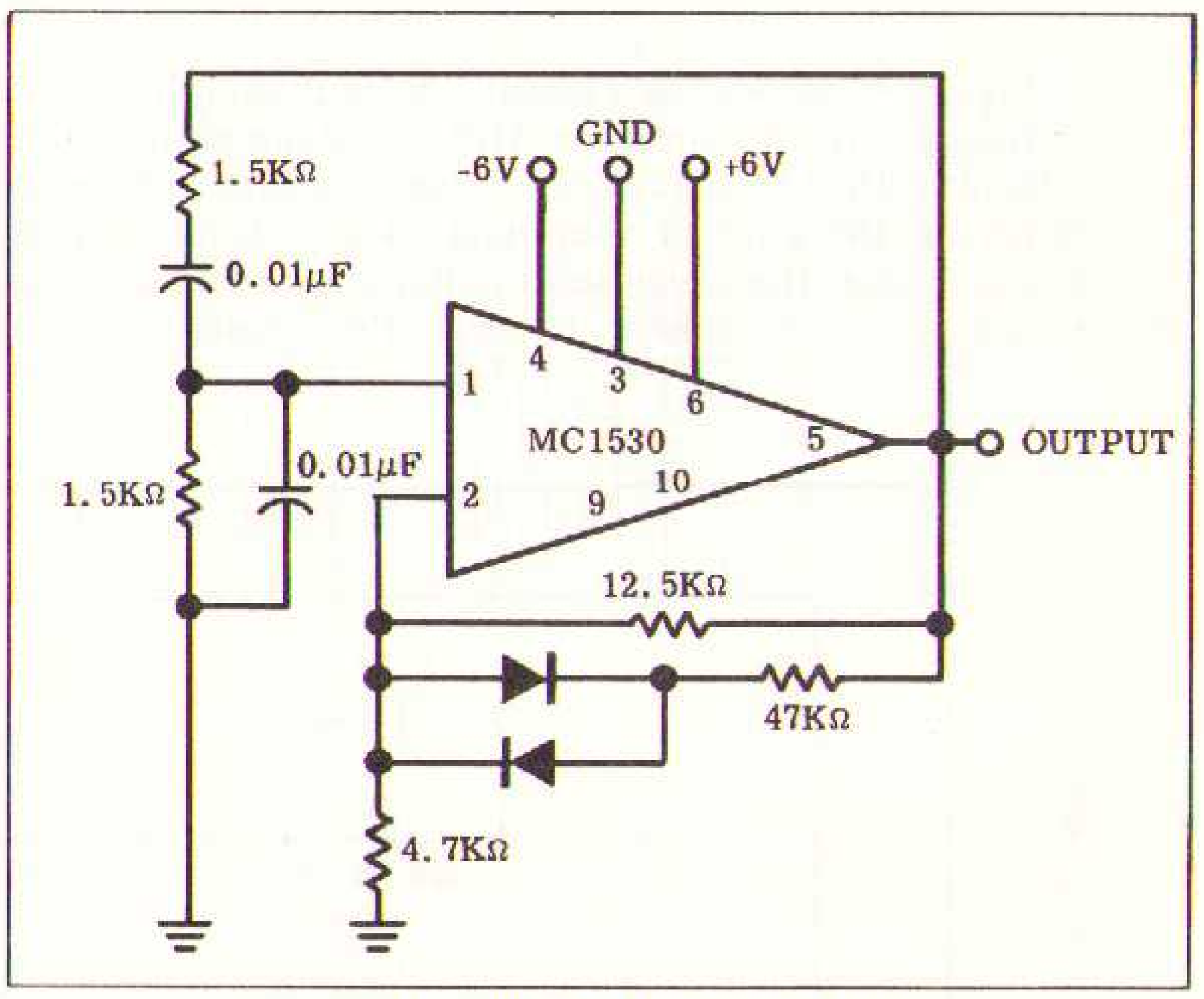


FIGURE 1 — WEIN BRIDGE OSCILLATOR

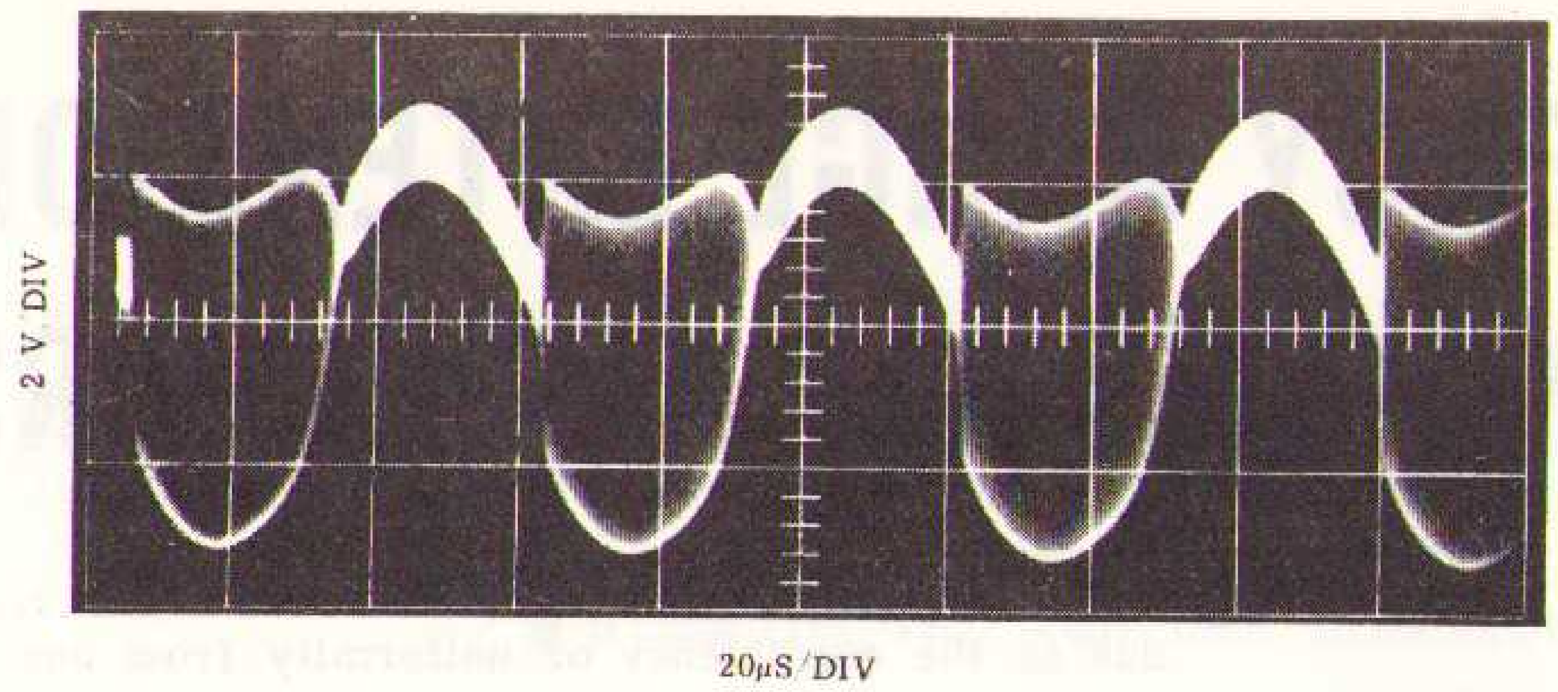


FIGURE 2 — WEIN BRIDGE OSCILLATOR OUTPUT SIGNAL WITHOUT POWER SUPPLY BYPASSING OR ROLLOFF CAPACITOR

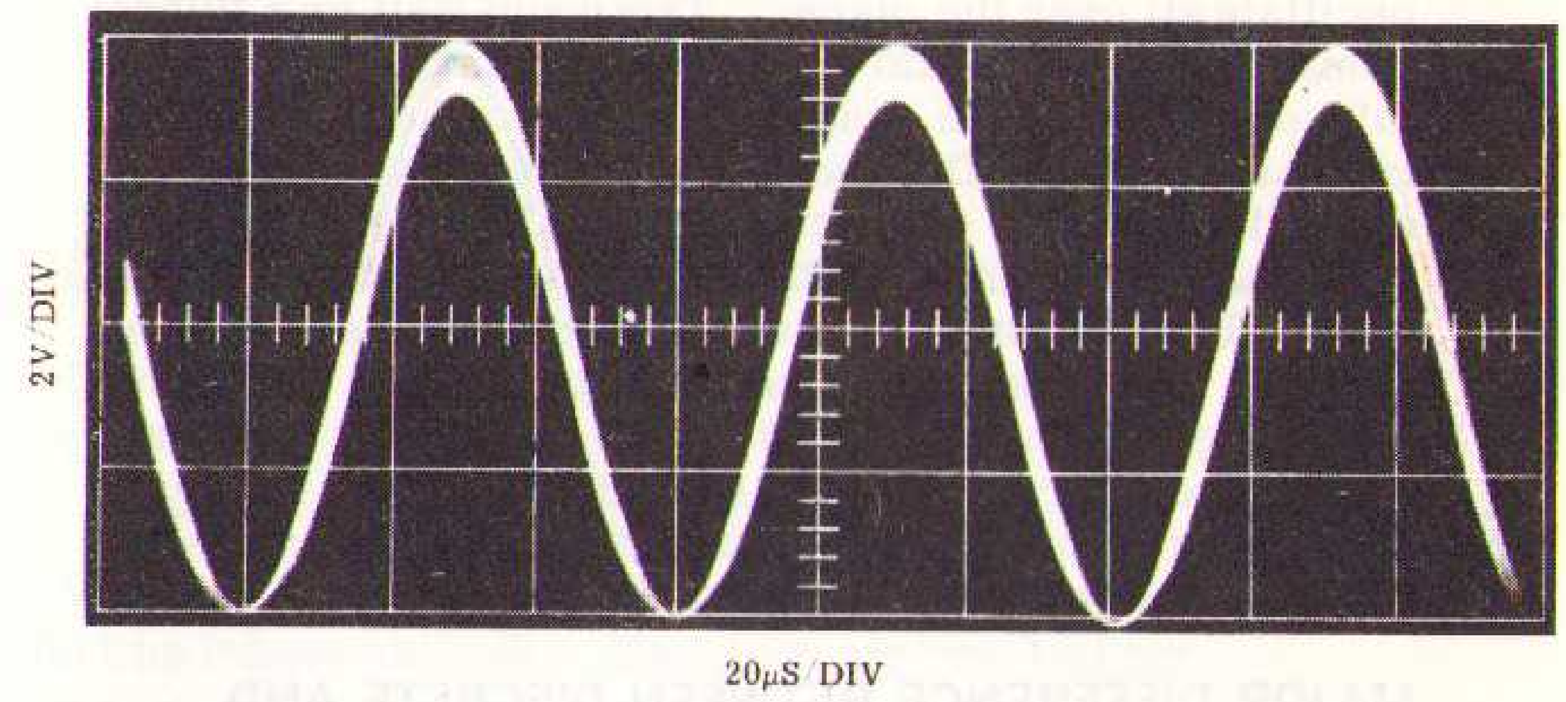


FIGURE 3 — WEIN BRIDGE OSCILLATOR OUTPUT SIGNAL WITH POWER SUPPLY BYPASSING ONLY

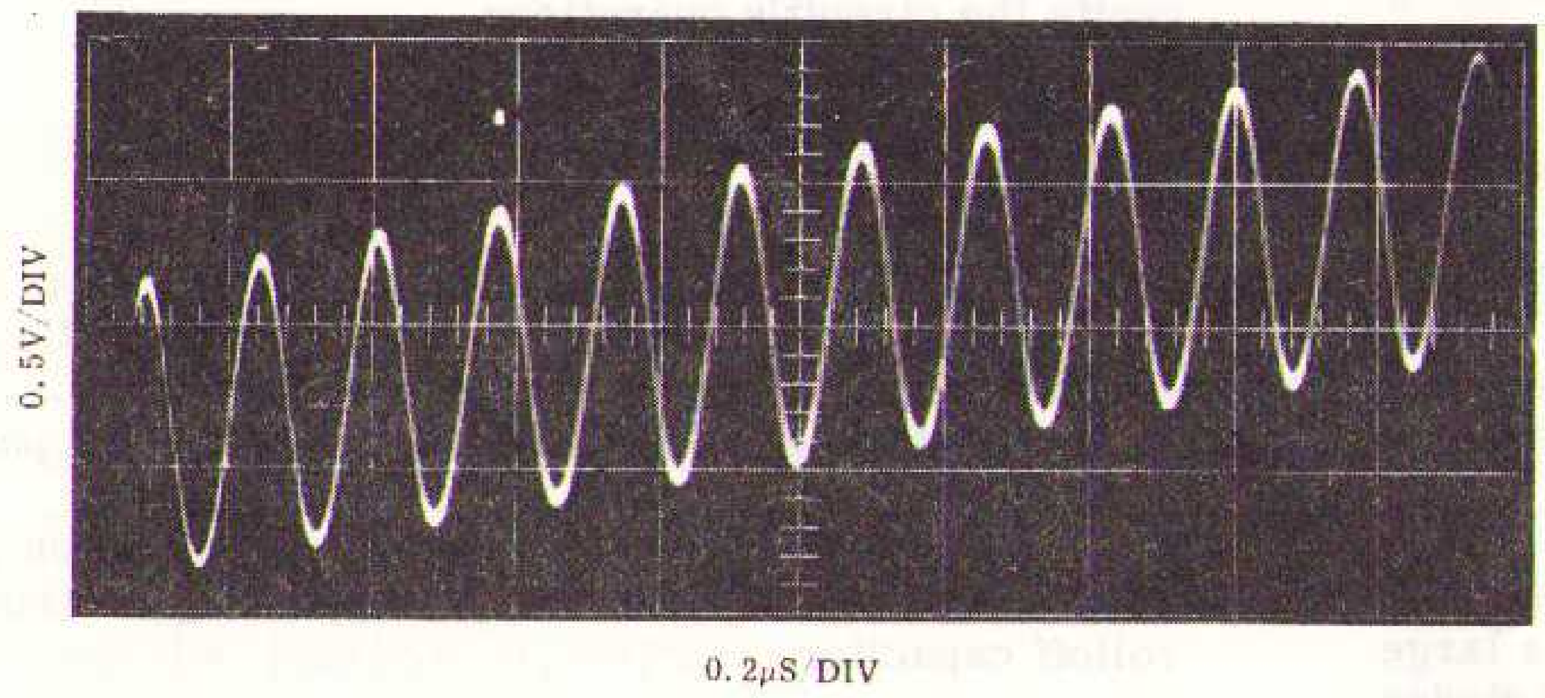


FIGURE 4 — EXPANDED SIGNAL SUPER-IMPOSED ON OUTPUT SIGNAL

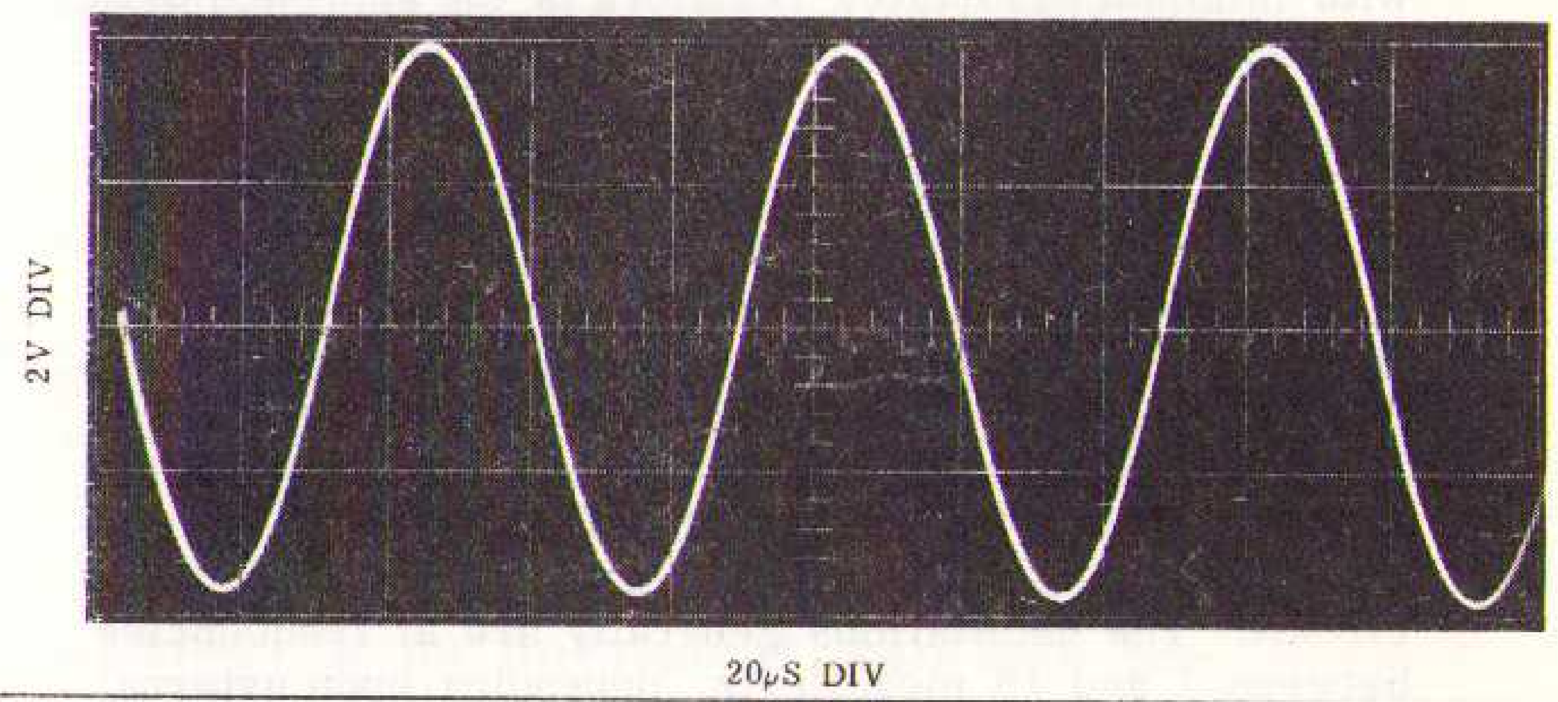


FIGURE 5 — DESIRED OUTPUT SIGNAL

DESIGN #1

Figure C shows the circuit configuration and frequency response for an amplifier with a voltage gain of 6 dB and a bandwidth of 11 MHz. To increase the bandwidth requires lowering the gain of the input stage (dc) and the output stage. Since the open loop voltage gain is low, compensation must be added to keep the closed loop voltage gain constant over the entire bandwidth. There will be approximately 0.4 dB voltage gain change from 500 Hz to 5 kHz caused by the gain change of the output stage. This variation could be eliminated with another lead network on the input similar to the network used in Design #2.

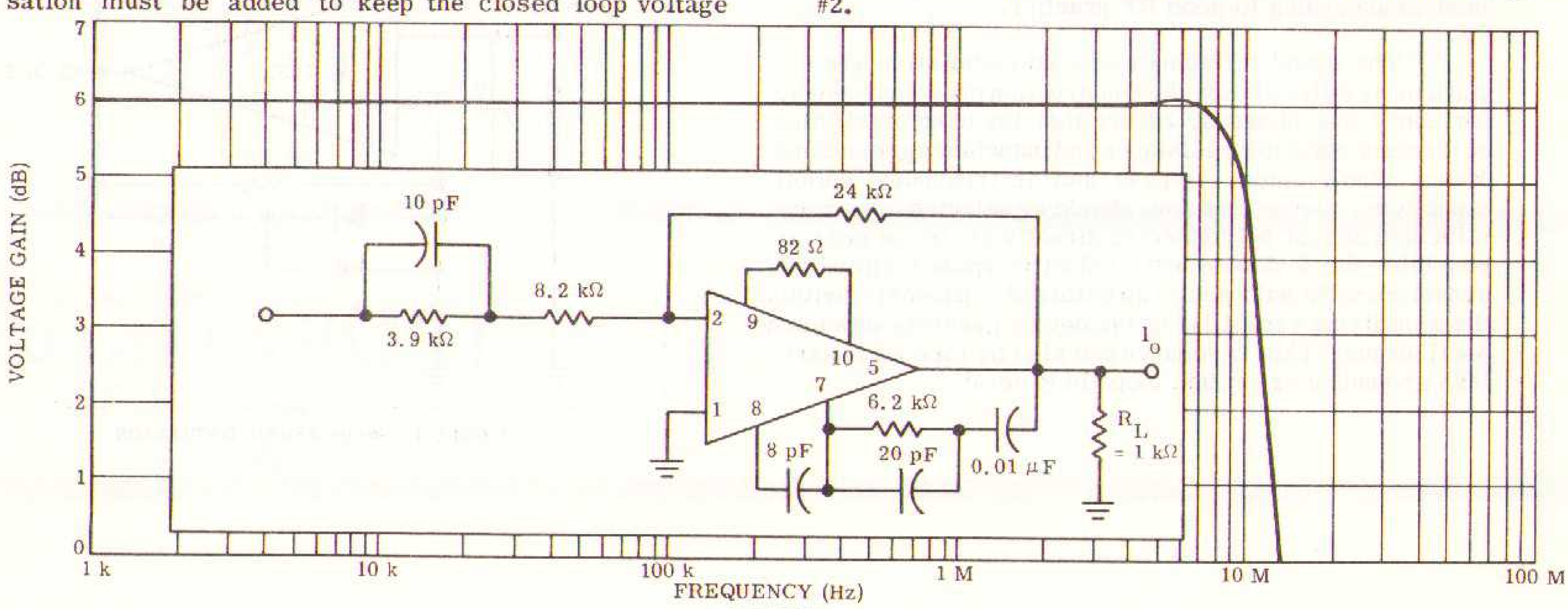


FIGURE C

DESIGN #2

Figure D shows the circuit configuration and frequency response for an amplifier with a voltage gain of 20 dB and a bandwidth of 15 MHz. This circuit uses a resistor to lower the gain of the first stage and the second stage is operated open loop with no frequency compensation. The output stage uses 3 separate frequency compensations: (a) lead network from Pin 7 to Pin 8, (b) lag network (3 pF shunting the 6.2 k), and (c) gain reduction resistor (6.2 k). The lead network (0.05 μF and 1 k) is required to compensate for the reduction in open loop gain of the output stage when the gain reduces from 5 to 1.

The output voltage swing will be 9 V_{P-P} at low frequencies (below 500 Hz) and 0.4 V_{P-P} at high frequencies, that is a sine wave with an amplitude of 9 V_{P-P} or 0.4 V_{P-P} could be passed with very good linearity.

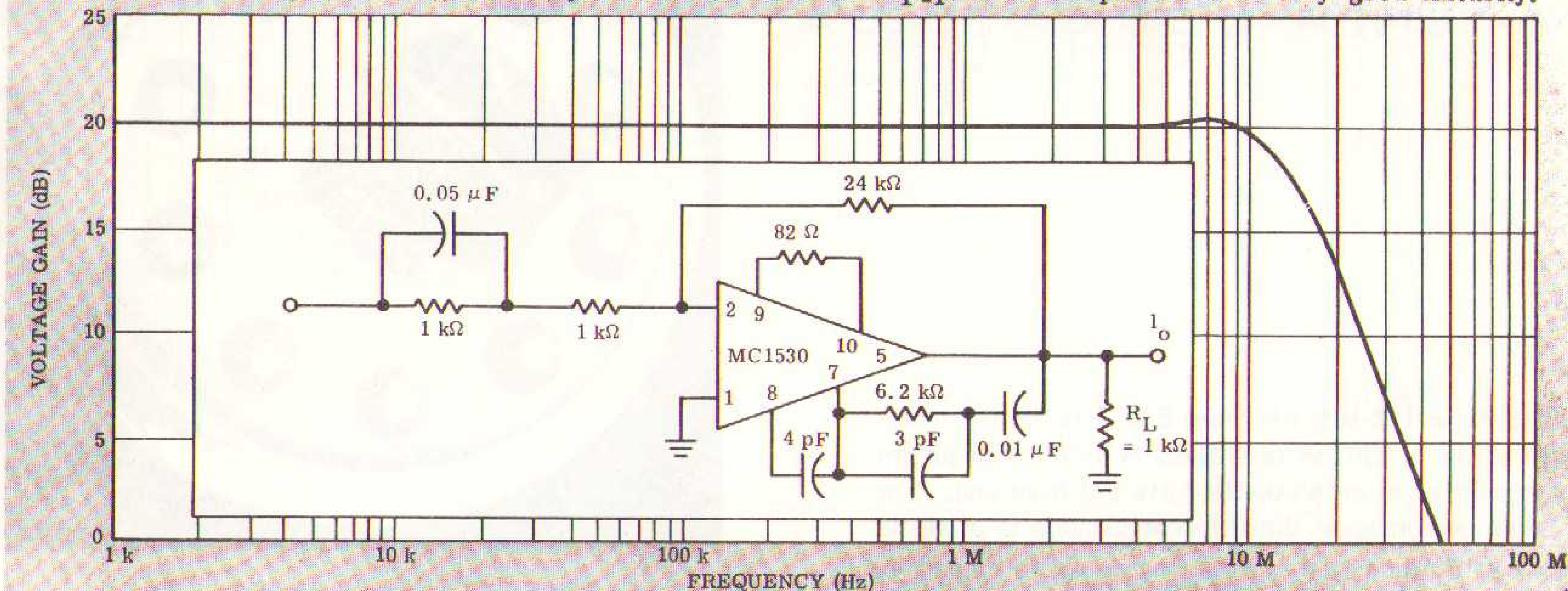


FIGURE D

DESIGN #3

Figure E shows the circuit configuration and frequency response for an amplifier with a voltage gain of 40 dB and a bandwidth of 14 MHz. This design has the highest gain bandwidth product (1.4 GHz); however, it requires more external compensation than the lower gain versions. The same techniques are used in this design that were used in the lower gain amplifier but the first stage is now operated with a gain of 8 instead of 0.8. The additional gain is required in order to achieve a closed loop voltage gain of 100.

