

## Introduction

Analog oscillators produce excellent sine waves, but they are temperamental and very hard to design. Also, analog oscillators require extensive redesign every time the oscillation frequency is changed. Digital oscillators are easier to design than analog oscillators, and digital signals already exist in digital systems, so it is often cost effective to derive sine waves from digital signals. The circuit described here derives a sine wave, whose frequency is 1/32nd of the input, from almost any periodic digital input signal.

The counter chain acts as a frequency divider (see Figure 1) so it and the digital input signal determine the frequency of the output sine wave. A 5-bit counter was chosen for this design because dividing the available digital signal by 32 yielded the sine wave frequency desired. Dividing by 32 separates the digital noise and switching steps from the sine wave frequency by the same factor, thus making it easier to filter the sine wave.

The more stages in the counter, the higher the frequency separation between the digital input and output sine wave, and the easier the filtering job will be.

The counter output is connected to the serial input of the shift register, so it determines if ones or zeros are shifted down the register. Because it is a 5-bit counter 16 ones will be shifted into the shift register followed by 16 zeros. The 16 ones make up the rising part of the sine wave, and the 16 zeros make up the falling part of the sine wave. Assume that all shift register outputs are low; now the parallel combination of all the resistors acts as a termination to the digital low level which serves as ground. The first shift register output,  $Q_A$ , has a 51K resistor connected to it, and when it goes to a high state the 51K pulls the junction voltage up slightly. Each succeeding resistor connected to the shift register outputs,  $Q_B$ , etc., pulls the junction voltage up in steps until all of the shift register outputs are high. When the shift register serial input waveform goes low, zeros are shifted into the shift register outputs, and the process is reversed thus forming the decreasing portion of the sine wave.

The resistors are weighted sinusoidally, therefore the output voltage take small steps when a sine wave has a slow ris-

ing/falling voltage. The resistor weighting insures that the voltage steps are larger during those periods when the sine wave voltage should have a fast rising/falling voltage. Notice that the resistors are symmetrical about 1/4th of the period; this insures that the rising and falling curves of the sine wave will be symmetrical. If the counter is increased to 6 bits, the output sine wave will be 1/64th of the input signal, the number of resistors and shift registers will double, and the purity of the sine wave will increase dramatically. If CMOS is used for the digital circuits no pull-up resistors are required, but bipolar digital circuits require pull up resistors to insure that the high level stays close to the supply rail.

The output filter is a second order low pass filter which has the cut off frequency set at 100kHz. This enables the circuit to deliver a very clean 86kHz sine wave output with a 2.78MHz digital input. There are no discernible switching glitches or voltages steps on the sine wave output with this filter. If the counter was only 4 bits some of the digital noise seen on the stepped sine wave would appear on the output sine wave, and if it were 6 bits the sine wave purity would not change much.

The filter [1] cutoff frequency can be scaled with the equation:

$$R_{NEW} = R_{OLD}(F_{OLD}/F_{NEW}),$$

or

$$C_{NEW} = C_{COLD}(F_{OLD}/F_{NEW}).$$

The HA-2841 was chosen for the active filter because it has the high bandwidth required to support an active filter. The op amp must have at least 20dB of open loop gain at the cut-off frequency if it is to function properly as an active filter. The HA-2841 far exceeds this criteria, thus it is usable for much higher frequency filters.

## References:

Berlin, Howard, "Design of Active Filters, With Experiments", Howard W. Sams & Co, 1977.

