Application of the CA3018 Integrated-Circuit Transistor Array

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The CA3018 integrated circuit consists of four silicon epitaxial transistors produced by a monolithic process on a single chip mounted in a 12-lead TO-5 package. The four active devices, two isolated transistors plus two transistors with an emitter-base common connection, are especially suitable for applications in which closely matched device characteristics are required, or in which a number of active devices must be interconnected with non-integrable components such as tuned circuits, large-value resistors, variable resistors, and microfarad bypass capacitors. Such areas of application include if, rf (through 100MHz), video, agc, audio, and DC amplifiers. Because the CA3018 has the feature of device balance, it is useful in special applications of the differential amplifier, and can be used to advantage in circuits which require temperature compensation of base-to-emitter voltage.

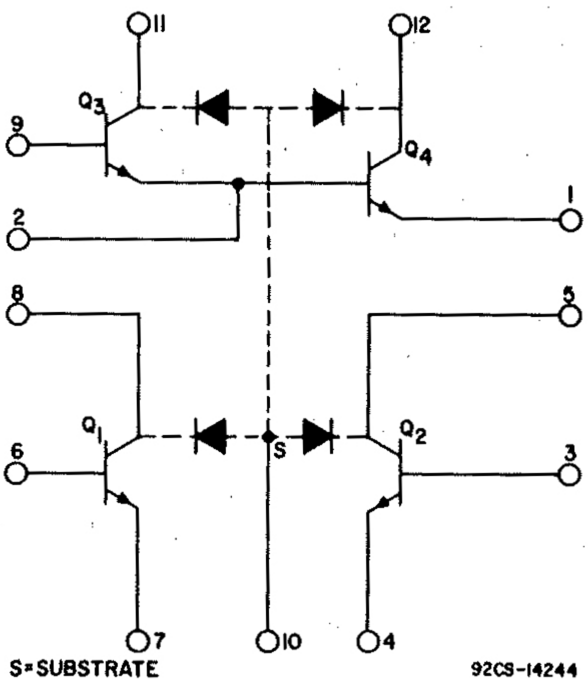

FIGURE 1. SCHEMATIC DIAGRAM AND T0-5 TERMINAL CONNECTIONS FOR THE CA3018 INTEGRATED CIRCUIT TRANSISTOR ARRAY

Circuit Description and Operating Characteristics

The circuit configuration for the CA3018 is shown in Figure 1. In a 12-lead TO-5 package, because it is necessary to provide a terminal for connection to the substrate, two transistor terminals must be connected to a common lead. The particular configuration chosen is useful in emitter-follower and Darlington circuit connections. In addition, the four transistors can be used almost independently if terminal 2 is grounded or AC grounded so that Q_3 can be used as a common-emitter amplifier and Q_4 as a common-base amplifier. In pulse video amplifiers and line-driver circuits, Q_4 can be used as a forward-biased diode in series with the emitter of Q_3. Q_3 may be used as a diode connected to the base of Q_4; in a reverse-biased connection, Q_3 can serve as a protective diode in RF circuits connected to operational antennas. The presence of Q_3 does not inhibit the use of Q_4 in a large number of circuits.

In transistors Q_1, Q_2, and Q_4, the emitter lead is interposed between the base and collector leads to minimize package and lead capacitances. In Q_3, the substrate lead serves as the shield between base and collector. This lead arrangement reduces feedback capacitance in common-emitter amplifiers, and thus extends video bandwidth and increases tuned-circuit amplifier gain stability.

Circuit Applications

The applications for the CA3018 are many and varied. The typical applications discussed in this Application Note have been selected to demonstrate the advantages of four matched devices available on a single chip. These few examples should stimulate the generation of a great many more applications.

Video Amplifiers

A common approach to video-amplifier design is to use two transistors in a configuration designed to reduce the feedback capacitance (appearing as a Miller capacitance) inherent in a single triode device. Three configurations which utilize two devices are (1) the cascode circuit, (2) the single-ended differential-amplifier, and (3) the common-collector, common-emitter circuit. In all three circuits, the output-to-input feedback capacitance is minimized by isolation inherent in the configuration. The availability of four identical transistors in a common package provides a convenient vehicle for these circuit configurations for video-amplifier design. Two of the many possible circuit variations are discussed in the following.

BROADBAND VIDEO AMPLIFIER

A broadband video amplifier design using the CA3018 is shown in Figure 2. This amplifier may be considered as two DC-coupled stages, each consisting of a common-emitter, common-collector configuration. The common-collector transistor provides a low-impedance source to the input of the common-emitter transistor and a high-impedance, low-capacitance load at the common-emitter output. Iterative operation of the video amplifier can be achieved by capacitive coupling of stages.

