Application Of The CA3020 And CA3020A …tipurpose Wide-band Power Amplifiers

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The discussions in this Note are applicable to both integrated circuit types. The CA3020A can operate in all circuits shown for the CA3020. The CA3020, on the other hand, has a lower voltage rating and must not be used in applications which require voltages on the output transistors greater than 18V. The integrated circuit protects the output transistor by limiting the drive to the output stages. The drive limited current capability of the CA3020 is less than that of the CA3020A, but peak currents in excess of 150mA are an assured characteristic of the CA3020.

The CA3020 and CA3020A integrated circuits are multipurpose, multifunction power amplifiers designed for use as power output amplifiers and driver stages in portable and fixed communications equipment and in AC servo control systems. The flexibility of these circuits and the high frequency capabilities of the circuit components make these types suitable for a wide variety of applications such as broadband amplifiers, video amplifiers, and video line drivers. Voltage gains of 60dB or more are available with a 3dB bandwidth of 8MHz.

The discussions in this Note are applicable to both integrated circuit types. The CA3020A can operate in all circuits shown for the CA3020. The CA3020, on the other hand, has more limited voltage and current handling capability and must not be used in applications which require voltage swings on the output transistors greater than 18V or peak currents in excess of 150mA.

The CA3020 and CA3020A are designed to operate from a single supply voltage which may be as low as +3V. The maximum supply voltage is dictated by the type of circuit operation. For transformer loaded class B amplifier service, the maximum supply voltages are +9V and +12V for the CA3020 and the CA3020A, respectively. When operated as a class B amplifier, either circuit can deliver a typical output of 150mW from a +3V supply or 400mW from a +6V supply. At +9V, the idling dissipation can be as low as 190mW, and either circuit can deliver an output of 550mW. An output of slightly more than 1W is available from the CA3020A when a +12V supply is used.

Circuit Description and Operation

Figure 1 shows the schematic diagram of the CA3020 and CA3020A, and indicates the five functional block into which the circuit can be divided for understanding of its operation. Figure 2 shows the relationship of these blocks in block diagram form.

A key to the operation of the circuit is the voltage regulator consisting of diodes D_1, D_2, and D_3 and resistors R_{10} and R_{11}. The three diodes are designed to provide accurately controlled voltages to the differential amplifier so that the proper idling current for class B operation is established in the output stage. The characteristics of these monolithic diodes closely match those of the driver and output stages so that proper bias voltages are applied over the entire military temperature range of -55^{o}C to +125^{o}C. The close thermal coupling of the circuit assures against thermal runaway within the prescribed temperature and dissipation ratings of the devices.

