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课程编号 30217000101

**深 圳 大 学 实 验 报 告**

**课程名称：­ 信号与系统实验**

**实验名称： 信号分解与合成实验**

**学 院： 电子与信息工程学院**

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**实验地点： 致信楼N413**

**实验时间： 2024 年 4 月 25 日 星期 四**

**实验报告提交时间： 2024年5月4日**

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| **I. Experimental Purpose :**   1. To observe the decomposition of signals. 2. To master the basic principles of decomposing periodic signals into the fundamental wave and its harmonics. 3. To understand the basic principles of synthesizing periodic signals from the fundamental wave and its harmonics. |
| **II. Experimental Content:**   1. To observe the process of signal decomposition and the harmonics contained in the signal. 2. To observe the signal synthesized from the harmonics. |
| **III. Experimental Equipment:**   1. One ELF-BOX experimental box (mainboard). 2. One signal decomposition and synthesis module. 3. One computer. 4. One signal generator. 5. One 20M dual-trace oscilloscope. |
| **IV. Experimental Principle:**   1. Any signal is composed of various sine waves with different frequencies, amplitudes, and initial phases. For periodic signals, according to its Fourier series expansion, the harmonics are integer multiples of the fundamental frequency. Non-periodic signals contain all frequencies from zero to infinity, with each frequency component's amplitude tending to be infinitely small, but their relative sizes are different. 2. A frequency selection network can extract a certain frequency component from the signal. This experiment uses a high-performance active band-pass filter as the frequency selection network. Therefore, the experimental scheme for the waveform decomposition of periodic signals is shown in Figure 3-1. 3. The measured square wave signal is applied to a series of active band-pass filter circuits tuned to its fundamental and odd harmonic frequencies. The corresponding frequency sine wave can be observed at the output of each active band-pass filter using an oscilloscope. The measured signal in the experiment is a periodic signal, and the output frequencies of the five active band-pass filters used as the frequency selection network are... (Note: in the ideal case, the even harmonics of the square wave should have no output signal and always be at a zero level, while the odd harmonics have good amplitude convergence. In the ideal case, the amplitude ratio of the first, third, fifth, seventh, and ninth odd harmonics should be 1:(1/3):(1/5):(1/7):(1/9). However, in practice, due to the difficulty in controlling the duty cycle of the input square wave to 50%, and the possibility of slight distortion in the square wave, as well as the limited filtering characteristics of the filters themselves, the even harmonic components cannot reach the ideal zero condition.) 4. To verify whether the phase difference between the third harmonic and the fundamental wave is 180 degrees, and whether the phase difference between the fifth harmonic and the fundamental wave is 0 degrees. The Lissajous figure method can be used for measurement.   The structural framework is shown in the figure below  BPF-  BPF-  BPF-  BPF-  BPF-  Graph 3-1 The process of signal decomposition  Specific method 1: Phase comparison between fundamental wave and standard same frequency and trust signal (Lissayu phase measurement method)  This method is used to compare the phase relationship between the fundamental wave and the original input signal. In this experiment, the original input signal is a square wave signal, which is output by channel 1 of the virtual signal generator, whose channel 2 can output a sine wave signal with the same amplitude as the square wave signal, which is directly connected to the oscilloscope channel 2, and then the fundamental wave of BPF- is connected to the oscilloscope channel 1. The oscilloscope uses X-Y mode to display and observe the Li Shayu pattern. (Note: When the gain of the filter is not 1, that is, when the signal amplitude of the X axis and the Y axis are inconsistent, the Lisayu pattern is not a circle but an ellipse, but it is a vertical ellipse, which is not the same as the ellipse of the time.)  When the phase difference between the two signals is, the waveform is a straight line; When the phase difference between the two signals is, the waveform is a circle; When the phase difference between the two signals is, the waveform is elliptical, as shown in Figure 3-2.  When ：  B    A    Figure 3-2 Figure of Lisayu  Specific method 2: Phase comparison between fundamental wave and each higher harmonic (Lisayu frequency test method)  Connect the fundamental wave at BPF- to the oscilloscope channel 1, and then connect the higher order at BPF- and BPF- to the oscilloscope channel 2 respectively. The oscilloscope displays in X-Y mode and observes the figure of Li Shayu, as shown in Figure 3-3.    Figure 3-3 Lisayu figure of phase difference between the fundamental wave and the third, fifth and seventh harmonics  In this experiment, we adopt the second method |