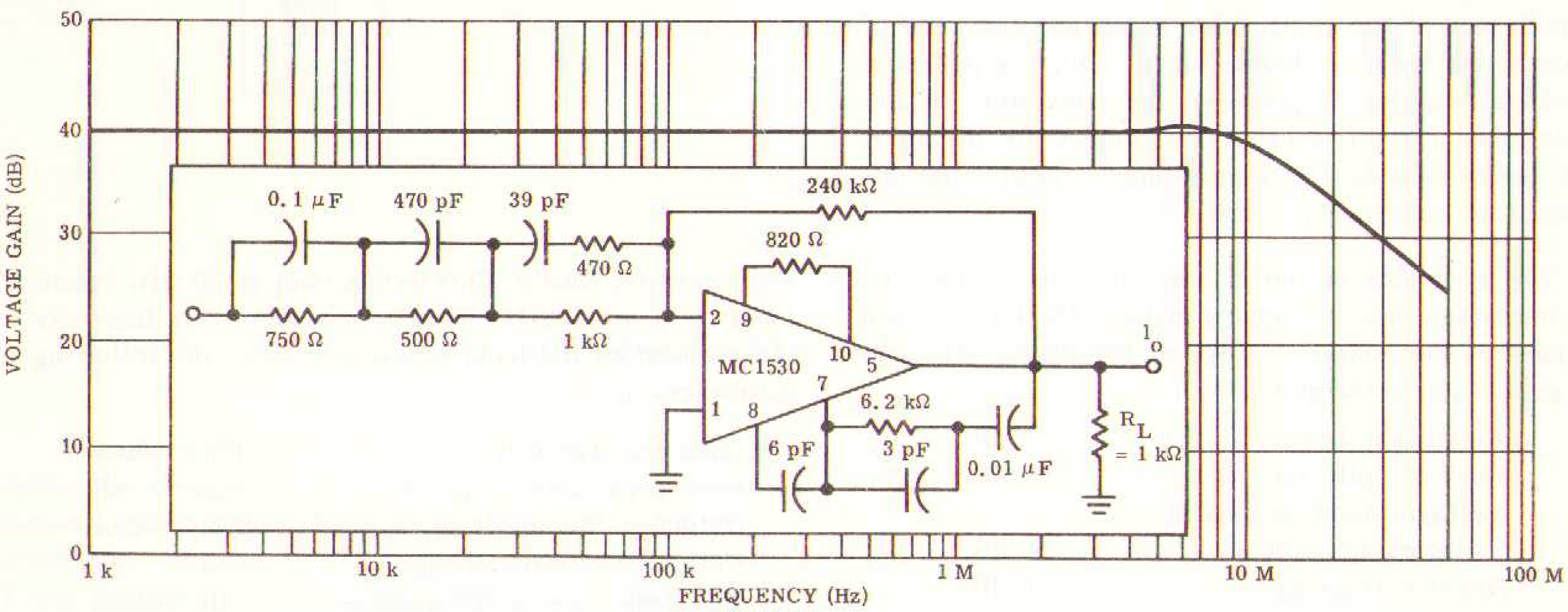


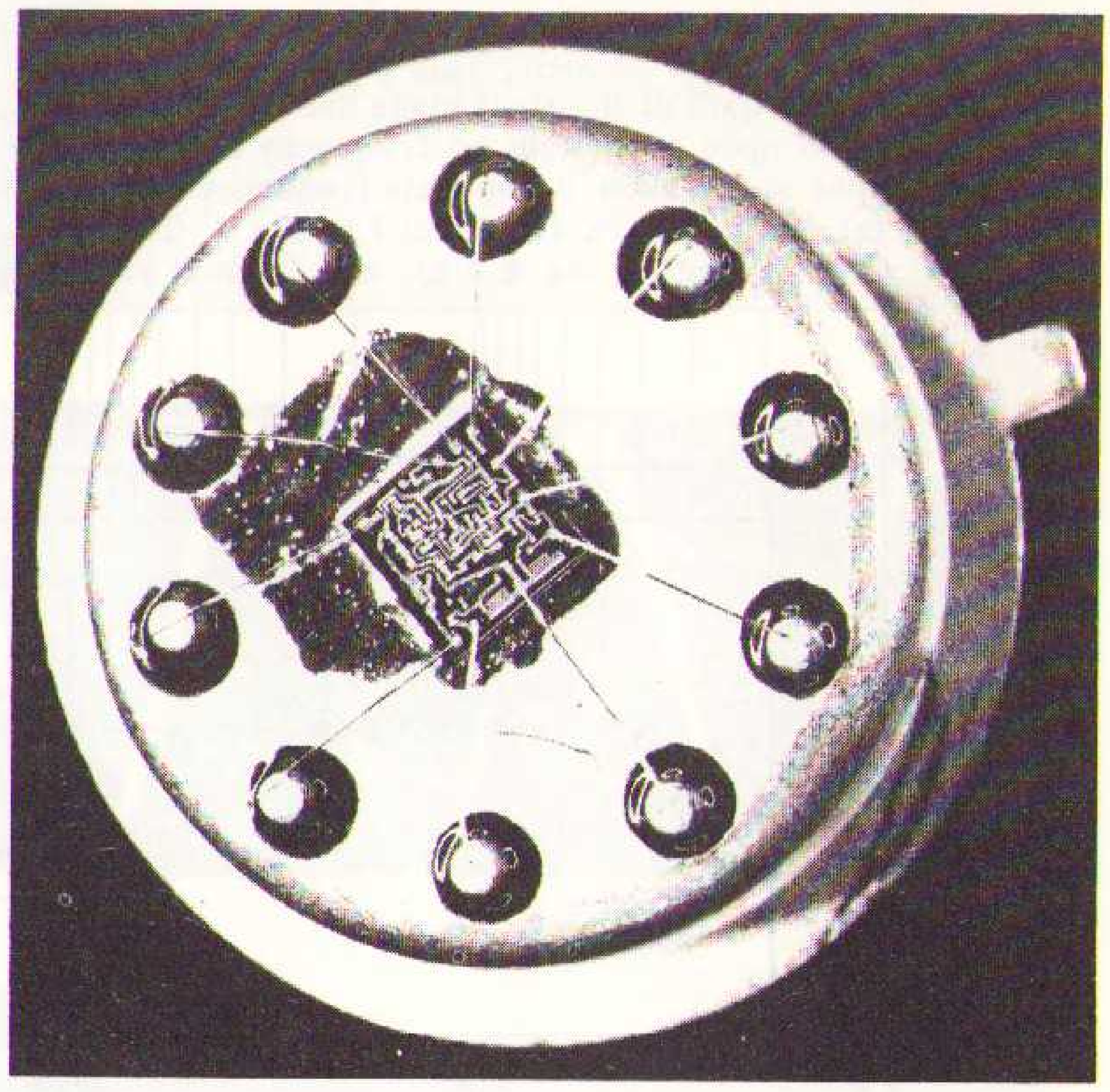
FIGURE E

De op pagina 3,4 en 5 opgenomen hoogfrequent-toepassingen van de MC 1530 gelden in nagenoeg dezelfde mate voor de MC 1430 (zie datasheet in onze technische documentatie deel 7-8 blz. 24 t/m 27.)

CONCLUSIONS

This amplifier makes a very useful device when an operational amplifier is needed to operate from dc to 10 MHz. The MC1530 can be operated at much higher frequencies than the data sheet indicates, providing the necessary precautions and certain limitations are considered. When using the amplifier at high frequencies, the output voltage swing is decreased in order to achieve the additional bandwidth.

FM-TUNER MET CA 3028A



IC chip mounted in TO-5 package assembly.

88-MHz-to-108-MHz FM Front End. Fig.10 illustrates the use of the CA3028A or CA3028B as an rf amplifier and a converter in an 88-to-108-MHz FM front end. For best noise performance, the differential mode is used and the base of the constant-current source Q_3 is biased for a power gain of 15 dB. The rf amplifier input circuit is adjusted for an insertion loss of 2 dB to keep the noise figure of the front end low. Because the insertion loss of the input transformer adds directly to the integrated-circuit noise figure of 5.5 dB, the noise figure for the front end alone is 7.5 dB, as compared to noise figures of about 6 dB for commercial FM tuners.

Although a single-tuned circuit is shown between the collector of the rf-amplifier stage and the base of the converter stage, a double-tuned circuit is preferred to reduce spurious response of the converter. If the double-tuned circuit is critically coupled for the same 3-dB bandwidth as the single-tuned circuit, the insertion loss remains the same.

The collector of the rf stage is tapped down on the interstage coil at approximately 1500 ohms, and the base of the converter stage at 150 ohms. RF voltage gain is computed as follows:

Antenna to base	0 dB
Base to collector.	22 dB
Voltage insertion loss of interstage coil	-13 dB
Net rf voltage gain.	9 dB

If an if converter transformer having an impedance of 10,000 ohms is used, the calculated voltage conversion gain is

$$VG_c = \frac{-y_{21}}{y_{22} + y_L} = 112 = 41.3 \text{ dB}$$

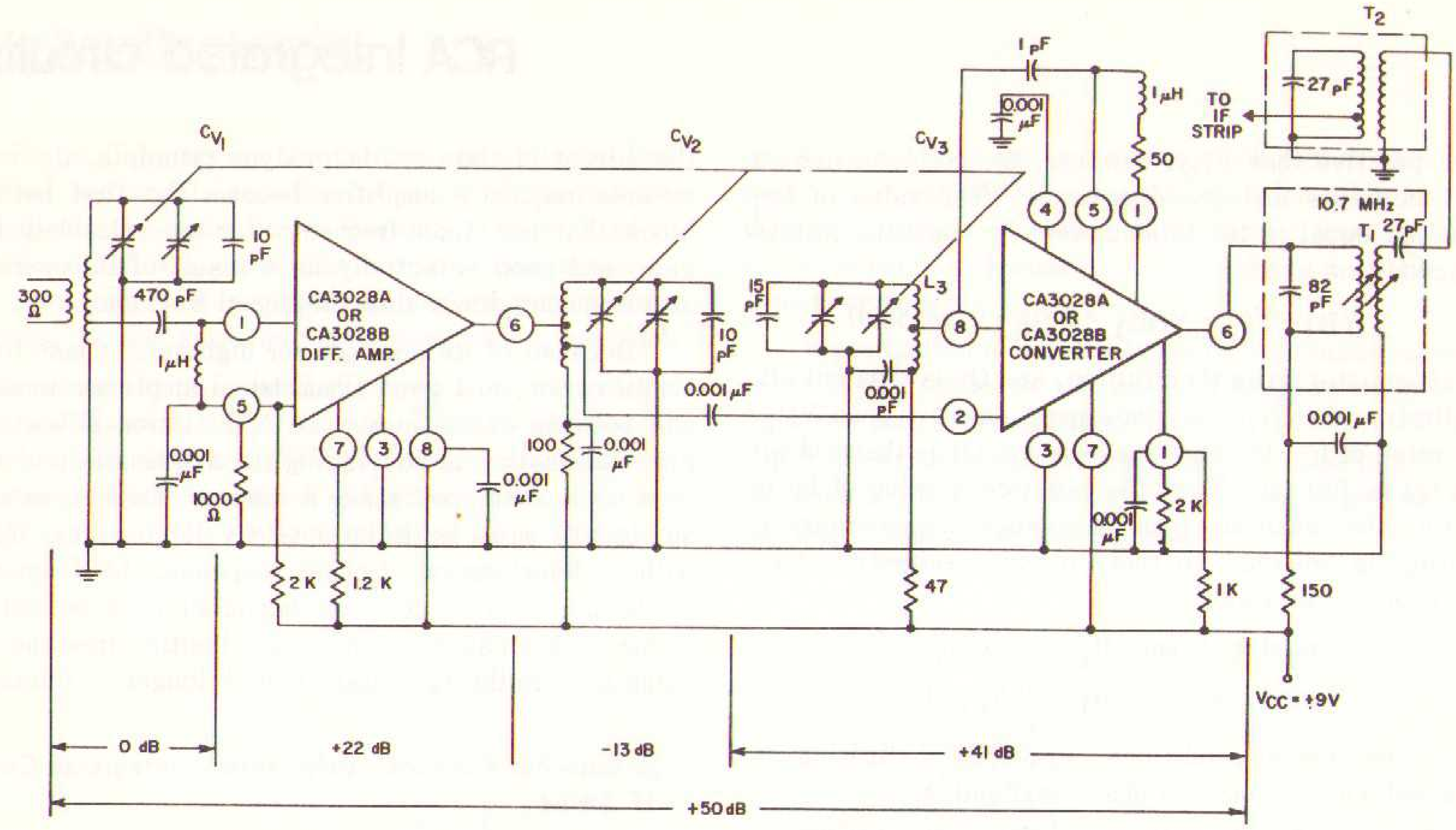
Measured gain into the collector of the converter is 42 dB. The measured voltage gain of the rf amplifier and converter into a 10,000-ohm load is 52 dB; calculated gain is 50 dB. When the converter is tuned for the commercial FM band (88 to 108 MHz), the following parameters apply:

Input resistance R_{in}	170	ohms
Input capacitance C_{in}	6.3	pF
Output resistance R_{out}.	80K	ohms
Output capacitance C_{out}.	3.5	pF
Conversion transconductance. . . .	13	mmhos

The rf amplifier and converter shown in Fig.10 were combined with the if amplifier shown in Fig.7, and the following performance data were measured at 100 MHz:

30-dB (S + N)/N IHFM Sensitivity . . .	3 μV
Image Rejection.	46 dB

Receiver noise figure is the limiting factor that permits a sensitivity of only 3 microvolts to be realized.



L_1: 3-3/4 T #18 tinned copper wire; winding length 5/16" on 9/32" form; tapped at 1-3/4 T; primary — 2 turns #30 SE.

L_2: 3-3/4 T #18 tinned copper wire; winding length 5/16" on 9/32" form; tapped at 6 2-1/4 T, A 3/4 T.

$C_{v1\text{-}2}$: variable $\Delta C \approx 15$ pF

T_1: Mixer transformer TRW #22484 or equiv.

T_2: Input transformer TRW #22485 or equiv.

L_3: 3-1/2 T #18 tinned copper wire; winding length 5/16" on 9/32" form.

$C_{v1\text{-}3}$: variable, $\Delta C \approx 15$ pF.

Fig.10 - 88-MHz-to-108-MHz FM front end.

MF-VERSTERKERS VOOR FM

Silicon monolithic integrated circuits that use a differential-amplifier configuration have certain design features which make them more attractive than discrete-component circuits for FM if-amplifier applications. These features include better performance, small size, light weight, and more potential circuit functions per dollar of cost.

The Differential Amplifier

The heart of integrated-circuit FM if amplifiers is the differential amplifier, which is probably the best simple configuration available today for symmetrical limiting over a wide input-voltage range. Each half of the differential amplifier is alternately cut off on positive and negative half-cycles of the input signal.

As shown in Fig.1, the total current through the circuit I_T is relatively constant. A current equal to $I_T/2$ flows through each transistor at balance (quiescent condition). When the base voltage V_{B1} is made

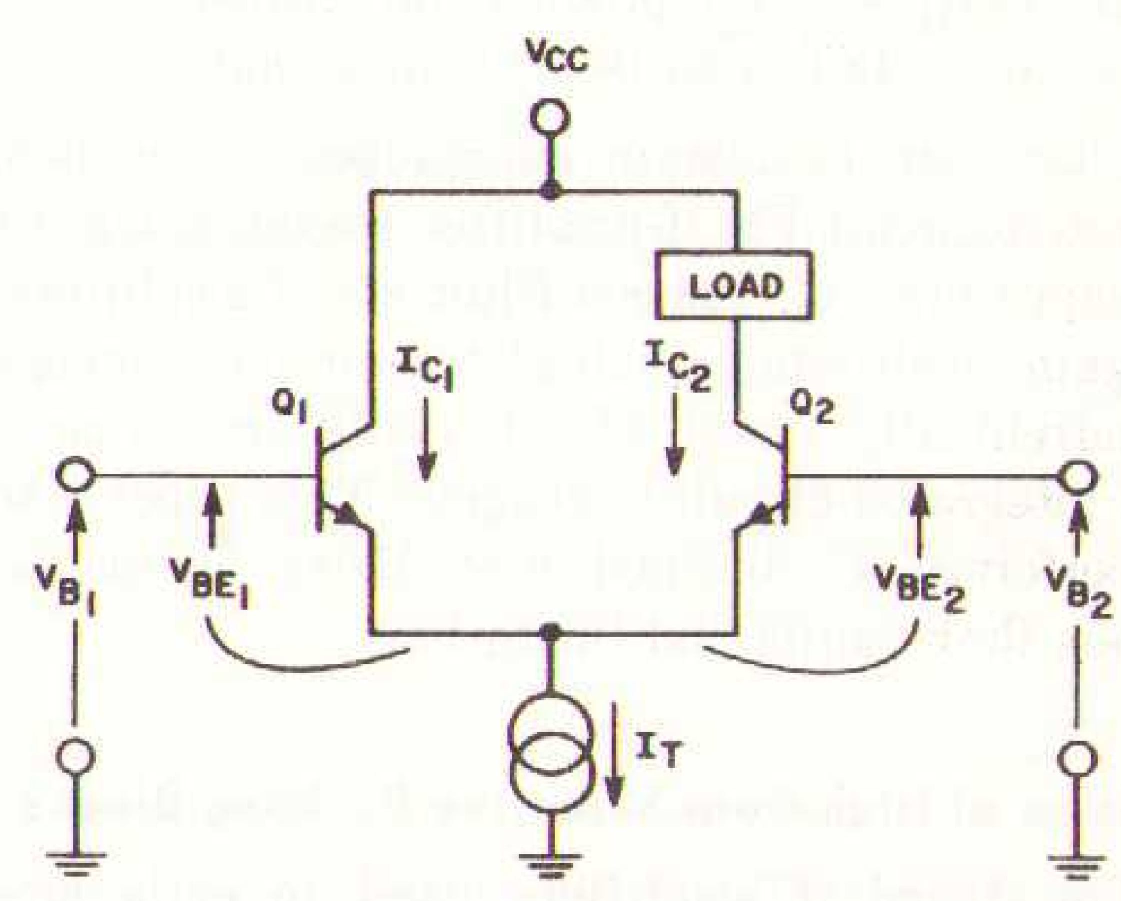


Fig.1 - Basic differential-amplifier configuration.

This material was presented at the IEEE Second Annual Semiconductor-Device Clinic on Linear Integrated Circuits in New York City, March 24, 1967.

more positive than V_{B2}, however, the collector current I_{C1} increases and I_{C2} decreases. The value of I_{C1} becomes equal to the total current I_T when the following condition exists:

$$V_{B1} - V_{B2} - V_{BE1} \geq V_{BE2} \text{ (threshold)}$$

The transistor Q_1 is then full on, and Q_2 is then cut off. Similarly, when V_{B1} is made more negative than V_{B2}, the value of I_{C2} becomes equal to I_T; Q_1 is then cut off and Q_2 is full on. When the worst-case value of I_T is known, the maximum load impedance for symmetrical limiting is selected so that collector saturation does not occur, as follows:

Resistive Load: $R_L = V_{CC}/I_T$

Tuned Load: $R_L = 2\,V_{CC}/I_T$

Under these conditions, symmetrical limiting is obtained without spurious phase modulation.

The transfer characteristics for a typical differential amplifier shown in Fig.2 illustrate the excellent

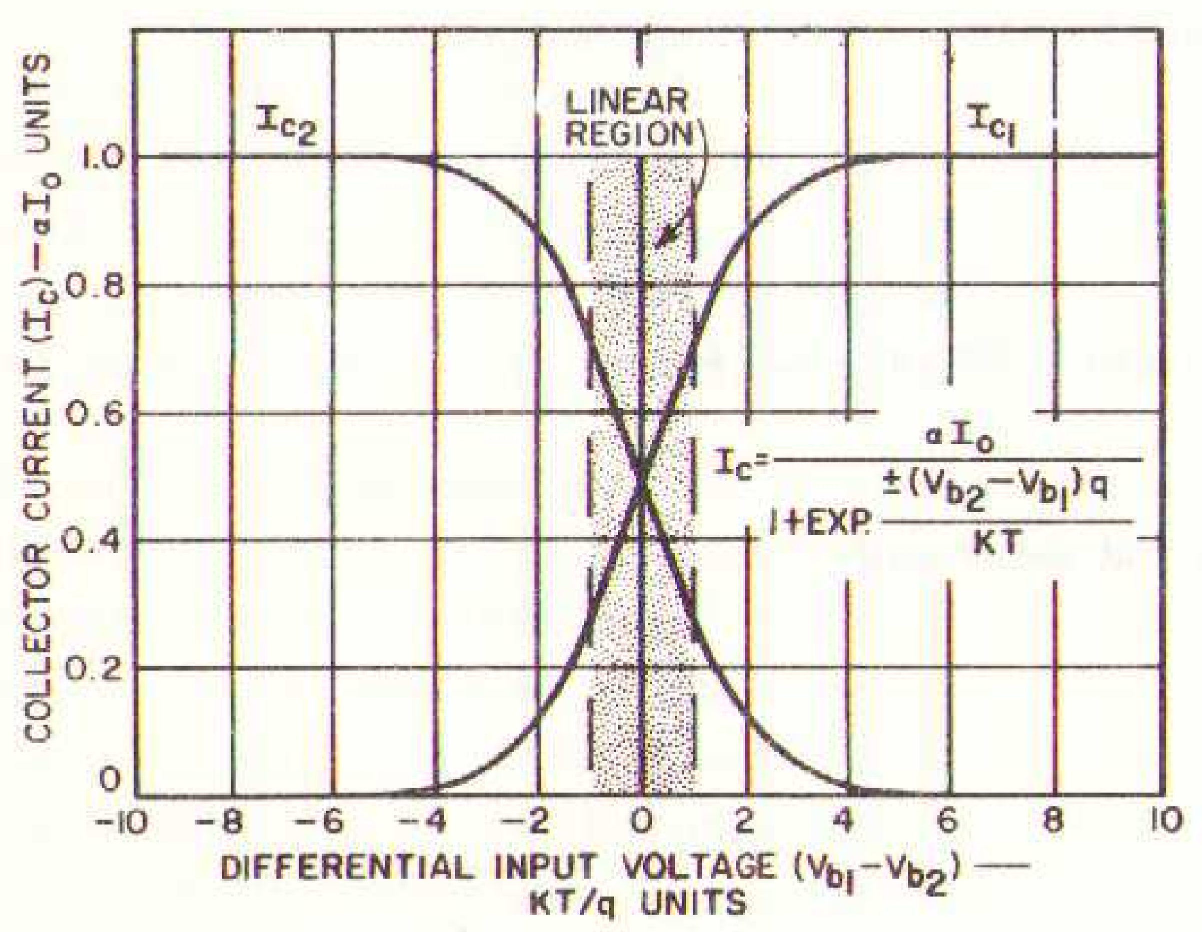


Fig.2 - Transfer characteristics of basic differential-amplifier circuit

limiting characteristics. Further increases in input voltage (V_{B1} - V_{B2}) produce no change in collector current above 4KT/q units of input signal.

There are two basic approaches to the design of integrated-circuit FM if-amplifier stages using differential amplifiers: (1) lumped-filter FM if amplifiers using high-gain multi-stage integrated-circuit packages, or (2) individually tuned FM if amplifiers using single-stage integrated-circuit packages. This paper discusses the performance obtained with these approaches and outlines their merits and limitations.

Evolution of High-Gain Selective Building Blocks

The tuned rf amplifiers used in early broadcast receivers soon exhibited a point of diminishing returns with regard to gain and selectivity improvements. With the advent of the superheterodyne principle, the intermediate-frequency amplifier became the first building block that had fixed-frequency tuning, relatively high gain, and good selectivity as a result of its operation at a frequency lower than the signal frequency.

Because of its demands for high gain, phase linear amplification, and good symmetrical amplitude limiting, and because of the numerous FCC station allocations, FM broadcasting is now facing the dilemma of providing selectivity with good phase response. That is, receiver selectivity must be maintained for large signal inputs without deterioration of phase response. (A discussion of the practical solution of this problem is beyond the scope of this paper.) Successive limiting from the last stage back to the first stage can no longer be tolerated.

High-Gain-Per-Package Differential Integrated-Circuit IF Strips

Fig.3 shows the schematic diagram of a high-gain integrated circuit, the CA3012, which can be used in an if-amplifier strip to drive a ratio detector. The CA3012 wideband amplifier, designed for use in FM broadcast or communications receivers, is basically an if amplifier-limiter intended for use with external FM detectors. It consists of three direct-coupled cascaded differential-amplifier stages and a built-in regulated power supply. Each of the first two stages consists of an emitter-coupled amplifier and an emitter-follower. The operating conditions are selected so that the dc voltage at the

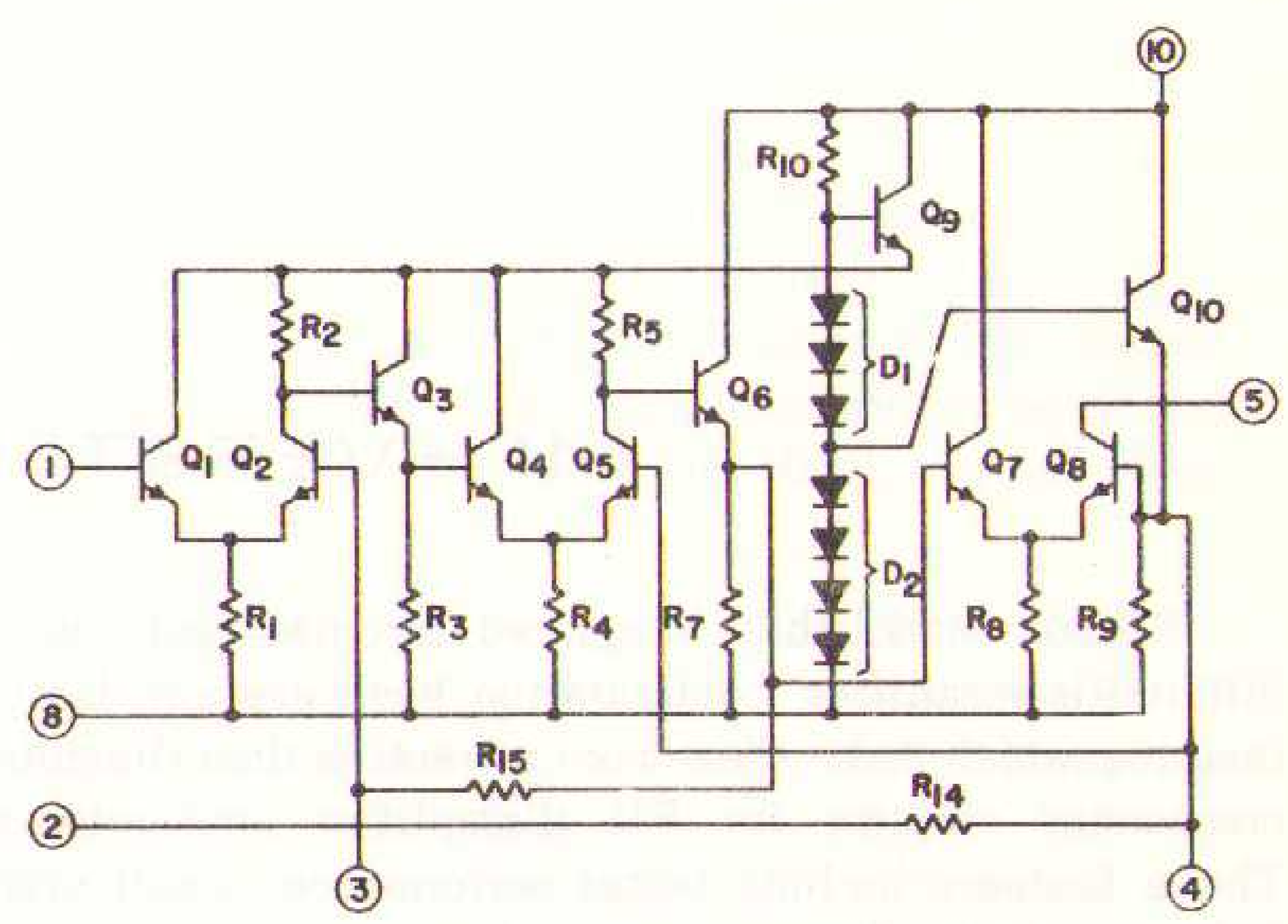


Fig.3 - Schematic diagram of CA3012 integrated-circuit wideband amplifier.

output of each stage is identical to that at the input of the stage. This condition is achieved by operation of the bases of the emitter-coupled differential pair of transistors at one-half the supply voltage and selection of the value of the common-emitter load resistor to be one-half that of the collector load resistor. As a result, the voltage drops across the emitter and collector load resistors are equal, and the collector of the emitter-coupled stage operates at a voltage equal to the base-to-emitter voltage V_{BE} plus the common base potential. The potential at the output of the emitter-follower, therefore, is the same as the common base potential.