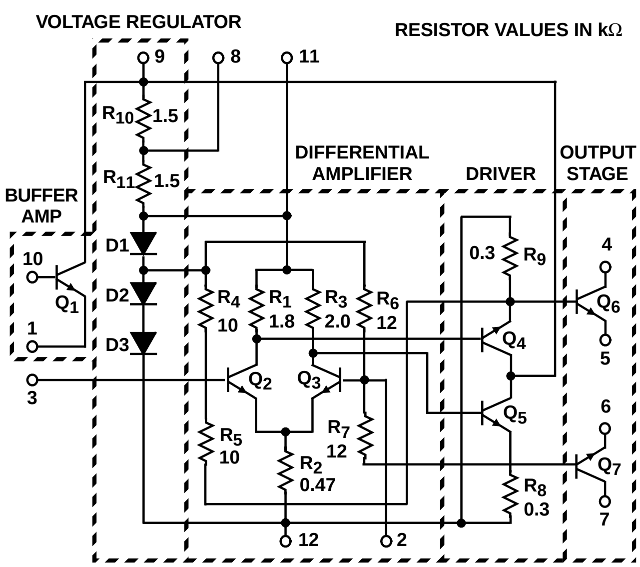


FIGURE 1. SCHEMATIC DIAGRAM OF CA3020 AND CA3020A INTEGRATED CIRCUIT AMPLIFIERS

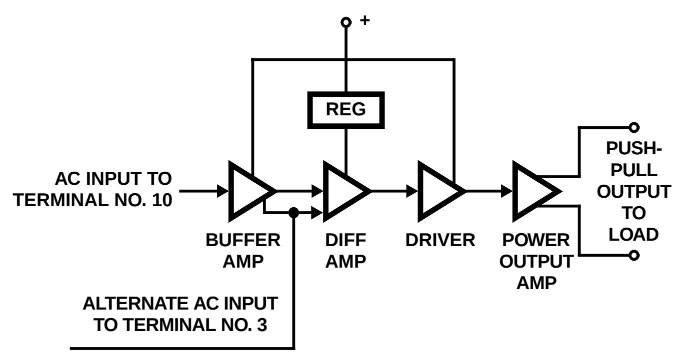


FIGURE 2. FUNCTIONAL BLOCK DIAGRAM OF THE CA3020 AND CA3020A

The differential amplifier operates in a class A mode to supply the power gain and phase inversion required for the push-pull class B driver and output stages. In normal operation, an AC signal is capacitively coupled to terminal 3, and terminal 2 is AC grounded through a suitable capacitor. When the signal becomes positive, transistor Q_2 is turned on and its collector voltage changes in a negative direction. The same current flows out of the emitter of Q_2 and tends to flow to ground through resistor R_2. However, the impedance of R_2 is high compared to the input impedance of the emitter of Q_8, and an alternate path is available to ground through the emitter-to-base junction of transistor Q_3 and then through the bypass capacitor from terminal 2 to ground. Because this path has a much lower impedance than R_2, most of the current takes this alternate route. The signal current flowing into the emitter of Q_3 reduces the magnitude of that current and, because the collector current is nearly equal to the emitter current, the collector current in Q_3 drops and the collector voltage rises. Thus, a positive signal on terminal 3 causes a negative AC voltage on the collector of transistor Q_2 and a positive AC voltage on transistor Q_3, and provides the out-of-phase signals required to drive the succeeding stages. It should be noted that the differential amplifier is not balanced; resistor R_3 is ten percent greater than R_1. This unbalance is deliberately introduced to compensate for the fact that all of the current in the emitter of Q_2 does not flow into Q_3. Use of a larger load resistor for transistor Q_3 compensates for the lower current so that the voltage swings on the two collectors have nearly the same magnitude.

The driver stages (transistors Q_4 and Q_5) are emitter follower amplifiers which shift the voltage level between the collectors of the differential-amplifier transistors and the bases of the output transistors and provide the drive current required by the output transistors.

The power transistors (Q_8 and Q_7) are large, high current devices capable of delivering peak currents greater than 0.25A. The emitters are made available to facilitate various modes of operation or to permit the inclusion of emitter resistors for more complete stabilization of the idling current of the amplifier. Inclusion of such resistors also reduces distortion by introducing negative feedback, but reduces the power-output capability by limiting the available drive.

Inclusion of emitter resistors between terminals 5 and 6 and ground also enhances the effectiveness of the internal DC feedback supplied to the bases of transistors Q_2 and Q_3 through resistors R_5 and R_7. Any increase in the idling current in either output transistor is reflected as an increased voltage at its base. This change is coupled to the input through the appropriate resistor to correct for the increased current.

A later section of this Note describes how stable class A operation of the output stages may be obtained.

Operating Characteristics

Supply Voltages and Derating

The CA3020 operates with any supply voltage between +3V and +9V. The CA3020A can also be operated with supply voltages up to +12V with inductive loads or +25V with resistive loads. Figure 3 shows the permissible dissipation rating of the CA3020 and CA3020A as a function of case and ambient temperatures. At supply voltages from +6V to +12V, a heat sink may be required for maximum power output capability. The worst case dissipation $P_{D\ MAX}$ as a function of power output can be calculated as follows:

$$P_{D\ MAX} = (V_{CC1}\ I_{CC1} + V_{CC2}\ I_{CC2}) + (V_{CC2}^2/R_{CC})$$

where V_{CC1} and V_{CC2} are the supply voltages to the differential amplifier and output amplifier stages, respectively; I_{CC1} and I_{CC2} are the corresponding idling currents; and R_{CC} is the collector-to-collector load resistance of the output transformer. This equation is preferred to the conventional formula for the dissipation of a class B output transistor (i.e., 0.84 times the maximum power output) because the $P_{D\ MAX}$ equation accounts for the device standby power and device variability.

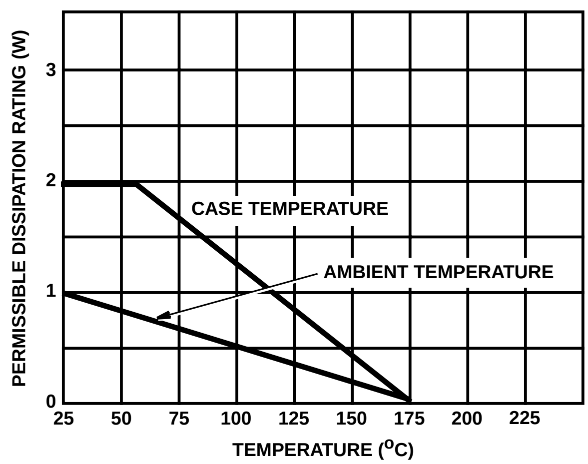
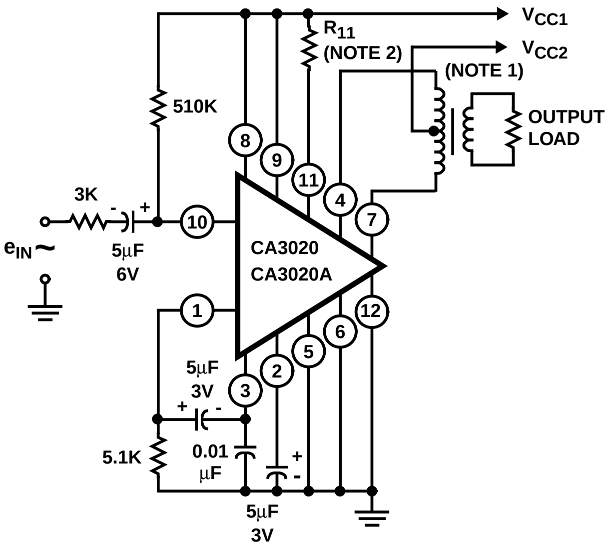


FIGURE 3. DISSIPATION RATING OF THE CA3020 AND CA3020A AS A FUNCTION OF CASE AND AMBIENT TEMPERATURES

Basic Class B Amplifier

Figure 4 shows a typical audio amplifier circuit in which the CA3020 or CA3020A can provide a power output of 0.5W or 1W, respectively. Table 1 shows performance data for both types in this amplifier. The circuit can be used at all voltage and power output levels applicable to the CA3020 and CA3020A.



