

## Introduction

The CA3094 unique monolithic programmable power switch/amplifier IC consists of a high-gain preamplifier driving a power-output amplifier stage. It can deliver average power of 3 watts of peak power of 10W to an external load, and can be operated from either a single or dual power supply. This Note briefly describes the characteristics of the CA3094, and illustrates its use in the following circuit applications:

- Class A Instrumentations and Power Amplifiers
- Class A Driver-Amplifier for Complementary Power Transistors
- Wide Frequency Range Power Multivibrators
- Current- or Voltage Controlled Oscillators
- Comparators (Threshold Detectors)
- Voltage Regulators
- Analog Timers (Long Time Delays)
- Alarm Systems
- Motor-Speed Controllers
- Thyristor Firing Circuits
- Battery Charger Regulator Circuit
- Ground Fault Interrupter Circuits

## Circuit Description

The CA3094 series of devices offers a unique combination of circuit flexibility and power-handling capability. Although these monolithic ICs dissipate only a few microwatts when quiescent, they have a high current-output capability (100mA average, 300mA peak) in the active state, and the premium-grade devices can operate at supply voltages up to 44V.

Figure 1 shows a schematic diagram of the CA3094. The portion of the circuit preceding transistors Q12 and Q13 is the preamplifier section and is generically similar to that of the CA3080 Operational Transconductance Amplifier (OTA) [1, 2]. The CA3094 circuits can be gain-programmed by either digital and/or analog signals applied to a separate Amplifier-Bias-Current ( $I_{ABC}$ ) terminal (No. 5 in Figure 1) to control circuit sensitivity. Response of the amplifier is essentially liner as a function of the current at terminal 5. This additional signal input "port" provides added flexibility in many applications. Thus, the output of the amplifier is a function of input signals applied differentially at terminals 2 and 3 and/or in a singly-ended configuration at terminal 5. The output portion of the monolithic circuit in the CA3094 consists of a Darling connected transistor pair with access provided to both the collector and emitter terminals to provide capability to "sink" and/or "source" current.

The CA3094 series of circuits consists of six types that differ only in voltage-handling capability and package options, as shown below; other electrical characteristics are identical.

OUTPUT MODE	OUTPUT TERM	INPUTS	
		INV	NON-INV
"Source"	6	2	3
"Sink"	8	3	2

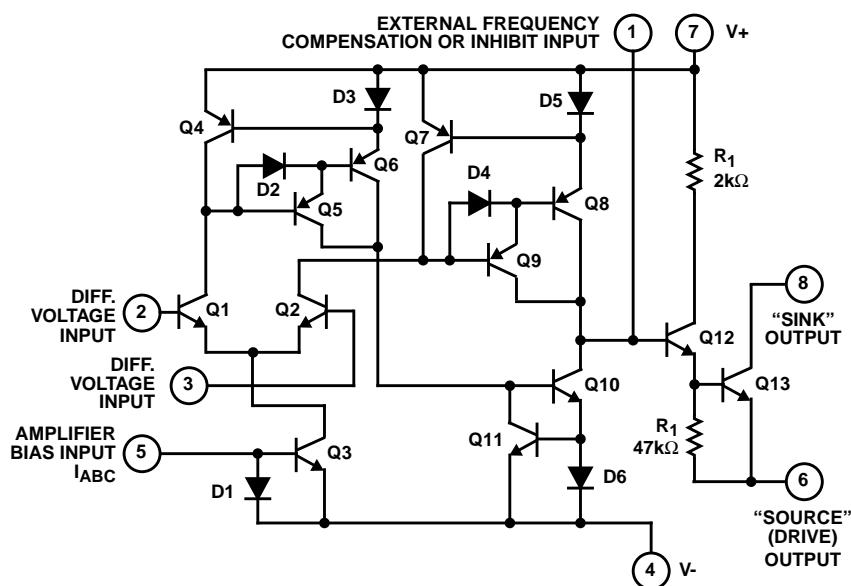


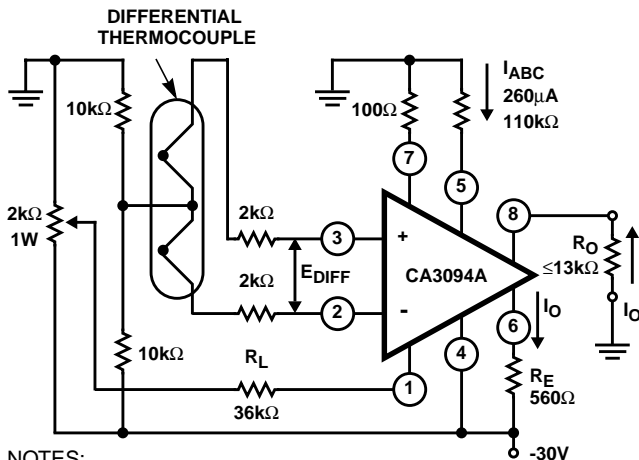
FIGURE 1. CA3094 CIRCUIT SCHEMATIC DIAGRAM

PACKAGE OPTIONS	MAXIMUM VOLTAGE RATING
CA3094S, CA3094T	24V
CA3094AS, CA3094AT	36V
CA3094BS, CA3094BT	44V

The suffix "S" indicates circuits packaged in TO-5 enclosures with leads formed to an 8 lead dual in line configuration (0.1 inch pin spacing). The suffix "T" indicates circuits packaged in 8 lead TO-5 enclosures with straight leads. The generic CA3094 type designation is used throughout the Note.

## Class A Instrumentation Amplifiers

One of the more difficult instrumentation problems frequently encountered is the conversion of a differential input signal to a single-ended output signal. Although this conversion can be accomplished in a straightforward design through the use of classical op amps, the stringent matching requirements of resistor ratios in feedback networks make the conversion particularly difficult from a practical standpoint. Because the gain of the preamplifier section in the CA3094 can be defined as the product of the transconductance and the load resistance ( $g_m R_L$ ), feedback is not needed to obtain predictable open-loop gain performance. Figure 2 shows the CA3094 in this basic type of circuit.



NOTES:

1. Preamp gain ( $A_V$ ) =  $g_m R_L = (5) (10^{-3}) (36) (10^3) = 180$  (Output at terminal 1).
2. For linear operation: Differential Input  $\leq \pm 26\text{mV}$  | (With approx. 1% deviation from linearity).
3. Output voltage ( $E_O$ ) =  $A_V (\pm e_{DIFF}) = (180) (\pm 26\text{mV}) = \pm 4.7\text{V}$

$$4. I_O \approx \frac{4.7\text{V}}{560\Omega} = 8.35\text{mA} \quad I_O \approx \frac{(g_m R_L)(e_{DIFF})}{R_E}$$

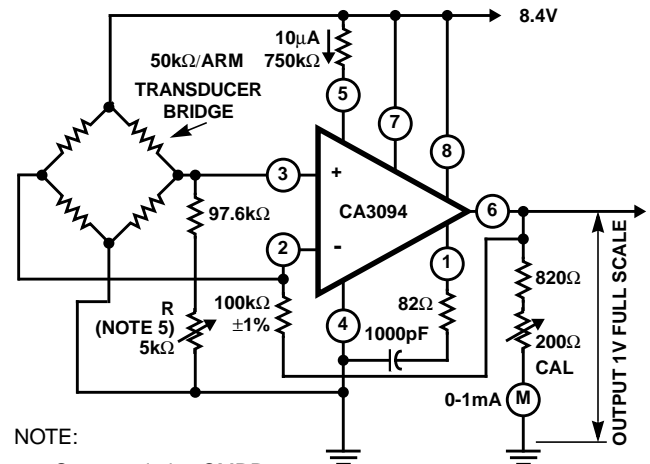
FIGURE 2. OPEN LOOP INSTRUMENTATION AMPLIFIER WITH DIFFERENTIAL INPUT AND SINGLE ENDED OUTPUT

The gain of the preamplifier section (to terminal No. 1) is  $g_m R_L = (5 \times 10^{-3}) (36 \times 10^3) = 180$ . The transconductance  $g_m$  is a function of the current into terminal No. 5,  $I_{ABC}$ , the

amplifier-bias-current. In this circuit an  $I_{ABC}$  of  $260\mu\text{A}$  results in a  $g_m$  of  $5\text{mS}$ . The operating point of the output stage is controlled by the  $2\text{k}\Omega$  potentiometer. With no differential input signal ( $e_{DIFF} = 0$ ), this potentiometer is adjusted to obtain a quiescent output current  $I_O$  of  $12\text{mA}$ . This output current is established by the  $560\Omega$  emitter resistor,  $R_E$ , as follows:

$$I_O \approx \frac{(g_m R_L)(e_{DIFF})}{R_E}$$

Under the conditions described, an input swing  $e_{DIFF}$  of  $\pm 26\text{mV}$  produces a variation in the output current  $I_O$  of  $\pm 8.35\text{mA}$ . The nominal quiescent output voltage is  $12\text{mA}$  times  $560\Omega$  or  $6.7\text{V}$ . This output level drifts approximately  $-4\text{mV}$ , or  $-0.0595\%$ , for each  $^\circ\text{C}$  change in temperature. Output drift is caused by temperature induced variations in the base emitter voltage of the two output transistors, Q12 and Q13.