At an operating point 3 dB down from the knee of the transfer curve, therefore, the CA3012 requires an input between 400 and 600 microvolts, depending on the ratio-detector design. Fig.4 shows the use of two CA3012 units in a 10.7-MHz if-amplifier strip. A double-tuned filter that has a voltage insertion loss of 8 dB is located between the two CA3012 units to provide a filter input of approximately 1000 microvolts (at terminal 5 of the first CA3012). For an if-strip sensitivity of 4 microvolts, a gain of 48 dB is required. However, if the CA3012 used has a load impedance of 1200 ohms, the available gain is 65 dB, or approximately 17 dB more than required. The extra gain is not wasted, but drives the second CA3012 harder, causing it to limit so that its gain is reduced by approximately 17 dB.

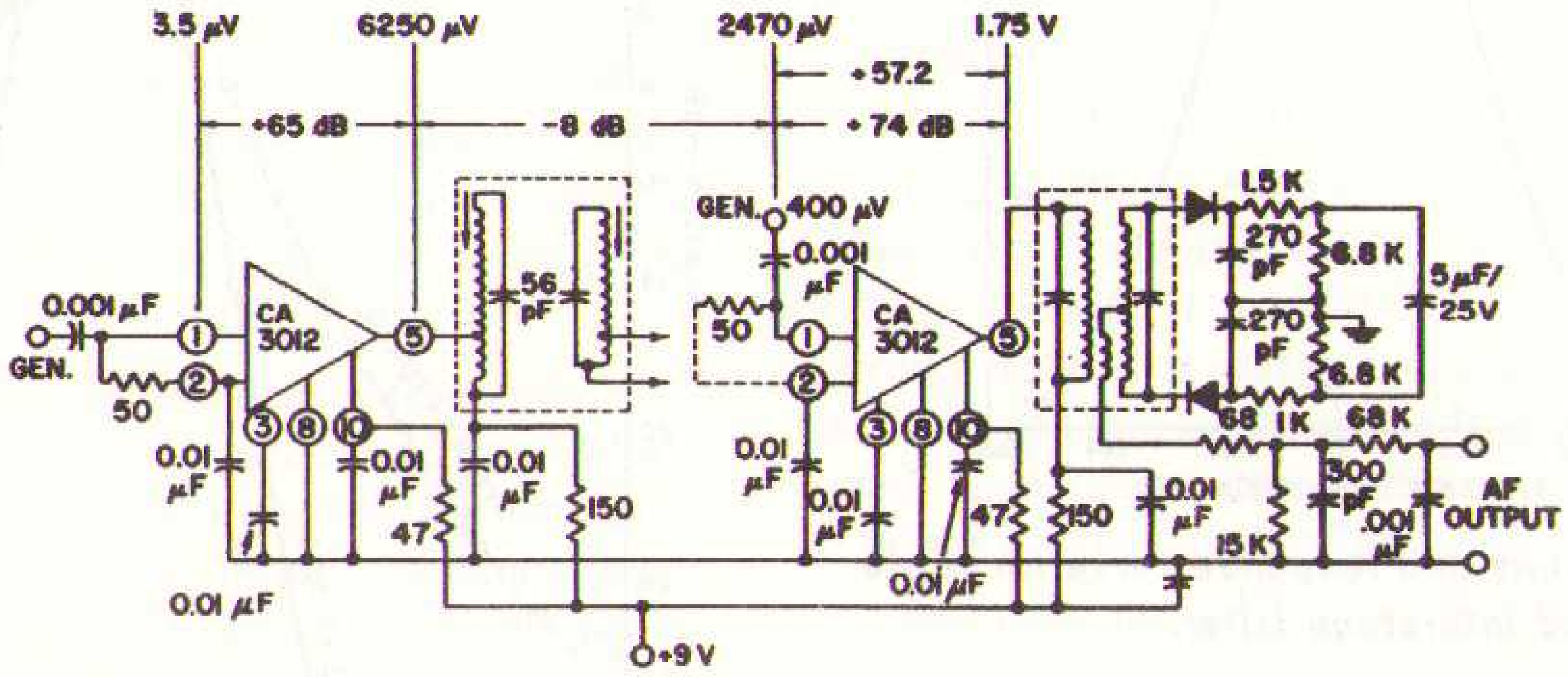


Fig.4 - 10.7-MHz if-amplifier strip using CA3012 integrated circuit.

Fig.5 shows the selectivity of the double-tuned interstage filter. The 3-dB bandwidth is 200 kHz at an input of 10 microvolts and 240 kHz at inputs from 500 microvolts to 0.5 volt. The coefficient of critical coupling is approximately 0.5 at 10 microvolts and increases to 1.0 but still maintains good phase response. The double-tuned filter should be coupled capacitance-aiding to avoid a nearly in-phase over-all relationship. Otherwise, bypassing of terminal 10 and the ratio-detector primary becomes critical and over-all stability is impaired.

The connection of the FM front end to the integrated-circuit if strip must provide good selectivity and good phase response. A double-tuned filter is not suitable from the standpoint of selectivity. An actual IHFM* receiver selectivity between 35 and 40 dB is practical and does not impose too much burden on alignment. Because IHFM selectivity includes other factors than passband, a combined filter design that provides second-channel attenuation between 52 and 60 dB becomes imperative.

Investigation of various types of inductance-capacitance filters indicates the use of a triple-tuned type to form the major lumped selectivity of the FM receiver. Fig.6 shows the response curve and two configurations for such a filter. Economy and ease of alignment are the major features in this approach.

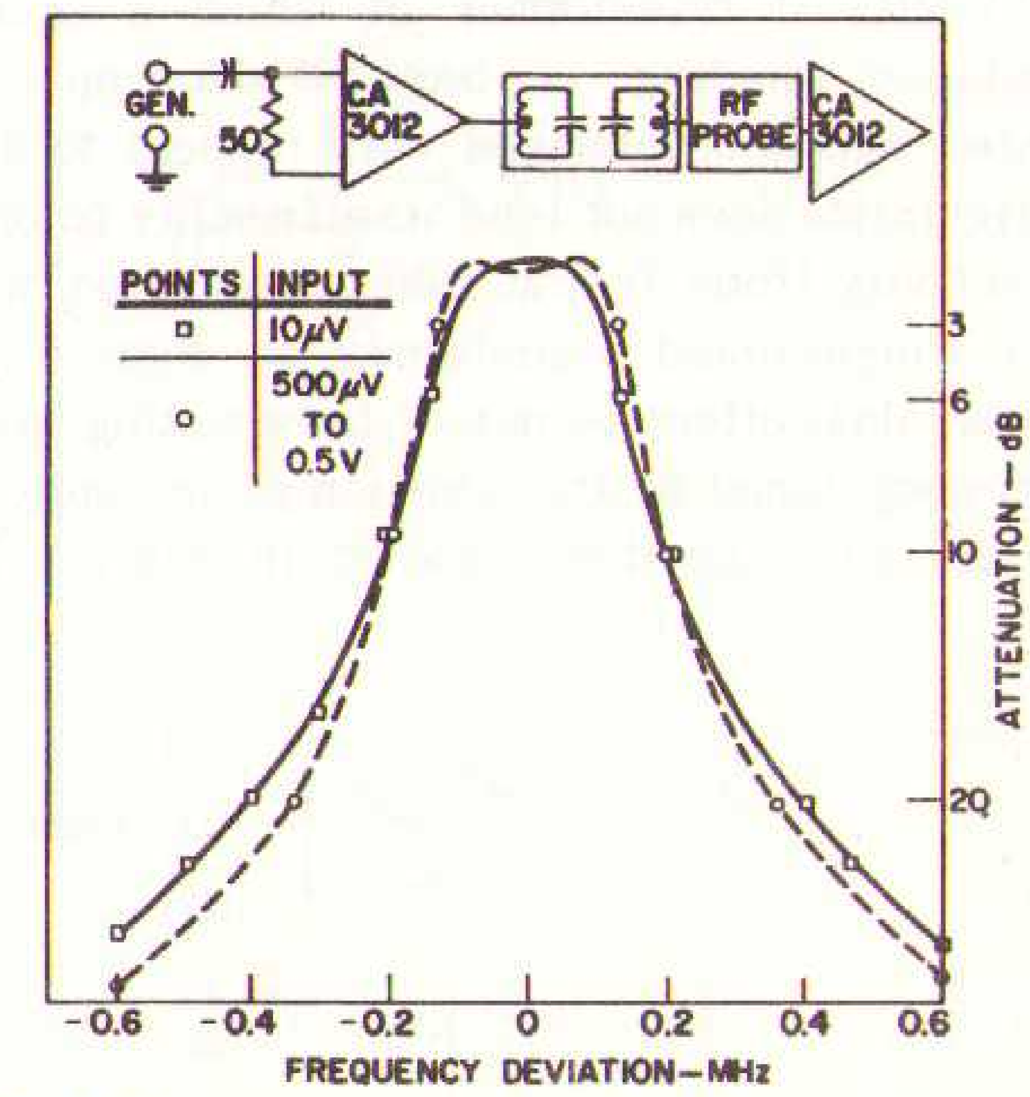


Fig.5 - Selectivity curve for double-tuned interstage filter.

The triple-tuned filter, which is located between the mixer and the first integrated circuit, may have a voltage insertion loss of 33 dB, depending on the desired gain distribution. The power insertion loss of the filter, which is between 12 and 17 dB, is the loss that contributes to if noise. If the primary impedance is reduced to provide a lower voltage insertion loss, the front-end gain is decreased by a corresponding amount. Stability criteria must be the deciding factor in impedance and gain distribution.

* Institute of High-Fidelity Manufacturers.

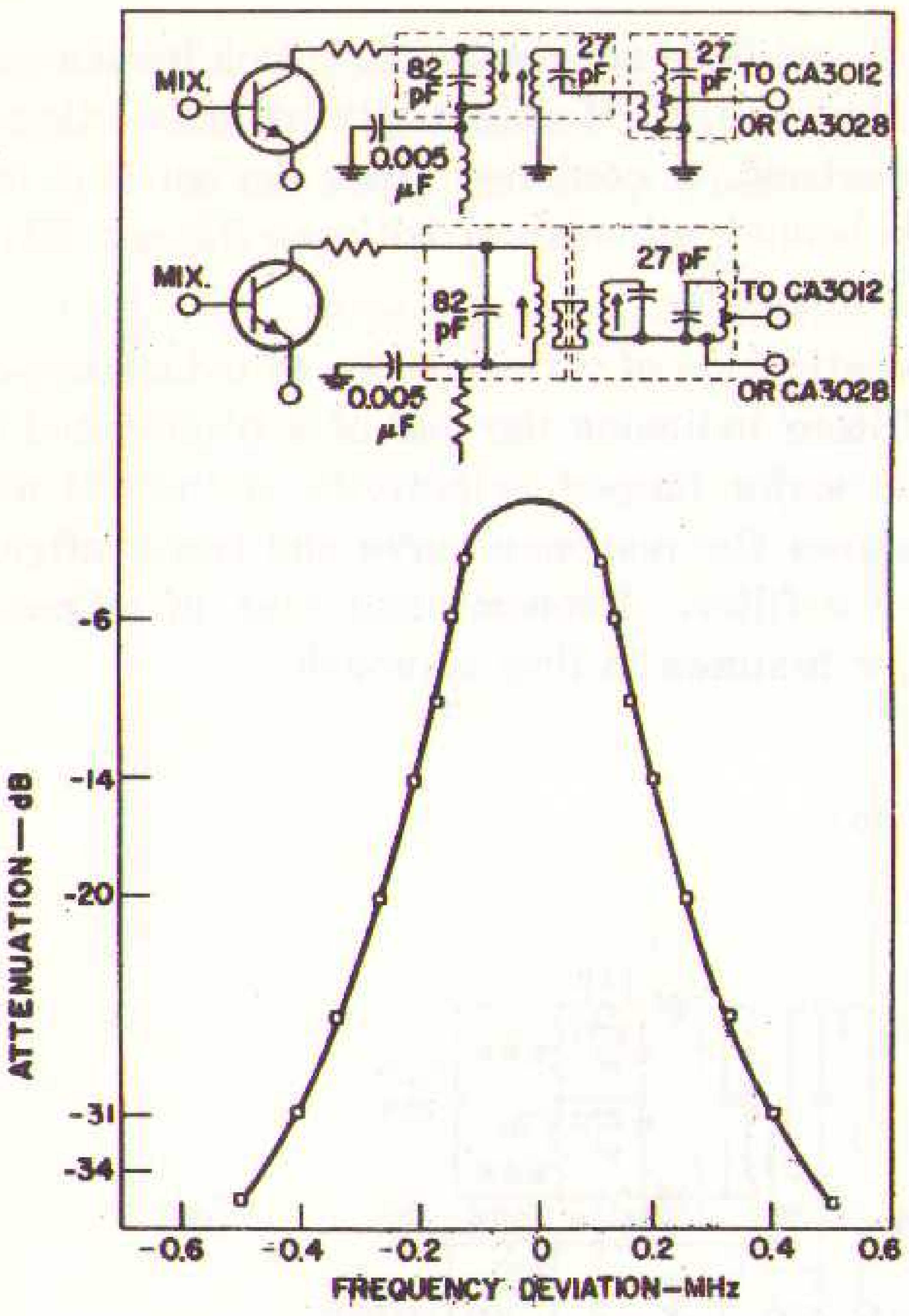


Fig.6 - Configurations and response curve for triple tuned interstage filter.

Most FM front ends come equipped with a double-tuned 10.7-MHz if transformer in which a secondary high-impedance winding is brought out capacitively unterminated and non-polarized with respect to ground. This configuration does not lend itself readily to optimum skirt selectivity (form factor) when connected with an additional single-tuned transformer to form a triple-tuned filter. Most effective use of the existing front-end filter is accomplished by the addition of another double-tuned filter, such as those shown in Fig.7. Either

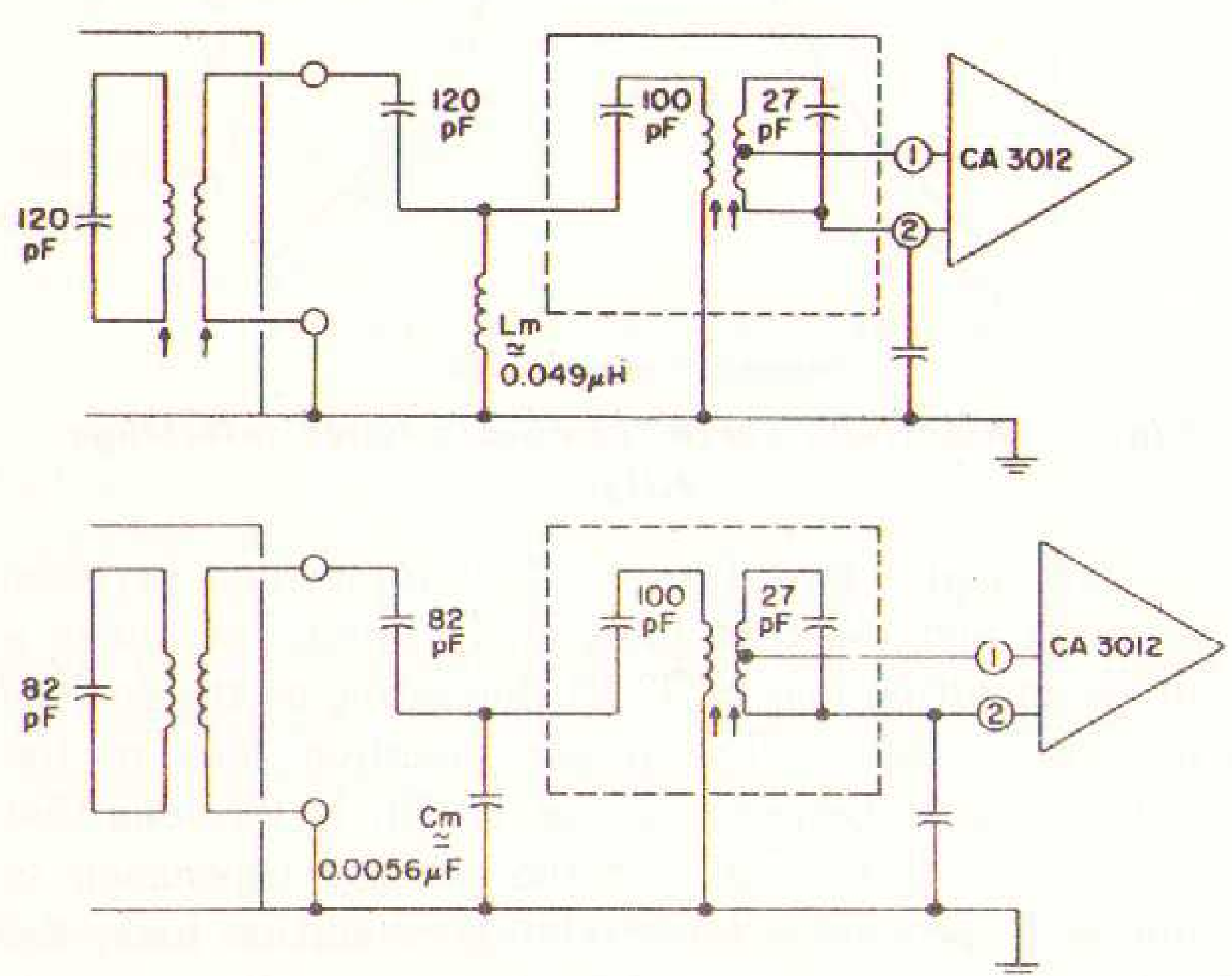


Fig.7 - Configurations of two quadruple-tuned interstage filters.

bottom inductance or capacitance coupling can be used. Voltage insertion losses from 18 dB to 26 dB can be expected. Fig.8 shows the response curve obtained

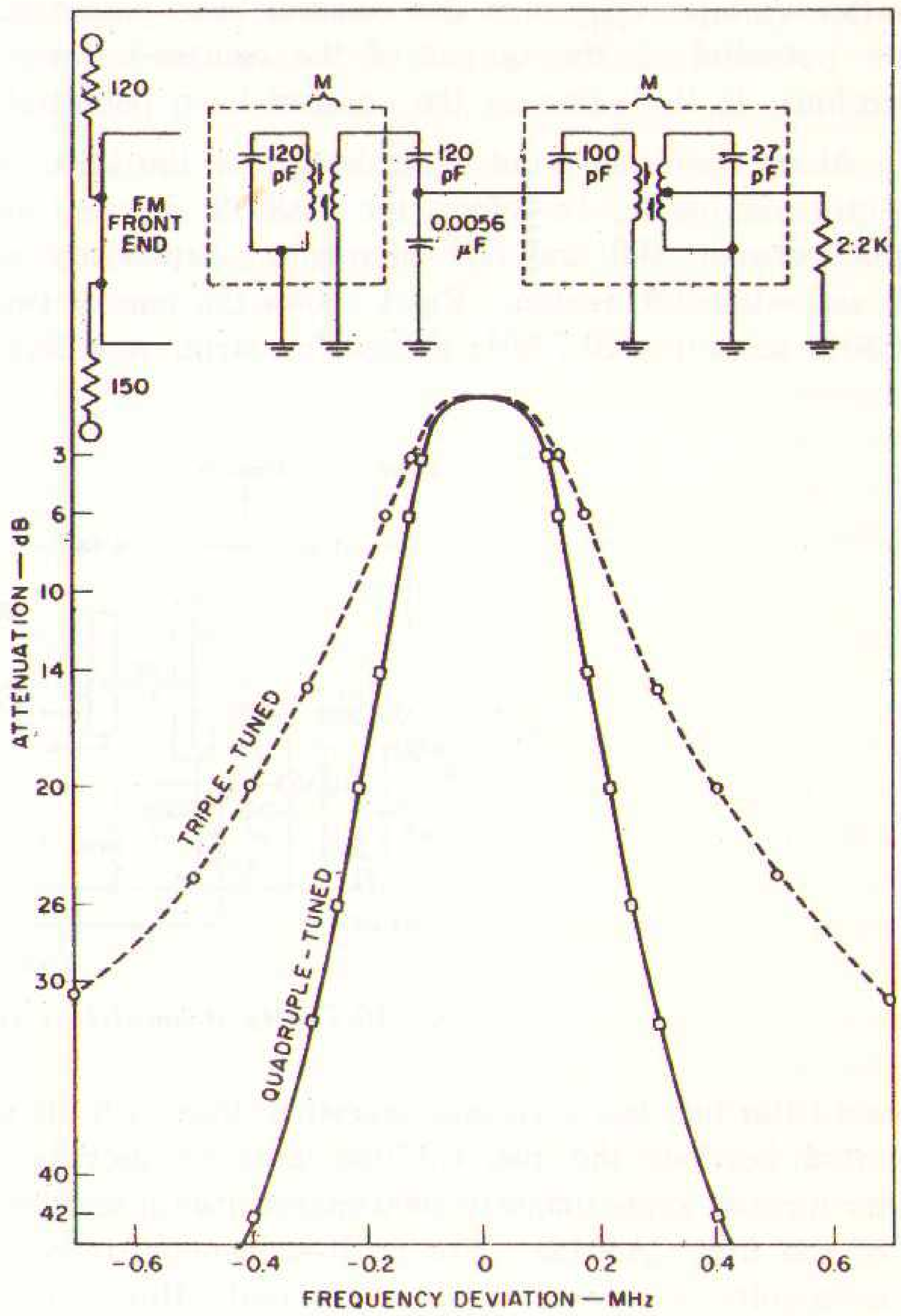


Fig.8 - Response curve obtained with quadruple-tuned filter.

with a quadruple-tuned interstage filter. The per-cent coupling between filters and the coupling mode must be determined on the basis of over-all stability and performance.

It may be appropriate to consider briefly the noise associated with high-insertion-loss filters. Over-all receiver noise F is calculated as follows:

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$$

where F_1, F_2, and F_3 are the noise figures of the first (rf), second (mixer), and third (if) stages, respectively; and G_1 and G_2 are the power gains of the first and second stages. If a value of 27 dB is assumed for the if noise figure F_3 (filter plus integrated circuit), 10 dB for the mixer noise figure, and 30 dB for mixer power gain, the effect of if noise on mixer noise is determined as follows:

$$F_2 = F_2 + \frac{F_3 - 1}{G_2} = 10 + \frac{27 - 1}{1000} = 10.026 \text{ dB}$$

If the rf stage is assumed to have a power gain of 15 dB and a noise figure of 5 dB, total receiver noise is then determined as follows:

$$F = F_1 + \frac{F_2 - 1}{G_1} = 5 + \frac{10.87-1}{31.7} = 5.285 \text{ dB}$$

These calculations show that the power gain of the rf-amplifier stage overrides both if noise and mixer noise. A minimum power gain of 10 dB is advisable.

The use of a tuning capacitance of 82 picofarads in the collector circuit of the mixer stage provides a loaded primary impedance of approximately 10,000 ohms and eliminates the need for a tap. The 27-picofarad tuning capacitances that comprise the other poles of this filter could be reduced to obtain more favorable loaded-to-unloaded-Q ratios without use of additional resistor loading. The choice of 27 picofarads was based primarily on circuit stability considerations.

Fig.9 shows one type of complete integrated-circuit if strip, and Fig.10 shows the accompanying voltage gains and impedances. Values are given for two levels of mixer output impedance. All other impedance levels shown have exhibited good stability. Over-all performance of the circuit is illustrated in Fig.11.

Capture ratio, which was measured at various levels, varies from 5 dB at 2 microvolts to 1.2 dB above 500 microvolts. With careful adjustment, values as low as 0.8 dB can be obtained. The selectivity curve for the integrated circuit if strip is shown in Fig.12. Over-all selectivity for a given ratio detector and the if strip is shown in Fig.13. Some distributed-selectivity receivers have very little second-channel selectivity at an antenna input of 2000 microvolts. The points marked in Fig.13 show such selectivity for several antenna input levels.

Fig.14 shows an if strip that combines high gain per package and the single-stage-per-package approach. CA3012 and CA3028 integrated circuits are used in a differential-mode connection. An if sensitivity of 15 microvolts can be obtained with this if strip.

If discrete circuits are directly replaced by single differential integrated-circuit amplifiers, a minimum of if transformer and printed-circuit-board redesign is required. Values of voltage gain and impedance are indicated on the block diagram in Fig.15. All three double-tuned transformers are made symmetrical with respect to primary and secondary windings and taps.