NOTES:

1. Better coil and transformer DF108A, Thordarson TR-192, or equivalent.
2. See text and tables.

FIGURE 4. BASIC CLASS B AUDIO AMPLIFIER CIRCUIT USING THE CA3020 OR CA3020A.

TABLE 1. TYPICAL PERFORMANCE OF CA3020 AND CA3020A IN CIRCUIT OF FIGURE 4 (NOTE)

CHARACTERISTIC	CA3020	CA3020A	UNITS
Power Supply			
V_{CC1}	9	9	V
V_{CC2}	9	12	V
Zero-Signal Idling Current			
I_{CC1}	15	15	mA
I_{CC2}	24	24	mA
Maximum Signal Current			
I_{CC1}	16	16.6	mA
I_{CC2}	125	140	mA
Maximum Power Output at 10% THD	550	1000	mW
Sensitivity	35	45	mV
Power Gain	75	75	dB
Input Resistance	55	55	kΩ
Efficiency	45	55	%
Signal-to-Noise Ratio	70	66	dB
% Total Harmonic Distortion at 150mW	3.1	3.3	%
Test Signal	1000Hz/600Ω Generator		
Equivalent Collector-to-Collector Load	130	200	Ω
Idling Current Adjust Resistor (R_{11})	1000	1000	Ω

NOTE: Integrated circuit mounted on a beat sink, Wakefield 209 Alum. or equivalent.

The emitter-follower stage at the input of the amplifier in Figure 4 is used as a buffer amplifier to provide a high input impedance. Although many variations of biasing may be applied to this stage, the method shown is efficient and economical. The output of the buffer stage is applied to terminal 3 of the differential amplifier for proper balance of the push-pull drive to the output stages. Terminals 2 and 3 must be bypassed for approximately 1000Ω at the desired low-frequency roll-off point.

At low power levels, the crossover distortion of the class B amplifier can be high if the idling current is low. For low crossover distortion, the idling current should be approximately 12mA to 24mA, depending on the efficiency, idling dissipation, and distortion requirements of the particular application. The idling current may be increased by connection of a jumper between terminals 8 and 9. If higher levels of operating idling current are desired, a resistor (R_{11}) may be used to increase the regulated voltage at terminal 11 by a slight amount with additional current injection from the power supply V_{CC1}.

In some applications, it may be desirable to use the input transistor Q_1 of the CA3020 or CA3020A for other purposes than the basic buffer amplifier shown in Figure 4. In such cases, the input AC signal can be applied directly to terminal 3.

The extended frequency range of the CA3020 and CA3020A requires that a high-frequency AC bypass capacitor be used at the input terminal 3. Otherwise, oscillation could occur at the stray resonant frequencies of the external components, particularly those of the transformers. Lead inductance may be sufficient to cause oscillation if long power-supply leads are not properly AC bypassed at the CA3020 or CA3020A common ground point. Even the bypassing shown may be insufficient unless good high-frequency construction practices are followed.

Figure 5 shows typical power output of the CA3020A at supply voltages of +3V, +6V, +9V, and +12V, and of the CA3020 at +6V and +9V, as measured in the basic class B amplifier circuit of Figure 4. The CA3020A has higher power output for all voltage supply conditions because of its higher peak output current capability.

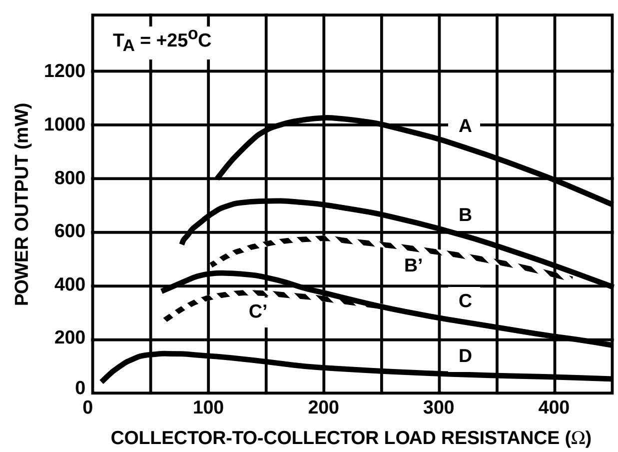


FIGURE 5. POWER OUTPUT OF THE CA3020 AND CA3020A AS A FUNCTION OF COLLECTOR-TO-COLLECTOR LOAD RESISTANCE R_{CC}

TABLE FOR FIGURE 5 CURVES

CURVE		IDLING CURRENT (mA)		POWER SUPPLY VOLTAGE (V)		R_{11} (Ω)
CA3020	CA3020A	I_{CC1}	I_{CC2}	V_{CC1}	V_{CC2}	
-	A	9	10	9	12	00
B’	B	9	10	9	9	00
C’	C	7	6	6	6	00
-	D	8	8	3	3	220

