THE IMPROVED μA702 WIDEBAND DC AMPLIFIER

by R. J. Widlar

I INTRODUCTION

This paper describes an improved version of the μA702 and also points out how to protect the amplifier from certain improper operating modes which have been responsible for failures in the past. The original amplifier is described elsewhere.[1]

The μA702A features simplified frequency compensation. It also gives higher gain-bandwidth products—up to 30 MHz. In addition, it has greater thermal isolation of input and output stages, which removes another source of unexplainable instabilities observed with moderate to large output powers. A larger output current capability is also provided; this minimizes the chances of failure due to overload conditions.

II MASK CHANGES

The most obvious difference between the μA702A and the μA702 is that an additional point within the circuit is brought out to facilitate frequency compensation, as shown in Fig. 1. A capacitor can be connected across the frequency compensation terminals to increase gain and reduce phase shift at high frequencies.

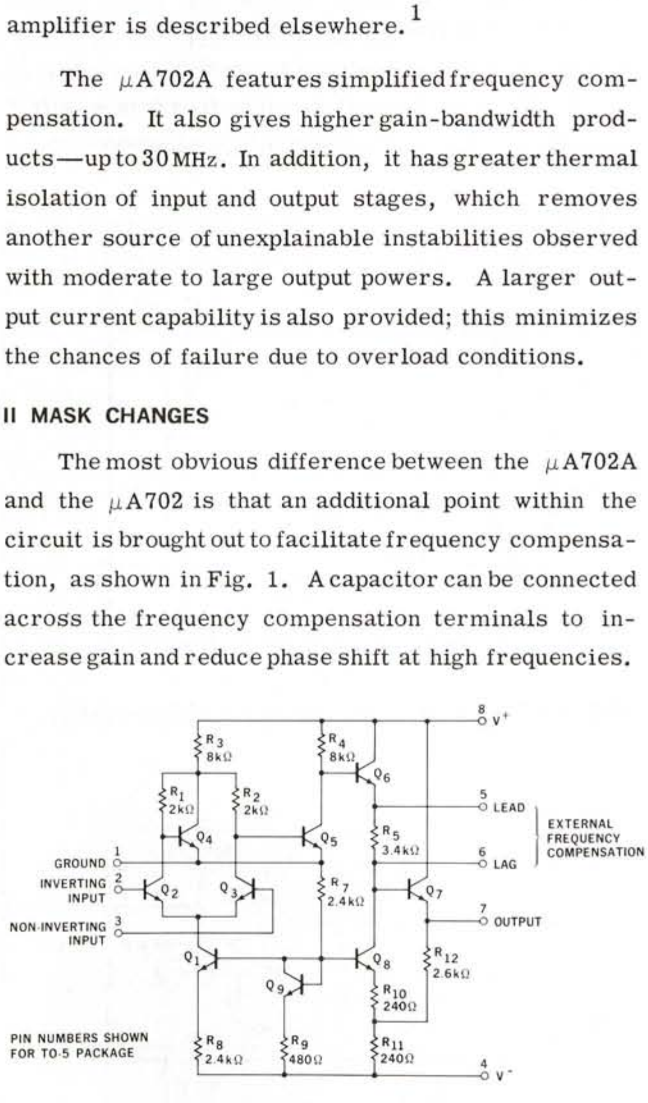

FIG. 1. Schematic diagram of the μA702A

A second change is a larger output transistor which can handle more current without excessive heating; the need for this was not recognized in the original design since the amplifier was intended for low-level applications. The output circuitry has been beefed up to the point where the output may be shorted to the negative supply for a few seconds without damage (although this is neither recommended nor guaranteed).

Other changes were more subtle: relocation of components to insure improved matching; lower offsets and better supply voltage rejection; slight changes in component values to give improved linearity; and modification of device structures for tighter gain distributions.

Although it features improved performance in many respects, the new unit in the TO-5 package is a plug-in replacement for the μA702. The flatpack lead configuration, however, has been changed to facilitate internal lead bonding.