Because the single- or double-tuned circuit used between the mixer and the if strip has inherently less

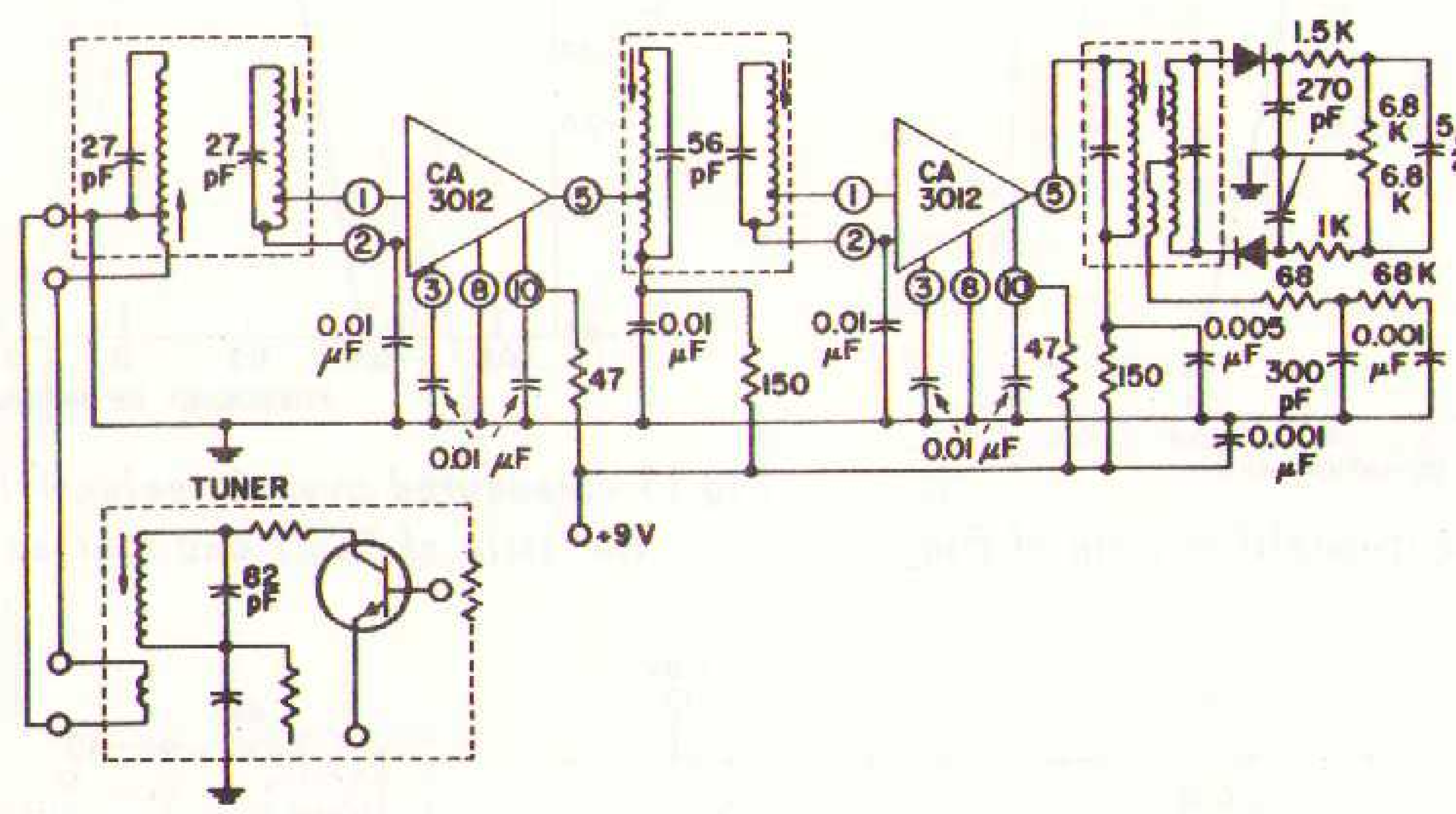


Fig.9 - Complete 10.7-MHz if-amplifier strip using two CA3012 integrated circuits.

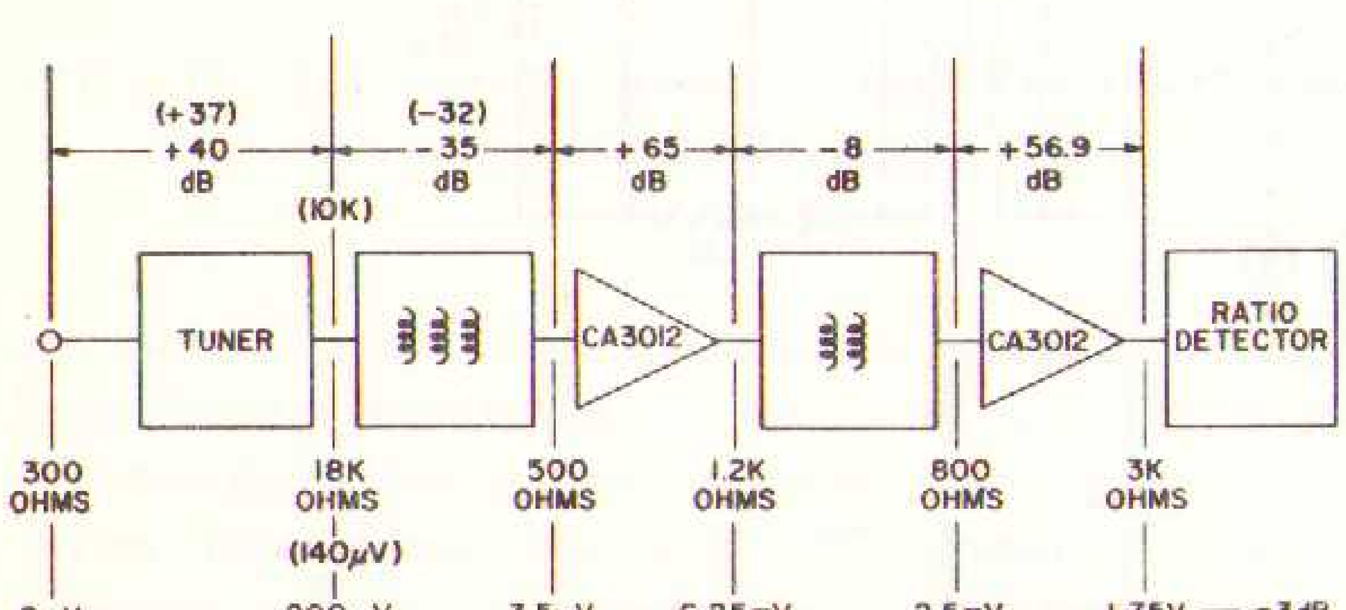


Fig.10 - Voltage gain and impedance values for if-amplifier strip of Fig.7.

insertion loss than a triple-tuned input filter, the input required is 20 instead of 3.5 microvolts. All three double-tuned if transformers have an insertion loss of 6 dB and a 3-dB bandwidth of 280 to 300 kHz. The ratio-detector primary impedance dictates the stage gain of 36 dB for the last integrated circuit. Each of the remaining three stages has a gain of 21.5 dB, for the total required gain of 100 dB. The impedance required for the desired stage gain was calculated to be 660 ohms for both the primary and secondary windings of the if transformers.

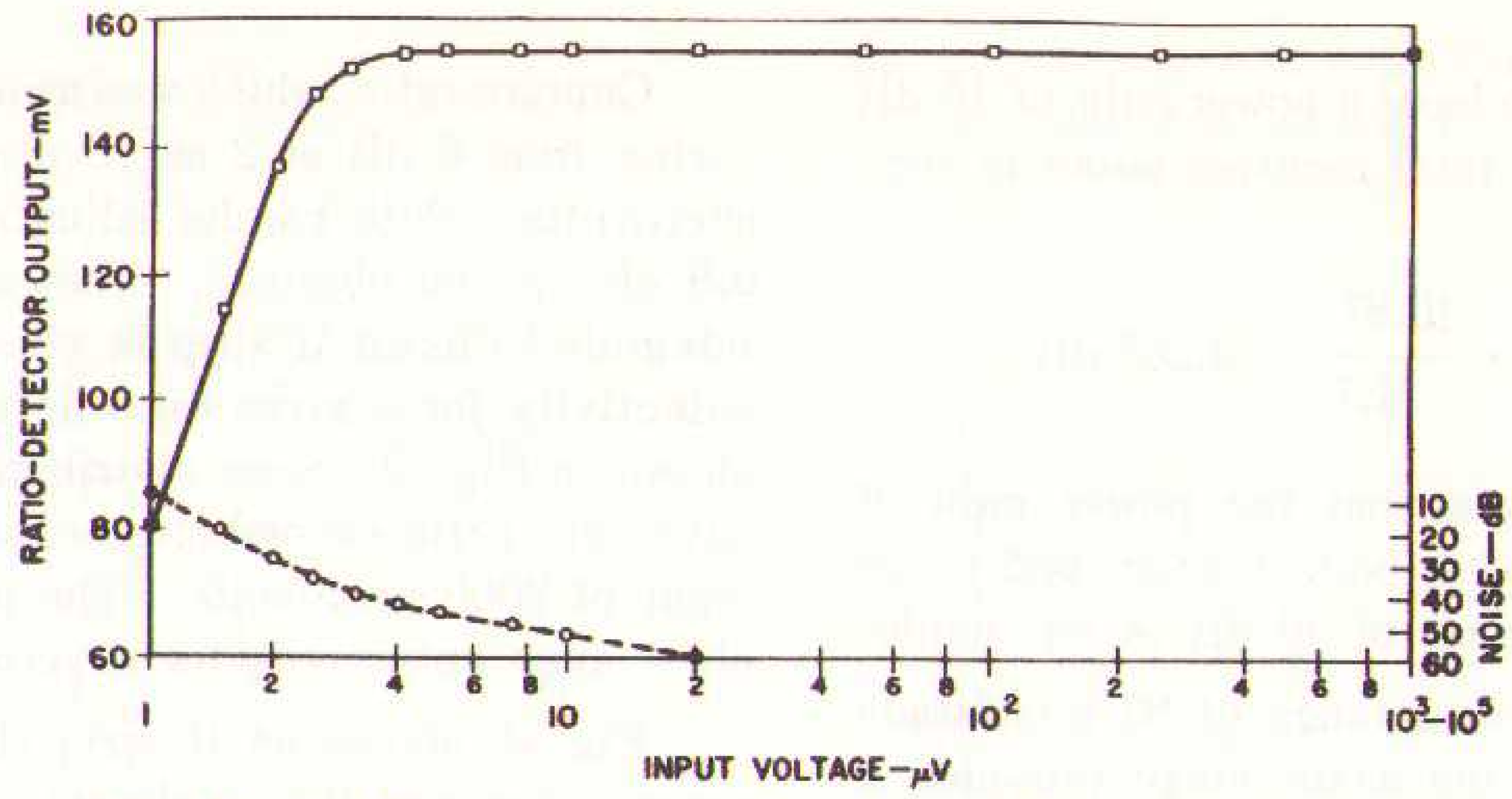


Fig.11 - Performance curves for if-amplifier strip of Fig.7.

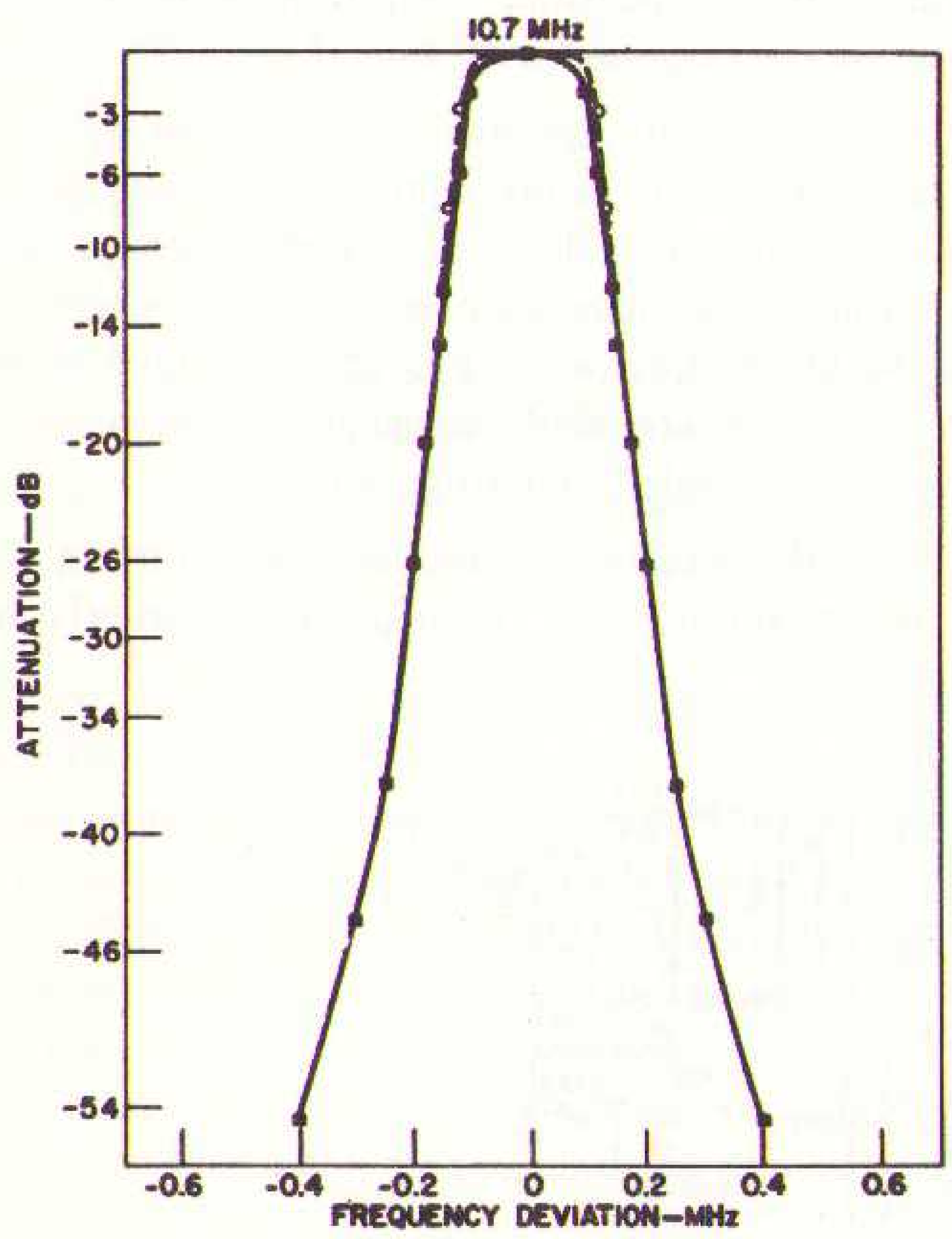


Fig.12 - Selectivity curve for if-amplifier strip of Fig.7.

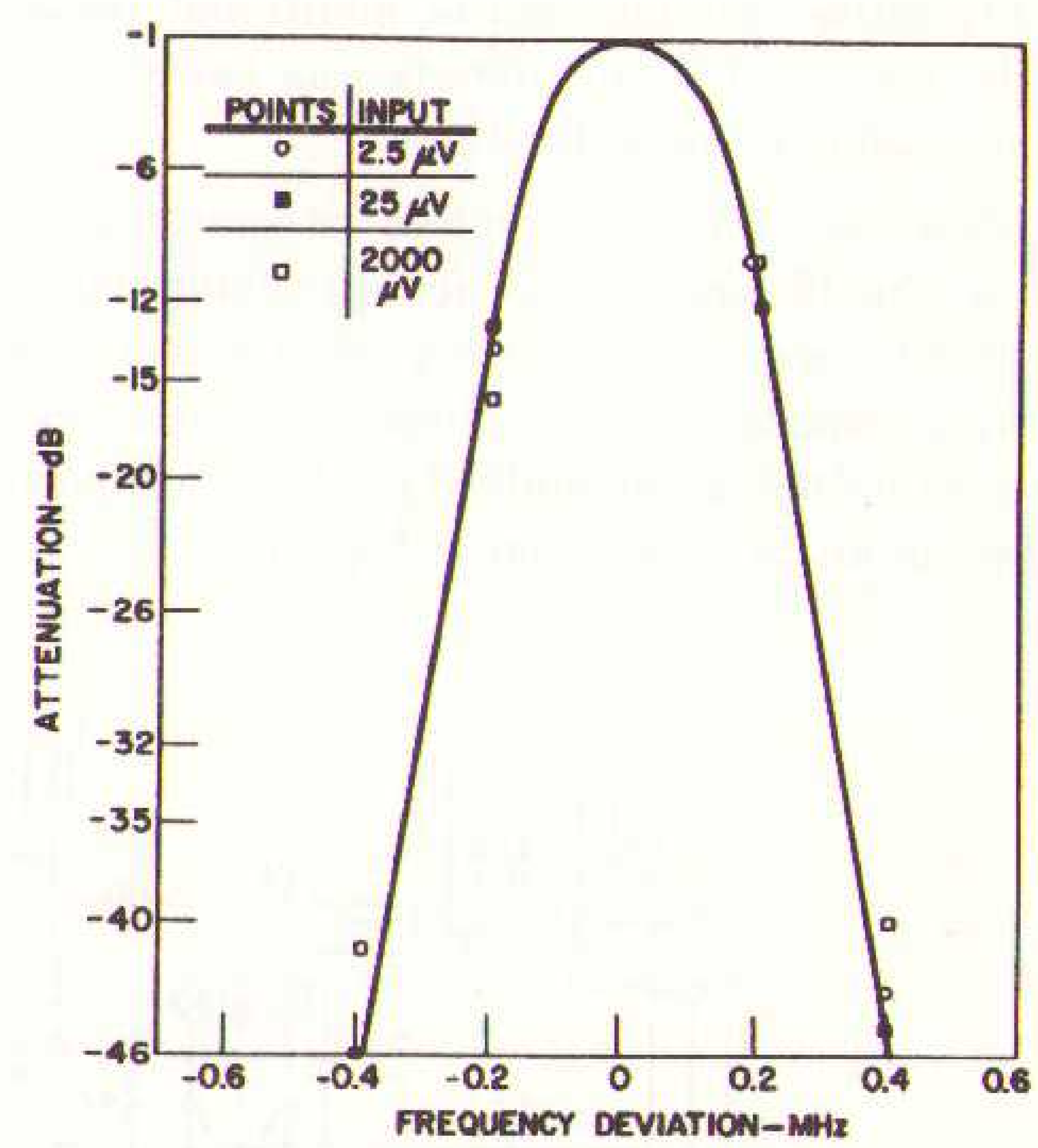


Fig.13 - Measured over-all selectivity curve for if-amplifier strip of Fig.7 and a given ratio detector.

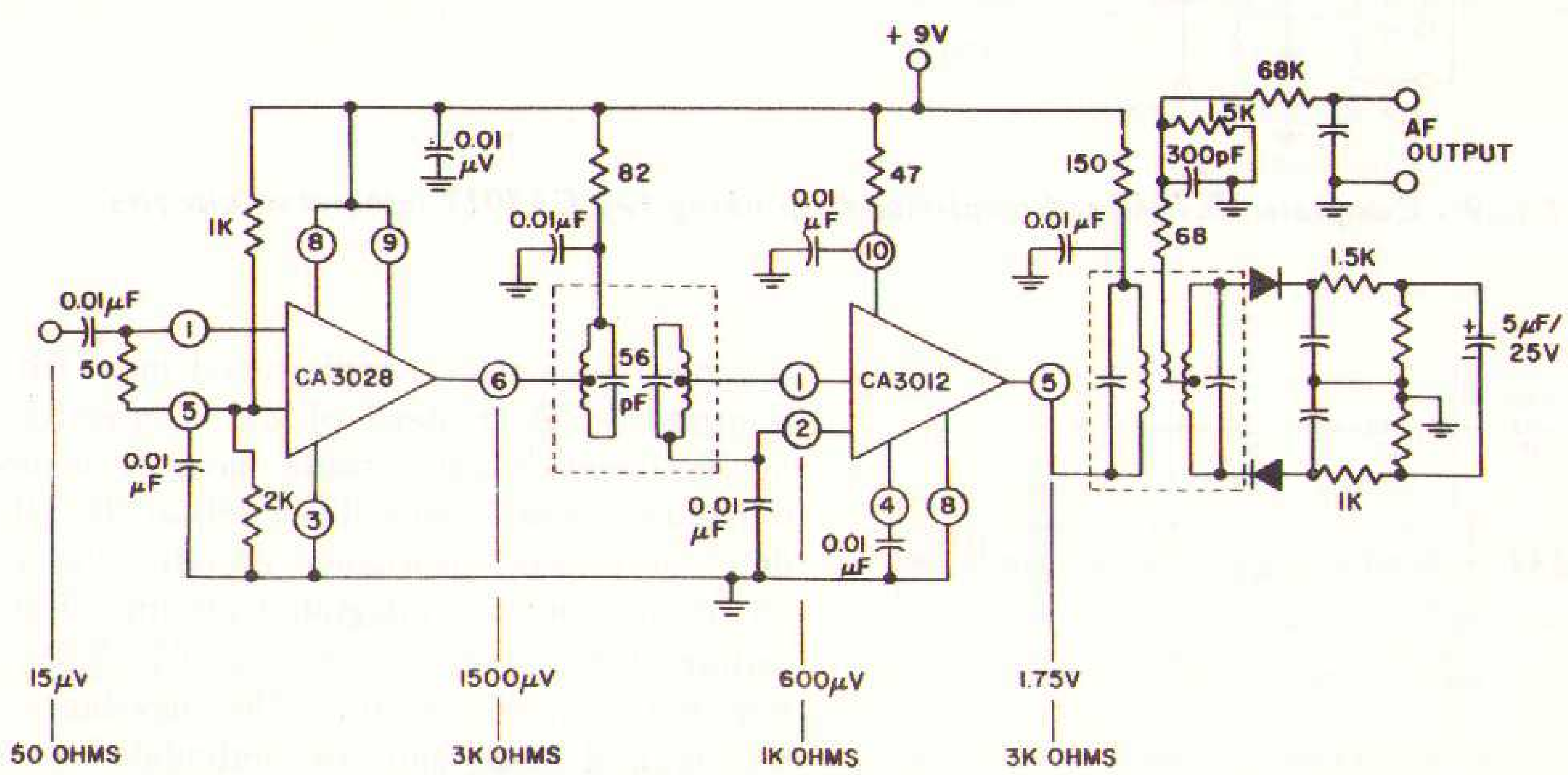


Fig.14 - IF-amplifier strip using CA3028 and CA3012 integrated circuits.

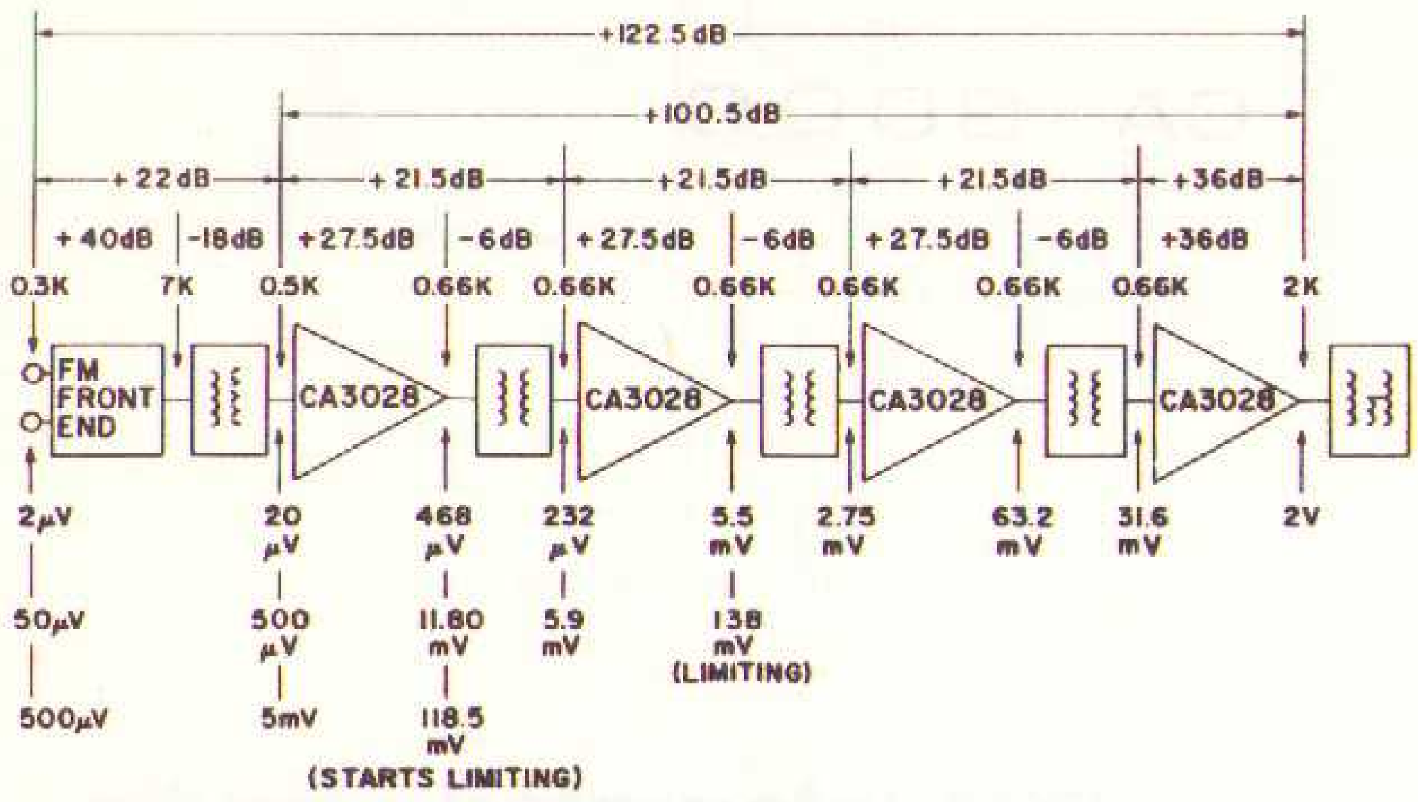
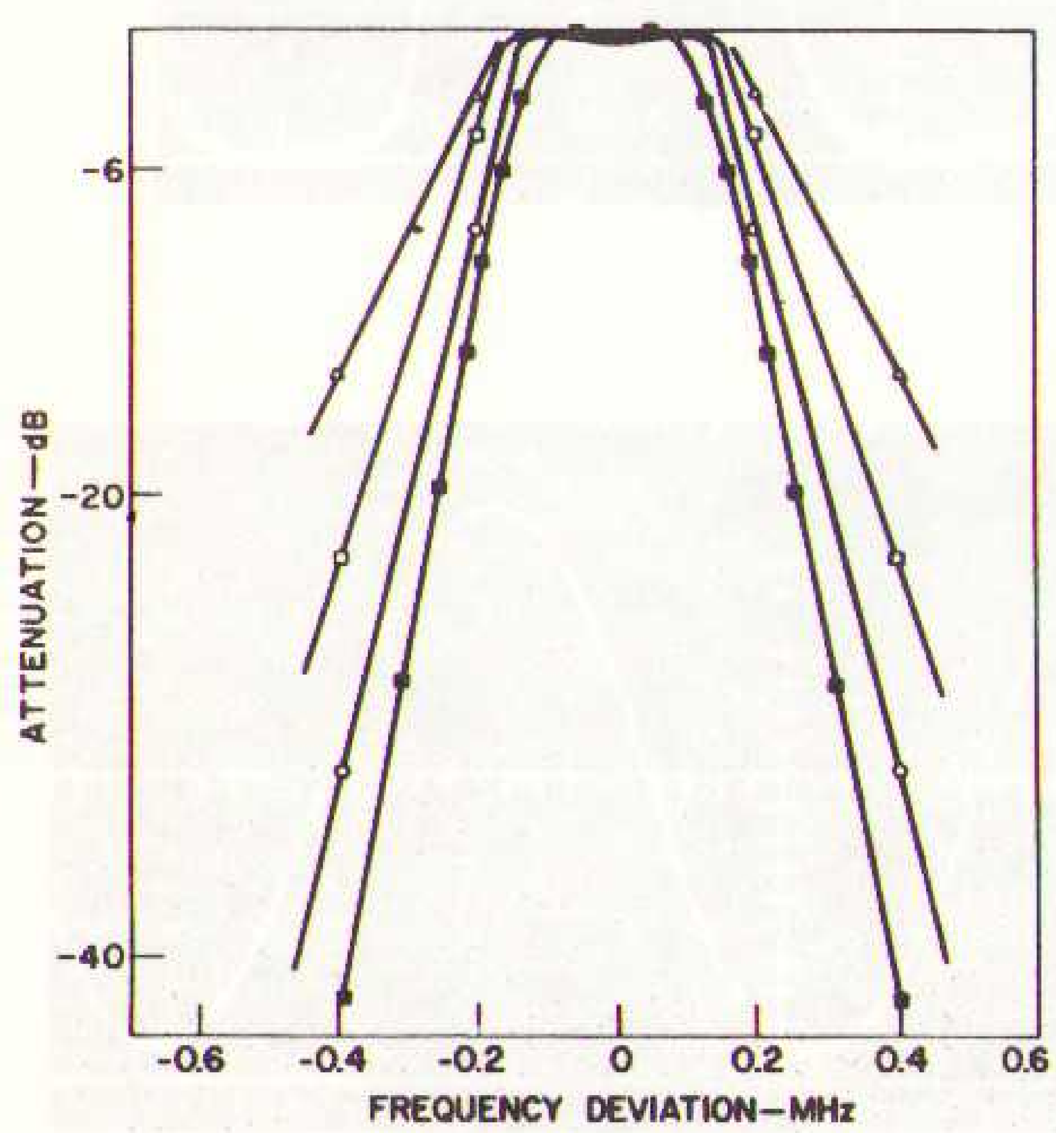


Fig.15 - Voltage gain and impedance values for if-amplifier strip of Fig.12.