Figure 6 shows total harmonic distortion (THD) as a function of power output for each of the voltage conditions shown in Figure 5. The values of the collector-to-collector load resistance (R_{CC}) and the idling-current adjust resistor (R_{11}) shown in the figure are given merely as a fixed reference; they are not necessarily optimum values. Higher idling-current drain may be desired for low crossover distortion, or a higher value of R_{CC} may be used for better sensitivity with less power-output capability. Because the maximum power output occurs at the same conditions of peak-current limitations, the sensitivities at maximum power output for the curves of Figures 5 and 6 are approximately the same. Increasing the idling current drain by reducing the value of the resistor R_{11} also improves the sensitivity.

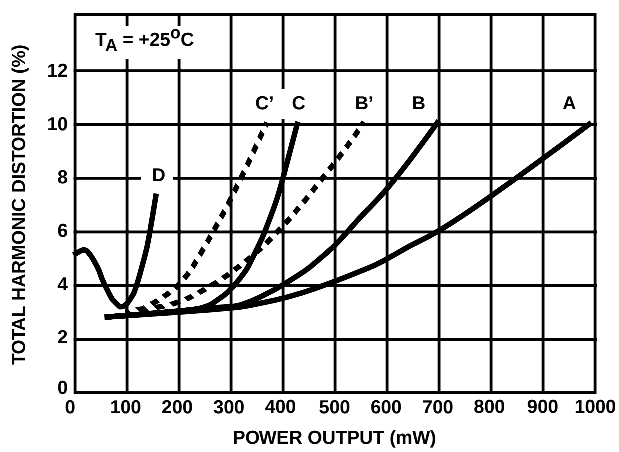


FIGURE 6. TOTAL HARMONIC DISTORTION OF THE CA3020 OR CA3020A AS A FUNCTION OF POWER OUTPUT

TABLE FOR FIGURE 6 CURVES

CURVE		IDLING CURRENT (mA)		POWER SUPPLY VOLTAGE (V)		R_{CC} (Ω)	R_{11} (Ω)
CA3020	CA3020A						
-	A	15	24	9	12	200	1000
B’	B	15	24	9	9	150	1000
C’	C	12	14	6	6	100	1000
-	D	9	9	3	3	50	220

Figure 7 illustrates the improvement in crossover distortion at low power levels. Distortion at 100mW is shown as a function of idling current I_{CC2} (output stages only). There is a small improvement in total harmonic distortion for a large increase in idling current as the current level exceeds 15mA.

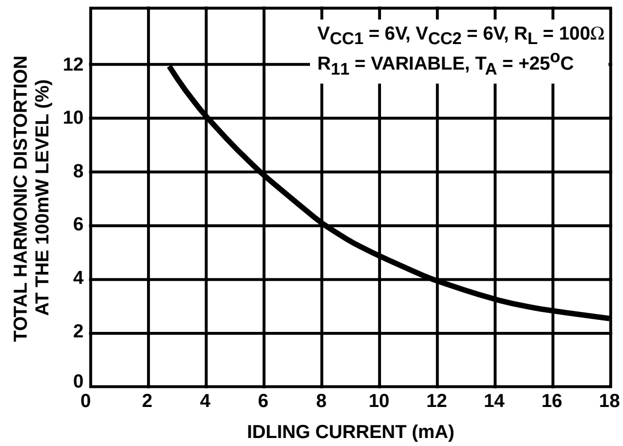


FIGURE 7. TOTAL HARMONIC DISTORTION AS A FUNCTION OF I_{CC2} IDLING CURRENT FOR A SUPPLY VOLTAGE OF 6V AND AN OUTPUT OF 100mW

Applications

Audio Amplifiers

The circuit shown in Figure 4 may be used as a highly efficient class B audio power output circuit in such applications as communications systems, AM or FM radios, tape recorders, intercoms, and linear mixers. Figure 8 shows a modification of this circuit which may be used as a transformerless audio amplifier in any of these applications or in other portable instruments. The features of this circuit are a power output capability of 310mW for an input of 45mV, and a high input impedance of 50,000Ω. The idling-current drain of the circuit is 24mA. The curves of Figure 5 may be used to determine the value of the center-tapped resistive load required for a specified power output level (the indicated load resistance is divided by two).