III IMPROVED FREQUENCY COMPENSATION TECHNIQUES

The purpose of the extra frequency compensation terminal is clearly demonstrated in Fig. 2. With an external capacitor, the useful bandwidth* of the amplifier can be extended substantially. It might be noted that the open-loop bandwidth of the μA702A is somewhat reduced. This is of absolutely no significance in a practical feedback circuit; in fact, the earlier first break makes the amplifier easier to compensate.

* An operational amplifier is useful only at frequencies where the internal rolloff is less than 12 dB per octave.

FAIRCHILD SEMICONDUCTOR
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION
313 FAIRCHILD DRIVE, MOUNTAIN VIEW, CALIFORNIA, (415) 962-5011, TWX: 910-379-6435

Some typical circuits using the new compensation techniques are shown in Figs. 3 through 6. Closed-loop gains down to 40 dB are possible, with only lead compensation, for bandwidths in excess of 30 MHz. If it is desired to use the amplifier with feedback for gains less than 40 dB, additional lag compensation is necessary. It is recommended that the compensation network be placed across the input terminals as shown in Figs. 4, 5, and 6 which reduces the effective input impedance and maintains a large output swing capability at high frequencies. The bandwidth of the circuits shown in Figs. 3 through 6 can vary from 12 to 40 MHz, depending on the low-frequency open-loop gain of the amplifier.

With the large bandwidths obtainable with this amplifier, some attention to input impedance levels and stray capacitances is necessary. If the source impedance for the amplifier is greater than a few hundred ohms, steps should be taken to insure that the stray capacitance from the output and frequency compensation terminals to the inverting input is larger than the stray capacitance to the non-inverting input. Alternatively, an inverting feedback configuration could be used and the non-inverting input bypassed with 50 pF or so. It is practically impossible to measure the open-loop input capacitance because it is dominated by these stray capacitances. These precautions, of course, are not necessary if the amplifier is rolled off at a low enough frequency so that the open-loop gain is less than unity at 10 MHz or less.

A simple frequency compensation network which provides a large gain-stability margin is shown in Fig. 7. This can be used as a standard compensation network when the performance of the amplifier above

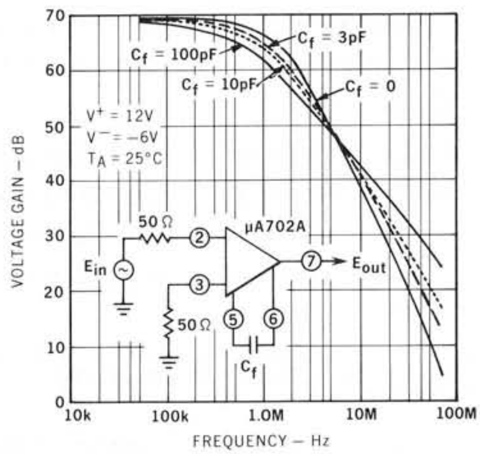

FIG. 2. Frequency response of the μA702A for various values of lead-compensation capacitors