NOTE:

5. Set to optimize CMRR.

FIGURE 3. SINGLE SUPPLY DIFFERENTIAL BRIDGE AMPLIFIER

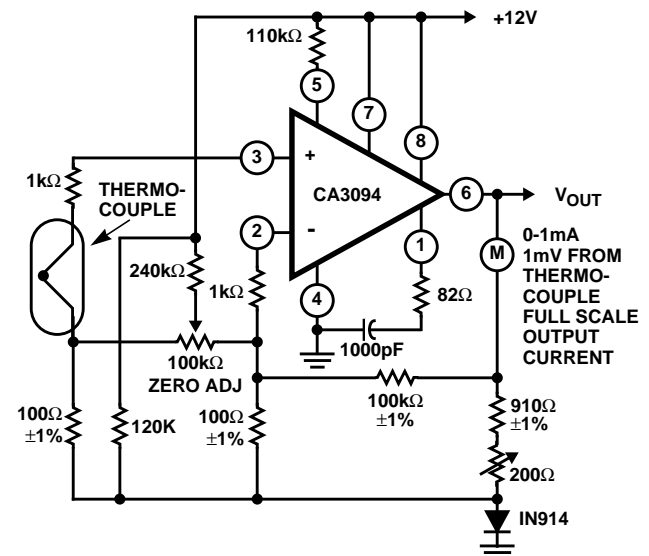


FIGURE 4. SINGLE SUPPLY AMPLIFIER FOR THERMO-COUPLE SIGNALS

Figure 3 shows the CA3094 used in conjunction with a resistive-bridge input network; and Figure 4 shows a single-supply amplifier for thermocouple signals. The RC networks connected between terminals 1 and 4 in Figure 3 and Figure 4 provide compensation to assure stable operation.

The components of the RC network are chosen so that

$$\frac{1}{2\pi RC} \approx 2\text{MHz}$$

## Class A Power Amplifiers

The CA3094 is attractive for power-amplifier service because the output transistor can control current up to 100mA (300mA peak), the premium devices.

CA3094B can operate at supply voltages up to 44V, and the TO-5 package can dissipate power up to 1.6W when equipped with a suitable heat sink that limits the case temperature to 55°C.

Figure 5 shows a Class A amplifier circuit using the CA3094A that is capable of delivering 280mW to a 350Ω resistive load. This circuit has a voltage gain of 60dB and a 3dB band width of about 50kHz. Operation is stable without the use of a phase-compensation network. Potentiometer R is used to establish the quiescent operating point for class A operation.

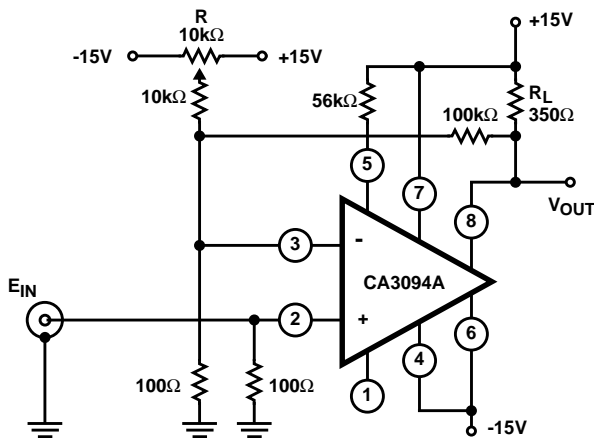
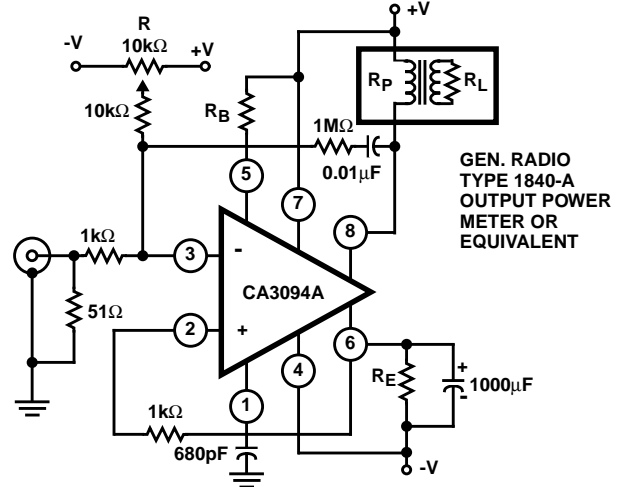


FIGURE 5. CLASS A AMPLIFIER -280mW CAPABILITY INTO A RESISTIVE LOAD

The circuit of Figure 6 illustrates the use of the CA3094 in a class a power-amplifier circuit driving a transformer-coupled load. With dual power supplies of +7.5V and -7.5V, a base resistor  $R_B$  of 30kΩ, and an emitter resistor  $R_E$  of 50Ω, CA3094 dissipation is typically 625mW. With supplies of +10V and -10V,  $R_B$  of 40kΩ, and  $R_E$  of 45Ω, the dissipation is 1.5W. Total harmonic distortion is 0.4% at a power output level of 220mW with a reflected load resistance  $R_P$  of 310Ω, and is 1.4% for an output of 600mW with an  $R_P$  of 128Ω. The setting of potentiometer R establishes the quiescent operating point for class A operation. The 1kΩ resistor connected between terminals 6 and 2 provides DC feedback to stabilize the collector current of the output transistor. The AC gain is established by the ratio of the 1MΩ resistor

connected between terminals 8 and 3 the 1kΩ resistor connected to terminal 3. Phase compensation is provided by the 680pF capacitor connected to terminal 1.



TYPICAL DATA

DEVICE DISSIPATION	625mW	1.5W
$R_B$	30kΩ	40kΩ
$V_+$	+7.5V	+10V
$V_-$	-7.5V	-10V
$R_E$	50Ω	45Ω
$P_O$	220mW	600mW
THD	0.4%	1.4%
$R_P$	310Ω	128Ω

FIGURE 6. CLASS A AMPLIFIER WITH TRANSFORMER COUPLED LOAD

## Class A Driver Amplifier for Complementary Power Transistors

The CA3094 configuration and characteristics are ideal for driving complementary power-output transistors [3]; a typical circuit is shown in Figure 7. This circuit can provide 12W of audio power output into an 8Ω load with intermodulation distortion (IMD) of 0.2% when 60Hz and 2kHz signals are mixed in a 4:1 ratio. Intermodulation distortion is shown as a function of power output in Figure 8.

The large amount of loop gain and the flexibility of feedback arrangements with the CA3094 make it possible to incorporate the tone controls into a feedback network that is closed around the entire amplifier system. The tone controls in the circuit of Figure 7 are part of the feedback network connected from the amplifier output (junction of the 330Ω and 47Ω resistors driven by the emitters of Q2 and Q3) to terminal 3 of the CA3094. Figure 9 shows voltage gain as a function of frequency with tone controls adjusted for "flat" response and for responses at the extremes of tone-control rotation. The use of tone controls incorporated in the feedback network results in excellent signal to noise ratio. Hum and noise are typically 700μV (83dB down) at the output.

In addition to the savings resulting from reduced parts count circuit size, the use of the CA3094 leads to further savings in the power supply system. Typical values of power supply rejection and common mode rejection are 90dB and 100dB, respectively. An amplifier with 40dB gain and 90dB power supply rejection would require a 31mV power-supply ripple to produce 1mV of hum at the output. Therefore, no filtering is required other than that provided by the energy storage capacitors at the output of the rectifier system shown in Figure 7.