## Application Note 9780

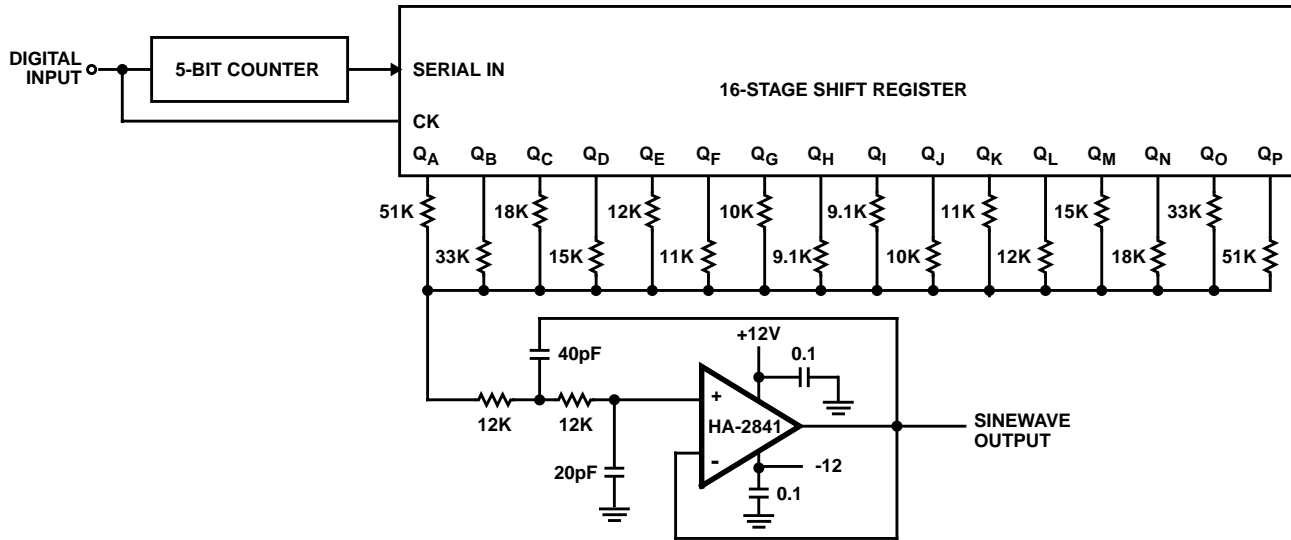


FIGURE 1. DERIVE PURE SINE WAVES FROM DIGITAL SIGNALS

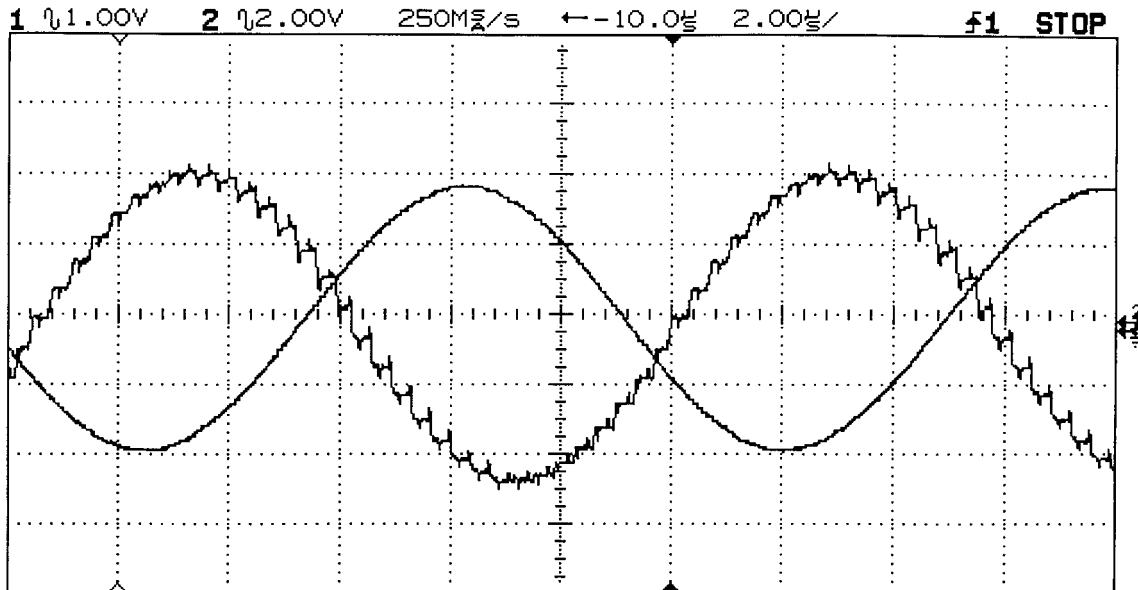


FIGURE 2. SINE WAVES

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