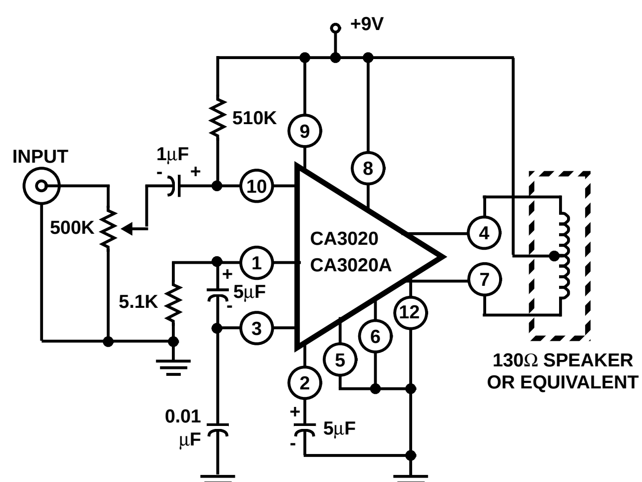


FIGURE 8. 310mW AUDIO AMPLIFIER WITHOUT TRANSFORMERS

The CA3020 or CA3020A provides several advantages when used as a sound output stage or as a preamplifier driver in communications equipment because each type is a compact and low power drain circuit. The squelching requirement in such applications is simple and economical.

Figure 9 shows a practical method of providing squelch to the CA3020 or CA3020A. When the squelch switching transistor Q_S is in the "on" state, the CA3020 or CA3020A is "off" and draws only fractional idling dissipation. The only current that flows is that of the buffer-amplifier transistor Q_1 in the integrated circuit and the saturating current drain of Q_S. For a circuit similar to that of Figure 8, the squelched condition requires an idling current of approximately 7mA, as compared to a normal idling-current drain of 24mA.

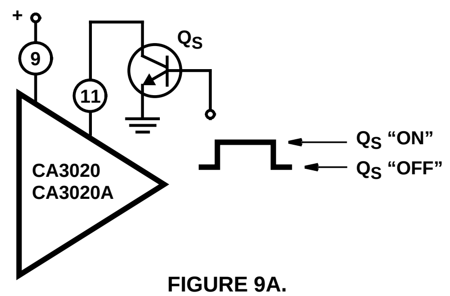


FIGURE 9A.

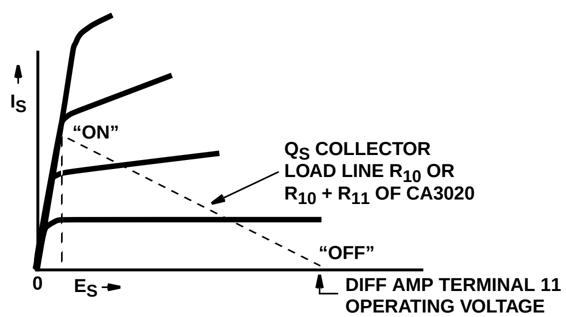


FIGURE 9B.

FIGURE 9. METHOD OF APPLYING SQUELCH TO THE CA3020 OR CA3020A TO SAVE IDLING DISSIPATION

In applications requiring high gain and impedance matching, the CA3020 or CA3020A can be adapted for use without complex circuit modifications. Detectors having low signal outputs or high impedances can be easily matched to the input of the CA3020 or CA3020A buffer amplifier. The typical integrated circuit input impedance of 55kΩ may be too low for crystal output devices, but the sensitivity may be sacrificed to impedance match at the input while still providing adequate drive to the CA3020 or CA3020A. Both types may be used in tape recorders as high-gain amplifiers, bias oscillators, or record and playback amplifiers. The availability of two input terminals permits the use of the CA3020 or CA3020A as a linear mixer, and thus adds to its flexibility in systems that require adaptation to multiple functions, such as communications equipment and tape recorders.

Figure 10 illustrates the use of the audio amplifier shown in Figure 4 in an intercom in which a listen/talk position switch controls two or more remote positions. Only the speakers, the switch, and the input transformer are added to the basic audio amplifier circuit. A suitable power supply for the intercom could be a 9V battery used intermittently rather than continuously.

T1: Primary 4Ω, Secondary 25,000Ω;
Stancor A4744 or equivalent.