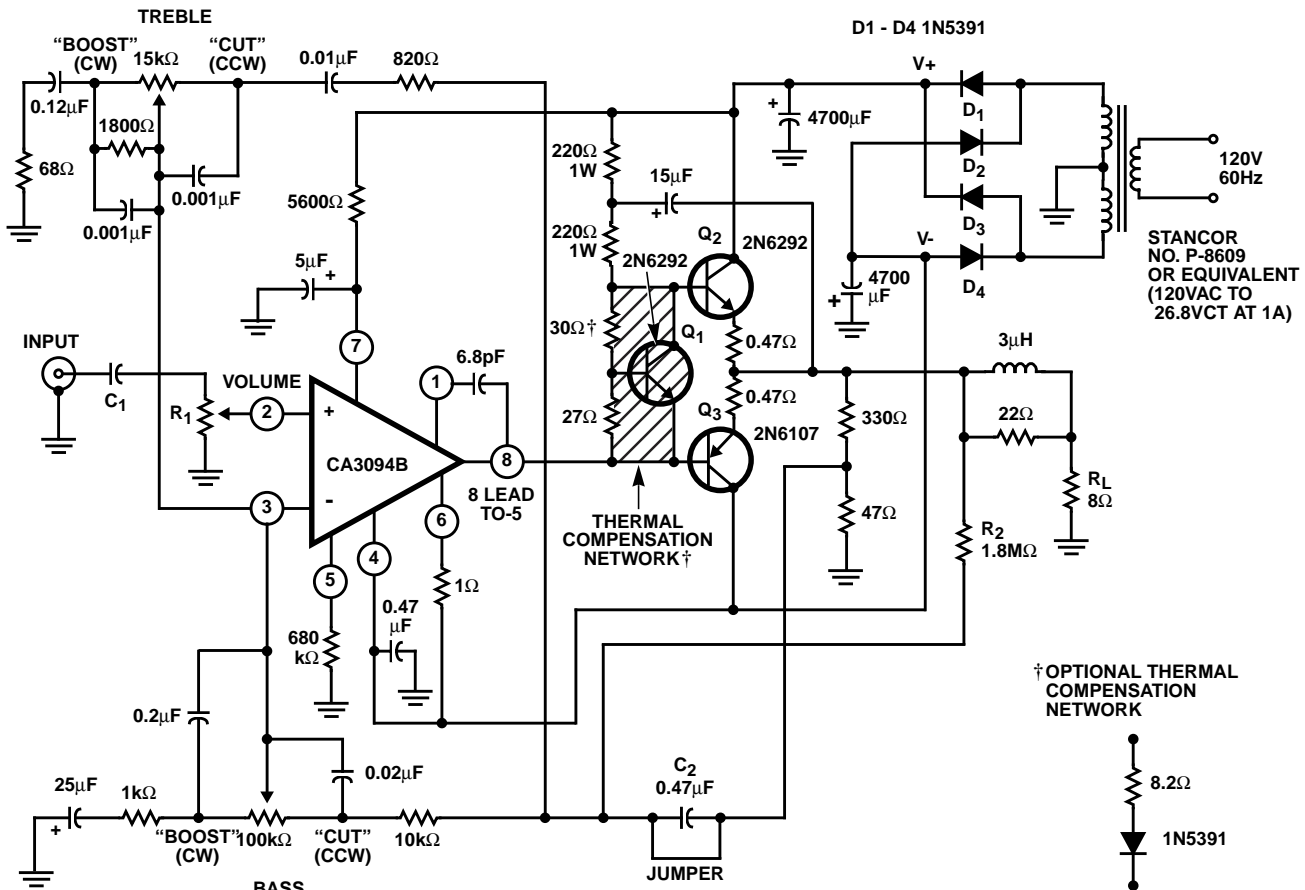
For application in which the operating temperature range is limited (e.g., consumer service the thermal compensation network (shaded area) can be replaced by a more economical configuration consisting of a resistor diode combination (8.2Ω and 1N5391) as shown in Figure 7.

## Power Multivibrators (Astable and Monostable)

The CA3094 is suitable for use in power multivibrators because its high current output transistor can drive low impedance circuits while the input circuitry and the frequency determining elements are operating at micropower levels. A typical example of an astable multivibrator using the CA9034 with a dual power supply is shown in Figure 10. The output frequency  $f_{OUT}$  is determined as follows:

$$f_{OUT} = \frac{1}{2RC_{IN}[(2R1/R2) + 1]}$$

If R2 is equal to 3.08 R1, then  $f_{OUT}$  is simply the reciprocal of RC.



**TYPICAL PERFORMANCE DATA FOR 12W AUDIO AMPLIFIER CIRCUIT**

Power Output (8Ω load, Tone Control set at "Flat")  
 Music (at 5% THD, regulated supply) . . . . . 15W  
 Continuous (at 0.2% IMD, 60Hz and 2kHz mixed in a 4:1 ratio, unregulated supply) See Figure 8 in AN6048. . . . . 12W  
 Total Harmonic Distortion  
 At 1W, unregulated supply . . . . . 0.05%  
 At 12W, unregulated supply . . . . . 0.57%

Voltage Gain . . . . . 40dB  
 Hum and Noise (below continuous power output) . . . . . 83dB  
 Input Resistance . . . . . 250kΩ  
 Tone Control Range . . . . . See Figure 9 in AN6048

### NOTES:

- For standard input: Short C<sub>2</sub>; R<sub>1</sub> = 250kΩ, C<sub>1</sub> = 0.047μF; remove R<sub>2</sub>.
- For ceramic cartridge input: C<sub>1</sub> = 0.0047μF, R<sub>1</sub> = 2.5MΩ, remove jumper from C<sub>2</sub>; leave R<sub>2</sub>.

**FIGURE 7. 12W AUDIO AMPLIFIER CIRCUIT FEATURING TRUE COMPLEMENTARY SYMMETRY OUTPUT STAGE WITH CA3094 IN DRIVER STAGE**

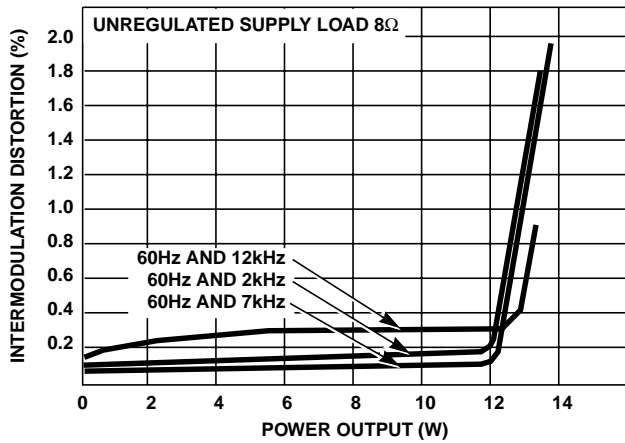


FIGURE 8. INTERMODULATION DISTORTION vs POWER OUTPUT

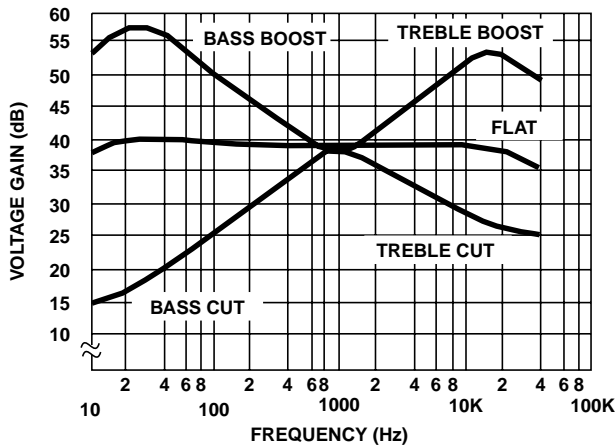


FIGURE 9. VOLTAGE GAIN vs FREQUENCY

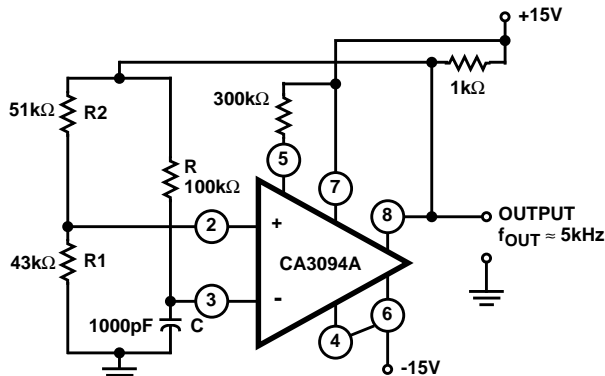


FIGURE 10. ASTABLE MULTIVIBRATOR USING DUAL SUPPLY

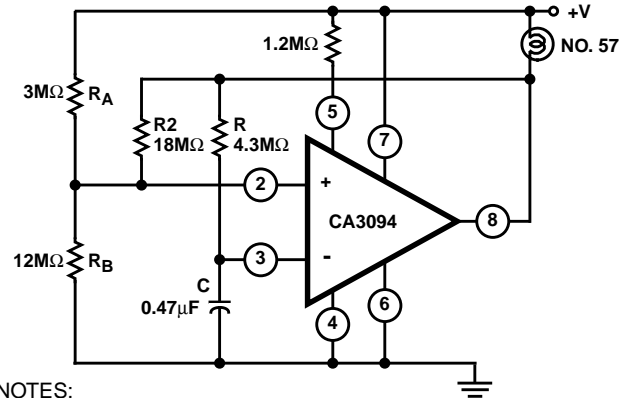
Figure 11 is a single supply astable multivibrator circuit which illustrates the use of the CA3094 for flashing an incandescent lamp. With the component values shown, this circuit produces one flash per second with a 25% "on" time while delivering output current in excess of 100mA. During the 75% "off" time it idles with micropower consumption. The flashing rate can be maintained with in  $\pm 2\%$  of the nominal value over a battery voltage range from 6V to 15V and a temperature excursion from 0°C to 70°C. The CA3094 series of circuits can supply peak-power output in excess of 10W when used in this type of

circuit. The frequency of oscillation  $f_{OSC}$  is determined by the resistor ratios, as follows:

$$f_{OSC} = \frac{1}{(2RC \ln)[(2R_1/R_2) + 1]}$$

where:

$$R_1 = \frac{R_A R_B}{R_A + R_B}$$



NOTES:

1. Flash/s.

$$f_{OSC} = \frac{1}{(2RC \ln)[(2R_1/R_2) + 1]}$$

where:

$$R_1 = \frac{R_A R_B}{R_A + R_B}$$

2. 25% Duty Cycle

3. Frequency Independent of V+ from 6V - 15V<sub>DC</sub>

FIGURE 11. ASTABLE MULTIVIBRATOR USING SINGLE SUPPLY

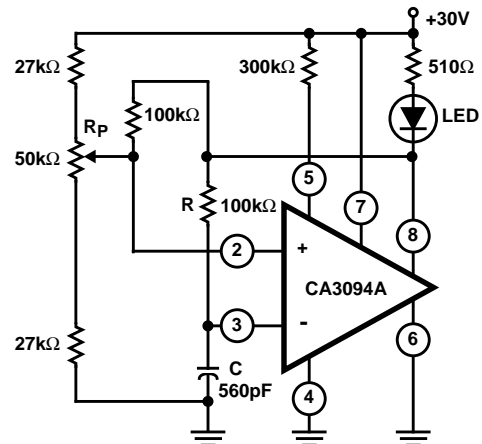
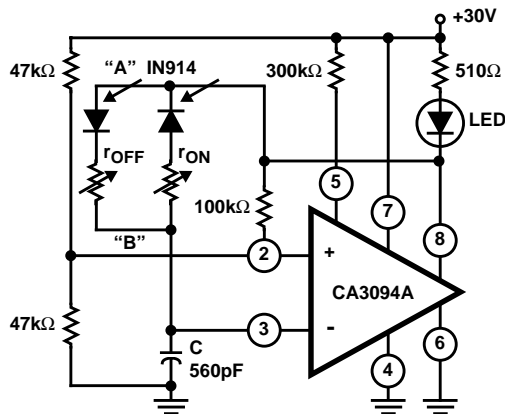


FIGURE 12. ASTABLE POWER MULTIVIBRATOR WITH PROVISIONS FOR VARYING DUTY CYCLE

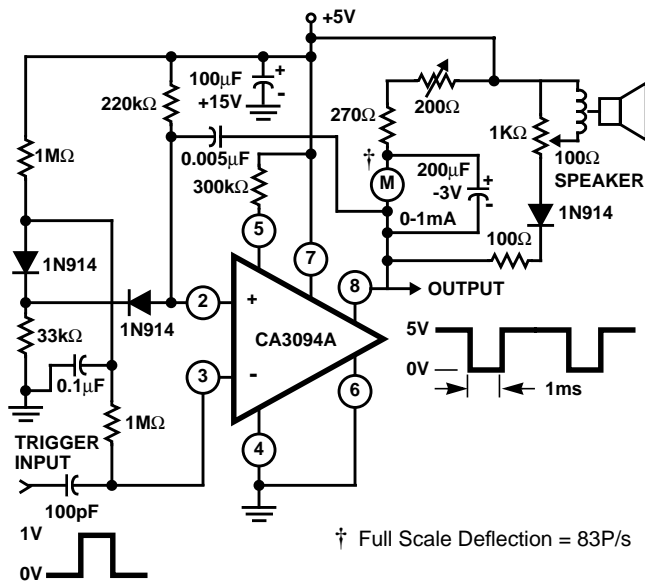
Provisions can easily be made in the circuit of Figure 11 to vary the multivibrator pulse length while maintaining an essentially constant pulse repetition rate. The circuit shown in Figure 12 incorporates a potentiometer  $R_P$  for varying the width of pulses generated by the astable multivibrator driving light emitting diode (LED).

Figure 13 shows a circuit incorporating independent controls ( $r_{ON}$  and  $r_{OFF}$ ) to establish the “on” and “off” periods of the current supplied to the LED. The network between points “A” and “B” is analogous in function to that of the 100k $\Omega$  resistor R in Figure 12.



**FIGURE 13. ASTABLE POWER MULTIVIBRATOR WITH PROVISIONS FOR INDEPENDENT CONTROL OF LED "ON-OFF" PERIODS**

The CA3094 is also suitable for use in monostable multivibrators as shown in Figure 14. In essence, this circuit is a pulse counter in which the duration of the output pulses is independent of trigger pulse duration. The meter reading is a function of the pulse repetition rate which can be monitored with the speaker.

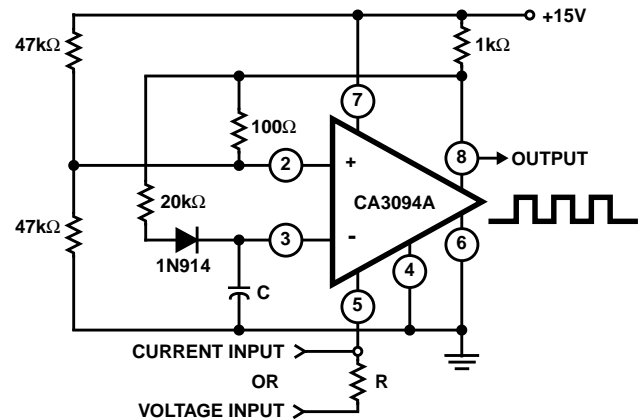


**FIGURE 14. POWER MONOSTABLE MULTIVIBRATOR**

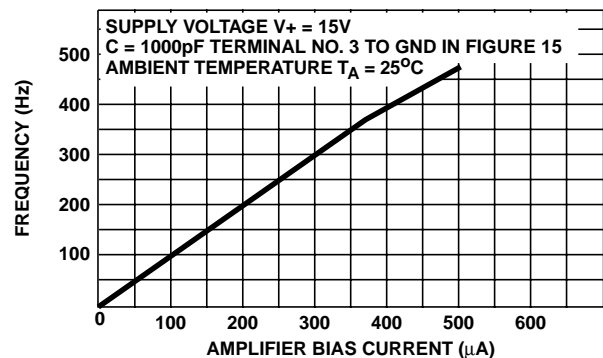
### ***Current or Voltage Controlled Oscillators***

Because the transconductance of the CA9034 varies linearly as a function of the amplifier bias current ( $I_{ABC}$ ) supplied to terminal 5, the design of a current or voltage controlled oscillator is straightforward, as shown in Figure 15. Figure 16 and Figure 17 show oscillator frequency as a function of  $I_{ABC}$  for a current controlled oscillator for two different values of

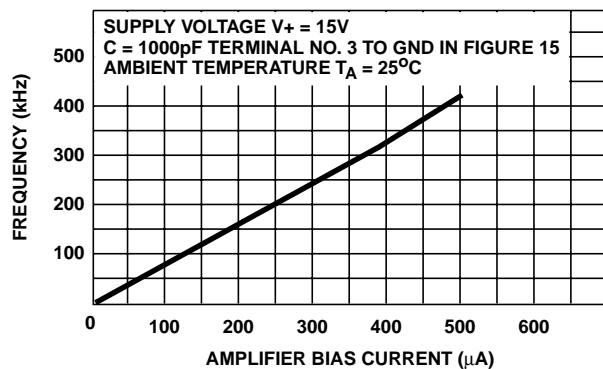
capacitor C in Figure 15. The addition of an appropriate resistor (R) in series with terminal 5 in Figure 15 converts the circuit into a voltage controlled oscillator. Linearity with respect to either current or voltage control is within 1% over the middle half of the characteristics. However, variation in the symmetry of the output pulses was a function of frequency is an inherent characteristic of the circuit in Figure 15, and leads to distortion when this circuit is used to drive the phase detector in phase-locked-loop applications. This type distortion can be eliminated by interposing an appropriate flip-flop between the output of the oscillator and the phase locked discriminator circuits.



**FIGURE 15. CURRENT OR VOLTAGE CONTROLLED OSCILLATOR**



**FIGURE 16. FREQUENCY vs  $I_{ABC}$  FOR  $C = 1000\text{pF}$  FOR CIRCUIT IN FIGURE 15**



**FIGURE 17. FREQUENCY vs  $I_{ABC}$  FOR  $C = 100\text{pF}$  FOR CIRCUIT IN FIGURE 15**



## Comparators (Threshold Detectors)

Comparator circuits are easily implemented with the CA3094, as shown by the circuits in Figure 18. The circuit of Figure 18A is arranged for dual supply operation; the input voltage exceeds the positive threshold, the output voltage swings essentially to the negative supply voltage rail (it is assumed that there is negligible resistive loading on the output terminal). An input voltage that exceeds the negative threshold value results in a positive voltage output essentially equal to the positive supply voltage. The circuit in Figure 18B, connected for single supply operation, functions similarly.

