|  |  |  |
| --- | --- | --- |
| **得分** | **教师签名** | **批改日期** |
|  |  |  |

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： 信号的采样和恢复**

**学 院： 电子与信息工程学院**

**指导教师： 郑能恒**

**报告人： 陈应权 学号： 2022280297**

**实验地点： 致信楼N413**

**实验时间： 2024 年 5 月 23 日 星期 四**

**实验报告提交时间： 2024年5月27日**

|  |
| --- |
| **I. Experimental Purpose:**   1. Understand the sampling methods and processes of signals and the methods of signal recovery. 2. Verify the sampling theorem. 3. To deepen the understanding of signal sampling theory through practical operation of experimental equipment and to master the techniques of signal sampling and recovery. |
| II. Experimental Content:   1. Observe the sampling pulse, sampled signal, and sampled recovery signal. 2. Observe the waveforms during the sampling process when aliasing and non-aliasing occur. |
| III. Experimental Equipment:   1. One ELF-BOX intelligent experiment box (mainboard). 2. One system time domain and frequency domain analysis module. 3. One computer. 4. One 20M dual-trace oscilloscope. |
| IV. Experimental Principle:   1. Discrete-time signals can be obtained from discrete signal sources or from the sampling of continuous-time signals. The sampled signalcan be seen as the product of a continuous signaland a set of switch functions.is a set of periodic narrow pulses, see Figure 4-1,TS is called the sampling period , and its reciprocalis called the sampling frequency.   S(t)    τ  Figure 4-1 Rectangular sampling pulse  By harmonic analysis the sampled signal, the frequency of the sampled signal includes the original continuous signal and an infinite number of translated original signal frequencies. The frequency of translation is equal to the sampling frequency  And its harmonic frequency 、……。When the sampled signal is a periodic narrow pulse, the frequency amplitude after translation according to  Regular decay. The spectrum of sampled signal is an extension of the original signal spectrum period, which occupies a much wider frequency band than the original signal spectrum.   1. After obtaining sufficient experimental data, we can connect a series of data points on the coordinate paper to get a smooth curve, just like the sampled signal can be restored to the original signal under certain conditions. As long as a low-pass filter with a cutoff frequency equal to the highest frequency fn in the original signal spectrum is used to filter out the high-frequency components, the signal obtained after filtering contains all the content of the original signal spectrum, so the restored original signal can be obtained at the output of the low-pass filter. 2. But the only way the signal can be restored is if ，among is sampling frequency, B is the bandwidth occupied by the original signal.but For the lowest sampling frequency, also known as“Nyquist sampling rate.”.When，The spectrum of the sampled signal will overlap, and we can not low-pass filter the full spectrum of the original signal from the overlapping spectrum. In practical use, a signal containing only a limited frequency is rare. So even if The signal distortion after restoration is inevitable. Figure 5-2 illustrates when sampling frequency (when not aliasing) and when sampling frequency The spectrum of an impulse sampling signal in both cases.                     0  0    (a) the spectrum of a continuous signal                  0          0    (b) sampling signal and spectrum at high sampling frequency (non-aliasing)          0  0                (c) sampling signal and spectrum at low sampling frequency (aliasing)  Figure 4-2 two conditions occur during the sampling process   1. The point frequency sampling restoration experiment adopts a discrete method. A 2kHz sine wave is sampled and restored. First, the 2kHz square wave is filtered through a low-pass filter with a cutoff frequency of 2.56kHz to obtain a 2kHz sine wave. Then, a tunable narrow pulse is used to sample the sine wave to obtain the sampled signal. After the sampled signal is filtered by a low-pass filter, the sine wave is restored.   Consider the following sinusoidal signal:  Assume twice the frequency of the sinusoidal signal  It is sampled by pulse train if the sampled impulse signal is added as input to a cut-off frequency of  Low-pass filter, the output would be: Fig. 4-3 signal sampling  Thus,when＝0 or is an integral multiple of the，As shown on the right, X (t) can be restored completely.  when， The signal is in the sampling period  The values at integer multiples are all zero; therefore, the signal generated at this sampling frequency is all zero. When this zero input is added to the ideal low-pass filter, the output is, of course, zero. |