T2: Better coil and transformer DF1084, Thordarson TR-192, or equivalent

Speakers: 4Ω

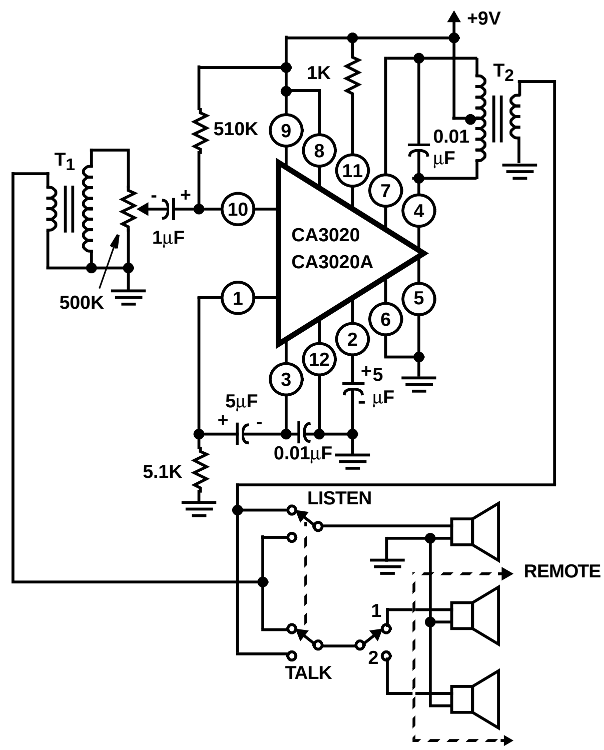


FIGURE 10. INTERCOM USING CA3020 OR CA3020A

Wide-Band Amplifiers

A major general-purpose application of the CA3020 and CA3020A is to provide high gain and wide-band amplification. The CA3020 and CA3020A have typically flat gain-bandwidth response to 8MHz. Although the circuits are normally biased for class B operation, only the output stages operate in this mode. If proper DC bias conditions are applied, the output stages may be operated as linear class A amplifiers.

Figure 11 shows the recommended method for achieving an economical and stable class A bias. The differential amplifier portion of the CA3020A is placed at a potential above ground equal to the base-emitter voltage V_{BE} of the integrated circuit transistors (0.5V to 0.7V). In this condition, the output stages have an emitter-current bias approximately equal to the base-to-emitter voltage divided by the emitter-to-ground resistance. The circuit in Figure 11 is a wide-band video amplifier that provides a gain of 38dB at each of the push-pull outputs, or 44dB in a balanced output connection.

The 3dB bandwidth of the circuit is 30Hz to 8MHz. Higher gain-bandwidth performance can be achieved if the diode-to-ground voltage drop at terminal 12 is reduced. The lower voltage drop permits the use of a higher ratio of output-stage collector-to-emitter resistors without departure from the desired portion of the class A load line. It is important to note that the temperature coefficient of the terminal 12-to-ground reference element should be sufficiently low to prevent a large change in the current of the output stages.

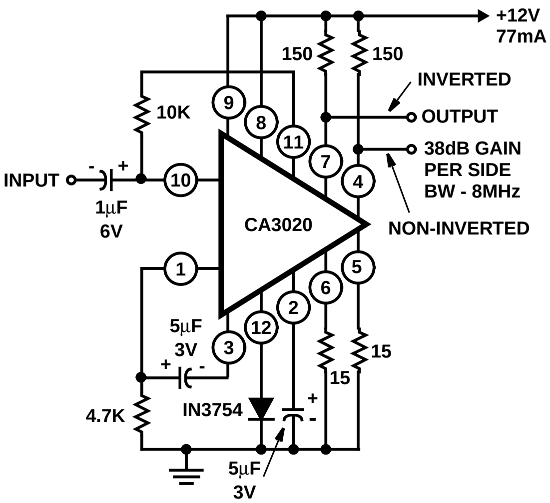


FIGURE 11. WIDE-BAND VIDEO AMPLIFIER ILLUSTRATING ECONOMICAL AND STABLE CLASS A BIAS OF CA3020A

The same method for achieving class A bias is used in the large signal swing output amplifier shown in Figure 12.

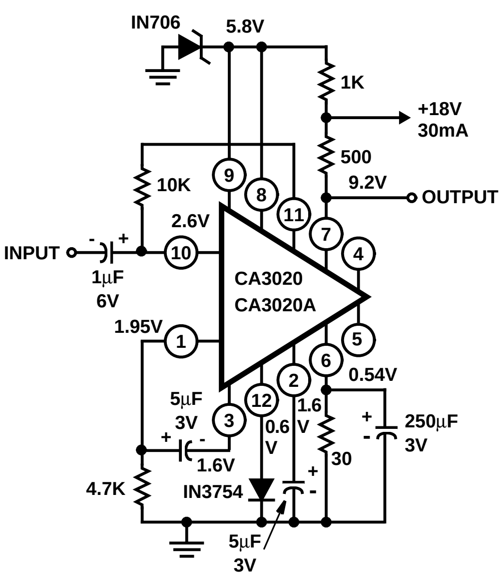


FIGURE 12. LARGE SIGNAL SWING OUTPUT AMPLIFIER USING CA3020 OR CA3020A

Either the CA3020 or the CA3020A may be used in this circuit with power supplies below +18V; the CA3020A can also be used with B+ voltages up to 25V with non-inductive loads. The circuit of Figure 12 provides a gain of 60dB and a bandwidth of 3.2MHz if the output transistor Q_7 has a bypassed emitter resistor. With an unbypassed output emitter resistor, the gain is 40dB and the bandwidth is 8MHz. The output stage can deliver a $5V_{RMS}$ signal when a supply of +18V is used. For better performance in this type of circuit, the input signal is coupled from the buffer amplifier Q_1 to the input terminal 3 of the differential amplifier. This arrangement provides higher gain because the collector resistor of the differential-amplifier transistor Q_3 is larger than that of Q_2. (This difference results from a requirement of differential drive balance that is not used in this circuit.) In addition, the terminals of the unused output transistor Q_6 help to form an isolating shield between the input at terminal 3 and the output at terminal 7. This cascade of amplifiers has a single phase inversion at the output for much better stability than could be achieved if terminal 4 were used as the output and terminal 3 as the input.