Two feedback loops provide DC stability of the broadband video amplifier and exchange gain for bandwidth. The feedback loop from the emitter of Q_3 to the base of Q_1 provides DC and low-frequency feedback; the loop from the collector of Q_4 to the collector of Q_1 provides both DC feedback and AC feedback at all frequencies.

The frequency response of the broadband video amplifier is shown in Figure 3. The upper 3dB break occurs at a frequency of 32MHz. The low-frequency 3dB characteristics are determined primarily by the values of capacitors C_1, C_2, and

C_3. The low-frequency 3dB break occurs at 800Hz. The mid-frequency gain of 49dB is constant to within 1dB over the temperature range from -55° to -125°C. The upper 3dB break is constant at 32MHz from -55°C to +25°C, and drops to 21MHz at +125°C.

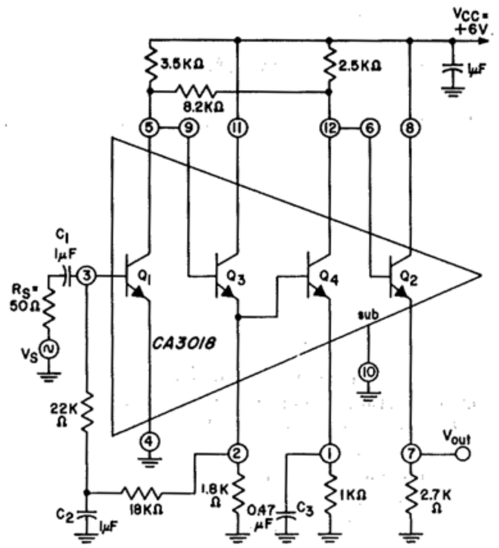

FIGURE 2. SCHEMATIC DIAGRAM FOR A CA3018 BROADBAND VIDEO AMPLIFIER

The total power dissipation over the entire temperature range is 22.8mW. The DC output voltage varies from 2.33V at -55°C to 3V at +125°C. The tangential sensitivity occurs at 20μV_{P-P}. The dynamic range is from 20μV_{P-P} to 4mV_{RMS} at the input.

The circuit of Figure 2 demonstrates a typical approach that can be altered, especially with regard to gain and bandwidth, to meet specific performance requirements.

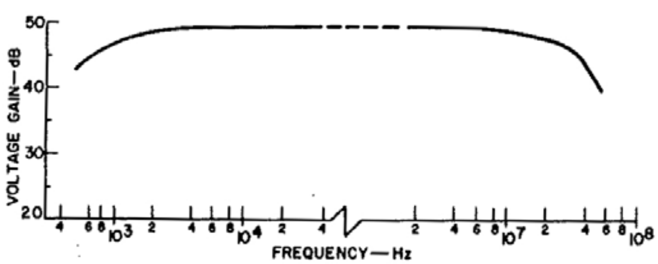

FIGURE 3. VOLTAGE GAIN AS A FUNCTION OF FREQUENCY FOR THE BROADBAND VIDEO AMPLIFIER OF FIGURE 2

CASCODE VIDEO AMPLIFIER

The cascode configuration offers the advantages of common-emitter gain with reduced feedback capacitance and thus greater bandwidth. Figure 4 shows a typical circuit diagram of a cascode video amplifier using the CA3018. Transistors Q_2 and Q_1 comprise the common-emitter and common-base portions of the cascode, respectively. The common-base unit is followed by cascaded emitter followers (Q_3 and Q_4) which provide a low output impedance to maintain bandwidth for iterative operation.

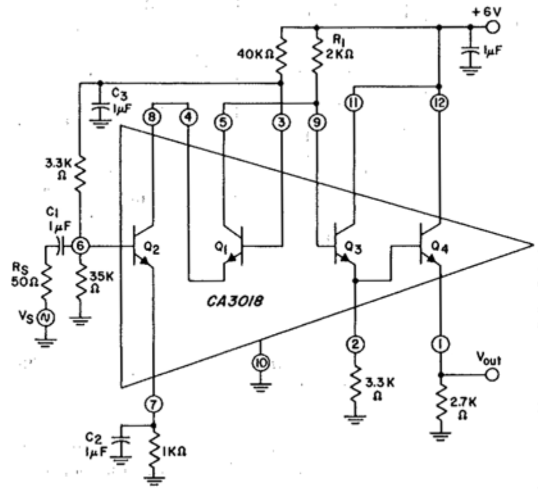

FIGURE 4. SCHEMATIC DIAGRAM FOR A CA3018 CASCODE VIDEO AMPLIFIER

The frequency response of the cascode video amplifier is shown in Figure 5. The lower and upper 3dB points occur at frequencies of 6kHz and 11MHz, respectively. The lower 3dB point is primarily a function of capacitors C_1, C_2, and C_3. The upper 3dB point is a function of the devices and of the load resistor R_1, and is 10.5MHz at -55°C and 5MHz at 125°C.