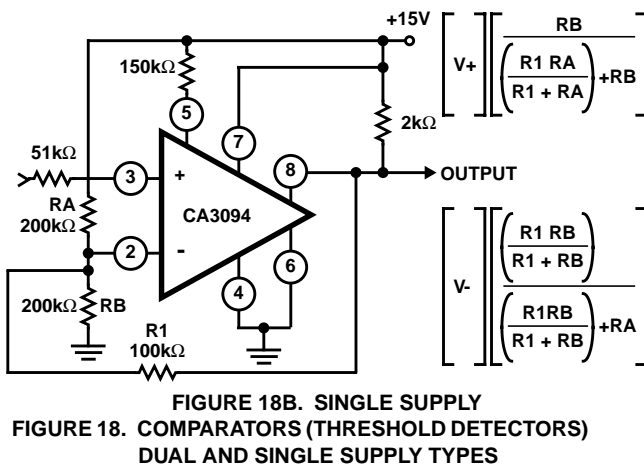
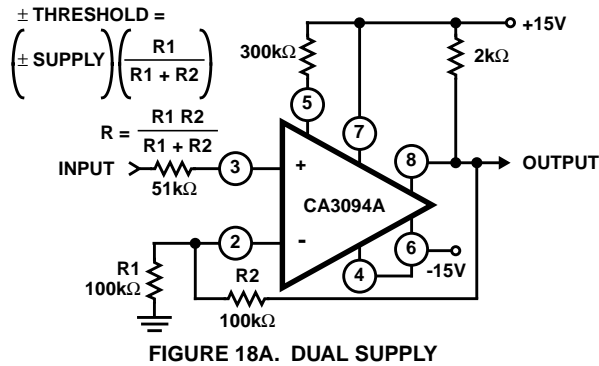


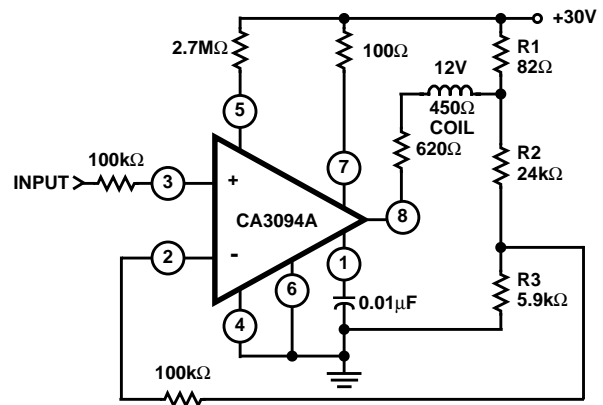
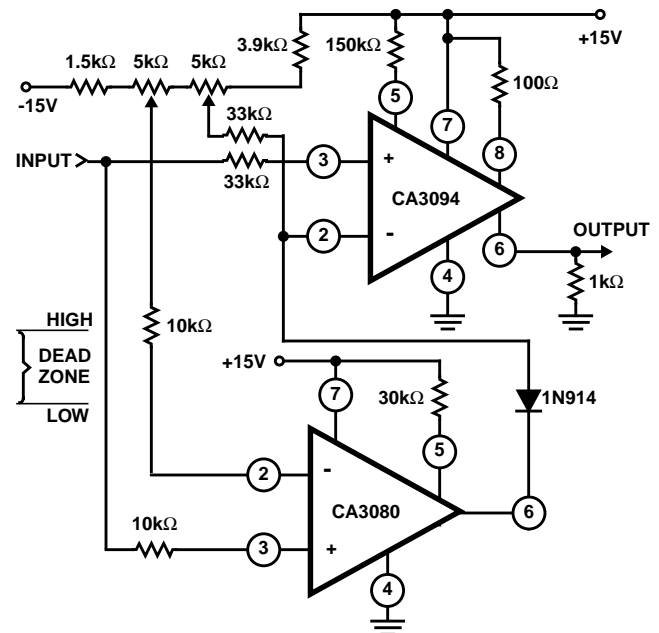
Figure 19 shows a dual limit threshold detector circuit in which the high level limit is established by potentiometer R1 and the low level limit is set by potentiometer R2 to actuate the CA3080 low limit detector [1, 2]. A positive output signal exceeds either the high limit or the low limit values established by the appropriate potentiometer settings. This output voltage is approximately 12V with the circuit shown.

The high current handling capability of the CA3094 makes it useful in Schmitt power trigger circuits such as that shown in Figure 20. In this circuit, a relay coil is switched whenever the input signal traverses a prescribed upper or lower trip point, as defined by the following expressions:

$$\text{Upper Trip Point} = 30 \left( \frac{R3}{R1 + R2 + R3} \right)$$

$$\text{Lower Trip Point} \cong (30 - 0.026R1) \frac{R3}{R2 + R3}$$

The circuit is applicable, for example, to automatic ranging. With the values shown in Figure 20, the relay coil is energized when the input exceeds approximately 5.9V and remains energized until the input signal drops below approximately 5.5V.



## Power Supply Regulators

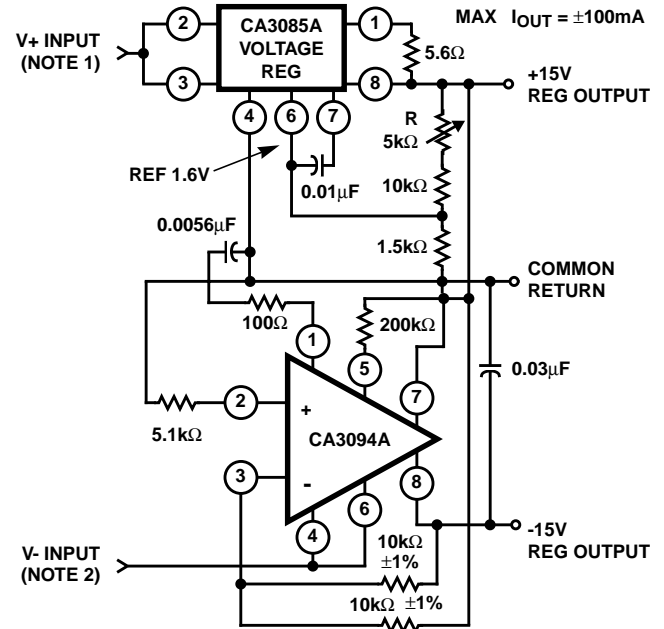
The CA3094 is an ideal companion device to the CA3085 series regulator circuits [4] in dual voltage tracking regulators that handle currents up to 100mA. In the circuit of Figure 21, the magnitude of the regulated positive voltage provided by the CA3085A is adjusted voltage supplies the power for the CA3094A negative regulator and also supplies a reference voltage to its terminal 3 to provide tracking. This circuit provides a maximum line regulation equal to 0.075% per volt of input voltage change and a maximum load regulation of 0.075% of the output voltage.

Figure 22 shows a regulated high voltage supply similar to the type used to supply power for Geiger-Mueller tubes. The CA3094, used as an oscillator, drives a step-up transformer which develops suitable high voltages for rectification in the 1N4007 diode network. A sample of the regulated output voltage is fed to the CA3080A operational transconductance amplifier through the  $198\text{M}\Omega$  and  $910\text{k}\Omega$  divider to control the pulse repetition rate of the CA3094. Adjustment of potentiometer R determines the magnitude of the regulated output voltage. Regulation of the desired output voltage is maintained within 1% despite load current variations of  $5\mu\text{A}$  to  $26\mu\text{A}$ . The DC to DC conversion efficiency is about 48%.

## Timers

The programmability feature inherent in the CA3094 (and operational transconductance amplifiers in general) simplifies the design of presettable timers such as the one shown in Figure 23. Long timing intervals (e.g., up to 4hrs) are achieved by discharging a timing capacitor C1 into the signal input terminal (e.g., No. 3) of the CA3094. This discharge current is controlled precisely by the magnitude of the amplifier bias current  $I_{ABC}$  programmed into terminal 5 through a resistor selected by switch S2. Operation of the circuit is initiated by charging capacitor C1 through the momentary closing of switch S1. Capacitor C1 starts discharging and continues discharging until voltage E1 is less than voltage E2. The differential input transistors in the CA3094 then change state, and terminal 2 draws sufficient current to reverse the polarity of the output voltage (terminal 6). Thus, the CA3094 not only has provision for readily presetting the time delay, but also provides significant output current to drive control devices such as thyristors. Resistor R5 limits the initial charging current for C1. Resistor R5 limits the initial charging current for C1. Resistor R7 establishes a minimum voltage of at least 1V at terminal 2 to insure operation within the common mode input range of the device. The diode limits the maximum

differential input voltage to 5V. Gross changes in time range selection are made with switch S2, and vernier trimming adjustments are made with potentiometer R6.



NOTES:

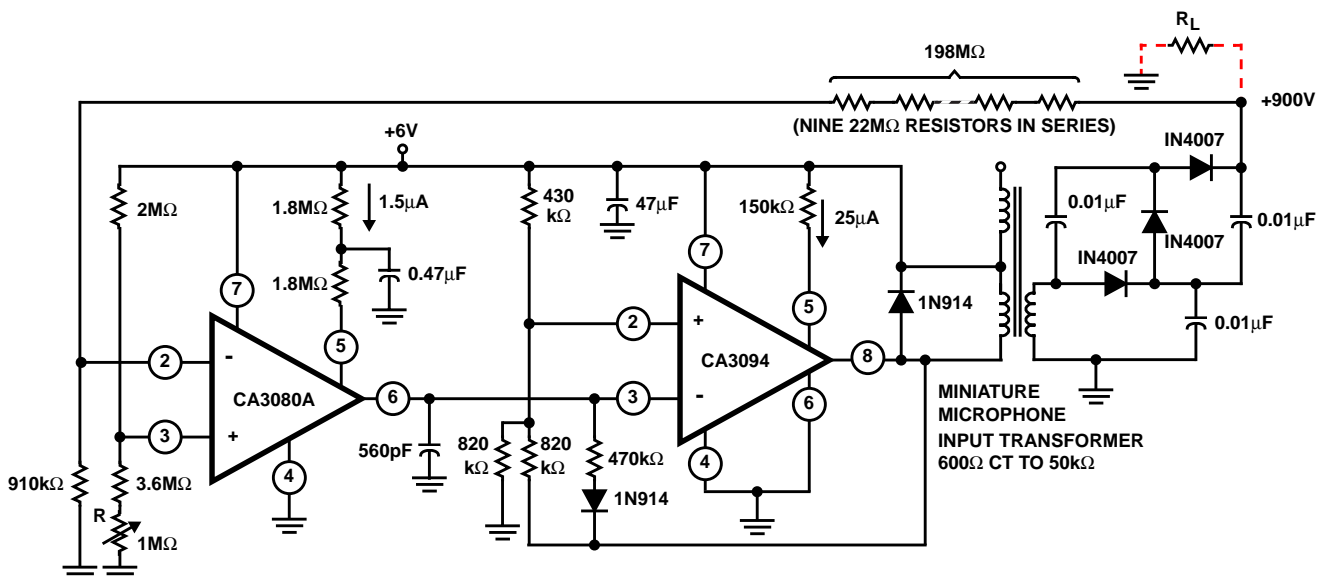
1. V+ input range = 19V to 30V for 15V output
2. V- input range = -16 to -30V for -15V output
3. REGULATION:

$$\text{MAX LINE} = \frac{\Delta V_{\text{OUT}}}{[V_{\text{OUT}}(\text{INITIAL})] \Delta V_{\text{IN}}} \times 100 = 0.075\%/V$$

$$\text{MAX LINE} = \frac{\Delta V_{\text{OUT}}}{V_{\text{OUT(INITIAL)}}} \times 100 = 0.075\% V_{\text{OUT}}$$