Figure 13 illustrates the use of the CA3020 or CA3020A as a class A linear amplifier. This circuit features a very low output impedance and may be used as a line driver amplifier for wide-band applications up to 8MHz. The circuit requires a 0.12V peak-to-peak input for a single ended output of 1V or a balanced peak-to-peak output of 2V from a 3Ω output impedance at each emitter. The input impedance is specified as 7800Ω, but is primarily a function of the external 10,000Ω resistor that provides bias to Q_1 from the regulating terminal 11.

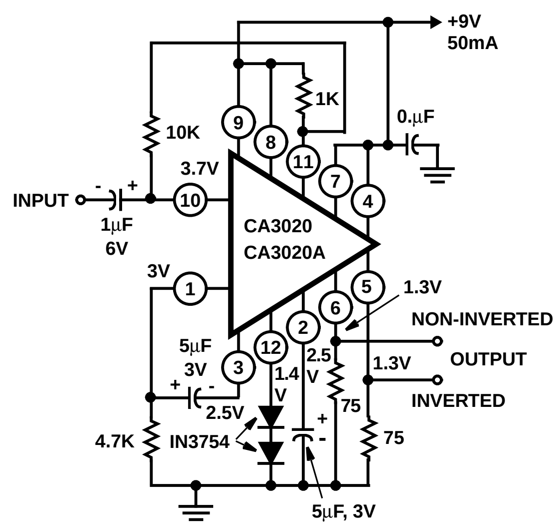


FIGURE 13. CLASS A LINEAR AMPLIFIER USING CA3020 OR CA3020A

Figure 14 illustrates the practical use of the CA3020 or CA3020A as a tuned amplifier. This circuit uses DC biasing similar to that shown previously, and has a gain of 70dB at a frequency of 160kHz. The CA3020 or CA3020A can be used as a tuned RF amplifier or oscillator at frequencies well beyond the 8MHz bandwidth of the basic circuit.

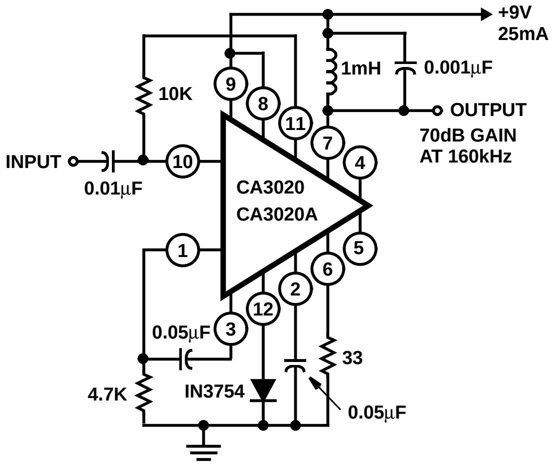


FIGURE 14. 160KHz TUNED AMPLIFIER USING THE CA3020 OR CA3020A

Driver Amplifiers

The high power-pin and power-output capabilities of the CA3020 and CA3020A make these integrated circuits highly suitable for use as drivers for higher power stages. In most applications, the full power output capability of the circuit is not required, and large emitter resistors may be used in the output stage to reduce distortion. The CA3020 and CA3020A can drive any transformer coupled load within their respective ratings. Several examples of typical applications are given below.

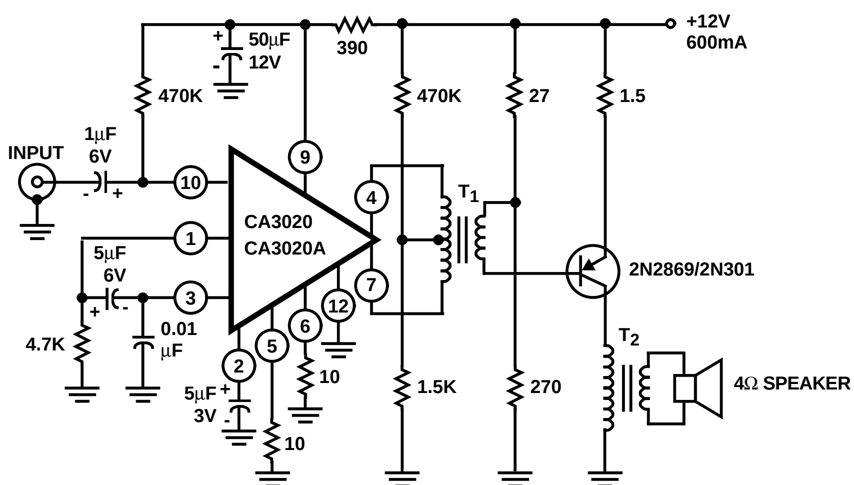
Figure 15 illustrates the use of the CA3020 or CA3020A to drive a germanium power output transistor to a 2.5W level. Because the integrated circuit is required to deliver a maximum power output of less than 50mW, an unbypassed emitter resistor can be used in the output stage to reduce distortion. Sensitivity for an output of 2.5W is 3mV; this figure can be improved at a slight increase in distortion by reduction of the 4.7Ω resistors between terminals 5 and 6 and ground.

