

EE4435 Fall 2002
Design Project 3
A Phase Shifter Effects Box

Object

The object of this experiment is to design a phase shifter circuit for special effects audio signal processing.

Background. Figure 1 shows a first-order all-pass filter with a JFET used as a variable resistor to control the pole and zero time constants in the filter transfer function. Let R_J be the resistance of the JFET. If we assume that this is a linear resistor, the transfer function is

$$\frac{V_o}{V_i} = \frac{\tau s - 1}{\tau s + 1}$$

where the time constant τ is given by

$$\tau = (R_2 \parallel R_J) C$$

By varying the control voltage V_c , the resistance of the JFET can be varied and this changes the time constant τ . The pole and zero frequencies of the transfer are equal and are given by

$$f_\tau = \frac{1}{2\pi\tau}$$

For $s = j2\pi f$, $|V_o/V_i| = 1$ for all f . For $f \ll f_\tau$, the phase of the transfer function is $+180^\circ$. For $f = f_\tau$, the phase is $+90^\circ$. For $f \gg f_\tau$, the phase is 0° .

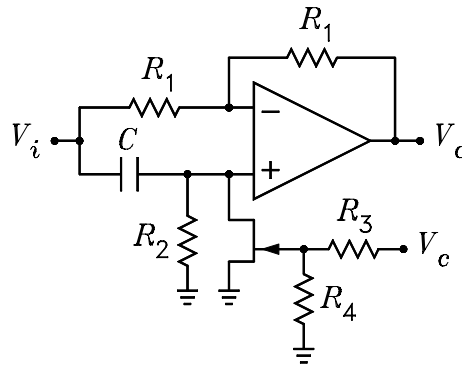


Figure 1: First-order all-pass filter.

This design project is to design a circuit consisting of an input buffer, four all-pass filter sections in cascade, a summing amplifier, and a triangle wave generator. The inputs to the summing amplifier are the signal input to the first all-pass filter and the signal output of the fourth all-pass filter. The control voltage V_c for each all-pass section is to be derived from the triangle wave generator. The triangle wave generator frequency is to be variable over the range from 0.05 Hz to 5 Hz. To prevent gate current from flowing, the gate-source voltage of each JFET must not go positive. The pole frequency in each all-pass section is to vary from 250 Hz to 4000 Hz as the output voltage of the triangle wave generator varies

from its most positive peak to its most negative peak. It is best to have matched JFET's for the four all-pass sections. However, mismatches can be compensated for by adjusting the resistors R_2 , R_3 , and R_4 . Because the JFET is not a linear resistor in its triode range, the signal level applied to the all-pass filters should not be too large when measuring the pole frequency. A suggested value is 100 mV peak. At the pole frequency, the phase shift from input to output of the all-pass filter is 90° . If the input sine wave is applied to the horizontal axis of the oscilloscope and the output signal is applied to the vertical axis, the oscilloscope should display a circle at the pole frequency.

Figure 2 shows the simulated frequency response of the effects box when the pole frequency of each filter is 1000 Hz.

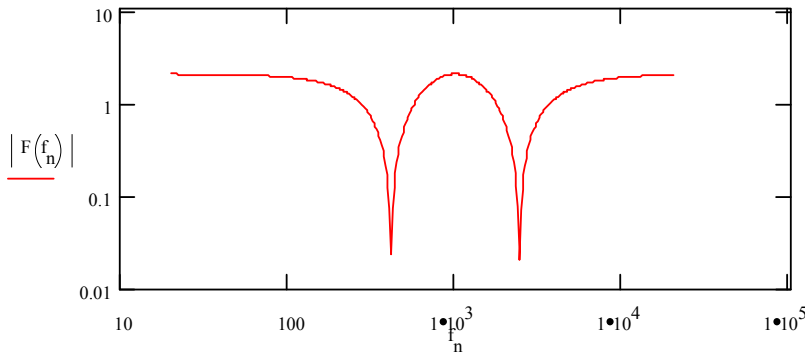


Figure 2: Frequency response for a pole frequency of 1000 Hz.

Specifications

- Input resistance of 10 k Ω .
- Output resistance of 100 Ω .
- With an input signal of 1 V peak, the peak voltage on each JFET is to be no larger than 100 mV.
- The overall gain of the circuit in the region between the nulls in Fig. 2 is to be unity.
- The triangle wave generator frequency must be variable from 0.05 Hz to 5 Hz.
- The control voltage applied to the gate of each JFET must be derived from the triangle wave generator in such a way that the gate-source voltage never goes positive on the positive peak of the triangle wave.
- Each all pass filter is to be designed so that the control voltage V_c and the resistors R_2 , R_3 , and R_4 cause the pole frequency to vary from 250 Hz to 4000 Hz over the peak-to-peak swing of the triangle wave.
- The depth of the nulls in the overall frequency response of the system is to be 40 dB or greater.