With inputs from 20 to 200 microvolts, second-channel selectivity as high as 52 to 59 dB can be attained for three double-tuned and four double-tuned filters, respectively, for a 3-dB bandwidth of 196 kHz. For higher inputs, the same deterioration of selectivity occurs as that experienced with discrete circuits, as shown in Fig.16.



	INPUT (μV)	ACA (dB)	2ACA (dB)
X	25	10	42.6
O	1000	8.6	32
□	5000	5	22
Δ	20K	3	15

Ist STAGE AGC.

Fig.16 - Selectivity curves for discrete-component if strip using six double-tuned filters.

Several receivers incorporating the if strips shown have been field-tested in areas of 200-kHz station separation, where a weak station was sandwiched between two strong stations. The weak station was received without interference, as compared to the performance of other high-quality FM receivers fabricated with discrete-component if circuits, where lack of selectivity marred reception.

Conclusions

The preceding discussion has shown that the simplest approach to the use of integrated circuits in FM if-amplifier strips is to replace each stage in present discrete-transistor if strips with a differential amplifier. This integrated-circuit approach requires a minimum of re-engineering because a cascade of individually tuned if stages is used. From a performance point of view, this approach results in better AM rejection than that obtained with discrete circuits because of the inherent limiting achieved with the differential-amplifier configuration.

This approach, however, is not the best for cost performance in the long run. The single stage of gain is most difficult to justify economically when a single transistor stage is replaced with a single integrated-circuit package. The boundary condition for such an approach is that ultimately the cost of fabricating a package containing three transistors and three resistors (a typical complement for a differential-amplifier stage) must be the same as that of the one transistor the stage replaces.

Approaches to FM if stages which use the high-gain-per-package concept achieve the excellent AM rejection of differential amplifiers, as well as superior adjacent-channel attenuation, because more gain is inserted between the selectivity elements. From a performance point of view, this approach is superior to both discrete-stage and individually tuned integrated-circuit if strips.

From the point of view of cost, this approach has better possibilities because two packages are equivalent to four single stages of gain (four integrated-circuit packages). This approach results in maximum utilization of present-day monolithic integrated-circuit technology, and is closer to the optimum FM if amplifier shown in Fig.17.

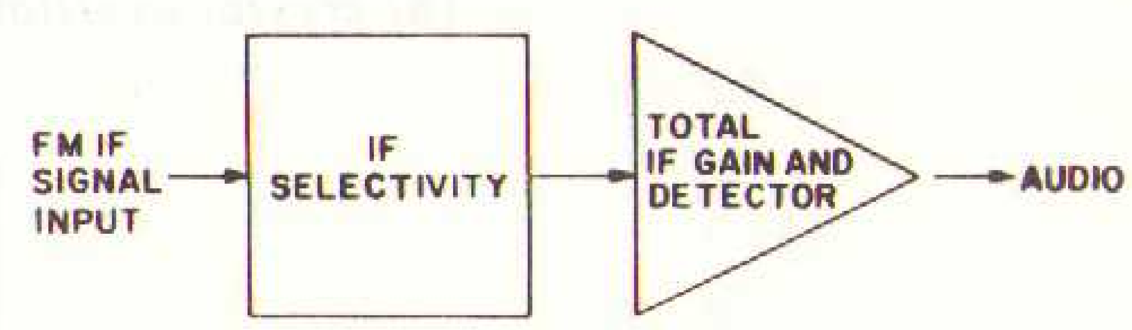
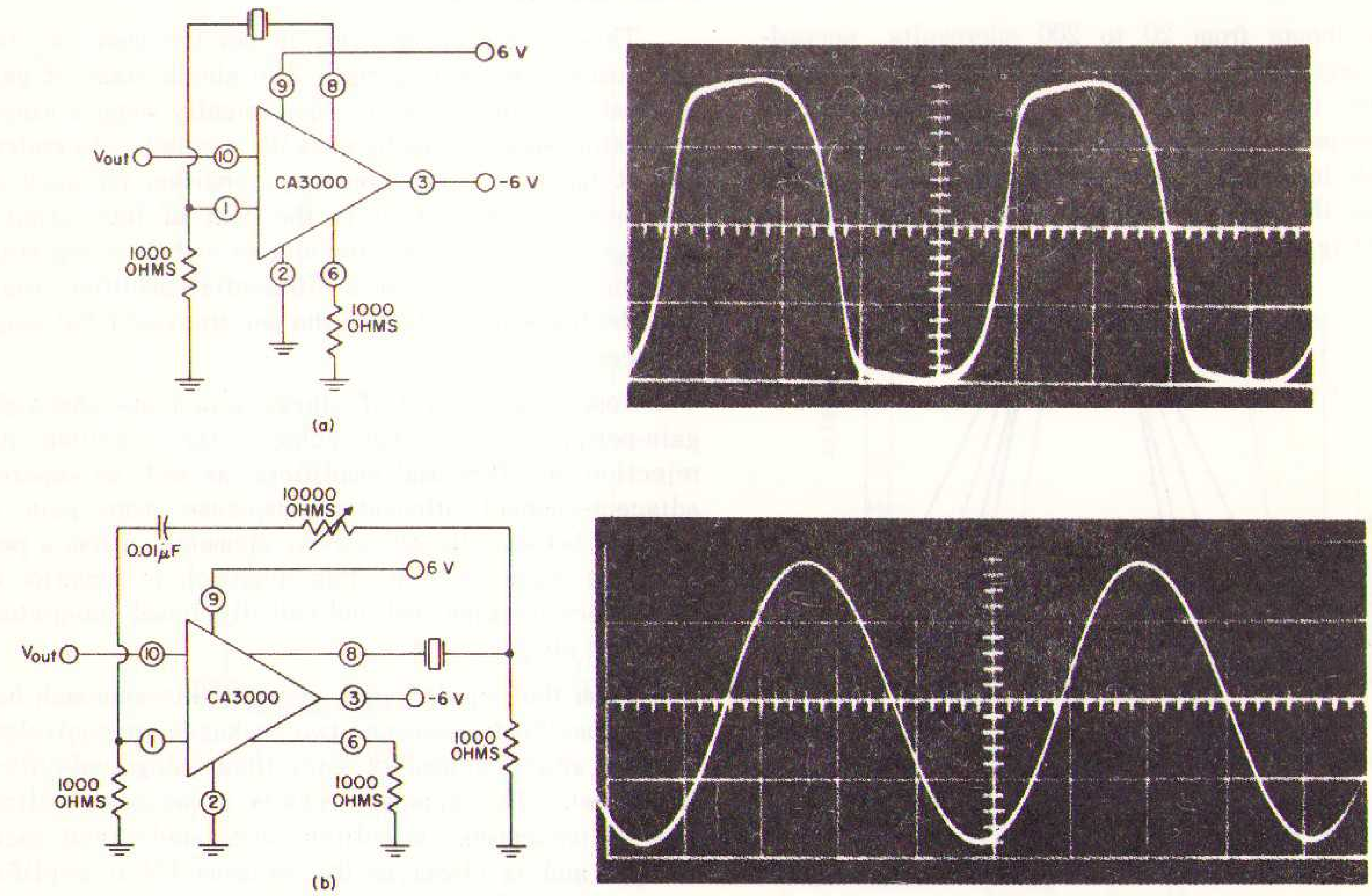
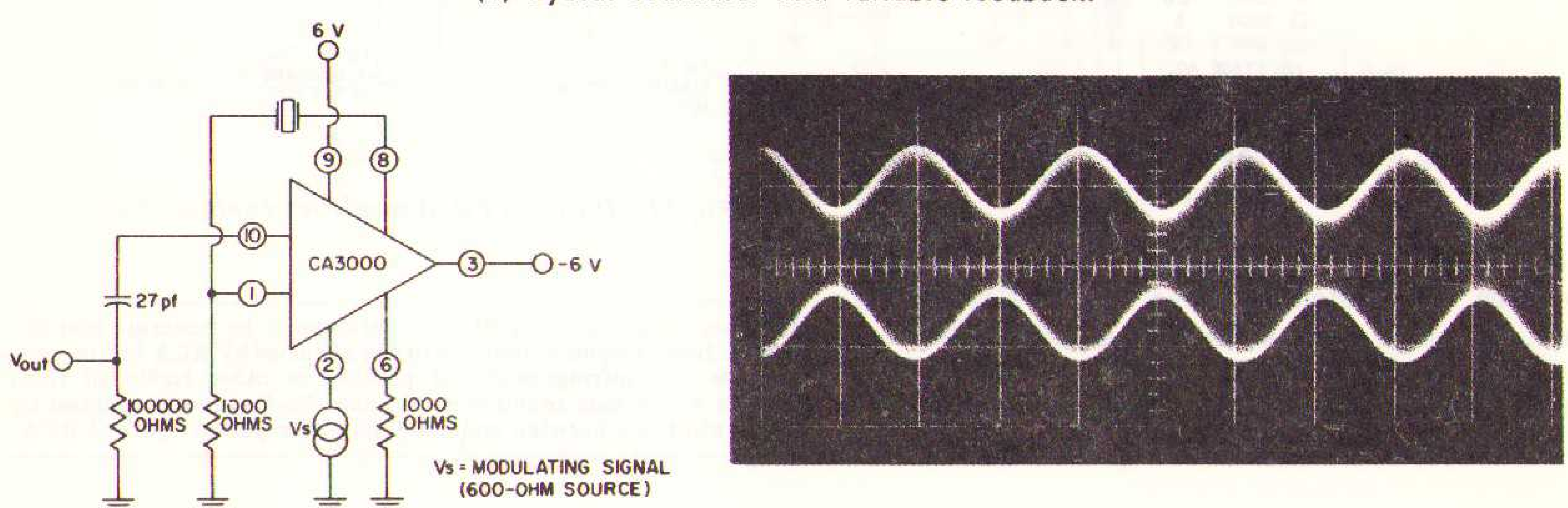


Fig.17 - Optimum FM if-amplifier configuration.

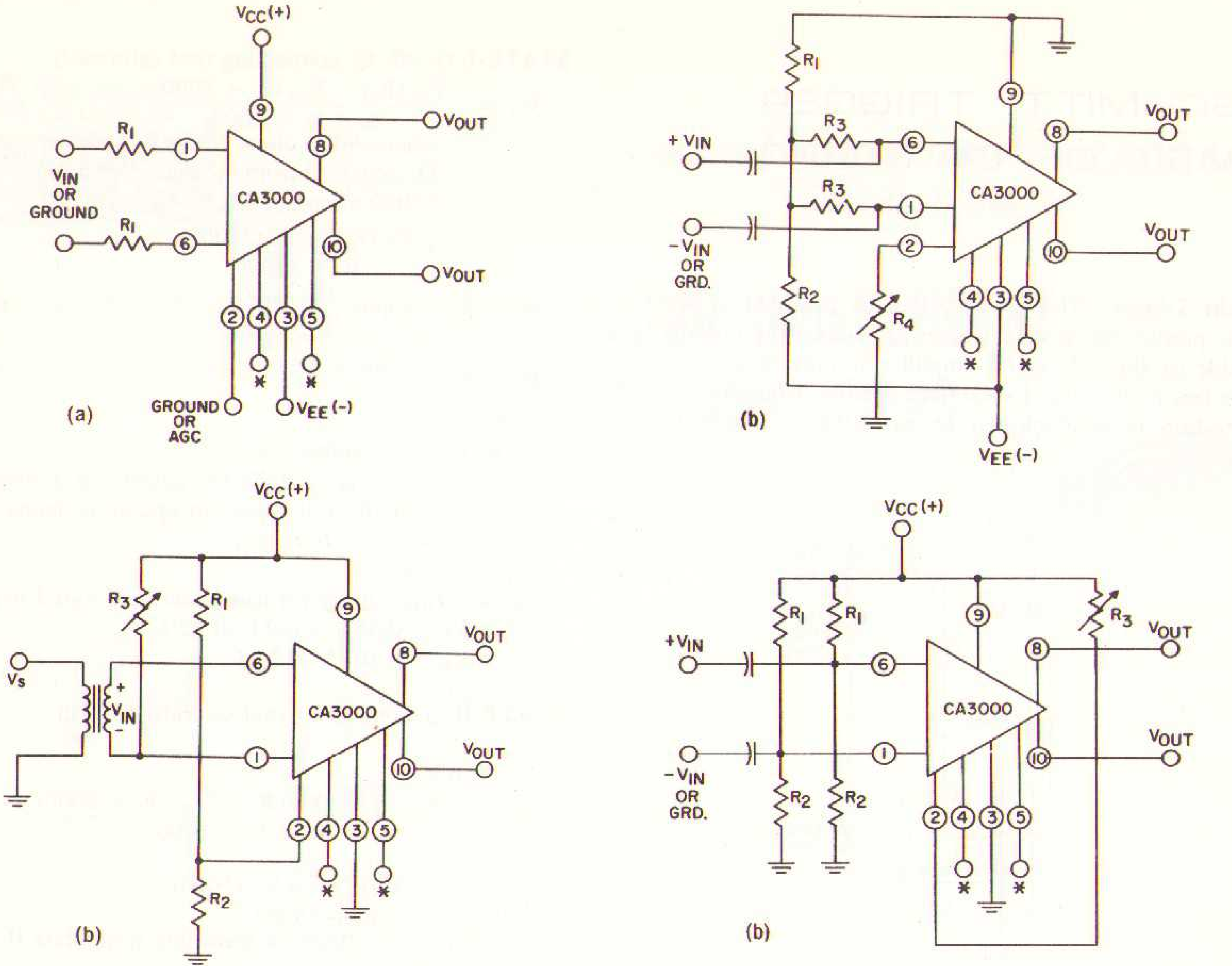
RCA integrated circuits application note



Schematic diagrams and output waveforms of (a) crystal oscillator and (b) crystal oscillator with variable feedback.

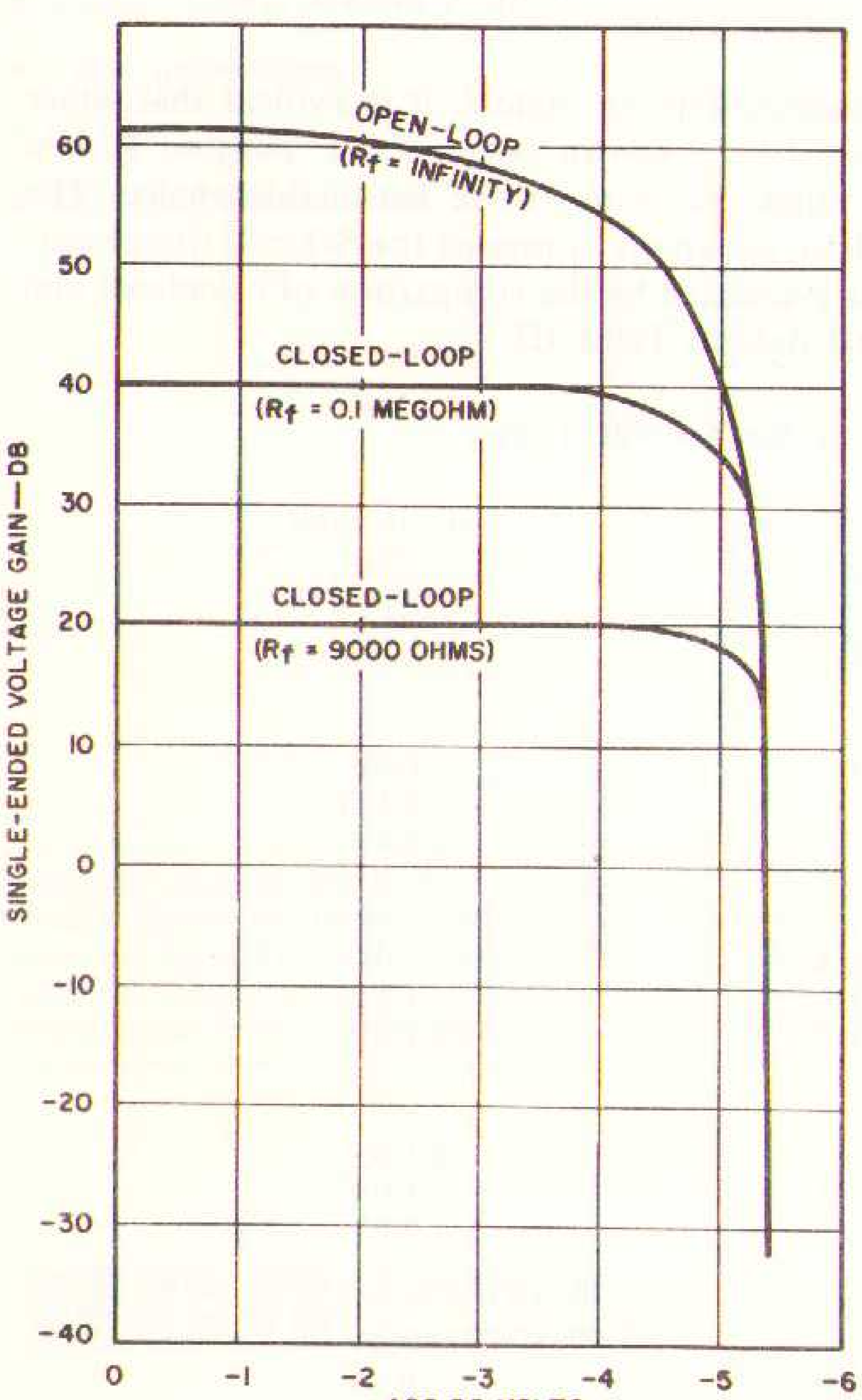


Schematic diagram and output waveform of CA3000 modulated oscillator.

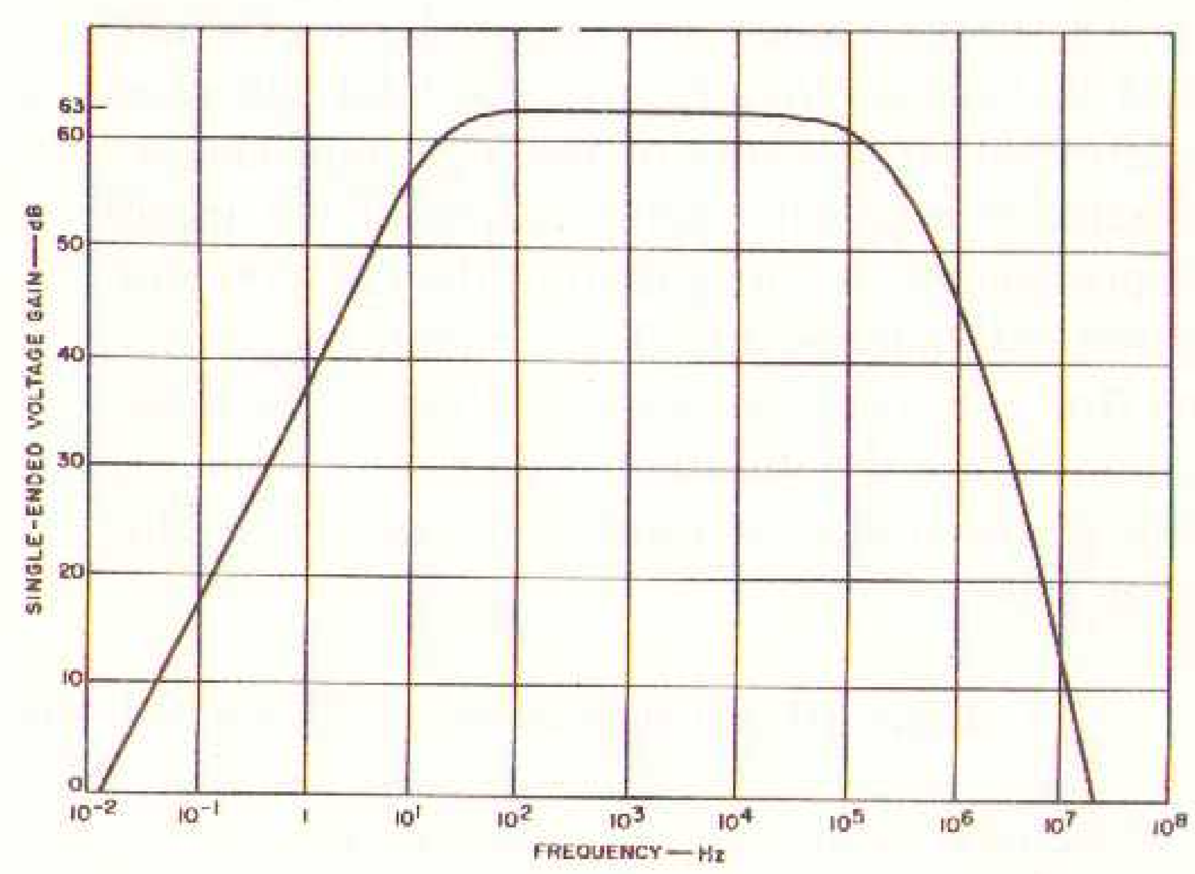


* Connection of terminals 4 and 5 depends on mode of operation.

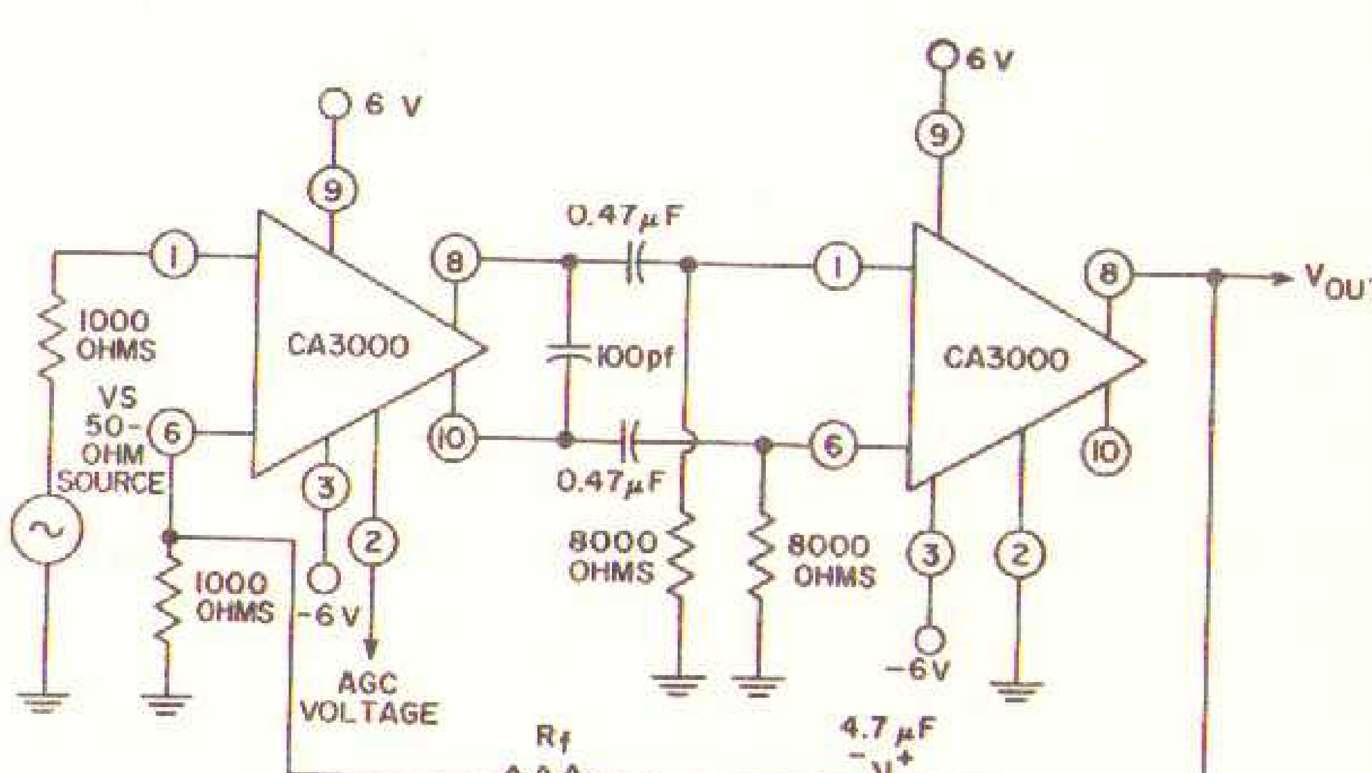
Typical biasing arrangements for the CA3000 for operation from (a) two separate voltage supplies, or (b) a single voltage supply.



