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Stable Sinusoidal Driver Circuit for Tuning Fork Choppers

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Abstract

A circuit is presented which can drive tuning fork choppers, such as the Bulova L40 and L2 series. The advantages of this circuit over the factory supplied 5A type driver are better drive amplitude stability, freedom from drift due to line voltage variations, and a cleaner, transient free sinusoidal reference signal. Test results indicate an improvement in long term stability by as much as a factor of 4.

I. Introduction

Mechanical choppers, especially those of the tuning fork variety, are used extensively in photometric and molecular beam systems today, in conjunction with phase sensitive detection, as a powerful method of signal enhancement. By shifting the center frequency of the information content of the beam from d.c. to the chopper frequency, a good portion of the 1/f noise in analog electronics can be overcome. The advantage of avoiding d.c. baseline drift by this method can be offset however, in cases where accurate measurements are required, by the drift in the amplitude of the mechanical chopper. Thus for optimum performance a stable driving circuit for these devices is required.

Starting with a factory supplied driver circuit to determine the necessary characteristics of the driving circuit, first an improvement was made on the standard circuit and finally a different circuit was developed which had the desired properties. The new circuit was tested against the improved standard circuit and found to give a more stable drive amplitude.

II. Circuit Development

Standard drive circuits for tuning fork choppers typically work by taking a signal from a pickup coil on the chopper, usually a slightly distorted sine wave, and amplifying it in a non-linear manner to produce an approximately square wave drive and reference waveform in phase with the pickup signal. In trying to drive the inductive load of the driver coil, switching transients are produced on both the drive waveform, Figure 1, and pickup coil waveform. The amplitude of the drive signal is proportional to the power supply voltage, and in the case of the Bulova 5A driver with just a full wave rectified bridge as a d.c. power source, the drive amplitude changes with variations in line voltage. A major improvement in long term stability was obtained by replacing the internal power supply with a regulated 28 vdc power supply. All further work and testing of the factory circuit was done with this configuration.

The new circuit, Figure 2, works as follows. First the pickup signal goes to a CA3130AT CMOS op amp, which acts as a comparator to produce a square wave. If the output of this particular amplifier is only lightly loaded its output will swing to within millivolts of the positive and negative supplies. Further, if a well regulated power supply is used the amplitude of the square wave will be very stable. The square wave is then attenuated by a potentiometer and fed into a four pole Butterworth filter whose cut-off frequency is set to be the same as the resonant frequency of the tuning fork. For this filter the square wave input will produce purely sinusoidal output of the same frequency and 180° out of phase (simply inverted). By reversing the polarity on the drive coil connections this well regulated sine wave output is now in phase with the pickup signal and will drive the chopper.

III. Circuit Construction

A driver was constructed for both a 400 Hz and an 1800 Hz choppers, the only difference being the values of R and C used in the filter. For a 4 pole Butterworth Filter using the Sallen-Key equal component configuration the value of R and C are set by the cutoff frequency (where the phase shift of the filter is 180°)[1,2]

$$RC = \frac{1}{2\pi f_o} \tag{1}$$

For the 400 Hz chopper C = .0047 μf and R = 8.25 KΩ. Metal Film 1% resistors and low leakage capacitors with ± 5 - 10% tolerances are recommended.

In order to assure positive startup, either a 3130 op amp can be selected which has several volts of positive output when both inputs are grounded in an open loop configuration, or this condition can be produced by adding a 10 KΩ offset adjusting pot. across pins 1 and 5 of the 3130.

The maximum drive voltage which a particular tuning fork can handle before harmonic modes are excited must be determined by experiment. By looking at the reference waveform while adjusting the drive amplitude the onset of severe distortion can be observed. On start up it may be necessary with some tuning forks to decrease the drive amplitude initially to a small value (.5 volts) until stable operation occurs. Then the amplitude can be increased to a level below the maximum level at which the tuning fork can operate.

VI. Test Results

In order to test the amplitude stability of the chopper movement directly, as opposed to just the driver voltage stability, a test arrangement was set up with a tungsten lamp shining through a 400 Hz tuning fork chopper onto a photodiode. By measuring the ratio of the A.C. to D.C. components of the photodiode signal a good measure of the chopper amplitude was obtained. Each drive circuit was tested for 1-1/2 hours, with sampling taking place every 5 minutes. The result was that the RMS deviation of the readings on the new driver was a factor of 4 smaller than that obtained for the improved factory supplied driver.