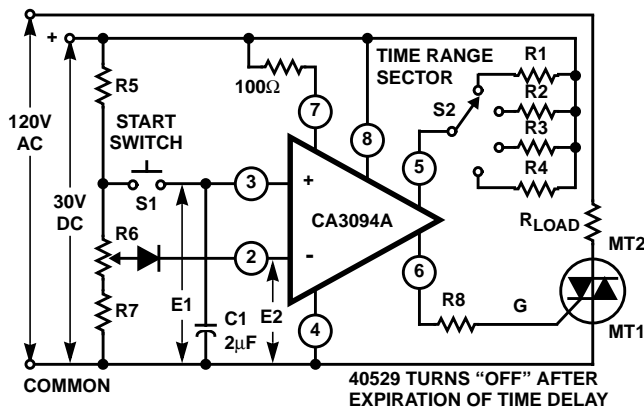
( $I_L$  FROM 1mA to 50mA)

**FIGURE 21. DUAL VOLTAGE TRACKING REGULATOR**



**FIGURE 22. REGULATED HIGH VOLTAGE SUPPLY**





TIME	RESISTOR VALUE	
3Min	R1 = 0.5MΩ	R5 = 2.7kΩ
30Min	R2 = 5.1MΩ	R6 = 50kΩ
2Hrs	R3 = 22MΩ	R7 = 2.7kΩ
4Hrs	R4 = 44MΩ	R8 = 1.5kΩ

FIGURE 23. PRESETTABLE ANALOG TIMER

In some timer applications, such as that shown in Figure 24, a meter readout of the elapsed time is desirable. This circuit uses the CA3094 and CA3083 transistor array [5] to control the meter and a load switching triac. The timing cycle starts with the momentary closing of the start switch to charge capacitor C1 to an initial voltage determined by the 50kΩ vernier timing adjustment. During the timing cycle the output of the CA3094,

which is also the collector voltage of Q1, is "high". The base drive for Q1 is supplied from the positive supply through a 91kΩ resistor. The emitter of Q1, through the 75Ω resistor, supplies gate-trigger current to the triac. Diode connected transistors Q4 and Q5 are connected so that transistor Q1 acts as a constant current source to drive the triac. As capacitor C1 discharges, the CA3094 output voltage at terminal 6 decreases until it becomes less than the  $V_{CESAT}$  of Q1. At this point the flow of drive current to the triac ceases and the timing cycle is ended. The 20kΩ resistor between terminals 2 and 6 of the CA3094 is a feedback resistor. Diode connected transistor Q2 and Q3 and their associated networks serve to compensate for nonlinearities in the discharge circuit network by bleeding corrective current into the 20kΩ feedback resistor. Thus, current flow in the meter is essentially linear with respect to the timing period. The time periods as a function of R1 and indicated on the Time-Range Selection Switch in Figure 24.

### Alarm Circuit

Figure 25 shows an alarm circuit utilizing two "sensor" lines. In the "no-alarm" state, the potential at terminal 5 ( $I_{ABC}$ ) is driven with sufficient current through resistor R5 to keep the output voltage "high". If either "sensor" line is opened, shorted to ground, or shorted to the other sensor line, the output goes "low" and activates some type of alarm system. The back-to-back diodes connected between terminals 2 and 3 protect the CA3094 input terminals against excessive differential voltages.

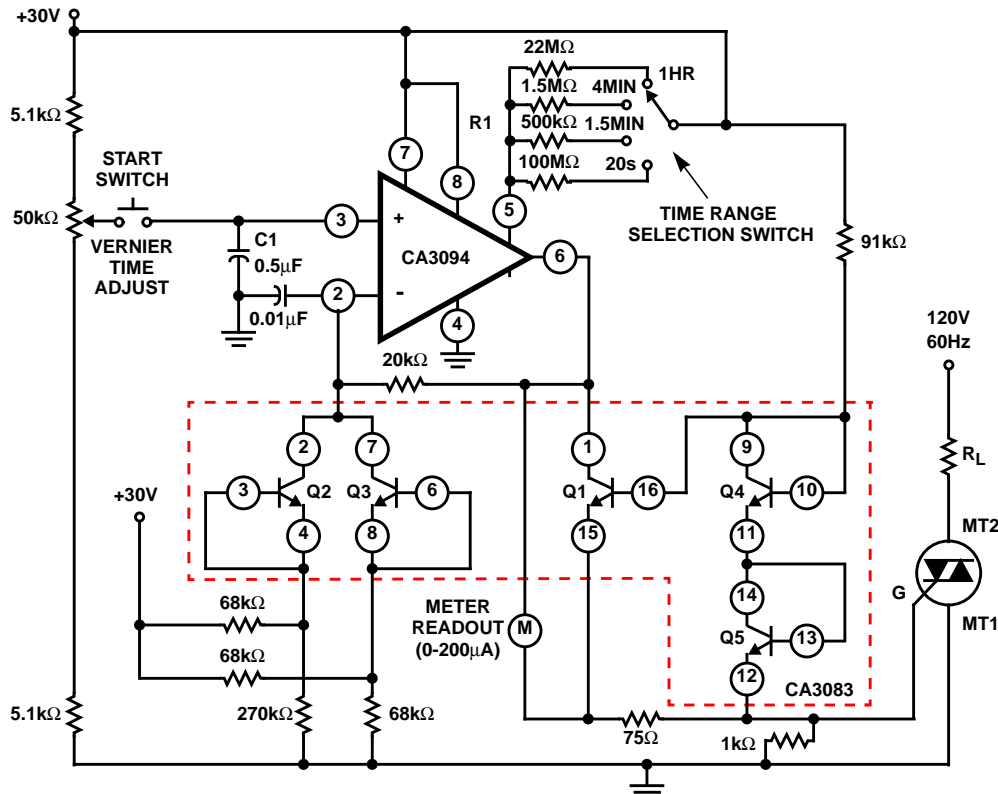


FIGURE 24. PRESETTABLE TIMER WITH LINEAR READOUT

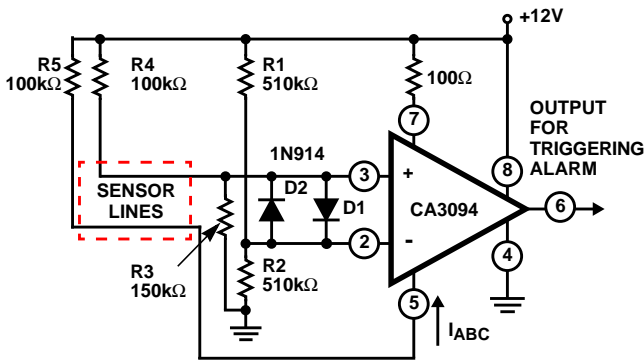


FIGURE 25. ALARM SYSTEM

## Motor-Speed Controller System

Figure 26 illustrates the use of the CA3094 in a motor-speed controller system. Circuitry associated with rectifiers D1 and D2 comprises a full wave rectifier which develops a train of half-sinusoid voltage pulse to power the DC motor. The motor speed depends on the peak value of the half-sinusoids and the period of time (during each half cycle) the SCR is conductive.

The SCR conduction, in turn, is controlled by the time duration of the positive signal supplied to the SCR by the phase comparator. The magnitude of the positive DC voltage supplied to terminal 3 of the phase comparator depends on motor-speed error as detected by a circuit such as that shown in Figure 27. This DC voltage is compared to that of a

fixed amplitude ramp wave generated synchronously with the AC line voltage frequency. The comparator output at terminal 6 is "high" (to trigger the SCR into conduction) during the period when the ramp potential is less than that of the error voltage on terminal 3. The motor current conduction period is increased as the error voltage at terminal 3 is increased in the positive direction. Motor-speed accuracy of  $\pm 1\%$  is easily obtained with this system.