(b)



(a) Gain-frequency and (b) agc characteristics of feedback amplifier



FOR $V_{AGC} = 0$

R_f	G_V
∞	63 db (OPEN LOOP)
100000 OHMS	40 db
9000 OHMS	20 db

Cascaded RC-coupled feedback amplifier using two CA3000 circuits.

SCHMITT TRIGGER MET DE CA 3000

Schmitt Trigger—The CA3000 can be operated as an accurate, predictable Schmitt trigger provided saturation of either side of the differential amplifier is prevented (hysteresis is less predictable if saturation occurs). Non-saturating operation is accomplished by operation in mode B

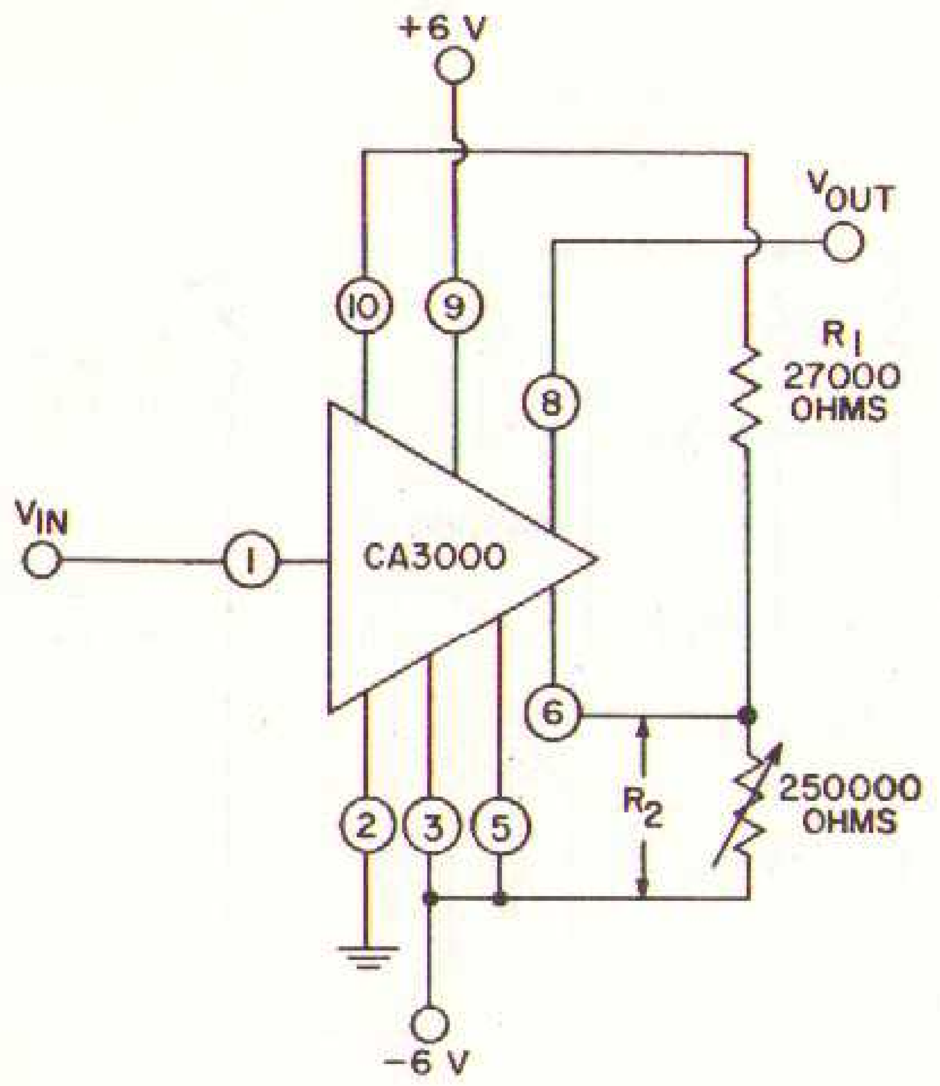


Fig.18 - Schematic diagram for Schmitt trigger using CA3000.

(terminals 3 and 5 shorted together) in the configuration shown in Fig. 18. Large values are required for external resistors R_1 and R_2 because they receive the total collector current from terminal 10. Because of the high impedances, resistor R_2 is actually a parallel combination of the input impedance (approximately 0.1 megohm) of the CA3000 and the 0.25-megohm external resistor. The Schmitt-trigger design equations (for $\alpha = 1$) are summarized below. In these equations, Q_2 and Q_4 are the differential-pair transistors, Q_1 and Q_5 are the emitter-follower transistors, and Q_3 is the constant-current sink.

STATE I: Q_2 off, Q_4 conducting (not saturated)

$$V_{6_I} = \frac{V_{CC}(R_2) - V_{EE}(R_1 + 8000)}{R_1 + R_2 + 8000}$$

where 8000 ohms is the output impedance of Q_4 (obtained from the published data). For $R_1 =$ 27000 ohms and $V_{CC} = V_{EE} = 6$ Vdc,

$$V_{6_I} = \frac{6V(R_2) - 6V(35000)}{R_2 + 35000} \qquad \text{(A)}$$

$$R_2 = (R_1 + 8000)\,\frac{V_{EE} + V_{6_I}}{V_{CC} - V_{6_I}}$$

$$R_2 = (35000)\,\frac{6V + V_{6_I}}{6V - V_{6_I}} \qquad \text{(B)}$$

$$V_{8_I} = V_{CC} - I_E\,(8000)$$

where I_E = collector current of transistor Q_3 $\approx$0.48 milliampere in operating mode B with $V_{EE} = -6$ volts dc.

$$V_{8_I} = 2.14\text{ V} \qquad \text{(C)}$$

$V_{F_I} \equiv$ Firing voltage for transition from state I to state II

$$V_{F_I} = V_{6_I} - 0.053 - 100\,I_E \text{ at } 25°\text{C}$$

$$V_{F_I} = V_{6_I} - 0.101\text{ V at } 25°\text{C} \qquad \text{(D)}$$

STATE II: Q_2 conducting (not saturated), Q_4 off

$$V_{8_{II}} = V_{CC}$$

$$V_{8_{II}} = 6\text{ V} \qquad \text{(A)}$$

$$V_{6_{II}} = \frac{(V_{CC} - I_E\,8000)\,R_2 - V_{EE}(R_1 + 8000)}{R_1 + R_2 + 8000}$$

$$V_{6_{II}} = \frac{2.14\text{ V}(R_2) - 6\text{ V}(35000)}{R_2 + 35000} \qquad \text{(B)}$$

$V_{F_{II}} \equiv$ Firing voltage for transition from state II back to state I

$$V_{F_{II}} = V_{6_{II}} + 0.053 + 100\,I_E \text{ at } 25°\text{C}$$

$$V_{F_{II}} = V_{6_{II}} + 0.101\text{ V at } 25°\text{C} \qquad \text{(C)}$$

HYSTERESIS VOLTAGE

$$V_{HYS} = V_{F_I} - V_{F_{II}}$$

$$= \frac{3.86\text{ V}(R_2)}{R_2 + 35000} - 0.202\text{ V at } 25°\text{C}$$

From the calculations for state I, it is evident that either V_{6_I} or R_2 must be a known design value. Because R_2 is a composite value, V_{6_I} is the more reasonable choice. The ability of these equations to predict the Schmitt-trigger performance is evidenced by the comparison of calculated and experimental data in Table III.

Table III — Comparison of Calculated and Experimental Data for Schmitt Trigger

Condition	*Parameter*	*Calculated*	*Experimental*
1) $V_{6_I} = -2V$	V_{F_I}	−2.1V	−2.2V
	$V_{F_{II}}$	−3.19V	−3.2V
	V_{HYS}	+1.09V	+1.0V
2) $V_{6_I} = -1V$	V_{F_I}	−1.10V	−1.0V
	$V_{F_{II}}$	−2.51V	−2.45V
	V_{HYS}	+1.41V	+1.4V
3) $V_{6_I} = 0$	V_{F_I}	−0.101V	0
	$V_{F_{II}}$	−1.83V	−1.8V
	V_{HYS}	+1.73V	+1.8V
4) $V_{6_I} = +1V$	V_{F_I}	+0.9V	+1.0V
	$V_{F_{II}}$	−1.15V	−1.0V
	V_{HYS}	+2.1V	+2.0V
5) $V_{6_I} = +2V$	V_{F_I}	+1.9V	+2.0V
	$V_{F_{II}}$	−0.472V	−0.5V
	V_{HYS}	+2.43V	+2.4V

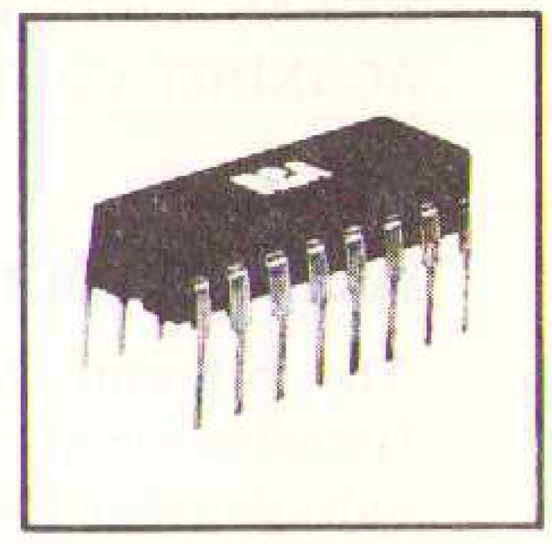
RCA linear integrated circuits

Amplifier Array CA3048

Monolithic Silicon

FOUR INDEPENDENT AC AMPLIFIERS

For Low-Noise and General AC Applications In Industrial Service



CA3048

The RCA CA3048 is a silicon monolithic integrated circuit consisting of four independent identical AC amplifiers which can operate from a single-ended power supply.

The amplifiers include internal DC bias and feedback to provide temperature-stabilized operation. They may be used in a wide variety of AC applications in which operational amplifiers have previously been used.

Each high gain amplifier has a high impedance non-inverting input, and a lower impedance inverting input for the application of feedback. Two power-supply terminals and two ground terminals are provided to reduce internal and external coupling between amplifiers.

The CA3048 is supplied in a 16-lead dual-in-line plastic package.

APPLICATIONS

- Multi-channel or cascade operation
- Low-level preamplifiers
- Equalizers
- Linear signal mixers
- Tone generators
- Multivibrators
- AC integrators

FEATURES

- Four AC amplifiers on a common substrate
- Independently accessible inputs and outputs
- Operates from single-ended supply

EACH AMPLIFIER

- Noise figure at 1 kHz.......................... 2 dB typ.
- High voltage gain .... 53 dB min.
- High input resistance .... 90 kΩ typ.
- Undistorted output voltage................... 2 V rms min.
- Output Impedance .... 1 kΩ typ.
- Open-loop bandwidth .... 300 kHz typ.

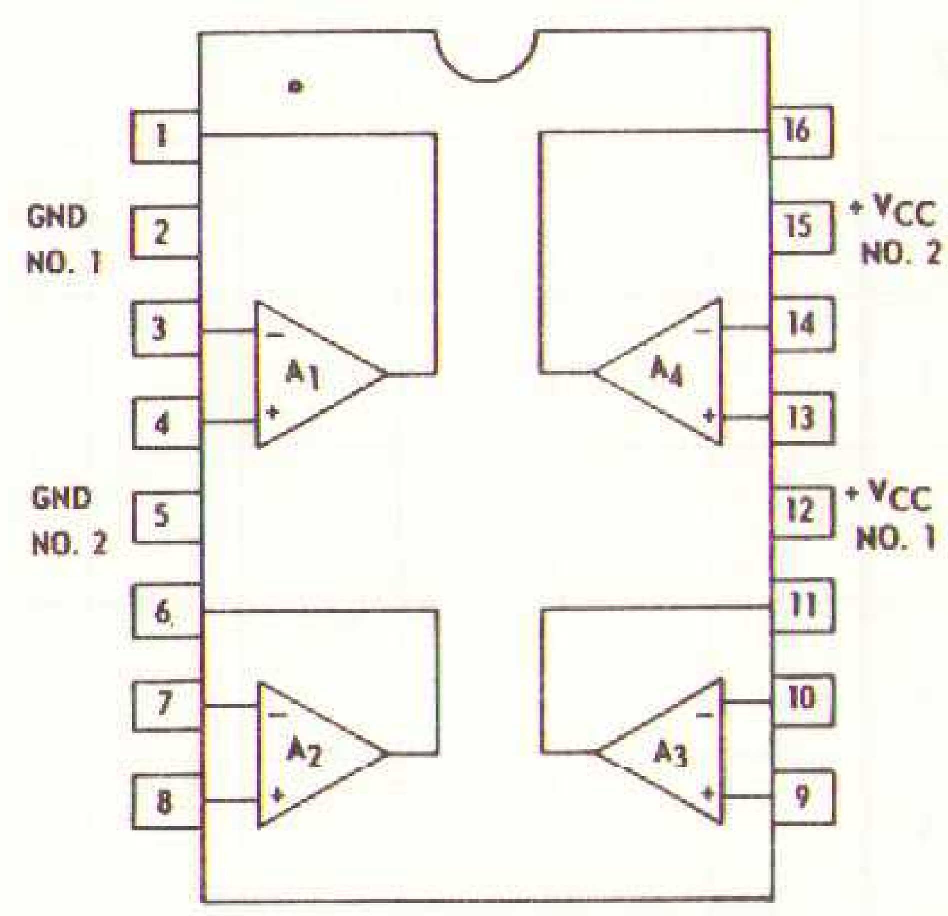


Fig.1 - Block diagram for CA3048.

RCA Electronic Components

ABSOLUTE-MAXIMUM RATINGS at T_A = 25°C:

DISSIPATION:

At T_A = 55°C . . . . 750 mW

Above T_A = 55°C . . . . Derate linearly at 7.7 mW/°C

TEMPERATURE RANGE:

Operating and Storage . . . . -25°C to +85°C

POWER SUPPLY VOLTAGE . . . . +16 V

AC INPUT VOLTAGE . . . . 0.5 V rms

MAXIMUM VOLTAGE RATINGS

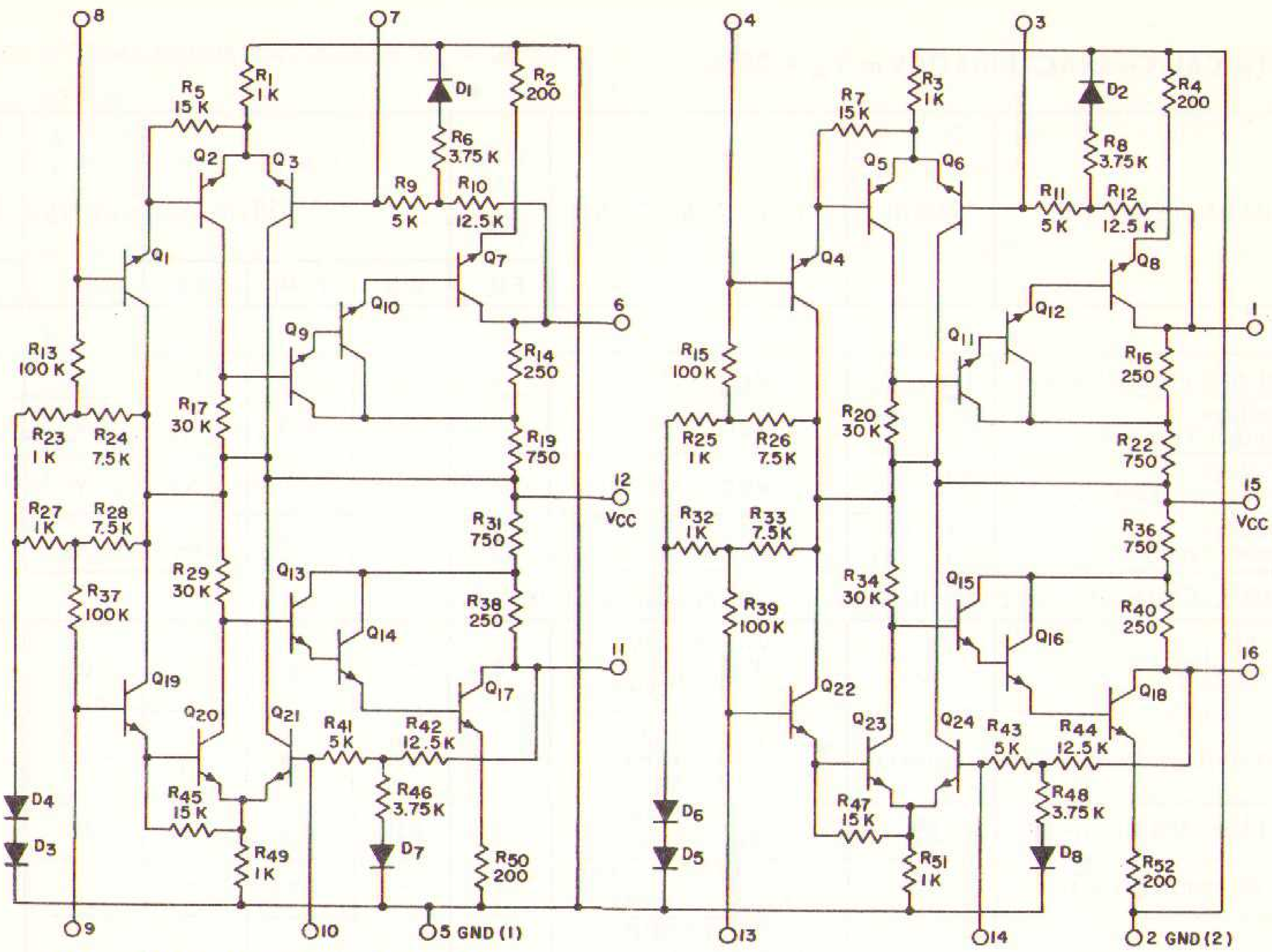
The following chart gives the range of voltages which can be applied to the terminals listed vertically with respect to the terminals listed horizontally. For example, the voltage range between vertical terminal 2 and horizontal terminal 4 is +2 to -3.6 volts.

TERMINAL No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		+16 0	*	*	*	*	*	*	*	*	*	*	*	*	0 -16	*
2			*	+2 -3.6	0	*	*	+2 -3.6	-3.6	*	*	+16 0	+2 -3.6	*	+16 0	0 -16
3				+5 -5	*	*	*	*	*	*	*	*	*	*	*	*
4					+3.6 -2	*	*	*	*	*	*	*	*	*	*	*
5						0 -16	*	+2 -3.6	+2 -3.6	*	0 -16	+16 0	+2 -3.6	*	+16 0	*
6							*	*	*	*	*	*	0 -16	*	*	*
7								+5 -5	*	*	*	*	*	*	*	*
8									*	*	*	*	*	*	*	*
9										+5 -5	*	*	*	*	*	*
10											*	*	*	*	*	*
11												*	*	*	*	*
12													0 -16	*	*	*
13														+5 -5	*	*
14															*	*
15																+16 0
16																

* Voltages are not normally applied between these terminals. Voltages appearing between these terminals will be safe if the specified limits between all other terminals are not exceeded.

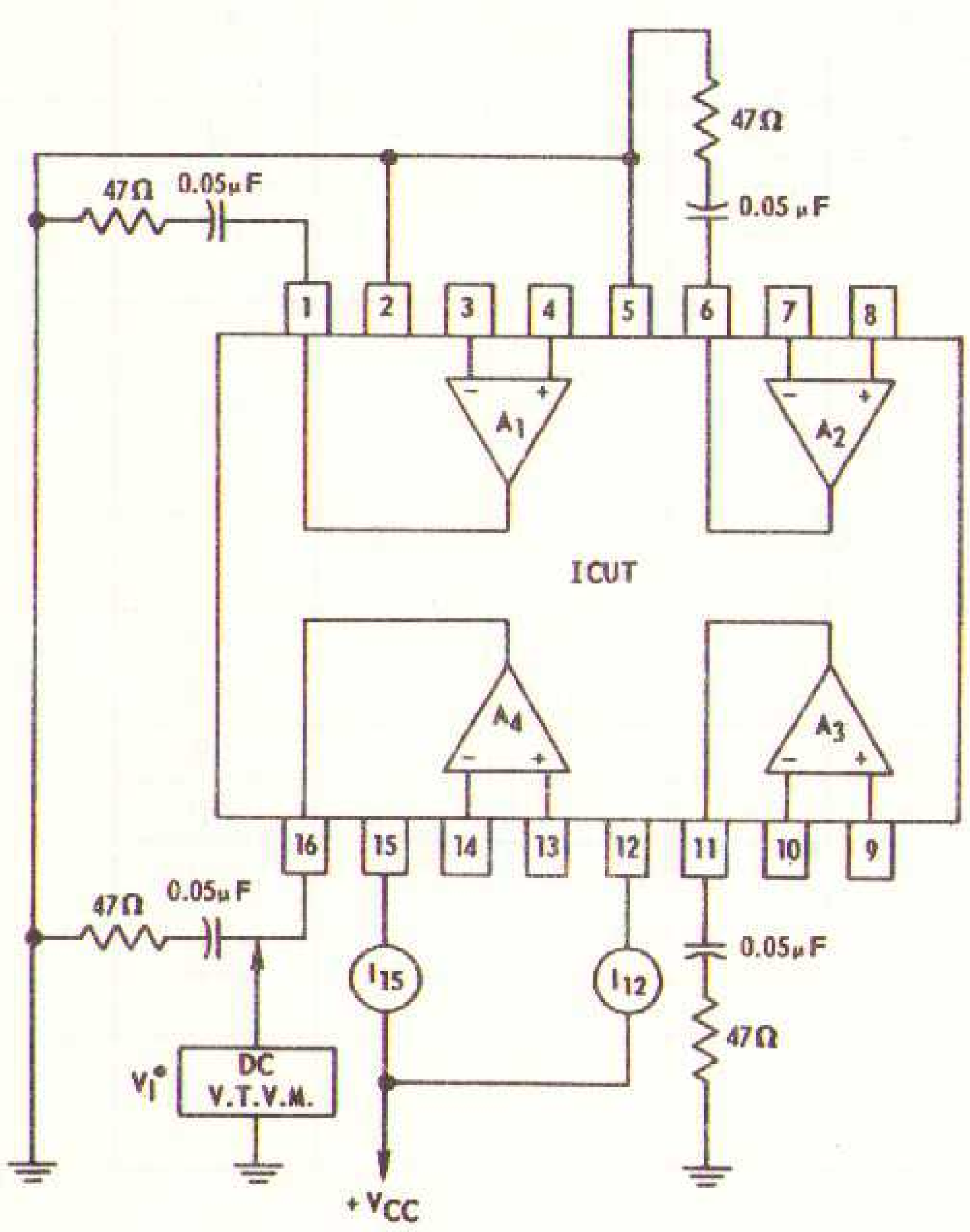
ELECTRICAL CHARACTERISTICS at T_A = 25°C

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS	TEST CIRCUIT FIG.	LIMITS CA3048 MIN.	TYP.	MAX.	UNITS	TYPICAL CHARACTERISTICS CURVES FIG.
STATIC								
Current drain per amplifier pair	I_{12} or I_{15}	V_{CC} = +12V	3	9.5	13.5	17.5	mA	4,5
DC Voltage at Output Terminals	V_1, V_6, V_{11}, V_{16}	V_{CC} = +12V	3	6.1	6.9	8.1	V	-
DC Voltage at Feedback Terminals	V_3, V_7, V_{10}, V_{14}	V_{CC} = +12V	3	1.7	2.0	2.3	V	-
DC Voltage at Input Terminals	V_4, V_8, V_9, V_{13}	V_{CC} = +12V	3	2.2	2.5	2.8	V	-
DYNAMIC (Characteristics given are for each amplifier with no AC feedback)								
Open-Loop Gain	A_{OL}	V_{CC} = +12V, E_{IN} = 2mV, f = 10kHz	6	53	58	-	dB	7,8
Output Voltage Swing	V_O(rms)	V_{CC} = +12V, f = 1kHz, THD = 5%	6	2.0	2.4	-	V	-
Open-Loop -3dB Bandwidth	BW	V_{CC} = +12V, E_{IN} = 2mV	6	250	300	-	kHz	9
Total Harmonic Distortion	THD	V_{CC} = +12V, f = 1kHz, E_{OUT} = 2V rms	6	-	0.65	-	%	10
Input Resistance	R_{IN}	OPEN LOOP Terminals 3, 7, 10, and 14 are bypassed to ground f = 1kHz	-	-	90	-	kΩ	-
Input Capacitance	C_{IN}	f = 1MHz	-	-	9	-	pF	-
Output Resistance	R_{OUT}	Terminals 3, 7, 10 and 14 are bypassed to ground	-	-	1	-	kΩ	-
Output Capacitance	C_{OUT}	f = 1MHz	-	-	18	-	pF	-
Feedback Capacitance (Output to non-inverting Input)	C_{FB}	V_{CC} = +12V, f = 1MHz	-	-	<0.1	-	pF	-
Broad-Band Output Noise Voltage	E_N	V_{CC} = +12V, R_S = 10 kΩ, A = 40dB, Equivalent Noise BW = 50kHz	11	-	0.3	1	mV	-
Output Noise Voltage "Weighted"	E_N(WT)		12	-	0.5	2.2	mV	-
Noise Figure	NF (R_S = 10kΩ)	f = 10Hz	-	-	10	-	dB	-
		f = 100Hz	-	-	5.8	-	dB	
		f = 1kHz	-	-	2	-	dB	
		f = 10kHz	-	-	1.1	-	dB	
		f = 100kHz	-	-	0.6	-	dB	
Inter-Amplifier Audio Separation "Cross Talk"		V_{CC} = +12V, f = 1kHz, 0dB = 0.78V	13	-	<-45	-	dB	-
Inter-Amplifier Capacitance (Any amplifier output to any *other* amplifier input)	C	V_{CC} = +12V, f = 1MHz	-	-	<0.02	-	pF	-



Note: All resistor values are in ohms

Fig.2 - Schematic diagram for CA3048.