Observation of the drive/reference waveform on an oscilloscope showed a symmetric sine wave, free of any switching transients. This feature may be advantageous in that a sinusoidal input is the optimum waveform for the reference channel of many lockin amplifiers.

V. Acknowledgment

This work was supported by the Division of Chemical Sciences, Office of Basic Energy Sciences, U.S. Department of Energy.

References

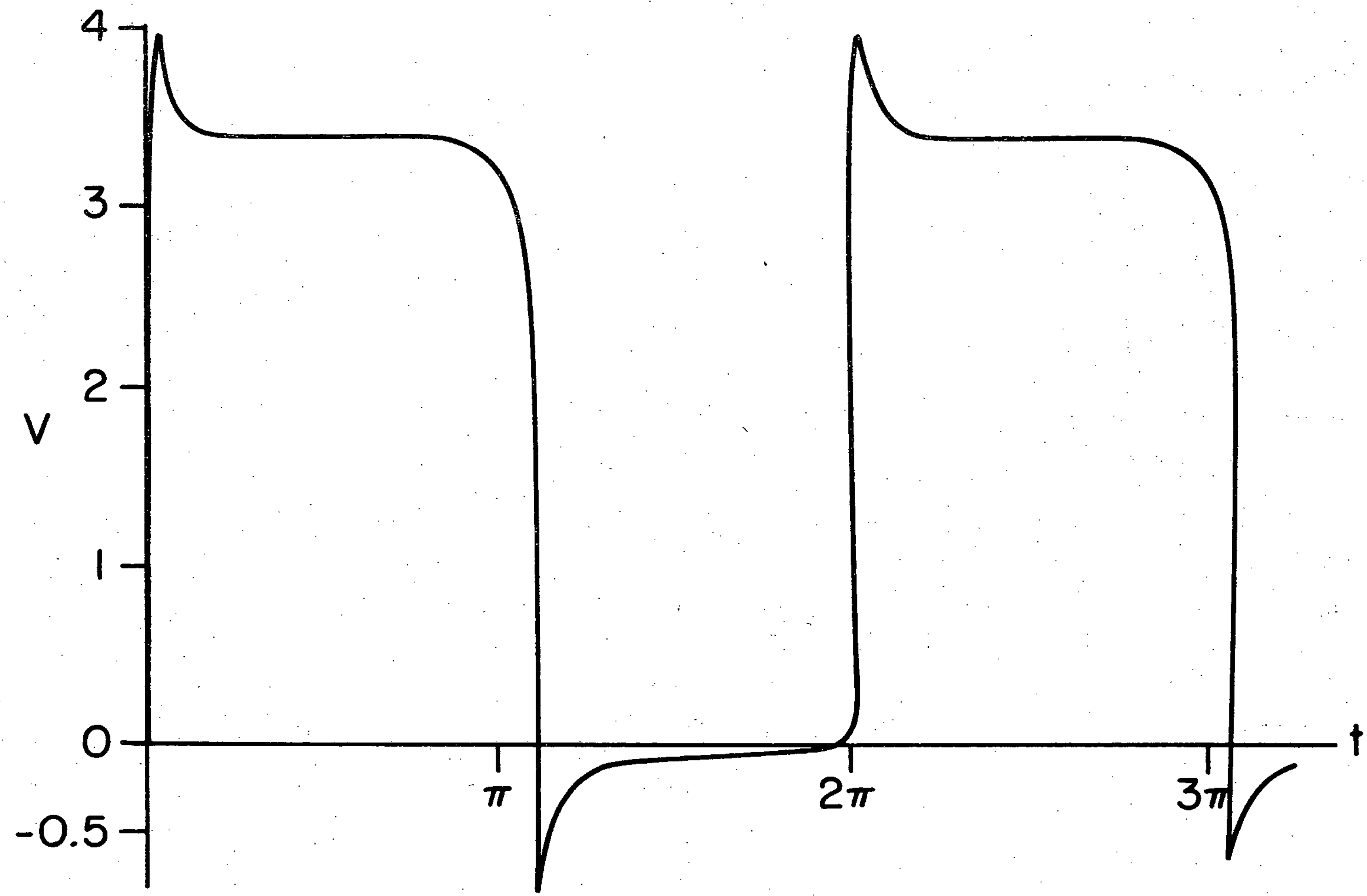
1. D. Lancaster, Active Filter Cookbook (Howard W. Sams, Indianapolis, 1975).