Because so little of the power output capability of the CA3020 or CA3020A is used, higher power class B stages can easily he accommodated by selection of suitable output transistors and appropriate transformers.

Figure 16 shows a medium power class B audio amplifier in which the CA3020 or CA3020A is used as a driver. The output stage uses a pair of TO-3-type germanium output transistors which must be mounted on a heat sink for reliable operation. Idling current for the entire system is 70mA from the 35V supply. Sensitivity is 10mV for an output of 10W.

Motor Controller and Servo Amplifier

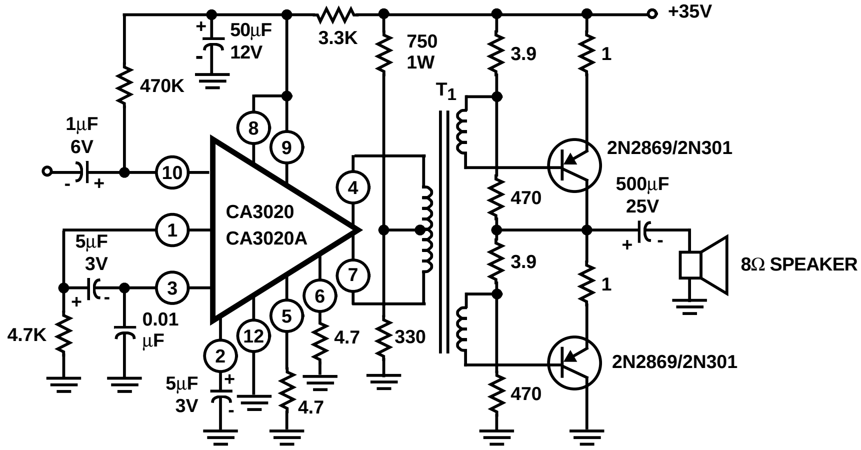
The CA3020 or CA3020A may he used as a 40Hz to 400Hz motor controller and servo amplifier, as shown in Figure 17.



T1: primary impedance, 10,000Ω; center-tapped at 160Ω; primary direct current, 2mA; Thordarson TR-207 (entire secondary), or equivalent.

T2: primary impedance, 20Ω;primary direct current, 0.6A; secondary, 4Ωs; Thordarson TR-304, Stancor TP62, or equivalent.

FIGURE 15. 2.5W CLASS A AUDIO AMPLIFIER USING THE CA3020 OR CA3020A AS A DRIVER AMPLIFIER



T1: primary impedance, 4,000Ω; center-tapped; secondary impedance, 600Ω; center-tapped, split; Thordarson TR-454 or equivalent.

FIGURE 16. 10W SINGLE-ENDED CLASS B AUDIO AMPLIFIER USING THE CA3020 OR CA3020A AS A DRIVER AMPLIFIER

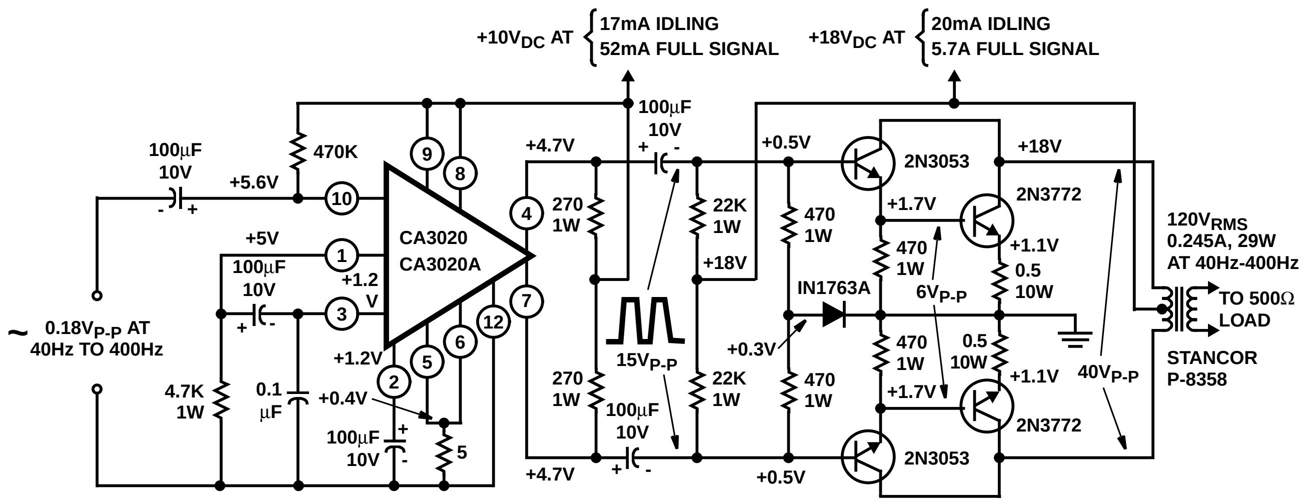


FIGURE 17. MOTOR CONTROLLER AND SERVO AMPLIFIERR USING CA3020 OR CA3020A