| **V. Experimental Steps:**   1. Connect the ELF-BOX experimental box to the power cord, turn on the power switch, and the motherboard will self-check. Then connect the USB cable, install the software on the computer, and open the Intelligent Signal and System Experiment Platform software. Connect the serial port, insert the signal decomposition and synthesis module into the motherboard, ensure good contact at the endpoints, and click to stop scanning and start scanning. 2. After scanning the module, connect signal source 1 to INPUT1, connect OUT-1 and OUT-3 to channel 1 and channel 2 of the oscilloscope, then select -12V +12V -5V +5V, click POWER\_OFF to change to POWER\_ON to take effect. As shown in Figure 3-4. 3. Open the acquisition card software, adjust the function signal generator to output a 10 kHz square wave (the duty cycle of the square wave must be 50%, which is quite strict), amplitude 1V (peak-to-peak 2V), bias 1V, and observe the output of each band-pass filter, that is, each harmonic with the oscilloscope. 4. The signal decomposition experiment uses an active band-pass filter to filter out each harmonic component from the original signal. Since the amplitude-frequency and phase-frequency characteristics of the filtering network affect the amplitude and phase of each harmonic, it is necessary to adjust the phase and amplitude of each harmonic. 5. Use the two channels of the oscilloscope to directly observe the phase relationship between the fundamental wave and the third harmonic, or use the Lissajous figure method to see if the phase difference is 180 degrees, and at the same time, examine the amplitude relationship, whether the amplitude ratio is 3:1 (you can use the phase and amplitude potentiometers in the corresponding band-pass filter to make the necessary adjustments. First, ensure that the phase relationship is met, and then adjust the amplitude potentiometer to meet the experimental requirements. The following steps can also use phase and amplitude adjustments to understand the importance of phase and amplitude in signal decomposition and synthesis). 6. Click "AddXY" to generate a Lissajous figure for phase adjustment; use "Measure" to measure the peak-to-peak values of the two waveforms for amplitude adjustment. 7. Use the same method, as shown in Figure 3-7, to observe the phase relationship between the fundamental wave and the fifth harmonic, and at the same time, examine the amplitude relationship, whether the amplitude ratio is 5:1. 8. Synthesis of square wave waveform:   (1) Click Power\_on to change it to Power\_OFF, then click reset. Connect the signal source 1 to INPUT1 (the input signal from the signal source remains unchanged), and use the oscilloscope probe cable to connect OUT-6 (synthesized waveform output) to channel 1 of the external oscilloscope (the black clip of the oscilloscope probe cable is grounded); check -12v +12V -5V +5V, click POWER\_OFF to change to POWER\_ON to take effect.  (2) To observe the synthesized waveform of the fundamental wave and the third and fifth harmonics, on the basis of the connections in Figure 3-9, click Power\_on to change it to Power\_OFF, do not click reset, but instead use another double clip line to connect the "OUT5 (fifth harmonic output)" of the module with "IN4 (fifth harmonic input)". After completing the connections, click POWER\_OFF to change to Power\_on to take effect. Use the external oscilloscope to observe the synthesized waveform, the synthesized waveform of the fundamental wave and the third and fifth harmonics.   1. At the end of the experiment, when removing the module, you must follow the steps: click "Power-off" to cut off the power, uncheck -12V, +12V, -5V, +5V, and finally click the "Reset" button. When the software main interface is as shown in Figure 3-12, the green connection on the experimental box motherboard disappears. Then turn off the external power of the experimental box to extinguish the red light on the experimental box motherboard before removing the module. Otherwise, it will cause a short circuit on the experimental box motherboard. 2. Close the software, turn off the computer, tidy up the USB connection cables, and organize the laboratory bench as required by the laboratory. |