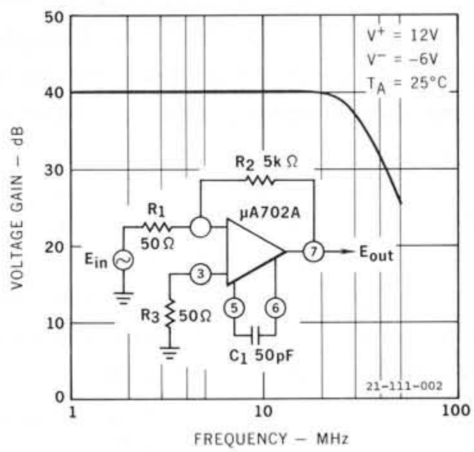

FIG. 3. Frequency response of a x100 amplifier

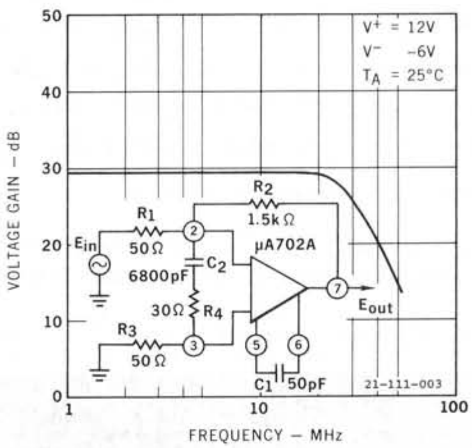

FIG. 4. Frequency response of a x30 amplifier

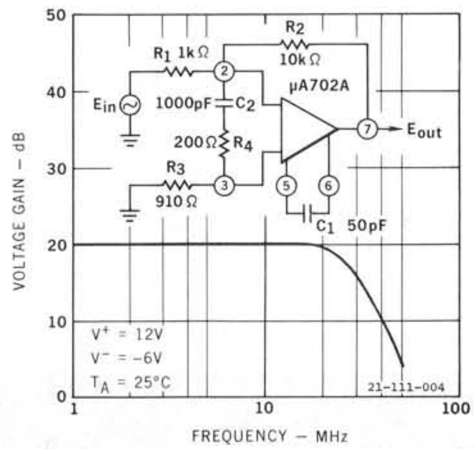

FIG. 5. Frequency response of a x10 amplifier

several hundred cycles is of little concern. With this configuration oscillation problems in any feedback connection are nonexistent unless the amplifier is operated from high source resistances. With high source resistances it is advisable to bypass the non-inverting input with a capacitor C_3 greater than 50 pF, as shown in the integrator circuit of Fig. 8.

IV DESTRUCTIVE OPERATING MODES

There are certain connections of the μA702 and μA702A which can induce catastrophic failure of the device. Since the source of the problem, in many cases, is not immediately evident, some of the difficulties will be pointed out here.

One circuit which has caused trouble in the past is the integrator shown in Fig. 8. If a clamping diode (D_1) is not used on the input, it is possible for an output transient to drive the amplifier beyond its positive common-mode limit through the integrating capacitor C_1. This can result in latch-up of the amplifier wherein excessive current is driven from the output emitter-follower through the collector-base junction of Q_2 and the emitter-base junction of Q_4. This current can reach destructive levels if the integrating capacitor is more than ten times larger than the frequency compensating capacitor on pin 6. The clamping diode, however, completely eliminates the problem by preventing latch-up; and a sufficiently large compensating capacitor will limit the peak diode current to a reasonable value.

Another circuit with a very similar problem is

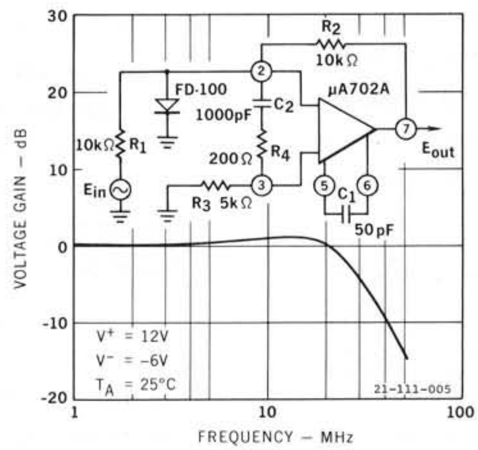

FIG. 6. Frequency response of a unity-gain amplifier

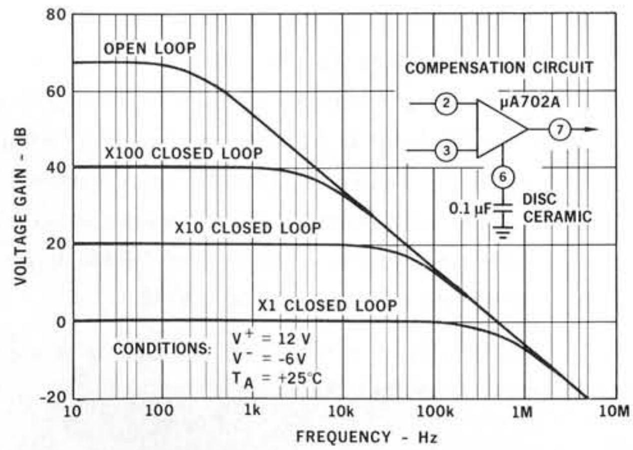

FIG. 7. Frequency response of the μA702A with conservative frequency-compensation network