2. J. G. Graeme, G. E. Tobey and L. P. Huelsman, Operational Amplifiers — Design and Applications (McGraw-Hill, New York, 1971).

Figure Captions

Figure 1. Drive waveform produced by factory supplied driver. Notice large spikes produced when the driver coil is switched on and off, and the asymmetry of the waveform.

Figure 2. Schematic of tuning fork driver circuit. For value of R and C in filter section, see text.



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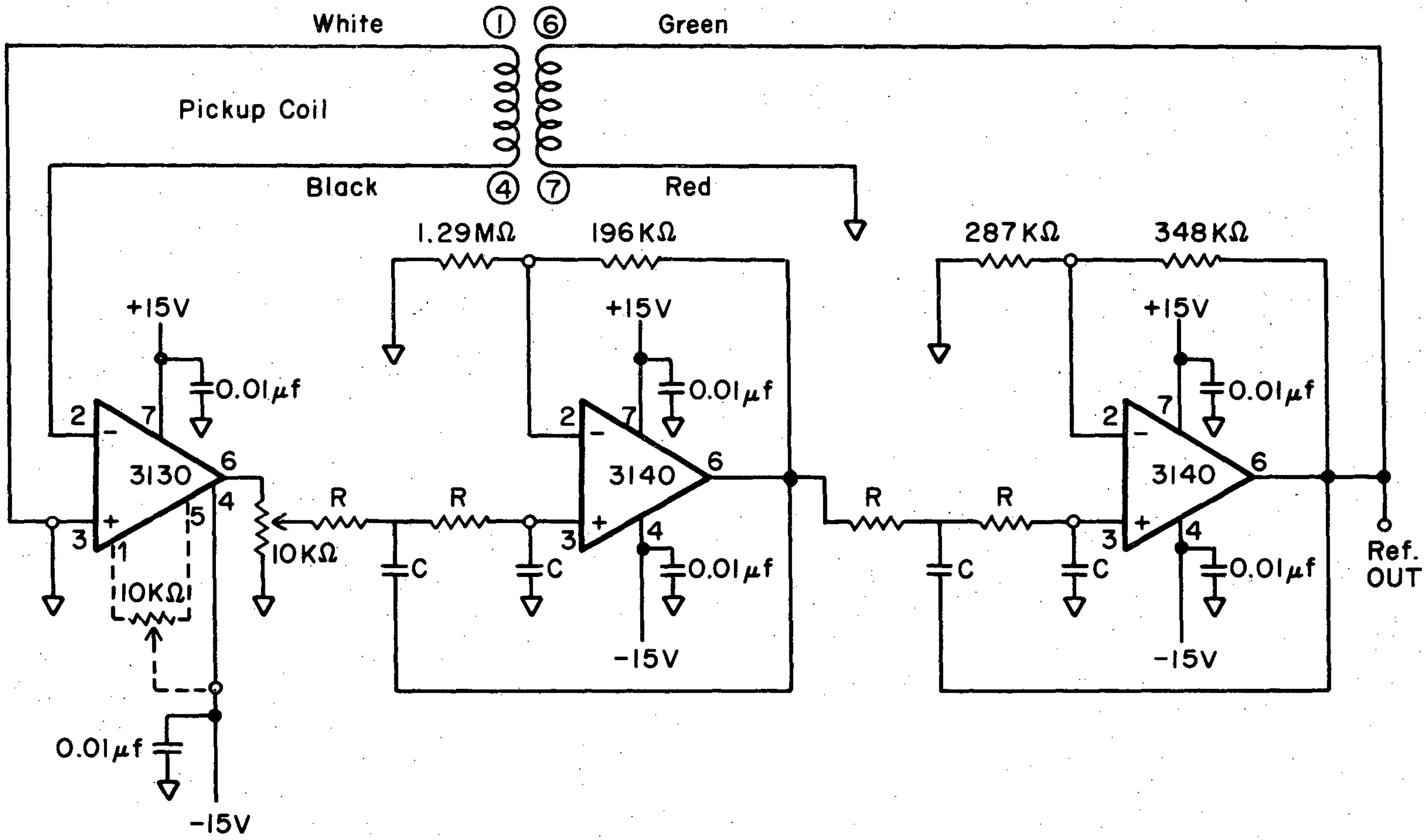
BULOVA L40 CHOPPER



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