| **VI. Data Recording:**  Third Harmonic Adjustment  After adjustment, the waveform of the fundamental wave and the third harmonic is as follows:    Chart 1: Waveform of the Fundamental Wave and the Third Harmonic  **Chart 2: Lissajous Figure**  Observe the amplitude ratio  **Chart 3: Amplitude Ratio of the Third Harmonic Component to the Fundamental Wave**  The phase difference between the fundamental wave and the third harmonic is 180°, and the amplitude ratio is approximately 3:1.  Fifth Harmonic Adjustment  After adjustment, the waveform of the fundamental wave and the fifth harmonic is as follows  :  **Chart 4: Waveform of the Fundamental Wave and the Fifth Harmonic**    **Chart 5: Lissajous Figure**  Observe the amplitude ratio  **Chart 6: Amplitude Ratio of the Fifth Harmonic Component to the Fundamental Wave** The phase difference between the fundamental wave and the third harmonic is 360°, and the amplitude ratio is approximately 5:1.  Synthesis of the Fundamental Wave, Third Harmonic, and Fifth Harmonic:  The waveforms obtained by synthesizing the fundamental wave, third harmonic, fifth harmonic, and the combination of the three are as follows:  Chart 7 combinate the fundamental wave, third harmonic, fifth harmonic |
| **VII. Experimental Conclusions and Discussion Questions:**  Conclusion:   1. This experiment is to first decompose square waves into fundamental waves, second harmonics,... Fifth harmonics, etc., respectively observe the amplitude and phase ratio of third harmonics, fifth harmonics and fundamental waves. This requires a 180° phase difference between the fundamental wave and the third harmonic with a amplitude of 3:1, and a 360° phase difference between the fundamental wave and the fifth harmonic with a amplitude of 5:1 to achieve the best results in the final synthesis. 2. The waveform synthesized by the final fundamental wave, third harmonic and fifth harmonic is not a square wave. However, observing its waveform, it is roughly similar to the square wave in the trend, and the peak position is not stable in a value like the square wave, but fluctuates in a certain value. 3. Phase can be regarded as delay in waveform synthesis, and the left and right movement of the waveform greatly affects the symmetry of the synthesized waveform, image rules and irregularities, so the phase will affect the shape of the waveform. In addition, if the phase difference is 180°, the two waveforms are reversed, the synthetic waveform is the subtraction of the two waveforms, such as the phase difference of 360°, the two waveforms are in phase, the synthetic waveform is the addition of the two waveforms. 4. The amplitude is the proportion of the synthetic waveform, which will affect the size of the up and down swing of the synthetic waveform, and the larger the proportion of the synthetic waveform, the larger the proportion. In addition, the amplitude of the waveform will also directly affect the amplitude of the synthesized waveform.   **reflection question:**  A.. What is the cause of the error in the experiment?  1. There are some physical errors in the test plate. (such as power supply and other noise interference for experimental instruments)  2. Due to the display accuracy of experimental display instruments, such as oscilloscopes, resulting in errors during debugging can not be accurate.  B. What is the Gibbs effect, how does it come about, and what are its specific manifestations? Gibbs effect: After Fourier series expansion of periodic functions with discontinuities (such as rectangular pulses), finite terms are selected for synthesis. The more terms are selected, the closer the peak in the synthesized waveform is to the discontinuity of the original signal. When the number of selected terms is large, the peak value tends to be a constant, about 9% of the total jump value.    Cause:  The two-dimensional Fourier transform of image data is essentially a Fourier expansion of a two-dimensional image. This two-dimensional image should be considered periodic. Since the transformation coefficient of the subimage is discontinuous at the boundary, the restored subimage will also be discontinuous at its boundary. As a result, the whole restored image composed of the restored sub-image will show a faint square block structure in the unit of the sub-image size, which will affect the whole image quality. This is more serious when the sub-image size is small.  Specific performance:  ringing effect occurs at the step/turn position of the time-domain signal (in short, obvious oscillation occurs at the turn of the signal) |
| 指导教师批阅意见： |
| 成绩评定：   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **预习**  （20分） | **操作及记录**  （40分） | 数据处理  25分 | 结果与讨论  5分 | 思考题  10分 | **总分** | |  |  |  |  |  |  |   1、报告内的项目或内容设置，可根据实际情况加以调整和补充。 |