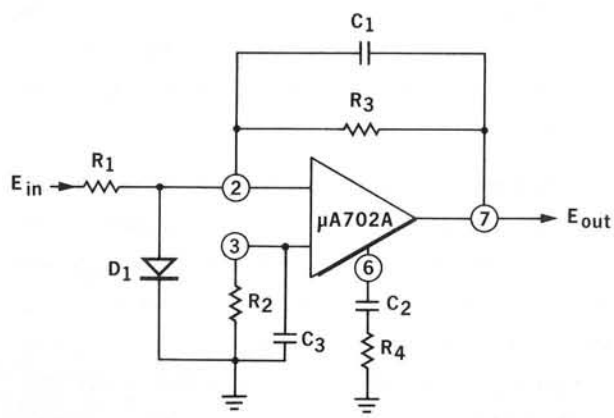

FIG. 8. The μA702A connected as an integrator, including an input clamping diode to prevent latch-up

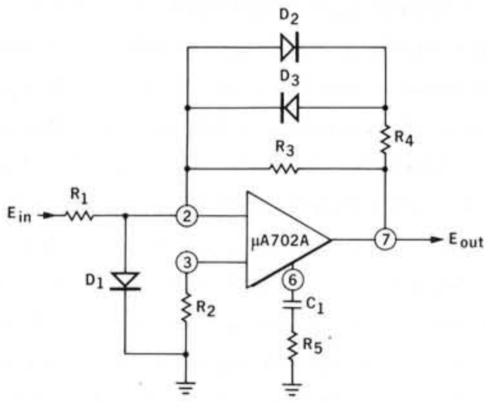

FIG. 9. Circuit showing use of input clamping diode to prevent latch-up with diode-feedback circuit

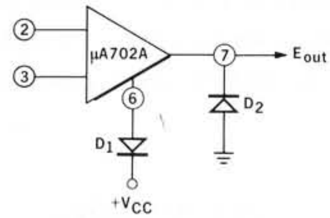

FIG. 10. Circuit showing location of output limiting diodes required when the μA702A is used to drive logic circuits

shown in Fig. 9. Diodes can be connected across the feedback resistor R_3 as indicated in the schematic to give a nonlinear (clipping) transfer characteristic. However, as with the previous circuit, it is possible to exceed the input common-mode range of the amplifier with an output transient if a limiting diode is not used on the input. It is also advisable to use a limiting resistor (R_4) to prevent excessive current through D_1.

A third problem can occur when the amplifier is used in conjunction with digital integrated circuits as, for example, a zero-crossing sensor or level detector. The drive voltage to the logic circuits must be limited to prevent forward biasing any of the isolation junctions and drawing excessive current from the amplifier. A method of accomplishing this is shown in Fig. 10. One diode is used on the base of the output emitter-follower (pin 6) to prevent the output of the μA702A from rising above the power supply voltage of the logic; and a second diode on the output terminal limits the negative output swing.

It has been reported in certain instances that the μA702 has burned out when the power supplies were turned on in the wrong order. Extensive testing has shown that the power supplies can be turned on in any order; further, they can be turned off either by opening the supply lead or by returning it to ground. Difficulties in this area have been traced to one of the aforementioned latch-up conditions. If a latch-up condition exists, however, sequencing the supplies is no cure since the latch-up mode can still be activated by some system transient. The cures described above are considered the only satisfactory solution.

Other failures have been traced to the use of ungrounded soldering irons to install the amplifier. Line transients can feed through the insulation of the iron (particularly with the transformer type) to destroy the circuit. If the iron is grounded, the circuit is either grounded or disconnected from any line-operated equipment, and when supply voltages are removed, there is no problem.

Other problems can arise when the output of the amplifier is loaded with a capacitor. Measures must be taken to insure that the charging current of the capacitor does not become excessive. This can be done easily by making the frequency compensation capacitor on pin 6 at least one-tenth of the load capacitor.

V CONCLUSIONS

The μA702A is a refinement of the μA702. It incorporates improvements suggested by extensive use of the μA702 in the field. The unit is more resistant to failures due to overload conditions. Further, it features simplified frequency compensation and also eliminates the more subtle causes of feedback instability observed with the original μA702.

The μA702A in the TO-5 package is a socket replacement for the μA702.

REFERENCE

1. R. J. Widlar, "Monolithic Operational Amplifier," Fairchild APP-105/3.