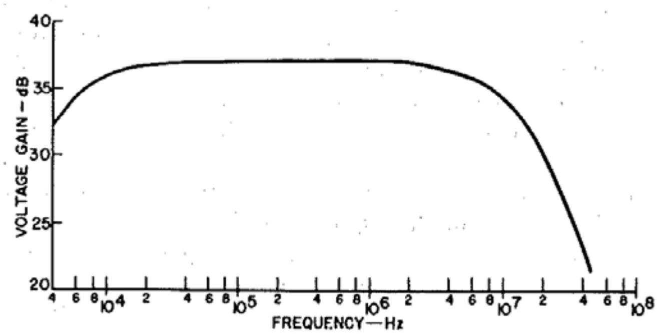

FIGURE 5. VOLTAGE GAIN AS A FUNCTION OF FREQUENCY FOR THE CASCODE AMPLIFIER OF FIGURE 4

The mid-frequency voltage gain of the amplifier is 37dB ±1dB over the temperature range from -55°C to 125°C. The power dissipation varies from 16.8mW at -55°C to 17.6mW at 125°C. The amplifier has a tangential sensitivity of 40μV_{P-P} and a useful dynamic input range from 40μV_{P-P} to 16.6mV_{P-P}.

15MHz RF Amplifier

Figure 6 shows a typical design approach for a tuned amplifier for use in the frequency range of 2 to 30MHz in military receivers. This circuit was designed for a mid-band frequency of 15MHz to demonstrate its capability. Gain is obtained in a common-emitter stage (Q_4). Transistor Q_2 is used as a variable resistor in the emitter of Q_4 to provide improved signal-handling capability with age. Transistor Q_1 is used as a bias diode to stabilize Q_4 with temperature, and the reverse breakdown of Q_3 as a diode is used to protect the common-emitter stage from signal overdrive of adjacent transmitters.

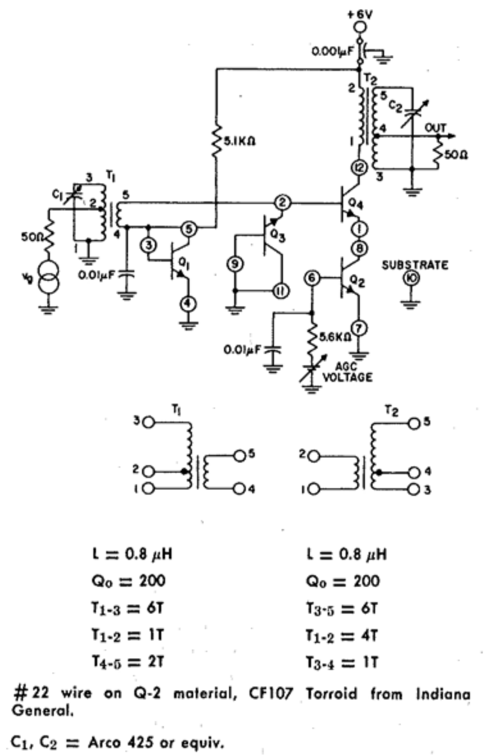

FIGURE 6. SCHEMATIC DIAGRAM FOR A CA3018 15MHz RF AMPLIFIER

The tuned-circuit design of Figure 6 utilizes mismatching to obtain stability. Although the usable stable gain for a common-emitter amplifier using this type of transistor is 26dB at 15MHz, the tuned RF amplifier was designed for a total gain of 20dB to obtain greater stability and more uniform performance with device variations. The general performance characteristics of the circuit are as follows:

Power Gain 20dB
Power-Gain Variation from -55 to ±125°C . . . . ±1dB
Bandwidth 315kHz
Noise Figure at Full Gain 7.4dB
AGC Range 45dB
Power Dissipation 1.8mW

Figure 7 shows the cross-modulation characteristics of the circuit for in-band signals. For out-of-band undesired signals, the cross-modulation performance is improved by the amount of attenuation provided by the input tuned circuit. Cross-modulation performance also improves (i.e. more interfering signal voltage is required for cross-modulation distortion of 10 percent) with increased agc as a result of the degeneration in the emitter of Q_4.