## Motor-Speed Error Detector

Figure 27A shows a motor-speed error detector suitable for use with the circuit of Figure 26. A CA3080 operational transconductance amplifier is used as a voltage comparator. The reference for the comparator is established by setting the potentiometer R so that the voltage at terminal 3 is more positive than that at terminal 2 when the motor speed is too low. An error voltage E1 is derived from a tachometer driven by the motor. When the motor speed is too low, the voltage at terminal 2 of the voltage comparator is less positive than that at terminal 3, and the output voltage at terminal 6 goes "high". When the motor speed is too high, the opposite input conditions exist, and the output voltage at terminal 6 goes "low". Figure 27B also shows these conditions graphically, with a linear transition region between the "high" and "low" output levels. This linear transition region is known as "proportional bandwidth". The slope of this region is determined by the proportional bandwidth control to establish the error correction response time.

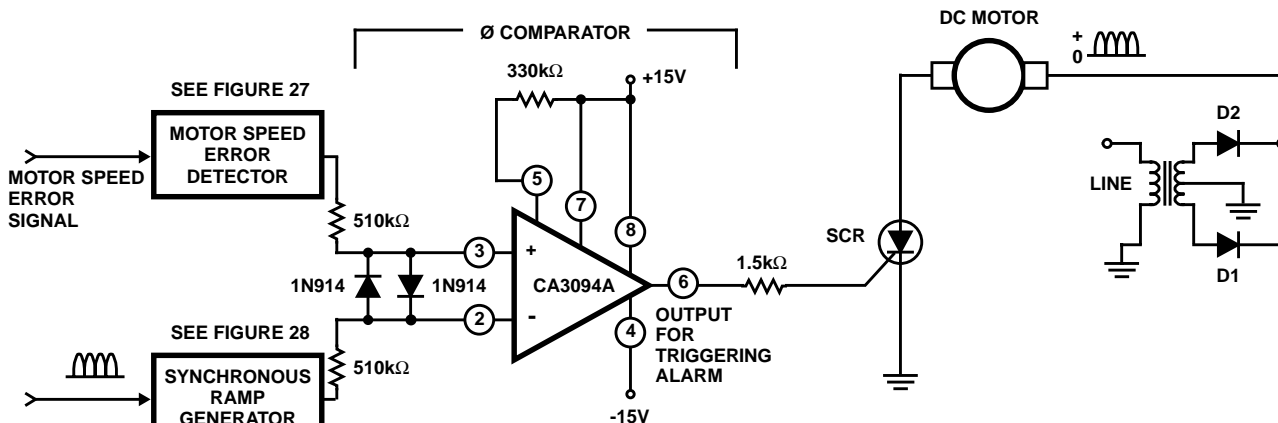


FIGURE 26A.

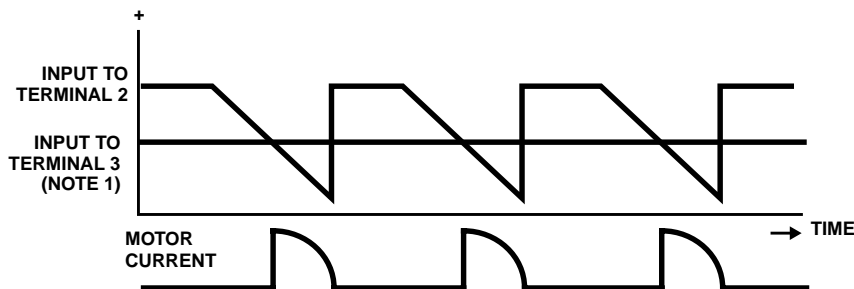
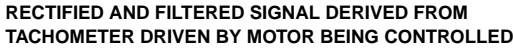


FIGURE 26B.

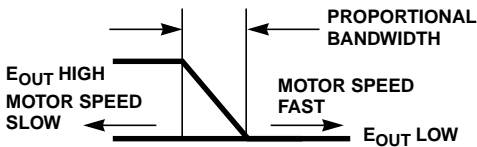
FIGURE 26. MOTOR SPEED CONTROLLER SYSTEM

NOTE:

1. This level will vary depending on motor speed. (See Text).



### FIGURE 26A. VOLTAGE COMPARATOR



**FIGURE 26B.**

### FIGURE 26. MOTOR SPEED ERROR DETECTOR

## Synchronous Ramp Generator

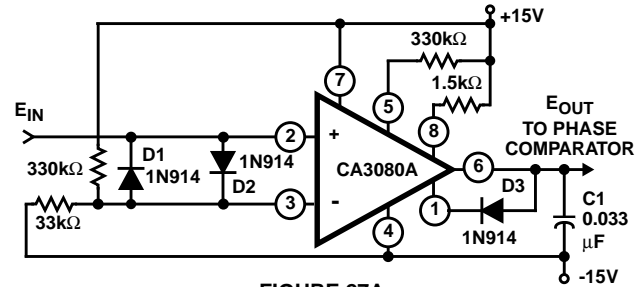
Figure 28 shows a schematic diagram and signal waveforms for a synchronous ramp generator suitable for use with the motor controller circuit of Figure 26. Terminal 3 is biased at approximately +2.7V (above the negative supply voltage). The input signal  $E_{IN}$  at terminal 2 is a sample of the half-sinusoids (at line frequency) used to power the motor in Figure 26. A synchronous ramp signal is produced by using the CA3094 to charge and discharge capacitor C1 in response to the synchronous toggling of  $E_{IN}$ . The charging current for C1 is supplied by terminal 6. When terminal 2 swings more positive than terminal 3, transistors Q12 and Q13 in the CA3094 (Figure 1) lose their base drive and become non-conductive. Under these conditions, C1 discharges linearly through the external diode D3 and Q10, D6 path in the CA3094 to produce the ramp wave. The  $E_{OUT}$  signal is supplied to the phase comparator in Figure 26.

## Thyristor Firing Circuits

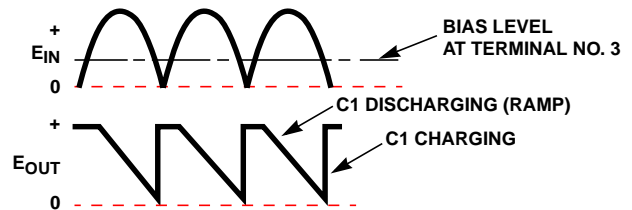
### Temperature Controller

In the temperature control system shown in Figure 29, the differential input of the CA3094 is connected across a bridge circuit comprised of a Positive Temperature Coefficient (PTC) temperature sensor, two 75kΩ resistors, and an arm containing the temperature set control. When the temperature is “low”, the resistance of the PTC type sensor is also low; therefore, terminal 3 is more positive than terminal 2 and an output current from terminal 6 of the CA3094 drives the triac into conduction. When the temperature is “high”, the input conditions are reversed and the triac is cut off. Feedback from terminal 8 provides hysteresis to the control point to prevent rapid cycling of the system. The 1.5kΩ resistor between terminal 8 and the

positive supply limits the triac gate current and develops the voltage for the hysteresis feedback. The excellent power supply rejection and common mode rejection ratios of the CA3094 permit accurate repeatability of control despite appreciable power supply ripple. The circuit of Figure 29 is equally suitable for use with Negative Temperature Coefficient (NTC) sensors provided the positions of the sensor and the associated resistor R are interchanged in the circuit. The diodes connected back to back across the input terminals of the CA3094 protect the device against excessive differential input signals.



**FIGURE 27A.**



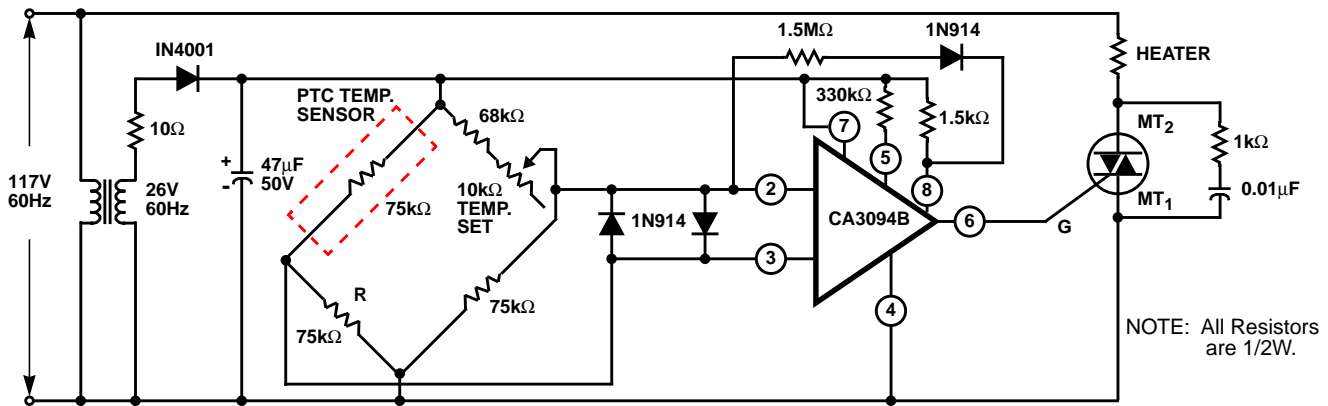
**FIGURE 27B.**

**FIGURE 27. SYNCHRONOUS RAMP GENERATOR WITH INPUT AND OUTPUT WAVEFORMS**

### Thyristor Control from AC Bridge Sensor

Figure 30 shows a line operated thyristor firing circuit controlled by a CA3094 that operates from an AC Bridge sensor. This circuit is particularly suited to certain classes of sensors that cannot be operated from DC. The CA3094 is inoperative when the high side of the AC line is negative because there is no  $I_{ABC}$  supply to terminal 5. When the sensor bridge is unbalanced so that terminal 2 is more positive than terminal 3, the output stage of the CA3094 is cut off when the AC line swings positive, and the output level at terminal 8 of the CA3094 goes "high". Current from the line flows through the IN3193 diode to charge the 100 $\mu$ F reservoir capacitor, and also provides current to drive the triac into conduction. During the succeeding negative swing of the AC line, there is sufficient remanent energy in the reservoir capacitor to maintain conduction in the triac.

