电子科技大学
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Communication Circuits Design – 2018-19, semester II

Lab 2 - Week 5

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Nonlinear mixing principles

The objective of this lab is to become familiar with the process of generating new frequencies by mixing together two signals at different frequencies as inputs of a nonlinear device. In this case the nonlinear device will be a simple Germanium diode.

Theory recap.

When two sinusoidal signals of different frequencies f_1 and f_2 are applied simultaneously to a nonlinear device, the mixing effect generates several different output frequencies including:

- The first and second harmonics of the original signals, so f_1 and f_2, as well as $2f_1$ and $2f_2$
- The sum and difference components so f_1+f_2 and $|f_1-f_2|$
- A DC offset at 0 Hz

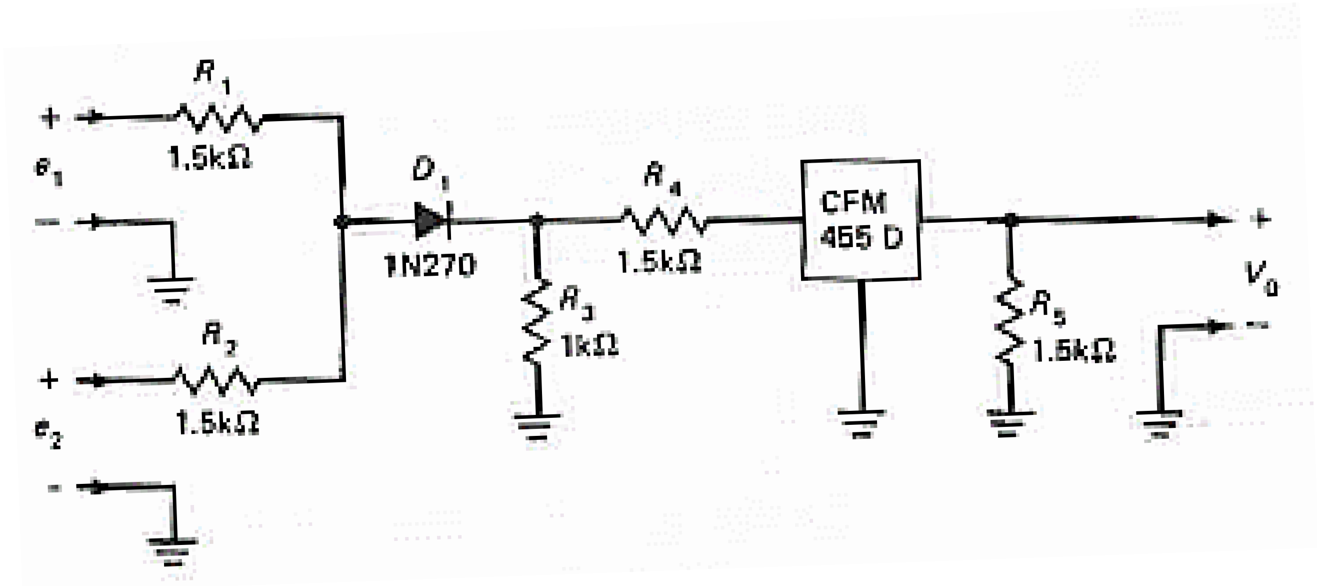
One method to prove this principle is to feed the output signal of the mixer through a sharp band-pass filter tuned to each of the expected output frequencies, and then check for the presence of a sinusoidal signal of that particular expected frequency at the output of the band-pass filter.

However, sharp filters, such as ceramic or crystal filters, are not available for any possible frequency, but typically only for standard frequencies used in radio design such as 455 kHz and 10.7 MHz

So, an alternate approach used in this experiment, is to carefully select the two input frequencies so that only one of the expected output frequencies of nonlinear mixing will be near the standard pass band of the available band-pass filter (in this case, the 455 kHz one).

Practical procedure.

1. Build the circuit shown in the figure below – Note the two inputs e1 e2 from the signal generator into the voltage divider of 2 resistors R1 R2, followed by diode and band-pass filter. The final output Vo goes to the oscilloscope.



2. Set the amplitude of the two input signals to 10 V peak to peak. Set the frequency of signal e1 to 455 kHz and e2 to 200 kHz. Monitor the output voltage using the oscilloscope.
   Carefully fine-tune the frequency of one of the two input signals so that the output reaches its maximum amplitude. Use the oscilloscope to measure the maximum amplitude and exact frequency at that point, and note the values in the table below.
3. Repeat the step 2 for the following combinations of input frequencies to populate the table.
   a. f1 = 200 kHz and f2= 455 kHz
   b. f1 = 227.5 kHz and f2= 300 kHz
   c. f1 = 300 kHz and f2= 227.5 kHz
   d. f1 = 355 kHz and f2= 100 kHz
   e. f1 = 755 kHz and f2= 300 kHz
   f. f1 = 295 kHz and f2= 80 kHz (if in serious trouble for this, carry on and see more info at question 7)

Input f1	**Input f2**	**Output amplitude [Vpk-pk]**	**Output frequency [Hz]**	**2f1**	**2f2**	**f1+f2**	**|f1-f2|**

4. Sketch the expected spectrum of the output signal just after the diode (between the diode and resistor R3) and after the ceramic filter (on resistor R5 basically) when the input signals are those given <u>in case 3e</u> above. Do not worry about the relative amplitude of each component, just make sure you sketch all the components

5. Which outputs were of largest amplitude in the table at step 3? (tick in the table the corresponding box to the nearest expected output among f_1 f_2 $2f_1$ $2f_2$ f_1+f_2 $|f_1-f_2|$)
6. If we completed step 2 using a new combination f1 = 682.5 kHz and f2= 227.5 kHz, what problem would occur in looking for the output difference frequency component, which is $|f_1-f_2|$?

7. In question 3f, the only output frequency that is within the pass band of the band-pass filter would be equal to f_1+2f_2, which is typically far smaller than the desired sum or difference components. This is called a 3rd order component (as generated by the sum of one input component plus twice the other).
   How many dBs down is this output frequency compared to the sum or difference components (2nd order harmonics) that you have recorded at question 3e and 3d?

8. What would be the expression of the other 3rd components? And what would be their frequency values if we refer to the case 3f?