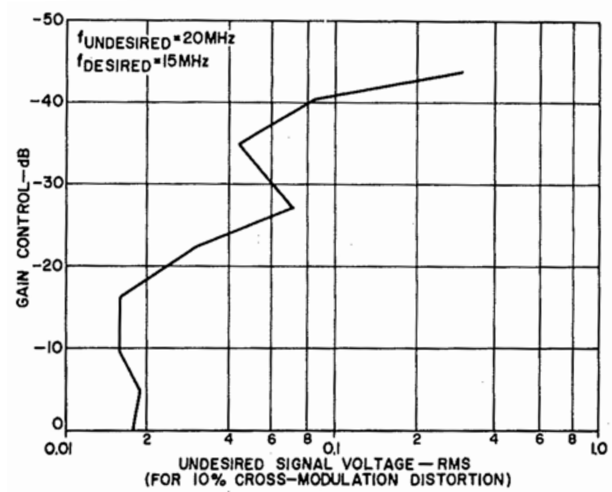

FIGURE 7. IN-BAND CROSS-MODULATION CHARACTERISTIC OF 15MHz AMPLIFIER OF FIGURE 6 (DATA TAKEN WITH UNTUNED INPUT)

Final If Amplifier Stage and Second Detector

Figure 8 illustrates the use of the CA3018 as a last If amplifier and second detector (0.1V emitter voltage on terminal 1). The bias on transistor Q_4 is maintained at approximately cutoff to permit the cascaded emitter-follower configuration (Q_3 and Q_4) to be used as a second detector. Because this stage is driven by a common collector configuration, the input impedance to the detector can be kept high. A low output load impedance can be used as a result of the output current capability of the cascaded emitter-follower configuration. The input impedance (terminal 9) of approximately 9000Ω is largely determined by the bias network. A minimum If input power of 0.4μW must be delivered to terminal 9 for linear operation. The audio output power for 60 percent modulation for this drive condition is 0.8μW. Linear detection is obtained through an input range of 20dB for 60 percent modulation. This detector arrangement requires less power output capability from the last If amplifier than a conventional diode detector yet allows a low DC load resistor to achieve a good AC-to-DC ratio for the first audio amplifier.

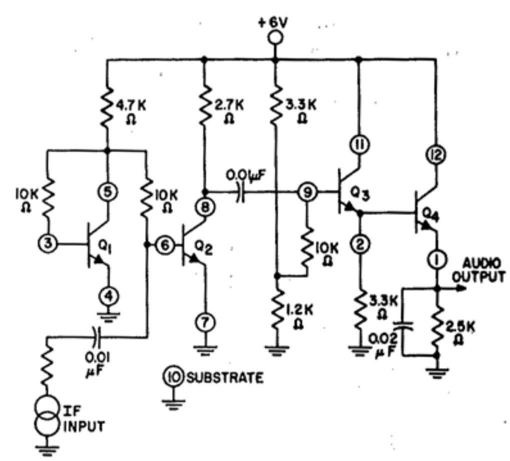

FIGURE 8. SCHEMATIC DIAGRAM FOR A CA3018 FINAL IF AMPLIFIER AND SECOND DETECTOR

The If amplifier of Figure 8 has a voltage gain of 30dB at 1MHz. Transistor Q_1 is used in the base-bias loop of the common-emitter amplifier Q_2 to stabilize the output operating point against temperature variations. This arrangement also eliminates the need for an emitter resistor and bypass capacitor, and thus provides a larger voltage-swing capability for Q_2. If Q_2 is biased conventionally with base-bias resistors, Q_1 can be made available for the first audio or agc amplifier.

Class B Amplifier

Characteristics were obtained on a low-level class B amplifier to establish the idling-current performance of nearly identical devices on a single chip with respect to temperature variations. The transistors in the CA3018 can be used only for low-power class B operation (maximum output of 40mW) because of the h_{FE} roll-off and moderately high saturation resistance at high currents. A typical circuit is shown in Figure 9. Idling-current bias is provided to Q_1 and Q_2 by use of transistor Q_3 as a diode (with collector and base shorted) and connection of a series resistor to the supply. The idling current for each transistor in the class B output is equal to the current established in the resistance-diode loop. Because the resistor R_1 is the predominant factor in controlling the current in the bias loop, the bias current is relatively independent of temperature. In addition, because the devices have nearly equal characteristics and are at the same temperature, the idling current is nearly independent through the full military temperature range. The total idling current for transistors Q_1 and Q_2 in Figure 9 varies from 0.5 to 0.6mA from -55 to +125°C. Excellent balance between output devices is achieved throughout the range.