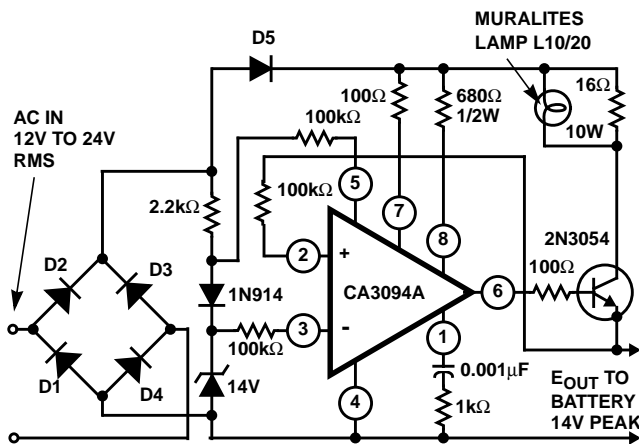
When the bridge is unbalanced in the opposite direction so that terminal 3 is more positive than terminal 2, the output of the CA3094 at terminal 8 is driven sufficiently “low” to “sink” the current supplied through the 1N4003 diode so that the triac gate cannot be triggered. Resistor R1 supplies the hysteresis feedback to prevent rapid cycling between turn on and turn off.



**FIGURE 28. TEMPERATURE CONTROLLER**

## Battery Charger Regulator Circuit

The circuit for battery charger regulator circuit using the CA3094 is shown in Figure 31. This circuit accurately limits the peak output voltage to 14V, as established by the zener diode connected across terminals 3 and 4. When the output voltage rises slightly above 14V, signal feedback through a 100kΩ resistor to terminal 2 reduces the current drive supplied to the 2N3054 pass transistor from terminal 6 of the CA3094. An incandescent lamp serves as the indicator of charging current flow. Adequate limiting provisions protect the circuit against damage under load short conditions. The advantage of the circuit over certain the types of regulator circuits is that the reference voltage supply doesn't drain the battery when the power supply is disconnected. This feature is important in portable service applications, such as in a trailer where a battery is kept "on-charge" when the trailer is parked and power is provided from an AC line.



### FIGURE 29. BATTERY CHARGER REGULATOR CIRCUIT

## **Ground Fault Interrupters (GFI)**

Ground fault interrupter systems are used to continuously monitor the balance of current between the high and neutral lines of power distribution networks. Power is interrupted whenever the unbalance exceeds a preset value (e.g., 5mA). An unbalance of current can occur then, for example, defective insulation in the high side of the line permits leakage of current to an earth ground. GFI systems can be used to reduce the danger of electrocution from accidental contact with "high" line because the unbalance caused by the leakage of current from the "high" line through a human body to ground results in an interruption of current flow.

The CA3094 is ideally suited for GFI applications because it can be operated from a single supply, has adequate sensitivity, and can drive a relay or thyristor directly to effect power interruption. Figure 32 shows a typical GFI circuit. Vernier adjustment of the trip point is made by the  $R_{TRIP}$  potentiometer. When the differential current sensor supplies a signal that exceeds the selected trip-point voltage level (e.g., 60mV), the CA3094 is toggled “on” and terminal 8 goes “low” to energize the circuit breaker trip coil. Under quiescent conditions, the entire circuit consumes approximately 1mA. The resistor R, connected to one leg of the current sensor, provides current limiting to protect the CA3094 against voltage spikes as large as 100V. Figure 32 also shows the pertinent waveform for the GFI circuit.

Because hazards of severe electrical shock are a potential danger to the individual user in the event of malfunctions in GFI apparatus, it is mandatory that the highest standard of good engineering practice be employed in designing equipment for this service. Every consideration in design and application must be given to the potentially serious consequences of component malfunction in such equipment. Use of "reliability through redundancy" concepts and so called "fail-safe" features is encouraged.

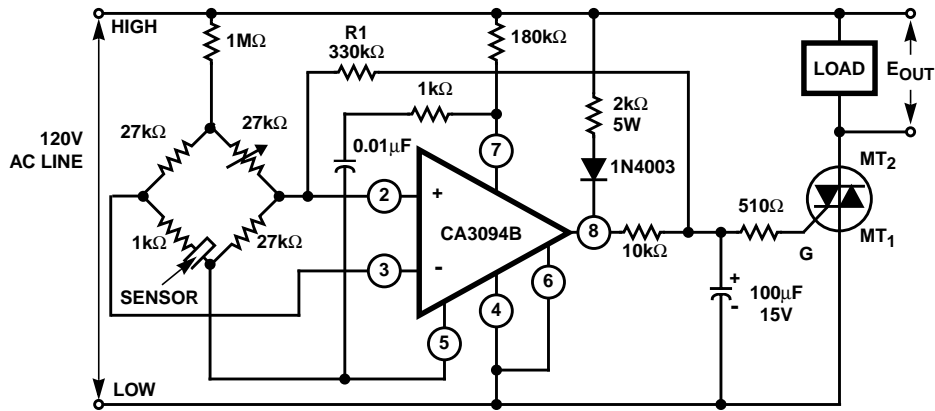
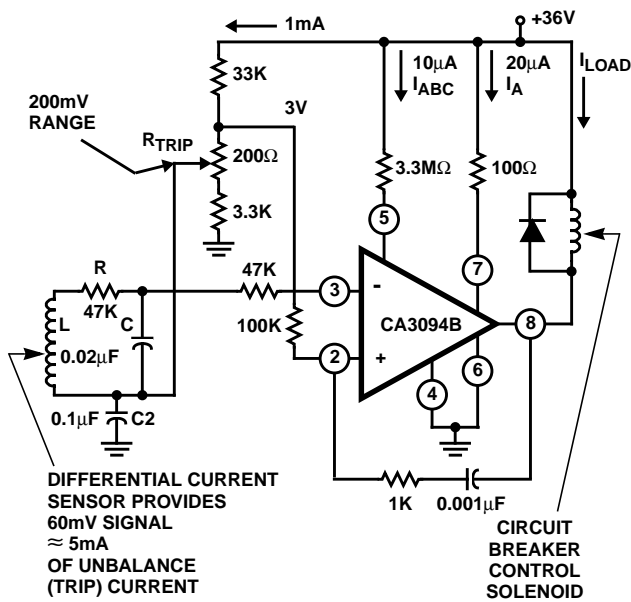


FIGURE 30. LINE OPERATED THYRISTOR FIRING CIRCUIT CONTROLLED BY AC BRIDGE SENSOR



NOTES:

1. All resistors in  $\Omega$ , 1/2W, 10%.
2. RC selected for 3dB point at 200Hz.
3. C2 = AC bypass.
4. Offset ADJ included in  $R_{TRIP}$ .
5. Input impedance from 2 to 3 equals 800K.
6. With no input signal terminal 8 (Output) at +36V.

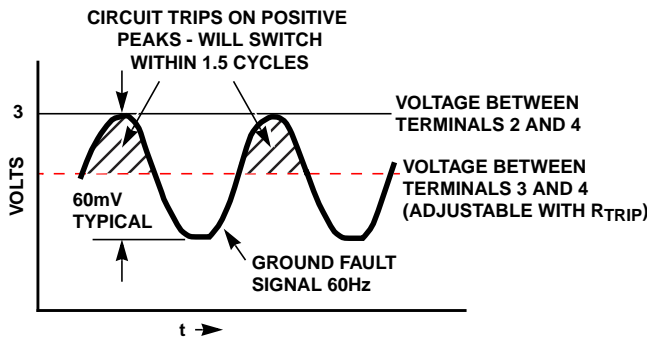


FIGURE 31. GROUND FAULT INTERRUPTER (GFI) AND WAVEFORM PERTINENT TO GROUND FAULT DETECTOR

References

For Intersil documents available on the internet, see web site <http://www.intersil.com/>  
Intersil AnswerFAX (407) 724-7800.

- [1] CA3080 and CA3080A Data Sheet, Intersil Corporation, FN475.
- [2] AN6668 Application Note, Intersil Corporation, "Applications of the CA3080 and CA3080A High Performance Operational Transconductance Amplifiers".
- [3] AN6077 Application Note, L. Kaplan and H. A. Wittlinger, Intersil Corporation, "An IC Operational Transconductance Amplifier (OTA) with Power Capability". Paper originally presented at the IEEE Chicago Springs Conference on Broadcast and TV Receivers, June 1972. Reprinted as AN6077.
- [4] CA3085 Data Sheet, Intersil Corporation, FN491.
- [5] CA3083 Data Sheet, Intersil Corporation, FN481.

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