* CONNECT TO APPROPRIATE TERMINAL TO READ VOLTAGE

Fig.3 - Test circuit for measurement of collector supply voltage and currents.

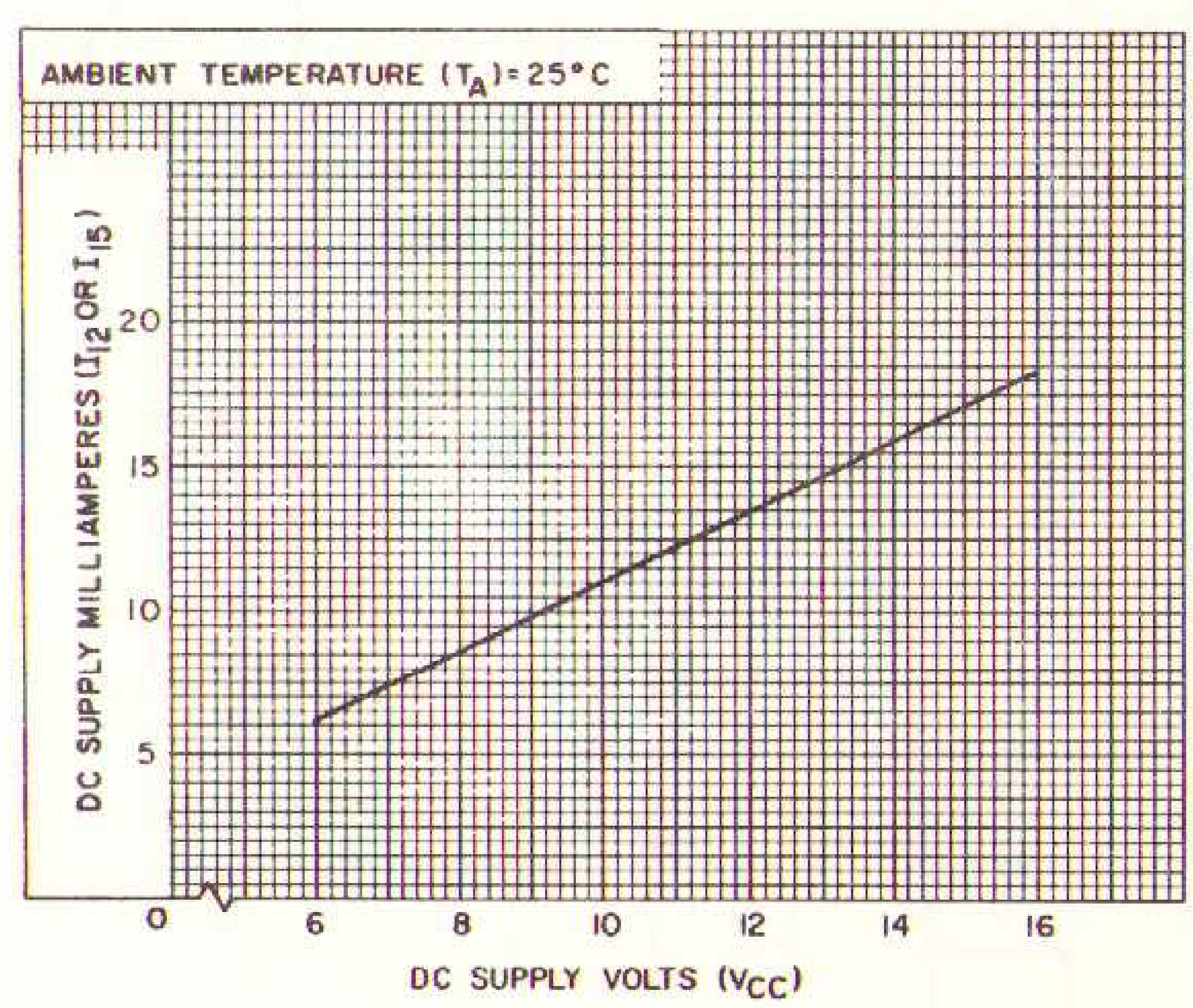


Fig.4 - Typical DC supply current vs supply voltage.

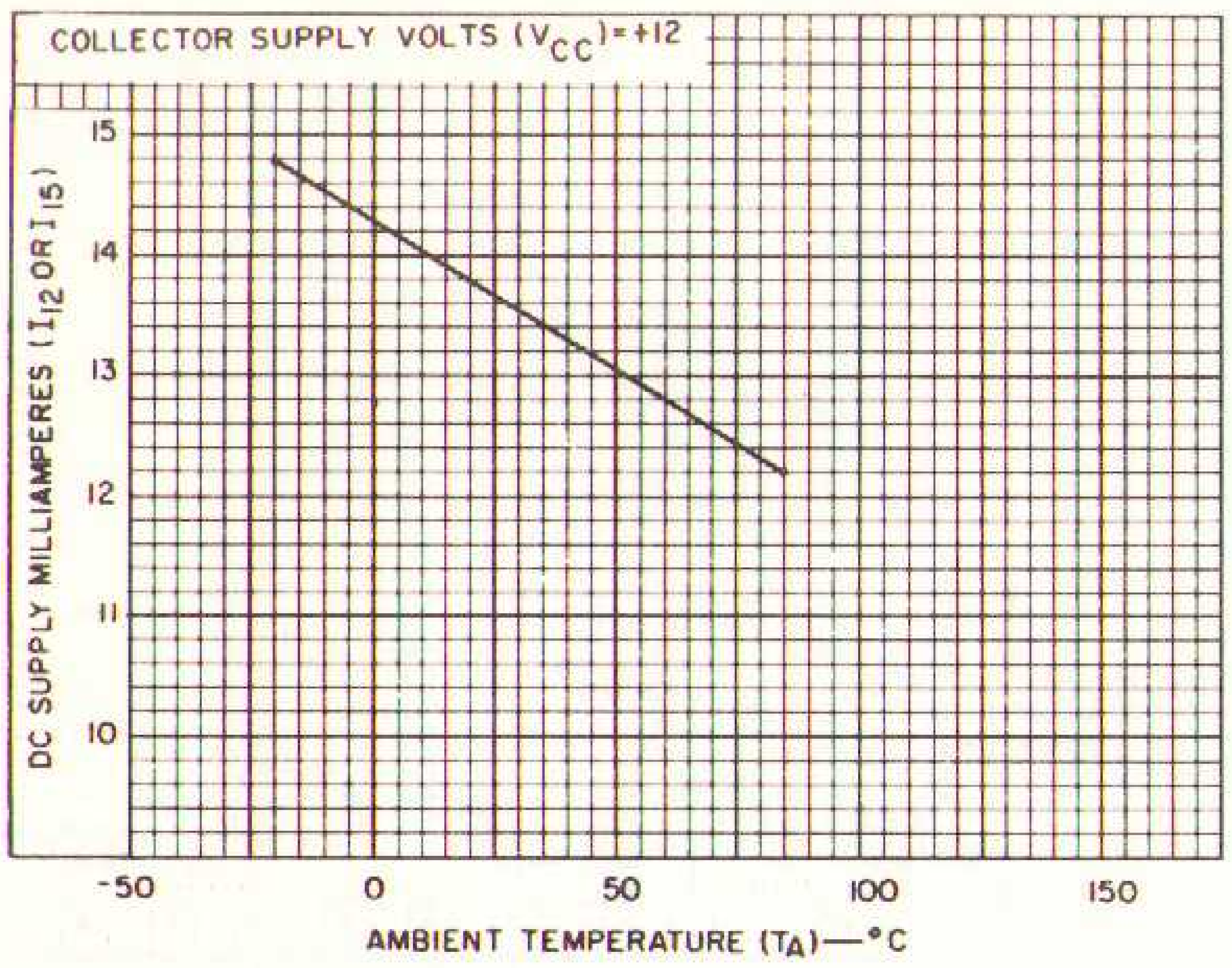


Fig.5 - Typical DC supply current vs ambient temperature.

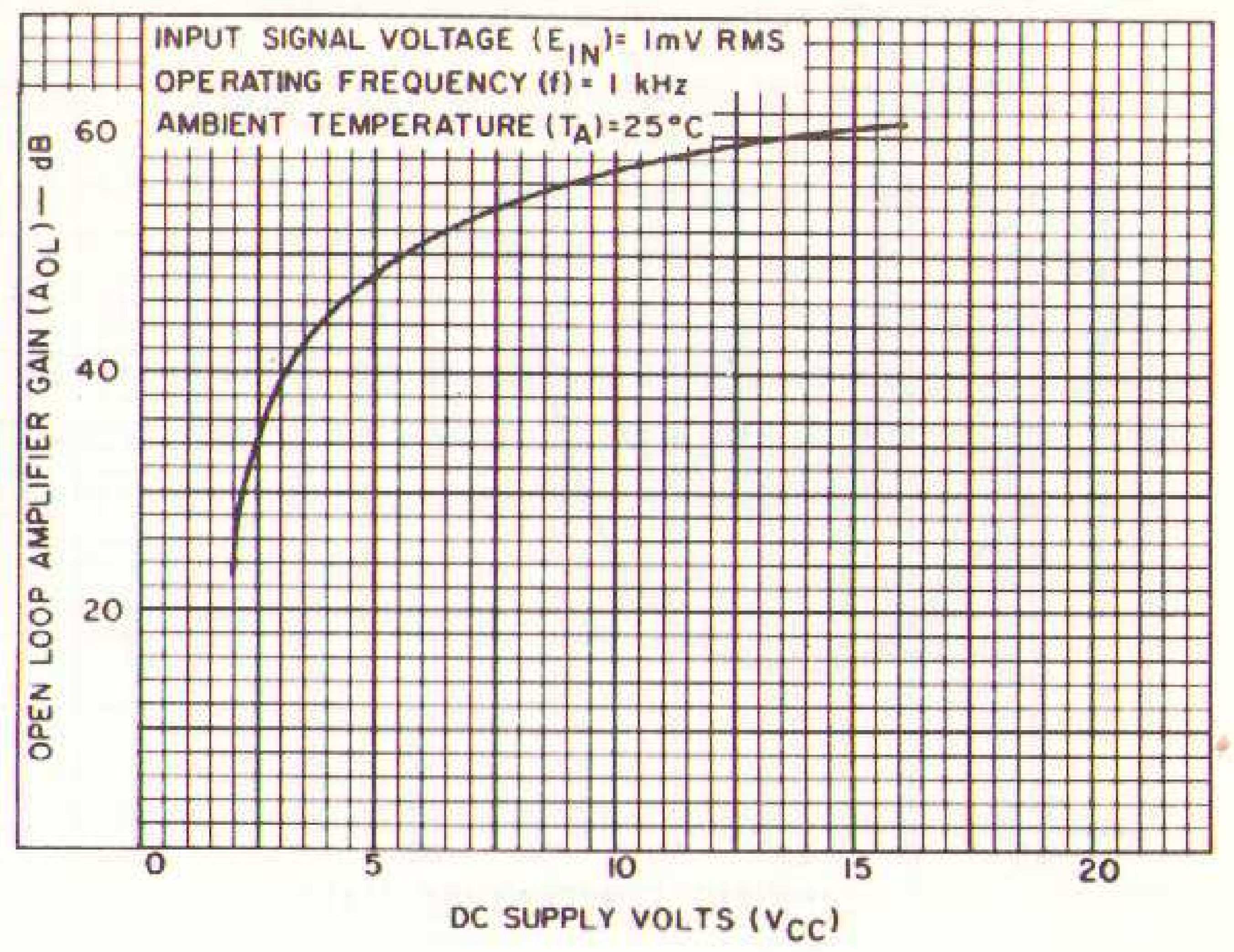
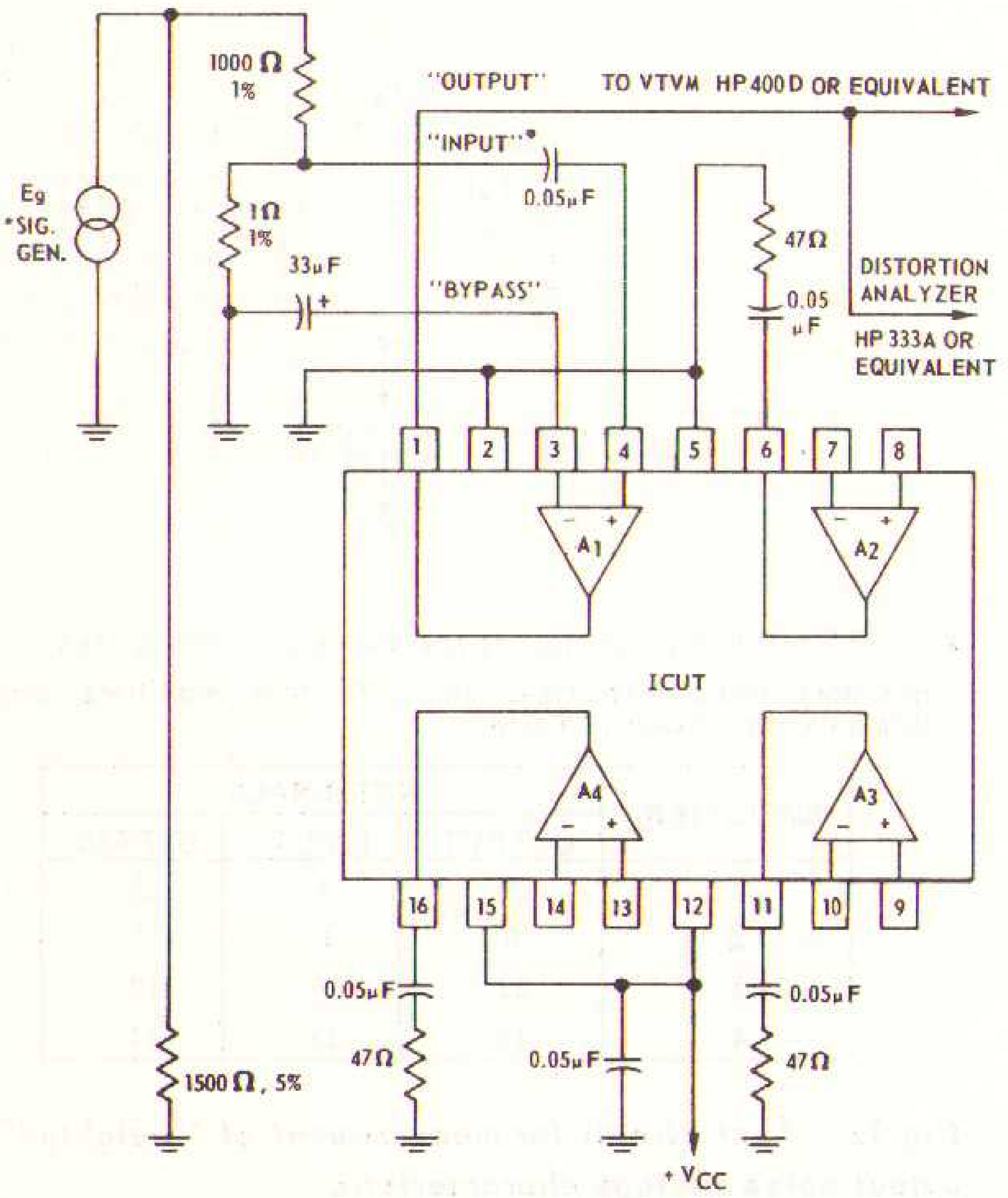


Fig.7 - Typical amplifier gain vs DC supply voltage.



* Sig Gen should be a low distortion type (0.2% THD or less) HP206A or equivalent.

● Adjustment of E_g to 2 volts will make E_S = 2 mV.

Test Circuit shows Amplifier #1 under test, to test Amplifiers 2, 3, or 4; Connect terminals as shown in Table.

AMPLIFIER	TERMINALS		
	OUTPUT	INPUT	BYPASS
1	1	4	3
2	6	8	7
3	11	9	10
4	16	13	14

Fig.6 - Test circuit for measurement of distortion, open-loop gain and bandwidth characteristics.

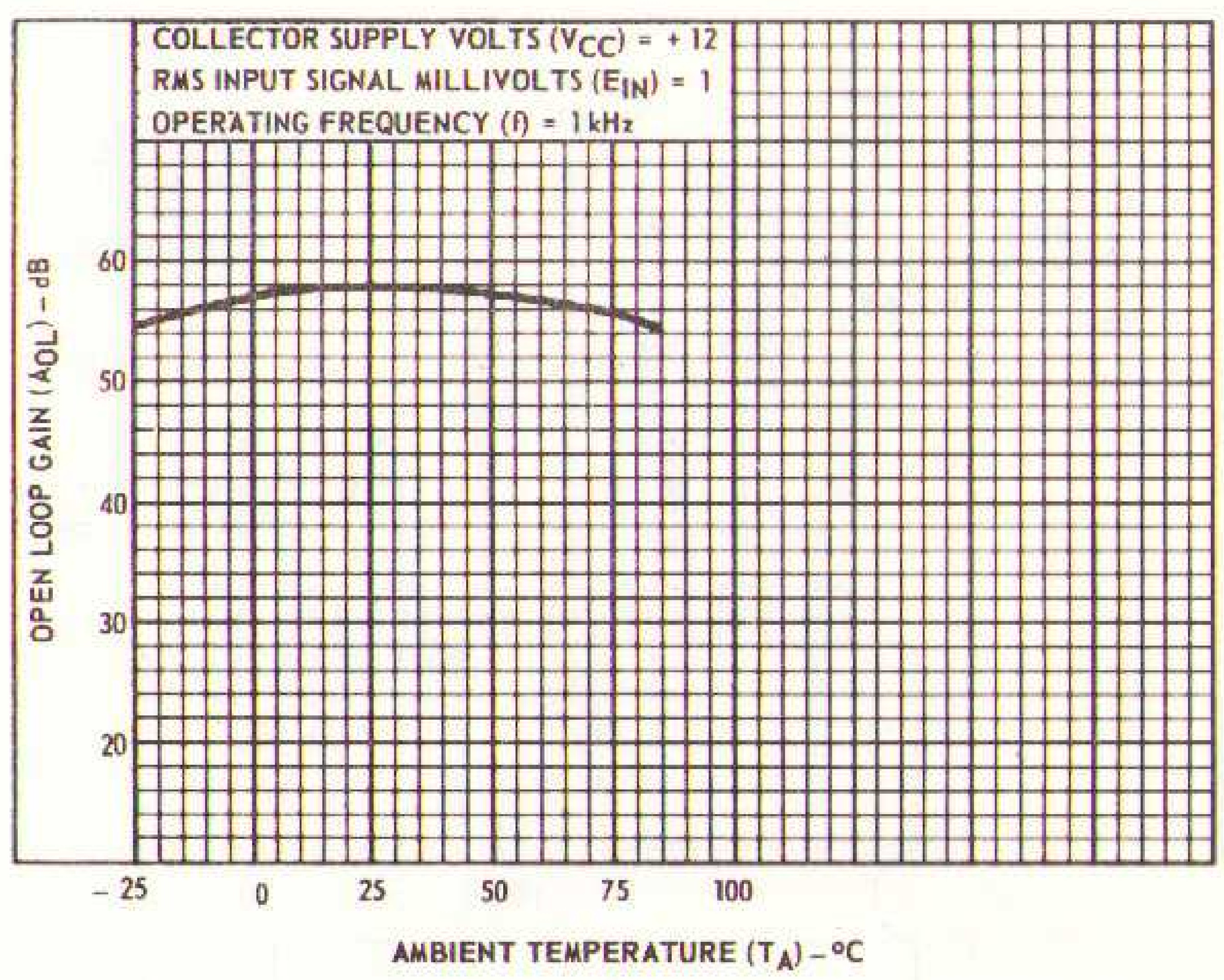


Fig.8 - Typical open-loop gain vs ambient temperature.

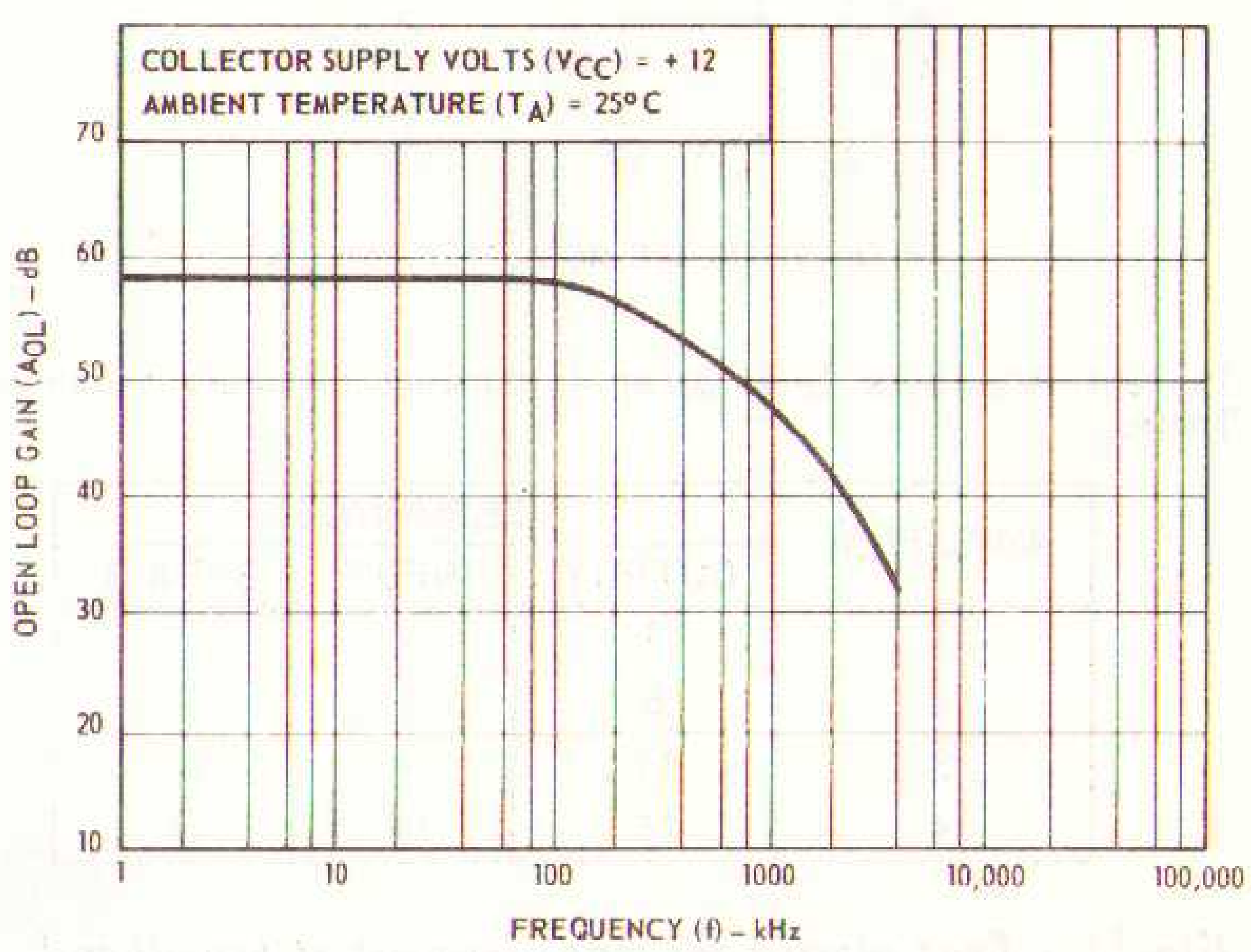


Fig.9 - Typical open-loop gain vs frequency.