AC feedback as well as DC feedback can be obtained by substitution of two resistors R_2 and R_3 in place of R_1, as shown by the dotted lines in Figure 9. These two resistors, which have a parallel combination equal to R_1. are connected between collector and base of transistors Q_2 and Q_1. The added feedback reduces the power gain by approximately 6dB (30 to 24dB), but improves the linearity of the circuit. Although the output-power capability for the circuit shown in Figure 9 is approximately 18mW, output levels up to 40mW can be obtained in similar configurations with optimized components.

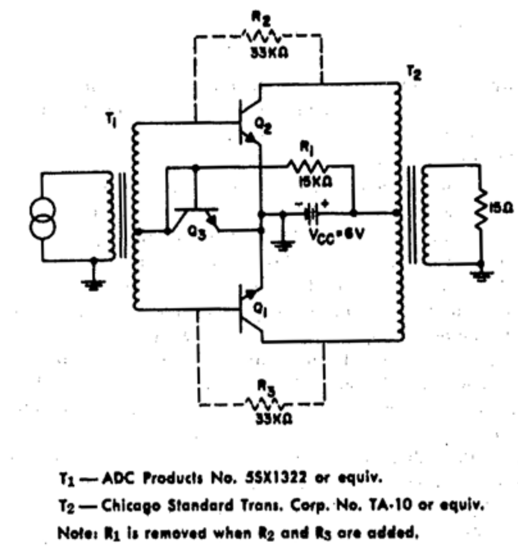

FIGURE 9. SCHEMATIC DIAGRAM FOR A CA3018 CLASS H AMPLIFIER

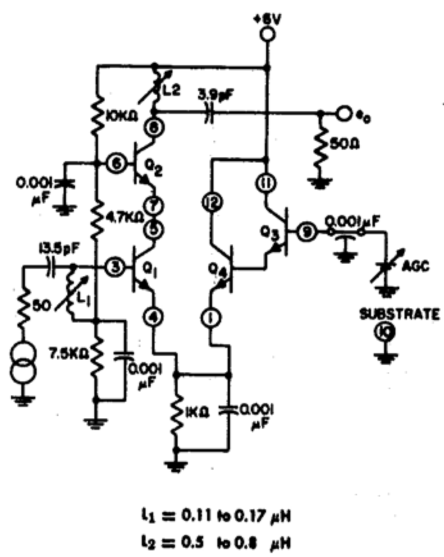

FIGURE 10. SCHEMATIC DIAGRAM FOR A CA3018 100MHz CASCODE AMPLIFIER

100MHz Tuned RF Amplifier

Figure 10 illustrates the use of the CA3018 in a 100MHz cascode circuit with an agc amplifier. Transistors Q_1 and Q_2 are used in a cascode configuration, and transistors Q_3 and Q_4 are used to provide an agc capability and amplification. With a positive-going agc signal, current in the cascode amplifier is transferred to the Darlington configuration by differential-amplifier action. This agc amplifier has the advantage of low-power drive (high input impedance). In addition, the emitter of Q_1 can be back-biased with respect to the base to provide larger input-signal-handling capability under full agc conditions.

The operating characteristics of the amplifier shown in Figure 10 are as follows:

Power Gain 26dB
Agc Range 70dB
3dB Bandwidth 4.5MHz
Noise Figure 6.8dB
Power Dissipation 7.7mW

The response characteristic is shown in Figure 11.

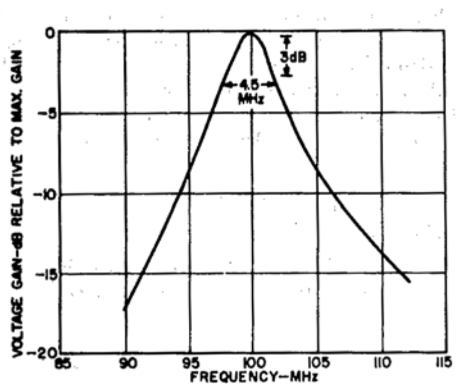

FIGURE 11. RESPONSE CHARACTERISTIC OF 100MHz AMPLIFIER OF FIGURE 10

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