| V. Experimental Steps:   1. Connect the ELF-BOX experiment box to the power cord, turn on the power switch, and the motherboard self-checks. Then connect the USB line, and install the software with the computer. Insert the system time domain and frequency domain analysis module into the motherboard, make sure the end point contacts are good, click Stop Scanning and Start Scanning, and the module appears on the software main interface**. Note that this module uses ±5V power, so the power end should be connected to the right power hole.** 2. The experimental test points are as follows: "INPUT-1": 128kHz square wave input, which provides the clock pulse for the low-pass switch capacitor filter (provided by the template built-in); "INPUT-2": Sampling pulse sequence fs input; "INPUT-3": 2kHz square wave input; "T02": The signal after the sine wave is sampled, that is, the "sampled signal". "OUT-1": The 2kHz square wave input is filtered and the 2kHz sine wave signal is output. "OUT-2": The restored sine wave signal. 3. Connect the signal source channel 1 to the INPUT-2 terminal; connect the signal source channel 2 to the INPUT-3 terminal. Connect OUT-1 to the oscilloscope channel 1 to observe the square wave input filtered by the low-pass filter with a cutoff frequency of 2kHz to obtain the 2kHz sine wave. Connect OUT-2 to the oscilloscope channel 2 to observe the restored waveform of the sine signal after sampling. INPUT-2 inputs the sampling pulse sequence fs. By adjusting the frequency of the sampling pulse, undersampling, critical sampling, and oversampling can be achieved. Check the -5V +5V, click POWER\_OFF to make the connection effective.   When the sampling pulse is 10KHz and the duty cycle is 10%, the sampling circuit will sample this sine wave, and then restore this sine wave through the restoration circuit.   1. During the experiment, you can also use an external oscilloscope to hook up to the T02 terminal to observe the waveform after the " Repeat the above operations to observe the distortion and non-distortion of the signal. 2. After the experiment is completed, when removing the module, you must follow: click "Power-off" to power off, uncheck -5V, +5V, and finally click the "Reset" button, the green line on the experiment box motherboard disappears; turn off the external power of the experiment box, and the red light on the experiment box motherboard goes out. You can then remove the module, otherwise it will cause a short circuit of the experiment box motherboard. Close the software, close the computer. Tidy up the USB connection line, and tidy up the experimental position according to the laboratory requirements. |
| VI. Data Recording:  1. The sampling frequency is 10KHz, and the restored signal can be restored without distortion.    Figure 1 original and restored signal waveforms The oscilloscope shows the sampling signal  2. The sampling frequency is 1 khz, and the recovered signal can not be recovered    Figure 2 original and restored signal waveforms The oscilloscope shows the sampling signal  3. The sampling frequency is 6KHz, and the recovered signal can be recovered, but the distortion occurs.    Figure 3 original and restored signal waveforms The oscilloscope shows the sampling signal  4. The sampling frequency is 2KHz, and the recovered signal can be recovered, but the distortion occurs. Because the sampling frequency is less than twice the original frequency, the aliasing phenomenon occurs, and the original frequency W0 is aliased into a lower frequency.    Figure 4 original and restored signal waveforms The oscilloscope shows the sampling signal |
| **VII. Experimental Conclusions and Discussion Questions:**  In the experiment, we observed the impact of different sampling frequencies on signal recovery. At a sampling frequency of 10kHz, the signal was recovered without distortion; whereas at a sampling frequency of 1kHz, the signal could not be recovered. Sampling frequencies of 6kHz can recover the signal, but is accompanied by varying degrees of distortion. These observations are consistent with the predictions of the sampling theorem.  When the sampling frequency is 2khz, it seems that the sinusoidal signal is recovered, but it is not, which is a pseudo-recovery. Its frequency is very different from the original signal, only because 2khz will just take a special point, and the recovered signal will be a sinusoidal signal .You can see the diagram below.    **Conclusion:**   1. When the sampling frequency is large enough (satisfying the sampling theorem), the sine wave can be restored, but there will be a certain time shift and amplitude change. 2. The sampling signal must be a periodic signal. 3. If the signal bandwidth is less than the Nyquist frequency (i.e., half of the sampling frequency), then these discrete sampling points can fully represent the original signal at this time. Frequency components above or at the Nyquist frequency will cause aliasing phenomena. When the sampling frequency is much greater than twice the original signal frequency, the signal can be restored without distortion. When the signal is slightly greater than or equal to twice the original signal frequency, the signal can be restored but distorted. When the sampling signal is less than twice the original signal frequency, the signal cannot be restored. |
| 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。 |