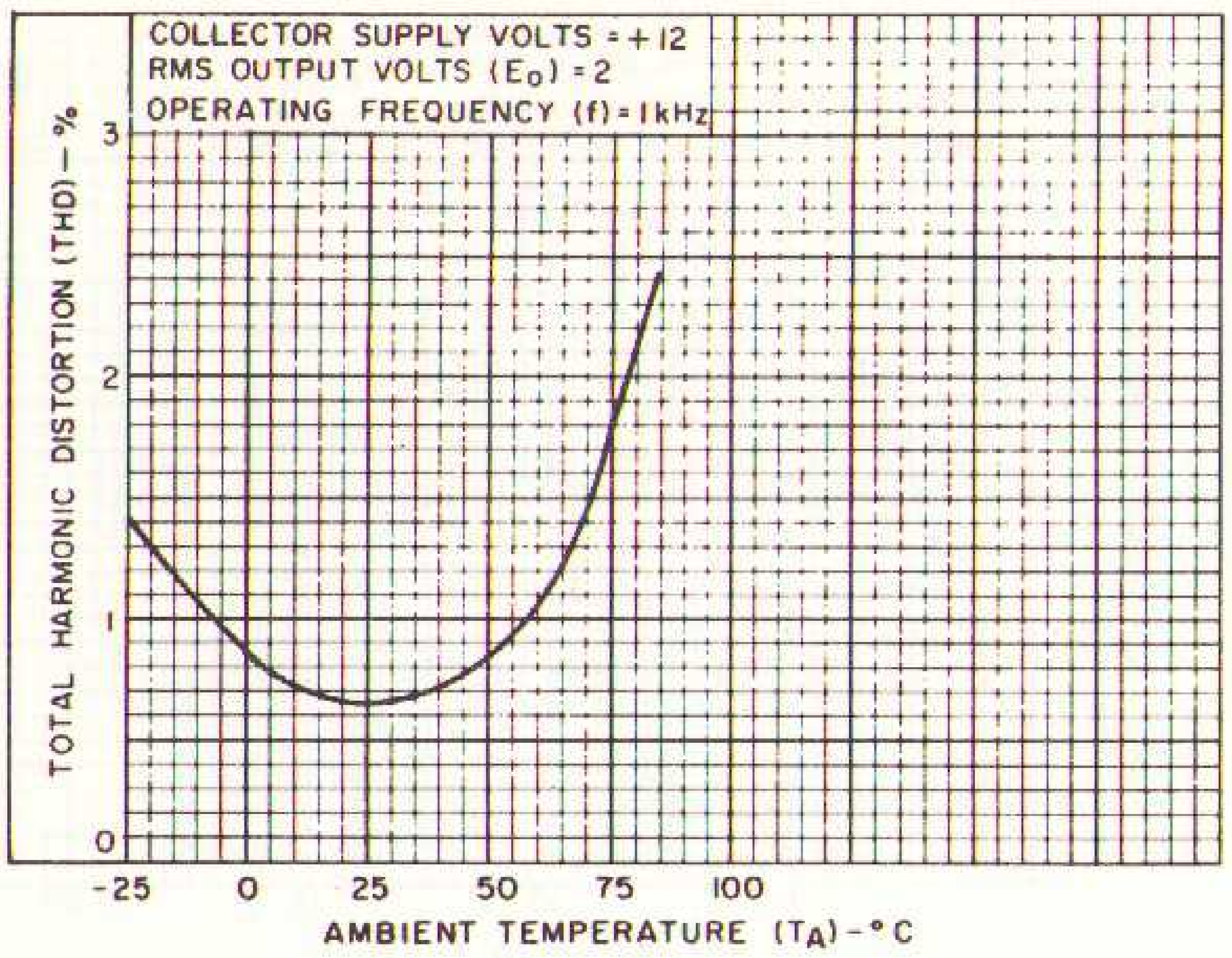
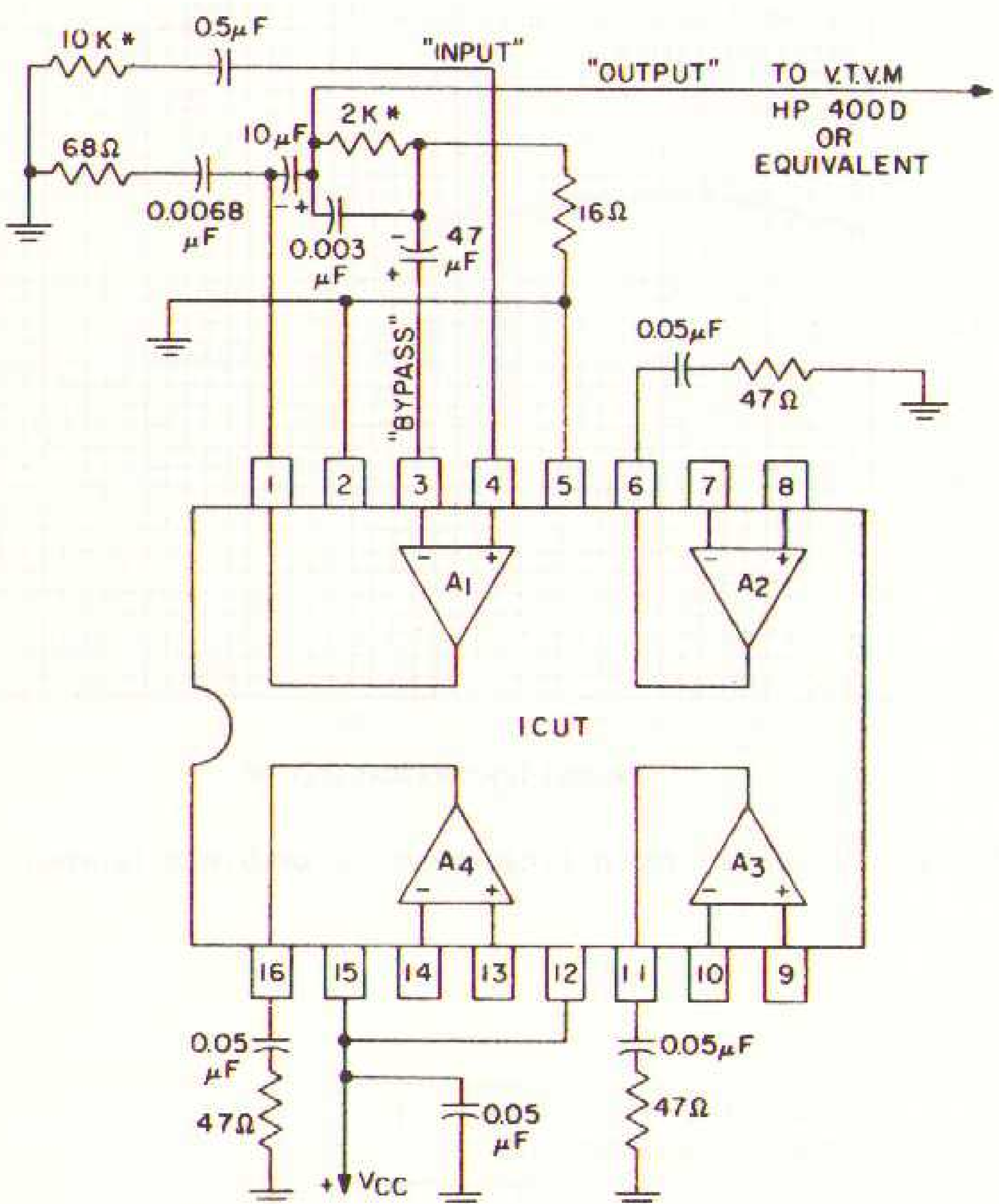


Fig.10 - Typical total harmonic distortion vs ambient temperature.

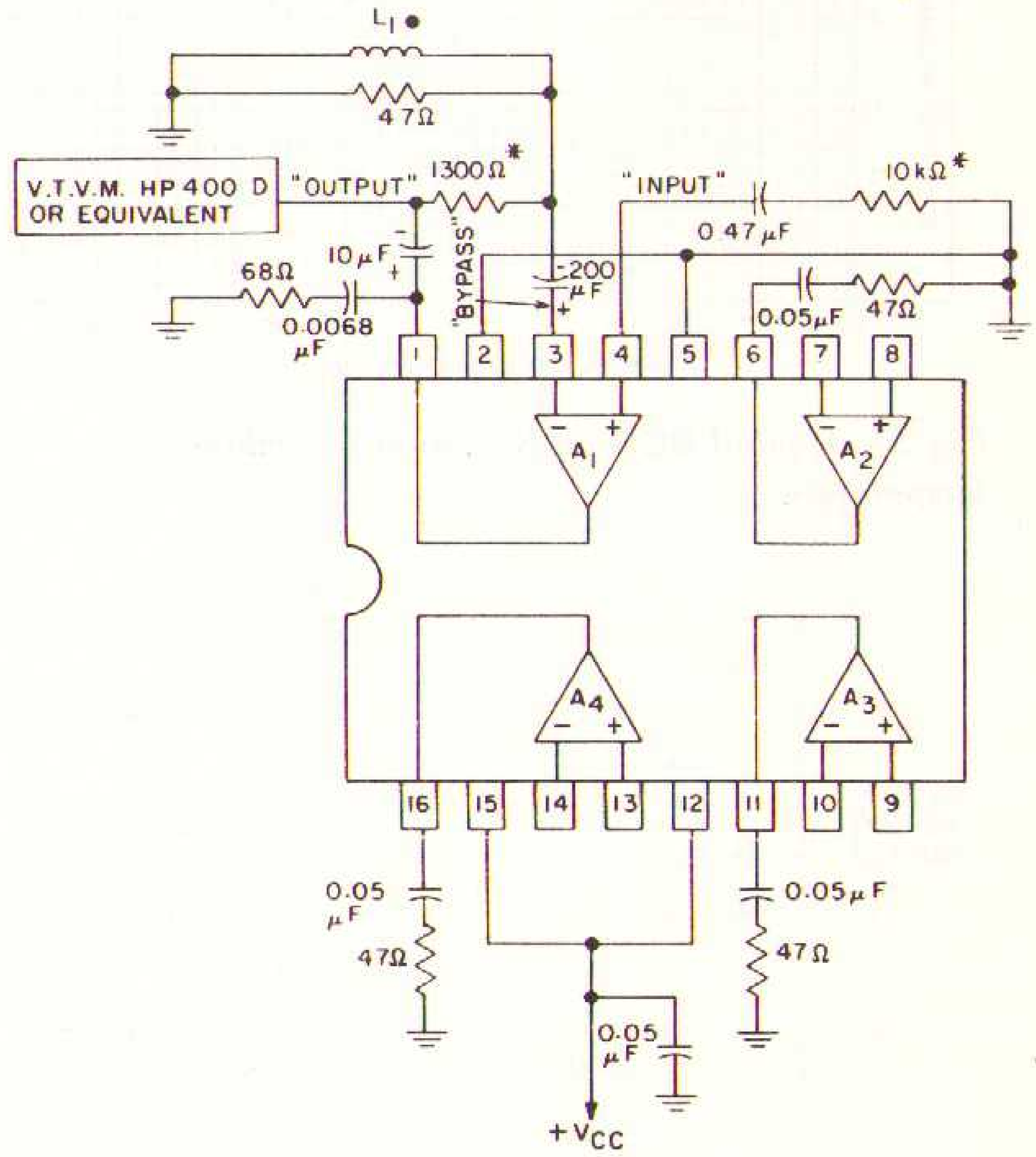


* RESISTORS ARE METALFILM TYPE, 1%

To test Amplifiers 1, 2, 3, or 4, connect terminals as shown in Table.

AMPLIFIER	TERMINALS		
	OUTPUT	INPUT	BYPASS
1	1	4	3
2	6	8	7
3	11	9	10
4	16	13	14

Fig.11 - Test circuit for measurement of broadband noise characteristic.

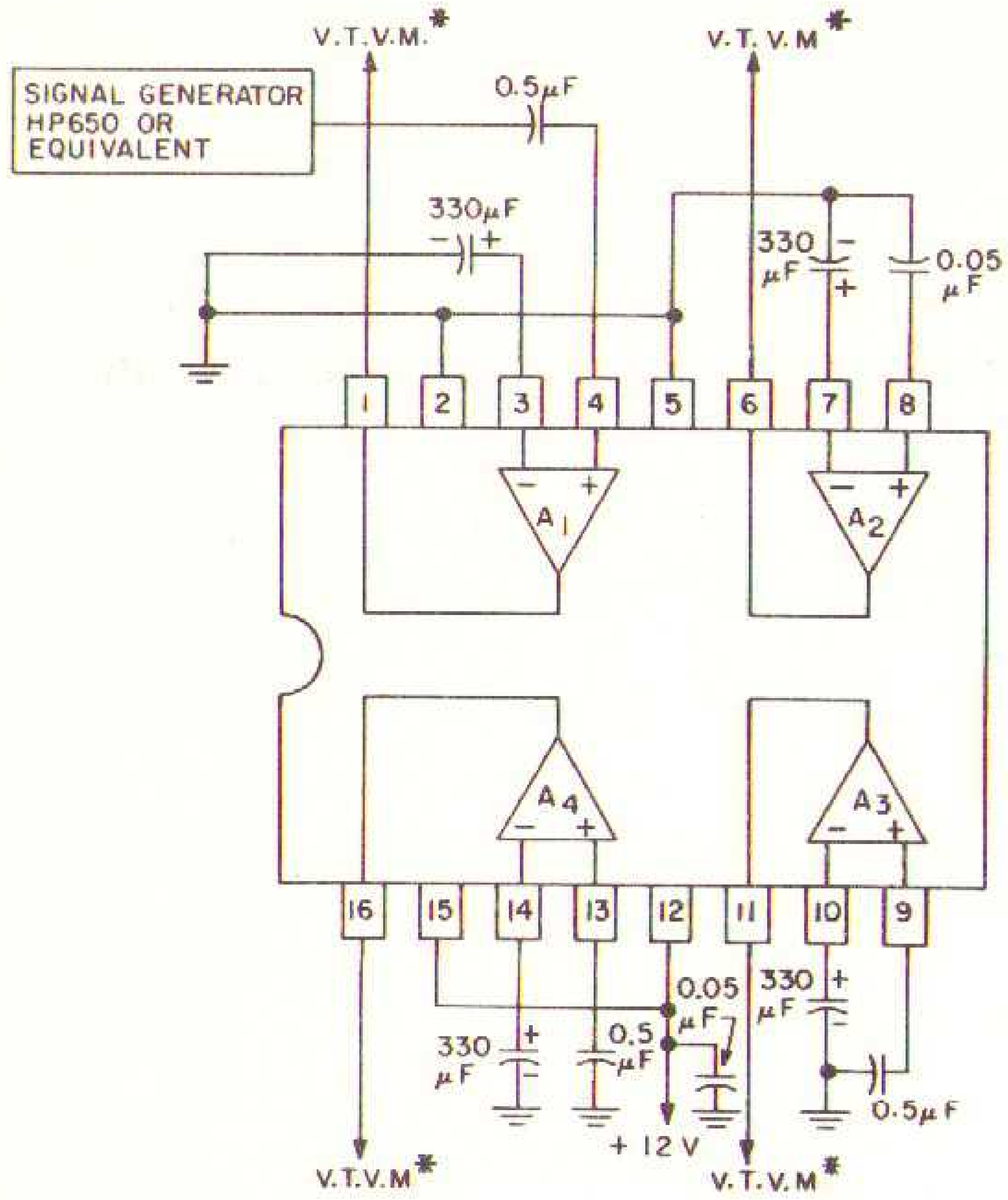


• L_1 - 2.5 millihenry inductor, dc resistance 0.3 ohms or less.

* Resistors metal film type, 1%. To test amplifiers, connect terminals as shown in Table.

AMPLIFIER	TERMINALS		
	OUTPUT	INPUT	BYPASS
1	1	4	3
2	6	8	7
3	11	9	10
4	16	13	14

Fig.12 - Test circuit for measurement of "weighted" output noise voltage characteristic.



* V.T.V.M. - Hewlett-Packard Model 400D or equivalent.

Procedure:

1. Adjust Signal Generator for 0 dB output at reference terminal.
2. Read voltage at other output terminals (Figure shows terminal #1 used as reference).

Fig.13 - Test circuit for measurement of inter-amplifier audio separation "cross talk" characteristic.

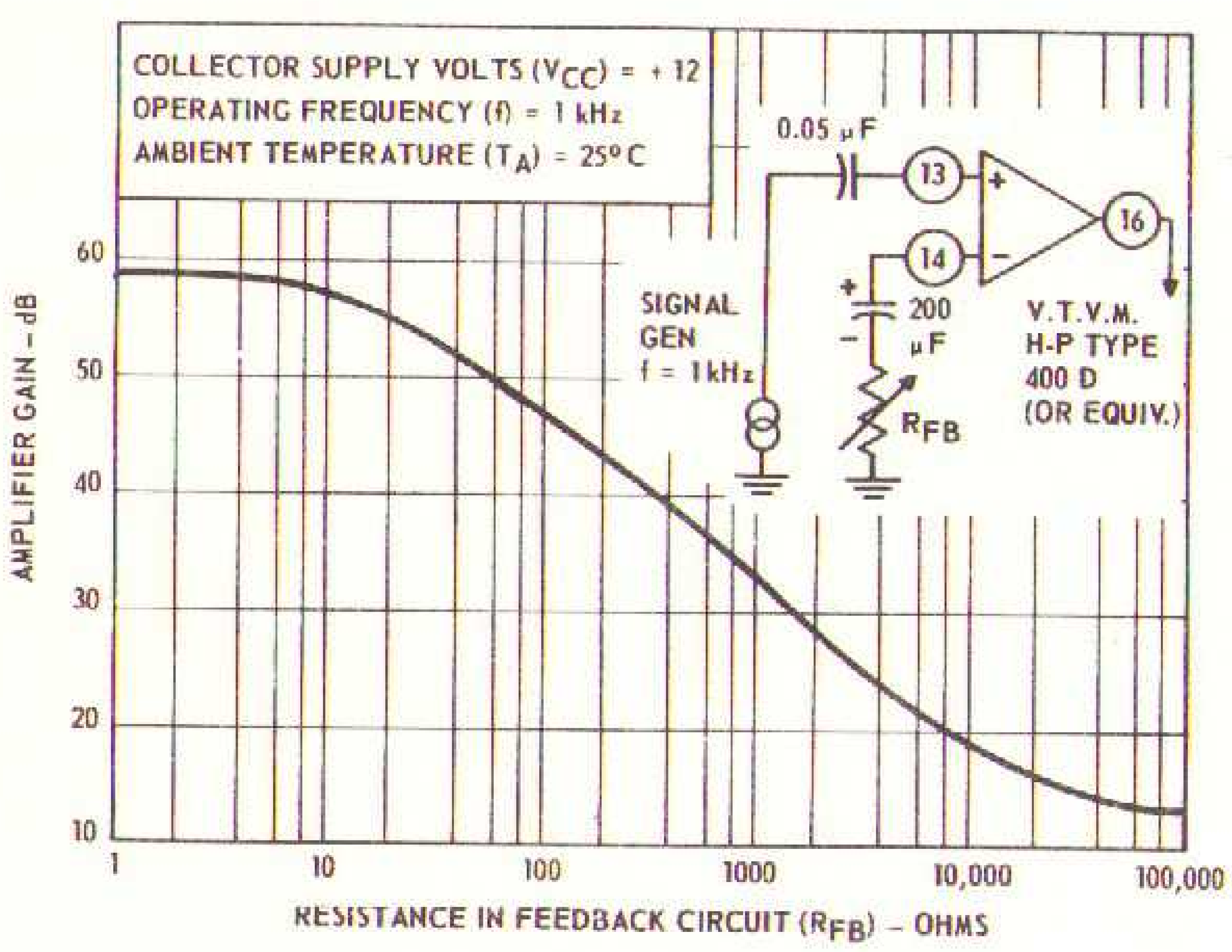


Fig.14 - Typical amplifier gain vs feedback resistance.

OPERATING CONSIDERATIONS

Economical Gain Control

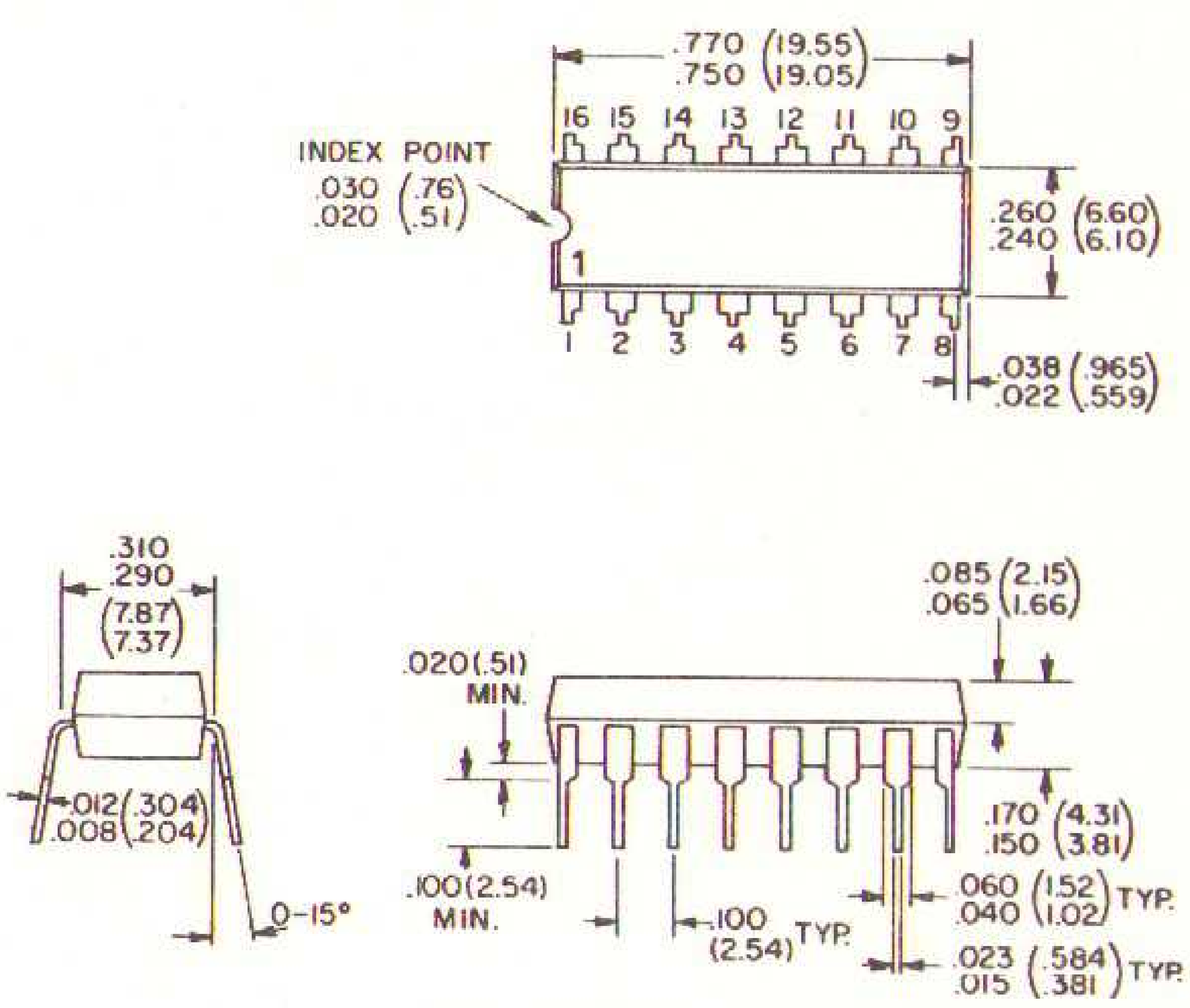
The CA3048 is designed to permit flexibility in the methods by which amplifier gain can be controlled. Fig.14 shows a curve of the gain of an amplifier when the internal resistive feedback of the device is used in conjunction with an external resistor. Although measured gain of various amplifiers will not be uniform, because of tolerances of internal resistances, this method is very economical and easy to apply.

Stability

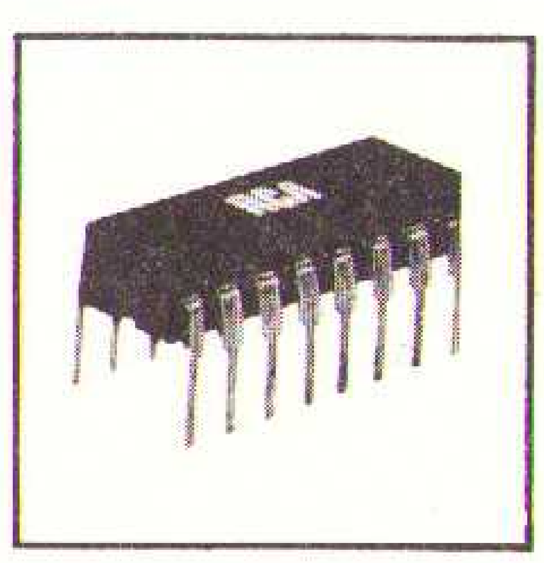
The CA3048, as in other devices having high gain-bandwidth product, requires some attention to circuit layout, design, and construction to achieve stability.

Should the CA3048 be left unterminated, socket capacitance alone will provide sufficient feedback to cause high frequency oscillations; therefore, all test circuits in this data bulletin include loading networks that provide stability under all conditions.

DIMENSIONAL OUTLINE



16-Lead Dual-In-Line Plastic Package



CA3048

van dam
ELEKTRONICA

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Giro: 295 550. Bank: AMRO-bank, Middell.str. te Rotterdam.
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Telefoon: 020 - 248967.

Wij zijn elke maandag in Rotterdam en Amsterdan de gehele dag gesloten !

Prijzen van de genoemde componenten:

MC 1430 P	(Operationele versterker dual-in-line)	*f* 27,15
CA 3000	(Differentiaal versterker met constante stroombron)	*f* 23,50
CA 3012	(MF-versterker met hoge versterking)	*f* 10,50
CA 3028	(Breedband differentiaal versterker met stroombron)	*f* 8,75
CA 3048	(Viervoudige audio-versterker ruisarme uitvoering).	*f* 23,50

Tevens wijzen wij U op de in ons leveringsprogramma opgenomen condensatoren van Siemens (styroflex), Rifa (metaal-papier en polyester) en Murata (miniatuur keramisch). Technische gegevens van Rifa worden U op aanvraag gaarne toegezonden. Hieronder nemen wij de gegevens van de styroflex condensatoren op:

Diëlektricum: polystyreen

Geleider: aluminium folie. Daar de aansluitdraden aan de wikkeling zijn gelast is deze condensator geschikt voor zeer lage spanningen.

Uitvoering: axiale aansluitingen.

Temperatuurgebied: -10 tot +70°C.

Verliesfactor tg δ (1kHz) x10^{-3}: 0,3

Isolatieweerstand: 200.000 MΩ.

Temperatuurs-coëfficiënt: -100 tot -250 x 10^{-6}/°C.

Stabiliteit: ± 0,2%

Capaciteitswaarden: 100 pF, 120pF, 150pF, 180pF, 220pF, 270pF, 330pF, 390pF, 470 pF, 560pF, 680pF, 820pF, 1,0nF, 1,2nF, 1,5nF, 1,8nF, 2,2 nF, 2,7nF, 3,3nF, 3,9nF; tolerantie: ± 5%.

Nominale spanning: 63 volt D.C.

Prijs per stuk: *f* 0,35 incl. B.T.W.

Levertijd: voorraad Rotterdam.

Bij afname van 250 of meer per type prijs op aanvraag.

NIEUWE PRODUKTEN:

Ontstoorspoelen voor thyristor- en triac-schakelingen. Deze spoelen voldoen aan de binnenkort ook in Nederland van kracht wordende CISPR-aanbeveling omtrent ontstoring van voornoemde schakelingen. Deze spoelen, waarvan meer gegevens in onze technische documentatie deel 11, zijn verkrijgbaar in de waarden:

0,6 ampère ..... *f* 4,90	1 ampère ..... *f* 5,10	1,6 ampère ..... *f* 8,95
2½ ampère ..... *f* 9,25	6 ampère ..... *f* 10,75	10 ampère ..... *f* 16,00

10 ampère als ingegoten printuitvoering .... *f* 25,00

Bovenstaande prijzen zijn incl. 12% B.T.W. en kunnen door koersverschillen en metaaltoeslagen aan verandering onderhevig zijn; wijzigingen zijn voorbehouden!